APPENDICES, VOLUME 2 OF 3

Environmental Impact Assessment

West African Gas Pipeline

5-A
5-B

June 2004

APPENDICES, VOLUME 2 OF 3

Environmental Impact Assessment

West African Gas Pipeline

5-A
5-B

Prepared for

West African Pipeline Company

June 2004

West African Gas Pipeline
Environmental Impact Assessment

Suite of Documents

Environmental Impact Assessments

- Regional Report
  - Benin
  - Ghana
  - Nigeria
  - Togo

Appendices

Volume 1:

- 1-A EIA Terms of Reference (One for Each Country)
- 1-B Local and International Regulations (Nigeria Only)
- 2A-1 Air Pollutant and Greenhouse Gas Analysis
- 2A-2 Natural Gas Sources and Transmission Infrastructure
- 2-B WAGP Waste Estimates
- 2-C Onshore-Offshore Commissioning Procedures and Specifications List
- 2-D Potential Hazardous Materials
- 5-C SPI Study Report
- 5-D Stakeholder Consultations (One for Each Country)
- 6-A Anchor Handling
- 6-B Air Quality Impact Assessment
- 6-C Qualitative Risk Assessments
- 7-A Measures for Baobab Tree in Tema (Ghana Only)
- 7-B HIV/AIDS Policy

Volume 2:

- 5-A First Season Environmental Baseline Survey
- 5-B Second Season Environmental Baseline Survey

Volume 3:

- 8-A Project Execution Plan Chapter 15: HSE Plan
- 8-B Operational Controls
- 8-C Environmental and Social Advisory Panel Terms of Reference

Resettlement Action Plans
(Referenced as Appendix 8B-3.1)

- Benin
- Ghana
- Nigeria
- Togo

Disclosure Locations

Venues at which the Environmental Impact Assessments, Appendices, and Resettlement Action Plans – and Other Documents Supporting the West African Gas Pipeline Project – have been Disclosed to the Public are as Follows:

Country	Venue	Location
UNITED STATES	World Bank Offices	Washington, DC
	MIGA	Washington, DC
NIGERIA	WAGP EA Rep Office	Lagos
	Lagos State Ministry of Environment	Lagos
	Ogun State Ministry of Environment	Abeokuta
	Liaison Office Federal Ministry of Environment	Lagos
	Liaison Office Federal Ministry of Environment	Abeokuta
	Badagry Local Government Office	Badagry
	Ado Odo Ota Local Government Office	Ado Odo Ota
	Ifo Local Government Office	Ifo
	Ogun State Ministry of Lands and Housing	Abeokuta
	Lagos State Lands Bureau	Lagos
	Federal Ministry of Environment	Abuja
TOGO	WAGP EA Rep Office	Lomé
	Ministère de l´Environnement et des Ressources Forestières	Lomé
	Gbetsogbe Palace	Gbetsogbe
	Domocile du chef traditionnel	Gbetsogbe
	Baguida	Baguida
	Ministère de l'Énergie et des Ressources Hydrauliques	Lomé
	Ministry of Land Affairs	Lomé
BENIN	WAGP EA Rep Office	Cotonou
	Documentation Center of the Ministry of Environment, of Habitat and Urbanism (MEHU)	Cotonou
	Beninese Agency for Environment (ABE)	Cotonou
	Documentation Center of Ministry of Mines, Energy and Hydraulic (MMEH)	Cotonou
	Mayoralty of Abomey-Calavi	Abomey-Calavi
	Mayoralty of Ouidah	Ouidah
	Institute of Endogenous Development and Exchanges (IDEE)	Ouidah
	Documentation Center of the University of Abomey-Calavi	Abomey-Calavi
GHANA	WAGP EA Rep Office	Tema
	EPA Library	Accra
	Greater Accra Regional Coordinating Council	Accra
	EPA Greater Accra Regional Office	Amasaman
	Accra Metropolitan Assembly	Accra
	Shama Ahanta East Metropolitan Assembly	Sekondi
	EPA Central Regional Office	Cape-Coast
	Central Regional Coordinating Council	Cape-Coast
	Western Regional Coordinating Council	Sekondi
	EPA Zonal Office	Tema
	Tema Municipal Assembly	Tema
	EPA Western Regional Office	Sekondi
	Volta Regional Coordinating Council	Ho
	EPA Volta Regional Office	Ho
	Ghana EPA	Accra

Table of Contents

Acronyms and Abbreviations
Authors and Contributions
Acknowledgements

Executive Summary ES-1
- Project Benefits ES-1
- Project Description ES-3
  - Pipeline and Facilities ES-3
  - Construction ES-5
- Alternatives ES-6
- Baseline Information ES-7
  - Natural Environment ES-7
  - Human Environment ES-8
- Impacts and Mitigation ES-9
  - Secondary and Cumulative Impacts ES-12
  - Results ES-12
- Management and Monitoring Plan ES-17
- Summary and Conclusion ES-17

Chapter 1 Introduction 1-1
- 1.1 Project Overview 1-1
- 1.2 Project Justification 1-4
  - 1.2.1 Global Perspective 1-6
  - 1.2.2 Regional Perspective 1-8
  - 1.2.3 National and Local Perspective 1-12
  - 1.2.4 Project Implementation 1-17
- 1.3 Legal and Policy Framework 1-18
  - 1.3.1 Introduction 1-18
  - 1.3.2 International Legislation 1-21
  - 1.3.3 Relationship of Project to World Bank Safeguard Policies and OPIC Prohibitions. 1-21

Chapter 2 Project Description 2-1
- 2.1 General Layout and Physical Description 2-1
- 2.2 Natural Gas Sources ("Upstream of WAGP") 2-10
- 2.3 Natural Gas Consumption ("Downstream of WAGP") 2-11
- 2.4 Design and Other Pre-construction Activities 2-13
- 2.5 Facility Descriptions 2-13
  - 2.5.1 Alagbado "Tee" 2-13
  - 2.5.2 Onshore Pipeline in Nigeria 2-20
  - 2.5.3 Lagos Beach Compressor Station 2-34
  - 2.5.4 Offshore Pipeline and Shore Crossings 2-46
  - 2.5.5 R&M Stations and Onshore Pipeline Laterals 2-56
  - 2.5.6 Ancillary Works (Concrete Weight-Coating Plant) 2-74
- 2.6 Waste from Operations 2-79

2.7 Operational Control and Safety Systems 2-80
2.8 Remaining Uncertainties 2-80

Chapter 3 Project Alternatives 3-1
3.1 Introduction 3-1
3.2 Project Alternatives 3-2
3.2.1 World Bank Regional Energy Sector Project Alternatives 3-2
3.2.2 EIA Project-Level Alternatives 3-3
3.3 World Bank Regional Energy Sector Alternatives Analysis 3-4
3.4 EIA Project-Level Alternatives Analysis 3-6
3.4.1 No-Project Alternative 3-9
3.4.2 The Proposed Project Alternative: Developing a Gas Pipeline and Piping Gas from Nigeria to Benin, Togo, and Ghana 3-9
3.4.3 Power Generation and Delivery Alternative: Developing Gas-Powered Electricity Generating Stations in Nigeria, and Transmitting the Electrical Power to Benin, Ghana, and Togo 3-10
3.4.4 Natural Gas Fuel Export Alternative: Converting the Gas to LNG or CNG and Exporting via Tanker or Road from Nigeria to Benin, Togo, and Ghana 3-11
3.4.5 Renewable Fuels Alternative: Meeting Electricity Generating Demands in Benin, Ghana, and Togo with Renewable Resources (Hydropower, Solar, Wind, Agrofuels) 3-12
3.4.6 Project-Level Alternatives Rankings 3-13
3.5 Overall Pipeline Routing Options 3-18
3.5.1 Onshore Option 3-20
3.5.2 Offshore Option 3-21
3.5.3 Onshore/Offshore Option – Selected Overall Routing Option 3-21
3.5.4 Comparison and Selection of Proposed Option 3-22
3.6 Conclusion 3-23

Chapter 4 Project Design Alternatives 4-1
4.1 Introduction 4-1
4.2 Evaluation Criteria for Alternatives 4-1
4.3 Routing Options from Existing Gas Transmission Network to Coastal Compressor Station 4-8
4.3.1 Selection Criteria for Onshore Route from Alagbado "Tee" to Compressor Station Site 4-8
4.3.2 Onshore Routing Options within Nigeria 4-8
4.3.3 Extending Pipeline Onshore for Gas Delivery to Benin 4-12
4.4 Onshore Lateral and R&M Station Alternatives 4-15
4.4.1 Onshore Lateral and R&M Station Alternatives in Benin 4-15
4.4.2 Onshore Lateral Alternatives in Togo 4-23
4.5 Design Considerations 4-23
4.5.1 Sizing of Offshore Pipeline and Midline Compression Facilities 4-23
4.5.2 Future Compression Facilities at Takoradi 4-27
4.6 Construction 4-27
4.6.1 Pipeline Construction Methods 4-27

4.6.2 Equipment Transport to Compressor Station 4-29
4.6.3 Ancillary Facility Construction 4-30
4.7 Commissioning and Start-up 4-32
4.7.1 Treatment of Hydrotest Water prior to Discharge 4-32
4.7.2 Discharge of Hydrotest Water 4-32
4.8 Project Operations 4-32
4.8.1 Liquid Storage Tanks 4-32
4.8.2 Waste Management 4-32
4.8.3 Sanitary Waste Water Disposal 4-33
4.8.4 Stormwater Management 4-33
4.8.5 Utilities 4-33

Chapter 5 Existing Situation 5-1
5.1 Existing Environment and Resources 5-1
5.1.1 Onshore Environment 5-5
5.1.2 Offshore Environment 5-45
5.1.3 Ecologically Sensitive Areas 5-66
5.2 Existing Socioeconomic Aspects 5-66
5.2.1 Introduction on Data Sources and SIA Methodology 5-66
5.2.2 Background and Geographic Detail 5-68
5.2.3 Macroeconomic Overview 5-70
5.2.4 Population and Demographics 5-71
5.2.5 Ethnic and Cultural Background 5-72
5.2.6 Historical and Cultural Resources 5-74
5.2.7 Infrastructure and Quality of Life 5-75
5.2.8 Education 5-77
5.2.9 Land Tenure and Residential Ownership 5-78
5.2.10 Land and Water Use 5-79
5.2.11 Energy Consumption 5-79
5.2.12 Microeconomic Situation 5-80
5.3 Existing Public Health Situation 5-86
5.3.2 Health Indicators 5-89
5.3.3 Food and Nutrition 5-90
5.4 Existing Safety Situation 5-90
5.4.1 Overview 5-90
5.4.2 Institutions Responsible for Health Care Delivery 5-91
5.4.3 Institutions Responsible for Fire Fighting 5-92
5.4.4 Institutions Responsible for Disaster Management 5-94
5.5 Stakeholder Consultations 5-95
5.6 Regulatory Oversight 5-96

Chapter 6 Impact Assessment 6-1
6.1 Introduction 6-1
6.2 Project Activities and Affected Media 6-2
6.2.1 Project Activities 6-2
6.2.2 Affected Media 6-3
6.3 Comprehensive Impacts Identification/Screening 6-4

6.4 Impact Severity Assessment Methodology 6-4
6.4.1 Significance Criteria 6-4
6.4.2 Likelihood Criteria 6-7
6.4.3 Severity Matrix and Conclusions 6-8
6.4.4 Uncertainties 6-9
6.5 Beneficial Impacts 6-13
6.5.1 Beneficial Environmental Impacts 6-14
6.5.2 Beneficial Socioeconomic Impacts 6-15
6.5.3 Community Development / Health and Safety Benefits 6-23
6.6 Potential Onshore Impacts 6-26
6.6.1 Site Preparation and Construction 6-26
6.6.2 Commissioning and Start-up 6-56
6.6.3 Operations and Maintenance 6-57
6.6.4 Decommissioning and Abandonment 6-59
6.7 Potential Offshore Impacts 6-60
6.7.1 Site Preparation and Construction 6-60
6.7.2 Commissioning and Start-up 6-67
6.7.3 Operations and Maintenance 6-68
6.7.4 Decommissioning 6-69
6.8 Emergency and Upset Conditions 6-69
6.8.1 Controlled Gas Release 6-69
6.8.2 Uncontrolled Gas Release 6-70
6.8.3 Fire 6-74
6.8.4 Explosion 6-75
6.8.5 Offshore Fuel Spills 6-77
6.9 Secondary and Cumulative Impacts 6-78
6.9.1 Environmental Secondary Impacts 6-78
6.9.2 Socioeconomic Secondary Impacts 6-81
6.9.3 Upstream and Downstream Development Impacts 6-81
6.9.4 Health and Safety Secondary Impacts 6-93
6.9.5 Cumulative Impacts 6-94

Chapter 7 Mitigation and Amelioration Measures 7-1
7.1 Introduction 7-1
7.2 Required General Mitigation Measures 7-3
7.3 Required Specific Mitigation Measures 7-3
7.4 Potential Mitigation Measures 7-24
7.4.1 Utilize Horizontal Directional Drilling for Wetland Crossings in Benin and Nigeria 7-25
7.4.2 Utilize Horizontal Directional Drilling for Lagoon Crossing in Benin 7-27
7.4.3 Perform the Shore Crossing from the North Side of the Lagos Lagoon Thus Avoiding the Barrier Island 7-28
7.4.4 Replacement of Topsoil at R&M Station Site after Decommissioning 7-29
7.4.5 Residual High Impacts from Onshore Construction in Nigeria 7-29

Chapter 8 Health, Safety, and Environmental Management Plan 8-1
8.1 Health, Safety, and Environmental Management System 8-3
8.1.1 Operational Controls 8-5
8.1.2 Change Management 8-11
8.1.3 Biological and Cultural Resource Chance Finds 8-13
8.2 Monitoring 8-13
8.2.1 Performance/Implementation Monitoring 8-13
8.2.2 Empirical Monitoring 8-14
8.2.3 Monitoring Oversight Responsibilities 8-14
8.3 WAPCo Human Resources, Roles, Responsibilities, and Authority 8-20
8.4 EPC Contractors 8-25
8.5 Government Regulatory Agencies 8-27
8.6 Financial Resources 8-28
8.7 Institutional Strengthening and Capacity Building 8-29
8.8 Reporting 8-30
8.9 Health, Safety, and Environment Management Plan Sections 8-31
8.9.1 Land Use 8-32
8.9.2 Topography, Geology, and Soils 8-36
8.9.3 Habitats, Biological Resources, Water Resources, and Hydrology 8-41
8.9.4 Air Quality 8-49
8.9.5 Solid, Liquid, and Hazardous Waste 8-54
8.9.6 Cultural Conditions 8-58
8.9.7 Socioeconomic Conditions 8-62
8.9.8 Public and Worker Health and Safety 8-67
8.9.9 Emergency Preparedness and Response 8-71

Chapter 9 Regional Conclusion 9-1

References

Appendices

Appendix 1-A: EIA Terms of Reference

Appendix 1-B: Nigeria Applicable Local and International Regulations

Appendix 2A-1: Air Pollution and Greenhouse Gas Emissions Analyses

Appendix 2A-2: Natural Gas Sources and Transmission Infrastructure (“Upstream of WAGP”)

Appendix 2-B: WAGP Waste Estimates

Appendix 2-C: Onshore-Offshore Commissioning Procedures and Specifications List

Appendix 2-D: Potential Hazardous Materials

Appendix 5-A: First Season EBS

Appendix 5-B: Second Season EBS

Appendix 5-C: SPI Study Report

Appendix 5-D: Stakeholder Consultations

Appendix 6-A: Anchor Handling

Appendix 6-B: Air Quality Impact Assessment

Appendix 6-C: Qualitative Risk Assessments

Appendix 7-A: Mitigation Measures for Baobab Tree in Tema

Appendix 7-B: HIV/AIDS Policy

Appendix 8-A: Project Execution Plan Chapter 15: HSE Plan

Appendix 8-B: Operational Controls

- 8B1.0 Tier 1: WAGP HSE Policy Statement
- 8B2.0 Tier 2: WAGP HSE Management System Procedures
  - 8B2.1 WAGP External Communications Procedures (To Be Developed)
  - 8B2.2 HES Training
  - 8B2.3 HES Audit Protocol
  - 8B2.4 WAGP Management of Change
  - 8B2.5 WAGP Compliance and Permitting Plan
    - 8B2.5.1 WAGP Project Authorizations
    - 8B2.5.2 WAGP Pipelines Hydrotesting Discharge Ecotoxicity Testing Plan (Rev A)
    - 8B2.5.3 WAGP Waste Water Discharge Controls (To Be Developed)
    - 8B2.5.4 WAGP Stormwater Management Plan
    - 8B2.5.5 WAGP Air Emissions Management Procedure
    - 8B2.5.6 WAGP Project Execution Plan Chapter 21: Operations Plan
  - 8B2.6 WAGP Waste Management Plan
  - 8B2.7 Emergency Response
    - 8B2.7.1 WAGP Spill Prevention and Control Procedure
  - 8B2.8 WAGP Habitat, Biological, Cultural Resource Management Procedures
    - 8B 2.8.1 ROW Reinstatement Criteria
    - 8B 2.8.2 Proposed Wetland PL Construction Methods Study
    - 8B 2.8.3 WAGP Sea Turtle Nesting Protection Procedure
    - 8B 2.8.4 WAGP Chance Finds and Archeological Salvage Procedure
    - 8B 2.8.5 WAGP Anchor Handling
    - 8B 2.8.6 WAGP Procedure for Preventing Salt Water Intrusion into Fresh Water Lagoons and Creeks
  - 8B2.9 Incident Investigation Procedure
- 8B3.0 WAGP Land Acquisition and Right of Way (ROW) Management Procedure
  - 8B3.1 WAGP Resettlement Action Plan
  - 8B3.2 WAGP ROW Access Policy
- 8B4.0 Risk Management
  - 8B4.1 Onshore Pipeline and Facilities Design Basis
  - 8B4.2 WAGP Environmental Design Basis
  - 8B4.3 WAGP Loss Prevention Design Basis
  - 8B4.4 Onshore-Offshore Technical Specifications List
- 8B5.0 WAGP Contractor Management Procedures

8B5.1 Exhibit F: HSE Standards
8B5.2 Exhibit N: WAGP Security Plan
8B5.3 Exhibit K: Drugs Standard-IFT

Appendix 8-C: Environmental and Social Advisory Panel Terms of Reference

Appendix 5-A

Final Draft

Environmental Baseline Survey

First Season

West African Gas Pipeline

Final Draft
West African Gas Pipeline
Environmental Baseline Survey
First Season

Prepared for

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

9 June 2003

ICF Consulting
33 Hayden Ave.
Lexington, MA 02421 USA
(781)676-4000

ICF Reference 022483.3.002.**07**

powered by perspective

Prepared by:

ICF Consulting Services, LLC
33 Hayden Avenue
Lexington, MA 02421 USA
(781) 676-4000

Centre pour l'Environnement, le Dèveloppement et l'Amènagement durables,
CEDA Consult
Cotonou, Benin

Environmental Solutions (ESL), LTD
Accra, Ghana

Environmental Resources Managers Limited, ERML
Lagos, Nigeria

Adotè Blivi
Universite de Lome
Lome, Togo

Table of Contents

Page

Chapter 1 Introduction..1-1

1.1 Environmental Baseline Survey Program Objectives 1-1

1.1.1 Specific Objectives 1-3

1.1.2 Additional Objectives 1-5

1.2 Report Organization..1-6

1.3 Regional background...1-7

1.3.1 Climate 1-7

1.3.2 Physical Setting...1-9

1.3.3 Onshore Biological Setting 1-11

1.3.4 Offshore Biological Setting 1-11

1.4 Ghana Background 1-15

1.4.1 Geological Setting...1-15

1.4.2 Meteorology 1-18

1.4.3 Physical and Chemical Oceanography...1-18

1.4.4 Biological Setting...1-20

1.5 Togo Background 1-29

1.5.1 Geological Setting...1-30

1.5.2 Meteorology 1-32

1.5.3 Physical and Chemical Oceanography...1-32

1.5.4 Biological Setting...1-32

1.6 Benin Background 1-34

1.6.1 Geological Setting...1-35

1.6.2 Meteorology 1-38

1.6.3 Physical and Chemical Oceanography...1-39

1.6.4 Biological Setting...1-39

1.7 Nigeria Background...1-40

1.7.1 Geological Setting...1-42

1.7.2 Meteorology 1-44

1.7.3 Physical and Chemical Oceanography...1-48

1.7.4 Biological Setting...1-50

1.8 Study Design 1-54

1.8.1 Offshore Study Design...1-56

1.8.2 Onshore Study Design 1-60

Table of Contents

Page

Chapter 2 Methods 2-1

2.1 Offshore field methods 2-1

2.1.1 Operations, Station Location, and Navigation 2-1

2.1.2 Mobilization and Pre-Sampling Preparations 2-8

2.1.3 Seabed Sample Collection 2-11

2.1.4 Water Column Sampling 2-12

2.1.5 Offshore Field Methods 2-14

2.1.6 Sediment Profile Imaging Camera Sampling 2-14

2.1.7 Offshore Benthic Community Characterization 2-16

2.1.8 Plankton Community Characterization 2-16

2.1.9 Fish Population Characterization 2-18

2.1.10 Aquatic Macrophyte Sampling 2-18

2.1.11 Marine Birds, Mammals, Reptiles 2-19

2.1.12 Meteorological Conditions and Ocean Currents 2-19

2.1.13 Documentation, Sample Tracking, Storage, and Shipping 2-19

2.2 Onshore Field Methods Overview 2-20

2.3 Analytical Methods 2-30

2.3.1 Physical Laboratory Methods 2-30

2.3.2 Chemical Laboratory Methods 2-32

2.3.3 Biological Laboratory Methods 2-36

2.4 Data Analysis and Reporting 2-40

2.5 Data Quality Objectives for Chemical and Physical Analyses 2-41

2.5.1 Data Quality Objectives 2-42

2.5.2 Field Quality Control Samples 2-45

Chapter 3 Offshore results 3-1

3.1 Offshore Sediment Characterization 3-1

3.1.1 Chemical Results 3-1

3.1.2 Physical Results 3-6

3.1.3 Sediment Profile Image Results 3-6

3.2 Offshore water characterization 3-12

3.2.1 Water Quality Profile 3-12

3.2.2 Discrete Water Samples 3-14

3.3 Offshore Biological Characterization 3-17

3.3.1 Benthic Infauna 3-17

3.3.2 Offshore Plankton Community characterization 3-35

3.3.3 Fish Population 3-51

3.3.4 Marine Birds, Mammals, and Reptiles 3-62

3.4 Meteorological Conditions and Ocean Currents 3-63

Table of Contents

Page

Chapter 4 ONSHORE RESULTS – GHANA 4-1

4.1 Vegetation 4-1

4.1.1 The Coastal Strand Vegetation of Tema 4-1

4.1.2 The Inland Coastal Scrub and Grassland Vegetation of Tema 4-1

4.1.3 The Mangrove Swamp of Tema 4-1

4.1.4 The Coastal Strand Vegetation of Aboadze/Takoradi 4-1

4.1.5 The Coastal Scrub Vegetation of Takoradi/Aboadze 4-4

4.1.6 The Freshwater Swamp at Aboadze 4-4

4.1.7 Species Composition and Diversity of the Vegetation of the Pipeline Route at Tema..4-4

4.1.8 Species Composition and Diversity of the Pipeline Route at Aboadze 4-6

4.1.9 Discussion 4-7

4.2 Soil Characterization 4-7

4.2.1 Physical 4-7

4.2.2 Chemical 4-8

4.3 Surface Water and Sediment Characterization 4-13

4.3.1 Physical 4-13

4.3.2 Chemical 4-19

4.3.3 Biological 4-28

4.4 Wildlife and Animal Resources 4-44

4.4.1 Tema 4-44

4.4.2 Aboadze/Takoradi 4-45

4.5 Fish and Fisheries Resources 4-46

4.6 Climate and Meteorology 4-53

4.6.1 Tema 4-53

4.6.2 Aboadze/Takoradi 4-54

Chapter 5 ONSHORE RESULTS – TOGO 5-1

5.1 Vegetation 5-1

5.1.1 Floral Resources...5-1

5.2 Soil Characterization 5-3

5.2.1 Physical 5-3

5.2.2 Biological 5-5

5.3 Surface Water and Sediment Characterization 5-7

5.4 Wildlife and Animal Resources 5-8

5.5 Fish and Fisheries Resources 5-8

5.6 Climate AND Meteorology 5-8

Table of Contents

Page

Chapter 6 ONSHORE RESULTS – Benin 6-1

6.1 Vegetation 6-1

6.1.1 Plant Inventory 6-1

6.1.2 Characterization of Plant Formations 6-1

6.2 Soil Characterization 6-3

6.2.1 Physical 6-3

6.2.2 Chemistry 6-5

6.2.3 Biological 6-6

6.2.4 Microbiology 6-8

6.3 Surface Water and Sediment Characterization 6-9

6.3.1 Physical 6-9

6.3.2 Chemical 6-10

6.3.3 Macroinvertebrates 6-14

6.4 Wildlife and Animal Resources 6-14

6.4.1 An Overview the Wildlife Habitat 6-14

6.5 Fish and Fisheries Resources 6-22

6.6 Climate and Meteorology 6-32

Chapter 7 Onshore Results – nigeria 7-1

7.1 VEGETATION 7-1

7.1.1 Coastal Area Habitats 7-1

7.1.2 Inland Habitats 7-9

7.2 SOIL CHARACTERIZATION AND LAND-USE 7-14

7.2.1 Physical Properties of the Soils 7-14

7.2.2 Chemical Properties of the Soils 7-22

7.2.3 Biological 7-25

7.3 SURFACE WATER AND SEDIMENT CHARACTERization 7-28

7.3.1 Physical Characterization 7-28

7.3.2 Chemical Characterization 7-33

7.3.3 Biological Characterization 7-38

7.4 SOIL AND GROUNDWATER CHARACTERIZATION (COMPRESSOR STATION) 7-46

7.4.1 Borehole Lithology and Hydrogeology 7-46

7.4.2 Groundwater Quality 7-49

7.5 WILDLIFE and Animal Resources 7-50

7.5.1 Diversity and Distribution 7-50

7.5.2 Species of Conservation Concern 7-52

7.6 FISH AND FISHERY RESOURCES 7-56

7.7 CLIMATE, METEOROLOGY, AND AIR QUALITY 7-59

7.7.1 Ambient Meteorology 7-59

7.7.2 Pollutant Gases and Noise 7-60

Table of Contents

Page

Chapter 8 Program and Data Quality Objectives 8-1

8.1 Evaluation of Study Design 8-1

8.1.1 Within Station Variability..8-1

8.1.2 Overall Variability 8-2

8.1.3 Quality Assurance and Quality Control....................................8-3

8.2 Method Comparisons, Verification, confirmation....................................8-4

8.2.1 Comparisons 8-4

8.2.2 Independent Verification 8-4

8.2.3 Confirmatory Analyses 8-4

Chapter 9 References, Acronyms and Authors 9-1

9.1 References...9-1

9.2 Acronyms...9-21

9.3 Authors and Contributors 9-35

CHAPTER 1
INTRODUCTION

This report presents the results of the First Season Environmental Baseline Survey (EBS) conducted as part of an Environmental Impact Assessment (EIA) for the proposed West African Gas Pipeline (WAGP) project. The EBS was conducted in accordance with established standard operating procedures (SOPs) and participating governments' guidelines. The results of the Second Season EBS will be reported at a later date. The first season represents dry conditions; while the second will represent wet.

This report provides physical, chemical and biological data for the study area, which is located offshore of Benin, Ghana, Nigeria, and Togo, as well as limited onshore areas of each of these four countries. In conjunction with the reviewed regional information presented in the Preliminary Draft EIA Reports (ICF, 2003) and summarized below, these site-specific data provide the initial basis for examining potential impacts from constructing, operating and decommissioning the proposed gas pipeline. An in-depth analysis and interpretation of the First Season EBS data will be included in the Initial Draft EIA submittals.

1.1 ENVIRONMENTAL BASELINE SURVEY PROGRAM OBJECTIVES

As part of the WAGP EIA, a thorough EBS was conducted to characterize relevant, pre-existing conditions of the offshore and onshore environments within the defined WAGP study area (See Map, Figure 1.1-1). The purpose of the WAGP EIA is to determine if WAGP construction activities and/or post-construction operations, including emergency situations, could have persistent, non-localized, adverse impacts to the environment. The objective of the EBS is to provide an adequate scientific basis for the WAGP EIA. It will be based on two seasons, wet and dry, of both offshore and onshore environmental field data sampling, analysis, and interpretation, and is augmented by a thorough review of the relevant literature.

The results of the EBS will be used by project engineers during the design phase to avoid, minimize, and mitigate potential negative impacts that might occur. Also, it will provide information for deciding how to minimize impacts to the environment where there is a choice among different pipeline route options and design measures.

EBS sampling emphasized environmental parameters that are of particular significance to the proposed project. The sampling data and interpretation provide physical, chemical and biological characterizations of the seabed, water column, terrestrial vegetation, terrestrial soil, groundwater, onshore surface water, and onshore sediment environments. Since laying the pipeline on the seabed will directly impact it and the benthic environment, sediments, and infauna that reside there, data about the seabed are particularly important. These data will indicate the effects of past physical disturbances and contamination and thereby establish the baseline ecological condition of the study area.

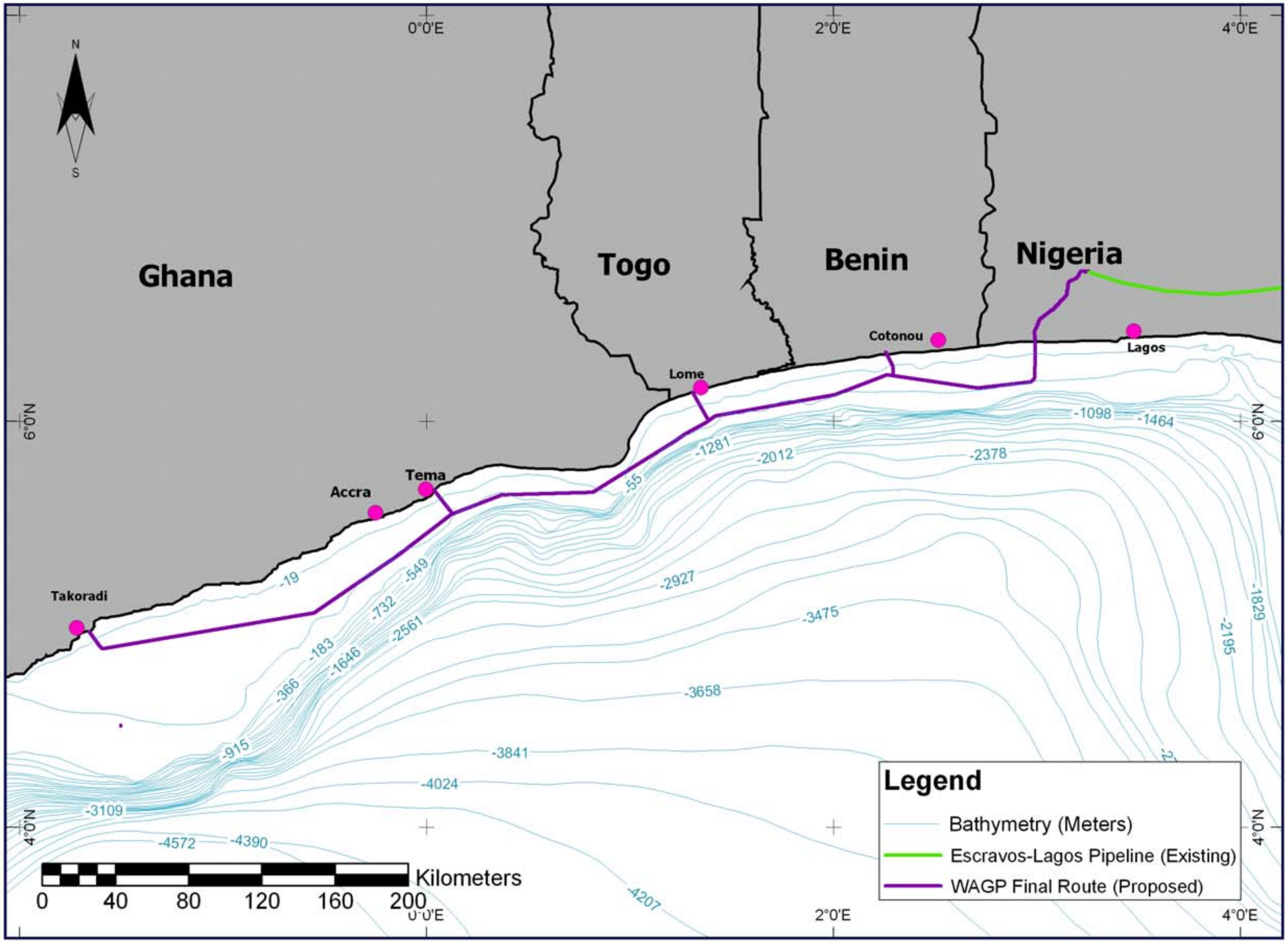


Figure 1.1-1 - WAGP EBS Location Map

Because the EBS information will be used to make predictions of potential adverse environmental impacts posed by the project, or to substantiate claims of no significant impact, the system of field sampling, laboratory testing, data analysis, and results interpretation reflect a rigorous design and implementation, as this document demonstrates.

1.1.1 Specific Objectives

The specific objectives of the EBS include providing adequate information to address the following questions and concerns:

a. What is the diversity of habitats in the study area for benthic and water column organisms?

b. What is the existing abundance and species diversity of benthic macroinvertebrates, fish, plankton in the habitats that are encountered?

c. What marine birds, mammals, and reptiles tend to be present?

d. Are threatened and/or endangered species, sensitive habitats, or commercially significant species/fishing zones present?

e. What is the character of the seabed and is there existing sediment impairment with respect to or as indicated by:

- Bulk Properties (grain size, total organic carbon (TOC))
- Organics (oil and grease, total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), aliphatic hydrocarbons)
- Trace Metals (aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), nickel (Ni), lead (Pb), vanadium (V), zinc (Zn))
- Nutrients and physicochemical properties (sulfate, ammonia nitrogen (N), orthophosphate phosphorous (P), total P, alkaline metals (calcium (Ca), magnesium (Mg), potassium (K), sodium (Na))

f. What is the character of the water column and is there water-quality impairment with respect to or as indicated by:

- Trace metals (Al, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn)
- Water quality (dissolved oxygen (DO), total dissolved solids (TDS))
- Nutrients and physiochemical properties (alkalinity, chemical oxygen demand, ammonia N, nitrate N, total N, orthophosphate P, total P, sulfate, alkaline metals (Ca, Mg, K, Na))
- Temperature, pH, electrical conductivity, turbidity, salinity, chlorophyll-a

- Contaminated fish tissue (specifically PAH and metals concentrations)

g. For all of the above is there significant seasonal variation that the EIA needs to consider?

h. By combining biological, chemical, and physical sampling parameters derived from the sampling data, what is the existing environmental quality of the resource?

i. Do meteorological and current patterns create concern with regard to exacerbating persistent, non-localized impacts?

Similarly it addresses the following questions for the onshore environment:

a. What is the diversity of terrestrial and aquatic habitats?

b. What are the presence, abundance and species diversity of terrestrial trees, shrubs, understory plants, wildlife, and intertidal zone aquatic macrophytes?

c. What are the presence and abundance of riverine (and adjacent water body) plankton, macrophytes, and macrobenthic infauna?

d. What is the character of the riverine fisheries resources?

e. Are threatened and/or endangered species, sensitive habitats, or commercially significant species/fishing zones present?

f. What is the character of the soil and is there existing soil impairment with respect to or as indicated by:

- Total petroleum hydrocarbons and PAH
- pH, TOC, and particle size distribution
- Trace metals
- Microbiology
- Macrobiology and soil ecology

g. What is the character of the groundwater and soil borings and is there impairment at the proposed compressor station location with respect to or as indicated by:

- TPH
- PAH
- Trace metals
- pH
- Grain size and porosity

h. What is the character of the riverine (and adjacent water body) surface water and is there surface water-quality impairment with respect to or as indicated by:

- Salinity

- Conductivity
- Turbidity
- DO
- TDS/Total Suspended Solids (TSS)
- Temperature
- Oil and grease
- Trace metals
- BOD5
- Total Alkalinity
- Anions
- Plankton productivity and biomass

i. What is the character of the riverine (and adjacent water body) sediments and is there sediment-quality impairment with respect to or as indicated by:

- TPH
- Trace metal
- TOC
- pH, grain size, redox potential, and temperature
- Macrobenthic infauna

j. Are there important sources of air emissions and what are the associated pollutant concentrations as indicated by:

- PM
- VOCs
- NO_x
- SO_x

k. For all of the above is there significant seasonal variation that the EIA needs to consider?

l. Would meteorological patterns likely exacerbate persistent, non-localized impacts?

1.1.2 Additional Objectives

An additional objective of the program design was to exchange scientific expertise between the participating scientists and organizations, with the goal of building in region capabilities and capacity. The EBS is an important vehicle for developing local capacity and capability. This was done, in part, by intentional sharing of responsibilities for project tasks including field work, data analysis, laboratory analysis, and report writing. For example, the offshore EBS work was conducted using a cross-functional and cross-national scientific crew (see cruise report in the appendix) who shared the burden of the field work and collaborated on the scientific methods and techniques. Further expertise will continue to be developed through providing equipment, training, and side-by-side field work and report preparation, with an objective of developing capacity and improving technical abilities in marine science, GIS, EIA process, laboratory operations, and environmental management, to facilitate the preparation of future environmental assessments.

1.2 REPORT ORGANIZATION

The report is organized into nine sections, which are described below.

Section 1 – Introduction This section presents the purpose of the EBS, citing the regulatory requirements and background for the investigation. This section also summarizes the site background, both offshore and within the onshore project area of the four countries, and includes: location, geological setting, physical and chemical oceanography, and marine biology. The study design is also presented in this section.

Section 2 – Methods This section presents a summary of field, laboratory, and data analytical procedures. Field methods are presented for station location, and sample collection, processing and transfer to laboratories. Laboratory analytical methods are summarized for chemical, biological and physical samples, including sample preparation, instrumentation and quality control. It includes methods of data analysis, including a brief description of statistics use to interpret the results.

Section 3 – Offshore Results This section presents the results of the offshore field sampling: physical and chemical characterization of sediment samples, sediment profiling imagery (SPI). It discusses the offshore water characterization, including water quality profiles and discrete water samples. This section presents the results of the characterization of the offshore biological community: benthic infauna, plankton community, fishes, marine birds, mammals and reptiles; as well as the meteorological conditions and the ocean currents observed.

Section 4 – Onshore Results – Ghana This section presents the results of the onshore field sampling of the study area that lies within Ghana. It includes data collected on vegetation, and the physical, chemical and biological characterization of soil, surface water and sediments, as well as wildlife, fish and fisheries and climate, and meteorology observed onshore.

Section 5 – Onshore Results – Togo This section presents the results of the onshore field sampling of the study area that lies within Togo. It includes data collected on vegetation, and the physical, chemical and biological characterization of soil, as well as wildlife, fish and fisheries and climate, and meteorology observed onshore.

Section 6 – Onshore Results – Benin This section presents the results of the onshore field sampling of the study area that lies within Benin. It includes data collected on vegetation, and the physical, chemical and biological characterization of soil, surface water and sediments, as well as wildlife, fish and fisheries and climate, and meteorology observed onshore.

Section 7 – Onshore Results – Nigeria This section presents the results of the onshore field sampling of the study area that lies within Nigeria. It includes data collected on vegetation, and the physical, chemical and biological characterization of soil, surface water and sediments, as well as wildlife, fish and fisheries and climate, meteorology and air quality observed onshore.

Section 8 – Program and Data Quality Objectives This section presents an evaluation of the study design, including variability, sampling density and replication. It includes a discussion of data quality and adherence to quality control objectives.

Section 9 – References This section presents the literature cited in the report, as well as an acronym list and list of contributors.

1.3 REGIONAL BACKGROUND

The project study area includes both the onshore and offshore environments of what could potentially be impacted by the proposed West African Gas Pipeline (WAGP) project. The areal extent of the study area is more limited in regards to the first season Environmental Baseline Survey (EBS) than that covered by the desktop literature review. The proposed pipeline right-of-way (ROW) (as discussed in Chapter 2) will be 25 meters (m) to 50m in width. For the onshore first season EBS, a study area of 1 kilometer (km) to 2km around the compressor station, regulating and metering (R&M) stations and the pipeline ROW were examined.

The offshore section of the pipeline extends about 581km along the Benin, Ghana, Nigeria, and Togo coasts from Lagos Beach to Takoradi and up to 30km offshore into the inner continental shelf of the Atlantic Ocean within the Gulf of Guinea. The scope of the offshore first season EBS study area is illustrated in Figure 1.3-1. The offshore desktop literature review encompasses an extensive portion of the Gulf of Guinea, whereas the scope for field sampling covers the pipeline installation corridor.

1.3.1 Climate

The onshore and offshore climates are similar in the region. The climate is an equatorial bimodal system with an alternating rainy and dry season. The climate in the Gulf of Guinea and Central Eastern Atlantic is influenced largely by the inter-tropical convergence zone (ITCZ) weather patterns (also known as the inter-tropical discontinuity and the inter-tropical front). Maritime tropical air masses, characterized by warm, humid southwesterly winds and continental air mass, characterized by hot, dry northeasterly winds, converge in the ITCZ. The alternating rainy season and dry season phenomenon is determined by the north-south oscillation of air masses in the ITCZ. Winds from the southwest and south-southwest blow year round with monthly averages between 2 meters per second (m/s) to 4m/s. While there are two main seasons during the course of the year, the annual weather patterns are somewhat more complicated due to a short break in rainy season in August.

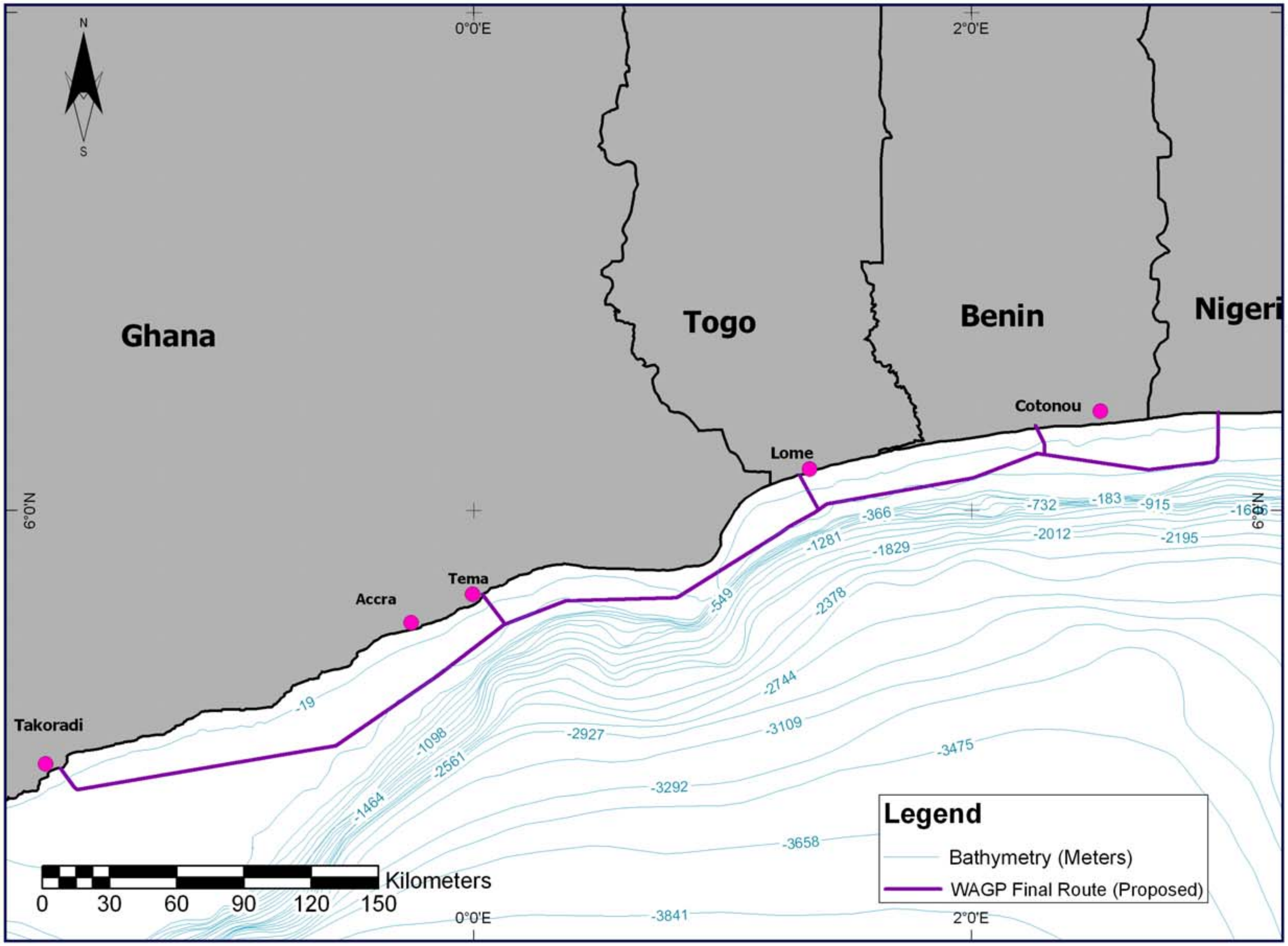


Figure 1.3-1 - Offshore Route Map

The typical weather is as follows:

- Long rainy period (southern summer monsoon season) stretches from April to July and starts with storms and humid SW winds of between 15m/s and 25m/s. There is an upwelling event along the shoreline in July;

- Short dry period occurs in August as rainfall amounts suddenly decline about 75 percent;

- Short rainy period is associated with decreasing winds and a weak upwelling during October and November. Ocean surface temperatures increase during September, reaching 28°C; and

- Long dry season stretches from December to March and is characterized by persistent Harmattan winds, which derive from anticyclone systems in the north.

Mean annual rainfall in the region ranges from 500 millimeters (mm) to 2,000mm. During the rainy season, daily rainfalls of 50 to 140mm can occur. High temperatures throughout the year, common to regions near sea level in the equatorial zone, prevail in the project area. Mean annual temperatures oscillate between 30.4°C and 32°C. During the extreme hot weather period from November to January, temperatures vary between 32°C and 34°C. Low temperatures of about 28°C occur during July and August. During the rainy season, relative humidity can be greater than 80 percent in the morning and 60 percent in the afternoon. During the dry season relative humidity tends to be lower than 50 percent in the morning and 25 percent in the afternoon.

1.3.2 Physical Setting

The project area is within the Gulf of Guinea. The entire Gulf spans 2,500km of coastline from Cape Palmas in Liberia to Port Gentil in Gabon, and includes the following nations: Angola, Benin Republic, Cameroon, Equatorial Guinea (including the Islands of Principe and Sao Tome), Congo, Cote d'Ivoire, Gabon, Ghana, Liberia, Nigeria, Togo, and Zaire. The project area lies on the sandy, continental shelf. The average width of this plateau is approximately 27km from the shore to the 100m isobath.

<u>**Bathymetry and Coastal Geology**</u>

The project area from Nigeria to Ghana lies along the Gulf of Guinea shelf. The continental shelf is narrow in the project area, ranging from 10km to 90km in width. The shelf breaks into the slope at approximately the 100m isobath. A reef of dead madreporarian coral lines the seaward edge of the continental shelf throughout the project area.

The shelf historically has been considered seismically stable, but recent tremors in Ghana and Nigeria suggest the presence of some crustal instability. In Ghana, there is active faulting, especially near the intersection of the east-west Coastal Boundary Fault Zone and the northeast to southeast Akwapim Fault Zone (Tsidzi et al., 1995). The first major reported seismic activity in Ghana was in Elmina (Central Region) in 1615 (Armah and Amlalo, 1998). Subsequent seismic events took place in 1636, 1862, 1906, 1939, and 1997. In 1997, siesmic events were recorded in January, February, and March with magnitudes on the

Richter scale of 3.8, 4.1, and 4.8, respectively. Burke (1969b) associated the seismic activities of the Accra and Kribi regions with the Romanche and Chain fracture regions. Along the coastline, currents move sands from west to east, forming a barrier beach system along much of the coastline. This littoral drift is interrupted at Lome and Cotonou by groynes built to reduce shoreline erosion.

Currents and Tidal Patterns

The oceanography of the region is influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral currents (Merle and Arnault, 1985; Fontaine et al., 1999). The cold Canary and Benguela Currents are warmed as they flow toward the equator along the coastal margins. These currents then turn westward near the equator and diverge as the North and South Equatorial Currents (Longhurst, 1962). Between the North and South Equatorial Currents flows the ECC. This ECC becomes known as the Guinea Current as it runs from Senegal to Nigeria. The Guinea Current flows the whole length of the coast, as far as the Bight of Biafra, year-round. It maintains its highest velocities during the season of the south-westerly winds from June to October (Longhurst, 1962).

The ECC is driven by westward wind stress. When this subsides during February to April and October to November, it is reversed (Garzoli and Katz, 1983; Richardson, 1984; Merle and Arnault, 1985). A small westward-flowing countercurrent lies beneath the Guinea Current. Below a depth of 40m, it appears to turn to the southwest with velocities ranging between 0.5m/s to 1.0m/s and 0.05m/s to 1.02m/s near the bottom (Akpati, 1975; Binet et al., 1991). The cold subsurface water could be a branch of the Benguela Current that penetrates and dominates the ECC.

The coastal waters experience seasonal changes at the surface of the Tropical Surface Water (TSW). There is little change in the subsurface waters. The TSW layer is characterized by warm, well-mixed water that extends from the surface to the depth of the thermocline (about 30m to 40m). Seasonal changes in the hydrographic regime come in the form of minor and major upwelling, alternating with periods of stratification. Between January and February, the surface waters tend to be slightly cooler, indicating a minor upwelling. By the end of June, there is an increase in the easterly wind in the western equatorial Atlantic that brings up cold South Atlantic Central Water (SACW) to replace the TSW (Moore et al., 1978). When the thermocline breaks, it signals the onset of the major upwelling. The sea surface temperature can fall from 30°C in May to 18°C in August.

Water Quality and Water Column Characteristics

In the tropical regions of the Atlantic, a thin stratum of warm, relatively low salinity water called TSW overlies cooler, higher density water to form a thermocline. Where the south-flowing TSW converges with a north-flowing SACW, a zone called the tropical convergence is formed. This zone is generally located at about latitude 10°S in the eastern half of the Atlantic Ocean, but can be as far south as 25°S.

There are three other types of water masses below the SACW: the Arctic Intermediate Water (AIW), Nroth Atlantic Deep Water (NADW), and Antarctic bottom water. The NADW is more saline and denser than the AIW, which is Antarctic surface water that sinks as it moves towards the equator.

Bottom Hazards and Areas of Existing Pollution

Abandoned ships are present along the rocky banks of the Port of Lomé within the project area. There is another shipwreck further seaward, in the ship sailing zone off the Port of Lomé. This is known by the harbormaster's office at the Port of Lomé, and was recently located by the French navy during the last ocean floor survey carried out in November 2002.

In general, pollution exists only along the beach. Other various sources of marine pollution originating from the city and industries have been identified. Little existing data are available on pollution farther out at sea.

1.3.3 Onshore Biological Setting

The onshore biological environments of the four West African countries participating in this project are very similar, with some minor exceptions. The areas affected by the pipeline routes, the subject of this study, are characterized by a coastline of low, sandy shore backed by plains and scrub. Along the coastline lies a belt of mangrove swamps intersected by branches of innumerable smaller rivers and creeks forming a typical estuarine environment. Typical of this region are a number of coastal lagoons. They are all located in the Gulf of Guinea coastal regime from Nigeria, situated at the extreme inner corner of the Gulf, north to Ghana, situated on the southern coast of the West African bulge.

Vegetation

The barrier-lagoon complex (coastal lagoons) stretches along much of the coastline in the study area. The coastal vegetation communities include: swamp forests, marshes, flooded prairies, floating vegetation, and mangrove forests (Ramsar Convention on Wetlands, 2000). Coconut trees dominate the coast, interspersed with sedges, grasses, and a few shrubs and trees.

1.3.4 Offshore Biological Setting

The offshore waters off the coast of Benin, Ghana, Nigeria and Togo are part of the Gulf of Guinea. This region is classified as a Large Marine Ecosystem (LME) by the United Nations Conference on the Environment and Development. As an LME, the Gulf of Guinea encompasses the onshore river basins and estuaries and the offshore environment extending to the continental shelf and seaward margin of the coastal current system. The northern subsystem of this marine ecosystem is thermally unstable and undergoes intensive seasonal upwellings. The southern half, which is thermally stable, depends on nutrient input that originates from land drainage, river flows, and wave turbulence. Although less intensive, periodic upwellings have been reported. These characteristics combine to make this area one of the world's most productive marine areas, rich in fishery resources and biological diversity.

Plankton

Species diversity and abundance is linked to seasonal variation of the oceanographic regime. During periods of thermal stability of the water column, the abundance of zooplankton is low but species diversity is high. During the upwelling, zooplankton are more abundant but have lower species diversity (Wiafe, 2002). *Calanoides carinatus*, a cold-water copepod species, tends to be the most abundant during the upwelling periods. Other common holoplankton found during the upwelling period are *Oikopleura longicauda*, *Euconchoecia chierchiea*, *Lucifer faxoni,* and *Sagitta enflata*. The Cladocera, an ephemeral form, can be found during all seasons. *Penilia avirostris* and *Evadne tergestina* become abundant during the upwelling and dominate the zooplankton community for a brief period.

The diatoms normally dominate the phytoplankton community, especially during the major upwelling season when the water temperature is relatively cold (20°C to 25°C) and conducive for their growth. Dinoflagellates, on the other hand, thrive well when the temperature is above 25°C. The principal species of diatoms recorded in Ghana during the upwelling belong to the genera *Skeletonema*, *Nitzschia*, *Chaetoceros*, *Rhizosolenia,* and *Thalassiosira*. In Nigeria, the most prevalent species are of the genera *Bidulphai, Coscinodiscus, Chaetoceros, and Ditylium*. Dinoflagellates are better adapted to survive under conditions of low nutrient levels (Harris, 1986), and thus abound during periods of thermal stability. For example, *Ceratium* spp. exhibit slow growth rate and have low nutrient requirements. The species most commonly recorded off Ghana and Nigeria are *C. extensum, C. trichoceros, C. massiliense,* and *C. vultur*.

In Ghana, it has been observed that Chaetognaths are sparse most of the year, but become prolific September to November. Thaliaceans, mainly *Thalia democratica,* become prolific only in December and July, and Appendicularians are often abundant in June and October (Thiriot, 1977).

Benthic Organisms

Offshore benthic organisms have been described by Buchanan (1957 and 1958). They include a range of polychaete worms, ribbon worms, amphipods, bivalves, gastropods, and decapod crustaceans.

The macrobenthic fauna in this region are comprised of essentially three phyla: Annelida (exclusively Polychaetes), Mollusca, and Crustacea. Rijavec (1980) found that the hard bottom substrate had substantially higher invertebrate biomass than soft bottom substrates. Crustaceans are the most abundant macrofauna. Crustaceans of primary commercial importance in this ecosystem are *Penaeus notialis, P. kerathurus, Parapeneus longirostis*, and *P. atlantica.* The juveniles of these species are caught in the estuaries, mangroves, and on the beach with beach seines during the upwelling season. In near-shore areas, the older peneids are caught by inshore trawlers.

Macro benthic algae, along with the micro algae, are the primary producers in the marine environment and key players in the ecosystem of the Gulf of Guinea. In general, macro benthic algae have low species diversity in the study area. Typically, species of Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae) are present. Populations are sparsely distributed in three potential habitats: brackish water, marine inter tidal, and sub tidal. In Ghana, the brackish water habitat has 10 recorded species, the marine inter tidal has 116, and the sub-tidal has 80 species. These represent 112 taxonomic genera (John and Lawson, 1997). Macro benthic algae grow among piles of dead coral branches, on dead portions of coral heads, and mixed with sea grasses (sea grasses form thin stands on sandy bottoms near the shore).

The three lobster species of high commercial value are *Panulirus argus* and *P. regius* (spiny lobster), and *Scyllares herklotsii* (slipper lobster). These are captured with bottom nets set by small canoes on rocky grounds. By far, the most widely occurring species is the deep-water rose shrimp, *Parapeanus longirostris*. In general, many more species are present during the rainy season than during the dry season. Five species are restricted to the rainy season, while only one species, *Callinectes pallidus,* is restricted to the dry season. Catches generally decrease with increasing distance from shore, both in number and weight.

Fisheries

Fish production in the Gulf of Guinea is high. The migration of important fish stocks is dependent on upwelling events and the movement of climatic fronts and ocean currents that has been described above. More than 400 species of both cartilaginous and bony fishes have been recorded in the Gulf of Guinea. The most common and abundant are pelagics and semi-pelagic. The Clupeidae, represented by *Sardinella* spp. and *Ethmalosa fimbriata,* the Scombridae, and the Carangidae are the families in which most of the species are caught. Others are the demersal species. The most abundant of these is the Sciaenidae, represented by *Pseudotolithus* spp., and the Sparidae, represented by *Dentex* spp. Others are the Serranidae, the Pleuronectiformes (Flatfishes), and Lutjanidae.

This rich fishery resource supports artisanal fisheries, local industrial fleets, and large commercial offshore fishing fleets from the European Union, Eastern Europe, Korea, and Japan. Since the 1960s, the offshore commercial fishing has negatively affected the resource catch per unit effort by exceeding sustainable yields in some countries (Ajaji, 1994) and species diversity and average total body length of the most important fish species has declined.

Small pelagic fish species that inhabit coastal areas are highly diverse. Four species have the highest economic value: *Sardinella aurita* (round sardine), *S. maderensis* ('herring'), *Engraulis encrasicolus* (anchovy), and *Scomber japonicus* (chub mackerel). Other species caught in smaller quantities include *Ilisha africana*, *Brachydeuterus auritus,* and several small carangids. The resource is exploited using various types of netting (e.g. encircling nets and beach seines).

In the coastal pelagic fishery, economically important species are linked to the availability of phytoplankton and zooplankton. In Ghana, for example, small pelagic fish species contribute over 50 percent to the total marine production of the fisheries yield indicating their importance to food security of the region. The target species off the coast of Ghana and Togo are *Sardinelia aurita*, *Sardinelia maderensis*, *Scomber japonicus,* and *Engraulis* *encrasicolus*. Further south from Benin to Democratic Republic of the Congo, the target species are *Ethmalosa fimbriata, Sardinella maderensis,* and *Ilisha africana*.

This group is made up of mainly tunas: *Thunnus albacares* (yellowfin), *T. obesus* (bigeye), *Katsuwonus pelamis* (skipjack), and *Euthynnus alleterratus* (black skipjack). Other large pelagic species of commercial importance include *Istiophorus albicans* (Atlantic sailfish), *Xiphias glaudius* (swordfish), *Makaira nigricans* (blue marlin), and *Tetrapturus albidus* (white marlin). Harvesting is either industrial or artisanal, using pole and line, purse seine, and gillnets.

Demersal fisheries are of higher economic value than pelagics. The target species are the croakers, (*Pseudotolithus elongatus*, *Psendotholitus senegalensis*, *Pseudotholitus typus)*, Polymenids, (*Galeoides decadactylus*, *Polydactylus quadrifilis)*, perches, big eye tuna, (*Brachydeuterus auritus)*, catfish, (*Arius* spp*., Pomadasys* spp*.),* soles and *Cynoglossus* sp.. In the highly lucrative coastal demersal shrimp fishery, the pink shrimp (*Paenus notialis)* is dominant but other target species include the *Parapenaeopsis atlantical* and *Penacus kerathurus*. Shrimping grounds cover 2,500 square miles off Nigeria, 190 square miles off Cameroon, and 180 square miles off Benin. White shrimp (*Nematopalaemon hastatus*), exclusively exploited by small-scale operators with passive cane or netting gear in the estuaries or with miniature trawls in the surf zone, is a major fishery resource off the Gulf of Guinea. The potential yield is about 150,000 tons per year off the coast of Nigeria. The shrimp are an important export species in this region.

In addition to the economically important fishes, there are several pelagic and demersal species that are important to maintaining the marine ecosystem balance. Four species of sharks, *Mustelus paragateus gruveli*, *Rhizoprionodon acutus*, and *Squatina aculata,* occur throughout the Gulf of Guinea. Four species of rays, *Torpedo torpedo*, *Raja miraletus*, *Rhinobatos albomacutus*, and *Dasyatis margarita* occur in the region as well. In addition, families such as Elopidae, Albulidae, and Mugilidae are highly valued fish in the market, but are not caught in large quantity.

Marine Birds, Mammals, Reptiles and Amphibians

The aquatic birds of the Gulf of Guinea comprise two distinct groups: creek birds (waterfowl, waders, and fish-eating birds) and oceanic birds, shearwaters, storm petrels, tropicbirds, frigatebirds, gannets, and boobies, that are rarely seen near the seashore. These oceanic birds do not appear to be as abundant in the Gulf as the coastal species. For instance, records dating back to the 1960s reveal only limited sightings of a few species (Elgood et al, 1994). The rarity of oceanic birds may be attributable to the absence of suitable breeding sites (e.g. remote islands and rocky cliffs) in the Gulf of Guinea.

In Togo, four marine mammal species have been identified (Agbo-zegue, 2002): three whale (*Phiseter macrocephalus, Megaptera novaengleae, Balalaeptera* spp.) and one dolphin species (*Delphnus capensis*). Current studies confirm the presence of these whale species around the Togolese coast from August through November.

There have been a few records of dolphins and whales being spotted at different places along the coastline in Ghana. In a survey by Waerbeek and Ofori-Danson (1999), six cetacean species were recorded: clymene dolphin (*Stenella clymene*); rough-toothed dolphin (*Steno bredanensis*); bottlenose dolphin (Tursiops truncates); dwarf sperm whale (*Kogia simus*); sperm whale (*Physeter macrocephalus*); and the humpback whale (*Megaptera novaeangliae*). Small cetaceans are regularly caught in artisanal gillnet fisheries operating from Apam in the Central Region to Kpone in the Greater Accra Region. Annual catches have been estimated to be in the low hundreds. During the December 2002 Offshore EBS, two Humpback whales and a calf were spotted and identified at N5°41.78" E0°53.32" as noted in the Offshore EBS Daily Shift Report for 12 December 2002.

The Atlantic coast of West Africa (approximately 14,000km), including the four countries addressed in this project, serves as a very important migration route, feeding ground, and nesting site for marine turtles. In the Gulf of Guinea, six species have been identified: the loggerhead (*Caretta caretta*); the olive ridley (*Lepidochelys olivacea*); the kemp ridley (*Lepidochelys kempii*); the hawksbill (*Erectmochelys imbricata*); the green turtle (*Chelonia mydas)*; and the leatherback (*Dermochelys coriacea*) (Armah et al., 1997a). The hawksbill is very rare and only seen occasionally. Sea turtles nest on sandy beaches beyond or at the high tide mark and always return to the same area to nest.

In Ghana, sandy beaches constitute about 70 percent of the coastline and stretch from the western border with Cote d'Ivoire to Axim, and from the east of Tema to the border with Togo. The prime turtle nesting sites are located within the rapidly eroding sites between Tema and the Volta estuary. The nesting period has been reported to be interspersed between July and December, with a peak in November (Armah et al., 1997b). In Togo, however, the nesting periods are from September through February in the sandy beaches of Agbodrafo to Aneho. Sea turtles are a protected species under several international treaties ratified by the four West African countries covered in this project. However, in reality, populations have decreased due to poaching and habitat destruction. The young turtles begin to appear in the sea from April. In Nigeria, these species are known to breed all along the coast from Badagry to Eket, especially in relatively undisturbed secluded sandy beaches found in some coastal states, notably Akwa, Ibom, Rivers, Delta, and Lagos States.

1.4 GHANA BACKGROUND

Figure 1.4-1 shows the location of the proposed project in Ghana.

1.4.1 Geological Setting

The coastal geological formations of Ghana were likely determined by continental drift during the Cretaceous period (about 135 million years ago), when Africa broke away from South America (Allersma and Tilmans, 1993). The geological composition consists of hard granites, granodiorites, metamorphosed lava, and pyroclastic rock. Some coastal areas are covered by Ordovician, Silurian, and Devonian sandstone and shales (Allersma and Tilmans, 1993).

Seismic studies have indicated that Ghana's seismicity is associated with active faulting, particularly near the intersection of the east-west trending Coastal Boundary Fault and the northeast to southeast Akwapim Fault Zone (Tsidzi et al., 1995). It has been reported that the first major seismic activity in Ghana occurred in Elmina (Central Region) in 1615 (Armah and Amlalo, 1998). Thereafter, subsequent events took place in 1636, 1862, 1906, 1939, and 1997. In 1997 alone, three events were recorded in January, February, and March with magnitudes of 3.8, 4.1, and 4.8, on the Richter scale respectively.

The continental shelf varies in width from a minimum of about 20 km off Cape St. Paul to about 90 km at the widest portion between Takoradi and Cape Coast. Submarine canyons exist off the Volta Delta (Edwards et al., 1997). The entire shelf is traversed by a belt of dead madreporarian coral beginning at 75m seaward. Beyond this coral belt, the bottom falls sharply, marking the transition from the continental shelf to the slope. Soft sediments predominate along the coastline up to the coral belt (Figure 1.4-2).

In Ghana, sandy beaches constitute about 70 percent of the coastline. The sediments along the coastline are redistributed mainly by a primarily eastward longshore current, in the form of littoral drifts and, less importantly, tidal currents. There are several coastal streams and lagoons along the coastline that deposit sediment into the marine environment. The amount of sediment transported is closely related to levels of river discharges into the sea (Mensah, 1991). The latter is a factor of the amount of rainfall during the rainy season (see Section 1.4.2). It has been estimated that the two major rivers in the country (Volta and Pra) transport a total of 17.9×10^6 tons of sediment per year into the sea.

The sediment ranges from coarse sand particles in the inner shelf, to fine sand, to dark grey mud in the outer shelf. The mean sediment size ranges from 0.29 to 2.00 Phi. The sediment types that dominate the offshore region contain more than 75 percent terriginous grains lying on most parts of the shelf and upper slope, detrital sands with an admixture of carbonate on most of the outer shelf and upper slope, and glauconite-rich sediment with mixtures of biogenic carbonate in the outer part of the shelf and upper slope. The carbonate-rich sediment found on the outer shelf and upper slope off Cape Three Points is mainly silty mud, composed primarily of molluscan debris.

From the inshore waters (~10m) down to 200m depth of the continental shelf margin, the surface coverage of the ocean bottom is comprised of 75 percent muddy to sandy mud, 23 percent hard and sandy, and 2 percent rocky type (Berncsek, 1986 from Armah & Amlalo, 1998).

Both WAGP near shore locations in Ghana are characterized by medium to high-energy intertidal rocky platforms with extensive algal growth and diverse fauna. At Tema, the nearshore sediment could be described as being sandy and the offshore as sandy-mud. At Takoradi, information from local fishermen suggests that the near shore is rocky, as well, with considerable colonization by barnacles.

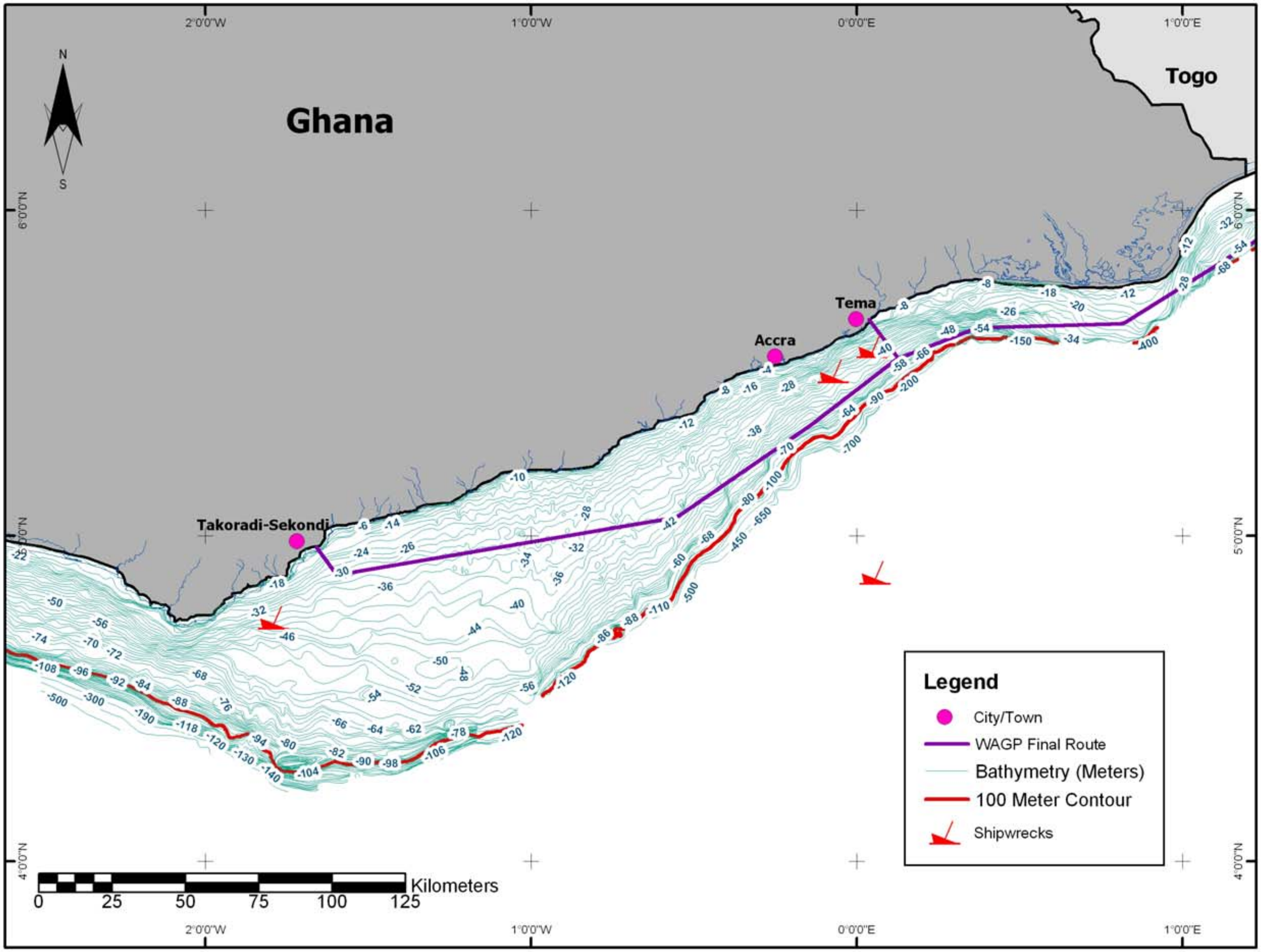


Figure 1.4-1 - Ghana Location Map

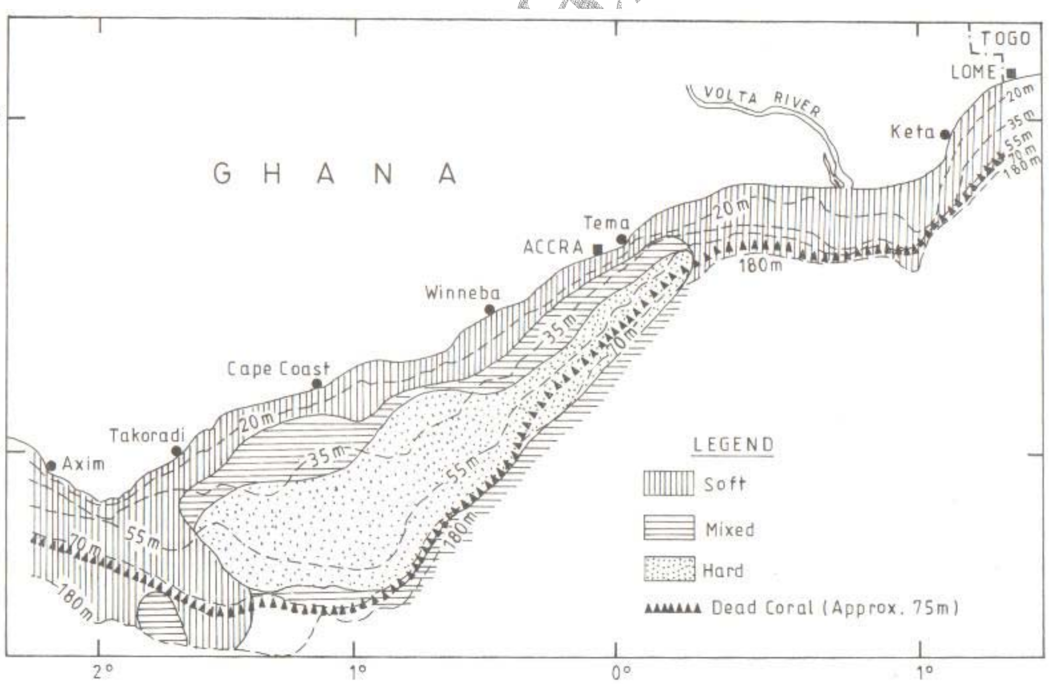
1.4.2 Meteorology

The climate of coastal Ghana is Equatorial with a bimodal rainfall distribution (June/July and September/October) and slight annual temperature variations (Church, 1980).

Tema falls in the coastal savannah zone with a mean annual rainfall of 800mm. The mean monthly temperature is estimated to be 26.7°C, while the mean monthly minimum temperature may be as low as 15°C, and mean monthly maximum temperature could be as high as 35°C. The relative humidity ranges from 50 to 80 percent. Day length is approximately 12 hours, varying by less than 0.5 an hour over the year. The winds blow predominantly in a south-westerly direction with an average speed of 3ms^{-1} throughout the year.

Takoradi lies in a region with annual rainfall of between 1250 and 1500mm. The mean daily temperature varies between 21 and 23°C while the mean daily maximum temperature varies between 27 and 31°C. Relative humidity is generally high, ranging from 70 to 100 percent.

Figure 1.4-2
Marine Environment of Ghana Showing Configuration of the Coastline and Bathymetry (Source: Armah and Amlalo, 1998)



1.4.3 Physical and Chemical Oceanography

<u>**Currents and Tidal Patterns**</u>

The oceanography of the region is influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral currents

(Merle and Arnault, 1985; Fontaine et al., 1999). The cold Canary and Benguela Currents are warmed as they flow toward the equator along the coastal margins. These currents then turn westward near the equator and diverge as the North and South Equatorial Currents (Longhurst, 1962). Between the North and South Equatorial Currents flows the ECC. This ECC becomes known as the Guinea Current as it runs from Senegal to Nigeria. The Guinea Current flows the whole length of the coast, as far as the Bight of Biafra, year-round. It maintains its highest velocities during the season of the south-westerly winds from June to October (Longhurst, 1962).

The ECC is driven by westward wind stress. When this subsides during February to April and October to November, it is reversed (Garzoli and Katz, 1983; Richardson, 1984; Merle and Arnault, 1985). A small westward-flowing countercurrent lies beneath the Guinea Current. Below 40m depth, it appears to turn to the southwest with velocities ranging from 0.5 to 1.0m/s and 0.05 to 1.02m/s near the bottom (Akpati, 1975; Binet et al., 1991). The cold subsurface water could be a branch of the Benguela Current that penetrates and dominates the ECC.

The coastal waters experience seasonal changes at the surface of the TSW. There is little change in the subsurface waters. The TSW layer is characterized by warm, well-mixed water that extends from the surface to the depth of the thermocline (about 30m to 40m). Seasonal changes in the hydrographic regime come in the form of minor and major upwelling events, alternating with periods of stratification. Between January and February, the surface waters tend to be slightly cooler, indicating a minor upwelling. By the end of June, there is an increase in the easterly wind in the western equatorial Atlantic that brings up cold SACW to replace the TSW (Moore et al., 1978). When the thermocline breaks, it signals the onset of the major upwelling. The sea surface temperature can fall from 30°C in May to 18°C in August.

The subsurface system appears to comprise all the principal water masses of the South Atlantic. In the tropical regions of the Atlantic, a relatively thin superficial stratum of TSW of high temperature and of varying salinity overlies a density discontinuity layer at the thermocline. The horizontal extent of the TSW in the central Atlantic is determined by the position of the Tropical Convergence where the south-flowing TSW meets the north flowing SACW. This convergence generally occurs at approximately the 10°S latitude in the eastern half of the Atlantic Ocean, but as far as 25°S in the western half, thus reflecting the effect of the gyral current system of the South Atlantic.

The SACW lies below the discontinuity layer and has a characteristic temperature-salinity profile. The salinity is 35 percent at 6°C, and 36 percent at 18°C (Longhurst, 1962; Houghton, 1983). There are three other types of water masses below the SACW: the AIW, NADW, and Antarctic Bottom Water. AIW originates in the Antarctic region as sinking Antarctic Surface Water moves towards the equator. The AIW and NADW are relatively homogenous, but the latter is more saline and denser than all the other water masses.

Existing Pollution

The potential threat of pollution in the marine environment is mainly from industrial, agricultural, and domestic sources. More than 250 industries are located in the coastal zone, mainly within the Accra-Tema metropolis and a few in the Sekondi-Takoradi urban area. Most of these industries discharge their wastes, either untreated or only partially treated, into drains which eventually end up in the sea. Available data on heavy metal concentrations in bottom sediments have revealed the presence of zinc, lead, copper, chromium and nickel in varying quantities (Ihenyen, 1998). However, investigations conducted on impacts of these pollutants on water quality and aquatic organisms in the coastal waters suggest that heavy metal levels have not yet reached undesirable toxic levels (Biney, 1986). It must be noted that much of the industrial activity has taken place only within the last decade, and therefore, resulting in heavy metal pollution may not show up until a later time.

The work of Joiris et al. (1997) indicates increasing effects of DDT, aldrin, and heptachlor in the coastal waters. Other work by Nyarko and Evans (1997) has also indicated the effects of tributylin (a compound used in the manufacture of antifouling paint used on ship hulls) on marine mollusk populations (*Thais haemostoma* and *T. nodosa*) from Tema.

The present situation, where a quarter of the population lives in the coastal zone, has brought about an increase in the amount of domestic waste discharged (untreated) into the marine environment. There has been concurrent fecal and nutrient-pollution of the marine environment, especially in high pollution areas such as Tema and Takoradi (Afoakwa et al., 1988; Wiafe and Quist, 2002).

1.4.4 Biological Setting

Biological Environment

Habitats in the project area include terrestrial, intertidal habitats of rocky and sandy shore organisms, and inshore and offshore habitats encompasing planktonic, nektonic, and benthic organisms. Other identifiable habitats include a coastal lagoon at Tema (the Gao Lagoon) and a wetland at Aboadze. While the R&M stations are not in or very near the Gao Lagoon, this report describes the area for informational purposes.

The vegetation at the Aboadze R&M site consists of coastal strand, characterized by flora of the *Cyperus-Ipomeoa* Association, which is dominated by: *Cannavalia obtusifolia*, *Cocos nucifera*, *Cyperus articulatus*, *C. maritimus*, *Imperata cylindrica*, *Ipomoea pes-caprae*, *Opuntia vulgaris*, *Paspalum vaginatum*, *Phoenix reclinata*, *Sporobolus virginicus*, *Thespesia populnea,* and *Triumfetta rhomboidea*. The major soils of the area are forest and coastal savanna ochrosols. Forest ochrosols develop in forest and savanna environments with rainfall between 900mm and 1650mm. The organic matter content of such soils is low, with pH generally less than 5.5. Coastal savanna ochrosols are mainly red and brown, moderately well drained, medium to light-texture soils, which developed over Voltaian sandstone, granite, phyllites and schists. They are also generally low in organic matter due to insufficient accumulation of biomass (less than 2 percent in the topsoil). Soil acidity ranges from near neutral (pH 6.0-7.0) near the surface, to moderately acidic with depth. The actual habitats surveyed were characterized by wetlands with burnt portions, which are prone to flooding during the rainy season. The area is dominated by coconut trees, grass, and thicket "islands."

The vegetation at the Tema R&M site consists of coastal scrub and grassland characterized by coastal grassland/thicket, having an almost continuous grass layer with small thicket "islands" and numerous termite mounds. Dominant floral species include: *Abutilon* spp., *Allophyllus warneckei, Andropogon* spp.*, Cassia mimosoides, Ctenium* spp., *Grewia carpinifolia, Heteropogon contortus, Securinega virosa,* and *Vetiveria* spp.. The area is characterized by lateritic sandy soils, which are either sandy or gravely in texture, and generally form the bulk material for the construction and building industries. The habitats surveyed were generally characterized by coastal grassland and neem tree thickets, interspersed with food crop farms of cassava, maize, okro, and pepper.

A list of possible fauna likely to be associated with the characteristic vegetation described above is presented in Table 1.4 -1.for the Aboadze swamps and the Tema strand vegetation.

Table 1.4-1
Possible Fauna Associated with the Vegetation at the R&M sites

Species	**Common Name**	**Likely-occurring Species**	
		Aboadze	**Tema**
Amphibia			
Bufo regularis	Common Toad	X	X
B. superciliaris	Giant Toad	X	
Dicroglossus occipitalis	Common Frog	X	X
Hylarana galamensis	Common Frog	X	X
H. viridiflavus	Common Frog	X	
Phrynobatrachus accraensis	Sharp-nosed Frog		X
Reptilia			
Chelonia (Tortoises/Terrapins)	Hinged Tortoise	X	
Kinixys homeana	Marsh Terrapin	X	X
Pelomedusa subrufa			
Squamata: Lacertilia			
Agama agama	Rainbow Lizard	X	X
Chamaeleo gracilis	Chameleon	X	X
Hemidactylus brookii	House (Wall) Gecko	X	
Lygodactylus conraui	Gecko	X	
Mabuya affinis	Skink	X	X
M. perroteti	Orange-flanked Skink	X	X
Panaspis togoensis	Skink		X
Varanus exanthematicus	Savanna Monitor	X	X
V. niloticus	Nile Monitor	X	X
Squamata: Serpentes			
Bitis arietans	Puff Adder		X
Causus maculates	Night Adder		X

		Likely-occurring Species	
Species	**Common Name**	**Aboadze**	**Tema**
Dasypeltis scabra	Egg-eating Snake	**X**	**X**
Dendroaspis viridis	Green Mamba		**X**
Lamprophis fuliginosus	House Snake		**X**
Naja melanoleuca	Black Cobra	**X**	
N. nigricollis	Spitting Cobra		**X**
Philothamnus semivariegatus	Green Tree Snake		**X**
Psammophis sibilans	Hissing Sand Snake		**X**
Python regius	Royal Python	**X**	**X**
P. sebae	African Python	**X**	**X**
Rhamphiophis oxyrhynchus	Beaked Snake		**X**
Thelothornis kirtlandii	Twig Snake	**X**	**X**
Aves (Birds)			
Ardeidae			
Ardea cinerea	Grey Heron	**X**	
Bubulcus ibis	Cattle Egret	**Xx**	**X**
Egretta garzetta	Little Egret	**Xx**	
Nycticorax nycticorax	Night Heron	**Xx**	
Accipitricidae			
Buteo augularis	Red-tailed Buzzard	**X**	**X**
Milvus migrans	Black Kite	**X**	**X**
Neophron monachus	Hooded Vulture	**X**	**X**
Falconidae			
Falco naumanni	Lesser Kestrel		**X**
Phasianidae			
Francolinus ahantensis	Ahanta Francolin	**X**	
Ptilopachus petrosus	Stone Partridge		**X**
Charadriidae			
Charadrius hiaticula	Ringed Plover		**X**
Haematopus ostralegus	Eurasian Oystercatcher		**X**
Himantopus himantopus	Black-winged stilt		**X**
Jacanidae			
Actophilornis africana	African Jacana		**X**
Burhinidae			
Burhinus senegalensis	Senegal Thick-knee		**X**
Columbidae			
Columba livia	Pigeon		**X**
Streptopelia semitorquata	Red-eyed Dove	**X**	**X**
S. senegalensis	Laughing Dove	**X**	**X**
Turtur afer	Red-billed Wood-dove	**X**	**X**
Psittacidae			
Agapornis pullaria	Red-headed Lovebird	**X**	
Musophagidae			
Crinifer piscator	Grey Plantain-eater	**X**	**X**
Tauraco persa	Green-crested Touraco		**X**
Cuculidae			
Centropus senegalensis	Senegal Coucal	**X**	**X**
Ceuthmocares aereus	Yellow-bill		
Chrysococcyx klaas	Klaas Cuckoo	**X**	**X**

Species	**Common Name**	**Likely-occurring Species**	
		Aboadze	**Tema**
Apodidae			
Apus affinis	Little Swift	X	X
Cypsilurus parvus	Palm Swift	X	X
Alcedinidae			
Ceryle rudis	Red/Pied Kingfisher	X	X
Halcyon malimbicus	Blue-breasted Kingfisher	X	
H. senegalensis	Senegal Kingfisher	X	
Bucerotidae			
Tockus fasciatus	Allied Hornbill	X	
T. nasutus	Grey Hornbill	X	X
Capitonidae			
Lybius vieilloti	Vieillot's Barbet		X
Pogoniulus subsulphureus	Yellow-fronted Tinkerbird		X
Corvidae			
Corvus albus	Pied Crow	X	X
Estrildidae			
Estrilda melpoda	Orange-cheeked Waxbill	X	
Lonchura cucullata	Bronze Mannikin	X	X
Nigrita canicapilla	Grey-crowned Negro-finch	X	
Hirundinidae			
Hirundo rustica	European Swallow		X
Laniidae			
Laniarius barbarus	Barbary Shrike		X
Lanius collaris	Fiscal Shrike	X	
Muscicapidae			
Cossypha niveicapilla	Snowy-crowned Robin-chat		X
Platysteira cyanea	Scarlet-spectacled Wattle-eye	X	X
Terpsiphone rufiventer	Red-bellied Paradise Flycatcher	X	
Trochocercus nitens	Blue-headed Crested Flycatcher	X	
Nectariniidae			
Nectarinia chloropygia	Olive-bellied Sunbird	X	
N. coccinigaster	Splendid Sunbird		X
N. cuprea	Copper Sunbird	X	
N. fuliginea	Carmelite Sunbird	X	
N. olivacea	Olive Sunbird	X	
N. oritis	Blue-headed Sunbird	X	
Ploceidae			
Euplectes orix	Red Bishop	X	X
Hirundo abyssinica	Lesser-striped Sparrow	X	
Lonchura cucullata	Bronze Mannkin	X	X

Species	Common Name	Likely-occurring Species	
		Aboadze	**Tema**
Malimbus scutatus	Red-vented Malimbe	X	
Passer griseus	Grey-headed Sparrow	X	
Ploceus cucullatus	Village Weaver	X	X
P. nigricollis	Spectacled Weaver	X	X
Tchagra senegala	Black-crowned Tchagra	X	X
Pycnonotidae			
Andropadus curvirostris	Cameroon Sombre Greenbul	X	
A. virens	Little Greenbul	X	
Chlorocichla simplex	Simple Leaf-love	X	X
Nicator chloris	West African Nicator	X	
Pycnonotus barbatus	Common Garden Bulbul	X	X
Sturnidae			
Lamprotornis purpureus	Purple Glossy Starling		X
Sylviidae			
Camaroptera brachyura	Grey-backed Camaroptera		X
Cisticola natalensis	Striped Cisticola		X
Hylia prasina	Green Hylia	X	
Prinia subflava	West African Prinia	X	X
Timaliidae			
Turdioides plebejus	Brown Babbler		X
T. reinwardii	White-capped Babbler		X
Turdidae			
Luscinia megarhynchos	Nightingale		X
Turdus pelios	West African Thrush	X	X
Mammalia			
Insectivora			
Crocidura oliveri	White-toothed Shrew	X	
Erinaceus albiventris	White-bellied Hedgehog		
Chiroptera			
Eidolon helvum	Straw-coloured Fruit Bat		X
Primates			
Cercopithecus aethiops	Green Monkey/Guenon		X
C. mona	Mona Monkey	X	
Galago senegalensis	Senagal Galago	X	
Galagoides demidoff	Demidoff's Galago		X
Perodicticus potto	Bosman's Potto	X	
Rodentia			
Arvicanthis niloticus	Rufous Nile rat		X
Atherurus africanus	Brush-Tailed Porcupine	X	
Cricetomys gambianus	Gambian Giant Pouched Rat	X	X

		Likely-occurring Species	
Species	**Common Name**	**Aboadze**	**Tema**
Dasynys incomtus	Shaggy Swamp Rat	X	
Euxerus erythropus	Unstriped Ground Squirel		X
Hystrix cristata	Crested Porcupine	X	
Lemniscomys striatus	Spotted Zebra Mouse	X	
Lophuromys flavipunctatus	Brush-furred Mouse	X	
Mastomys erythroleucus	Multimammate Mouse	X	X
Praomys tullbergi	Soft-furred Rat		X
Rattus rattus	Common Rat		X
Thryonomys swinderianus	Grasscutter	X	X
Lagomorpha			
Lepus zechi	Togo Hare		X
Pholidota			
Phataginus tricuspis	Tree Pangolin	X	
Uromanis tetradactyla	Long-tailed Pangolin	X	
Carnivora			
Civettictis civetta	African Civet	X	
Mungos gambianus	Gambian Mongoose	X	X
Hyracoidea			
Dendrohyrax dorsalis	Tree Hyrax	X	
Procavia ruiceps	Rock Hyrax		X
Artiodactyla			
Cephalophus maxwelli	Maxwell's Duiker	X	X
Neotragus pygmaeus	Royal Antelope	X	X
Potamochoerus porcus	Red River Hog	X	
Tragelaphus scriptus	Bushbuck	X	X

The inshore and offshore phytoplankton can be grouped as diatoms, dinoflagellates, and coccolithophores. They are microscopic and range between 30µm and 60µm in size. Their occurrence is limited to the euphotic zone of the pelagic environment. Species diversity and abundance is linked to seasonal variation of the oceanographic regime; namely, high diversity and low abundance during thermal stratification, and low diversity but high abundance during upwelling periods (Wiafe, 2002).

Diatoms normally dominate the phytoplankton community, especially during the major upwelling season when the water temperature is relatively cold (20°C to 25°C) and conducive for their growth. Dinoflagellates, on the other hand, thrive well when the temperature is above 25 °C. The principal species of diatoms recorded in Ghana during the upwelling belong to the genera *Skeletonema, Nitzschia, Chaetoceros, Rhizosolenia,* and *Thalassiosira*.

Dinoflagellates are better adapted to survive under conditions of low nutrient levels (Harris, 1986), and thus abound during periods of thermal stability. For example, *Ceratium* spp. exhibit slow growth rate and have low nutrient requirements.

Other planktonic groups, while normally sparse, can become prolific. For example, chaetognaths can become more abundant in September to November. Very marked proliferation of thaliaceans, mainly *Thalia democratica*, can occur in December and July, while appendicularians can be more abundant in June and October (Thiriot, 1977). The explosive development of these plankton groups in the offshore and inshore locations have a rippling effect on the development of the fishery of the nearshore and adjoining coastal water bodies as much production is made available to the fishery of the nearshore habitats.

Benthic Organisms

The benthic macrofauna within inshore habitats have been described by Bassindale, (1961), Buchanan (1957), Edmunds (1978), and Evans et al. (1993). The organisms include polychaetes, arthropods, molluscs, bryozoans, and echinoderms. Edmunds (1978) has recorded 68 taxonomic families of molluscs. Some species appear to be declining in abundance (e.g., *Cymbium* spp., a gastropod; and *Panulirus* spp., the spiny lobster), while others have disappeared altogether (e.g., *Astropecten* spp., a sea star; Armah and Amlalo, 1998).

Sea turtles

At present, five species of sea turtles have been identified in Ghanaian waters (Armah et al., 1997a). These are the leatherback (*Dermochelys coriacea*), the hawksbill (*Erectmochelys imbricata*), green turtle (*Chelonia mydas*), the loggerhead (*Caretta caretta*) and the most abundant of all, the olive ridley (*Lepidochelys olivacea*). The hawksbill is very rare and only seen occasionally. In Ghana, sandy beaches constitute about 70 percent of the coastline and stretches from the western border with Cote d'Ivoire to Axim, and from the east of Tema to the border with Togo. The prime turtle nesting sites are located within the rapidly eroding sites between Tema and the Volta estuary. The nesting period has been reported to begin as early as July to March, with a peak in November (Armah et al., 1997b).

Hydrobiology and Fisheries

The aquatic systems associated with the project areas include the open Gao lagoon, the adjoining sea at the Tema site, and the swamp complex, as well as the Anankware Lagoon and the adjoining sea at the Aboadze site. The near shore fishery forms part of the prolific and dynamic fishery complex that characterizes the whole Ghanaian coastline. The open lagoon systems of Gao at Tema and Anankware, near Aboadze, facilitate year-round fishing, the intensity of which is dictated by the nature and dynamics of the inshore and offshore artisanal fishery. The Aboadze swamps, in contrast, comprise a dense growth of aquatic and semi-aquatic vegetation, as well as the typical swamp forest vegetation. The complex nature of the swamp setting in Aboadze restricts the nature of fishing exploitation to the use of basket traps and occasional use of hook and line.

The hydrobiological regime of the water bodies is equally complex. While the Gao Lagoon maintains a twice-daily flushing regime from tidal water, it nonetheless receives a lot of exogenous materials from the catchment area which are comprise of domestic waste and industrial effluents of anthropogenic origin. The soft bottom terrigenous ooze is largely derived from a combination of sea waves-deposit sand and accumulation of allochthonous materials, including eroding soils, derived from farming activities within the catchment area. The general vegetation along the banks of the lagoon is largely strand. Although there are luxuriant stands of mangrove swamps along the Eastern banks of the lagoon, its distribution is very patchy and appears to be a direct result of conservation practice put up by the local Kpone community, which uses the area as a shrine. The distribution of the mangrove swamps becomes more patchy further upstream in the northeastern and northwestern directions of the lagoon. The water quality parameters are expected to follow trends typified by stressed coastal water bodies. The elemental contamination of the terrigenous sediment is expected to follow trends that will reflect the contents of the industrial wastes that are indirectly discharged into the system. The microbial load is also expected to reflect the extent and type of domestic waste discharged into the system.

Although information on the productivity of the lagoon is scarce, the lagoon has been described as being moderately rich in fish and other shellfish species (Adomako and Armah, 1989). Some of the species recorded in the lagoon are *Tilapia* spp. and several juvenile marine fishes that follow the tide to forage in the coastal lagoons and other nearshore water bodies. The narrow strip of mangrove forest that lines the eastern bank of the lagoon may be a major breeding ground for some marine fishes (Adomako and Armah, 1989).

At Aboadze there is a *Cyperus articulatus*-dominated wetland (Oteng-Yeboah, 1994) near the pipeline route and the R&M station. During the wet season, the entire wetland area becomes flooded and joins the nearby Anankware lagoon, located to the southwest of the proposed R&M site. This allows for a cross transport of materials bidirectionally between the freshwater and the sea. The biota has been described as varied and diverse. The wetland is also thought to harbour fishes and edible crabs (Adomako and Armah, 1989).

A checklist of expected terrestrial faunal forms likely to be associated with the Aboadze and Tema areas is provided in Table 1.4-1. Another checklist of expected fish and fisheries resources expected to be associated with the water bodies in Tema and Aboadze is provided in Table 1.4-2.

Table 1.4-2
Species of fish and shellfish expected from onshore water bodies and the near shore fishery

Fish Species	Sakumono Near Shore Fishery	Gao Lagoon	Anankware Lagoon	Aboadze Swamps
Alectis alexandrinus	X	X	X	
Balistapus aculeatus	X			
Balistes punctatus	X			
Balistes capriscus	X			
Bothus podas africanus	X	X	X	
Brachydeuterus auritus	X	X	X	
Caranx crysos	X	X		

Caranx hippos	X	X		
Caranx senegallus	X			
Chloroscombrus chrysurus	X	X	X	
Cynoglossus monodi	X	X	X	
Cynoglossus senegalensis	X			
Daysatis margarita	X			
Decapterus punctatus	X	X	X	
Decapterus rhonchus	X			
Drepane africana	X			
Echeneis naucrates	X			
Elops lacerta	X	X	X	
Engraulis encrasicolus	X			
Ephippion guttifer	X			
Epinephelus aeneus	X	X	X	
Ethmalosa fimbriata	X		X	
Eucinostomus melanopterus	X			
Fodiator acutus	X			
Galeiodes decadactylus	X	X	X	
Gerres nigri	X	X	X	
Hemiramphus brasiliensis	X			
Hemicaranx bicolor		X	X	
Ilisha africana	X	X	X	
Lagocephalus laevigatus	X	X		
Lagocephalus lagocephalus	X			
Lethrinus atlanticus	X			
Lichia amia	X			
Liza falcipinnis	X	X	X	
Monacanthus setifer	X			
Melicthys niger	X			
Pellonula leonensis	X	X	X	
Pentanemus quinquarius	X	X	X	
Plectoryhncus macrolepis	X			
Pomadasys rogerii	X	X	X	
Polydactylus quadrifilis	X	X	X	
Priacanthus arenatus				
Pseudotholithus brachygnathus	X			
Pseudotholithus elongatus	X	X	X	
Pseudotholithus senegalensis	X			
Pseudotholithus typus	X			
Rhinobatus cemicullus	X			
Sarda sarda	X			
Sardinella aurita	X	X	X	
Sardinella maderensis	X	X	X	
Sarotherodon melanotheron	X	X	X	
Selene dorsalis	X	X	X	

Sphyraena sphyraena	X	X	X	
Stromateus fiatola	X			
Torpedo nobliana	X			
Trachinotus glaucus	X			
Trachinotus goreensis	X	X	X	
Trachinotus ovatus	X			
Trichiurus lepturus				
Fish Species	**Sakumono Near Shore Fishery**	**Gao Lagoon**	**Anankware Lagoon**	**Aboadze Swamps**
Tylosorus crocodilus crocodiles	X			
Umbrina canariensis	X			
Umbrina steindachneri	X			
Clarias sp.				X
Hemichromis bimaculatus				X
Hemichromis fasciatus				X
Heterobranchus sp.				X
Heterotis niloticus				X
Parophiochalus obscurus				X
Polypterus sp.				X
Tilapia zilli				X
Crustaceans				
Callinectes marginatus	X	X	X	
Callinectes pallidus	X	X	X	
Gymnura sp.	X			
Exhippolysmata hastatoides	X			
Nematopalaemon hastatus	X			
Panulirus regius	X			
Paramola cuvieri	X			
Parapeneopsis atlantica	X	X	X	
Parapenaeus longirostris	X	X	X	
Penaeus notialis	X	X	X	
Penaeus kerathurus	X	X	X	
Plesiopenaeus edwardsianus	X			
Isopod	X			
Amphipods	X	X	X	
Molluscs				
Ostrea sp.		X	X	

1.5 TOGO BACKGROUND

The stretch of seacoast identified for the laying of the gas pipeline is mainly a sandy beach, which has recently begun to recede as a result of erosion. It is situated on the outskirts of

Lomé between the village of Gbetsogbe and the Ramatou hotel. The distance between the north and south ends of the onshore route zone is one kilometer. This zone is heavily used and displays homogeneous features. Figure 1.5-1 shows the Togo project location.

1.5.1 Geological Setting

The geology of the seaboard is essentially comprised of sand deposits. The features of the sea coastline are made up of two generations of offshore strips: the internal sand bar and external sand bar.

The internal or yellow sand bar is comprised of continental deposits from the Zio River. This bar is established on the northern part of the coastline and is found at various sections of the lagoon system. It is made up of fine-to-medium homogeneous sand in a proportion ranging from 88 to 91 percent.

The external offshore bar is an alignment of sand deposits parallel to both the coast and to the undulating topographic surface. It is oriented to the east in the direction of the coastal drift and made up of medium to coarse sand with elements of broken or whole shells.

Coarse sand is found high up the beach whereas finer sand is found offshore. In the lagoon zone, the sand mixes with lagoon silt deposits.

Bathymetry and Coastal Geology

The continental shelf is narrow in the project area, and approximately 10km in width. The shelf breaks into the slope at approximately the 100m isobath. A reef of dead madreporarian coral lines the seaward edge of the continental shelf thoughout the project area.

The origin and evolution of the Gulf of Guinea shelf dates as far back as the Cretaceous Period, about 135 million years ago, when the South American plate separated from the African plate. Continued separation of the two continents has produced recognizable margins and deep ocean fracture zones. The separation has produced subsiding basins and troughs where marine and continental sediments are deposited. Bedrock consists of hard granite, granodiorite, metamorphosed lava, and pyroclastic rock. In some areas, these are covered by Ordovician, Silurian, and Devonian sandstone and shales (Allersma and Tilmans, 1993).

Along the coastline, currents move sands from west to east, forming a barrier beach system along much of the coastline. This littoral drift is interrupted at Lomé by groynes built to reduce shoreline erosion.

Soils and Terrain Topography

In Togo, the soils are largely made up of iron and manganese sesquioxides and ferralitic soils, which cover about 75 percent of the land as a whole, with less fully developed raw mineral soils (making up 15 percent), vertisols, and hydromorphic soils, largely accounting for the remainder.

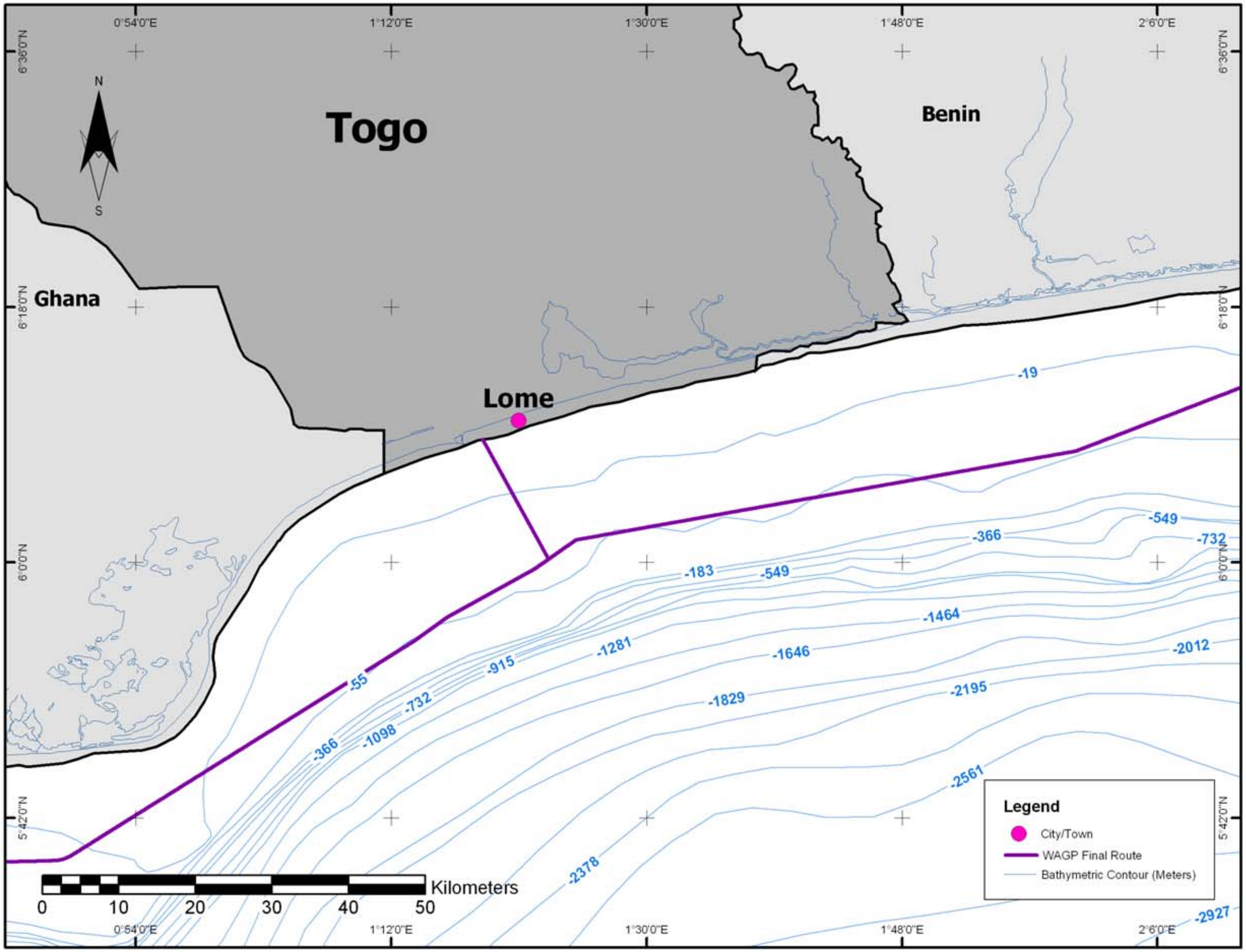


Figure 1.5-1 - Togo Location Map

The soils of the coastal strip are apparently uniform, but fall into two categories. Firstly, raw mineral soils made up of marine deposits along the shore, under a fringe of a few tens of meters, are recent deposits of mainly sand and quartz materials, and with no organic matter or clay content. Their moisture (at ground surface level 50m from the sea and after 6 hours) is about 2 percent. These soils are brownish-grey, sandy and show particular structures. They are lacking in plant-assimilable elements, are unfit for agriculture, and support no vegetation. They are used in the urban areas as quarries for the extraction of building materials: sand, fine gravels, shells, etc. As a result of erosion along the coastline and pollution from nearby settlements, they correspond to the zone most exposed to degradation.

Secondly, the less-fully formed soils, made up of marine materials deposits, exhibit a thick profile differing little from the parent material. They differ from the raw mineral soils by the formation of an A profile of 15 to 20cm, brownish-grey in colour, sandy, slightly humiferous and of a weak, curdled structure. This soil contains a large number of roots of coconut trees, grasses and sedges. The texture of the soils is sandy, their organic matter content low, and it has notable lack of water-retention capacity.

With the application of fertilizer and irrigation, food crops and garden-market produce may be cultivated on these soils. Thus certain farmers take advantage of this technique to practice a so-called "urban agriculture." It is practiced on the coastal strip year-round by watering the soils daily. This practice has taken on an unprecedented magnitude and provides the urban population of Lomé with vegetables.

1.5.2 Meteorology

The mean annual rainfall in the region ranges from 500 to 2000mm. During the rainy season, daily rainfalls of 50 to 140mm can occur. High temperatures throughout the year, common near sea level in the equatorial zone, prevail in the project area. Mean annual temperatures vary between 30.4°C and 32°C. During the extreme hot weather period from November to January, temperatures vary between 32°C and 34°C, and low temperatures of about 28°C occur during July and August.

1.5.3 Physical and Chemical Oceanography

The physical and chemical oceanography of the coastal waters is characteristic of that described in Section 1.3.

1.5.4 Biological Setting

<u>Vegetation</u>

Greater Lomé, up to and around the Ramatou hotel, is located in the Togolese coastal plain (Ern, 1979).

Among these vegetation formations, there are certain notable characteristics:

- The most frequently occurring marine grass and grass-asssociated species are: *Remires maritima*, *Sporobolus virginicus*, *Commelina erecta, Dactyloctnium egyptium,* and *Canavalia roseus*;

- Littoral grass savann with scattered pure clusters of certain species such as *Aristida sieberiana* and *Aristida adscensionis*;

- Bushes scattered in these littoral savannas, which are marked by a codominance of species akin to the Guineo-Congolese and Sub-Guinean species (forest-type); and

- Fallow areas near coconut plantations or bordering small isolated sacred forests; the characteristic species of these communities are: *Cleome viscsa, Phyllanthus amarus, Spermacoce radiata, Passiflora foetida, Aneilema beninense, Portulaca olerecea, Andropogon gayanus, Indgofera arreeta, Indgofera pilosa,* and *Ahysicarpus glumaceus*.

Besides these typical seashore formations, there exist patchily distributed thickets of *Balanites aegyptiaca*, some of which are dense. The presence of these thickets, of the *Aristida adescensionis* clusters, and of isolated stocks of *Parinari macrophylla*, all akin to the Sudanese species, is an indication of the poor quality of the strata coupled with the very low rainfall records in recent years.

Also worth noting is the presence of fragments of sacred forests at Amédéhoevé, Bè and Togoville. Kokou et al. (1999). There have elucidated the dynamism of the littoral vegetation in this place where anthropogenic influence dates back to the ancient times resulting in heavy degradation. Considerable coastal erosion, which has been exacerbated by the construction of the Lomé Port Authority (Togo), has contributed to the loss of biotopes of certain plant species on the coastline (Akpagana, 1992).

Fisheries

Species generally associated with the maritime fishing industry include: *Brachydeuterus auritus*, *Dentex* spp., *Epinephelus* spp., Scianidae, and Lutjanidae. A summary of fish catch data is provided in Table 1.5-1.

Table 1.5-1
Catches Connected With the National Fishing Industry
(in tonnes)

	1998	1999	2000	2001
Small scale fishing	13,80	21,876	17,277	18,163

	6			
Maritime industrial fishing	707	NA	NA	NA
Total	14,513	17,927	17,277	18,163

NA: not available

Daytime trawling research cruises were conducted in the western zone of the Gulf of Guinea (Benin, Côte d'Ivoire, Ghana, and Togo) in 1999, 2000 and 2002. In 2000, the biomass of certain clupeids such as *Sardinella aurita* and *S. maderensis* was estimated at 4,000tn. Anchovy biomass was estimated at 25,000tn. In 2000, the biomass of the group of fish comprised of the carangids, scombrids, barracudas and swordfish was estimated at 2,500tn. In 1999, the results of Benin and Togo combined yielded a total of 9,000tn of biomass for the same group of species (FAO, 2002).

<u>**Marine Birds, Mammals, Reptiles and Amphibians**</u>

According to the results obtained from water bird counts (DFC/OMPO, 2001), 53 species belonging to 17 families have been identified in the coastal zone. Most of these species are paleartic migratory birds. They breed in the damp zones of Europe with the African dam zones serving as their inter-nuptial and hibernation grounds. The period of observation of these species on the Togolese coast is between November and February. The main sites of observation of these migratory birds on the Togolese coast are: the Wharf of Lomé, the main jetty of the port, the Aneho Lagoon and the Mono River. Including water birds (pelicans, cormorants, limicoles, ducks, and ardreids) West Africa has 122 bird species, most of which visit the coast of Togo. The presence of juvenile birds indicated of the probable existence of feeding and breeding grounds of these species off the Togolese coasts. These are pelicans, cormorants, egrets, storks, ducks, and limicoles.

The Atlantic shore of Africa (14,000km) has migration corridors, feeding grounds and nesting sites of great importance for six (6) species of marine turtles, namely *Caretta caretta*, *Chelonia mydas*, *Lepidochelys kempii*, *L. olivacea*, *Eretmochelys imbricata*, and *Dermochelys coriacea*. Of these species four (4) are found in Togo: *C. mydas*, *E. imbricata*, *L. olivacea*, and *D. coriacea*. The breeding sites of turtles can be identified relatively easily. Many young *C. mydas* and *E. imbricata* were identified on the Togolese coast, namely on the beaches at Gbétsogbé and Agbodrafo. In fact, hatching areas have been identified on the coast of Togo at Agbodrafo, Gbetsogbe, Ablogame, and Aneho.

The presence of two types of cetacean species is noted on the coast of Togo, including: whales and toothed dolphins. Fishing resources are great and numerous, and sea-mammals are frequently found among them in the Gulf of Guinea at particular seasons, due to the relationship of cetacean movement and the sea surface temperatures.

1.6 BENIN BACKGROUND

Figure 1.6-1 shows the location of the proposed project in Benin.

1.6.1 Geological Setting

Coastal Geology

Trapezoidal in shape and cornered in the Gulf of Guinea, the Beninese continental plateau covers a surface area slightly more than 2800km^2 between isobaths 10 and 100m, but reaching 3,000km^2 at a depth of 200m, according to the estimates of COPACE (TROADEC and Coll. 1979). Extending over about 110 km of coastline, its width varies between 22 and 24km in the west up to Ouidah and reaches 31.50km at the Benin-Nigerian border in the east. Figuer 1.6-1 shows the Benin project location.

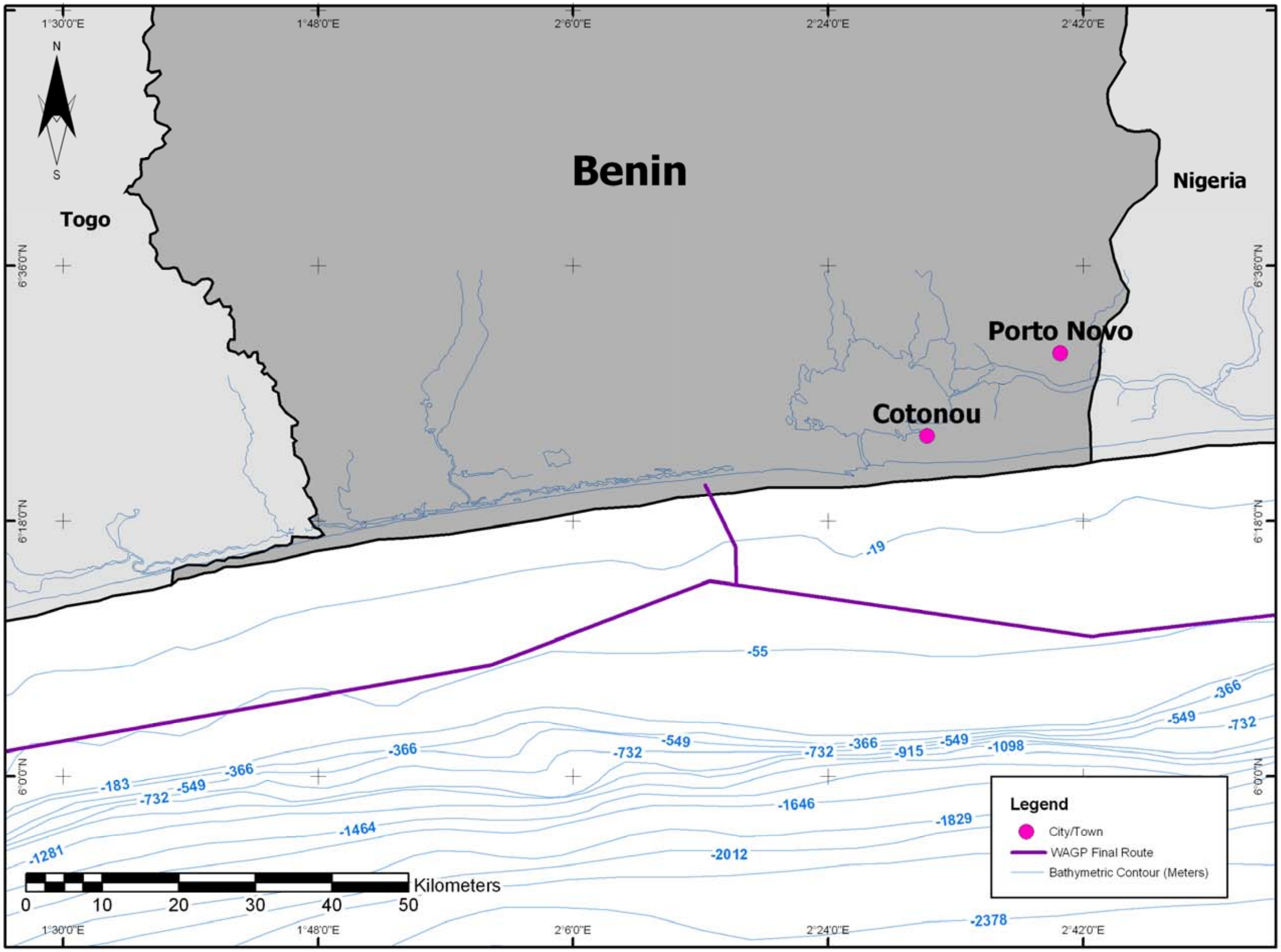


Figure 1.6-1 - Benin Location Map

At a depth of approximately 35m from Agoué to Ouidah-Beach, and between 35 and 45m from Godomey-Beach to Sèmè-Beach, a slight break in the slope marks the end of the shelf at a coral reef located at an average depth of 55m. From this barrier to around the talus, one observes numerous scattered rocky outcrops that greatly limit demersal trawling in these zones.

Waves break obliquely on the Benin shore and transport sediments generally toward the east. The shoreline segment where the pipeline is proposed to cross, between Djègbadji and Adounko-Plage, is generally a stable area, although some areas (near Togbin, for example) are susceptible to erosion.

Dredging operations carried out during the ″OMBANGO″ campaigns of 1963 revealed the existence of four types of bottoms arranged in parallel bands following isobaths 10 to 100m (Crosnier and Berrit 1966). These four types of sediments are described below.

- **Hard bottoms** (two categories).
    - Gorgonian bottoms, located at a depth of less than 15m east of Grand-Popo and near Godomey. They are made up of clayey-ferruginous cement micro-conglomerates covered with gorgonia in several places.
    - Coral bottoms, represented by a coral barrier stretching between Ouidah and Cotonou at a depth of 52 to 56m. From this barrier up to the fall of the plateau, numerous rocky peaks are scattered. These coral formations apparently date back as far as the Holocene period like those studied in Nigeria (Allen and Wells, 1962).
- **Muddy sand bottoms.** These bottoms, which contain 5 to 25 percent colloidal powder, are divided into two major sectors: coastal bottoms developed up to 17m deep around the mouths of lagoons and rivers which coincide with the pass from Boca del Rio to Grand-Popo and that of the Cotonou lagoon, and the sector parallel to the coast, which is less than 4m wide beyond 35m. It presents a slight slope break in its lower boundary located at a depth of 45m.
- **Sand bottoms.** Relatively more homogenous, they contain less than 5 percent powder and colloids and extend to a depth of 35m. These are coarse sand mixed with gravels within 20 to 30m with little rocky or coralline outcroppings. The width of these bottoms vary from one place to the other; 12km in front of Agoué, 8km between Avlo-Beach and Ouidah, where they are more or less muddy, and 13 to 15km east from Cotonou.
- **Sandy mud and muddy bottoms.** The sandy mud, which contains 25 to 90percent powder and colloids, and the mud, with more than 90 percent, occupy the deep part of the continental plateau respectively east of Ouidah. These bottoms, which appear from 45m deep, are about 6km wide between Hila - Kondji and Agoin - Houta, but only 300 to 500m behind the coral barrier up to Cotonou and beyond. They are also spiked with coralline or rocky outcrops.

Onshore Geology

Grey and brown sands are found along lagoon depressions. Mainly quartzous, they are average, coarse-grained sands with increasing clay content near the depressions. Clay content varies between 5 percent and 25 percent. Yellow sands are average to fine-grained sands that contain small amounts of clay, i.e., less than 10 percent. In sand quarries, they appear in bulk without sedimentary formations and fossils. A is a clay and sand formation made up of lateritic clays that result from the destruction of old soils. Bars are characterized by well-pronounced sedimentology. There can also be soil formation on the bars as a result of organic matter deposition. The pipeline ROW crosses three generations of bars separated by depressions. From south to north, they are as follows:

- A narrow, brown sandbar that stretches parallel to the sea. Its plane morphology shows intertwining ripples and butts at the local level;
- A first depression that results in lagoons such as the one south of Togbin and Adounko villages;
- A grey sandbar, 2 to 4m high, such as that which lies between the Wegba depression in the north and the coastal lagoon in the south. The edge of the lagoon is made up of wetlands and sandy spits. The whole area is mostly flooded during the wet seasons;
- A second depression named Wegba, such as that between Godomey and Dekoungbe. This depression is connected to Lake Nokoue;
- A “yellow sandbar” such as that which lies between Ouidah and Cotonou. Its height varies from 5 to 6m, with some ridges reaching up to 7m high;
- A third depression, which is about 400m wide, stretches along the south edge of the plateau. This is the west-east oriented Djonou depression from Cococodji to Godomey. It has nearly permanently flowing water, contributed by Towo, Todouba, and Date Rivers. These rivers drain the tablelands en route to Lake Nokoue; and
- A bar plateau with altitudes reaching 40m to 50m in the southern part of Abomey Calavi.

1.6.2 Meteorology

The climate of the Gulf of Benin is classified as “beninian” (subequatorial) with two rainy seasons (mid-March to July and September to November) and two dry seasons. The average rainfall is 1,200mm per year, decreasing toward the west (1,400mm per year in Sémè and 850 mm per year in Lomé); the decrease is due to the configuration of the coast in relation to the marine winds. The temperature is constantly high (yearly average is 27°C) with the average maximum in March (33°C) and the average minimum in August (25°C) when temperatures can fall to 22.5°C. The months of January, February and March exhibit high thermal amplitudes (12°C). These variations are reduced during the rainy season.

The predominant direction of the wind is from the southwest with average speeds of 4 to 6m/s (3). The winds from the south-southeast sector are infrequent and they blow in April and May. Because of the relatively even relief, the pattern of winds does not vary much according to seasons. In the dry season, the wind strength is weak-to-moderate (2 to 5m/s) in the morning. It is stronger during the day (5 to 7m/s) and becomes moderate in the evening and at night (4 to 6m/s). During the rainy season, a moderate wind blows (4-6m/s) in the morning, which becomes stronger in the afternoon (6 to 8m/s) and remains constantly moderate-to-strong (5-8m/s) in the evening and at night. The peak speeds are reached during the passage of rain lines (east to west direction) with an average speed of 15m/s and accompanied by harsh winds and rainstorms.

1.6.3 Physical and Chemical Oceanography

The Benin coast is part of the Gulf of Guinea, which is subject to two main currents: the Guinea Current (GC), or equatorial current, and the Equatorial Counter Current, which is submarine. The GC is on the surface and persists throughout the year. Its speed varies between 1.5 to 0.5m/s. It moves from west to east along the Benin coast. From June to December, driven by northeast winds, the speed of the current is at its maximum. Between July and August, the GC moves from the east to the west and is slower.

On the Benin coast, the tide is regular and semi-diurnal. The average level of the sea in Cotonou is +0.93 hydrographical zero (ZH). The difference between the zero of the National Geographic Institute (IGN) and the ZH is 0.53m. During spring tides, the high sea reaches ZH +1.00m (low sea at ZH+0.40m). In dead water, the high sea reaches ZH+1.00m (low sea at ZH-0.20m).

Long swells of distant origin, whose wavelengths may vary between 160 and 220m, are typical along the Benin coast. These swells break on the bar at 150 to 200m away from the shore. The height of the swell observed in Cotonou varies between 1.0 and 2.0m.

Weak swells whose mean range varies between 0.9 and 1.3m occur between December and March, and those whose mean range varies between 1.6 and 1.9m occur between June and August. Larger swells, as high as 4.5 m, can be observed between June and September.

1.6.4 Biological Setting

Phytoplankton

The presence of diatoms, dinoflagellates, various microscopic alga, and nannoplankton (coccolithes) is reported on the Beninese continental plateau of the Atlantic Ocean. (Fiogbé, 2000, John et al., 2001).

Zooplankton

Foraminiferans, radiolarians, copepods (with higher biomass than all other animals), small shellfishes, amphipods, isopods, decapods, ostracods, which constitute the link between primary plant productivity and species exploited are adequately represented in the Atlantic Ocean at the southern border of Benin (Wiafe et al., 2001). The major species have been listed by Wiafe et al. (2001) in the Gulf of Guinea including Benin.

Benthic Organisms

The major groups of benthic macroinvertebrate species harvested in West Africa by Yankson and Kendall (2001) are sufficiently represented in Benin.

Marine Turtles

According to Fischer et al. (1981) the marine tortoises of the center-East Atlantic are grouped into two families, five genera and 6 species (*Caretta caretta caretta, Chelonia mydas mydas, Eretmochelys imbricata, Lepidochelys kempii, Lepidochelys olivacea, Dermochelys coriacea coriacea*). The two families: Chelonidae and Dermochelidae are often fished accidentally on the coast of Benin. Capturing of marine turtles is prohibited in Benin as in most Gulf of Guinea countries, due to population depletion.

Whales and Dolphins

Humpback or "Jubarte" whales *(Megaptera novaeangliae)* have been very recently observed on the Beninese continental plateau at depths generally varying between 13 and 35m, with less frequent observations between 27 and 600m depth. Bottlenose dolphins *(Tursiops truncates)* have also been observed at depths of approximately 31m.

Marine Fishes

To date, 449 marine fish species have been recorded on the coasts of Benin (out of the 25000 species known worldwide). These 449 species, identified from about 1000 collections of the Fisheries Department and the Department of Zoology/FAST/UNB, were caught at various habitats of the Atlantic Ocean at the southern border of Benin. They include benthic or demersal fishes, open sea or pelagic fishes and abyssal fishes from great depths. Based on the taxonomical group, FishBase (2000) has reported a total of 3 classes containing 37 orders. In these orders, 129 families have been identified, involving 294 genera and 449 species.

According to Vanden Bossche and Bernacsek (1990), among the fish species identified fish on the coast of Benin, 373 are marine, 76 marine and brakish water; 261 are recognized as having potential for commercial fishing, 4 have aquaculture potential (*Megalops atlanticus, Ethmalosa fimbriata, Epinephelus aeneus,* and *Mugil curema*), 16 have potential for live export; 77 for sport fishing; 15 are said to be endangered fishes (Serranidae, Rhincodontidae, Scombridae, Xiphiidae, etc.), 2 potentially protected (*Dalatias licha,* and *Hippocampus hippocampus*); and 34 are recognized as endangered (including *Epinephelus itajara, Xiphias gladius, Carcharias taurus, Pristis microdon, Pristis pectinata*, etc.).

1.7 NIGERIA BACKGROUND

This subsection discusses the physical and biological environment of the onshore parts of WAGP the project in Nigeria. The environment discussed here covers the onshore stretch of the pipeline, from the tie-in point at Alagbado, Ogun State, to Badagry Beach, Lagos State and to the Nigeria-Benin Republic border. Figure 1.7-1 shows the proposed WAGP route

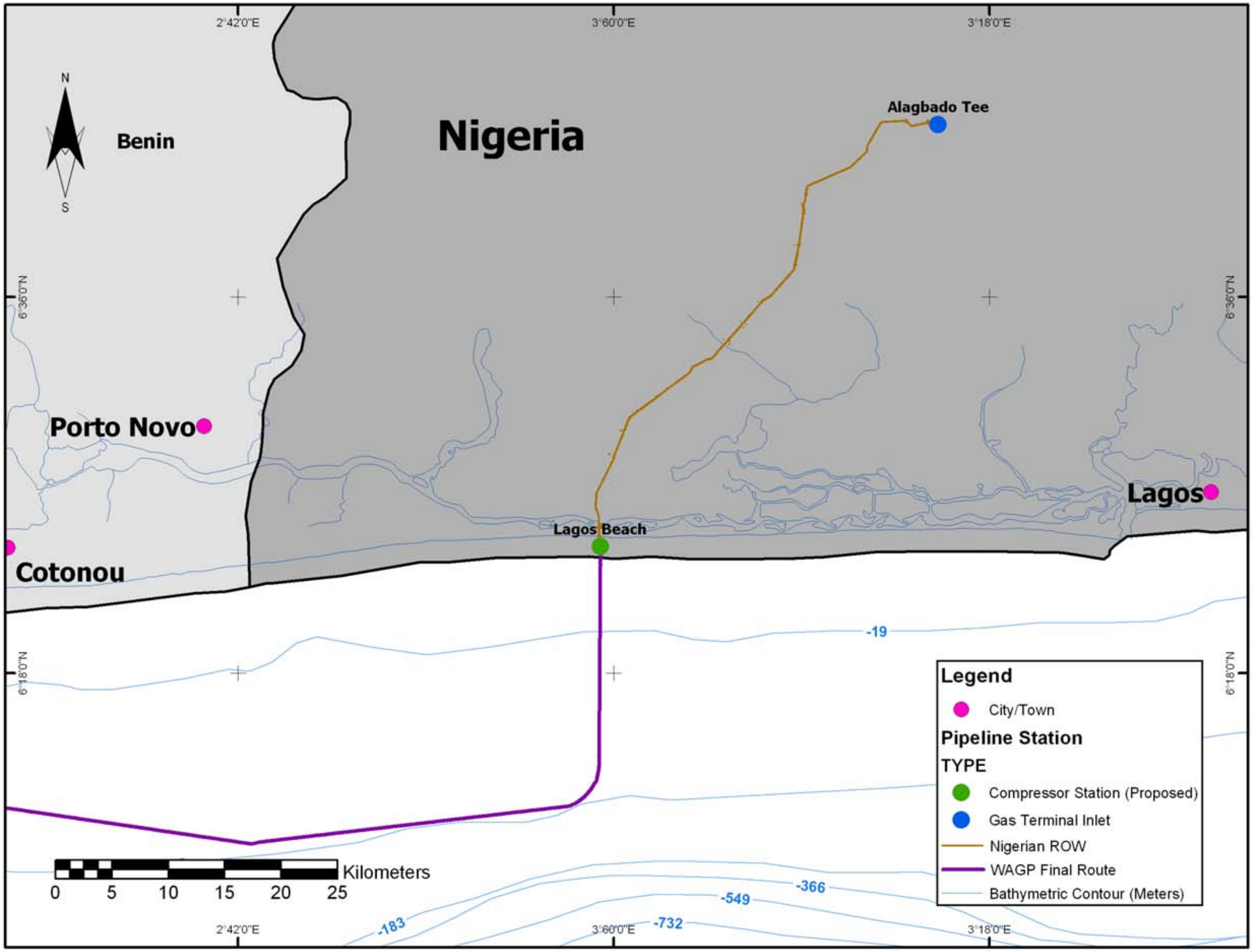


Figure 1.7-1 - Nigeria - WAGP Route from Alagbado Tee to Badagri

from Alagbado to Badagri. Figure 1.7-2 shows Badagri Creek and the location of the proposed compressor station.

The existing pipeline ROW terminates at Alagbado from where the present extension begins. The extension runs for about 60km from Alagbado to the sea with two compressor stations located close to the two terminal ends: the Itoki Compressor Station (06^0 43.112^{1}N, 003^0 17.206^1 E) in Ifo LGA, Ogun State, and the Ajido Compressor station near Ajido (approx. 6^0 25^1 N, 002 59.3 E) in Badagry LGA, Lagos State.

The pipeline ROW traverses or runs very close to a number of settlements both in Lagos State and Ogun State. From the south to the north, these communities include: Imeke (06^0 26.1^1 N, 003^0 00^1 E), Ala (06^0 28.2^1 N, 003^0 0.2^1 E), and Ilogbo (06^0 29.8^1 N, 003^0 1.4^1 E) all in Badagry LGA of Lagos State. Others are Idanyin-Isagu (06^0 31.15^1 N, 003^0 2.9^1 E), Ore – Akinde (06^0 36.035^1 N, 003^0 07.506^1 E), Oko-Omi (06^0 37.543^1 N, 003^0 08.678^1 E) Ewupe (06^0 43.1^1 N, 003^0 11.9^1 E), and Ijako (06^0 39.8^1 N, 003^0 12.9^1 E) all in Lagos State. The ROW crosses the Lagos-Badagry express road west of Agbara close to Araromi village, the Ipata-Ilogbo road close to Ilogbo village, and the Aradagun-Ajido road at the Ajido compressor station.

1.7.1 Geological Setting

The onshore part of the project area in Nigeria lies in the SW part of the country. The geology of this area is mostly sedimentary, classified as Cretaceous – Tertiary and Quaternary sediments (Buchanan and Pugh, 1955). Jones and Hockey (1964) recognized five major geological formations in this area (Table 1.7-1). The oldest sediments in this area were laid down during the transgression of the sea from the south in late Senonian times. Subsequently, the history is one of gradual retreat of the sea accompanied by subsidence, which allowed accumulation of sediments near the present-day coastline in the southwest and southeast.

Table 1.7-1
Sedimentary Formations in the Nigeria Onshore Part of the Project Area

Geological Formation	Age
Alluvium	Recent
Coastal Plain Sands	Pleistocene to Oligocene
Ilaro Formation (Sands, clays & shales)	Upper Eocene
Ewekoro Formation (Shales and Limestones)	Paleocene
Abeokuta Formation (Sandstones and clays)	Upper Senonian

Generally, the Abeokuta Formation is predominantly arenaceous at the base, with considerable thickness of clays and shales of continental to marine origin. It is bounded to the north by the basement complex and merges imperceptibly into the Ewekoro Formation to

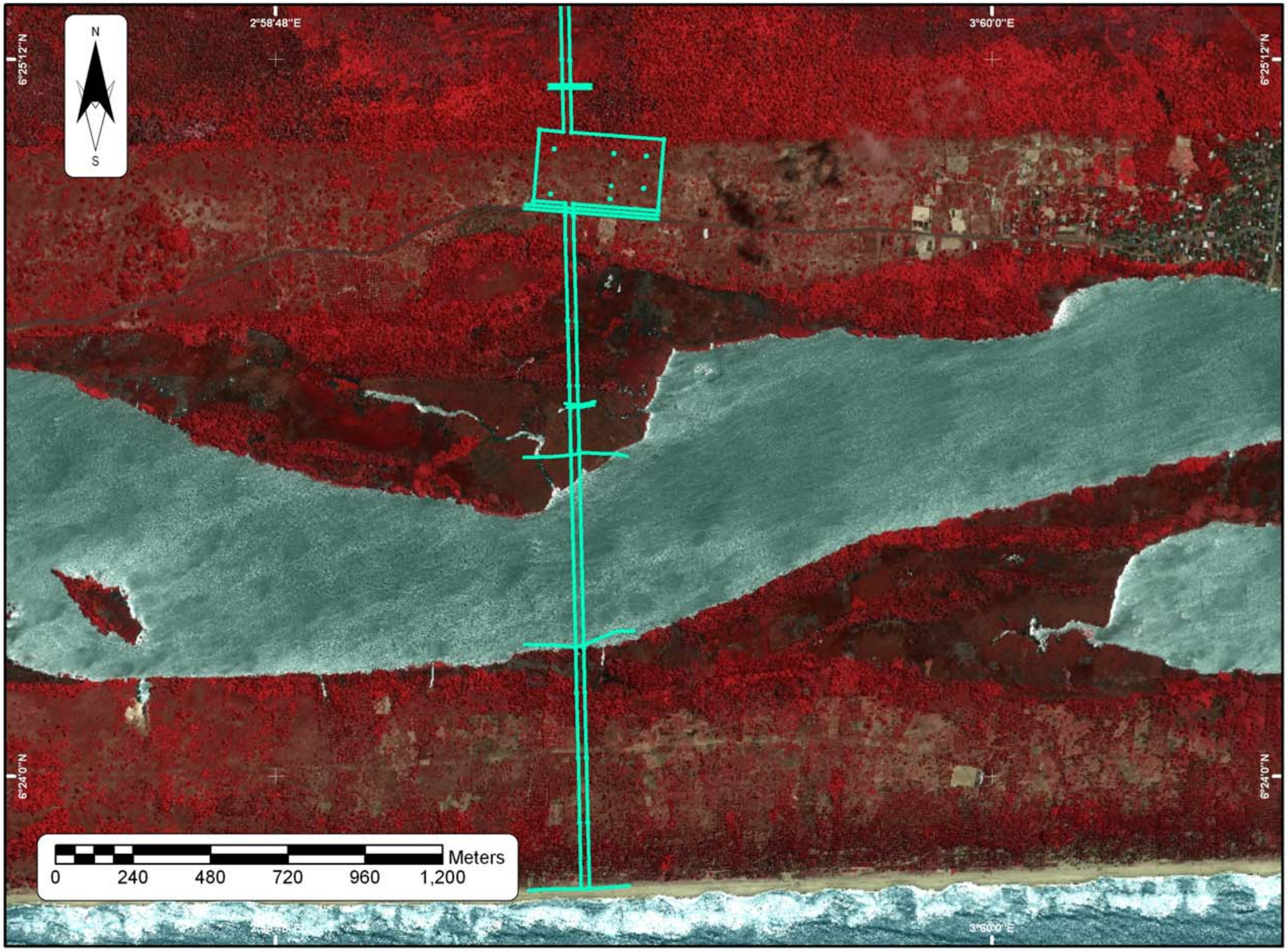


Figure 1.7-2 - Badagri Creek and Compressor Station

the south. The Ewekoro Formation consists of fossiliferous Paleocene limestone and shales. The shale gives rise to a distinct group of clayey soils, most of which are poorly drained to seasonally swampy.

The coastal plain sand is mostly soft, poorly sorted, clayey sands; pebble sands; and sandy clay; and is lithologically indistinguishable from the Ilaro Formation. They all weather into red and brown sandy soils and clayey grits, but are modified by the seasonally fluctuating water table as conditioned by topography (relief). The recent alluvial material overlies the coastal plain sand, and Ilaro and Ewekoro Formations and is mainly a deposit of littoral and lagoonal sediments of the coastal belt and the alluvial sediments of the major rivers.

Soils and Terrain/Topography

Soils in the project area are considered to have developed in the superfacial recent alluvium (Thomas, 1959; Hansell, 1965). It was observed that the recent alluvial material deposits were more than 67.2m and 125m deep in areas around Pakuro (near Ilaro) and Dahomey (Benin Republic), respectively. Therefore, the various underlying sedimentary formations might have very little or no influence on the soils.

Marine deposition of sand (Adejuwon, 1974) and the accumulation of lagoonal and continental dead organic matter, along with the sedimentation of materials brought down by rivers and fluvial sorting of the sand ridge materials after emergence above sea level contribute to the production of the recent alluvium. This gives rise to the soils in the area. Moss (1957) and also indicated that soils in the area were developed from sandstone, terrace sands, shale, and river alluvium.

The soils of the area are highly variable and support a number of habitats including: marshes, bare land, bush fallows, farmlands, and coastal savannahs. The soils of the marshy areas are slightly acidic in the top horizons (pH range of 4.3 to 6.0) and this acidity increases with soil depth (subsoil pH ranges from 3.5 to 4.8). The exchangeable bases and cation exchange capacity are generally low (Amusan and Ashaye, 1989), varying from 0.34cmol (+) Kg^{-1} to 14.82cmol (+) Kg^{-1} and 1.14cmol (+) Kg^{-1} to 21.06cmol (+) Kg^{-1} soil, respectively, and suggesting low inherent fertility status of the soils. The percent aluminum saturation of the soils is high, especially in the subsoil, and this suggests possible mobilization of heavy metals in the subsoil, due mainly to poor drainage, poor aeration, and acidic solum.

1.7.2 Meteorology

Aspects of the offshore meteorology as it relates to the relative oscillation of the ITCZ and climate/seasons as discussed in section 1.3 also apply in the onshore area. The classification and other highlights of the climate of the study area, especially the section covered by the WAPG project are given in Table 1.7-2. Following the classification scheme of Papadakis (1965), there are broadly two climate types in the area, namely: the Humid Semi-Hot Equatorial climate and the Dry Semi-Hot Equatorial climate. The former prevails in the Forest belt of the area, stretching eastward from Cotonou/Port Novo (Benin Republic) through Badagry to Lagos and beyond. The Dry Semi-Hot Equatorial type prevails in the coastal savanna belt of the area and beyond westward. It is characterized by moderate maximum temperatures (with average daily maximum of the warmest month less than 33.5ºC), annual rainfall about 44 to 100 percent of annual potential evapotranspiration, and low drought stress. In the Humid Semi-Hot Equatorial climate, no month of the annual cycle is *sensu stricto* dry, although one or more months may not be particularly humid.

Table 1.7-2
The climate characteristics of major Nigerian towns bordering the WAPG project study area.

Characteristics	Badagry	Lagos
Latitude (N)	6º24′	6º27′
Longitude (E)	2º53′	3º24′
Altitude m(asl)	6.1	3.1
Climate type[a]	1.122	1.121
Humid season	3-7,9-10	3-10
Dry season	0	0
Annual rainfall (mm)	1532	1821
Rainfall surplus (mm)	ND	1138
Drought stress (mm)	ND	737

[a] = According to Papadakis (1965)
m (asl) = meters above mean sea level
ND = No Data

Figure 1.7-3 represents the mean monthly rainfall values in the project area. Figure 1.7-4 shows the temperature characteristics of the studied sites within the project area.

Figure 1.7-3
Mean monthly rainfall values around the project axis (mm)

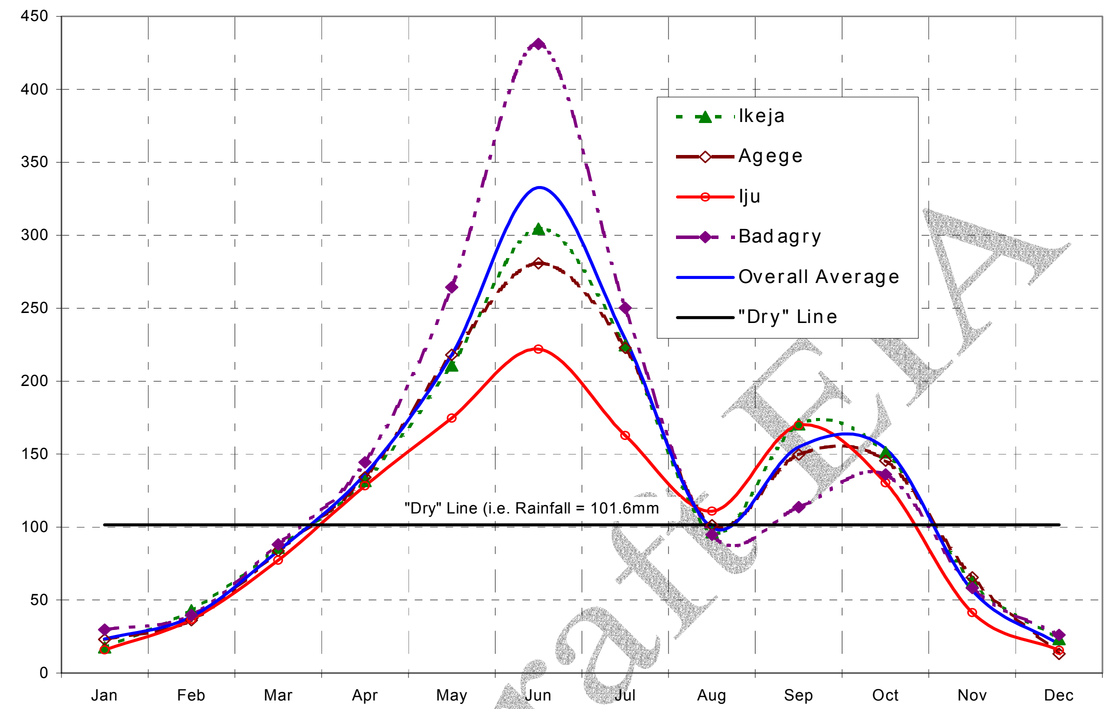
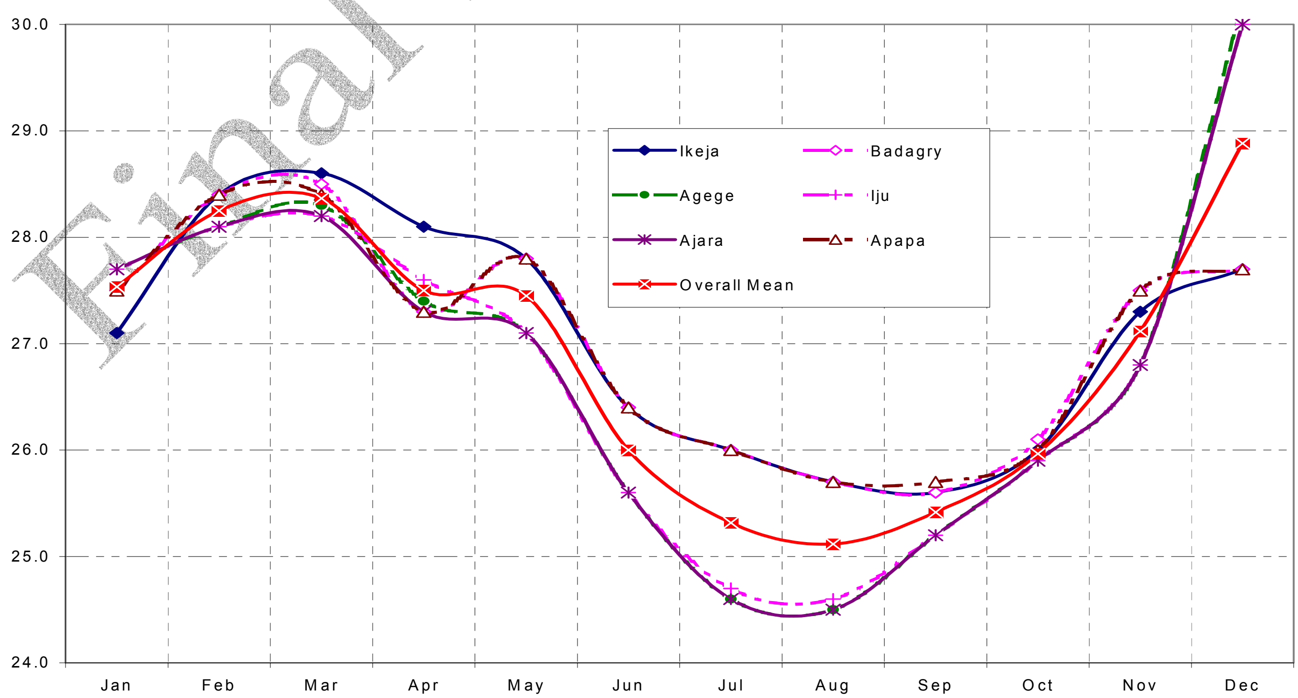


Figure 1.7-4
Temperature characteristics of the studied sites within the project area (^oC)



Rainfall and temperature over the annual cycle in the study area are characterized by two maxima and two maxima each (Fig 1.7-2). In general, total annual rainfall and rainfall surplus show significant positive correlation with longitudinal position in the area ($P < 0.05$), weak positive correlation with latitude but weak negative correlation with altitude ($P > 0.05$). These relationships reflect the south westerly-westerly directions of the moisture bearing prevailing winds in the area. In Badagry and Lagos there are no dry months. However, whereas the humid season in Lagos forms one continous series, in Badagry the season is interrupted in August by a relatively short dry spell, the "August break."

Rainfall in Apapa, Lagos did not reach annual levels lower than 1000mm between 1980 and 1998. The mean expected onset and cessation of the rainy season span over 260 days from March 11 to November 25 (Table 1.7-3).

Table 1.7-3
Expected Onset and Cessation of Rainy Season in Lagos.

Occurrence of Rainy Season	Expected	Early	Late
Mean Onset Date	March 11	February 24	March 26
Mean Cessation	November 25	November 10	December 10
Duration	259	259	259
Source : Akintola (1986)			

Temperatures are generally high but characterized by low annual amplitudes of variation (maximum daily temperature = 30.14 ± 1.5ºC and minimum daily temperature = 23.8 ± 0.9ºC). The peaks in both maximum and minimum daily values occur in March with a secondary peak in November/December. On the other hand, primary minimum temperatures occur in July/August and a secondary minimum occurs in January during the Harmattan.

The study area is generally humid with the air almost saturated at dawn in Lagos (Table 1.7-4). As with radiation, relative humidity is characterized by very little or no diurnal change at sunrise and sunset, but much more variable in the afternoon.

Table 1.7-4
Relative Humidity (%) in the Project Area

Location	**Time of Day**	**Month of the Annual Cycle**												
		J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**A**	**N**	**D**	Mean ± s.d.
Lagos (Nigeria)**	0600	98	97	98	98	98	98	97	97	97	98	98	98	98 ± 1
	0700	89	85	84	84	86	89	90	88	88	88	88	89	87 ± 2
	1200	62	64	65	73	78	82	79	78	77	77	70	69	75 ± 8
Source * =Ojo (1977) ** = Udo (1970)														

1.7.3 Physical and Chemical Oceanography

An east-west trending lagoon barrier complex characterizes the coastal area. Behind Nigeria's barrier system lie lagoons of Lagos, Lekki, and Yewa. Creeks, navigable only by small craft, link the lagoons.

While the pipeline ROW avoids the Ologe Lagoon, it traverses a number of its headwaters and influent streams, notably the Owo River system. The physical landscape of the area is characterized by a complex of freshwater swamp forest, lagoons (the Ologe lagoon) creeks (e.g. Badagry creek), islands (Topo Island), beach ridges and sandbars typical of the coastal area of southwestern, Nigeria. More than 77 percent of the pipeline ROW passes through the non-tidal region of the study area, while the remainder passes through tidal swamps, creeks and beach ridge (Table 1.7-5).

Table 1.7-5
ROW Length through the major water regions.
(Determined by superimposing maps of the proposed pipeline route on existing land use/land cover maps.)

Landscape Feature	Length of ROW (km)	% ROW total length
Non-Tidal Region	**46.4**	**77.3**
Tidal Region		
(i) swamps, rivers & streams	**11.0**	**18.3**
(ii) Badagry Creek	**2.0**	**3.3**
(iii) Beach ridge	**0.6**	**1.0**
Total	**60.0**	**100.0**

The drainage system is dominated by a network and series of creeks and lagoons and a number of north-south flowing coastal rivers discharging into them from the northern boundary about 30m above the sea level. A coastal strip of fine, unconsolidated sand fronts the open sea separating the lagoons and creeks. This tract stands out in aerial view as it is completely devoid of plant cover. The formation of this and other lagoons in the area is believed to result from the movement of sand from west to east along a previously notched coast, a process which has taken place since the last glacial period (Webb, 1958). Between Badagry and Lagos, the width of the land strip separating the open sea from the lagoon is only about 1.6km. A few kilometers away from the lagoon, the land becomes much firmer and closely dissected by rivers, notably the Owo river system, draining southwards into the lagoon. The morphology and morphometric characteristics of the Owo river system at Agbarra are given in Table 1.7-6 (Adeniyi, 1991). The tributary streams include the following rivers: Abesan, Iju, Illoh, and River Ore, in order of increasing size. The drainage pattern is dendritic, draining a total area of about 1530km^2, including the Ota industrial estate. The basin is characterized by a high circularity ratio.

Table 1.7-6
The Morphology and Mophometric Characteristics of R. Owo Catchment Basin at Agbarra

Parameter	Value
Shape Circularity ratio Elongation ratio Form factor Lemniscate ratio	 0.98 0.85 0.57 0.44
Main stream length (km)	70
Perimeter (km)	140
Area (km^2)	1530
River order	4
Drainage density (km^{-1})	0.24
Source = Adeniyi (1991*)*	

River Owo and its tributaries are characterized by pronounced seasonal variability in flow velocity and discharge (Table 1.7-7). Discharge is lowest in February (i.e. before the onset of the rains) and highest in July i.e. after the primary peak of rainfall. The contribution of rivers Illoh and Abesan to the discharge of river Owo at Agbarra is evaluated to be 18% and 10% respectively (T&T Associates Ltd, 1991). The generally low velocities of flow along the river could be due to the narrowing of the flow path by vegetation and continous siltation in the riverbed. Being connected to the open sea in Lagos (through the Lagos Harbour), the lagoon system is subjected to tidal variation typical of the Atlantic Ocean. The tidal regime is semi-diurnal and in general, the tidal amplitude tends to increase from the west to east.

Table 1.7-7
Mean Monthly Discharge of River Owo (m^3/s) at Two Stations

Station	**Month of the Year**											
	J	F	M	A	M	J	J	A	S	O	N	D
Agbarra	4.9	3.7	5.0	6.1	12.3	17.8	20.3	16.2	20.0	19.4	18.4	6.1
Camp Davies	2.4	1.8	2.6	3.0	6.0	8.7	9.9	7.9	9.8	9.5	9.0	3.0
Source = T&T Associates Ltd. (1991)												

Information on the water quality of the coastal waters of West Africa in the study area is relatively scant. Most of the available information is concentrated on the Lagos Lagoon, especially the area of Lagos Harbour (Olaniyan, 1961; Olaniyan, 1975; Akpata and Ekundayo, 1977; and Oyewo *et al*. 1982). Again, most of the work relates to water temperature and salinity of the lagoon waters. Olaniyan (1975) has shown the seasonal patterns of variations in the surface water temperature of the lagoons between Epe (06^0 35'N, 003^0 59'E) and Badagry (06^0 34'N, 002^0 35'E). In general, lower temperatures are recorded during the rainy season than in the dry season within the study area; surface water temperatures ranges from 25 to 26.5ºC during the rainy season compared to 28.5 to 30ºC during the dry season. In general, temperature tends to decrease eastward from Badagry through to Lagos. During the rainy season, water salinity shows a gradual decrease along the Badagry creek from about 9.5 percent (parts per thousand) to about 6 percent in Lagos area. On the other hand, the reverse occurs during the dry, season especially towards the Lagos end where salinity increases to about 25 percent (Olaniyan, 1975). Phosphate concentration in the lagoon is positively correlated with salinity during the rainy season, both-decreasing from the west to the east of the lagoon. In general, salinity shows an inverse relationship with rainfall pattern (Hill &Webb, 1958; Olaniyan, 1975) and usually the values are lower at bottom than at surface waters.

An assessment of the environmental pollution of Lagos lagoon was undertaken by Ekundayo (1977). A wide range of microorganisms was isolated from the lagoon. The number of coliform bacteria was highest at sewage disposal stations and decreased substantially toward the sea where the salinity of the water was very high (Ekundayo, 1977).

Information relating to the aspects of the physico-chemical qualities of the Owo River system during the rainy season can be obtained from the technical reports of T&T Associates Limited (1991) and TEE Associates Environmental consultants (1991) to the Ministry of the Environment and Physical Planning, Lagos State. The results of these two surveys showed that the waters are turbid brown in coloration, soft and acidic in chemical reaction. The values of chemical indicators of pollution such as BOD_5 and COD are high and indicative of organic pollution of River Owo at Captain Davis, Isassi and Agbarra at its inlet into Ologe Lagoon (T&T Associates Ltd; 1991). Electrical conductivity values over the waters were in the range of 48 – 162μScm^{-1} with pH values mostly in the range of 5.65 to 6.90. The waters were generally characterized by low levels of dissolved oxygen concentrations and percent saturation (TEE Associates, 1991).

1.7.4 Biological Setting

Vegetation

The pipeline right of way and compressor station site for the WAGP project fall within a number of habitat types which can be classified into two major areas, coastal and inland. In the inland-onshore area, habitat types identified consist of: swamps; coastal savanna; a mosaic of fallow land, farmland and built-up areas; and forest. The nearshore coastal habitats include sandy beach, swamps, open/coastal savanna, and rainforests.

Immediately inland of Badagry creek is a swamp populated with a preponderance of *Cyperus* sp. and a few stands of wildly growing coconut palm trees. From Badagry Creek to Alagbado Tee onshore, the ROW crosses many swamps populated by pure stands of *Cyperus* sp. and either degraded or healthy raffia palms. The stress on the raffia palms was observed to be due to annual bush fires or to changes in the local hydrology by anthropogenic features such as roads and buildings.

The coastal savanna is characterized by tall grasses, scattered shrubs and a few trees. At some locations, most of the grasses are either burnt out in the traditional dry season bush burning practice or heavily overgrazed by cattle.

A mosaic of fallow land, farmland and built-up areas is widespread in the inland areas of the WAGP ROW especially as it approaches the big towns in the inland areas such as Otta, Ijanikin and Agbara. In this habitat, the ROW passes very close to settlements, across tarred and earthen roads, farmlands and fallow plots.

The forest habitat, consisting predominantly of secondary forest, is patchy, probably due to human interference. Field observations of the study area did not result in the encounter of a forest reserve or plantation. In terms of morphological, physical and chemical characteristics and their susceptibility to water erosion, soils in this habitat are the same as those under the mosaic of farmland, fallow and built-up areas.

Prior to clearing, a large portion of the land area within the proposed project area supported a climax tropical high forest, as described by Keay (1959). Intensive agriculture, rapid industrial growth, and urban development in the area, however, have given rise to scattered agricultural crops, thickets, bush re-growth, and extensive urban and industrial developments. The extensive, but scattered, swamp forest areas support typical hydrophytic communities.

The morphology of the barrier lagoon complex that stretches along the coastline has been described in several reports (Clason et al 1954; Hill and Web, 1958a and 1958b; Awosika and Ibe, 1993 and 1994). A very narrow beach with a foreshore gradient of about 1:50 fronts the barrier system in Lagos area. The shoreline is backed by narrow, sandy beach ridges, which are aligned parallel to the coastline. Environmental factors controlling vegetation in the barrier lagoon system include salinity, nutrient level, herbivore populations, hurricanes, and human activities, such as housing developments, industry, and agriculture, replace natural habitat.

Between the coastline and Badagry Creek lies a barrier island, which is 1.6km wide at the widest and less than 500m wide in other parts. Within this barrier island alone, up to three habitat types occur, including sandy beaches, mature coconut palm and farmland mosaic, and freshwater swamps. Most of these habitats have been significantly modified by anthropogenic activities.

In the coastal nearshore area of the WAGP ROW along the seaside, bare sandy beach, commonly fringed by stranded vegetation exists. The medium grained, loose, and generally exposed beach sand along the beachside is dotted with thatched huts.

Immediately next to the beach, close to the shoreline, lies an extensive, highly homogenous coastal savanna habitat type with tall grasses and a few scattered shrubs species. Bare land with tall grasses and a few scattered shrub species are present. The bare land areas, mostly cultivated or tilled ground, are common features in this area of the barrier island. A pattern of tall and closely spaced coconut palms followed by more scattered stands of coconut palms are located from the shoreline to the Badagry Creek. Bordering Badagry Creek is a fresh water swamp colonized mostly by *Cyperus* sp..

Coastal vegetation covering the barrier system is very sparse, with scattered mangroves, marshes, and freshwater swamps. Coconut trees, especially along Badagry Beach, dominate the coast. According to RPI (1986), coastal vegetation within the study area consists of sedges, grasses, and a few shrubs and trees such as *Parinari robusta*. According to Steentoft (1986), who has given an account of strand vegetation that is relevant to the study area, typical strand species disappear at the landward boundary of the main strand zone, and the ground is cultivated. Hedges of prickly pear (*Opuntia vulgaris*), sisal (*Agave sisalana*), and *Furcraea foetida* are commonly planted. Behind the barrier bar is the Lagos Lagoon, which is one of the largest lagoons along the Guinea coast, covering about 350km^2.

Terrestrial Fauna and Wildlife

As described above, onshore areas of the project location cover a variety of habitat types, and for this reason support a diverse number of species. Along the coastline and into the sea, several wildlife species also occur, but the most important groups are reptiles, birds, and mammals. Virtually all groups of animals occur within the onshore area, including small arthropods like crabs and insects.

A number of reptilian species are known to occur in the project area. These include smaller animals such as lizards and skinks, as well as the larger ones like the pythons and crocodiles. The habitat type largely influences the distribution of these species. For instance, the Nile crocodile (*Crocodylus niloticus*) and monitor lizards *(Varanus niloticus)* occur within the swamps around Badagry, while the leopard tortoise (*Testudo paradilis*) occurs further inland within the rain forests around Otta. Very little data exist on the availability and populations of these species around the study area.

Avian species occur in large numbers around the project area. Similar to reptiles, their distribution is greatly influenced by habitat type. As such, diving birds like the crested kingfisher (*Ceryle rudis*) and white egrets (*Egretta gazetta* and *E. alba*) occur along the coastline and the many water bodies that dot the terrain. Species such as *Streptopelia vinacea S. semitorquata* (dove), and the village weaver (*Ploceus cuculatus)* occur inland in the farmlands and bush fallows. Generally, their populations are quite high, and even though both predatory animals and human beings regularly prey on them, their high fecundity rates enable them to maintain high population levels (Nason, 1992).

By far, the most ubiquitous mammalian group throughout the project area is rodents. They are highly fecund and quite adaptable and have therefore successfully colonized all the areas. Smaller species like the multimammate rat (*Rattus natalensis*), larger species such as the cane rat (*Thyronomys swinderianus*), and the crested porcupine (*Hystrix cristata*), all occur in the project area. In spite of avid hunting by human beings and predation by carnivorous animals within the forests, their populations have remained high, sometimes even bordering on epidemic levels, especially around farmlands where they cause damage to farm crops.

Other mammals that have been documented in the area include bats (*Eidolon helvum*), pangolins (e.g., *Manis gigantea* and *M. tricuspis*), and various monkeys, such as the colobus monkey (*Colobus polykomos*). In addition, various predatory species, such as felines, also occur. Herbivores such as the antelopes and duikers (e.g. *Sylvicapa grimmi*) also occur and are regularly hunted both for food and for their skins.

All five species of marine turtles found in the Gulf of Guinea: The loggerhead turtle (*Caretta caretta*), the hawksbill (*Eretmochelys imbricata*), the olive ridley (*Lepidochelys olivacea*), the green sea turtle (*Chelonia mydas*), and the leatherback (*Dermochelys coriacea*); are known to breed along the Nigerian coast from Badagry to Eket, particularly on undisturbed sandy beaches (Schneider, 1990; Arma, et al. 1997). Breeding takes place from late August to March, with the young beginning to appear in the sea from April.

The marine mammals of the Nigerian coastal waters are mainly the West African manatee (*Trichechus senegalensis*), which is found in the creeks and estuaries, as well as dolphins.

Soil Organisms

Previous studies of the soil of coastal areas in Nigeria have shown that soil microarthropod densities are extremely low in sandy soils and freshwater swamps when compared with mineral soils in areas where the vegetation is heterogeneous and the clay content of the soil is low (Imevbore et al., 1993; Odeyemi et al. 1994). This implies that such soils, most of which occur in the hinterland, are more suitable for agriculture than sandy and swampy soils. These arable soils occur in patches in the coastal areas, and are as suitable for agriculture as soils in the hinterland.

Hydrobiology and Fisheries

Like water quality, most of the available information on the aquatic biological resources of the Nigerian coastal lagoons is from the Lagos Lagoon. The macrobenthic fauna are composed primarily of molluscs (primarily bivalves and gastropods), crustaceans (most of which are important shellfish), and polychaete annelids. The fish fauna comprise about 30 species, dominated by catfishes, clupeids and cichlids. In a survey of the fish fauna of the Owo River system, Arawomo (1991) recorded about 18 species belonging to 12 families. The family Cichlidae seemed to dominate both qualitatively and quantitatively. Shrimps were also found in abundance.

In the study area, water hyacinth, (*Eichhornia crassipes*), together with a wide range of other floating and rooted macrophytes, occurs. Most of them belong to the plant families of Azollaceae, Lemnaceae, Araceae, Lentibulariaceae, Convolvulaceae, and Euphobia.

Olaniyan (1975) has provided some information on the plankton fauna and flora of the Lagos Lagoon system, including the abundance of the dominant species. A number of the species are common both to the Lagoon and the nearby open sea. The chief among these are the copepods, which seem to be able to tolerate a wide range of salinity. Phytoplankton flora consists mainly of species of *Chaetoceros, Biddulphia,* and *Surrirella.* Nwankwo (1990a) recorded 48 diatom species from Lagos Lagoon and the adjacent sea. The dinoflagellates were dominated by species of *Ceratium* and *Peridinium* (Nwankwo, 1990b).

1.8 STUDY DESIGN

The objective of the offshore and onshore study design was to provide an analytical basis for the WAGP EIA, that is, to provide an accurate and comprehensive analysis of the existing environment as it relates to the proposed construction and operation of the project, and to do so in the most efficient and cost-effective manner. The ICF Scientific Team designed the first season EBS based upon the expertise of its scientists and the experience it has derived from past experience and surveys in West Africa and elsewhere.

The sample design was intended to evaluate spatial patterns of physical, chemical, and biological conditions that are of particular significance to the proposed project and that may be adversely affected. It provided physical, chemical and biological characterizations of the seabed, water column, terrestrial vegetation, terrestrial soil, groundwater, onshore surface water, and onshore sediment environments. Due to the nature of the proposed project, the study emphasized the baseline biological conditions. However, the chosen study design was comprehensive and generated over 14,000 chemical, physical, and biological data points for analysis and interpretation. A summary of the first season biological and meteorological sampling is shown in Table 1.8-1.

The ICF EBS Scientific Team subsequently made an assessment for each of the EBS questions (see Section 1.1) regarding whether sufficient data were collected to produce valid statistical results. Graphs, such as species-areas curves, were plotted to indicate whether the addition of new sampling points would add significantly new information to the survey results. Resulting data deficiencies have been flagged for further investigation--mainly this includes focusing the second season study design on closing these data gaps.

A system of monitoring, tracking, and data quality control that was described in the EBS work plan and followed during the EBS ensured that field sampling and laboratory testing were performed adequately.

Before the EBS was implemented, the study design was critically evaluated and presented to WAGP and regulatory bodies. It was evaluated as to whether the design met the study objectives and tests the appropriate hypothesis and whether the technical and statistical elements of the design are appropriate.

This section, 1.8 Study Design, is intended to provide a overview of how the EBS was designed to provide appropriate information and analysis to adequately address the EBS objectives. Detailed offshore and onshore EBS methods are presented in Section 2.0.

Table 1.8-1
Summary of Plan for First Season Onshore and Offshore Biological and Meteorological Sampling

Parameter	Sample Quantity
Vegetation Individual Species Abundance Individual Species Frequency Species Diversity	62 Samples
Fish Individual Species Abundance Individual Species Frequency Species Diversity	25 Trawl Catches
Plankton Individual Species Abundance Individual Species Frequency Species Diversity	75 Trawl Catches (25 each of ichtyo-, zoo-& phyto-plankton)
Aquatic Macrophytes Individual Species Abundance Individual Species Frequency Species Diversity	40 Sample Points (2 transects x 4 sample points x 5 quadrats)
Offshore Benthic Infauna Individual Species Abundance Individual Species Frequency Species Diversity Species Evenness	56 Samples (51 sample stations + 10 percent duplicate sample analysis)
Onshore Benthic Infauna Individual Species Abundance Individual Species Frequency Species Diversity	50 Samples (10 water bodies x 5 samples)
Marine Birds, Mammals, Reptiles Individual Species Abundance Individual Species Frequency Species Diversity	Observations as encountered
Onshore Wildlife and Animal Resources Individual Species Abundance Individual Species Frequency Species Diversity	102 Samples (17 habitats x 3 days x 2 times/day)
Offshore Meteorological Conditions Air temperature Wind speed and direction Atmospheric pressure Doppler current Wave Height	105 Locations (55 pipeline stations & 25 fish trawl station & 25 plankton trawl stations)

1.8.1 Offshore Study Design

Sampling Station Layout

A total of 50 offshore sampling stations were sampled during December 2002, using a research vessel. The timing was chosen to represent dry season conditions. Thirty-five of the stations were placed along the main pipeline route: Nigeria (3), Benin (7), Togo (5), and Ghana (20). The remaining 15 stations were on the laterals that bring the pipeline onshore in Nigeria (3), Benin (3), Togo (3), and Ghana (6). See Plate 1.8-1: West African Gas Pipeline Proposed Pipeline Route and 2002 Offshore Sampling Stations for placement of the sampling stations.

In order to perform statistical analysis of the collected data, it was necessary that there be an element of randomisation in the placement of sampling points. Sampling points were located using a stratified random method as follows: For the main pipeline, the route was divided into 18km segments. Then a random number generator was used to select a number between one and 36. This random number indicated at which half-kilometer interval along the route, starting at the beginning of the 18km segment, the sampling point was to be placed.

For the laterals, a similar approach to sampling station placement was used; however, in these cases the length of the segments depended upon the water contour depth. Sampling points on the lateral routes corresponded to the following (also see Section 2.1):

- the 15m contour depth;
- a water depth 15m deeper than the water depth at the intersection with the main pipeline route or 5km south of the intersection with the principal pipeline route, whichever is the shorter distance;
- the depth-midpoint between the intersection with the main pipeline route and the 15m contour depth.

Sediment Biological Characterization Design

To address the benthic and seabed questions presented above, sediment grab samples were collected at each of the 50 sampling stations for biological, physical, and chemical characterization. Two replicate samples for benthic infaunal community analyses were taken at each of the 35 main pipeline stations. Only one of two replicate samples collected along the main pipeline route was analyzed in the laboratory. On the laterals, four replicate samples were taken at each of the 15 stations; but only one of the replicate samples collected along the pipeline laterals was analyzed in the laboratory. The remaining samples were archived until Sediment Profile Imagery (SPI) was analyzed to evaluate benthic community and seabed homogeneity.

The SPI remotely collected sediment reduction/oxidation (redox) potential, sediment type and overburden, and biological community composition information. SPI was taken at three points per sampling station, one on the pipeline route and two off the pipeline route: one at each end of a 2km transect that is perpendicular to the pipeline route and bisected in half by it. Information on the parameters from the SPI was used to determine whether the grab samples that were taken on the pipeline or laterals route were representative of the larger area in the vicinity of the route. If the grab samples, as indicated by SPI, were not representative, then additional grab samples were analyzed at the SPI station where images indicated a non-homogenous condition. This resulted in five additional SPI station sediment grabs. SPI was also be used for later comparison and interpretive support of physical, chemical and biological data. Organism-Sediment Index (OSI) summary mapping statistics were calculated on the basis of four independently measured SPI parameters: apparent mean redox potential discontinuity (RPD) depth, presence of methane gas, low/no dissolved oxygen at the sediment-water interface, and infaunal successional stage.

Using SPI results on seabed heterogeneity as shown in Figure 1.8-1, WAGP First Season Analytical Flow for Benthic Analyses, eight additional replicates were analyzed for biological characterization.

Macrobenthic infauna were identified to the lowest possible taxon and from this was determined abundance (number of individuals of each taxon per grab sample) and frequency (as proportion of how many times that taxon occurred in the grab samples out of the total number of grab samples analyzed).

The justification using the analytical flow decision tree (shown in Figure 1.8-1) stems from the main purpose of the benthic infauna analysis, which is to define broad regional conditions and the range of regional variability and, given a fixed budget, doing so by using a large spatial coverage and non-replicated samples. The approach follows Cuff and Coleman "Optimal Survey Design: Lessons from a Stratified Random Sample of Macrobenthos" (J. Fish. Res. Bd. Can. 36: 351-361, 1975) and optimizes our sampling effort for geographic coverage with consideration of the limitation of the available time and cost resources. Cuff and Coleman found that preferable results were derived from the same total number of grab samples by increasing the number of stations at the expense of the number of grabs per station. They concluded the optimum number of grabs, given the regional objective, was one per station to maximize the area covered.

Macrobenthic infauna sampling data was analyzed to derive measures of species diversity and evenness. Species diversity indices to be useful must address both the measures of abundance and evenness of species present. The Shannon diversity index (*H*), which takes both into account, was calculated. In the Shannon index, the proportion of species *i* relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by (–1).

$$H = -\sum_{j=1}^{S} p_i \ln p_i$$

Evenness (J) was determined using the following formula:

$$J = H/\ln(S)$$

Where H is the Shannon Diversity Index, ln is the log base (e), and S is equal to the number of taxa. This index expresses H relative to the maximum value that H can obtain when all the species in the sample are perfectly even with one individual per species.

Sediment Physical and Chemical Characterization

In addition to the biological characterization, sediment samples were at each station collected specifically for laboratory analysis to determine key physical and chemical parameters. These are described in Section 1.1.

Water Quality Characterization

Water sampling was carried out at each of the 50 offshore sampling stations on the proposed pipeline route, as close as practical to the locations where the sediments were taken. *In situ* measurements were made using a CTD and water samples were collected at two depths: near the water surface (<1m) and at 1m above the bottom; and submitted for laboratory analysis.

Fish and Plankton Characterization

Trawl sampling at 25 stations in the study area were conducted for fish, ichthyoplankton, phytoplankton, and zooplankton during February 2003. Trawls were conducted at approximately the same locations as the sediment sampling stations described above. In addition, 10 trawls were conducted at approximately 50km intervals along the main pipeline route. Trawl depths were chosen to collect representative samples of fish and plankton assemblages. Selected tissue samples from fish commonly used for human consumption were obtained from the trawls for PAH and metals analyses.

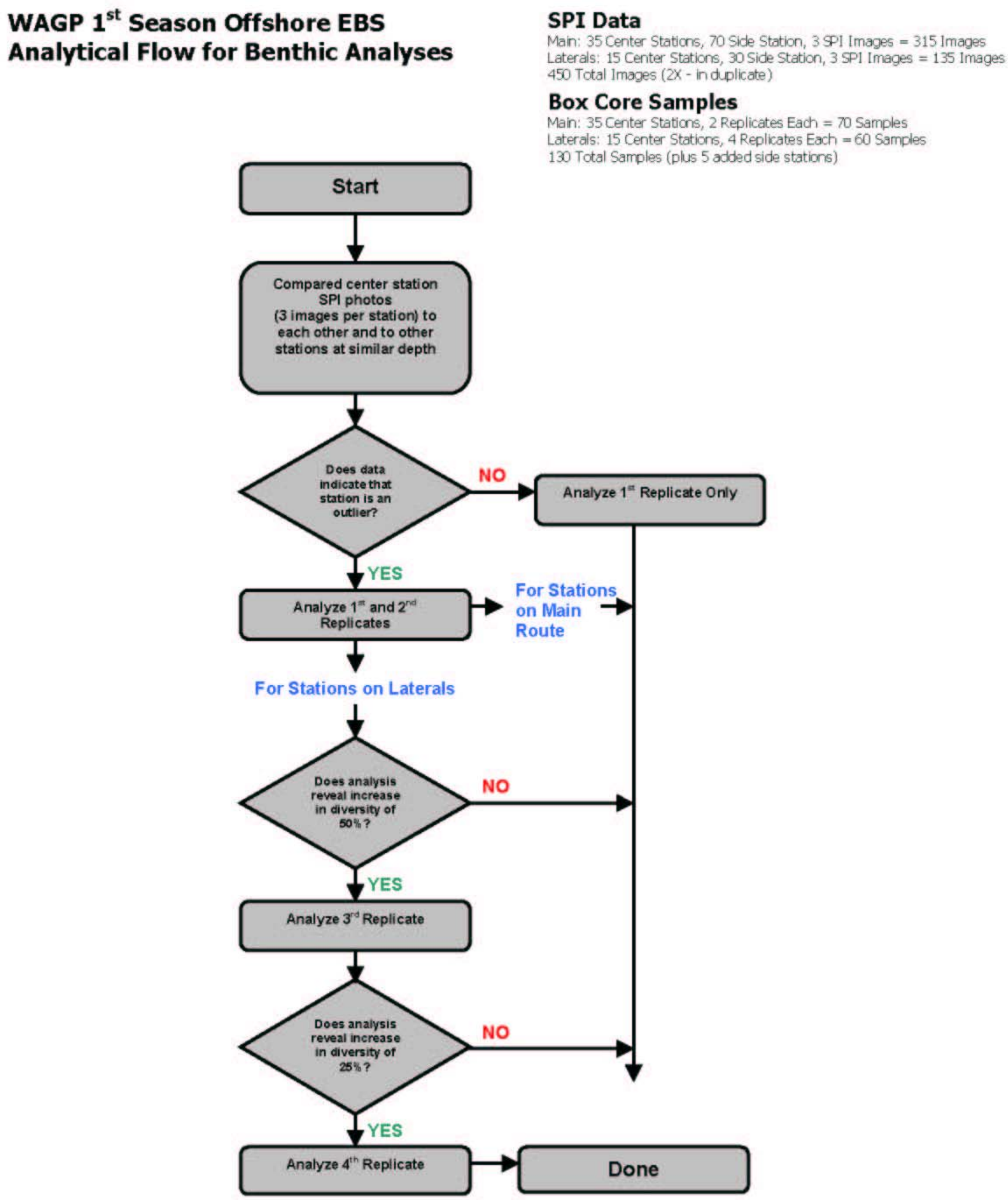
Marine Birds, Mammals, And Reptiles Characterization

Information on marine birds, mammals, and reptiles was obtained during field operations from deliberate observations of species distributions, estimated numbers, and behavior. Special attention was given observing whales, dolphins, sea turtles, and West African manatees that were known to be of concern in the study area.

Meteorological Characterization

Measurements of meteorological conditions, i.e., air temperature, wind speed and direction, current speed and direction, and wave height were carried out during field sampling and trawling operations.

Figure 1.8-1


WAGP 1st Season Offshore EBS
Analytical Flow for Benthic Analyses
SPI Data
Main: 35 Center Stations, 70 Side Station, 3 SPI Images = 315 Images
Laterals: 15 Center Stations, 30 Side Station, 3 SPI Images = 135 Images
450 Total Images (2X - in duplicate)
Box Core Samples
Main: 35 Center Stations, 2 Replicates Each = 70 Samples
Laterals: 15 Center Stations, 4 Replicates Each = 60 Samples
130 Total Samples (plus 5 added side stations)
Start
Compared center station SPI photos (3 images per station) to each other and to other stations at similar depth
Does data indicate that station is an outlier?
NO
Analyze 1st Replicate Only
YES
Analyze 1st and 2nd Replicates
For Stations on Main Route
For Stations on Laterals
Does analysis reveal increase in diversity of 50%?
NO
YES
Analyze 3rd Replicate
Does analysis reveal increase in diversity of 25%?
NO
YES
Analyze 4th Replicate
Done

1.8.2 Onshore Study Design

Vegetation Characterization

For the first season onshore EBS a field data collection was conducted during December and January 2002. The timing was chosen to represent dry season conditions. Onshore field observation and study design documented existing conditions in each of the major habitat types (e.g., beach/inter-tidal, strand, emergent wetlands, wet prairie, short mangrove forest, palm plantation) found in the study area. Each vegetation community serves as a habitat type. Ground reconnaissance and satellite imagery was used to define 17 habitats along the onshore route and landfall locations. Each habitat was sampled along a 60m transect or in the case of vegetation near the shoreline, a shorter, 10m transect. Stratified random sampling was used to locate each transect. There were four sampling points spaced at 20m intervals along the longer transects (0m, 20m, 40m, and 60m) and the shorter transects had three sampling points a closer intervals (0m, 5m, and 10m). Sampling at shorter intervals in the near shore transects reflects rapid habitat transitions found in this zone. At each sampling point along a transect, information leading to plant species diversity and abundance for trees, saplings, and understory plants was collected. Refer to Section 2.2, for a detailed description of vegetation sampling and analysis.

Soils Characterization

Soil samples were collected at the same sampling points used for vegetation sampling. Additional samples were collected as composites for each transect. Soils were assessed in terms of regional and local characteristics, susceptibility to erosion, physical and chemical characteristics and soil biota.

Animal and Wildlife Resource Characterization

Field observations on animal and wildlife resources were carried out during early morning walks along beaches and footpaths and slow boat rides along creeks and around landfalls in each of the 17 habitat locations.

Proposed Compressor Station Groundwater Characterization

An assessment of the baseline physical and chemical characteristics of the uppermost groundwater bearing layer(s) including information regarding aquifer hydraulic properties beneath the proposed compressor station in Nigeria was performed. The monitoring wells and their installation were intended to provide direct measurement of the chemical and physical properties of soil and water-bearing layers. Based on a current understanding of the location and depth of near coastal groundwater systems in the project area, the depth of the monitoring wells was chosen to be 10m. To estimate the aquifer hydraulic conductivity, slug tests were carried out at each monitoring well. Three soil samples were retained from each borehole for laboratory analyses. One groundwater sample from each monitoring well plus one duplicate sample from one monitoring well was collected for analysis in the laboratory.

Surface Water Body Characterization

Surface water bodies, i.e., rivers, marshes, and estuaries, were characterized. Water sampling was done using *in-situ* measurements and by collecting water and sediment samples for laboratory analysis.

Fish and Fisheries

Fisheries observations were carried out for surface water bodies within 17 selected habitats. Fish studies were done by observing fisherman landings. The entire catch was observed for its composition. Fish species were taxonomically identified and fishing gear, tools, and technology commonly used by local fishermen were noted.

Rocky Intertidal Zone Characterization

A survey for the occurrence and abundance of marine algae in the rocky tidal zone that occurs on the pipeline route in Ghana was carried out along the laterals using a 60m transect that extends seaward from the high-tide mark with sampling point locations at 0m, 20m, 40m, and 60m.

Meteorology Characterization

A mobile meteorological station was set-up near the proposed compressor station site to provide information on current meteorological conditions, e.g. wind speed and direction, temperature, humidity, barometric pressure and precipitation. Data retrieved from the meteorological station in Nigeria was used for air quality characterization. Baseline survey information in Ghana, Togo, and Benin was collected from existing sources of meteorological information such as from nearby airports.

Air Quality Characterization

A limited air quality study was conducted in the vicinity of the proposed compressor site. One portable air sampler equipped with 6L Tedlar bags was stationed at the site to collect ambient air grab samples. Three sample periods per day were collected over a two-week period. The elements of the air samples analyzed were analogous to compressor facility potential pollutants of concern (PM, VOCs, CO, and NO_x).

CHAPTER 2
METHODS

2.1 OFFSHORE FIELD METHODS

2.1.1 Operations, Station Location, and Navigation

Operations

Field operations were conducted from the vessel R/V GeoExplorer™, a 44m research vessel subcontracted by TDI-Brooks International. The vessel was outfitted with a hydraulic winch spooled with 9/16th stainless-steel wire and a starboard-mounted A frame used for gear deployment. Smaller diameter wire was used to deploy plankton-sampling gear. The GeoExplorer™ was also equipped with enclosed laboratory spaces, sheltered work deck, and refrigerator and freezer space. The vessel was equipped with Differential Global Positioning System (DGPS) receivers and propulsion systems capable of positioning and navigating to an accuracy of ±5m during sampling and WinFrog™ navigation software.

Station Location

Fifty offshore sampling station transects were visited during the Offshore EBS. Of these 35 were along the main pipeline route: Nigeria (3), Benin (7), Togo (5), and Ghana (20) and 15 along the 5 laterals. Along the main pipeline route sampling transects were located using a stratified random method as follows: the main pipeline route was divided into 18km segments. Each 18km segment was subdivided into 36 half-kilometer segments, one of which was randomly chosen to be the center station for the sampling transect. The two additional sampling stations were then positioned 1km North and South of the center station. The element of randomization was added to the method of station location to facilitate statistical analysis of the data, as described in Appendix H, WAGP Offshore and Onshore Environmental Baseline Survey Work Plan.

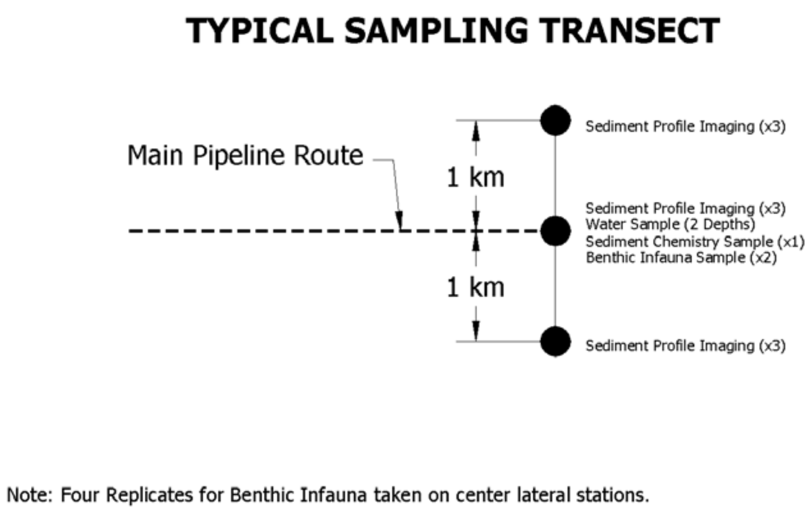
Along the laterals, three transects were established perpendicular to each lateral using a different method. The center station of each transect was positioned using a different method. The vessel navigated to the intersection of a lateral and the main pipeline route (the *intersection*) and marked the depth, *D1*. The center station of each transect was then located as follows:

- The center station of the northern-most transect on a lateral was located by navigating the vessel from the *intersection*, along the lateral route, towards shore until the first sustained (1/2 kilometer) 15m depth was found.
- The center station of the seaward most transect on each lateral was located by navigating along the lateral, past the *intersection,* until the depth was D1 + 15m or a distance of 5km had be covered, whichever occurred first.

- The center station of the middle transect on each lateral was located by navigating the vessel from the *intersection* towards shore until the depth was equal to (D1-15)/2, which located the station at the depth-midpoint between the northern-most transect and the main pipeline route.

Two additional stations were then positioned 1km East and West of each lateral center station. A typical sampling transect is shown in Figure 2.1-1.

Figure 2.1-1
Typical Sampling Transect



A list of sampling stations, locations, and water depth at each station is presented in Table 2.1-1. A map of the proposed pipeline route and all the offshore sampling stations is shown in Figure 2.1-2.

Table 2.1-1
December 2002 Offshore EBS Sampling Stations

SITE	DATE	TIME	LATITUDE	LONGITUDE	DEPTH (M)
B01C	12-Dec-02	18:47:56.7	N06 10.5269	E002 37.9616	55.0
B01N	12-Dec-02	18:34:23.7	N06 11.0465	E002 38.0293	50.0
B01S	12-Dec-02	18:16:39.6	N06 09.9776	E002 37.8370	58.7
B02C	12-Dec-02	14:46:06.0	N06 11.9293	E002 28.4028	36.5
B02N	12-Dec-02	14:33:23.7	N06 12.4388	E002 28.4892	31.5
B02S	12-Dec-02	14:07:55.2	N06 11.3616	E002 28.2863	42.0
B03C	12-Dec-02	12:11:54.6	N06 13.4405	E002 18.0908	24.5
B03N	12-Dec-02	11:59:08.3	N06 13.9372	E002 18.1511	23.3
B03S	12-Dec-02	11:28:33.8	N06 12.8493	E002 18.0260	26.7
B04C	12-Dec-02	05:02:05.8	N06 11.7876	E002 17.5004	39.8

SITE	DATE	TIME	LATITUDE	LONGITUDE	DEPTH (M)
B04E	12-Dec-02	04:32:46.3	N06 11.7796	E002 18.0471	39.2
B04W	12-Dec-02	04:49:35.0	N06 11.8094	E002 16.9756	39.0
B05C	12-Dec-02	06:52:54.2	N06 15.0641	E002 17.5345	20.1
B05E	12-Dec-02	06:23:44.2	N06 15.0583	E002 18.0810	20.1
B05W	12-Dec-02	06:41:44.2	N06 15.0744	E002 17.0169	19.7
B06C	12-Dec-02	08:18:57.7	N06 16.8385	E002 17.5604	15.7
B06E	12-Dec-02	07:49:07.7	N06 16.8302	E002 18.0948	16.4
B06W	12-Dec-02	08:06:47.2	N06 16.8429	E002 17.0376	18.1
B07C	12-Dec-02	02:51:08.0	N06 11.4243	E002 09.5372	46.7
B07N	12-Dec-02	02:36:33.7	N06 11.9411	E002 09.3468	36.9
B07S	12-Dec-02	02:10:56.2	N06 10.9002	E002 09.6823	51.3
B08C	11-Dec-02	21:00:05.5	N06 07.3161	E001 57.2416	61.9
B08N	11-Dec-02	20:47:25.3	N06 07.8311	E001 57.1419	57.1
B08S	11-Dec-02	20:28:08.0	N06 06.7683	E001 57.2962	66.3
B09C	11-Dec-02	18:48:14.7	N06 06.0135	E001 49.9981	58.0
B09N	11-Dec-02	18:32:22.2	N06 06.5592	E001 49.9146	53.9
B09S	11-Dec-02	18:14:11.5	N06 05.4961	E001 50.1013	61.7
B10C	11-Dec-02	16:32:46.2	N06 04.6737	E001 42.2297	60.0
B10N	11-Dec-02	16:18:34.3	N06 05.1610	E001 42.1247	56.9
B10S	11-Dec-02	15:54:53.8	N06 04.1104	E001 42.2980	64.4
G01C	10-Dec-02	14:15:06.1	N05 49.0968	E001 04.9608	47.5
G01N	10-Dec-02	14:01:49.8	N05 49.4749	E001 04.6256	46.0
G01S	10-Dec-02	13:40:48.6	N05 48.6820	E001 05.3468	49.0
G02C	10-Dec-02	12:06:36.2	N05 45.0574	E000 58.5247	19.7
G02N	10-Dec-02	11:54:06.2	N05 45.5266	E000 58.2898	18.9
G02S	10-Dec-02	11:21:53.0	N05 44.5384	E000 58.7424	21.1
G03C	10-Dec-02	09:57:33.2	N05 40.5394	E000 51.3583	15.9
G03N	10-Dec-02	09:46:27.7	N05 40.9718	E000 51.0166	15.3
G03S	10-Dec-02	09:27:44.1	N05 40.1019	E000 51.6792	16.9
G04C	10-Dec-02	05:28:14.2	N05 38.8338	E000 42.2920	24.6
G04N	10-Dec-02	05:14:35.7	N05 39.3865	E000 42.2940	23.4
G04S	10-Dec-02	04:56:52.2	N05 38.2888	E000 42.2814	25.3
G05C	10-Dec-02	03:09:53.2	N05 38.5610	E000 32.9146	41.4
G05N	10-Dec-02	02:56:34.7	N05 39.1092	E000 32.9156	39.3
G05S	10-Dec-02	02:39:48.2	N05 38.0146	E000 32.9115	43.2
G06C	09-Dec-02	04:43:38.0	N05 37.3769	E000 19.7918	66.5
G06N	09-Dec-02	05:22:47.2	N05 37.8968	E000 19.5997	59.2
G06S	09-Dec-02	04:16:21.7	N05 36.8664	E000 19.9882	75.7
G07C	09-Dec-02	02:00:35.2	N05 34.0458	E000 11.1249	57.5

SITE	DATE	TIME	LATITUDE	LONGITUDE	DEPTH (M)
G07N	09-Dec-02	02:45:49.8	N05 34.5436	E000 10.9002	53.5
G07S	09-Dec-02	01:31:10.5	N05 33.5377	E000 11.3467	62.5
G08C	08-Dec-02	23:10:48.0	N05 29.4640	E000 03.3084	51.2
G08N	09-Dec-02	00:02:25.0	N05 29.8858	E000 02.9464	47.7
G08S	08-Dec-02	22:41:27.1	N05 29.0480	E000 03.6252	52.5
G09C	09-Dec-02	21:37:11.2	N05 31.2939	E000 08.6121	63.8
G09E	09-Dec-02	23:02:12.6	N05 31.6311	E000 09.0493	64.2
G09W	09-Dec-02	21:00:59.2	N05 30.9825	E000 08.1969	63.8
G10C	09-Dec-02	14:35:46.0	N05 35.7894	E000 05.1871	32.5
G10E	09-Dec-02	15:23:04.1	N05 36.1238	E000 05.6385	32.1
G11C	09-Dec-02	12:37:06.2	N05 38.2122	E000 03.3498	15.4
G11E	09-Dec-02	12:11:23.5	N05 38.4980	E000 03.7472	15.6
G11W	09-Dec-02	13:24:31.7	N05 37.8768	E000 02.9077	16.3
G11W	09-Dec-02	14:08:27.6	N05 35.4530	E000 04.7843	33.8
G12C	08-Dec-02	20:21:58.8	N05 26.4165	W000 00.6401	50.0
G12N	08-Dec-02	19:52:44.1	N05 26.8578	W000 00.9828	48.5
G12S	08-Dec-02	21:30:28.1	N05 25.9879	W000 00.3543	51.5
G13C	08-Dec-02	16:01:05.1	N05 16.0342	W000 14.8141	62.7
G13N	08-Dec-02	16:49:10.3	N05 16.5519	W000 15.0170	59.0
G13S	08-Dec-02	15:31:57.5	N05 15.5482	W000 14.5990	66.5
G14C	08-Dec-02	13:18:30.1	N05 11.2040	W000 21.8371	52.0
G14N	08-Dec-02	14:07:33.2	N05 11.7237	W000 22.0919	50.5
G14S	08-Dec-02	12:54:26.6	N05 10.7252	W000 21.6235	54.0
G15C	08-Dec-02	10:47:35.6	N05 06.1027	W000 29.2634	47.9
G15N	08-Dec-02	10:21:48.8	N05 06.6007	W000 29.5002	46.4
G15S	08-Dec-02	11:31:21.1	N05 05.6122	W000 29.0335	49.4
G16C	08-Dec-02	06:03:57.2	N05 03.1405	W000 34.5989	41.8
G16N	08-Dec-02	06:43:40.1	N05 03.6859	W000 34.6758	40.0
G16S	08-Dec-02	05:31:26.2	N05 02.6064	W000 34.5137	43.1
G17C	08-Dec-02	02:49:01.2	N05 00.8590	W000 48.1561	29.8
G17N	08-Dec-02	02:26:39.6	N05 01.3923	W000 48.2213	28.9
G17S	08-Dec-02	03:28:54.3	N05 00.3019	W000 48.0880	31.1
G18C	07-Dec-02	23:31:04.2	N04 58.6393	W001 01.1954	29.7
G18N	08-Dec-02	00:24:10.2	N04 59.1735	W001 01.3022	29.3
G18S	07-Dec-02	23:09:54.2	N04 58.1124	W001 01.0761	29.7
G19C	07-Dec-02	21:34:53.7	N04 57.9735	W001 05.2531	30.0
G19N	07-Dec-02	21:08:00.2	N04 58.4985	W001 05.3790	29.2
G19S	07-Dec-02	22:17:11.1	N04 57.4282	W001 05.0646	30.7
G20C	07-Dec-02	17:57:36.7	N04 55.6511	W001 18.7807	30.8

SITE	DATE	TIME	LATITUDE	LONGITUDE	DEPTH (M)
G20N	07-Dec-02	19:00:19.6	N04 56.2203	W001 18.8477	30.0
G20S	07-Dec-02	16:48:02.7	N04 55.1054	W001 18.7427	33.3
G21C	07-Dec-02	03:18:43.0	N04 54.6337	W001 24.8157	30.8
G21N	07-Dec-02	15:42:47.0	N04 55.1861	W001 24.8937	28.6
G21S	07-Dec-02	15:09:51.7	N04 54.0849	W001 24.7650	30.8
G22C	07-Dec-02	00:06:09.6	N04 53.1477	W001 33.5812	29.6
G22N	07-Dec-02	01:53:28.2	N04 53.6835	W001 33.6341	29.2
G22S	07-Dec-02	01:24:15.2	N04 52.5938	W001 33.5330	30.8
G23C	06-Dec-02	06:40:57.2	N04 52.8766	W001 35.5224	29.5
G23N	06-Dec-02	10:27:25.7	N04 53.4505	W001 35.5490	27.5
G23S	06-Dec-02	11:33:44.5	N04 52.3462	W001 35.5141	29.0
G24C	06-Dec-02	21:43:19.2	N04 50.3742	W001 34.4480	32.9
G24E	06-Dec-02	23:22:35.7	N04 50.5308	W001 33.9391	33.8
G24W	06-Dec-02	22:52:46.0	N04 50.2203	W001 34.9730	32.9
G25C	06-Dec-02	18:11:13.2	N04 55.2817	W001 37.4385	22.9
G25E	06-Dec-02	19:20:37.1	N04 55.6250	W001 37.0159	21.8
G25W	06-Dec-02	20:00:15.0	N04 54.9432	W001 37.8562	22.5
G26C	06-Dec-02	13:40:49.7	N04 56.6605	W001 38.5441	14.8
G26E	06-Dec-02	16:18:06.2	N04 56.9340	W001 38.0634	16.0
G26W	06-Dec-02	16:53:11.5	N04 56.3687	W001 38.9903	15.4
N01C	13-Dec-02	07:30:22.0	N06 20.8305	E002 59.3149	15.6
N01E	13-Dec-02	07:13:50.3	N06 20.8214	E002 59.8767	15.8
N01W	13-Dec-02	06:42:04.1	N06 20.8439	E002 58.7838	15.9
N02C	13-Dec-02	05:12:10.5	N06 15.7100	E002 59.2484	38.4
N02E	13-Dec-02	04:59:10.3	N06 15.6938	E002 59.7861	38.9
N02W	13-Dec-02	04:40:12.5	N06 15.7123	E002 58.7179	37.8
N03C	13-Dec-02	02:54:47.7	N06 10.9252	E002 59.1783	76.3
N03E	13-Dec-02	02:39:21.8	N06 10.9122	E002 59.7049	77.5
N03W	13-Dec-02	02:18:08.6	N06 10.9364	E002 58.6306	74.6
N04C	13-Dec-02	00:48:36.1	N06 12.1077	E002 58.4627	63.5
N04N	13-Dec-02	00:34:11.2	N06 12.6416	E002 58.3872	59.0
N04S	13-Dec-02	00:12:24.7	N06 11.5687	E002 58.5416	68.5
N05C	13-Dec-02	13:07:46.5	N06 11.4144	E002 53.8007	66.0
N05N	13-Dec-02	12:52:43.6	N06 11.8995	E002 53.7220	61.5
N05S	13-Dec-02	12:27:56.7	N06 10.8578	E002 53.8812	70.0
N06C	12-Dec-02	21:21:42.7	N06 10.3654	E002 47.1932	68.5
N06N	12-Dec-02	20:47:17.2	N06 10.8984	E002 47.0539	63.7
N06S	12-Dec-02	21:07:57.7	N06 09.8693	E002 47.3402	73.2
T01C	11-Dec-02	14:45:11.6	N06 03.8967	E001 38.1648	50.0

SITE	DATE	TIME	LATITUDE	LONGITUDE	DEPTH (M)
T01N	11-Dec-02	14:29:49.6	N06 04.4179	E001 38.0665	50.6
T01S	11-Dec-02	13:50:30.2	N06 03.3741	E001 38.2327	54.1
T02C	11-Dec-02	01:59:52.2	N06 03.1037	E001 33.5340	49.7
T02N	11-Dec-02	01:47:40.5	N06 03.6460	E001 33.4276	47.8
T02S	11-Dec-02	01:29:49.2	N06 02.5707	E001 33.6273	51.7
T03C	10-Dec-02	23:33:40.8	N06 01.6213	E001 25.2719	48.0
T03N	10-Dec-02	23:19:25.2	N06 02.1608	E001 25.1829	46.7
T03S	10-Dec-02	22:57:01.7	N06 01.0677	E001 25.3555	50.6
T04C	10-Dec-02	18:56:54.7	N05 57.6798	E001 18.7072	58.2
T04N	10-Dec-02	18:37:10.8	N05 58.1458	E001 18.4666	51.0
T04S	10-Dec-02	18:15:49.2	N05 57.1663	E001 18.9150	68.2
T05C	10-Dec-02	21:52:08.3	N05 58.9301	E001 23.9684	67.2
T05E	10-Dec-02	21:36:49.0	N05 59.1942	E001 24.3969	66.0
T05W	10-Dec-02	21:19:45.3	N05 58.6581	E001 23.5012	68.1
T06C	11-Dec-02	05:41:00.2	N06 03.4746	E001 21.3562	33.6
T06E	11-Dec-02	05:26:41.6	N06 03.7472	E001 21.8244	32.3
T06W	11-Dec-02	05:07:39.3	N06 03.2054	E001 20.8821	35.0
T07C	11-Dec-02	07:31:59.7	N06 06.8507	E001 19.4237	16.1
T07E	11-Dec-02	07:16:09.0	N06 07.1233	E001 19.8788	15.8
T07W	11-Dec-02	06:58:40.7	N06 06.5919	E001 18.9555	15.8
T08C	10-Dec-02	17:23:36.6	N05 57.1030	E001 17.6490	62.7
T08N	10-Dec-02	17:09:36.5	N05 57.5702	E001 17.4000	52.2
T08S	10-Dec-02	16:49:32.6	N05 56.5674	E001 17.8446	72.7

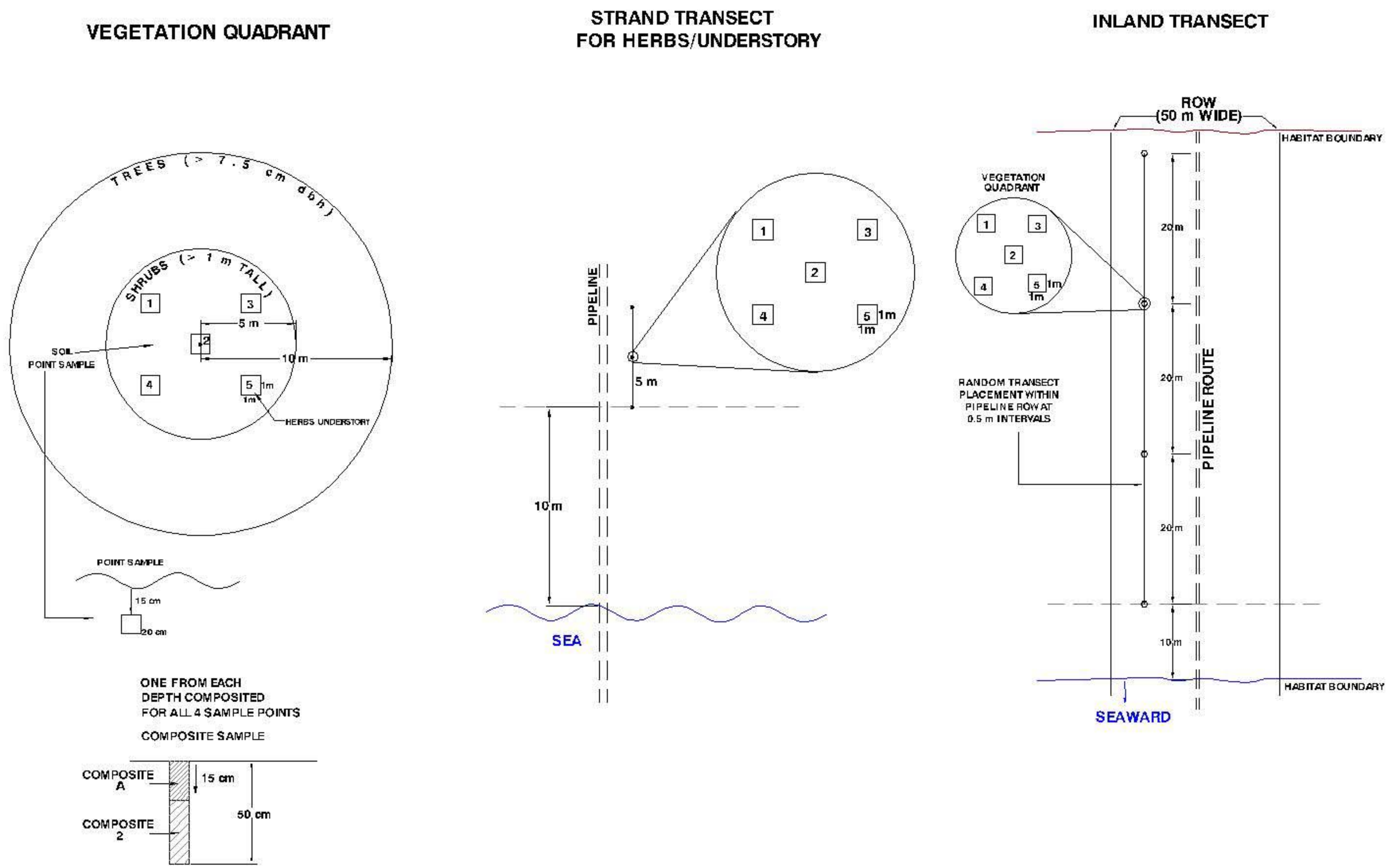


Figure 2.2-1 - Transect and Sediment Compositing Scheme

Navigation

Station locations were plotted in a geographic information system (GIS). The stations were then located by transferring the Latitude and Longitude of the station from the GIS into the WinFrog™ navigation system as waypoints, which then used DGPS to navigate to, and position the vessel directly over the station. The offset of the A-frame from the GPS antenna was recorded and programmed into the navigation system so that the position recorded was the position of the A-frame, rather than the position of the GPS antenna.

2.1.2 Mobilization and Pre-Sampling Preparations

Mobilization

The scientists from the United States and the United Kingdom arrived in Accra, Ghana on the evening of 30 November 2002, and traveled to Takoradi, Ghana on 1 December 2002. The scientists from Ghana and Nigeria arrived in Takoradi on the morning of 2 December 2002. Participants from Benin and Togo arrived on the afternoon of 2 December 2002. A list of scientists, their nationality, and role on the EBS Cruise is presented in Table 2.1-2.

Table 2.1-2
December 2002 Offshore EBS Scientific Staff

Name	Nationality	Position/Expertise
Emile Didier Fiogbe	Benin	Benthos
Zacharie Sohou	Benin	Benthos
Cossi Georges Epiphane Degbe	Benin	Benthos
Graig Andrew Reid	British	SPI Camera
Kofi Debrah-Mireku	Ghana	Plankton, Fisheries
Emmanuel Lamptey	Ghana	Benthos
Selorm Dzako Ababio	Ghana	Water Chemistry, Benthos
Samuel Nii Kpakpa Quaatey	Ghana	Shift Leader – trawls, Trawl Master
Daniel Wilberforce Ofori-Adu	Ghana	Fisheries, Plankton
Peter Lanre Olorunda	Nigeria	Sediment Chemistry
Isah Ibrahim Attah	Nigeria	Water Chemistry
Micah E. Okun-Omo	Nigeria	Benthos
Menouko T. Lina Edorh-Hokameto	Togo	Plankton
Yaovi Sevi Acakpo-Addra	Togo	Benthos
William Henry Camp	USA	Shift Leader

Name	Nationality	Position/Expertise
Theodore H. Coogan	USA	Shift Leader
Linos Cotsapas	USA	Chief Scientist
Joseph D. Germano	USA	SPI Camera

For on-board work, the scientific staff was divided into 3 shifts:

00:00 – 12:00: SPI, Water Chemistry, Sediment Chemistry, Benthos

12:00 – 24:00: SPI, Water Chemistry, Sediment Chemistry, Benthos

06:00 – 18:00: Trawls (Plankton, Fisheries)

On the morning of 2 December 2002 Camp, Coogan, Cotsapas, Germano, and Reid met with representatives of the agents and shippers (Hull Blyth and Panalpina) to check on the status of the equipment shipped from the USA as well as to make arrangements for necessary visas, work-permits, equipment inventory/review and storage, and vessel arrival/departure formalities.

On 4 December 2002, the gear was inspected and inventoried, and a walkthrough of some of the gear was conducted to help familiarize the participating scientists with its operation.

On 5 December 2002, Cotsapas, Camp, and Coogan conducted an audit of the R/V GeoExplorer™. Upon completion of the audit, the scientific staff mobilized from the hotel and started to load gear and equipment on the R/V GeoExplorer™.

All members of the scientific team went through a 45-minute vessel orientation and safety tour/briefing conducted by the vessel crew. Ship operation and safety procedures were also covered at this time. Each member of the scientific party signed the Vessel Introduction and Safety form after completion of the tour and briefing.

The R/V GeoExplorer™ departed Takoradi at 2200 on 5 December 2002.

<u>Pre-Sampling Preparation</u>

Participants of the offshore EBS met for a series of meetings that were held between 2 and 4 December 2003 in Takoradi to review the objectives of the studies, finalize the on-board work plan, and determine how to best achieve the work objectives. All of the scientists who participated on the offshore EBS, plus a number of other scientists (from Nigeria: Victor Imevbore, Adeolu Ojo, Elijah Ohimain, and from Ghana: A.K. Armah) attended these meetings. A summary of the principal topics covered in the meetings follows:

- Scope of EBS Program- Overview and Goals
- Health & Safety Briefing

- Roles and Responsibilities
- Daily schedule, Shifts and shift assignments
- Review of Health & Safety Issues
- Personal and Protective Gear
- Review of Generalized Sampling Procedures
- SPI
- Water and Sediment Chemistry
- Benthos, Plankton, and Fisheries
- Cruise and Sampling Plan (Station ID, Sampling Process, etc.)
- Data Management and Chain-of-Custody forms
- QA/QC issues
- Sample archiving, storage and transportation
- Laboratory Studies– on-board versus land-based

During the pre-sampling meetings numerous administrative issues that pertained to departure formalities and vessel requirements were also addressed.

Figure 2.1-3
2002 Offshore EBS Pre-Sampling Meeting

2.1.3 Seabed Sample Collection

Seabed sediment samples were collected using a 25cm x 25cm GOMEX-type box corer deployed and retrieved on the 9/16th inch stainless steel cable over the starboard side of the GeoExplorer™ with the hydraulic A-frame. When the box corer was returned to the deck of the ship, the shift leader inspected the sample to determine if it was adequate for collection. Figure 2.1-4 shows the box corer on deck after sub-sampling. Examples of inadequate samples include over-penetration of the box corer and partial or complete washout or disturbance of the sample while the box corer was being returned to the surface. If the sample was determined to be inadequate, it was discarded and the box corer redeployed until a good sample was collected. The sediment was sub sampled from the box corer by removing the top 2cm of the sediment using a Kynar™-coated scoop and placing the sample in pre-cleaned glass containers for chemistry analyses. Figure 2.1-5 shows undisturbed sediment in the box corer before sub sampling.

After chemistry samples were collected, the box corer was deployed 2 additional times at each station (4 times on the lateral stations) to collect sediment for benthic infauna analysis.

Prior to the collection of any samples, the sampling equipment was decontaminated immediately before deployment by successive washes of Alconox™ non-phosphate powder, methanol, and filtered seawater.

Figure 2.1-4
Box Corer on Deck After Sub-Sampling

Figure 2.1-5
Undisturbed Sediment in Box Corer

2.1.4 Water Column Sampling

The water column was sampled using both electronic profiling instruments and discrete water samples. Comprehensive water column profiles were collected using an electronic YSI 6600 Sonde™ conductivity, temperature and depth (CTD) profiler. The YSI 6600™ profiler was augmented with additional sensors for dissolved oxygen, pH, turbidity, oxidation reduction potential (ORP) and chlorophyll-*a*. The YSI 6600 was attached to the frame of the SPI Camera (see Section 2.1.6) using duct tape and band clamps, as shown in Figure 2.1-6, for deployment. Data were collected from 1 m below the water surface to approximately 5m above the seafloor at a frequency of 2 samples per second and stored in memory and retrieved and reviewed upon each cast completion. The YSI 6600 is multi-parameter instrument, designed for both short and long-term *in situ* monitoring and profiling. The YSI 6600™ profiler uses standard YSI 6-Series probes, including YSI's Rapid Pulse™ stirring-independent dissolved oxygen sensor, and self-cleaning turbidity probe excludes variations in ambient light resulting in hydrographic data for the 50 stations for depth, temperature, turbidity, chlorophyll-*a*, dissolved oxygen saturation, pH, and ORP. All results archived represent the full cast data collection. The down cast data were reviewed and trimmed for data display, due to operational interferences affecting the specific conductance probe.

In situ measurements were collected at the 50 stations along the proposed pipeline route from December 6-14, 2002. Discrete water samples were collected using two 5-L Niskin™ polycarbonate samplers deployed on the winch cable to collect surface (< 3m) and near-bottom (1m above seabed) samples. Sample bottles were deployed open and then closed with a brass messenger at the targeted depth. The samplers were decontaminated with Alconox™ and rinsed with deionised water before each deployment. Figure 2.1-7 shows a Niskin™ bottle being prepared for deployment.

Figure 2.1-6
CTD Mounted on SPI Camera

Figure 2.1-7
Preparing Niskin™ Bottle for Deployment

2.1.5 Offshore Field Methods

Several analytical methods were conducted aboard the R/V *GeoExplorer*™ in addition to the parameters gathered by the CTD. Seabed sediment samples were measured using electrodes for redox potential, pH, electrical conductivity and temperature. Water column samples were analyzed for nitrate using Hach Method 8039 and a Hach DR/2010 Spectrophotometer. Phosphate in water column samples was determined using Hach Method 8048 and a Hach DR/2010 Spectrophotometer. Total suspended solids were also determined.

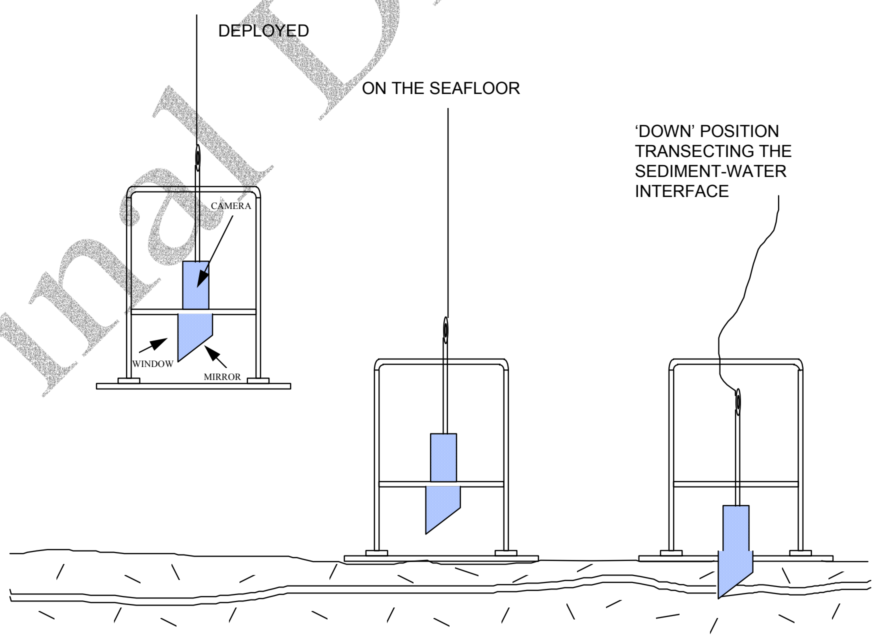
2.1.6 Sediment Profile Imaging Camera Sampling

The purpose of using Sediment Profile Imaging (SPI) during the survey was to provide a rapid assessment of sediment features such as sediment grain size, presence of methane, low/no dissolved oxygen, depth of the redox potential discontinuity (RPD), and biological community type in the field to assist in decisions concerning number and location for grab sampling stations, and to provide a later comparison as well as interpretative support of the additional physical, chemical, and biological data collected on the cruise. The complete Sediment Profile Imaging Report is included in Appendix C of this report.

A Benthos Model 3731 sediment profile camera was used to collect a total of 1100 sediment profile images at 150 stations visited during the course of the Offshore EBS.

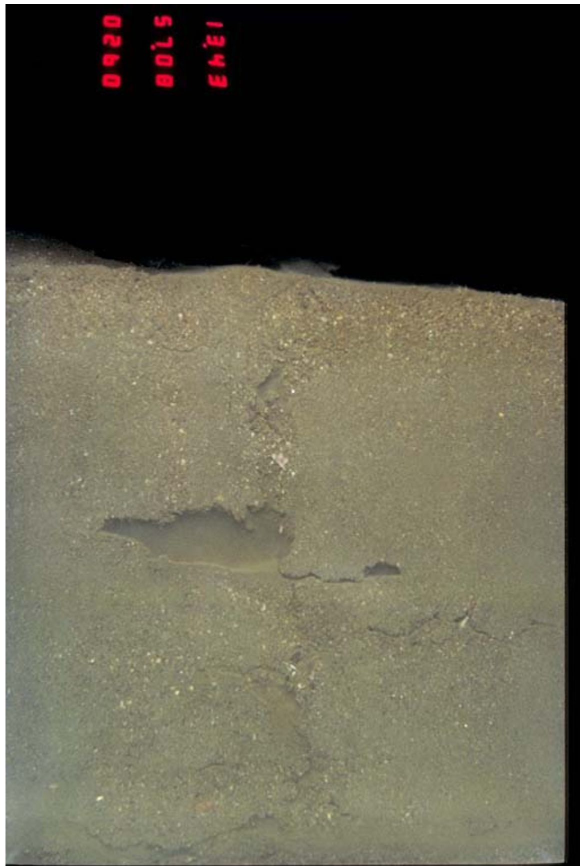
The sediment profile camera works like an inverted periscope. A deep-sea 35mm camera mechanism is mounted horizontally inside a watertight housing on top of a wedge-shaped prism. The prism has a Plexiglas® faceplate at the front with a mirror placed at a 45° angle at the back. The camera lens looks down at the mirror, which is reflecting the image from the faceplate. The prism has an internal strobe mounted inside at the back of the wedge to provide illumination for the image; this chamber is filled with distilled water, so the camera always has an optically clear path to shoot through. This wedge assembly is mounted on a moveable carriage within a stainless steel frame. As shown in Figure 2.1-8, below, the frame is lowered to the seafloor on a winch wire, and the tension on the wire keeps the prism in its "up" position. When the frame comes to rest on the seafloor, the winch wire goes slack and the camera prism descends into the sediment at a slow, controlled rate by the dampening action of a hydraulic piston so as not to disturb the sediment-water interface. On the way down, it trips a trigger that activates a time-delay circuit to allow the camera to penetrate the seafloor before any image is taken. The knife-sharp edge of the prism transects the sediment, and the prism penetrates the bottom. The strobe is discharged twice with each lowering to obtain two cross-sectional images of the upper 20 cm of the sediment column. After the two replicate images are obtained at the first location, the camera is then raised up about 2 to 3 meters off the bottom to allow the strobe to recharge. The strobe recharges within 5 seconds, and the camera is ready to be lowered again for another two images. Surveys can be accomplished rapidly by "pogo-sticking" the camera across an area of seafloor while recording positional fixes on the surface vessel. The resulting images give the viewer the same perspective as looking through the side of an aquarium half-filled with sediment. Figure 2.1-9 is a typical sediment profile image taken at Station G14C.

Figure 2.1-8
SPI Camera Deployments



The central cradle of the camera is held in the "up" position by tension on the winch wire as it is being lowered to the seafloor (left); once the frame base hits the bottom (center), the prism is then free to penetrate the bottom (right) and take the photograph.

Figure 2.1-9
Sediment Profile Image from Station G14C



2.1.7 Offshore Benthic Community Characterization

Offshore macrobenthic fauna was sampled with a 0.30 m x 0.30 m x 0.60 m box corer. Two replicate samples were taken at the stations along the main pipeline route labeled as center stations. At the spur laterals, four replicate samples were taken. Two replicate samples were also taken at a kilometer interval either north and south or east and west of stations along the main pipeline route. Each replicate sample at each station was split. The samples were emptied into sample trays, washed and screened through a sieve with a mesh size of 0.5 mm. The resulting samples were put into plastic containers, fixed in 10% formalin solution and taken to the laboratory for sorting and identification into major taxonomic groups using a Leica Zoom 2000 dissecting microscope and a Leica Gallen III microscope.

2.1.8 Plankton Community Characterization

Samples of ichthyoplankton, phytoplankton and zooplankton were collected using step-oblique trawl methods that divide the trawl durations equally between bottom, mid-depth, and surface waters. Each net had an integrated flow meter to record the volume of water that passed through the net. Plankton trawls were conducted using the net specifications listed in Table 2.1-3.

Table 2.1-3
Plankton Net Specifications

Organism	Net Type	Mesh/Model	Ring Radius
Ichthyoplankton	Bongo Net	330µm/Model WP3	50cm
Zooplankton	Nason Net	200µm/Model WP2	28.5cm
Phytoplankton	Nason Net	60µm/Model P200	27cm

The nets were deployed over the starboard side of the vessel using the hydraulic A-frame as illustrated in Figure 2.1-10. Upon return to the deck, the nets were suspended vertically and any plankton adhering to the mesh washed into the cod end using low-pressure, filtered seawater as shown in Figure 2.1-11. Phytoplankton samples were fixed and preserved in Lugol's iodine solution. Zooplankton samples were fixed and preserved in 5 percent formalin. Plankton tow start- and end-points were determined using the vessel's DGPS and recorded in the ship's navigation system and the Chief Scientist's Station Logs.

Figure 2.1-10
Bongo Nets Being Deployed

Figure 2.1-11
Net Handling Upon Retrieval

2.1.9 Fish Population Characterization

Twenty-five trawls were conducted to characterize the fish and macroinvertebrates population. Fish trawls were conducted coincident with the plankton trawls, except where bottom conditions or obstructions warranted otherwise. The trawls were conducted using a 7.6m (25ft) Marinovich Otter Trawl sampler equipped with a cod-end mesh size of 2cm. Each trawl was deployed along a predetermined transect with at scope of at least 3:1 (wire length:depth) ratio, with the starting point being recorded as when the net is fully deployed on the bottom. The net was towed at a rate of 3 knots for 10 minutes and retrieved while the GeoExplorer™ maintained a speed of 5 knots. The end point of the trawl was recorded as when the retrieval commenced. The start and end points of each trawl were determined by the vessels DGPS and recorded in both the ship’s log and on the Chief Scientist’s Station Log.

Upon net retrieval, the contents of the net were transferred to plastic tubs where the organisms were sorted by species and identified to the lowest taxon possible, counted, photographed, measured for length, width, weighed, and sexed if possible. Representatives of each species were preserved for future reference.

2.1.10 Aquatic Macrophyte Sampling

An initial survey for the occurrence and abundance of marine algae in the rocky intertidal zone was carried out along transects that are coincident with the laterals. This early reconnaissance of the study area suggested that these habitats, which tend to support macroalgae, are only present on the two Ghanaian laterals, whereas the other sites had sandy bottom substrates. Therefore, even though this habitat is an offshore one, the sampling was done in association with the onshore fieldwork (correspondingly, the results can be found within the Ghana onshore results, Section 4). Sampling was not conducted in the freshwater areas since freshwater aquatic macrophytes were low in density. Two of the 60m onshore transects with four sampling points each at 20m interval, starting at the high tide mark, but randomly located laterally in the pipeline ROW, were used to sample these two habitats in Ghana.

The high and low water marks' coordinates were determined using a GPS and recorded. The habitat, shore type, biotope and community of macroalgae in the general shore area was described for a 10m-line transect drawn from where macroalgae cover begins and move seawards. The intertidal area was divided into lower and upper shores and abundance or cover was estimated. One-meter square quadrats were placed at the 1, 5, 7 and 9-meter marks on the line transect drawn. The algal species within the bare ground and their percentage cover/abundance were estimated by eye. Algae observed while sampling were collected, photographed, preserved, and identified to as low a taxon as possible. The presence of faunal forms and other characteristic species in the general quadrat area were noted and recorded, as well.

2.1.11 Marine Birds, Mammals, Reptiles

Information on the local populations of Marine Birds, Mammals, and Reptiles was obtained primarily from the literature. However, deliberate observations of species distributions, estimated numbers, and behavior was recorded when obtainable during the cruise. These observations were recorded by the Chief Scientist or Shift Leader in the Daily (Shift) Report. In addition, sightings data from the previous, geophysical cruise are incorporated into this report.

2.1.12 Meteorological Conditions and Ocean Currents

Meteorological conditions and ocean currents were recorded during sampling activities on each Station Log and on the GeoExplorer's Bridge Log. The observations recorded include:

- Wind Speed
- Wind Direction
- Wave Height
- Current Speed
- Current Direction

All observations were originally recorded by the ship's crew into the Bridge Log and transcribed onto the Station Logs by the Chief Scientist or Shift Leader.

2.1.13 Documentation, Sample Tracking, Storage, and Shipping

Documentation

Documentation included of the following:

- Daily (Shift) Reports
- Station Logs
- Fish Trawl Logs
- Plankton Trawl Logs
- Bridge Logs
- Field Notebooks (for on-board laboratory results)
- Chain-of-Custody Forms
- Photographs

Daily Reports and Station Logs were maintained by either the Chief Scientist or the appropriate Shift Leader. Trawl Logs were maintained by the Trawl Master. Bridge Logs were maintained by the crew of the GeoExplorer™. Field notebooks, used to record the results of shipboard analyses were filled out by the laboratory staff. ICF has maintained custody of all original field documentation, notebooks, electronic navigation logs, and still and video photography. All data was recorded in ink.

Chain-of-Custody (CoC) forms were used to record the identification of each sample along with the preservation method, required analyses and were sign by scientific party personnel.

The CoC forms accompanied the samples at all times during transport from the vessel to the laboratory where analyses were to be conducted.

The 2002 Offshore EBS Cruise is documented in narrative form in a comprehensive Cruise Report submitted by the Chief Scientist in January 2003 and is included with this document as Appendix I.

Sample Tracking, Storage, and Shipping

All samples were placed in appropriate storage containers immediately after collection and affixed with a unique label containing the following information: sample identification number, date and time of collection, technician's initials, type of analysis (e.g., metals), and preservative. This information was used to generate sample chain-of-custody forms and shipping manifests for sample transfer and shipment to the analytical laboratories. Sediment chemistry samples were then transferred to freezers. Benthic samples were fixed in borax-buffered 15 percent formalin and stored at room temperature. Water column samples were refrigerated or processed onboard.

Samples designated for analysis at western laboratories and archive samples were stored frozen and then placed in coolers with blue ice for transport via international airfreight. Samples analyzed in West African laboratories were transported from the vessel to the analytical laboratories in a similar manner. Shipping coolers included a high coolant to sample ratio to maintain stable temperatures during transport. Each shipping cooler included a chain-of-custody form and a copy of the shipping manifest.

2.2 ONSHORE FIELD METHODS OVERVIEW

The conceptual sampling plan for onshore environments was developed based on the need to sample across a variety of habitats but with flexibility to allow regional experts and field teams to exercise professional judgment while collecting data and adapt to field observations as well as the local regulatory requirements. The plan was documented in a formal work plan that was submitted and approved by the appropriate scientific and regulatory stakeholders.

In this section, the conceptual and general approaches are described. The details of the work that was actually performed in each of the onshore surveys in Benin, Ghana, Nigeria, and Togo are described in the Appendices F, D, G, and E, respectively. The descriptions also describe any modification made to adapt to field observations.

Vegetation Sampling

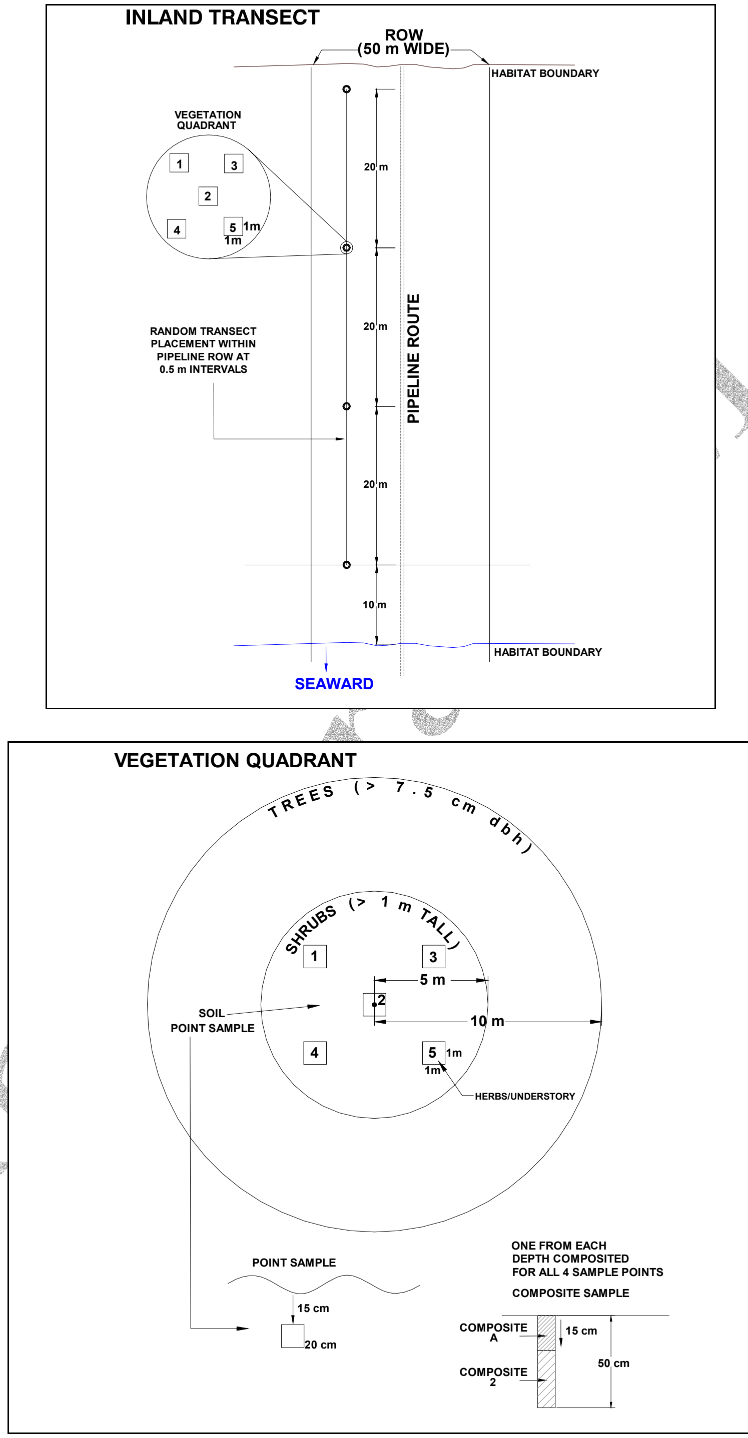
Vegetation Quadrats

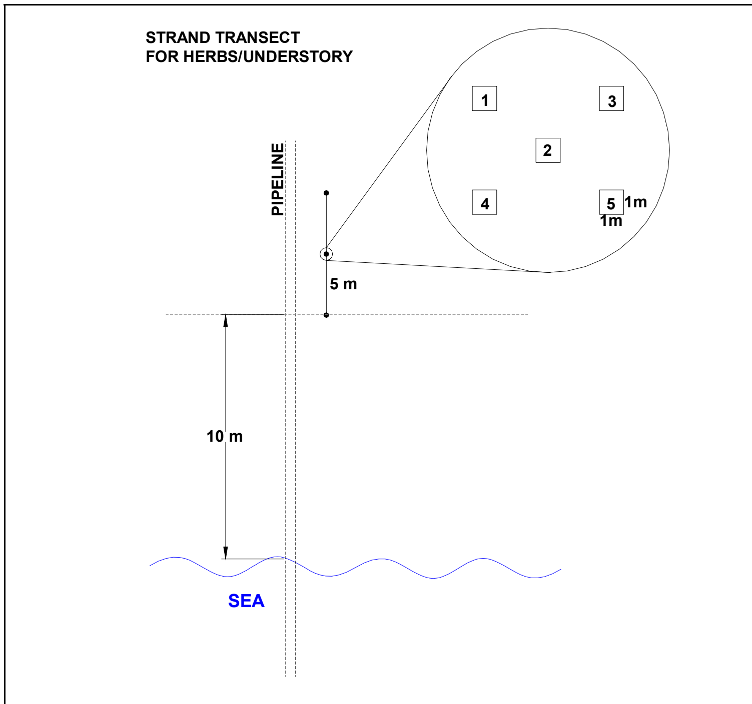
At each sampling point along a transect, data to assess plant species diversity and abundance was collected. The sampling quadrats were a 10m circular radius for trees greater than 7.5cm diameter at breast height (dbh) (trees), 5m radius for shrubs and saplings greater than 1m tall but less than 7.5cm dbh (saplings) and five randomly placed 1m x 1m square quadrats for herbaceous plants and trees less than 1m tall (understory plants). See Figure 2.2-1 for an illustration of the transect and quadrat design. Within the 10 m radius quadrats, the dbh measurement for each tree and its species name was recorded. In the 5m radius plots, the number of saplings of each species was recorded. In the 1m x 1m quadrats, plant species cover were estimated by species and recorded using the following abundance categories:

90-100%	=	10
80-89%	=	9
70-79%	=	8
60-69%	=	7
50-59%	=	6
40-49%	=	5
30-39%	=	4
20-29%	=	3
10-19%	=	2
0-9%	=	1

The approximate height of the tree canopy, sapling canopy, and understory stratum was recorded at each sampling point. Also recorded at each sampling point was the phenology of the dominant vegetation and any abnormal senescence, yellowing, insect/fungal damage, or shedding of leaves.

Figure 2.2-1
Onshore Sampling Design





In the beach/inter-tidal habitat area, transects were established perpendicular to the shoreline in order to reveal gradients in vegetation type. Only the five randomly placed 1m x 1m quadrats were to be used at each of the three sampling points per transect. Plant species cover was estimated by species and recorded using pre-designed forms. Plant health status was visually assessed and plant species that could not be identified in the field were taken for identification at a herbarium or using other appropriate expertise.

Data collection forms designed for the survey (in both French and English) were used for vegetation sampling. Examples are provided in Attachment J. Coordinates for soil samples were reported using decimal degrees on these forms. The equipment list for onshore sampling can be found in Attachment C.

Measures of Vegetation Abundance

The abundance of trees in each habitat (for those habitats with trees) was expressed in terms of average stand basal area. Stand basal area, denoted by the symbol *G*, is the sum of the basal area of all (living) trees in a stand, expressed in m^2/ha. Basal area for a single sampling point on a transect was calculated from measurements of the diameter (dbh incm) of all trees in the area of the 10m radius quadrat (*a* shall be expressed in square hectares) using the following formula:

$$G = \frac{\Pi}{40000} * \frac{\sum dbh^2}{a} = 0.0000785398 * \frac{\sum dbh^2}{a}$$

Average basal area of the habitat was derived by averaging the sample point basal areas across the four sampling points along the transect.

The abundance of saplings in each habitat was expressed as average number of stems, which is calculated by adding the number of stems for all species of saplings at a sampling point and then averaging that number across the four sampling points along the transect. The abundance of understory in each habitat was expressed as average cover of understory species, which was calculated by adding the total cover for all species of understory vegetation at a sampling point and then averaging that number across the three or four sampling points along the transect.

Measure of Vegetation Species Diversity

Species diversity indices was calculated using the Shannon diversity index (H), which takes into account both abundance and evenness of species present. In the Shannon index, the proportion of species i relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by –1:

$$H = -\sum_{j=1}^{S} p_i \ln p_i$$

For determining the proportion of species, the number of stems is used for trees and saplings and the abundance categories (1-10) are used for understory species. Average species diversity of the habitat was derived by averaging the sample point species diversity across the three or four sampling points along each transect.

Soil Sampling

Soil samples were collected along the same habitat transects used for vegetation sampling. In the original approach, a total of approximately 62 soil point samples (44 inland and 18 nearshore) were to be collected. This was modified somewhat based on field observations as described for each specific country (see the report appendix).

Soils in each of the habitat types identified in the study areas were assessed in terms of regional and local characteristics, susceptibility to erosion, physical and chemical characteristics, and biota (soil organisms).

Discreet samples (i.e., point samples) were collected from the upper soil layer (0 to 15cm) and were analyzed for the following physical and chemical parameters:

- pH
- Total hydrocarbons
- TOC
- Trace metals (Al, Cd, Cr, Cu, Fe, Hg, Mg, Ni, Pb, V, Zn)
- Particle size distribution

Additional samples were collected as composites for each transect. The necessary number of additional samples needed to create a composite sample was dependent upon the heterogeneity of soil on the transect and Field Team Leaders made judgments about this in the field. Two composite samples were created at each transect-one composite sample for the upper soil layer (0 to 15cm) and one composite for the deeper soil layer (15 to 50cm) (see Figure 2.2-1). The composite samples were collected and analyzed for the following parameters:

- PAH
- Microbiology
- Macrobiology/soil ecology

Coordinates for soil samples were reported using decimal degrees as indicated on the Onshore EBS Data Collection Forms that are provided in Attachment J.

Surface Water and Sediment Quality Hydrobiology

Water sampling was conducted in study areas that contain surface water bodies. *In situ* water sampling at each station (one sampling station per water body), during both dry and wet season sampling periods, included measurements of:

- Salinity
- Conductivity
- Turbidity
- DO
- pH
- TDS
- Temperature

In addition to *in situ* measurements, where feasible water samples were collected at the water surface (upper depth) and at the water-sediment interface (lower depth). Where water bodies were tidally influenced, samples were collected during both high and low tide regimes. In general, samples were taken from each station by directly dipping the sampling container into the surface water or for subsurface water by using a specialized water sampler (e.g., Niskin-type). Sampling containers used were compliant with the appropriate requirements such as Nigeria DPR, 2002. It was planned that in Nigeria, 3 water bodies will be sampled, 3 in Benin, and 4 in Ghana. There were no water bodies in Togo in the study area. The samples were analyzed in the laboratory for the following:

- Oil and grease (or other hydrocarbon measure)
- Trace metals
- BOD5
- Total alkalinity
- Anions (SO4-2, NO3, NH3+)
- Primary productivity of phytoplankton (excluding macrophytes)
- Plankton (phytoplankton and zooplankton) biomass

In situ measurements of ambient and water temperature were taken using a thermometer. Total water depth was sounded and turbidity was measured using a lead line attached to a Secchi disc or a portable electronic multi-probe. Water pH, conductivity, and salinity were measured *in situ* using portable meters.

The geographical co-ordinates for each sampling station were determined using a portable GPS unit. The equipment list for onshore sampling can be found in Attachment C.

Plankton Standing Crop and Primary Productivity

For plankton analysis, samples of surface water were collected at each sampling point. The water was strained through a phytoplankton net (mesh size of about 45µm) to a concentrate volume of about 25 to 30ml. The strained sample was preserved in formalin solution.

Separate samples were collected for the *ex situ* determination of respiration and productivity under natural light conditions in the laboratory.

Sediments and Macrobenthic Fauna

Where applicable, sediment samples were collected from the benthic environment at the surface water sampling stations. The loose surface accumulation was removed and then samples taken from approximately 30 to 50cm depth. Measurements of the sediments were taken *in situ* of:

- pH
- Redox potential
- Temperature

The collected sample was split and one half, sieved, and macrobenthic organisms collected and preserved in 10 percent buffered formalin solution. The other half was stored on ice and transported to the laboratory for the following chemical analyses:

- Grain size
- TPH
- TOC
- Trace metals

<u>In-Situ Methods</u>

A variety of *in situ* measurements were conducted for each of the sampled media. These are described in each specific section (e.g., "Soil Sampling," Surface Water," etc.).

<u>Wildlife and Animal Resources</u>

Field observations were carried out in each of the onshore habitat locations in order to acquire data on the animal and wildlife resources within the study area. Observations during evening and early morning for three days in each habitat were made while walking along beaches and footpaths and slowly riding in boats along creeks and around landfalls in the study area. Animal and wildlife resources were taxonomically identified. Wherever possible, pictures of the wildlife, their parts, footprints, nesting sites, and fecal droppings were taken as evidence of their presence.

In addition, information was obtained through interviews, focus group discussions and other interactive sessions. These interactions involved hunters, trappers, traders in wildlife materials, and farmers from settlement and village locations within the study area.

<u>Fish and Fisheries Resources</u>

Fisheries observations were carried out within the selected habitat-sampling areas by observation of fisherman landings and fish market surveys in the study area. The entire catch was observed for its composition and representative specimens. The fish species were taxonomically identified and fishing gear, tools, and technology commonly used by local fishermen were noted. Information on the collected fish shall include the species name, the length, weight, and health status, among other characteristics.

<u>Sample Tracking, Storage, and Shipping</u>

Soil, sediment, and water sample collection and handling was carried out using the protocols described in the approved work plan. Protocols were in accordance with the requirements of the applicable country (e.g., Nigeria DPR , 2002 Part VIII D (2): Sampling and handling of samples). The equipment list for onshore sampling can be found in Attachment C.

The methods of analyses also followed applicable requirements (such as Nigeria DPR guidelines and standards) and other international analytical standards such as in Methods of Soil Analysis (Page, et al. 1987), U.S. Agronomy No 9: Soil Survey Analytical Continuum (USDA/SSIR No 42 Version 3.0 of 1996), Methods of Soils and Plant Tissue Analysis (International Institute for Tropical Agriculture (IITA), Ibadan, 1979).

For *in situ* field measurements and sample collection, practices such as regular, periodic calibration of the instruments and standardized observational procedures were instituted to reduce the likelihood of errors. The sampling equipment (e.g., soil auger and sampling tube) was decontaminated before and after each sampling event. Pre-cleaned aluminum foil sheets shall be used to line sampling buckets and disposable hand-gloves shall be changed after each bulk/composite sample.

After collection, the samples collected for chemical analysis were inventoried stored in a secure area immediately. The inventory includes counting samples to ensure that all samples were collected and placed in the custody area in the vehicle, documenting all samples, and preparing a Chain of Custody form (see example in Attachment F) or other form of sample tracking documentation for all samples.

The Field Team Leader was responsible for arranging sample delivery to the applicable laboratory and for maintaining secure custody of samples during transfer. Soil samples meant for laboratory analysis were iced immediately after collection and in the laboratory, these samples were refrigerated or frozen during the period of storage.

Vegetation, Soil, Wildlife, and Surface Water Forms (Attachment J) were printed and maintained in a 3-ring binder, protected from the environment as best possible. This logbook was maintained by each Field Team Leader and signed at the completion of each station. Field data was recorded using ink and where photo documentation was taken, comments were recorded in field notebooks.

Original field notebooks, field forms, navigation and instrument electronic files, photographic files, chains of custody were transferred to the respective Field Team Leader at the end of sampling operations for review, appropriate processing, and storage. These records will ultimately be stored as part of this report.

<u>Soil and Groundwater at the Proposed Compressor Site</u>

An assessment of the baseline physical and chemical characteristics of the uppermost groundwater bearing layer(s) in the vicinity of the proposed compressor station site, including information regarding aquifer hydraulic properties beneath the construction site, was performed. Electrical reconnaissance geophysical methods (vertical electrical sounding) were used and supplemented with the installation, sampling and testing of three groundwater monitoring wells. The geophysical methods were used to provide a quick and efficient indication of the depth to the water bearing layers, as well as the direction of groundwater flow, and gross groundwater quality (conductivity) over a large area. This information was used to aide in the final design and placement of the monitoring wells. Using the borehole sediment types, the results from the vertical electrical sounding (VES) were calibrated to indicate subsurface conditions over a much broader area than that provided by either method alone.

Electrical Soundings

Geophysical prospecting methods involving the use of electrical resistivity principles were conducted primarily to guide monitoring well installation. To conduct the survey, collinear arrays were configured for vertical electrical soundings (VES) over the study area to achieve a profile depth of at least 30m is achieved. Electrical current sources were provided by portable generating equipment. A commercially available software packages was used to interpret the data.

Soil Borings

The results of the electrical soundings were used to guide the siting of the locations of three monitoring wells. The wells were installed using rotary drilling equipment with a mechanical auger. The soil core samples were obtained following applicable protocols using a split-spoon sampling systems.

Borehole sediment was classified in the field as to type and texture using the USCS soil classification system and borehole logs were prepared to document the soil classifications. The boreholes were drilled to a diameter sufficient to accept a 10cm diameter PVC well casing and screen placed in a centralized position in the borehole.

Soil Sampling and Analysis

Samples of the soil core from each borehole were selected and retained for laboratory analyses. The depths sampled was based on the occurrence of staining or major lithologic changes. The sample was placed in appropriate glassware and transported in chilled coolers to the analytical laboratory under standard chain-of-custody control. The samples was analyzed for the following parameters:

- TPH
- Trace metals (Al, Cd, Cr, Cu, Fe, Hg, Mg, Ni, Pb, V, Zn)
- Grain size/porosity

Soil sample handling procedures were as described elsewhere.

Monitoring Well Construction

Once completed, the boreholes were converted into monitoring wells constructed of 10cm diameter PVC casing and screen configured so that the screen was aligned adjacent to the water-bearing layer that was to be tested and monitored. Once inserted, the annular space in the borehole between the screen and wall of the boring was gravel-packed from the bottom of the borehole to a depth of 1m above the screened interval. The remainder of the annular space received a 1m bentonite plug and cement grouted to the surface.

The well was completed with a protective, lockable surface casing over the wellhead and a cement pad and bollard posts placed around the protective surface casing. The horizontal locations of the monitor wells was determined using a portable GPS unit. The ground surface and top of each monitoring well casing was surveyed on a relative basis to the nearest 0.010ft by legal survey referenced to a permanent retrievable construction datum. Once the well was completed and sampled (see below), it was properly capped in order for it to be secured for future sampling.

Groundwater Analysis

The wells were sampled after they were allowed to recover, more than 48 hours after their installation. Prior to sampling, the wells were developed to remove drilling residuum. Development monitoring was determined by removing by bailing the well contents and screening in the field for pH, specific conductance, turbidity and temperature and monitoring for constant readings as an indication that development was complete.

During the field survey, groundwater samples from each monitoring was removed and retained for analysis in the laboratory. Sampling was carried out with clean sampling implements at each well and the sample was placed in cleaned glassware and transported in chilled coolers to the analytical laboratory under standard chain-of-custody control. The samples were analyzed in the laboratory for the following parameters:

- pH
- PAH
- Trace metals (Al, Cd, Cr, Cu, Fe, Hg, Mg, Ni, Pb, V, Zn)

Hydraulic Conductivity

To estimate the hydraulic conductivity, a single well tests (slug tests) was carried out at each monitoring well using both falling and rising head methods. Portable water level indicators and data loggers were used for this measurement and the results are intended for future monitoring activities.

Onshore Field Sampling–Climate and Meteorology

A mobile meteorological station was set-up near the proposed compressor station site to provide information on current meteorological conditions. Data retrieved from the meteorological station in Nigeria will be used during subsequent air quality characterization.

Baseline survey information in Ghana, Togo, and Benin was collected from existing sources of meteorological information (e.g., nearby airports).

Onshore Field Sampling–Air Quality

A limited air quality study focused on the vicinity of the proposed compressor site was conducted to provide baseline data for potential pollutants of concern: particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), and oxides of nitrogen (NO_x). One portable air sampler equipped with 6L Tedlar bags was positioned at the site to collect ambient air grab samples. Three sample periods per day were collected over a two-week period. Particulate matter was collected on a filter and then measured in the laboratory. Gaseous were analyzed in the laboratory for CO and NO_x concentrations. Because oxides of sulfur (SO_x) are expected to be absent in the WAGP supply, they were not analyzed.

For the other onshore areas, important sources of air emissions were identified by literature review and sensitive receptors identified and characterized by field observations.

2.3 ANALYTICAL METHODS

The descriptions below provide an overview of the methodologies used, references to the methods used, a discussion of comparability of different where appropriate, and information about the quality of data the methods are capable of generating. Specific details about the procedures used by the specific countries and laboratories follow in the respective appendix for each country.

2.3.1 Physical Laboratory Methods

Grain Size/particle Size Distribution

Mechanical sieving of larger size particles and hydrometer separation of finer particles were used to determine the grain size and/or particle size distribution of soils and sediments. The methods referenced include the Bouyoucous (1951) method, sieve/hydrometer methodology equivalent to ASTM D-422, or by the semi quantitative Page et al.(1987) method measuring settling of particles against standard published rates. The methods are considered to provide data of comparable quality although direct comparison of the data may be difficult depending on the series of sieve sizes used and the relative particle size distribution of the soil samples. All methods produce comparably usable information at larger grain sizes. The hydrometer method is preferred over the Page et al. (1987) method at small grain sizes (less then 50µm).

Sieve Method

This test method covers the quantitative determination of the distribution of particle sizes in soils. The sieve method determines size constituents based on passing the dried material through sieve screens of various sizes and weight determinations of the fractions retained on each the sieve. In most cases the addition of a dispersion agent (sodium hexametaphosphate) aids uniformity of the soil mixture and accurate sieving. The accuracy and division of this data is based on the number and division of screens employed which can vary widely. The distribution of particle sizes larger than approximately 75µm (retained on the No. 200 sieve) is determined by sieving.

Hydrometer Method

The distribution of particle sizes smaller than approximately 75µm is determined by a sedimentation process, using a hydrometer. The hydrometer methodology quantitatively determines the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer. The hydrometer method of estimating particle size analysis (sand, silt and clay content) is based on the dispersion of soil aggregates using a sodium hexametaphosphate solution and subsequent measurement based on changes in suspension density. The use of the ASTM 152 H-Type hydrometer is based on a standard temperature of 20°C and a particle density of 2.65 g/cm^3 and units are expressed as grams of soil per liter. Corrections for temperature and for solution viscosity may be made by taking a hydrometer reading of a blank solution. The method has a detection limit of 1 percent sand, silt and clay (dry soil basis) and is generally reproducible within 8 percent (relative). In the Page (1987) settling method, after sieve fractionation, the finer silt and clay particles are suspended and allowed to settle. Given published rates of migration of known particle sizes pipette samples are taken, dried and weighed to estimate the mass of clay and (by difference) the mass of silt. Accuracy of this method is lower and considered only semi-quantitative.

pH/Soil reaction

The pHs of soil samples were determined using the saturated paste and pH meter. This quantitative but screening level method determines the pH of soil, using a saturated paste prepared from the soil and a pH meter. It is most applicable to soils with a pH ranging from 4.0 to 9.0. It is not possible to determine the total acidity or alkalinity of the soil from pH because of the nature of the colloidal system and junction potential. This method does however provide information on the disassociated H-ions affecting the sensing electrode. The method is generally reproducible within 0.2 pH units.

2.3.2 Chemical Laboratory Methods

Alkalinity

Onshore and offshore surface water samples were analyzed for alkalinity. Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity of water is due primarily to the presence of bicarbonate, carbonate, and hydroxide ions. Salts of weak acids, such as borates, silicates, and phosphates, may also contribute. Salts of certain organic acids may contribute to alkalinity in polluted or anaerobic water. Bicarbonate is the major form of alkalinity. Carbonates and hydroxide may be significant when algal activity is high, and in certain industrial water and wastewater, such as boiler water. Alkalinity is expressed as phenolphthalein alkalinity or total alkalinity. Both types can be determined by titration (APHA 2310 STD Method, 19^{th} ed. 1995) with a standard sulfuric acid solution to an end point pH, evidenced by the color change of a standard indicator solution (generally methyl orange) or by pH meter.

Biochemical Oxygen Demand (BOD5)

Onshore surface water samples were analyzed for BOD5 to determine the extent to which oxygen within a sample can support microbial life. Analyses were performed according to the Winkler titration method equivalent to APHA 422 (STD Method 19^{th} ed., 1995). Initially samples are initially seeded with microorganisms and supplied with a carbon nutrient source of glucose-glutamic acid. The sample is then introduced to an environment suitable for bacterial growth at reproducible temperatures, nutrient sources, and light within a 20^{o}C incubator such that oxygen will be consumed. Quality controls, standards and dilutions are also run to test for accuracy and precision. Determination of the dissolved oxygen within the sample can be determined through Winkler titration methods. The difference in initial DO readings (prior to incubation) and final DO readings (after 5 days of incubation) predicts the BOD of the sample.

Carbon Monoxide (CO)

Air samples were analyzed for carbon monoxide in the area of the Nigeria compressor substation. Samples are collected by drawing into Tedlar bags. The CO concentration in the sample is measured spectrophotometrically using the reaction of CO with p-sulfaminobenzoic acid. In the known presence of high levels on NOx and Sox, removal of these interferents by passing the gas through alkaline permanganate solution is required to eliminate false positive determination.

Chemical Oxygen Demand (COD)

Onshore and offshore surface water samples were analyzed for COD. The mg/L COD results are defined as the mg of O_2 consumed per liter of sample under conditions of this procedure. The samples are analyzed using the closed reflux method with spectrophotometric or titrimetric determination equivalent to APHA 5220D (STD Method 19th ed., 1995) or APHA 5220D (STD Method 19th ed., 1995). In the reactor digestion method, the sample is heated for two hours with a strong oxidizing agent, potassium dichromate. Oxidizable organic compounds react, reducing the dichromate ion (Cr2O72-) to green chromic ion (Cr3+).

Mercuric sulfate addition is critical to removal of chloride interferences. Spectrophotometer or titration measurements provide essentially equivalent quantitation of the concentration of chromic ion.

Electrical Conductivity

Onshore surface water samples were analyzed for electrical conductivity in certain countries. Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, and valence; and on the temperature of measurement. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all. Electrical conductivity was measured *in situ* in surface water samples using standard conductivity meters.

Exchangeable Acidity

Onshore and offshore sediment samples were analyzed for exchangeable acidity to provide a measure of the cation exchange capacity of the soils in combination with alkaline metal analyses. Cation exchange capacity is a criterion in assessment for disposal or utilization of organic or industrial wastes for agricultural crops. Exchangeable acidity is determined by titration relative to known buffer solutions.

Metals (Al, Cd, Cr, Cu, Fe, Hg, Mg, Ni, Pb, V, Zn)

Onshore and offshore sediment, surface water, and soil samples were analyzed for metals. Metals were determined by procedures varying from atomic absorption through inductively coupled plasma/Mass Spectrometer (ICP/MS) equivalent to APHA 3111 B (STD Method 19th ed., 1995) and USEPA Method 6010/6020. All determination are initiated by acid digestion to remove organic material interferents. Analysis involves instrumental measurement and quantitation versus known standard concentrations. ICP/MS provides additional spectral information to verify identification and eliminate potential background interferences. Mercury determination were made using cold vapor atomic absorption (Method 245.1). The sample is digested with a dilute potassium permanganate-potassium persulfate solution. The digestion oxidizes all forms of mercury to Hg(II). The Hg(II) in the digested water sample is reduced with stannous chloride to elemental mercury which is sparged from the sample and detected by atomic absorption.

Nitrogen forms (Nitrate, Nitrite, Ammonia Nitrogen, Total Nitrogen)

Various measurements of nitrogen were analyzed for in onshore and offshore surface water, sediment, and soil samples. The forms of nitrogen measured include nitrate, nitrite, ammonia nitrogen, total nitrogen, although in cases only specific forms of nitrogen were measured in the same series of samples. The analyses of the various forms rely on chemical reaction of the samples with catalyzing agents (for example cadmium metal in the analysis of nitrate nitrogen reduces nitrate in the sample to nitrite) to ensure or distinguish chemical forms of nitrogen. Then reaction with color forming agents (for example sulfanic acid in nitrate analysis) to form specifically colored complexes and/or compounds. Measurements of the concentrations of the nitrogen form are then made spectrophotometrically at specific wavelengths against standard concentration curves.

NOx

Measurement of various nitrous oxides (commonly referred to as NOx) were performed in air samples in the area of the Nigerian compressor station. Samples were collected in Tedlar bags and analyzed by direct instrument readings in the laboratory. The NOx analyzer utilizes the uses the normal pressure chemoluminescence method. While when fully calibrated and analyzed *in situ* the detector is capable of quantitative measurement, the collection in the Tedlar bag and subsequent lab analysis limits these measurements to semiquantitiative results.

Oil and Grease

Onshore and offshore surface samples were analyzed for oil and grease, also known as hexane extractable organic. A similar method of pentane extractable organics was performed on soil and sediment samples from selected countries. Method variations arose due to statutory removal of the more common and historical freon (chlorofluorocarbon) extractable organic tests due to ozone depletion regulation. Many countries and regulatory bodies have become divided on the best approach to characterizing the fractionating of the possible petroleum impacts. Each of the methods involves extraction of samples in small volumes of solvent (in this cases either pentane or hexane), spectrophotometric analysis at a specified wavelength (420 nm) and comparison against a standard concentration curve.

Particulate Matter

Air samples were analyzed for particulate matter in the area of the Nigeria compressor substation. Samples are collected by drawing known volumes of air through pre-weighed filters. The collected samples are weight and the difference equal to the determination of particulate matter above the pore size of the filter. Careful handling of the filters is critical to accurate determinations but the method provides a quantitative determination of particulate matter.

Phosphorus forms (phosphate, orthophosphate, reactive phosphorus, total phosphorus)

Onshore and offshore water samples were analyzed for forms of phosphorus. Phosphates are important nutrients at low concentration, at higher levels can be an indicator of discharges, and at high levels can lead to eutrophication under certain conditions. Phosphorus analyses APHA 4500-PE (STD Methods 19th ed) consist of two general procedural steps: (*a*+) conversion of the phosphorus form of interest to dissolved orthophosphate, and (*b*) colorimetric/spectrophotometric determination of dissolved orthophosphate. The primary forms determined in this program were reactive phosphorus and total phosphorus. Phosphates that respond to colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample are termed ‘‘reactive phosphorus.’’ While reactive phosphorus is largely a measure of orthophosphate, a small fraction of any condensed phosphate present usually is hydrolyzed unavoidably in the procedure. Reactive phosphorus occurs in both dissolved and suspended forms. Total phosphorus (orthophosphate, condensed, and organically bound) can be determined by acid oxidation with persulfate, followed by the reactive phosphorus test. Organically bound phosphate can then be determined by subtracting the acid-hydrolyzable phosphorus.

Polyaromatic Hydrocarbons (PAHs)

PAH analysis was performed on soil, sediment, and surface water samples. PAH analysis provides a measure of higher molecular weight organic compounds often related to petroleum products or contamination or combustion products. Measurements of total PAHs involve preparation of the sample to concentrate the PAHs, and analysis by gas chromatography typically by flame ionization although possibly also by mass spectrometry (MS) for verification of specific compound identification with minimal loss of sensitivity. Additional extract clean ups may precede analysis where other suspected interfering compounds may be present. Quantitation of the results as total PAHs provides a relative measure of the concentrations of PAH compounds where identification of specific PAH compounds can add to the interpretation of the source of elevated PAHs.

Solids (Total Suspended Solids, Total Dissolved Solids)

Measurements of solid components (TSS and TDS) were determined in offshore and onshore water samples. TDS/TSS provides a measure of the total water soluble/insoluble fraction and do not reveal the quantity or type of individual contaminants in the sample TDS analyses were determined using *in situ* meter determinations calculated at reference conditions from conductance. TDS laboratory measurements were determined from gravimetric procedures equivalent to APHA 2540 C (STD Method, 19th ed, 1995). TSS was determined using gravimetric procedures equivalent to APHA 2540 D (STD Method, 19th ed, 1995).

Sulfate

Determination of sulfate in surface water samples was based on the barium chloride turbidity method equivalent to APHA 4500-Si (STD Method, 19th ed, 1995). Barium chloride is added and turbidity caused by barium sulfate suspension which is proportional to sulfate concentration is measured either spectrophotometrically or using a turbidimeter.

Total Petroleum Hydrocarbons (TPH)

TPH analysis was performed on soil, sediment, and surface water samples. TPH analysis provides a determination of organic petroleum –related compounds. Measurements of TPH involve preparation of the sample to concentrate the compounds of concern, and analysis by gas chromatography typically by flame ionization. Additional extract clean ups may precede analysis where other suspected interfering compounds may be present. Quantitation of the results as TPH provides a relative measure of the petroleum related concentrations.

Total Organic Carbon

Determination of total organic carbon in sediment and soil samples was by the Walkley and Black (1934) method modified by Nelson and Somners (1982) using potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement. This method quantifies the amount of oxidizable organic matter in which OM is oxidized with a known amount of $Cr_2O7_2^-$ in the presence of sulfuric acid. The remaining Cr_3^+ chromate is determined spectrophotometrically at 600nm wavelength. The calculation of organic matter is based on organic matter containing 58 percent carbon. The method has a detection limit of approximately 0.01% and is generally reproducible within 8 percent. Alternatively the loss of ignition method (Page et al., 1987) was utilized which is not directly comparable but provides sufficient data quality when compared with data using the same methodology.

Turbidity

Turbidity was measured in offshore and onshore surface water samples. Measurements varied from in situ determination via Secchi disk method to APHA 2130 B (STD Method 19th ed., 1995). Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. Although the methods are not comparable, the determinations are internally comparable and consistent. For clarification the Secchi disk determinations will be termed clarity while turbidity will be applied only to optical scattering instrumental determinations (nephelometer). Secchi disk measurement provides field screening level determination of clarity. Nephelometer measurements are considered fully quantitative.

Volatile Organic Compounds (VOCs)

Air samples were analyzed by direct instrument reading in the area of the Nigeria compressor substation. Photoionization detectors were utilized capable of detecting many volatile organic species to provide an estimate of total volatile organics. The detector is somewhat selective as only species with first ionization potential below the detector lamps ionization energy are detectable although most common VOCs are in the range of the commonly utilized lamps. Instrument response varies depending on the compound detected although standard published values of relative response can allow correction of the raw reading when particular components are known. However, the method is considered screening level only with unusual detects typically requiring independent confirmation analyses that are capable of both improved quantitation and more definitive compound identification.

2.3.3 Biological Laboratory Methods

Biological laboratory methods for assessment of phytoplankton, zooplankton, phytoplankton productivity, microbiology identifications, and macrobenthic identification and diversity were performed to characterize the biological baseline conditions.

Plankton and Productivity

In the laboratory known values of water samples for phytoplankton analysis were analyzed using a microscope at multiple magnifications. Sedimentation was carried out in counting chambers, cell counts were made in duplicate and average cell counts per ml computed.

Filamentous and colonial forms were counted as individuals and their numbers multiplied by the average numbers of cells for filament or colony (determined for some 20 individuals) as carried out by Lund et al. (1958). Identifications were carried out standard reference materials, which may have differed based on accepted country standards.

The formulas used for estimation of respiration, photosynthesis and relative productivity were as per Wetzel and Likens (1990).

1. Respiratory activity per unit volume
   Per time interval (mg0_2/L/hr)
   IB - DB (IB = initial oxygen)
   (DB = 0_2 Dark bottle)

2. Net photosynthetic activity per unit
   Volume per time interval (mg0_2/L/hr)
   LB - IB (IB = initial oxygen)
   (LB = 0_2 light bottle)

3. Gross photosynthetic activity (mg0_2/L/hr)
   (LB - IB) + (IB - DB) = Net photosynthesis + Respiration

4. Relative production (mg C/m^3/hr)

$$\frac{[(0_2\ LB) - (0_2\ DB)]\ \times (1000)\ (0.375)}{(PQ)\ t}$$

0.375 = ratio of moles of carbon to moles of oxygen (12 mgC/32 mg0_2)
t = time of exposure = 12 hrs

PQ = 1.2 = Dimensionless number indicating the relative amount of carbon Involved in the processes of photosynthesis and the constant is given as 1.2

Relative productivity ranges are

1.0mgC/hr/m^3/ for sea (Doty and Oguri, 1957)
11(- 29) (mg C/hr/m^3) for Inland water (Elster, 1965)

<u>Quantitative Estimation of Bacterial Flora</u>

Total Viable Bacterial Density Determination

Viable heterotrophic bacterial populations were determined for all the water and soil samples using the heterotrophic plate count procedure (Standard Methods, 1998) at 22 ± 0.50C and 37 ± 0.50C. The low-nutrient medium NWRI agar (HPCA) (Standard Method, 1998) was used. One (1.0) ml of each sample was mixed with liquefied (450C) NWRI agar, in sterile Petri dishes and the mixture allowed to solidify. One set of Petri dishes was incubated at 220C and another set at 370C for 48 hours. Bacterial colonies, which developed, were counted using the Karl Kolb Colony Counter (Model D-6072), and the value obtained was converted to number of CFU per milliliter of sample.

Total Coliform Counts

The membrane filtration method (Standard Methods, 1995) was used to determine the levels of total coliform bacteria. 50ml of each of the water samples and one (1.0) ml of each soil (solution) were separately filtered using 0.45μm membrane filter (Millipore). Each membrane filter was incubated on M-Endo agar (Oxoid) and incubated at 37 ± 0.50C for 18 to 24 hours. All colonies that showed metallic sheen were counted as positive total coliform bacteria. Deep red colonies were confirmed as coliforms using MacConkey broths.

Faecal Coliform Counts

The membrane filtration method was used. 20ml of each water sample and one (1.0) ml of each soil (solution) filtered. Each membrane filter was then incubated on MFC agar (Difco) and incubated at 44 + 0.50C for 18 to 24 hours. All colonies that showed blue colors were counted as positive faecal coliforms.

Sulfate Reducing Bacteria Counts – *Desulphovibrio* spp.

1ml of each water and soil sample was inoculated into molten beef-peptone agar (with 1 percent lead acetate) in sterile Petri plates. Inoculated plates were incubated anaerobically at 20 to 220C for 6 days. Bacterial colonies, which developed, were counted and the value obtained was converted to number of CFU per milliliter of sample.

Sulfate Reducing Bacteria Counts – Clostridium spp.

10ml of each of the water and soil samples were separately pasteurized at 800C for 10 mins. 1ml of each water and soil sample was inoculated into molten yeast extract agar (Oxoid) in sterile Petri plates. Inoculated plates were incubated anaerobically at 370C for 48 hours. Bacterial colonies, which developed, were counted and the value obtained was converted to number of CFU per milliliter of sample.

***Pseudomonas* Counts**

50ml of each of the water sample and 1ml of each soil solution was passed through a 0.45μm membrane filter and the filter transferred to Petri dish containing Cetrimide agar (Difco). Inoculated plates were incubated aerobically at 370C for 48 hours. Bacterial colonies, which developed, were counted and the value obtained was converted to number of CFU per milliliter of sample.

Hydrocarbon Degraders – Hydrocarbon decomposers

1ml of each water and soil sample was added to molten medium made up of Distilled water, 1000ml; NH_4NO_3, 1g; K_2HPO_4, 1g; K_2HPO_4, 1g; $MgSO_4 \cdot 7H_2O$, 0.2g; $CaCl_2 \cdot 6H_2O$, 0.02g; FeCl3.6H2O 2 drops and Agar, 20g. Sterile petroleum was thinly spread on the solidified surface and incubated at 20 – 220C for 7 days. Colonies were counted and the value obtained was converted to number of CFU per milliliter of sample.

Hydrocarbon Degraders – Hydrocarbon oxidizers

One ml of each water and soil sample was added to molten medium containing tap water 1000ml; KNO_3, 1g; K_2HPO_4, 1g; $MgSO_4{\cdot}7H_2O$, 0.2g; NaCl, 1g; and agar, 20g. Sterile petroleum was thinly spread on the solidified surface and incubated at 20 to 220C for 7 days. Colonies counted were converted to number of CFU per milliliter of sample.

Quantitative Estimation of Fungal Flora

Moulds Determination

One ml of each water and soil sample was inoculated separately into Neopeptone-glucose-rose Bengal aureomycin agar (Standard Methods, 1998) in sterile Petri plates. 0.05ml of tetracycline (1g water soluble antibiotic/150ml distilled water) was added to the molten mixture to check the growth of bacteria. Incubation was at 20 to 220C and plates were counted after 3, 5 and 7 days. Colonies counted were converted to number of CFU per milliliter of sample.

Yeasts count

One ml of each water and soil sample was inoculated separately into yeast extract-malt extract-glucose agar (Standard Methods, 1998). Inoculated plates were incubated at 20 to 220C and plates counted after 2 to 3 days. Colonies were counted and the value obtained was converted to number of CFU per milliliter of sample.

Macrobenthic infauna

In the laboratory, each of the macrobenthic samples was emptied into a Petri-dish and examined under the dissecting microscope. The recorded organisms were sorted out, identified and counted. Identification was done as much as possible to species level using relevant literature. Where fragmented animals were found, only those with heads were counted. The determination of diversity (species richness and diversity indices) of the original macrobenthic communities were based on the measurements made. Taxa richness was computed using Margalef's index (D) expressed as

$$D = \frac{S-1}{\ln N}$$

Where S = number of taxa

N = total number of all individuals

ln = natural logarithm

General species diversity using Shannon Wiener (H) index was computed as

$$H' = \frac{N\log N - \sum_{i=1}^{k} n_i \log n_i}{N}$$

where: n = total number of individuals
n_i = number of individuals in species
k = total number of species

Evenness index (E) which expresses the degree of uniformity in the distribution of individuals among the taxa in the collection was also calculated as follows:

$$E = \frac{H'}{H_{max}}$$

where: H' = Shannon-Wiener index
H_{max} = maximum expected diversity expressed as logs
S = number of taxa

Besides the application of the diversity indices, interstation comparisons were carried out to test for significant differences in the faunal abundance using one-way analysis of variance (ANOVA) according to Zar (1984).

2.4 DATA ANALYSIS AND REPORTING

Management of the environmental data was distributed across the project teams with ICF playing a central and coordinating role. The initial responsibility for data management and quality resided in the individual participating organizations and laboratories. For the onshore programs, overall field and final laboratory was managed by the individual teams, who also verified data quality in terms of the project goals. ICF performed a back up role. For the offshore program, ICF played a central role in managing and reporting the field and laboratory data, although the laboratories conducting the analyses were key to this process.

Relative to management of chemical data for this report, data were managed electronically, mainly in the form of computer spreadsheet applications (e.g., Microsoft Excel), which reduced the need for transcription and potential for errors. A database was used to track and monitor the sample analyses from the onshore and offshore programs while they were in progress. It is intended that the final laboratory results for the chemical and biological parameters from this survey, as well as additional data collected in the second season of data acquisition, be managed in a project–specific database.

Data analyses in this report is presented essentially as reported by the participating organizations and laboratories. These same organizations provided brief interpretation of the data and in some case conducted some data analysis and limited statistics.

2.5 DATA QUALITY OBJECTIVES FOR CHEMICAL AND PHYSICAL ANALYSES

To ensure data quality, a comprehensive quality program was implemented. Elements of the quality program include the following:

- Development of planning documents including work plan and SOPs
- Audits of the participating laboratories and organizations prior to and following the project
- Oversight of field sampling operations
- Collection of field quality control samples (Equipment blanks, field blanks, field replicates)
- Analysis of laboratory quality control samples (Laboratory Blanks, duplicates, matrix spikes, interference control samples

These elements of the quality program are intended to ensure that the data generated in the studies are usable for intended purposes and meet minimum data quality standards. Data quality objective standards vary based on the expected use of the data and on the data generation process. The different levels are by convention discussed as DQO Levels I through III as described in table below varying from low data quality requirements and concomitant low data usability (DQO I) through highest level of data quality and widespread data usability (DQO III).

These standards are typically interpreted in terms of data quality indicators: precision, accuracy, representativeness, completeness, comparability and sensitivity (PARCCS). These elements are described further below.

An assessment of the data quality was performed upon completion of the program. The results of this assessment are discussed in Chapter 8.

Table 2.5-1
Summary of data quality objectives and levels.

Data Quality/Usability	DQO Level	Method
High	Level III	Standard, accepted methods with fully implemented QA/QC according to the methods (for example APHA, SW846, ASTM, NIOSH, etc.)
Moderate	Level II	Field analyses or laboratory analyses with minimal quality control (for example Hach kits, turbidity, colorimetric methods, titrimetric methods, gravimetric methods)
Low	Level I	Field analysis, meters with limited or no quality control (for example ph, temperature, dissolved oxygen, etc.)

2.5.1 Data Quality Objectives

Precision

Precision is defined in as a measure of agreement among individual measurements of the same property. For this program, high precision was obtained by:

- Use of standardized sampling procedures
- Linear or consistent instrument calibration
- Field and laboratory QC sample analysis

Field samples collected to assess precision include field duplicates and replicates, which may be spiked with compounds of interest prior to analysis. Laboratory QC samples which are used to assess precision include laboratory duplicates and replicate analyses. In addition to these QC samples, surrogate recovery can be used as a relative measure of precision. The types and frequency of QC sample collection and analysis is detailed below. The following three items are key components of precision evaluations.

Standardized Sampling Procedures

Field sampling procedures were detailed in the approved work plan, which guided all field operations. The procedures were based on accepted procedures for sample collection and standardized forms were used to document the field work. These elements helped insure a high degree of precision.

Analysis of Calibration Standards

Analysis of calibration standards are method specific. Guidelines for calibration were based on DQO level. DQO level I field analyses required analysis of a minimum one point calibration and regular (once per day) calibration check. DQO level II field analyses utilized at least a multi-point calibration curve. Fixed laboratory analyses at DQO levels III normally require a multi-point calibration.

Analysis of Field and Laboratory Duplicates and Replicates

The relative percent difference (RPD) is calculated from the results of field sample replicates (spiked or unspiked) to assess precision. The DQO Level III methods required matrix spike analysis or laboratory control spike (i.e., blank spike) and laboratory control spike duplicate. Acceptable RPDs are differentiated by media, method, analyte, and concentration level (it is more difficult to be precise for example at very low spike levels) although generally acceptable RPDs are 25 percent for aqueous matrices and 50 percent for other matrices.

Accuracy

Accuracy is defined as the degree of agreement of a measurement or average of measurements with an accepted reference or true value. For this program high accuracy was attained by:

- Use of standardized sampling procedures
- Collection of field blanks and equipment blanks
- Use of high quality analytical reference materials
- Instrumental performance
- Laboratory QC sample analysis

Field samples collected to assess accuracy include matrix spike samples, matrix spike duplicates for organic analyses, field blanks (bottle, trip, and equipment), and Performance Evaluation (PE) samples. Laboratory QC samples which are used to assess accuracy include matrix spikes, matrix spike duplicates, laboratory control spikes, method blanks, and instrument blanks. In addition to these QC samples, surrogate recovery can be used as a relative measure of accuracy. The following items are key components of accuracy evaluations.

Reference Materials

All reference materials used for calibration standards or spiking solutions were the highest purity available. Where possible, reference materials independent of the calibration standard material were utilized to insure accurate calibration.

Instrument Performance

Each instrument used on a project was required to be checked on each day that it is used to demonstrate acceptable performance. For example, the gas chromatography methodologies included daily calibration, and system performance checks. Comparable requirements exist for other analyses. The specific instrument performance requirements had to meet the appropriate DQO level and the analytical method specifications.

Recovery of Spiked Analytes

Either the field sample matrix or a standard matrix, such as deionized distilled water or blank soil, is spiked with a known amount of the analyte. The recovery are calculated for each spiked analyte using the results of the analysis. The choice of spiked samples versus standard matrices is based on the method selected. In order to assess accuracy, analysis of spiked samples or standard matrices should be utilized wherever possible based on the DQO level and according to the analytical method. Acceptable recoveries are differentiated by media, method, analyte, and concentration level (it is more difficult to be accurately recover at very low spike levels) and no common standard exists for all applications. Evaluation of spike results will rely on documented method criteria.

All samples for GC/MS analysis are spiked with known amounts of surrogate compounds. The recovery and bias are calculated for each spiked surrogate using the results of the analysis. Surrogate limits are based on well-established analytical methods. Evaluation of surrogate results will rely on documented method criteria.

Completeness

Completeness is defined as a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under average conditions. Valid data are defined as data meeting the DQOs specified in the site-specific QAPjP. The project objective for completeness is 90 percent.

Representativeness

Representativeness is defined as an expression of the degree to which the data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Samples collected for the purpose of chemical or physical characterization of a population must be representative of the populations they are intended to characterize. The results obtained from the analysis of the sample will be used to assess the character of the whole, and frequently these results will be used to determine whether a process, a product, or a condition is acceptable as compared with some predetermined standard or regulation. Therefore, sample selection, collection, and handling methodologies must be based on or derived from procedures or practices that will either deliver a portion of the whole either as it originally existed or altered in a controlled manner.

For this project, the principal sources of uncertainty with respect to representativeness are sample collection and handling methods, temporal variations, and spatial variations. Variability associated with location (spatial) is generally expected to be the largest source of uncertainty.

Objectives for representativeness are based on the proper implementation of a well thought out and defined sampling plan. To minimize the uncertainty, the sampling plan was designed with consideration of the following:

1. The purpose of collecting the sample;

2. The ultimate use of the data;

3. The important components or aspects of the source (or process) being studied;

4. Sample collection methods;

5. Sample location strategy, including, where appropriate, a statistical assessment of the probabilities of either under or over estimating the extent or level of contamination;

6. Timing and frequency of sample collections;

7. Individual sample size;

8. Sample preservation and control procedures; and

9. Quality control sample needs (co-located and replicate samples, split samples, trip and equipment blanks, or matrix spikes).

Evaluation of representativeness is a qualitative judgment based on overview of the entire program including field sample oversight, auditing, and planning documents. An assessment of data represetativeness is made and discussed in Section 8.

Comparability

Comparability is defined as an expression of the confidence with which one data set can be compared to another. Comparability is assured by development and specification of reporting requirements so that the analytical methods used for analysis are clear and that data results are easily interpreted (e.g., data units expressed uniformly).

Sensitivity

Sensitivity is the capacity of the methods used to meet decision criteria that may be based on regulatory standards or scientific need. Demonstration and documentation of method sensitivity limits were required from the participating laboratories.

2.5.2 Field Quality Control Samples

Specific field quality control samples were added to the EBS program to help assess the data relative to the data quality objectives.

Equipment Blanks

Equipment blanks are collected when sampling involves use of collection equipment that comes into direct contact with the sample (i.e., the modified Van-Veen grab) during or following the collection of sediment chemistry samples. The equipment blank is representative of potential contamination associated with the equipment.

For the EBS, blanks were collected as part of the offshore survey. To collect the equipment blanks, the grab was first decontaminated according to the procedure outlined in the work plan. Then the inside of the bucket is rinsed with high-purity, deionized water and the rinsate is collected directly into a clean, pre-labeled water sample container. The rinsate was refrigerated at 4°C and analyzed for metals and organic parameters.

Field Blanks

Field blanks are collected, which are representative of any atmospheric or other contamination that the field samples may be subject to and also of any potential contamination associated with the glassware.

For the EBS, blanks were collected as part of the offshore survey. A clean, pre-labeled sample jar of the same batch used for sample collection was opened during the collection of one sample and returned to the laboratory with the field samples and analyzed for metals and organic parameters.

Replicate Samples (Field Duplicates)

Field replicates are samples collected at the same location and time. The collection frequency and station designation for replicate samples was assigned by Chief Field Scientist and guided by the work plan. The number and type of samples wad based on site observations, daily sampling method frequency, and analytical aliquots collected. For the offshore survey, five replicates were collected.

Split Samples

Split samples are replicate samples collected according to the SOP and work plan requirements for replicate samples that are then analyzed independently by separate laboratories. The analysis of split samples allows for interlaboratory comparison to understand the relative comparability and overall data quality of the individual laboratories. For the project, split samples were collected during the offshore survey and analyzed by both the in-region, primary laboratory, and a US laboratory.

CHAPTER 3
OFFSHORE RESULTS

3.1 OFFSHORE SEDIMENT CHARACTERIZATION

Sediment data collected from the offshore environment are presented in this section. Chemistry results, which consist of hydrocarbons, metals, and physicochemical properties, are presented in Section 3.1.1. This section includes a discussion of regional patterns of distribution. Grain size and total organic carbon (TOC) results are presented in Section 3.1.2. Characterization data from the Sediment Profile Image (SPI) study is presented in Section 3.1.3.

3.1.1 Chemical Results

Hydrocarbons

Hydrocarbons from both natural sources and anthropogenic (human) activities are common in the marine environment (Brassell and Englington 1980). While the offshore route of the proposed pipeline is substantially remote, even distant locations have been reported to receive anthropogenic hydrocarbons via atmospheric fallout (LaFlamme and Hites 1978) and proper characterization of the hydrocarbon background – including recognizing potential sources both non-point and localized - is important to the baseline study.

Results of the analysis for hydrocarbons at each of the offshore stations is presented in Appendix A2. Data are reported for totals ("total hydrocarbons" or "THC"), the aliphatic fraction, and the polynuclear aromatic hydrocarbon (PAH) constituents.

Low levels of hydrocarbons, measured as THC, were observed throughout the offshore area with slightly elevated concentrations in some stations off of Benin and a select few other localized areas. Concentrations ranged from 7.49 to 70.23 mg/kg with a mean THC concentration of 24.38 mg/kg. Relatively elevated concentration (defined as greater than the mean plus standard error, or 38.07 mg/kg) were detected in stations off the coast of Benin (B01 through B05) and stations G15 and G21 off of Ghana. These results and the location of the stations suggest localized sources of hydrocarbons, in the case of Benin possibly related to port activities. Notably, the stations along the pipeline laterals closest to shore (N01, B06, T07, G11, and G26) did not exhibit higher than average THC levels as might have been expected due to their nearshore locations.

In terms of aliphatic hydrocarbon distribution, concentration of the sum of the targeted saturated hydrocarbons is reported in Appendix A2. Because of the limitations of the methodology (gas chromatography) and potential for interferences during sample processing, the limit of detection for the analysis was set at 10.00 mg/kg. Detections of total aliphatics below this limit were not considered to be reliable. Relatively higher levels were again detected at five stations off of Benin (B01 through B05 – average of 32.36 mg/kg) and at station G15 (17.73 mg/kg). Station G23 was also elevated relative to average but below the criteria limit used for this evaluation (>17 mg/kg total aliphatics).

Distribution of the targeted saturated hydrocarbons can sometimes be used to provide information about the type of source. Concentration were plotted and evaluated to determine whether patterns could be observed. For the samples from stations off the coast of Benin, distribution of the saturated hydrocarbons (Figure 3.1-1) centered in the heavy fuel oil range, from tetradecane (n-C14) through triacontane (n-C30). The fact that heavier saturated hydrocarbons (i.e., hexatriacontane – n-C36) were not detected implies that the hydrocarbon source is primarily petroleum and not due to naturally occurring (biogenic) sources. Levels of these samples are sharply contrasted to those of the majority of offshore stations. The sediment from station G15 (Figure 3.1-2) demonstrated a distribution similar to that at B01, but with concentrations levels approximately one-half less. The pattern indicates a petroleum related source for the hydrocarbons as discussed for station B01 above.

Figure 3.1-1
Distribution of Aliphatic Hydrocarbons for Station B01

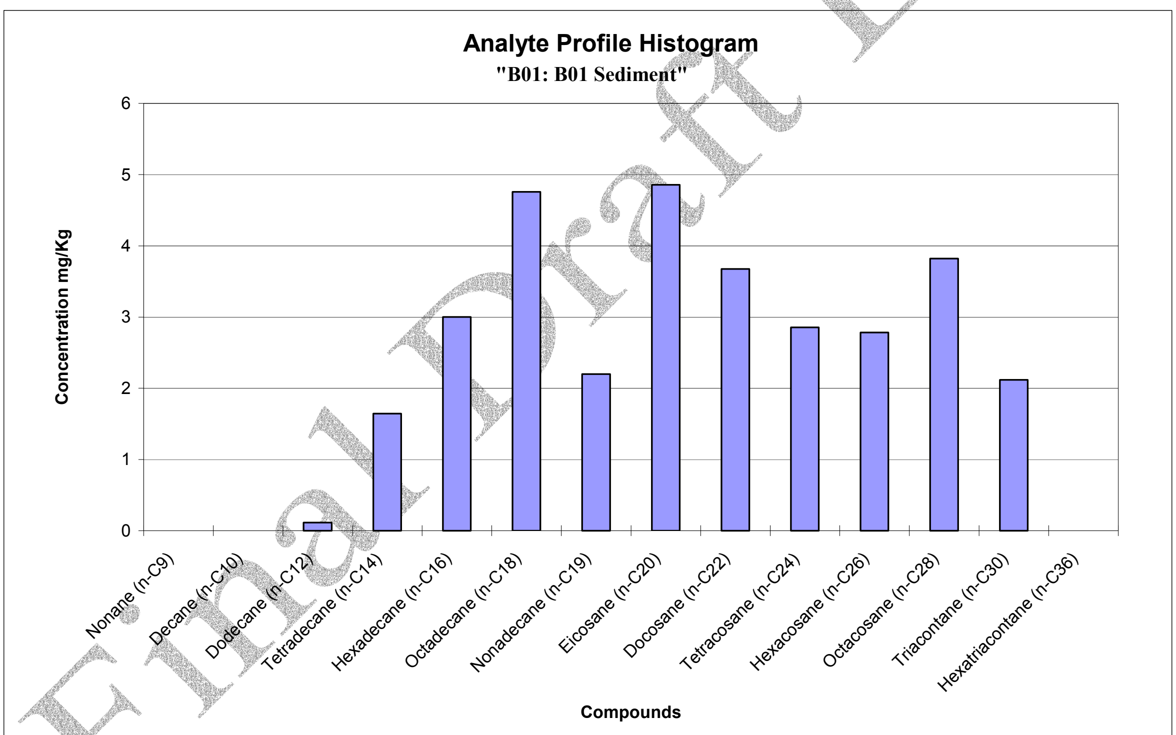
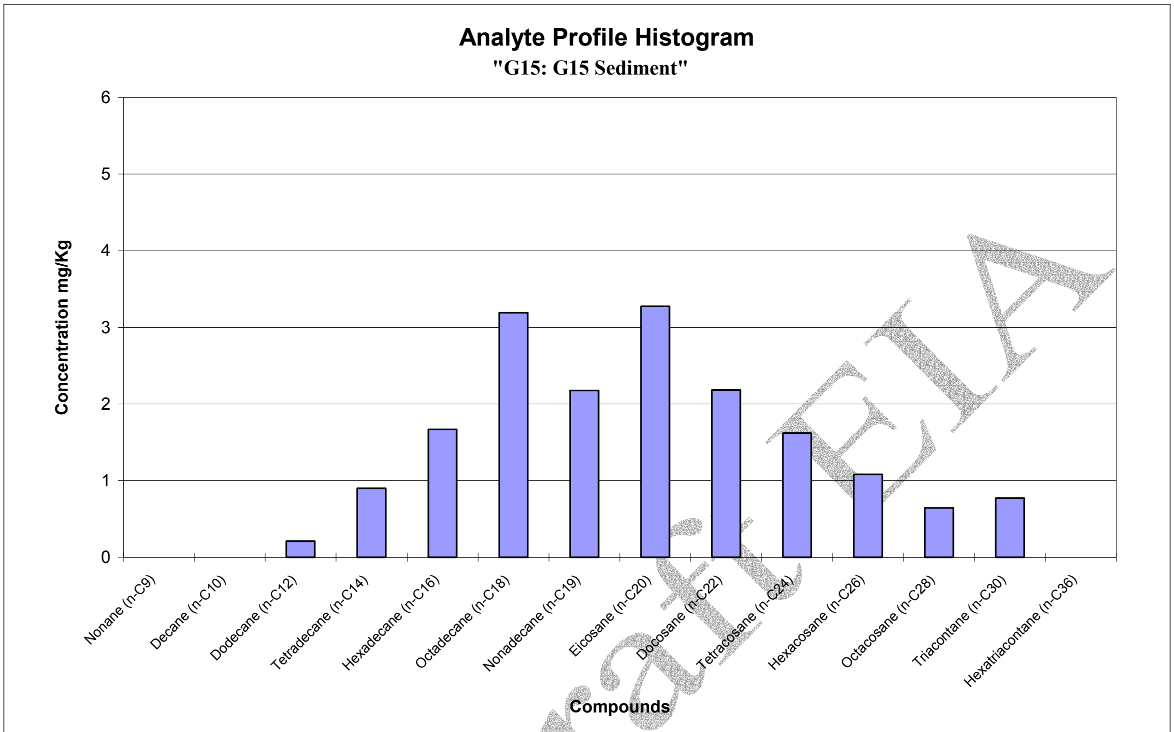


Figure 3.1-2
Distribution of Aliphatic Hydrocarbons for Station G15



For the aromatic fraction, concentrations of targeted individual PAH and total PAH (i.e., the sum of the targeted concentrations) is reported in Appendix A2. Again, due to the limitations of the method, including the potential for laboratory-related interference, the limit of detection for the method was set at 10 mg/kg. None of the samples analyzed had had results reported above this limit. Detailed review of the results for these samples indicate sporadic elevation of generally one of the targeted PAHs but this was not confirmed by analysis of a subset of the samples by a U.S. based laboratory and are thus considered suspect.

Heavy Metals and Other Elements

Concentrations of eleven elements were measured at the offshore sampling stations along the proposed pipeline route. Concentrations in the sediments, reported as either ug/g or mg/g dry weight, are tabulated and included in Appendix A2. While concentrations of many metals were similar to average continental crust concentrations, some elements exhibited overall elevated concentrations. There were instances of relatively higher levels of some elements in individual samples as well, as can be seen by in plots of the metals concentrations included in the referenced appendix.

In general, concentrations of lead, mercury, and zinc appeared to be slightly elevated over that reported for average continental crust: 14.8μg/g, 0.04μg/g, and 65μg/kg respectively (Wedepohl 1995). The atmosphere represents a route of entry for these elements to the sea via combustion of leaded gasoline. Other anthropogenic sources related to industrial activity also exist for these elements. Note however that the values reported by the laboratory for mercury were not verified by confirmatory analysis of a percentage of the samples and in fact mercury was not detected in any of the sediment samples analyzed. For zinc, the confirmatory QC analyses indicated zinc levels on average one-forth that reported. This would indicate that the results reported are likely elevated due to matrix interferences in the methodology. Lead levels however were consistent with that determined by QC analyses and would be representative of the background in the project area.

Physicochemical Properties

Sediment samples were analyzed for a variety of physicochemical properties to establish baseline conditions. At the time of sample collection (i.e., aboard the survey vessel), measurements of sediment pH, temperature, redox potential and electrolytic conductivity were taken. These data are presented in Appendix A2. The samples were analyzed again in the laboratory for pH and EC in the fixed laboratory. The pH measurements conducted in the laboratory are the most precise due to controlled conditions of that analysis.

In addition, sediment samples were analyzed for exchangeable acidity, sulfate, total phosphorus, total nitrogen, and cations (Na, K, Ca, and Mg). A summary of the results is provided as Table 3.1-1.

Table 3.1-1
Summary of Sediment Physicochemical Measurements

Parameter	pH	EC ($mScm^{-1}$)	Exch. Acid (mEq/ 100g)	SO_4^{2-} (ppm)	Total P ($mgkg^{-1}$)	Total-N (%)	Na (mEq/100g)	K (mEq/100g)	Ca (mEq/100g)	Mg (mEq/100g)
Mean	8.25	16.38	0.38	1051.64	130.24	0.14	28.45	1.75	7.33	9.58
Minimum	7.60	7.79	0.10	175.11	3.97	0.03	0.90	0.09	1.87	0.71
Mean	8.70	42.40	0.80	4038.71	1304.69	0.52	87.64	5.12	16.54	27.01

3.1.2 Physical Results

The bulk properties of the sediments were measured by analysis for total organic carbon (TOC) and grain size. These physical parameters influence the chemical distribution and benthic community structure of the sediment and are important for the interpretation of data.

The results of the sediment grain size characteristics are provided in Appendix A2. Sediment samples were primarily sand with over half of the samples comprised of greater than 70 percent sand. Another large percentage of samples are comprised of sand mixed with clay. Distributions of sediment types over the study area varied as would be expected considering the large area evaluated. Additional sediment physical characterization from the SPI data is discussed later in this section.

Total organic carbon concentrations ranged from 0.08 to 5.09 percent and averaged 1.09 percent. More than 90 percent of the samples had a moderate TOC concentration (<3 percent) with notably higher concentrations at stations G10, N03, and N04, reported as 3.20 percent, 3.20 percent and 5.09 percent respectively.

3.1.3 Sediment Profile Image Results

As part of offshore survey, a Sediment Profile Imaging (SPI) survey was conducted to provide a rapid assessment of sediment features such as sediment grain size, depth of the redox potential discontinuity (RPD), and biological community type. The results of the analysis were used to assist in decisions concerning number and location for grab sampling stations. In addition, the analysis provides additional physical, chemical, and biological data collected which is presented here. The complete SPI report is included as Appendix C. The report includes a map showing all the SPI stations sampled and complete analysis for the 150 images selected.

During the survey, team scientists made visual assessment by examining the individual images using a light table with a film magnifying loupe. The results from the rapid field assessment are presented in Table 3.1-2.

Table 3.1-2
Rapid Field Assessment of Sediment

Station	Position	Description
G26	C	Medium to coarse sand, shell hash
	E	Medium sand with silt, active sediment transport
	W	Medium sand over mud
G25	C	Medium sand, light shell hash, active sediment transport
	E	Coarser sand and higher shell hash, stalked anemone present
	W	Hard bottom, no penetration
G24	C	Rippled bottom, active sediment transport
	E	Well-sorted medium sand, uniform bottom, active sediment transport
	W	Medium to coarse sand, rippled bottom, active sediment transport
G23	C	Sandy mud, coral

Station	Position	Description
	N	Sandy mud with deposit feeders; substantial feeding voids
	S	Different bottom type, fine to medium sand
G22	C	Medium, well-sorted sand, active sediment transport
	S	Medium sand, thin mud surface dusting, Stage 1, active transport
	N	Muddy sands, shallow penetration, active transport, rippled bottom
G21	C	Muddy medium sands, low penetration, rippled bottom
	S	Muddy sand, lower mud fraction, low penetration
	N	Muddy sands, low penetration, rippled bottom
G20	C	High shell hash, scallop shells on surface
	S	Poorly-sorted medium sand, scallop shell lag present, high shell hash
	N	Muddy sand with shell hash, low penetration
G19	C	Compacted sandy mud, low penetration, active sediment transport
	S	Medium to coarse sand, rippled bottom, active transport
	N	Compacted sandy mud
G18	C	Fine to medium sand, low penetration, rippled bottom, dense tube assemblage in second replicate
G18	S	Muddy sand, low penetration, rippled bottom
	N	Medium coarse shell hash, low penetration
G17	C	Sand, shell hash, low penetration
	S	Coarse sand with broken coral fragments on surface, muddy sand
	N	Medium sand with shell hash, low penetration, rippled bottom
G16	C	Poorly sorted sediments, muddy sand, shell lag and coralline algae on surface
	S	Coarse sand with shell hash, coral, rippled bottom
	N	Medium sand, shell hash, coral fragments
G15	C	Sandy mud, Stage 1 on 3
	S	Sandy mud, Stage 1 on 3 with ripples
	N	Sandy mud, medium penetration, Stage 1 on 3
G14	C	Sandy mud, surface ripples, Stage 1, intense bioturbation, burrows
	S	Muddy sand, low penetration, some cobble
	N	Low penetration, sandy mud, urchin, serpulid polychaetes
G13	C	Silt/clay, Stage 3, urchin present in field of view
	S	Silt/clay, Stage 3, extensive feeding voids
	N	Silt/clay, Stage 3, stomatopod burrow
G12	C	Sandy mud, least amount of cobble here
	S	Poorly sorted cobble, shell, and mud
	N	Poorly sorted cobble, shell, and mud
G11	C	Hard sand, rock cobble, coral
	E	Hard sand, cobble, low penetration
	W	Hard sand, cobble, coral, low penetration, rubble
G10	C	Muddy fine sand, low penetration
	E	Muddy fine sand, low penetration
	W	Muddy fine sand, low penetration

Station	Position	Description
G9	C	Sandy mud, Stage 3, active bioturbation
	E	Sandy mud, Stage 1 on 3, deep reworking
	W	Sandy mud, Stage 3
G8	C	Sandy mud, Stage 3
	S	Medium sand with mud, varied penetration (1st rep. had no penetration, hard bottom)
	N	Less penetration, sandy mud with higher sand fraction than other images
G7	C	Extensive burrows, fine-grained sediments, Stage 1 on 3
	S	Fine-grained sediments, high penetration, Stage 1 on 3
	N	Stage 1 on 3, mud with shell fragments
G6	C	Fine-grained mud, Stage 1 on 3
	S	Low penetration, muddy sands, shell on surface, gorgonian coral
	N	Sandy mud, extensive burrows and feeding voids, Stage 1 on 3
G5	C	Silt/clay, Stage 3, deep reworking
	S	Silt/clay, Stage 3
G5	N	Silt/clay, Stage 3, deep burrows, light sand fraction
G4	C	Medium sand, shell hash, cobble
	S	Medium sand, shell hash, low penetration
	N	Medium sand, shell hash, low penetration
G3	C	fine sand, ripple
	S	fine sand, ripple
	N	fine sand, ripple
G2	C	Sandy mud, Stage 3, deep feeding voids
	S	Sandy mud, Stage 3
	N	Sandy mud, Stage 3
G1	C	Silt clay, Stage 3
	S	Silt clay, Stage 3
	N	Silt clay, Stage 3
T8	C	Silt clay
	S	Silt clay, Stage 1 on 3
	N	Sandy mud, Stage 1 on 3
T7	C	Well-sorted fine sands, rippled
	E	Well-sorted fine sands, rippled
	W	Rippled bottom, fine to medium sand
T6	C	Muddy sand, Stage 3, rippled bottom
	E	Sandy mud, Stage 3, some sand ripples
	W	Higher sand fraction, Stage 3
T5	C	Silt clay, Stage 3
	E	Silt clay, Stage 3
	W	Mud with sand surface layer, Stage 3
T4	C	Silt clay, Stage 1 on 3
	S	Silt clay, Stage 1 on 3, well-developed redox layer

Station	Position	Description
	N	Cobble, shell hash
T3	C	Silt clay, sand at surface, Stage 3
	S	Silt clay, some sand, Stage 3
	N	Silt clay, sand at surface, rippled bottom, Stage 3
T2	C	Silt clay, Stage 3, sand at surface
	S	Silt clay, Stage 3, sand at surface
	N	Silt clay, Stage 3, sand at surface
T1	C	Silt clay, minor sand fraction, Stage 1 on 3
	S	Mud with sand component, Stage 1 on 3
	N	Silt clay, bioturbation, Stage 1 on 3
B10	C	Silt clay, very little sand, Stage 3, extensive bioturbation
	S	Pure silt clay, no sand, Stage 3
	N	Silt clay, Stage 3, deep reworking
B9	C	Silt clay, Stage 3, extensive reworking
	S	Silt clay, Stage 3, deep reworking
	N	Silt clay, Stage 3, extensive reworking
B8	C	Silt clay, Stage 3
B8	S	Silt clay, Stage 3
	N	Silt clay, Stage 3, minor sand fraction
B7	C	Sandy muds, Stage 3
	S	Silt clay, Stage 3
	N	Muddy sands, rippled bottom
B6	C	Sandy bottom, sand waves
	E	Sandy bottom, sand waves
	W	Sandy bottom, sand waves
B5	C	Sandy bottom, medium sand, rippled bottom
	E	Sandy bottom, medium sand, rippled bottom
	W	Sandy bottom, medium sand, rippled bottom
B4	C	Sandy mud, Stage 3
	E	Sandy mud, Stage 3
	W	Sandy mud, Stage 3
B3	C	Medium sand, low penetration, rippled bottom
	S	Medium sand, low penetration, rippled bottom
	N	Medium sand, low penetration, rippled bottom
B2	C	Sandy mud, Stage 3
	S	Sandy mud, Stage 3
	N	Sand
B1	C	Silt clay, Stage 3, healthy bottom
	S	Silt clay, Stage 3
	N	Silt clay, Stage 3
N6	C	Silt clay, Stage 3
	S	Silt clay, Stage 3
	N	Silt clay, Stage 3

Station	Position	Description
N5	C	Silt clay, Stage 1 on 3
	S	Silt clay, Stage 1 on 3
	N	Silt clay, Stage 1 on 3
N4	C	Silt clay, Stage 3
	S	Silt clay, Stage 3
	N	Silt clay, Stage 3
N3	C	Silt clay, Stage 3
	E	Silt clay, higher sand content, Stage 3
	W	Silt clay, Stage 1 on 3, fine-grained, deep bioturbators
N2	C	Sandy mud, Stage 3
	E	Silt clay, Stage 3, sand in upper fraction, healthy bottom
	W	Silt clay, Stage 3, little bit of sand at surface
N1	C	low penetration, sand
	E	mud with sand surface layer, Stage 3
	W	Silt clay, Stage 3

One representative image from each location was selected for complete image analysis; the results from this comprehensive analysis provide the basis for the spatial characterization of the sediments and benthic habitat presented in this below.

Sediment Grain Size and Bottom Kinetic Gradients

The sediments throughout the entire area surveyed ranged from fine-grained silt-clays, (representing low-energy, depositional environments) to coarse sand or granules on rippled bottoms or with shell lag deposits at the sediment-water interface (representing high-energy, sediment transport zones). Water depths throughout the area surveyed ranged from approximately 14 to 77m; while there were a few exceptions (e.g., G23-N, N1-W), most fine-grained stations occurred at depths exceeding 37m. However, in this nearshore, relatively shallow and generally high-energy regime parallel to the coast, sediment type is more a function of kinetic gradients resulting from a combination of bottom currents, shoreline slope, and transport patterns rather than water depth. Sandy and/or hard cobble/coral bottoms were found throughout the entire depth range sampled and were probably more a factor of geographic location in relation to longshore transport and wave energy profiles in the nearshore zone.

Regional patterns of bottom kinetic gradients indicate that as one moves in toward shore along the perpendicular transects sampled in each of the countries (2 transects in Ghana, 1 each in Togo, Benin, and Nigeria), the sediments along all five show evidence of either active or aperiodic sediment transport. All of the stations sampled along these five shoreward transects have either sandy sediments or hard, cobble bottom reflecting the relatively high-energy regimes in these areas. In the western region of the survey off the coast of Ghana, there is a relatively large portion of the main survey line running parallel to shore (Stations G22 – G16) that is a high energy area represented by both well- and poorly-sorted fine to coarse sands with active bedforms and ripple patterns.

Moving eastward from Station G16 leads into an area of transitional sedimentary facies, where bottom currents or wave energy occasionally get strong enough to cause sediment transport. The high-energy periods are infrequent enough to allow mixing of these different strata by the reworking activities of infaunal deposit-feeders. Finally, moving further east to Station G13, we find the typical sediment profile representing the low-energy, depositional environments in this region of coastal West Africa: silt-clay bottoms showing evidence of extensive infaunal re-working by deposit-feeding fauna. These facies patterns are repeated as one continues eastward passing Tema, alternating between transitional facies and low-energy depositional areas along the main pipeline path. It is noteworthy that east of Station G2, the majority of the stations along the main pipeline route are characterized by low energy, depositional environments; areas of active sediment transport only occur as one heads along the perpendicular transects toward shore.

There does appear to be a major transition in energy regime correlated with depth along one area of the pipeline route as one crosses over the border to Togo. Station T4-N (47m water depth) has a very coarse sand/granule bottom, while the three locations at the adjacent Station T8 (N, C, and S located in 52, 65, and 73m of water, respectively) show a gradual transition from sandy mud in the shallower northern station to well-sorted, uniform silt-clay profiles at the deeper center and southern stations. Fifty meters appears to be a critical depth at this one location where wave energy orbits or longshore transport from bottom currents start to drop off below the saltational energy threshold for fine-grained sediment transport. However, one cannot apply this 50m depth cutoff as a general rule of thumb; moving approximately 15km to the east, one finds a low-energy, depositional facies at Station T3N in approximately 47m of water. The pattern of alternating bottom energy regimes continues eastward to the end of the surveyed area, with the three stations at the terminal location (N1) being excellent examples of all three energy regimes and illustrating the small scale over which these changes can occur.

Surface Boundary Roughness

Surface boundary roughness ranged from 0.31 to 4.58cm, and varied in origin depending on bottom type. Most small-scale roughness elements on the medium to coarse sandy bottoms generally were small ripples or bedforms due to bottom currents, while those on the fine-grained bottoms generally were due to biogenic activities (tube structures, fecal piles, or burrow mound openings). The small-scale roughness elements along the main pipeline route are generally less than 2cm and tend to increase as one heads toward shore.

Prism Penetration Depth

The prism penetration depth varied widely during this survey (0 to 16.6cm), due to differences in both sediment types and sediment geotechnical properties. Because of the wide range in sediment types and the need to constantly change both the stop collar settings on the camera as well as the number of weights in the carriage holders it would be meaningless to plot the variation in prism penetration along the pipeline route, because it would give an erroneous indication of the magnitude of variation in relative sediment shear strength. Stop collar settings were varied as much as 10cm from station to station, depending on initial readings of prism penetration depth, and the amount of additional lead weights used on the camera carriage varied from none up to a maximum of 250lbs. While the presence of rock/coral fragments had an obvious, dramatic effect in limiting camera prism penetration, biological mixing depth and the amount of bioturbation was equally important.

<u>Apparent Redox Potential Discontinuity Depth</u>

There was no evidence of high sediment-oxygen demand or stress on the benthic habitat due to low oxygen in the overlying water at any of the stations surveyed. Similarly, excess organic loading did not appear to be a problem in any of the low-energy, depositional areas; there was no evidence of subsurface methane in any of the images taken. Overall, the mean apparent RPD depths generally exceeded 2cm (only 9 stations had mean apparent RPD depths between 1 to 2cm), and none of the stations surveyed had less than 1cm for the average thickness of the surface oxidized layer. At the sandy locations where prism penetration was minimal, the reported apparent RPD depths are equal to the recorded penetration depths and are minimum estimates for those stations. Oxygen would be able to penetrate these coarser, more porous sediments much deeper than in locations where silt/clay sediments are present, not only due to differences in grain-size, but also because of the interaction between bottom currents, surface roughness elements, and dissolved oxygen in the water column. (Huettel et al., 1996; Forster et al., 1996; Ziebis et al., 1996).

3.2 OFFSHORE WATER CHARACTERIZATION

3.2.1 Water Quality Profile

Water column profiles of temperature, turbidity, chlorophyll-a, dissolved oxygen, pH, oxidation reduction potential, and specific conductivity were taken at the 50 offshore sampling stations in the study area using the YSI profiler. Data collected during this effort is included in Appendix A4. A brief description of the data is provided below.

<u>Depth</u>

Representative depth plots for each water quality parameter are summarized and organized by offshore country locations and can be found in Appendix A. The average depth at stations along the main pipeline parallel to the shore was 159ft, while the deepest station was N06C at 235ft, and the shallowest station was G03C at 59.5ft. Individual maximum depths per station are displayed on in Appendix A. The average depth at stations along the lateral pipeline routes heading to the shore was 118.7ft, while the deepest lateral station was N03C at 261ft and the shallowest lateral station was G26C at 55.2ft. Stations were plotted on bathymetric maps and reviewed for underwater canyons, mounds and steep, vertical drops. The offshore bottom contour off of Ghana displays notable such vertical drops in depth, which affect seasonal mixing, upwelling, and stratification of the water column.

<u>Temperature</u>

Temperature profiles taken in Fall 2002 also showed a thermally stratified water column. Surface temperatures of the photic zone were similar throughout the pipeline area, on average 27.8°C. Surface waters are generally expected to be cooling in the late fall months relative to late summer when surface waters have reached the annual maximum. The minimum temperature on the pipeline route was 16.3°C (T08C, bottom 215ft) while the maximum was 28.8°C (N05C, surface 17ft).

Many deepwater sites exhibited numerous distinctly stratified thermoclines (e.g., stations G01C, G06C, and G08C), while shallow, nearshore sites demonstrated a distinct primary thermocline with a linear temperature gradient to the bottom (e.g., stations B08C, T01C, and T03C), indicating mixing of stratified layers already present. A strong density gradient in the euphotic zone, limiting the vertical exchange of nutrients between surface and deep waters, is likely to exist under these conditions during fall and winter months. Appendices 3.2-# through 3.2-# display a profile of depth vs. temperature.

Station G14C demonstrated an evenly mixed temperature gradient with increasing depth from the primary thermocline, 28.0°C at 24ft, with an almost constant rate of 0.065°C/ft to the bottom depth of 165ft at 18.9°C.

Station G04C indicated isothermal water mass 1.0°C higher than surface water temperature moving through the midwater column at a depth range of 26-83ft. In the 83 to 88ft depth range there was a rapid change of -1.0°C to the bottom temperature.

Turbidity

Turbidity, as measured in NTUs (Nephelometric Turbidity Units) was used to determine the relative ambient concentration of suspended particulate matter in the water column. In general, turbidity values were comparable throughout the pipeline area with a slight elevation in upper surface water during the start of the down cast and a decreasing in values down to the thermocline, and stabilizing toward the bottom. The general trend in turbidity was low readings (3-5 NTU range) with minor changes and low standard deviations. Turbidity spikes in the CTD figures (Appendix A) reflect as isolated incidents and are not representative of an influence to the water mass.

Turbidity maxima were generally observed near the seafloor at several stations. These plumes caused by re-suspension of the sediments due to the impact of the Sediment Profile Imagery (SPI) camera, which was supporting the YSI6600 Sonde profiler. After reaching the bottom on the first down cast the SPI was "pogo sticked" to take three discrete photographs.

Chlorophyll-*a*

Chlorophyll-*a* concentrations ranged between 0.0 to 62.8µg/L throughout the water column (the highest being at station G11C, surface depth 3ft). Relatively higher concentrations were measured above the thermocline throughout most of the sampling area. Station B03C represents a typical observation: 36.8µg/L at the surface, decreasing by half to 18µg/L at 5ft depth; readings dropped off after the thermocline at 50ft to a stable 0.7µg/L and continued at that range until the final depth around 88ft.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations throughout the pipeline region ranged from 0.0–91.6 percent saturation. The highest dissolved oxygen profiles observed in surface waters were close to supersaturated concentrations with a concentration of 91.6 percent (Station G19C). Supersaturated conditions typically occur in shallow productive areas, since oxygen is a by-product of phytoplankton photosynthesis and the physical mixing effects of wave action at the surface interface. DO Values generally decreased below the thermocline delineation. DO declined steadily with depth reaching lower concentrations around 2-10 percent in the deeper waters (>175ft). This decline is likely due to the consumption of oxygen by fauna and bacteria and from the lack of mixing between oxygen-rich surface waters and depleted subsurface waters.

pH

Water column profiles of pH were also very uniform throughout the sampling area. A slight but insignificant decrease in pH was observed below the thermocline and the lowest pHs were observed at the great depths of the deepwater stations. Increased pH values were found at the primary thermocline of many stations. The station with the lowest pH value was N06C at 7.69 (depth 235ft) and the station with the highest pH value was G14C at 8.87 (depth 6.1ft). The overall average pH of all stations was 8.4 with a standard deviation of 0.1.

Oxidation reduction potential

Oxidation reduction potential (ORP) tended to decrease from the upper surface water after the primary thermocline to the deepest points at the stations in shallow water. As station depths increased to deep water (>175') several sites demonstrated an increase in ORP values (sometimes higher than surface water levels; e.g. stations G12C, G01C, and N04C). The stations exhibiting this characteristic ORP profile appear to coincide with nearby steep drops in depth.

Specific Conductivity

Due to interferences generated by a pinger system located on the SPI camera framework specific conductivity cannot be reported within accurate limits and will not be reported at this time.

Regional Country Summaries

Representative depth plots for each water quality parameter are summarized and organized by offshore country locations and can be found in Appendix A.

3.2.2 Discrete Water Samples

Review of the results of the discrete water samples indicates little above anticipated background concentrations in seawater (Figures 3.2-1 through 3.2-3). Variations from individual sample measurements are within the normal range of expected values and represent expected method variability.

Figure 3.2-1
Offshore stations' surface water metal concentrations.

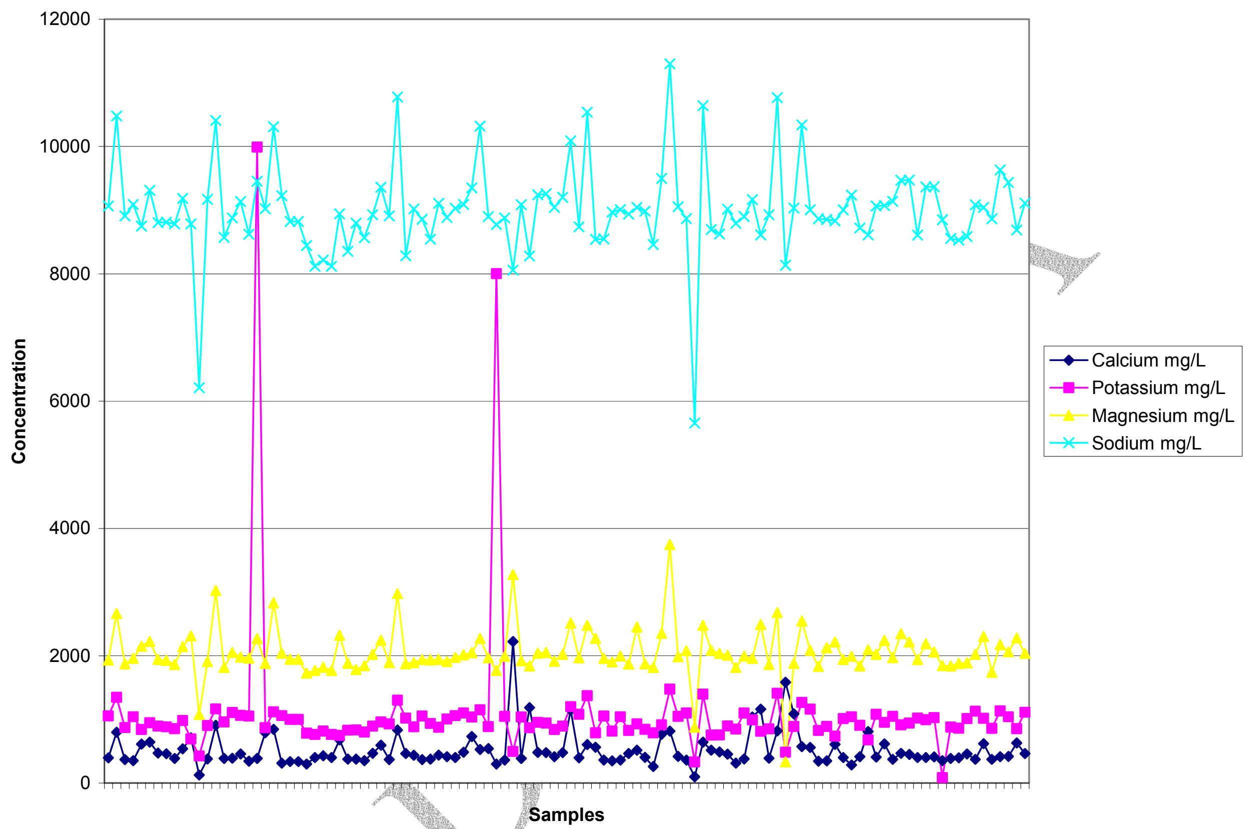


Figure 3.2-2
Offshore stations' surface water nutrient concentrations.

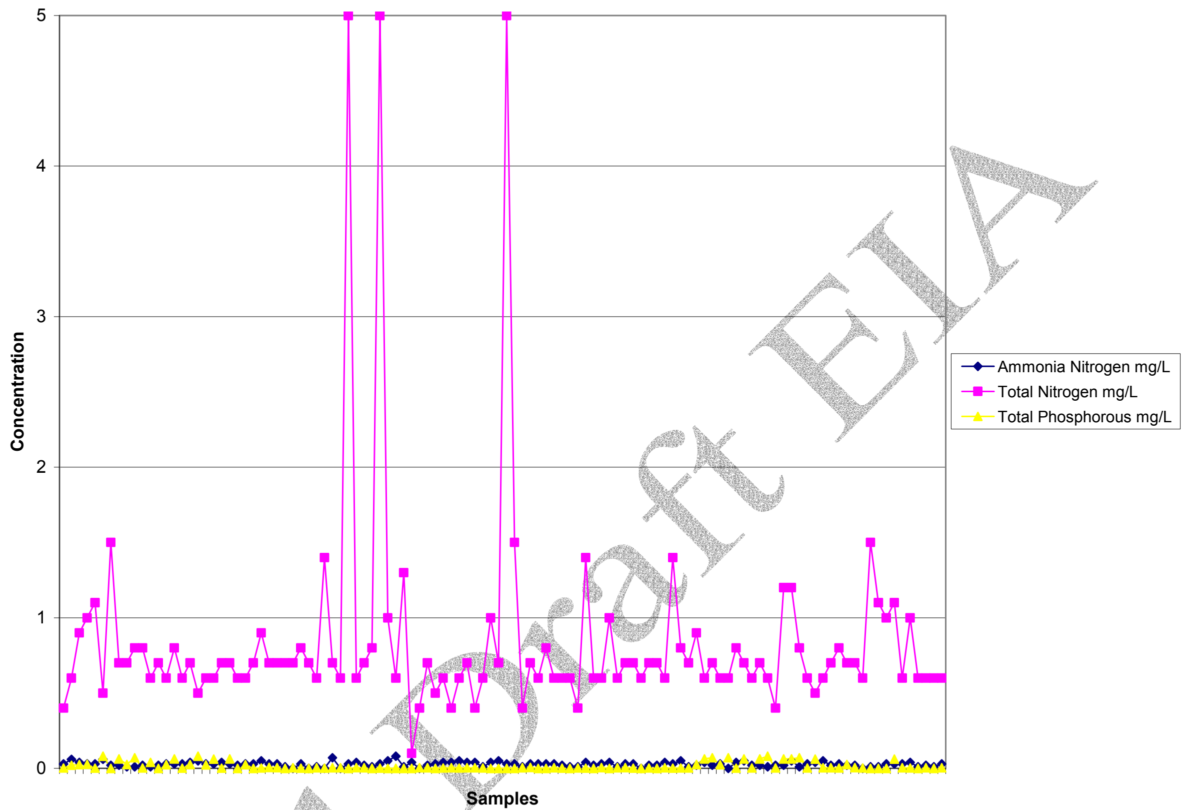
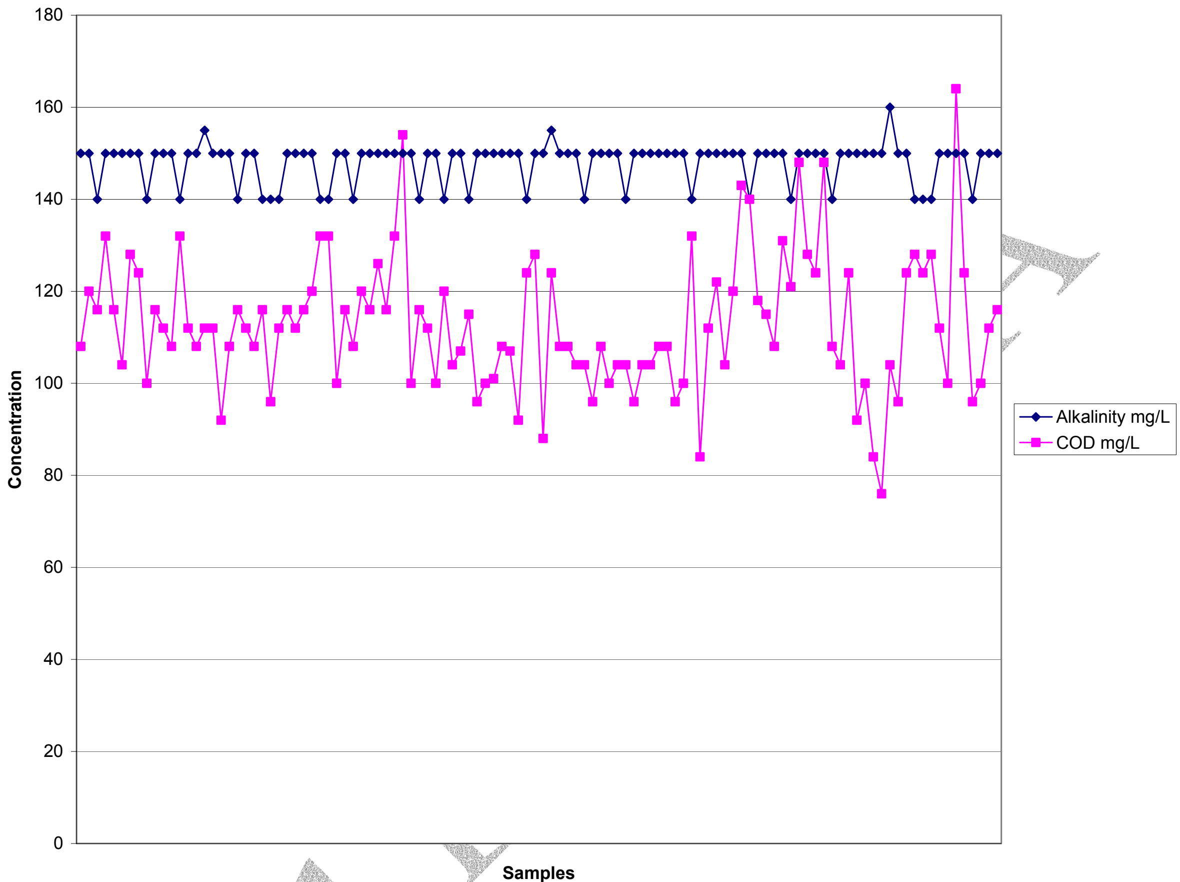


Figure 3.2-3
Offshore stations' surface water alkalinity and COD concentrations.



Nutrient and COD analyses in the offshore samples do not indicate elevated or sharply contrasted concentrations that might indicate impact from either industrial or populated areas. Metals analyses are, in general, in the area of background concentration, although slightly elevated levels of mercury and cadmium were noted in certain samples. Analysis results and summary graphs are provided in Appendix A. The elevated levels were not apparently spatially distributed and appeared sporadically higher across locations. Comparably higher levels of mercury were detected in blank samples, which indicate that the elevated levels may be an artifact of sampling or analysis procedures, although no determination of the source of the slight elevations is definitive from the current data set.

3.3 OFFSHORE BIOLOGICAL CHARACTERIZATION

3.3.1 Benthic Infauna

Of the 62 benthic samples analyzed (which represent 50 offshore locations), 1264 individual organisms were identified, made up of about 220 polychaete and crustacean species, and species grouped as ‘others’. The species grouped as ‘others’ were mainly ophiuroids, bivalves, gastropods, sipunculids, oligochaetes, etc. (Appendix B).

The number of species and the diversity indices calculated per station for each country along the main pipeline route and the laterals are presented in Figures 3.3-1 to 3.3-18. Stations are arranged from west to east along the main pipeline route; and from south to north (generally corresponding to a trend of deeper water to shallower water) on the laterals.

The diversity indices calculated included species richness (d), Pielou’s evenness (J’), and the Shannon-Wiener Diversity Index (H’ $\log_e$). Species richness (as per Margalef) is a measure of the number of species present, taking into account the number of individuals present. Pielou's evenness index is a measure of equitability; a measure of how evenly the individuals are distributed among the different species. These are useful quantitative tools for determining changes that might occur in the future.

Ghana

In the Ghanaian waters, 165 taxonomic groups were identified, made up of 129 polychaete species, 18 crustacean species and 18 species classified as ‘others’. Nineteen stations were sampled along the main pipeline route, three stations along the Tema lateral, and four stations along the Takoradi lateral.

Main Pipeline Route

Figures 3.3-1 and 3.3-2 show the number of species and the diversity indices estimated for the stations along the main pipeline route off of Ghana. The main pipeline route ranges in depth from 50 to 80m. The species count per station did not show any clear east-west trend. Low species counts were observed at Stations G22-C and G06-C, while high species counts were observed at stations G20-C, G15-C, G12-C, and G02-C. The dominant taxonomic group in all the stations except G06-C was the polychaetes. Crustacean species were not recorded at six stations (G22-C, G21-C, G20-C, G15-C, G08-C, and G04-C), while two stations (G22-C and G14-C) did not record any organisms for the ‘others’ group.

Figure 3.3-1
Offshore Benthic Macrofauna Distribution on Main Pipeline Route in Ghana.

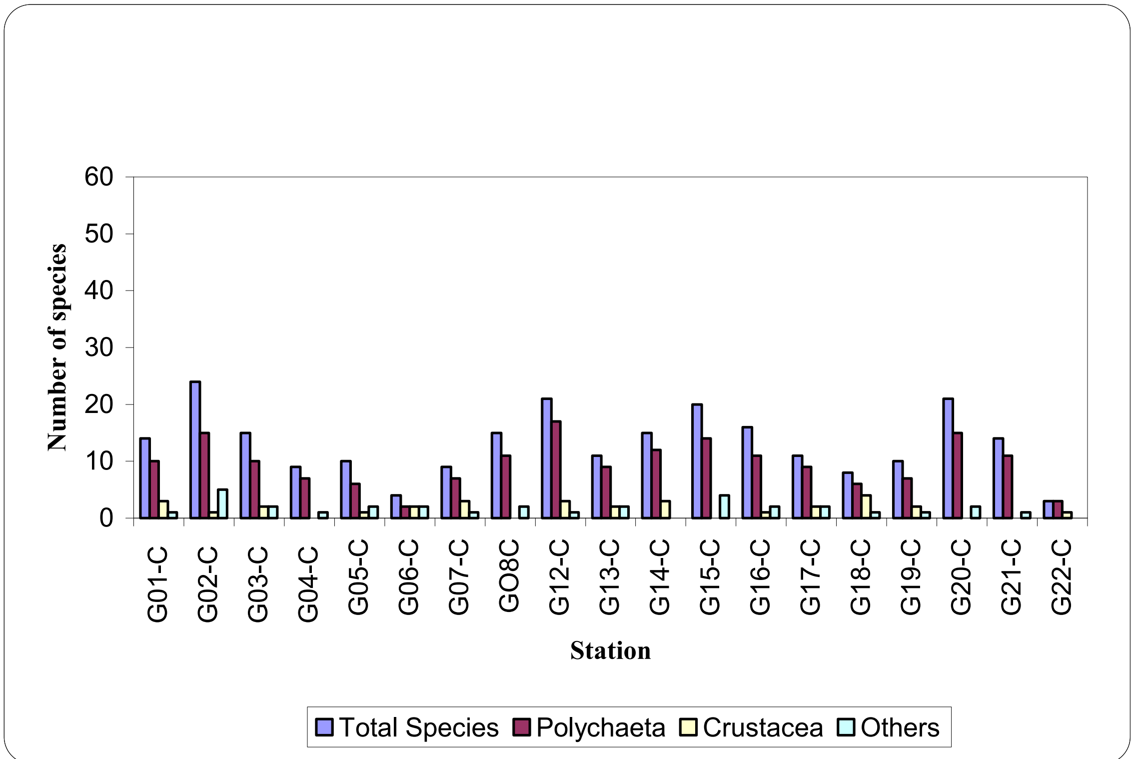
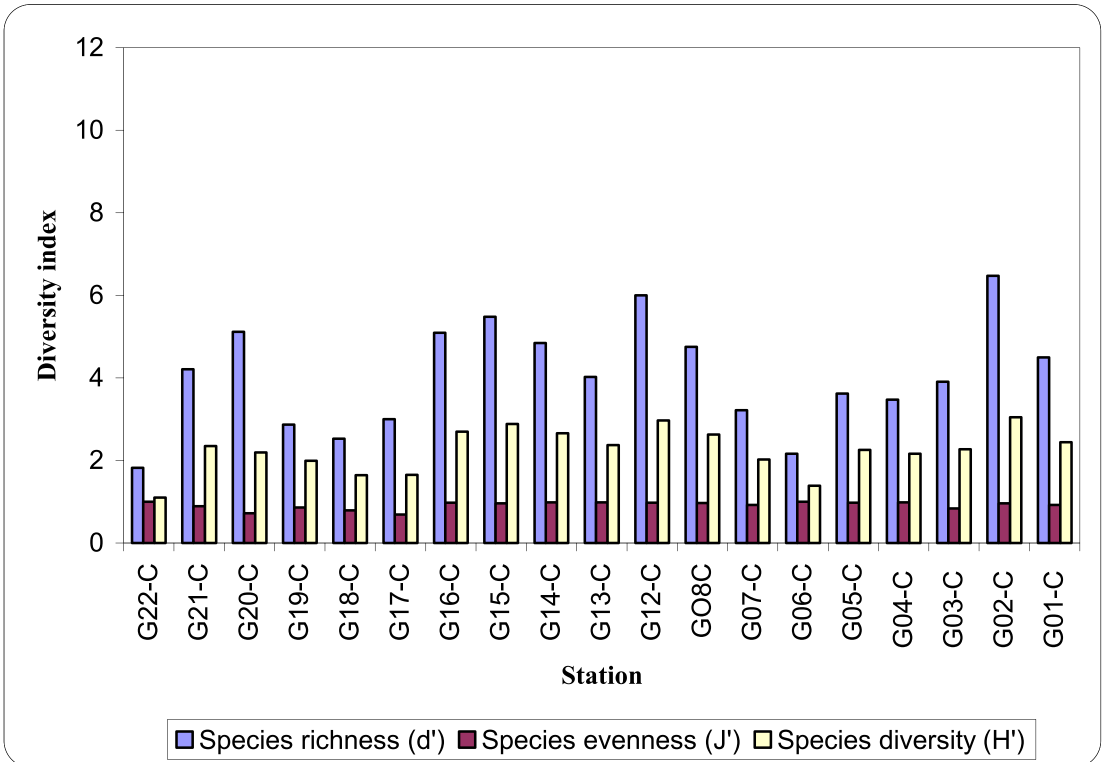


Figure 3.3-2
Offshore Benthic Macrofauna Diversity index Distribution on Main Pipeline Route in Ghana.



The diversity index distributions showed a trend reminiscent of the species count distribution. Species richness was highest at Station G02-C and lowest at Station G22-C. The species evenness distribution showed some variability and was lowest at Station G20-C and G17-C.

Lateral Route

Figures 3.3-3 to 3.3-6 show the species count per station and the diversity indices calculated for the Tema and Takoradi laterals. Station G11-C, which is the northern-most and shallowest station on the Tema transect, exhibited the highest number of species along the Tema lateral. Stations G11-C and G09-C exhibited higher numbers of polychaete species than the centrally placed Station G10-C. Crustacean species and species classified under the ‘others’ group both showed a north-south attenuation in number of species recorded. Crustacean species dominated the species identified at Station G10-C.

Figure 3.3-3
Offshore Benthic Macrofauna Distribution along the Tema Lateral.

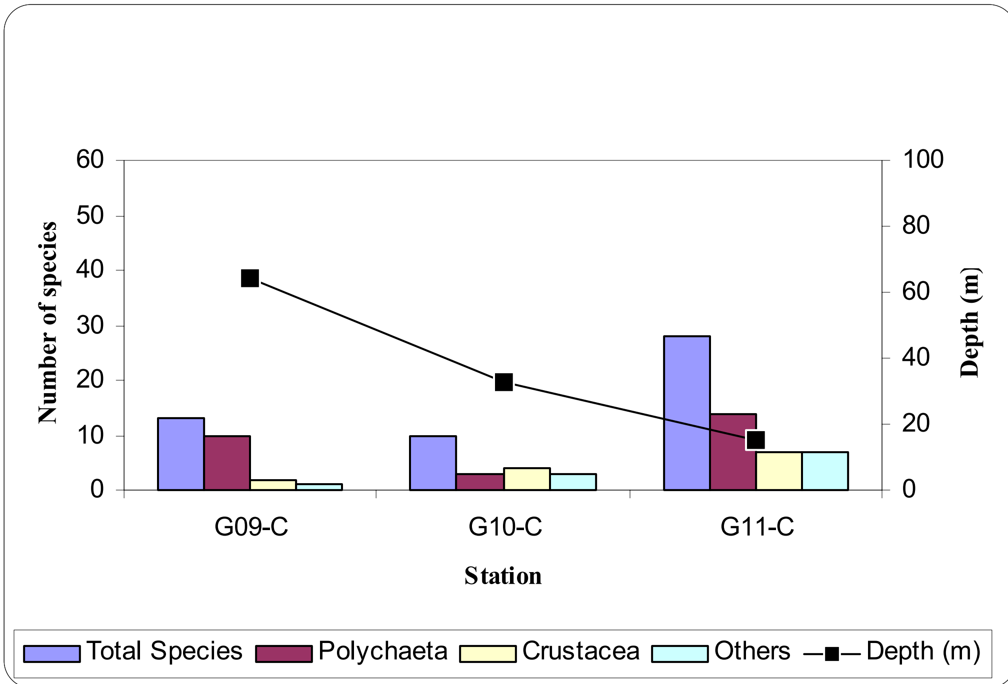


Figure 3.3-4
Offshore Benthic Macrofauna Diversity index Distribution along the Tema Lateral.

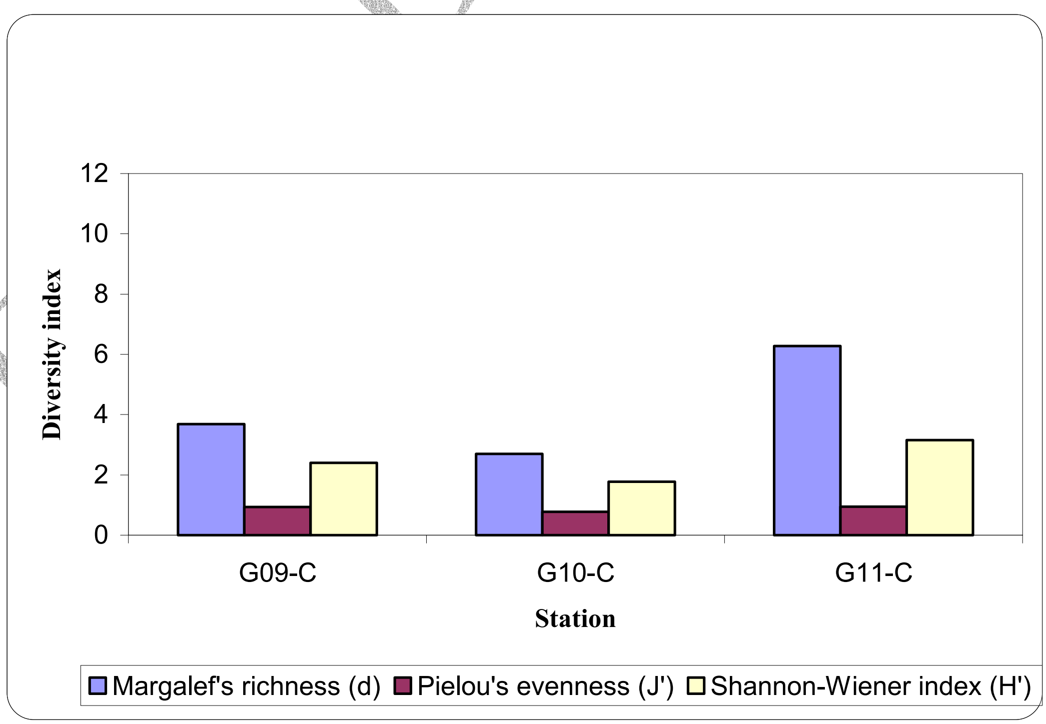


Figure 3.3-5
Offshore Benthic Macrofauna Distribution along the Takoradi Lateral.

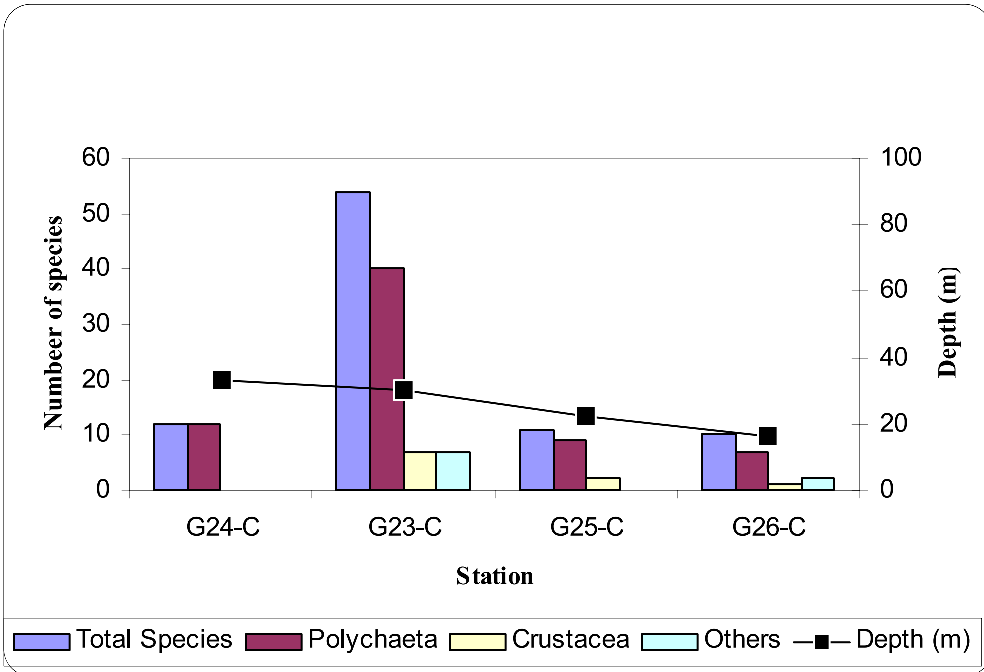
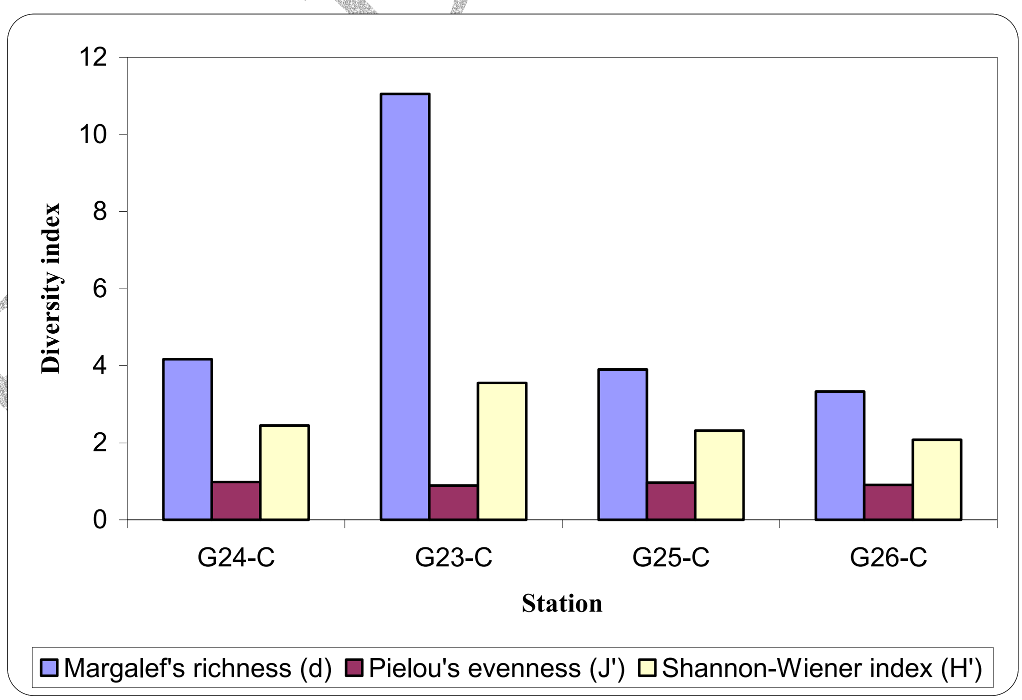


Figure 3.3-6
Offshore Benthic Macrofauna Diversity index Distribution along the Takoradi Lateral.



The dominant species along the Takoradi lateral were polychaetes. No clear distribution pattern was observed. The number of species counted was higher at Station G23-C than at the other stations along the transect. Crustacean species were absent from Station G24-C, while species classified, as ‘others’ were not present at both Stations G24-C and G25-C.

The species diversity and species richness distributions show patterns similar to the species count distribution. Species evenness data was, however, similar along both laterals.

<u>Togo</u>

Sixty-five taxonomic groups were identified off Togo, including 47 polychaete species, 9 crustacean species, and 9 species classified as ‘others’. Five stations were sampled along the main pipeline route and four stations along the lateral.

Main Pipeline Route

Figures 3.3-7 and 3.3-8 show the number of species and the diversity indices estimated for the stations along the main pipeline route in Togo. The main pipeline route off Togo ranges in depth from 45 to 65m. The number of species identified per station did not show any clear east-west trend. However total species observed and polychaete counts were highest for Station T03-C and lowest for Station T04-C. The lowest crustacean count was at Station T02-C. The polychaete species were dominant in all the stations sampled.

Figure 3.3-7
Benthic Macrofauna Distribution on the Main Pipeline Route in Togo.

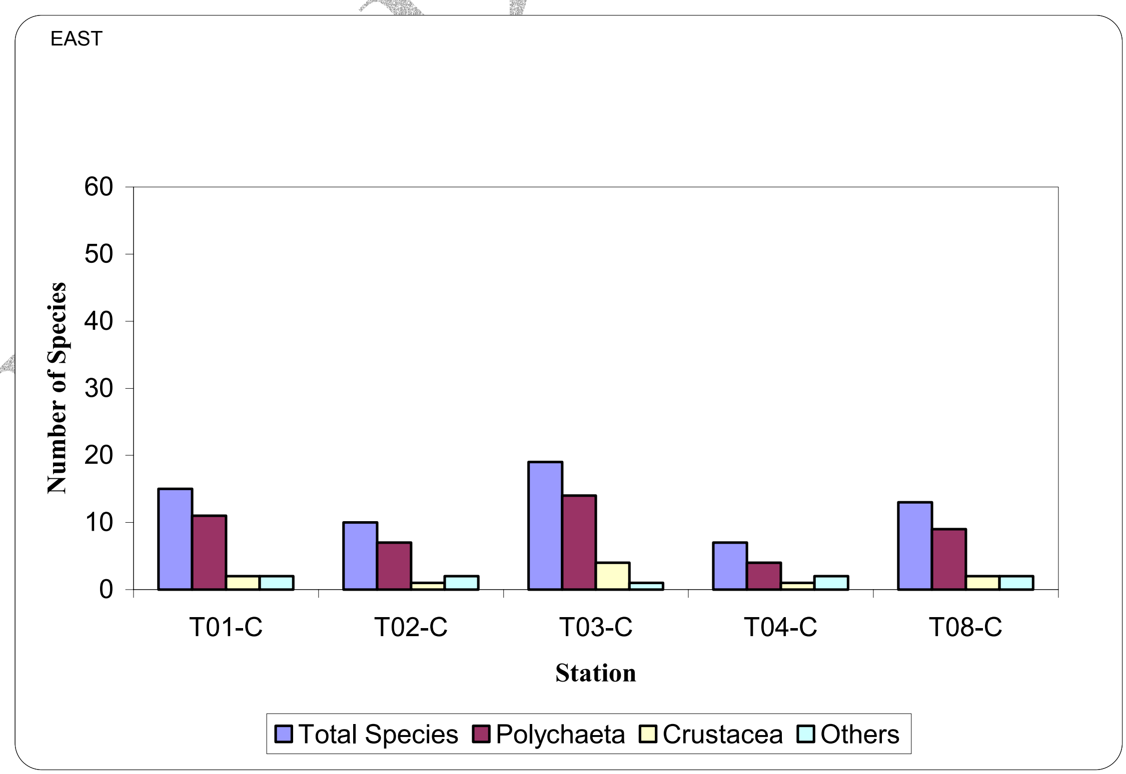
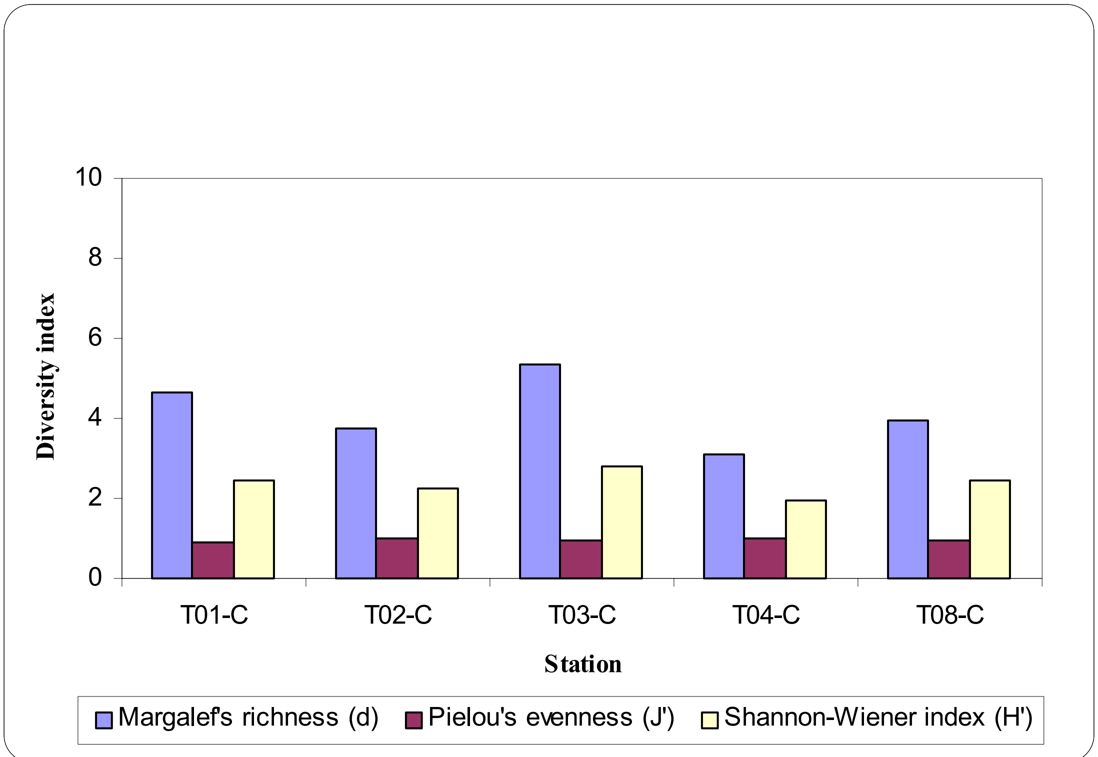


Figure 3.3-8
Offshore Benthic Macrofauna Diversity index Distribution on Main Pipeline Route in Togo.

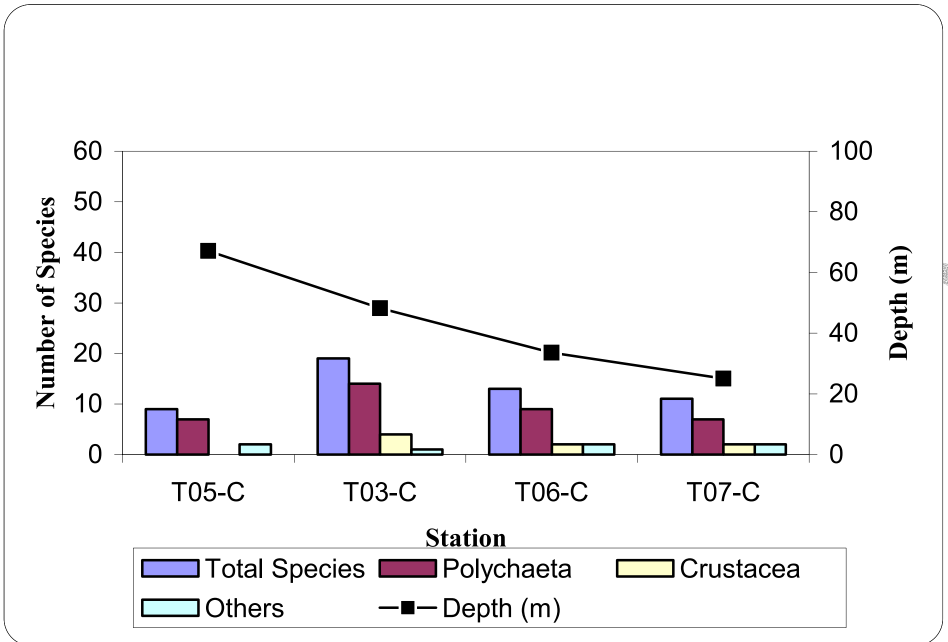


The diversity index showed a trend similar to the species diversity with Station T03-C having the highest species richness and Shannon-Wiener Index. The species evenness (J'), however, was fairly constant across the stations along the main pipeline route.

Lateral Route

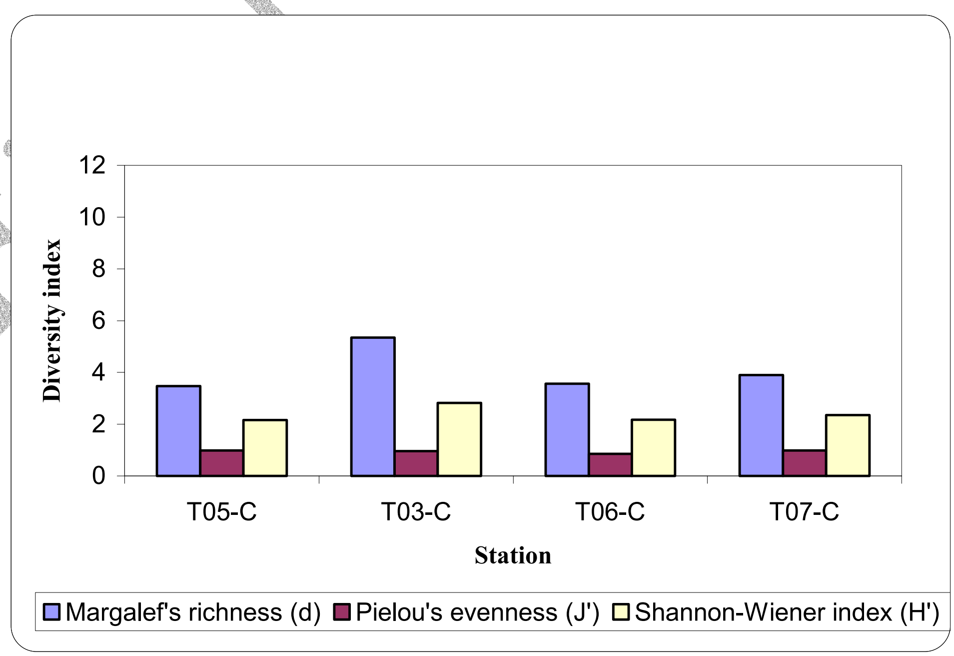
The number of species recorded along the lateral (Figure 3.3-9) showed a southward increase in number of species between Stations T07-C and T03-C. Station TO3-C exhibited the highest species count along the lateral, but had the lowest count for species belonging to the 'others' group. Station T05-C did not exhibit the trend experienced at the other stations. The station also did not record any crustacea.

Figure 3.3-9
Benthic Macrofauna Distribution along the Togo Lateral.



The species richness (d) and Shannon-Wiener Index showed distributions (Figure 3.3-10) similar to the number of species counted for each station. The evenness data as shown is similar for the four stations off the lateral in Togo.

Figure 3.3-10
Offshore Benthic Macrofauna Diversity index Distribution along the Togo lateral.



Benin

Seventy-two taxonomical groups were identified, made up of 50 polychaete species, 12 crustacean species and 10 species classified as 'others'. Seven stations were sampled along the main pipeline route off Benin and four stations were sampled along the laterals.

Main Pipeline Route

Figures 3.3-11 and 3.3-12 show the number of species and the diversity indices estimated for the stations off the main pipeline route. The main pipeline route off Benin ranges in depth from 50 to 70m. From the graph, the number of species per station showed a gradual decline westward, though Station B07-C, which is centrally placed, exhibited the lowest number of species. The polychaete species were dominant in all the stations sampled. No crustaceans were observed at Station B01-C and B07-C.

Figure 3.3-11
Benthic Macrofauna Distribution on Main Pipeline Route in Benin.

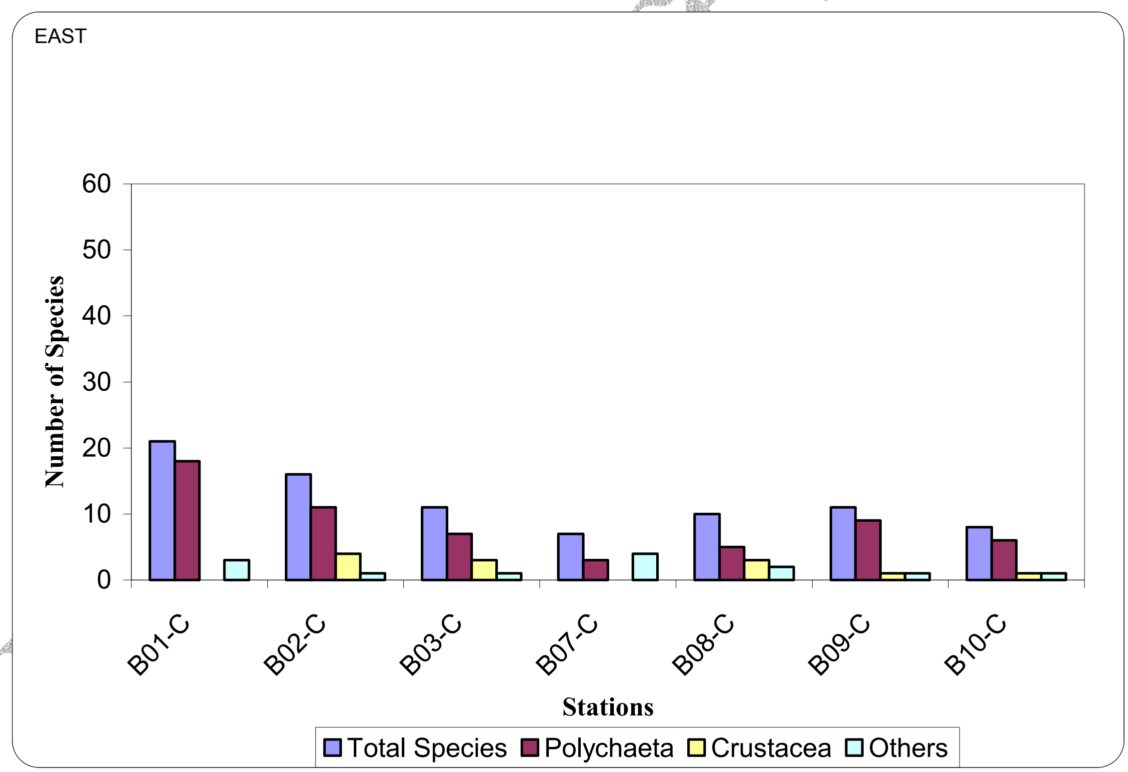
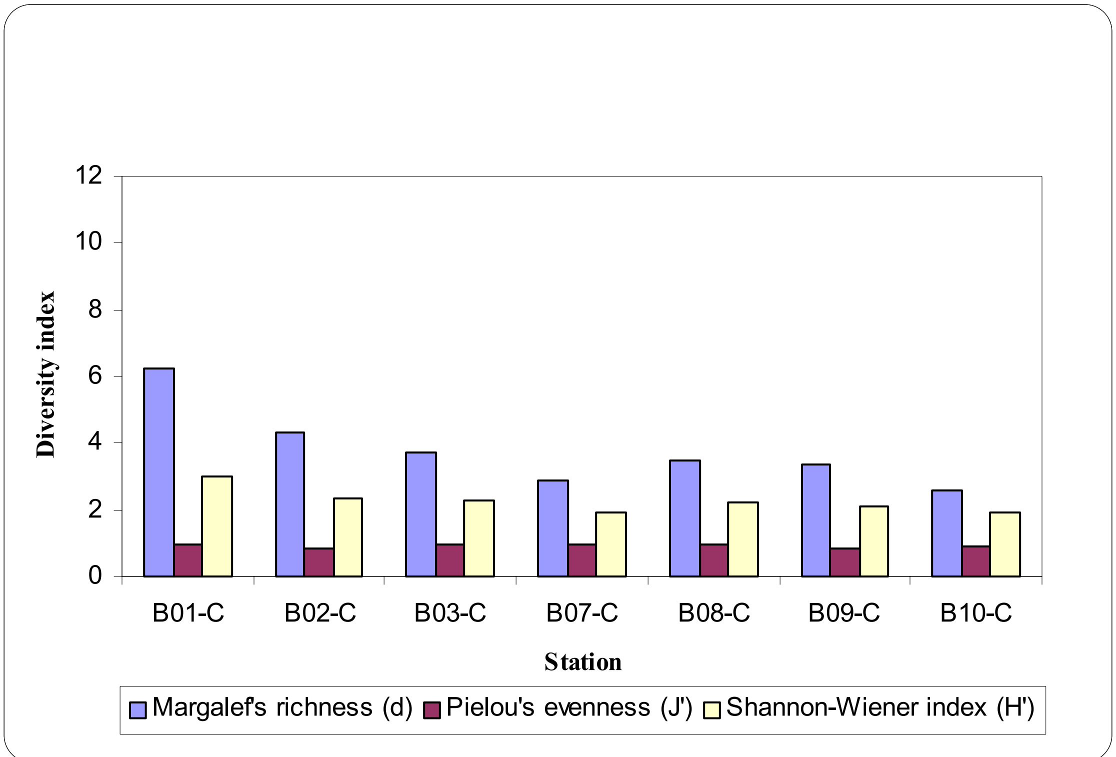


Figure 3.3-12
Offshore Benthic Macrofauna Diversity index Distribution on main pipeline route in Benin.



The diversity index also showed a trend similar to the number of species. Species evenness (J') was fairly constant across the stations along the main pipeline route.

Lateral Route

The number of species recorded along the lateral (Figure 3.3-13) show that Station B06-C, which was closest to land, recorded the lowest count for total species observed and polychaetes, and no value for the 'others' group. Stations B03-C and B05-C on the other hand recorded the highest numbers for the total species observed and the number of polychaetes observed. The species richness (d) and Shannon-Wiener Index showed distributions similar to the number of species counted for each station. The evenness data as shown is similar for the four stations off the lateral.

Figure 3.3-13
Benthic Macrofauna Distribution along the Benin lateral.

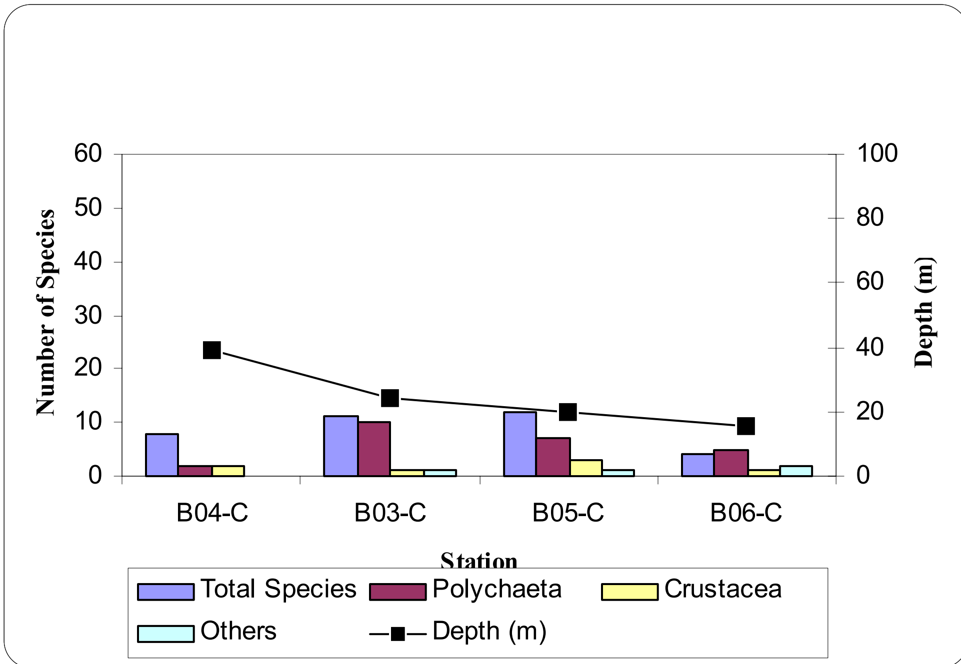


Figure 3.3-14
Offshore Benthic Macrofauna Diversity index Distribution along the Benin lateral

Nigeria

Thirty-three taxonomic groups were identified, made up of 25 polychaete species, 7 crustacean species and 4 species classified as 'others.' Three stations were sampled along the main pipeline route and four stations were sampled along the lateral.

Main Pipeline Route

Figures 3.3-15 and 3.3-16 show the number of species and the diversity indices estimated for the stations off the main pipeline route. The main pipeline route off Nigeria ranges in depth from 50 to 80m. No clear spatial distribution pattern was observed for the number of species enumerated. Station N05-C showed the highest total species and polychaete counts while Station N04-C showed the least counts. Benthic macrofauna grouped under 'others' was absent in samples from both Stations N04-C and N06-C. Polychaete species were dominant in all the stations sampled.

Figure 3.3-15
Benthic Macrofauna Distribution on Main Pipeline Route in Nigeria.

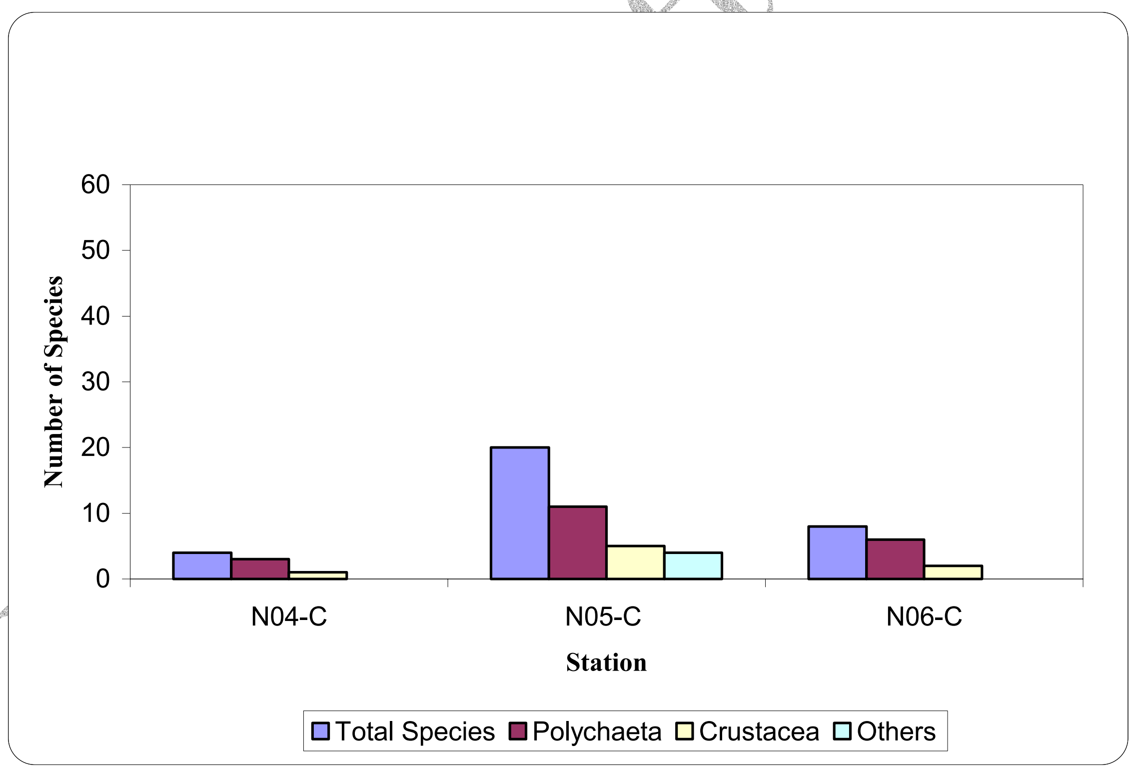
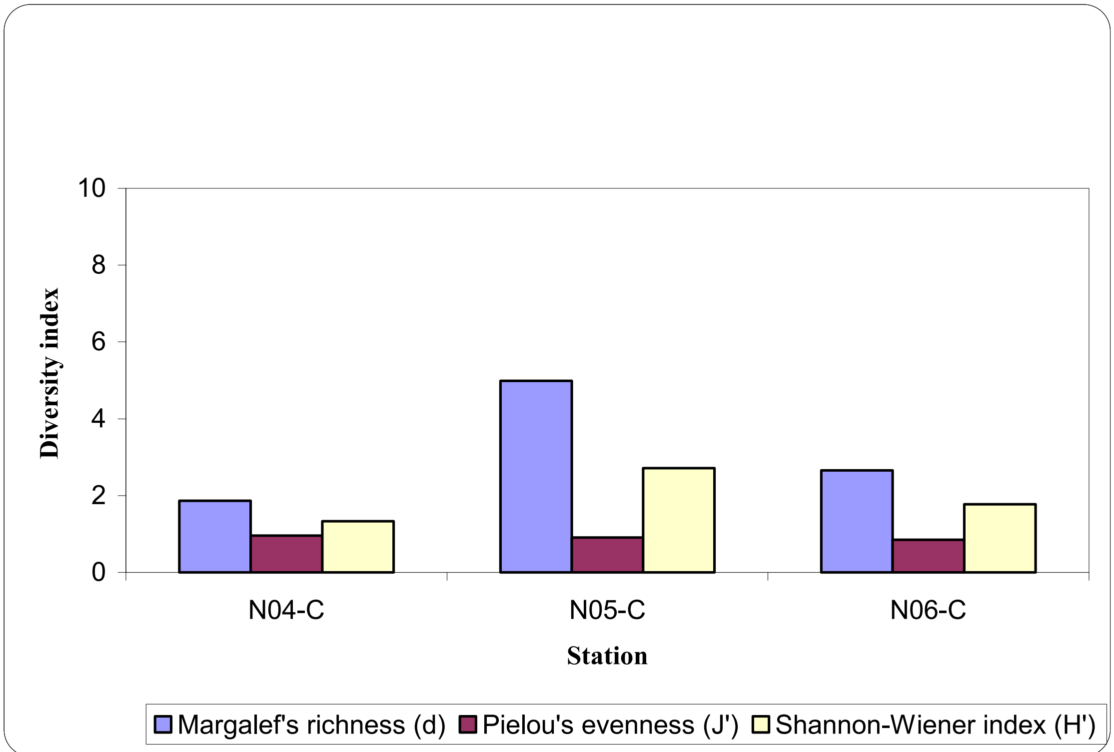


Figure 3.3-16
Offshore Benthic Macrofauna Diversity index Distribution on Main Pipeline Route in Nigeria.



The diversity index also showed a trend similar to the species diversity. Species evenness (J'), however, was fairly constant across the stations along the main pipeline route.

Lateral Route

The species count for the stations sampled on the lateral were similar (Figure 3.3-17) but low, compared with the other stations. The dominant species observed belong to the polychaetes. No crustacean species was recorded at Station N01-C and no species classified under the 'others' group was recorded at any of the stations along the lateral off Nigeria. The diversity index distribution (Figure 3.3-18) for the lateral indicates that station NO3-C had the highest diversity and species richness compared to the other stations.

Figure 3.3-17
Benthic Macrofauna Distribution along the Nigeria lateral

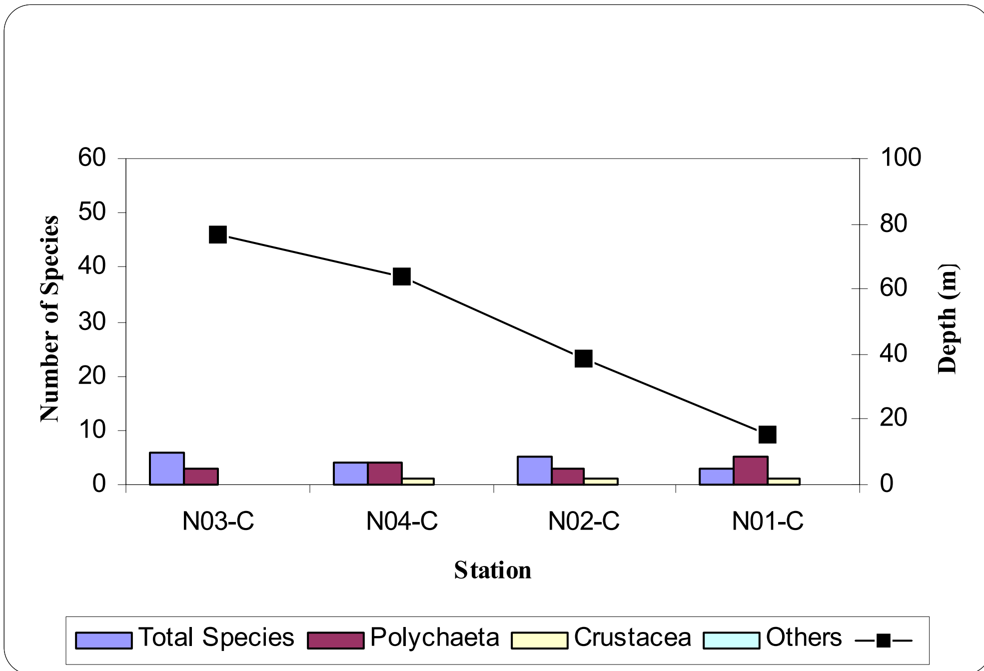
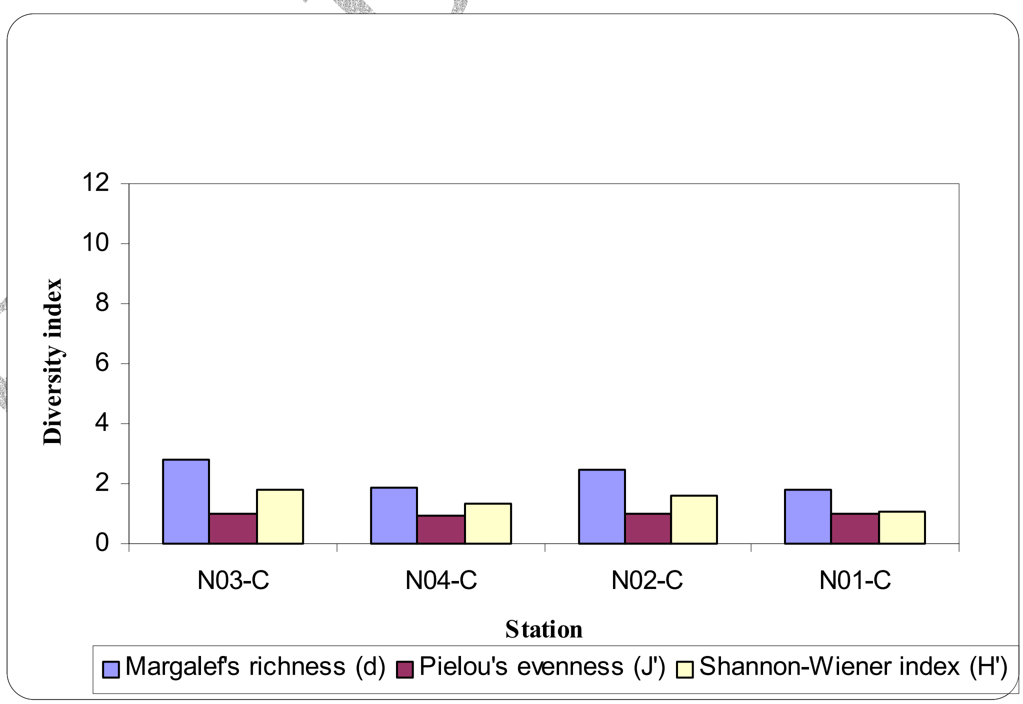


Figure 3.3-18
Offshore Benthic Macrofauna Diversity index Distribution along the Nigeria lateral.



Discussion

Polychaetes were the dominant organisms of benthic infauna. Polychaetes occur in two basic forms, errant and sedentary types, based on habits. Errant types are generally mobile predators with jaws for catching prey. Sedentary types are tube dwellers and generally are detritivores or filter feeders. A total of 625 individual polychaetes belonging to 38 families were recorded in the offshore waters. Of this number, a total of 237 individuals (38 percent of the polychaetes by number) belonging to 14 families were errant polychaetes, while the sedentary polychaetes included 388 individuals (62 percent of the polychaetes by number) comprising 24 families. Polychaete families with counts exceeding 20 individuals were classified as dominant. Based on this classification, the dominant families among the errrants were the Eunicidae, Nephtyidae, and the Glyceridae, and comprised 72 percent of the entire errant forms. Among the sedentary types, the dominant forms included the Maldanidae, Spionidae, Orbinidae, Cirratulidae, Lumbrinereidae, Onuphidae, Capitellidae and the Ampharetidae. They constituted 62 percent of the sedentary forms.

The relative occurrence of the dominant errant and sedentary polychaetes are presented in Figures 3.3-19 and 3.3-20. Figures 3.3-21 and 3.3-22 also show the hierarchical dominant errant and sedentary families for the entire offshore study area. The Maldanidae and Spionidae families were the most common, while the Ampharetidae was the least abundant in the hierarchical order.

Figure 3.3-19
Occurrence of Dominant Sedentary Polychaetes Across Countries.

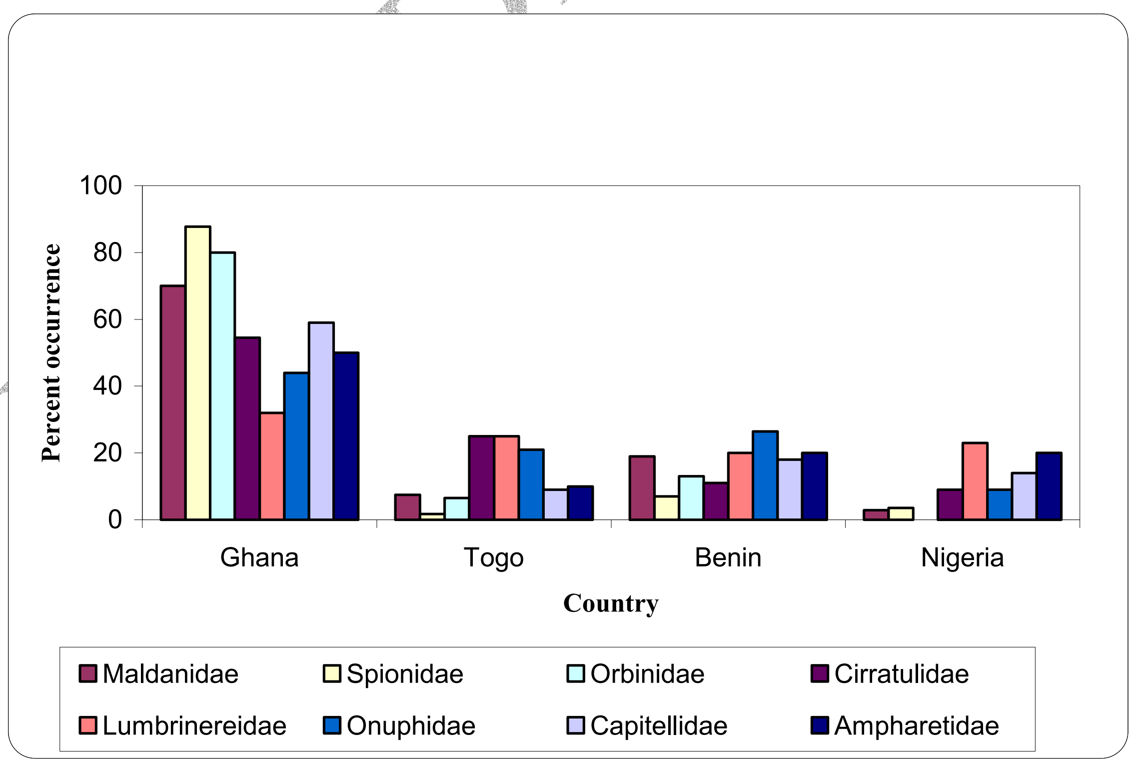


Figure 3.3-20
Occurrence of Dominant Errant Polychaetes Across Countries.

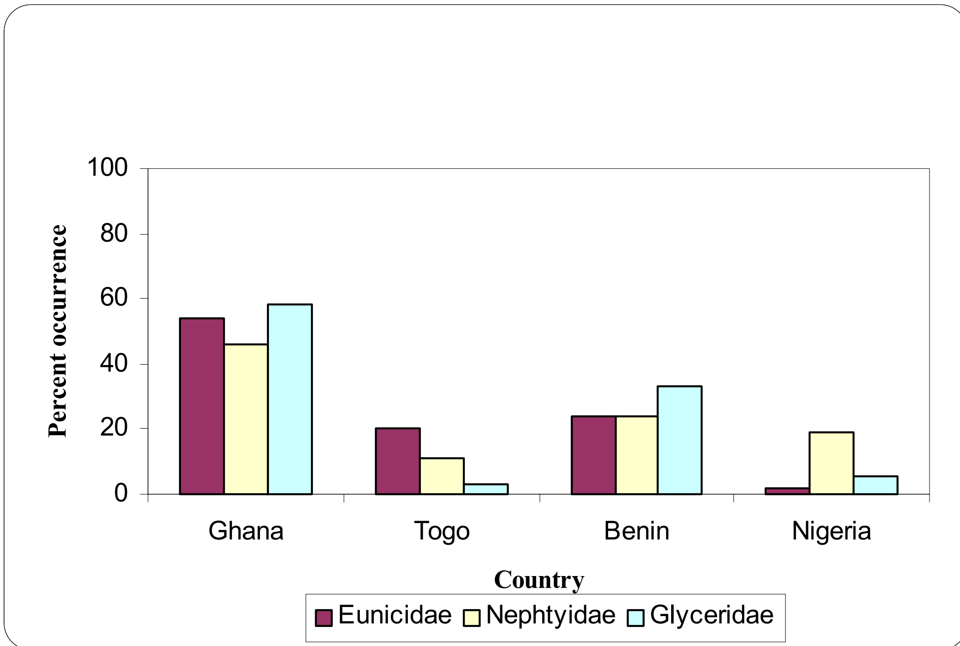


Figure 3.3-21
Occurrence of Dominant Sedentary Polecats.

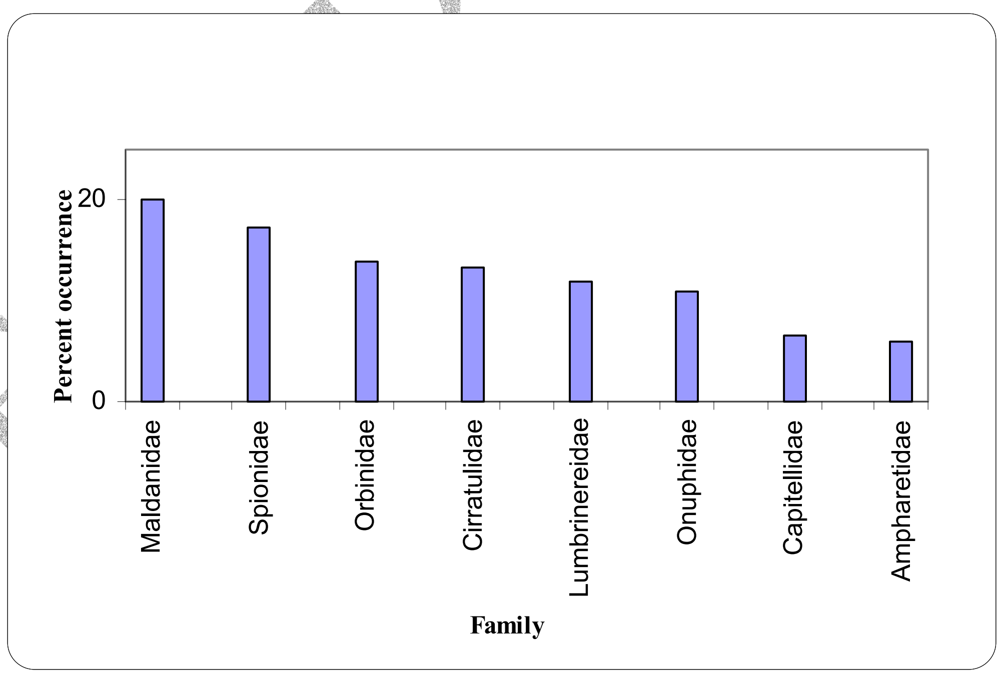
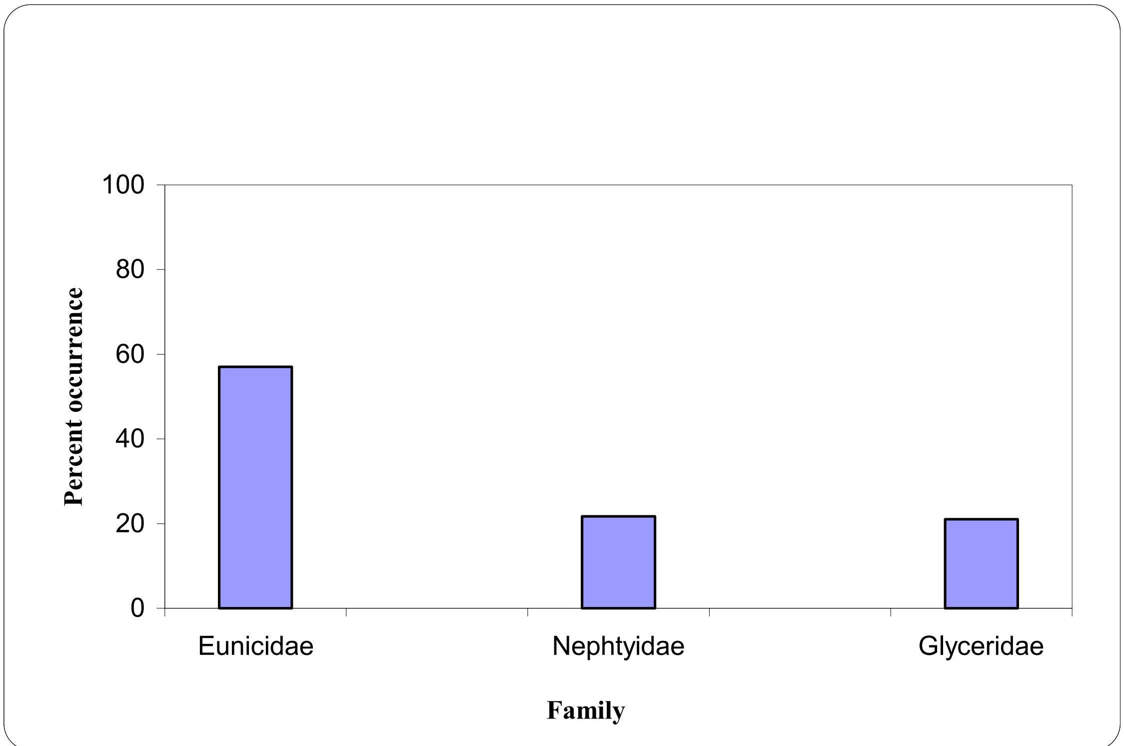


Figure 3.3-22
Occurrence of Dominant Errant Polychaetes.



SPI Analysis of Infaunal Successional Stage

Using the SPI images, it was difficult to determine either successional stage or faunal presence on many of the coarse-grained, sandy bottoms, not only because of limits to the camera prism's penetration depth, but also because these types of sediments are typically used as habitat primarily by small, mobile epifauna (amphipods, decapods, etc) that may or may not be present at the time of sampling. However, the majority of fine-grained stations surveyed were distinguished by relatively rich infaunal abundance and the presence of mature, deposit-feeding communities. There was no evidence found at any location of a stressed or compromised benthic community.

The amount of deposit-feeding activity and bioturbation at many of the silt-clay and sandy mud stations was quite impressive; polychaetes, crustaceans, and bivalves had reworked the sediment to depths in excess of 5 to 10cm with extensive networks of burrows and feeding voids. In addition to the diverse subsurface assemblages, many stations had communities of suspension or surface-deposit feeding taxa at the sediment-water interface. Epifauna were not just confined to the sandy/hard bottom areas; some of the sandy mud locations had anemones or sea pens present, enriching the faunal diversity at these locations.

SPI Organism-Sediment Index

The OSI values in this survey ranged between +4 to +11. An OSI of 6 or less typically indicates that a benthic habitat has experienced physical disturbances, organic enrichment or some other form of eutrophication, or excessive bioavailable contamination in the recent past. A quick glance at the map will reveal that the majority of areas sampled have OSI values in excess of +6; in fact, of the nine stations with values between 4 and 6, only three stations (G10-C, G10-E, and T6-W) really qualify to remain in this category. The low values at the other six stations are an artifact from shallow camera prism penetration, reducing the actual component values for RPD depth and/or successional stage.

The relatively high OSI values throughout the entire area reflect the healthy, undisturbed conditions of this nearshore area: no evidence of low oxygen or excessive organic loading, well-developed redox boundaries, and relatively mature infaunal communities throughout the entire region, especially in the fine-grained sediments.

SPI Discussion

The prevalence of Stage III infauna throughout large portions of the surveyed area and high OSI values reflect a mature stage of benthic community development in equilibrium with the local physical conditions; these deposit-feeding assemblages play a key role in "ventilating" the seafloor, both in terms of oxygen flux and nutrient exchange through their feeding and burrowing activities.

3.3.2 Offshore Plankton Community characterization

Results

In all, the number of taxa (mostly species) of phytoplankton and zooplankton identified were 69 and 52, respectively. These have been shown in order of increasing mean abundance for total individuals in all samples in Tables 3.3-1 and 3.3-2. The phytoplankton community was dominated by *Chaetoceros* spp. whiles *Penilia avirostris* dominated the zooplankton. Among the phytoplankton species identified in the samples was *Dinophysis acuta*, which is a harmful micro-algae with the potential to cause diarrhetic shellfish poisoning in bloom condition. At concentrations above 500 x10m^3 Cells m^{-3}, *Dinophysis acuta* is considered as being in bloom condition (Anderson et al., 2001). For the samples analysed, peak abundance of *Dinophysis* spp. did not exceed 10 x10m^3 at any station, and is not currently harmful to the fisheries.

Table 3.3-1
Summary of plankton species composition and abundance from samples collected off Ghana, Togo, Benin and Nigeria in December, 2002.

Taxa	Mean (Cells m^{-3})	Std. Error
Chaetoceros spp.	65,283	13,867
Rhizosolenia spp.	4,738	1,279
Trichodesmium (Oscillatoria)	3,908	1,143
Ceratium vultur	3,832	1,467
Thalassionema nitzschioides	2,550	560
Blue green algae	2,032	621
Ceratium furca	1,994	779
Rhizosolenia hebetata semispina	1,813	436
Skeletonema costatum	1,654	377
Silicoflagellate	1,573	549
Rhizosolenia calcar avis	1,484	502
Ceratium trichoceros	1,482	350
Bacteriastrum spp.	1,359	698
Ceratium fusus	1,349	616
Ceratium pentagonum	1,141	704
Dinophysis spp.	1,113	387
Ceratium extensum	1,107	393
Ceratium teres	1,092	557
Ceratium tripos	1,024	334
Nitzschia spp.	1,003	292
Acantharia	996	472
Coccolithaceae	908	295
Rhizosolenia alata alata	889	216
Dinoflagellate cysts	771	318
Ceratium massiliense	765	219
Navicula spp.	735	292
Coscinodiscus spp.	651	302
Tintinnid	650	208
Corethron spp.	641	283
Ceratium hexacanthum	615	206
Fragilaria spp.	612	183
Climacodium spp.	604	263
Ornithocercus spp.	595	236
Ceratium macroceros	583	197
Gonyaulax spp.	579	284
Paralia spp.	511	176
Ceratocorys spp.	508	196
Hemiaulus spp.	488	142
Peridinium spp.	389	139

Taxa	Mean (Cells m^{-3})	Std. Error
Ceratium horridum	386	141
Ceratium candelabrum	381	131
Thalassiothrix longissima	327	155
Dictyocha spp.	285	126
Ceratium arietinum	282	155
Thalassiosira spp.	279	80
Prorocenturm spp.	250	63
Biddulphia aurita	235	44
Ditylum brightwelli	230	66
Dactyliosolen mediterraneus	220	99
Asterionella japonica	202	78
Amphsolenia spp.	198	72
Ceratium minutum	188	60
Podolampas spp.	173	57
Ceratium bucephalum	149	35
Thalassionema fraunfeldii	144	76
Ceratium lunula	122	77
Exuviaella spp.	115	41
Ceratium carriense	94	53
Ceratium breve	87	36
Detonula confervacea	86	60
Ceratium contortum	83	51
Schroederella delicatula	59	29
Scrippsiella spp.	53	26
Ceratium lineatum	53	31
Lithodesmium undulatum	50	28
Scrippsiella trochidea	24	19
Rhizosolenia setigera	19.490	19.490
Lauderia spp.	14.254	10.444
Ceratium kofoidii	4.755	4.755

Table 3.3-2
Summary of zooplankton species composition and abundance from samples collected off Ghana, Togo, Benin and Nigeria in December, 2002.

Taxa	Mean	Std. Error
Penilia avirostris	1,128.0	363.4
Temora stylifera	702.5	134.9
Centropages furcatus	344.5	79.3
Eucalanus pileatus	319.9	65.1
Decapoda	225.9	51.2
Oithona spp./*Lubbockia* spp.	206.3	46.7

Taxa	**Mean**	**Std. Error**
Oikopleura longicauda	166.8	49.9
Oncaea spp.	150.2	54.2
Paracalanus parvus	137.7	47.8
Conchoecia spp.	95.2	78.2
Euchaeta paraconcina	63.7	14.2
Pluteus	61.9	30.9
Sagitta hispida	59.7	13.9
Evadne spp.	52.3	18.6
Sagitta enflata	51.3	20.9
Lucifer faxoni	43.2	15.1
Corycaeus spp.	42.9	11.4
Fish eggs	29.4	10.8
Undinula vulgaris	27.7	7.5
Eucalanus attenuatus	27.0	10.5
Farranula gracilis	26.9	7.6
Thaliacea	26.7	10.3
Sagitta friederici	25.1	6.1
Eucalanus crassus	23.7	7.4
Muggiaea spp.	22.8	4.7
Acartia spp.	20.5	5.1
Corycaeus speciosus	20.3	5.4
Centropages chierchiae	18.6	6.1
Thecosomata	18.0	7.6
Clausocalanus spp.	14.2	4.0
Fish larvae	11.2	3.4
Sagitta spp.	10.5	5.8
Hyperidea	10.2	4.2
Cyphonautes	9.6	3.1
Nannocalanus minor	9.3	2.6
Scolecithrix danae	8.3	3.0
Euchaeta marina	7.4	2.7
Sapphirina spp.	6.9	2.4
Copilia spp.	6.7	2.0
Euphausiacea	6.6	2.8
Rhincalanus cornutus	6.4	2.9
Medusae	5.9	1.8
Echinoderm larvae	5.6	2.4
Euterpina acutifrons	5.4	2.5
Calocalanus spp.	5.2	2.1
Pontellina plumata	4.3	2.4
Foraminifera	4.1	1.8
Candacia spp.	3.4	1.7
Polychaeta	3.0	1.6

Taxa	**Mean**	**Std. Error**
Harpaticoida	1.1	0.7
Pleuromamma spp.	0.5	0.3
Pleurobrachia pileus	0.3	0.3

Distribution of total plankton abundance per sampling station in Ghana showed the highest phytoplankton abundance at Station G02 with lowest abundance being recorded off Station G08 (Figure 3.3-23). In the case of Togo, the highest abundance was at Station T02 and lowest at Station T01 (Figure 3.3-24). Benin recorded highest and lowest abundance at Stations B04 and B02, respectively (Figure 3.3-25). Off Nigeria, the highest and lowest abundance were recorded off Stations N03 and N01, respectively (Figure 3.3-26).

Figure 3.3-23
Distribution of total phytoplankton abundance at sampling stations off Ghana.

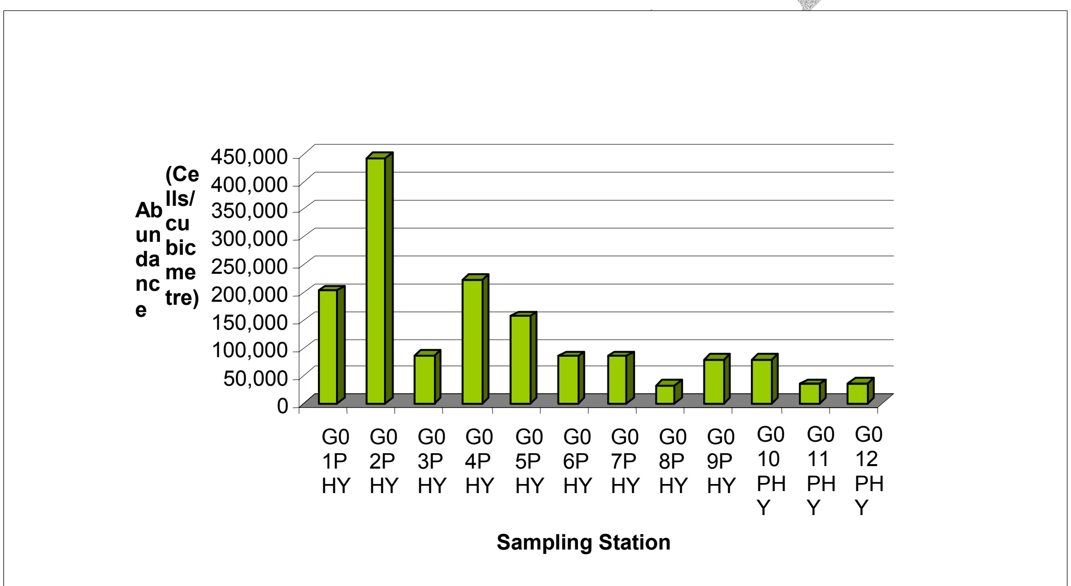


Figure 3.3-24
Distribution of total phytoplankton abundance at sampling stations off Togo.

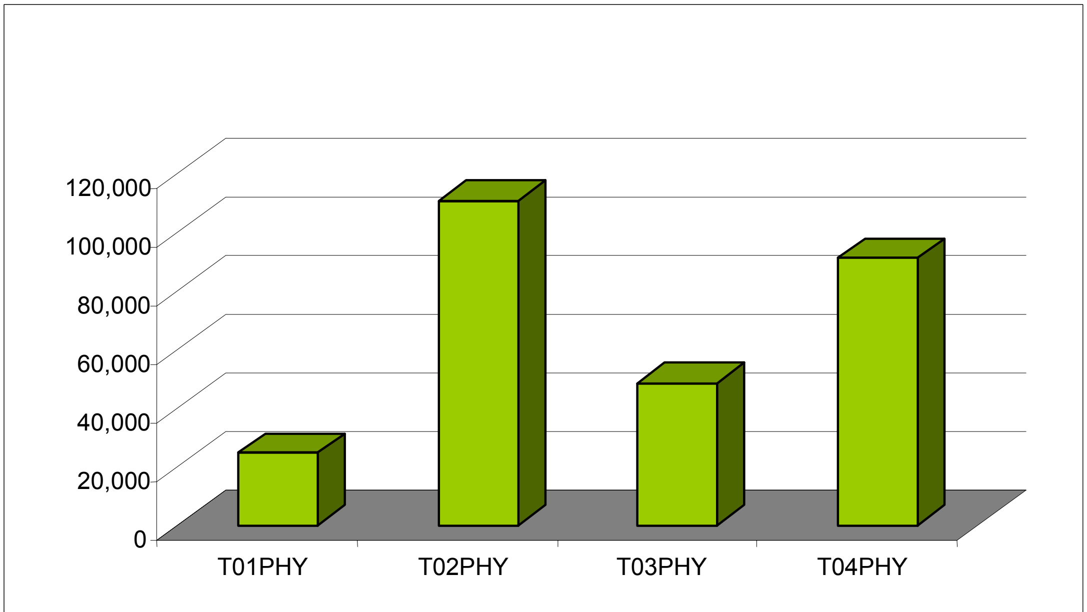


Figure 3.3-25
Distribution of total phytoplankton abundance at sampling stations off Benin.

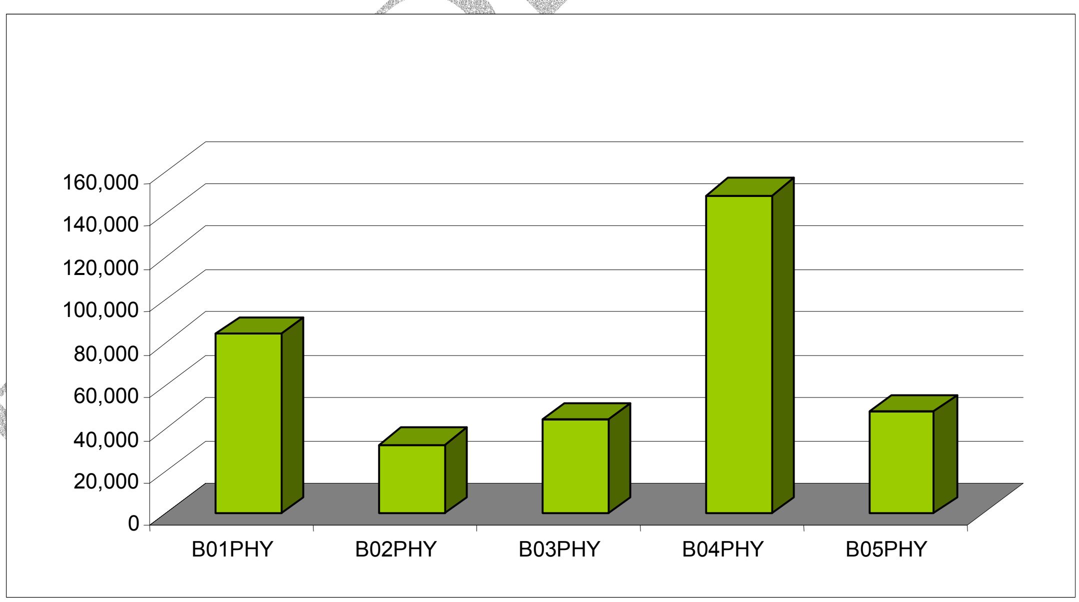
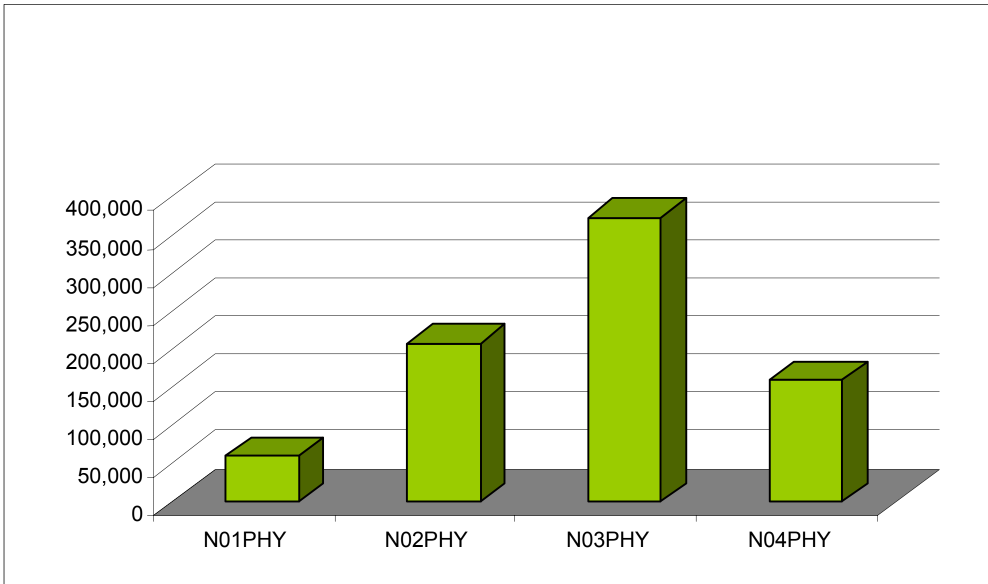


Figure 3.3-26
Distribution of total phytoplankton abundance at sampling stations off Nigeria.



With regard to the zooplankton, distribution of the total per sampling station for each country showed highest phytoplankton abundance at Station G03 in Ghana with lowest abundance being recorded off Station G06 (Figure 3.3-27). In the case of Togo, highest abundance was at Station T03 and lowest at Station T02 (Figure 3.3-28). Benin recorded highest and lowest abundance at Stations B02 and B05, respectively (Figure 3.3-29). Off Nigeria, the highest and lowest abundance were recorded off Stations N02 and N01, respectively (Figure 3.3-30).

Figure 3.3-27
Distribution of total zooplankton abundance at sampling stations off Ghana.

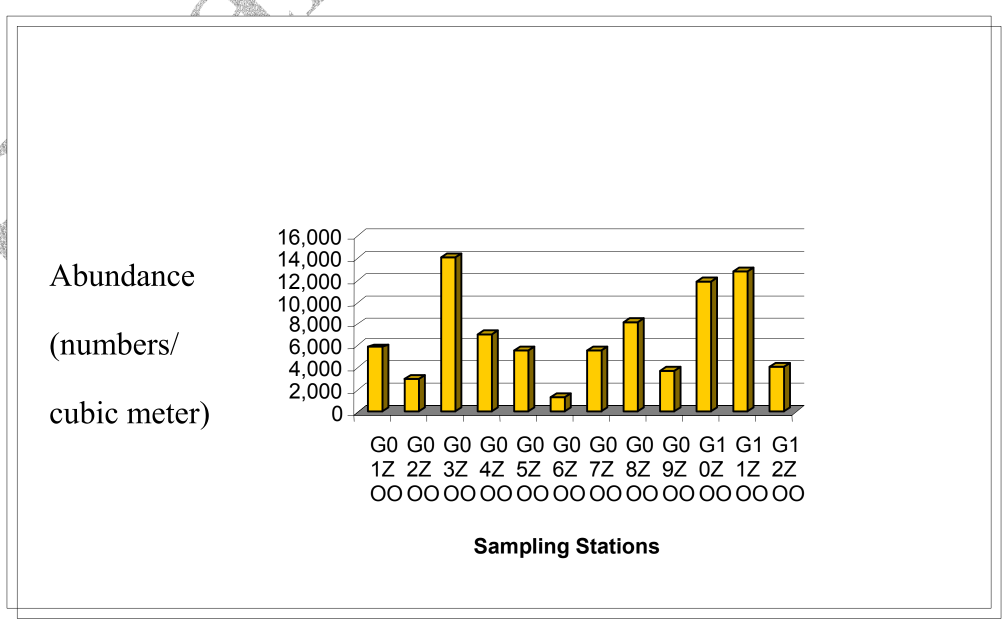


Figure 3.3-28
Distribution of total phytoplankton abundance at sampling stations off Togo.

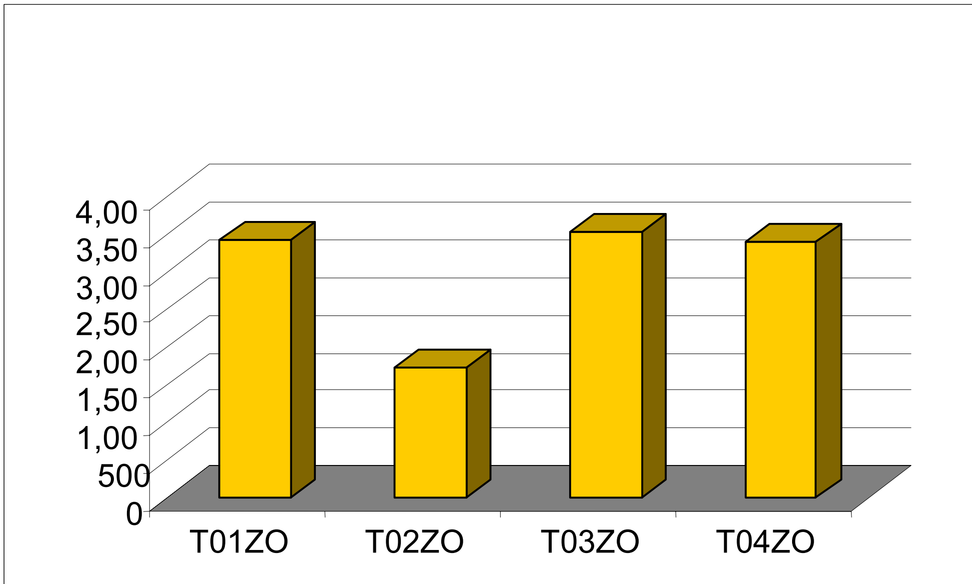
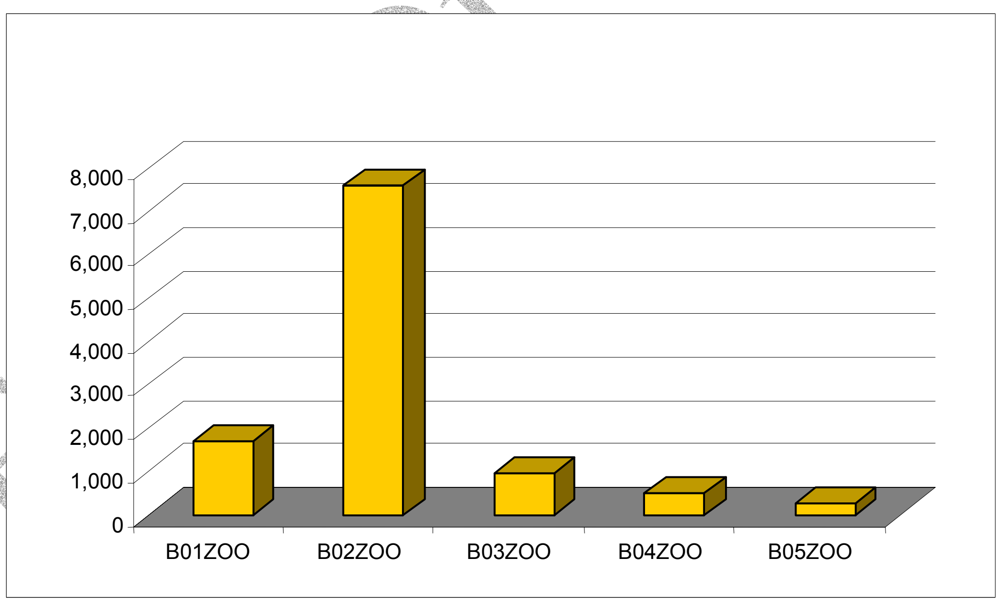


Figure 3.3-29
Distribution of total zooplankton abundance at sampling stations off Benin.



The sampling of plankton revealed the highest phytoplankton abundance off station G02, with a high variability about the mean (Table 3.3-3). A dinoflagellate species, *Chaetoceros* sp., occurred in high abundance at all stations, but particularly peaked in abundance at Station G02 (Appendix B). This was a contributory factor to the observed high variability at this station (Figure 3.3-31).

Figure 3.3-30
Distribution of total zooplankton abundance at sampling stations off Nigeria.

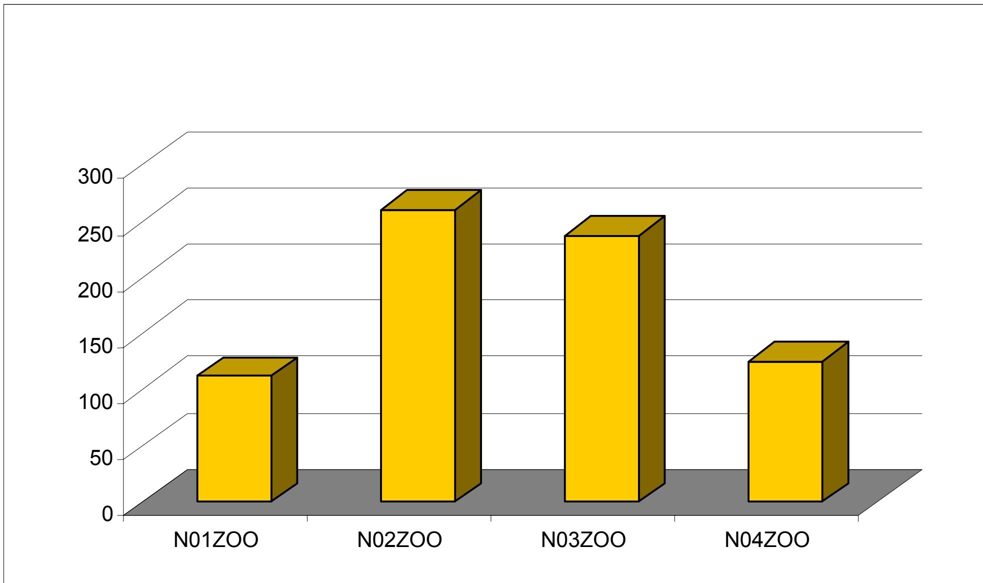
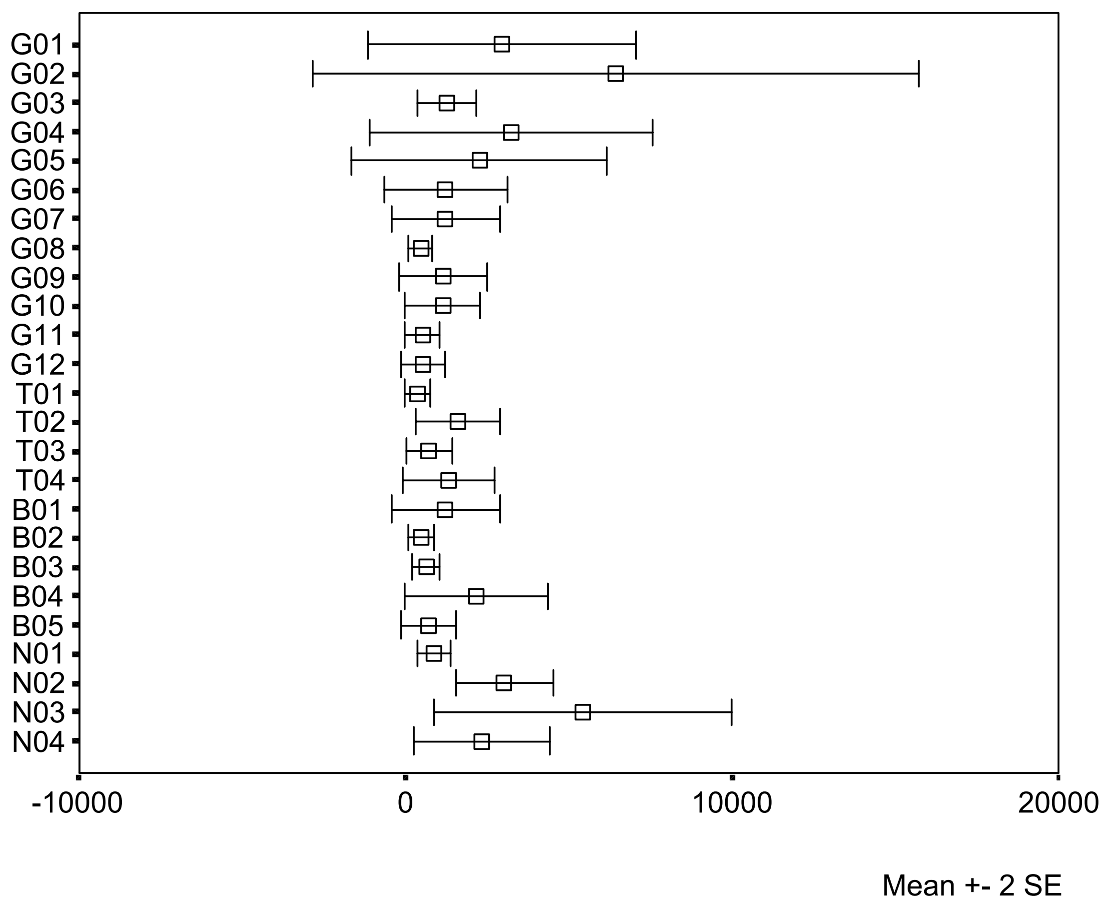


Table 3.3-3
Distribution of total phytoplankton abundance at each of the sampling stations.

Station	Numbers per cubic meter of sea water		
	Sum	Mean	Std. Error
G02	443,079.8	6,421.447	4,644.361
N03	373,125.7	5,407.619	2,282.209
G04	223,339.2	3,236.800	2,165.514
N02	208,100.6	3,015.951	741.887
G01	203,347.2	2,947.061	2,064.798
N04	159,672.7	2,314.098	1,042.925
G05	156,010.7	2,261.025	1,959.232
B04	148,621.4	2,153.933	1,108.946
T02	110,699.9	1,604.346	641.622
T04	90,994.2	1,318.756	703.152
G03	86,251.2	1,250.017	442.713
G06	84,216.3	1,220.526	945.749
G07	84,180.6	1,220.009	831.233
B01	83,787.9	1,214.317	828.086
G09	79,400.3	1,150.729	684.617
G10	78,034.3	1,130.932	570.765
N01	58,957.4	854.456	256.864
T03	48,605.3	704.425	352.185
B05	47,571.8	689.447	426.056

Station	Numbers per cubic meter of sea water		
	Sum	Mean	Std. Error
B03	43,591.4	631.759	211.827
G12	36,332.7	526.560	350.341
G11	34,614.7	501.663	257.249
B02	31,843.3	461.497	195.880
G08	31,272.3	453.222	183.537
T01	24,711.9	358.143	208.209

Figure 3.3-31
Mean distribution of phytoplankton collected from sampling stations off Ghana, Togo, Benin and Nigeria in December, 2002.

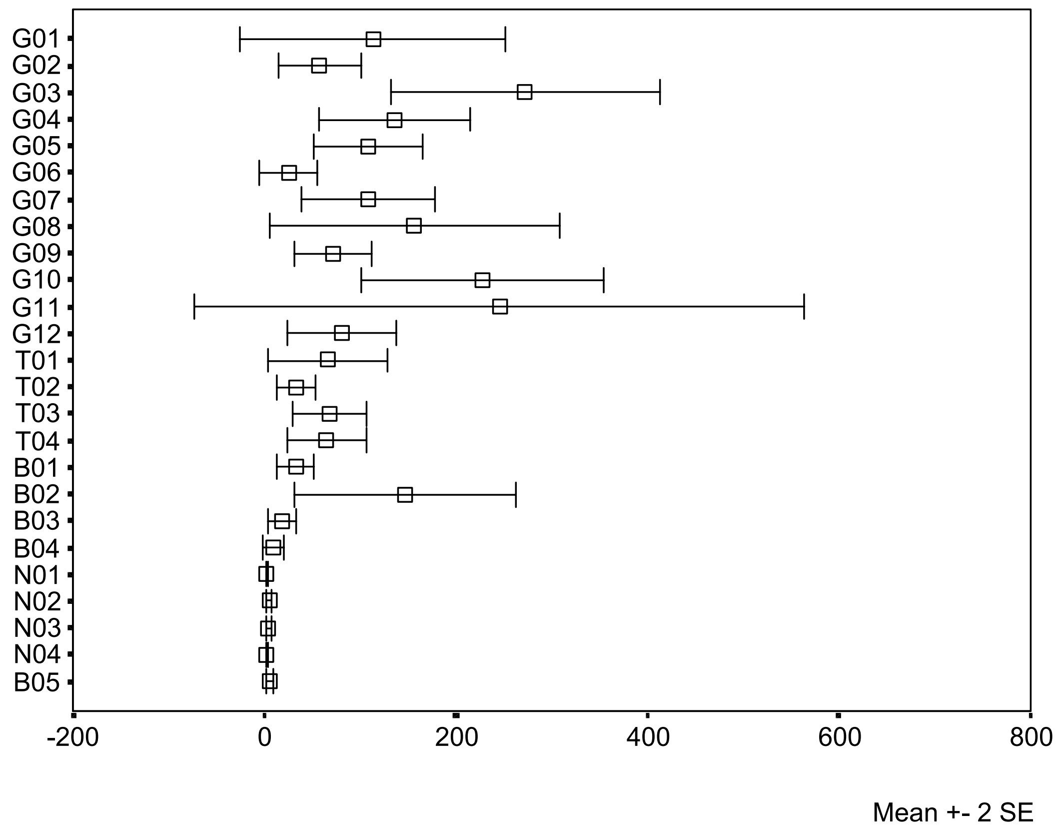


The greatest abundance of zooplankton was observed off Stations G03 and G11. The latter station recorded the highest variability about the mean (Table 3.3-4; Figure 3.3-32). From individual species distribution, *Penilia avirostris*, a cladoceran, dominated the community, and its abundance in this particular station far exceeded any other (see Appendix B).

Table 3.3-4
Distribution of total zooplankton abundance at each of the sampling stations.

Stations	Numbers per cubic meter of sea water		
	Sum	Mean	Std. Error
G03	14,167.7	272.455	70.128
G11	12,752.6	245.242	159.362
G10	11,837.9	227.652	63.534
G08	8,143.6	156.608	75.693
B02	7,601.2	146.176	57.784
G04	7,040.3	135.391	39.219
G01	5,870.2	112.888	69.032
G05	5,653.0	108.711	28.666
G07	5,650.5	108.664	34.952
G12	4,179.5	80.375	28.210
G09	3,737.4	71.874	19.996
T03	3,525.6	67.801	19.336
T01	3,423.3	65.832	31.167
T04	3,384.6	65.089	21.065
G02	2,982.6	57.358	21.648
T02	1,717.9	33.037	9.987
B01	1,679.9	32.305	9.467
G06	1,333.6	25.646	15.137
B03	948.7	18.245	7.601
B04	480.8	9.246	5.126
B05	278.8	5.362	2.156
N02	259.6	4.993	1.370
N03	237.2	4.561	1.327
N04	125.0	2.404	.622
N01	112.2	2.157	.582

Figure 3.3-32
Mean distribution of zooplankton collected from sampling stations off Ghana, Togo, Benin and Nigeria in December, 2002.



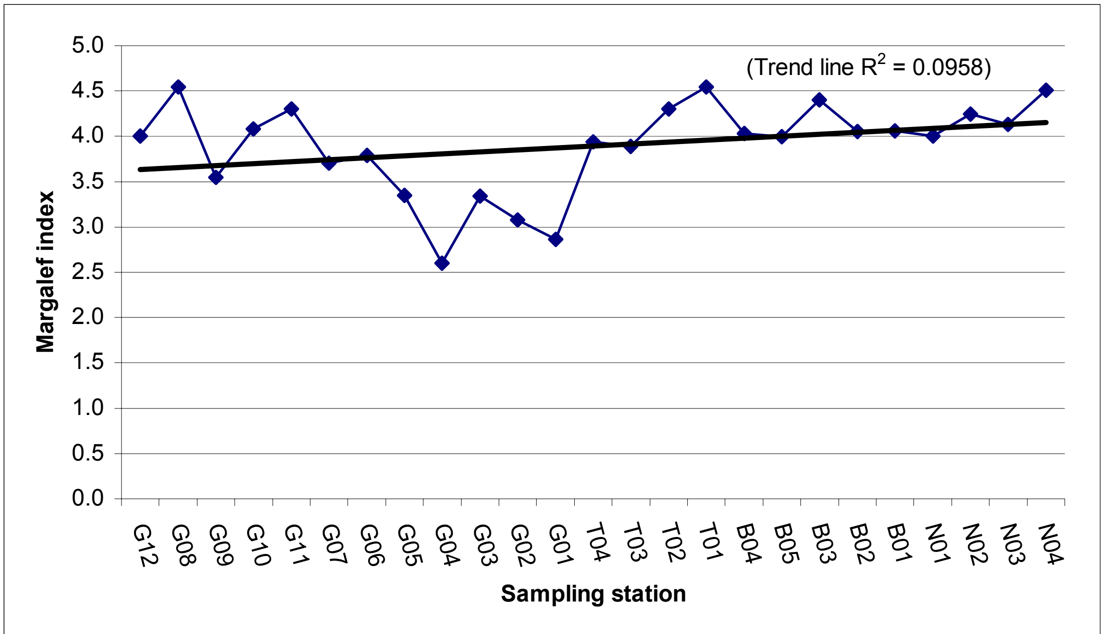
Calculation of diversity indices showed a relatively high phytoplankton species diversity off Nigeria. Margalef's diversity index incorporates species composition and total number of individuals in its computation {i.e., d = (S-1)/log N}, and is more commonly used in diversity analysis. For all samples analyzed, the highest value of Margalef index (d) for phytoplankton was obtained at Stations G08, T01 and N04 (Table 3.3-5). In terms of species richness (S), Station G04 ranked least among the other stations (Table 3.3-5).

Table 3.3-5
Calculation of suite of diversity indices for phytoplankton collected off Ghana, Togo, Benin and Nigeria in December, 2002. (S, Species richness; N, number of individuals; d, Margalef's index; J', Pielou's evenness index; H', Shannon-Wiener index).

Station	S	N	d	J'	H'(log_e)
N04	55	159,673	4.5	0.6	2.4
N03	54	373,126	4.1	0.6	2.4
N02	53	208,101	4.2	0.8	3.2
T02	51	110,700	4.3	0.6	2.5
B04	49	148,621	4.0	0.6	2.2
G08	48	31,272	4.5	0.6	2.4
B03	48	43,591	4.4	0.7	2.5
G10	47	78,034	4.1	0.5	2.1
T01	47	24,712	4.5	0.5	2.0
B01	47	83,788	4.1	0.4	1.6
G11	46	34,615	4.3	0.6	2.2
T04	46	90,994	3.9	0.6	2.1
N01	45	58,957	4.0	0.7	2.8
G06	44	84,216	3.8	0.3	1.1
B05	44	47,572	4.0	0.5	1.8
G07	43	84,181	3.7	0.4	1.6
G12	43	36,333	4.0	0.4	1.6
T03	43	48,605	3.9	0.6	2.4
B02	43	31,843	4.1	0.6	2.4
G02	41	443,080	3.1	0.4	1.4
G05	41	156,011	3.3	0.2	0.8
G09	41	79,400	3.5	0.5	1.8
G03	39	86,251	3.3	0.7	2.7
G01	36	203,347	2.9	0.4	1.5
G04	33	223,339	2.6	0.5	1.6

A plot of the Margalef index for phytoplankton against sampling station, fitted with trendline using least squares revealed a slight increase in diversity from Ghana to Nigeria. The R^2 value, which indicates the proportion of variability accounted for by the trend line, was 9.6% (Figure 3.3-33).

Figure 3.3-33
Margalef's diversity index calculated for each phytoplankton community at each sampling station.



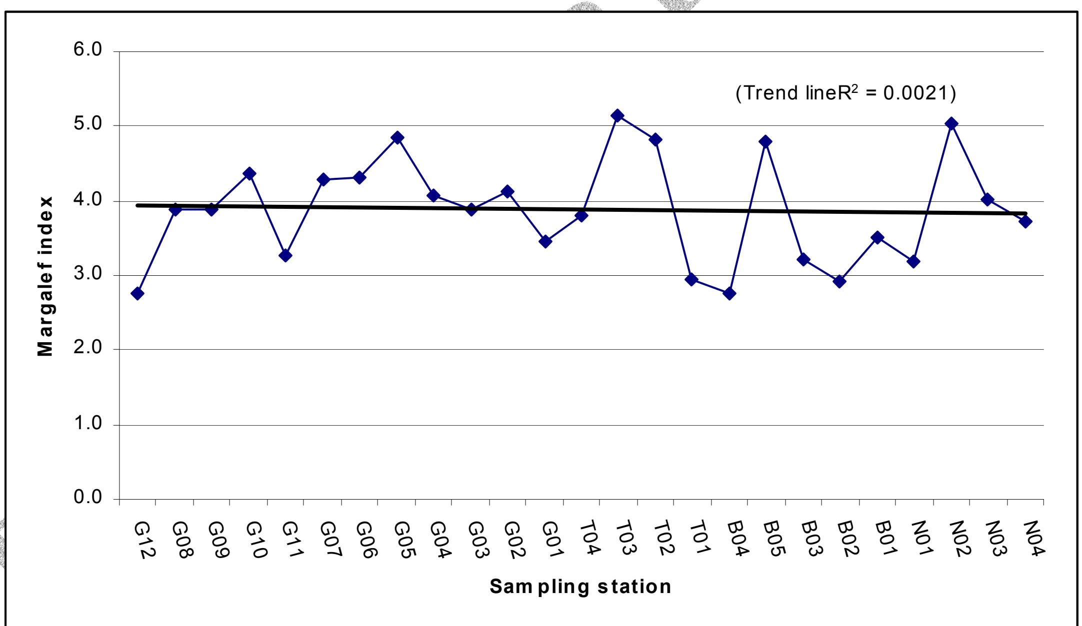
In the case of zooplankton, Stations G05, T03 and G10 ranked highest in species richness (S) (Table 3.3-6). The distribution of Margalef index for zooplankton community showed an overall stable trend, which accounted for less than one percent (Figure 3.3-34).

Table 3.3-6
Calculation of suite of diversity indices for zooplankton collected off Ghana, Togo, Benin and Nigeria in December, 2002. (S, Species richness; N, number of individuals; d, Margalef's index; J', Pielou's evenness index; H', Shannon-Wiener index).

Station	S	N	d	J'	H'(log_e)
G05	43	5,653	4.9	0.8	2.9
T03	43	3,526	5.1	0.8	3.0
G10	42	11,838	4.4	0.7	2.8
G03	38	14,168	3.9	0.8	2.8
G07	38	5,651	4.3	0.7	2.6
G04	37	7,040	4.1	0.7	2.7
T02	37	1,718	4.8	0.7	2.7
G08	36	8,144	3.9	0.6	2.1
G02	34	2,983	4.1	0.7	2.4
G09	33	3,737	3.9	0.8	2.7
G06	32	1,334	4.3	0.5	1.8
G11	32	12,753	3.3	0.4	1.5
T04	32	3,385	3.8	0.8	2.6

Station	S	N	d	J'	H'(log_e)
G01	31	5,870	3.5	0.5	1.7
N02	29	260	5.0	0.8	2.9
B05	28	279	4.8	0.7	2.5
B01	27	1,680	3.5	0.8	2.6
B02	27	7,601	2.9	0.7	2.3
T01	25	3,423	2.9	0.6	2.1
G12	24	4,179	2.8	0.7	2.4
B03	23	949	3.2	0.7	2.2
N03	23	237	4.0	0.8	2.6
N04	19	125	3.7	0.9	2.7
B04	18	481	2.8	0.6	1.8
N01	16	112	3.2	0.9	2.6

Figure 3.3-34
Margalef's diversity index calculated for each zooplankton community at each sampling station.



Hierarchical clustering with group-average linking, based on sample similarity matrices such as Bray-Curtis, has proved a useful technique in plankton community studies (Clarke and Warwick, 1994). Subjecting the data to cluster analysis showed that all the stations exhibited similarity in community structure above Bray-Curtis similarity of 60 percent (Figure 3.3-35). A similar situation occurred for zooplankton communities, with the exception of stations N03 and N04 (Figure 3.3-36). However, at Bray-Curtis similarity of 50 percent, all the zooplankton communities could be considered as being similar.

Figure 3.3-35
Dendrogram for hierarchical clustering of phytoplankton communities, using group-average linking of Bray-Curtis similarities calculated on fourth root transformed abundance data.

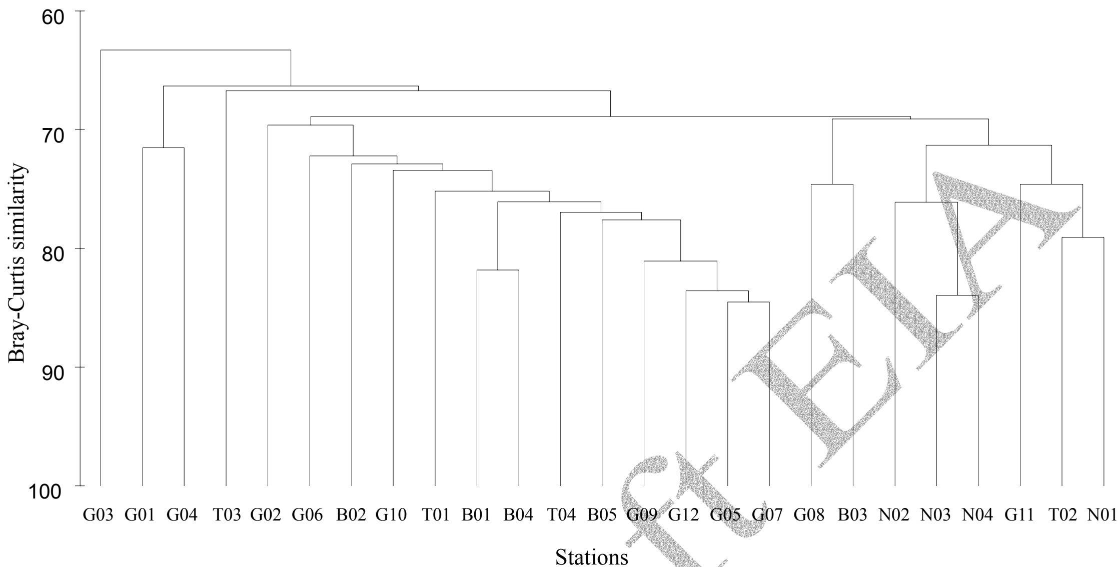
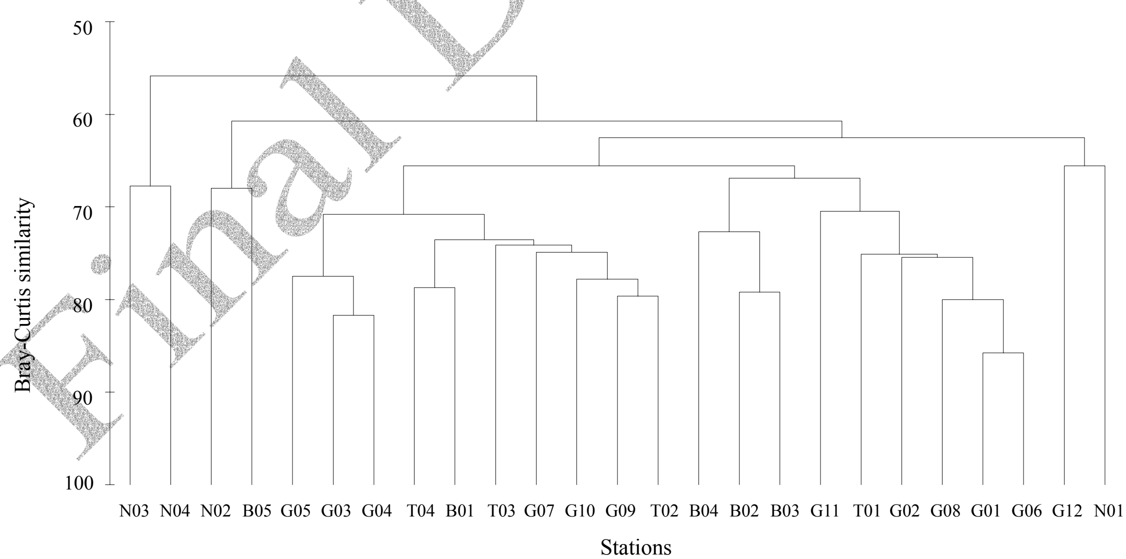


Figure 3.3-36
Dendrogram for hierarchical clustering of zooplankton communities, using group-average linking of Bray-Curtis similarities calculated on fourth root transformed abundance data.



Discussion

It was observed that some species, i.e. *Chaetoceros* spp. and *Penilia avirostris,* dominated the phytoplankton and zooplankton communities, respectively. This could be a result of response to seasonal changes in the hydrographic regime. Although this could not be confirmed from the data used in the plankton analysis, it is the most plausible factor to consider based on the fact that plankton respond significantly to seasonal changes in the hydrographic regime (Wiafe, 2002).

Plankton community characterisation, based on hierarchical clustering, showed that the entire project area is a homogenous system, at Bray-Curtis similarity above 50 percent, for both phytoplankton and zooplankton communities. This suggests that environmental conditions responsible for structuring the pelagic communities were appreciably similar for all the stations sampled during this season. However, introduction of any new material in significant quantities could adversely affect the ecological balance in terms of primary and secondary productivity. Such an adverse material could be fine sediment in large quantities, which has the potential of clogging the feeding apparatus of zooplankton. This is the main issue for consideration in the construction of the pipeline in the project area.

The plankton samples were collected from the upper 20 – 30m column of the sea, and the zooplankton species identified were predominantly epipelagic. It has been observed that a thermocline exists between 30 – 40m of the water column in the project area during this season (Bainbridge, 1972). This serves as a barrier to the zooplankton during vertical migration. In order to obtain a good representation of the zooplankton community in the project area, it is recommended that future sampling should include vertical tow above 5 – 10m from the bottom of the sampling station.

3.3.3 Fish Population

Species Composition and Catch Rates

The species composition, catch rates (kg/haul) and numbers of individual species by stations for Ghana, Togo, Benin and Nigeria are presented in Appendix B3. Figures 3.3-37 through 3.3-38 are graphical representations of the catch rates by stations for Ghana, Togo, Benin, and Nigeria, respectively.

Figure 3.3-37
Catch rates along pipeline in Ghana.

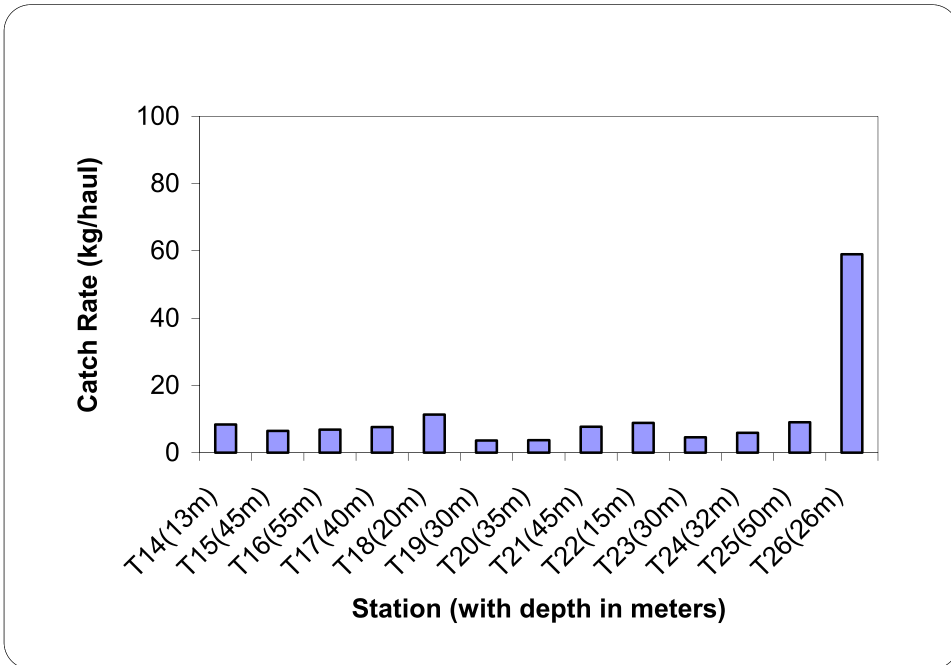


Figure 3.3-38
Catch rates along pipeline in Togo.

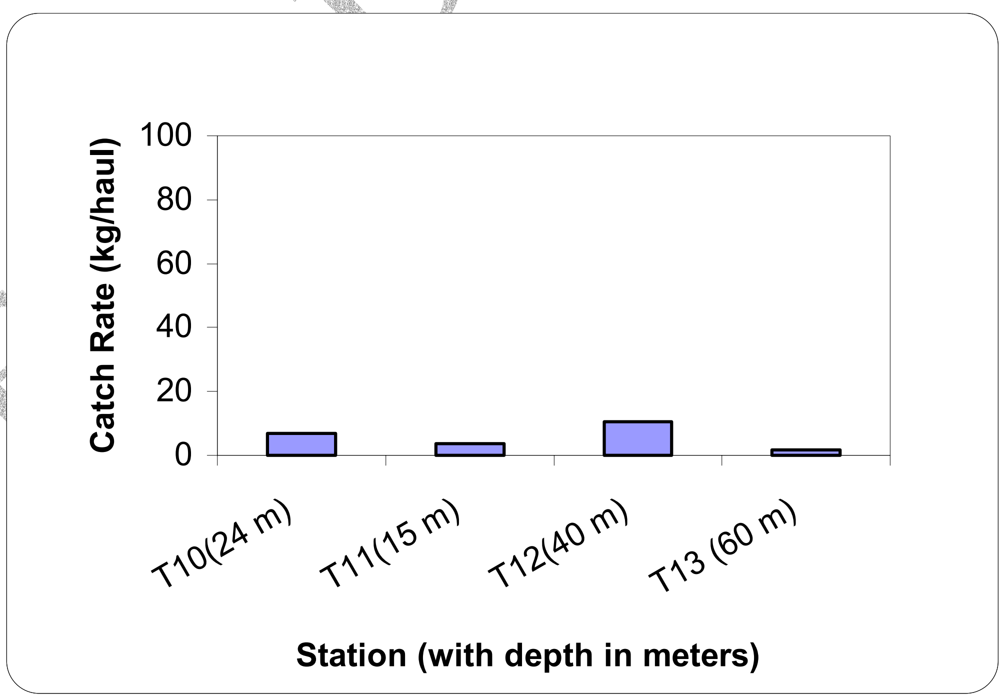


Figure 3.3-39
Catch rates along pipeline in Benin.

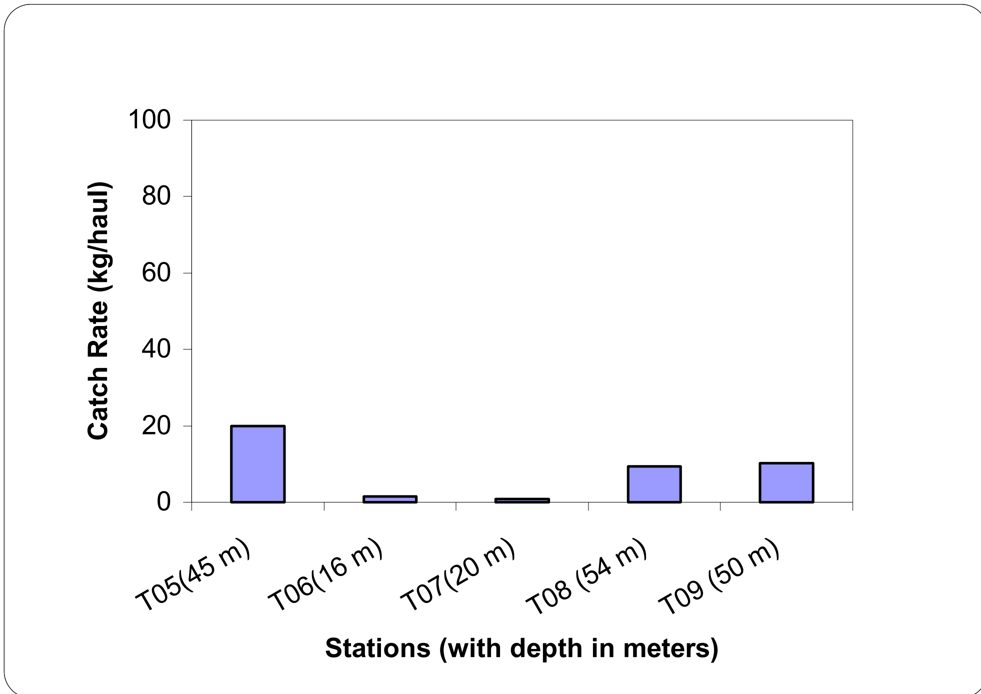


Figure 3.3-40
Catch rates along pipeline in Nigeria.

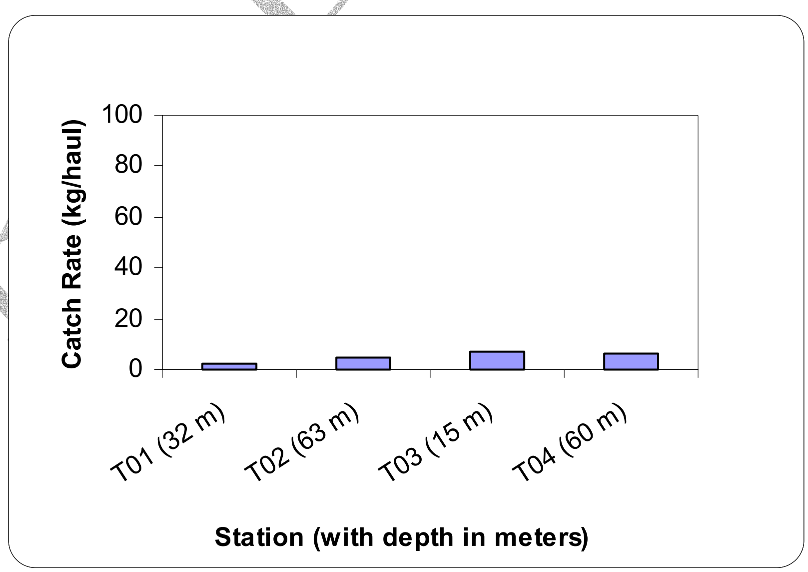


Figure 3.3-41 shows the variation among catch rates along the laterals while Figure 3.3-42 gives the variation of catch rates along the main line route. The data for species composition and catches along the main pipeline route and the laterals are presented in Appendix B.

Figure 3.3-41
Catch rates at indicated depth ranges along the laterals.

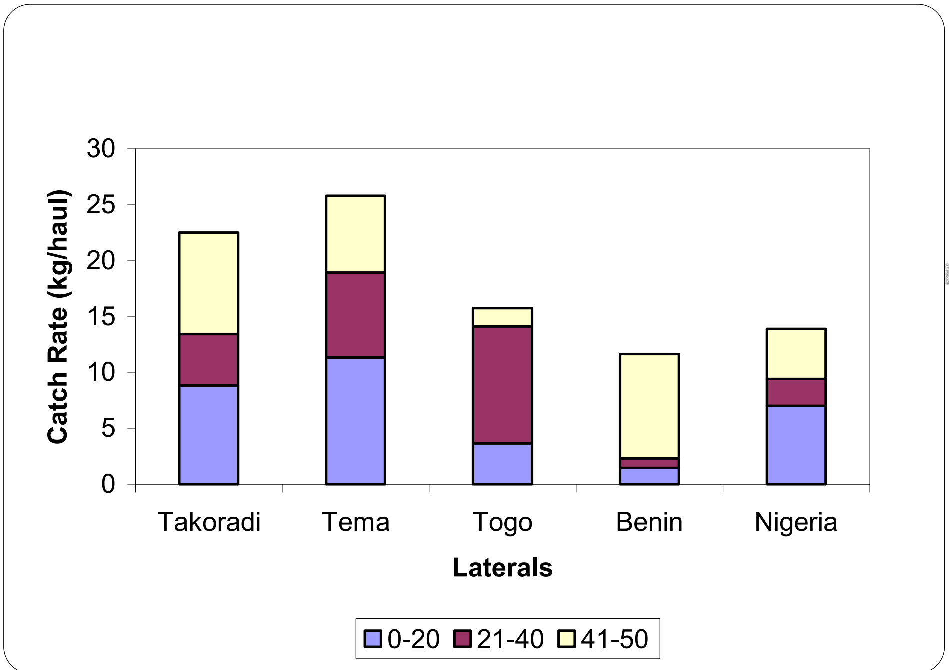
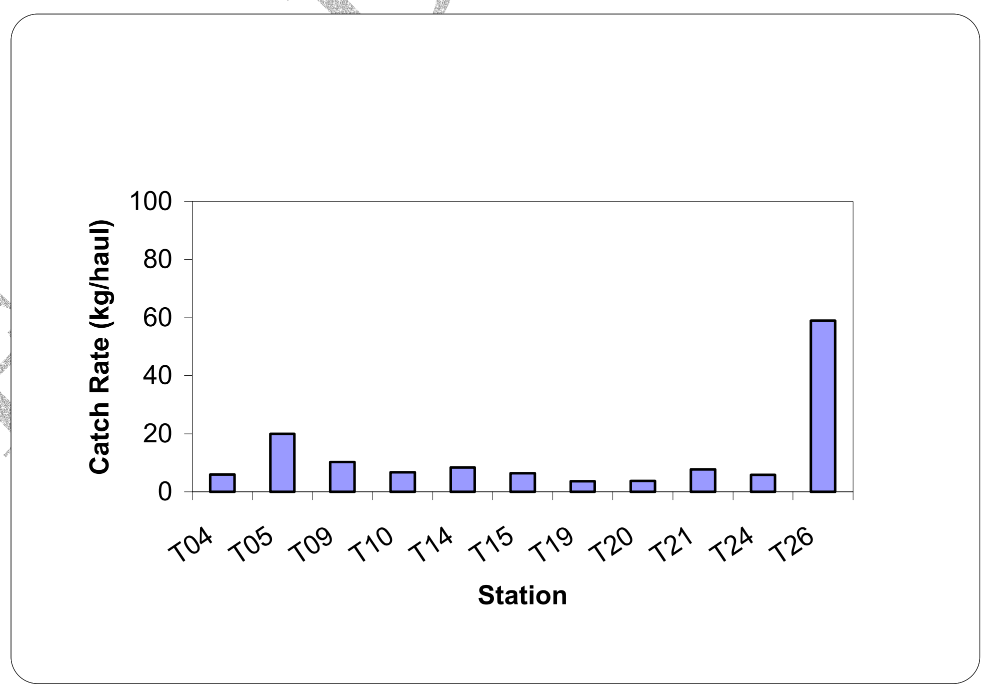


Figure 3.3-42
Catch rate of stations along the main pipeline route.



Ghana

A total of 115 different species belonging to 62 families were caught in Ghanaian waters during the survey (Appendix B). Of these, 16 were crustaceans, 4 molluscs, 4 invertebrates and 84 finfishes. The crustaceans were mainly the true crabs and bivalves, while the molluscs consisted of cuttlefish and squids.

Togo

A total of 46 different species belonging to 33 families were caught off Togo (Appendix B). This included 12 crustaceans, 3 molluscs, 8 invertebrates and 21 finfishes. The most abundant species were *Torpedo torpedo* (0.75kg/haul). *Echinocardium* spp. (0.65kg/haul), *Xyrichthys novacula* (0.35kg/haul) *Chlamys purpurata* (0.25kg/haul) *Syacium micrurum* (0.24kg/haul), *Raja miraletus* (0.22kg/haul) and *Sepia officinalis* (0.15kg/haul).

Benin

A total of 52 species belonging to 33 families were recorded off Benin during the survey (Appendix B). There were 8 crustaceans, 2 molluscs, 3 invertebrate species and 39 finfishes.

The most abundant species were jellyfish (2.08kg/haul), *Sepia officinalis* (0.71kg/haul. *Grammoplites gruveli* (0.67kg/haul), *Trigla lyra* (0.46kg/haul, *Citharus linguatula* (0.31kg/haul) and *Syacium micrurum* (0.10kg/haul).

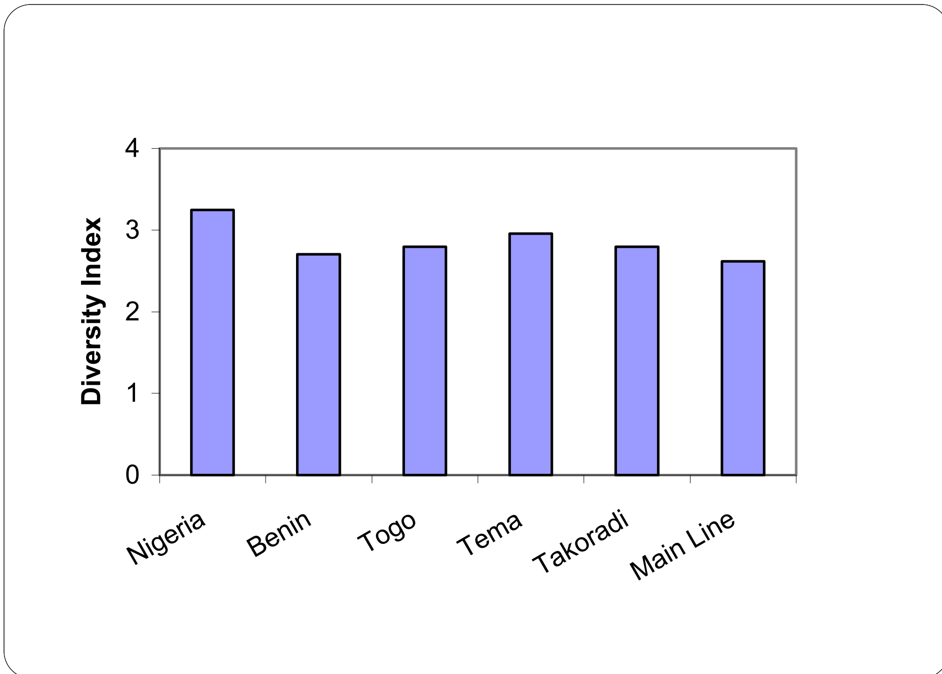
Nigeria

A total of 55 species belonging to 36 families were recorded in Nigeria waters during the survey (Appendix B). There were 10 crustaceans, 1 mollusc, 1 invertebrate and 43 finfishes. The most abundant species recorded were *Trigla lyra* (0.78kg/haul), *Pseudotolithus typus* (0.32kg/haul), *Galeoides decadactylus* (0.25kg/haul), *Portunus validus* (0.25 kg/haul), *Raja miraletus* (0.15kg/haul), *Callinectes pallidus* (0.15kg/haul), and *Grammophites gruveli* (0.14kg/haul).

<u>Species Diversity</u>

The calculated values of the Shannon Diversity Index on the laterals in each country and along the main pipeline are presented in Figure 3.3-43. The figure shows that species diversity was highest off the Nigeria lateral followed by the Tema the lateral. The species diversity was lowest along the Benin and Takoradi laterals.

Figure 3.3-43
Shannon Diversity Index of fisheries species along the laterals and main pipeline.



Discussion

Species composition

Ghana

The differences in species composition among stations may be attributed, in part, to differences in depths and nature of the seabed at the stations. In all cases, *Syacium micrurum, Grammoplites gruveli, Bothus podas africanus, Sepia officinalis, Pseudupeneus prayensis,* and *Trigla lyra* occurred at almost all the stations in Ghanaian waters.

Togo

The crustaceans mainly consisted of true crabs and bivalves, while the molluscs mainly consisted of cuttlefish and squid. Species composition also varied from station to station but *Sepia officinalis, Trigla lyra, Grammoplites gruveli, Citharus linguatula,* and *Syacium micrurum* occurred at almost all the stations.

Benin

The crustaceans consisted of true crabs and shrimps, while molluscs consisted of cuttlefish and squid. *Sepia officinalis, Grammoplites gruveli, Syacuim micrurum, Trigla lyra*, and *Citharus linguatula* occurred at almost all the stations.

Nigeria

The crustaceans consisted of mainly true crabs and shrimps, while molluscs were represented by cuttlefish. *Sepia officinalis, Grammoplites gruveli, Syacuim micrurum, Trigla lyra* and *Brachydeuterus auritus* occurred at almost all the stations.

<u>Catch Rates by Countries and Stations</u>

The composition and abundance of demersal fish fauna on the continental shelf and slope of the western Gulf of Guinea change with depth (William, 1968). Environmental factors are known to determine what demersal fish occur in an area in the Gulf of Guinea (Longhurst and Pauly, 1987; Koranteng, 2001) and these include the amount of organic mud in the bottom deposits, the occurrence of isolated patches of rocky bottom, the occurrence of an estuarine condition associated with lagoons and rivers, and the nature of the oceanic water masses lying over the continental shelf. As these factors vary from area to area, so do species compositions, catch rates, and diversity of species.

Ghana

The catch rates of the species varied with stations and depth. Generally, the lowest catch rates were recorded for stations with depths between 20 and 30m except for Station T26. The highest catch rates were recorded at stations in the 10 to 20m depth range, followed by stations at depths of 31 to 50m. Station T26 (15m) exhibited the highest catch rate off Ghana. This was due to the large catch of the bivalve, *Chlamys purpurata,* which contributed over 93 percent of the total catch at the station.

Togo

The catch rates varied with stations. Generally, the catch rates increased with increasing depths (i.e. 15 to 40m), followed by a decrease in deep waters (60m).

Benin

The catch rates also varied with depth. In general, the catch rate increased with increasing depth (15 to 45m), followed by a decrease at greater depths (50 to 54m). Thus, the most productive area occurred around the 45m depth contour. It must be noted, however, that the highest catch rate was related to high catch of jellyfish, which contributed over 50 percent of the total catch at the corresponding station.

Nigeria

Catch rates varied with station and depths. The catch rates decreased from shallow waters (15m) to inshore waters (32m), followed by an increase in deep water (60 to 63m). Thus the most abundant area was the shallow waters.

Catch rates along laterals

Generally, the catch rates were highest along the laterals off Ghana (Tema and Takoradi), followed by Togo (Lome), Nigeria (Lagos) and Benin (Cotonou). Thus, the abundance of fish species along the laterals off Ghana was the highest.

For each lateral, catch rates varied with depth. Off the Takoradi and Cotonou laterals, the highest catch rates were recorded in deeper waters (i.e. 41 to 50m), while that off Tema and Lagos were recorded in shallow waters (15 to 20m). The highest catch rate off Lome was recorded in the mid-range of 21 to 40m depth.

Species Diversity

All the calculated values of the Shannon Diversity Index fall within the acceptable range of 1 to 3.5 (Magurran, 1991). The high species diversity off Nigeria is expected given the influence of the Niger delta on species abundance in shallow waters.

Since a diversity index can be used to indicate the general 'health' of the ecosystem, these values may be considered as baseline for the purposes of monitoring possible changes in the project area.

Conclusion

Species composition varied from country to country with the highest number of species recorded in Ghanaian waters. The species composition also varied among laterals, with the highest number of species recorded off Tema, Ghana. However, the Shannon Diversity Index was highest off Lagos. Mean catch rates also varied according to depth. Highest catch rates were recorded off Ghana, whereas in Nigeria the catch rates were highest in shallow waters. In Togo and Benin, the highest catch rates were in inshore waters.

In total, about 110 fish and invertebrate species from 60 families were represented in the fish trawl survey. Nine fish species were found to be dominant out of the total number of species in terms of numbers and frequency of occurrence at all the 26 stations sampled. Figures 3.3-44 to 3.3-48 show these dominant species, ranked according to their presence/absence in trawls at the various stations along the entire pipeline route. *Sepia officinalis* emerged the most dominant and *Torpedo torpedo*, the least dominant fish species for the entire pipeline route (Figure 3.3-44). Similarly, *Sepia officinalis* was the most dominant fish species of Ghana and *T. torpedo,* the least dominant (Figure 3.3-45).

Figure 3.3-44
Occurrence of common species along the entire pipeline route.

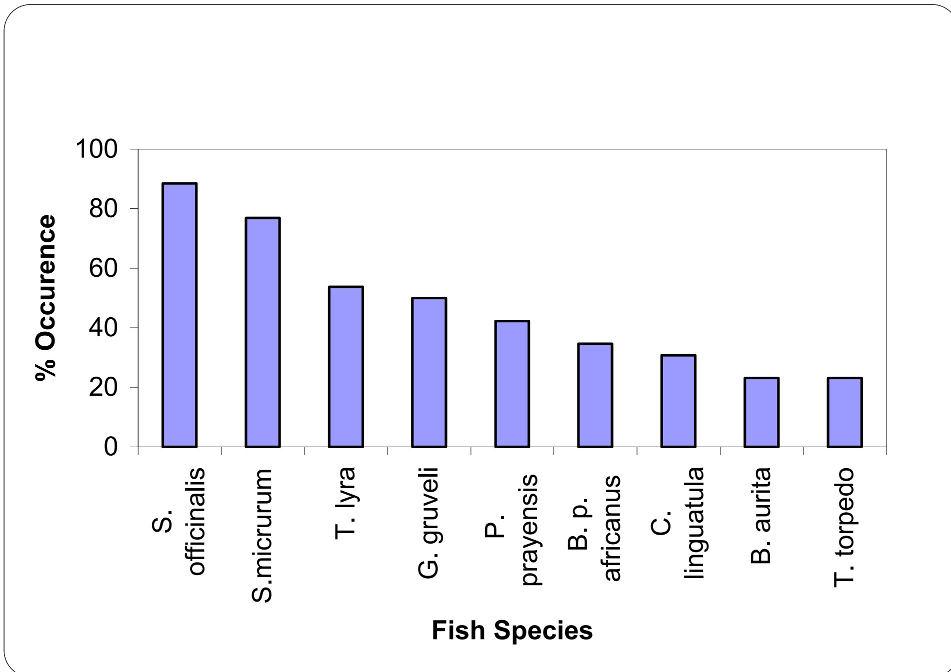
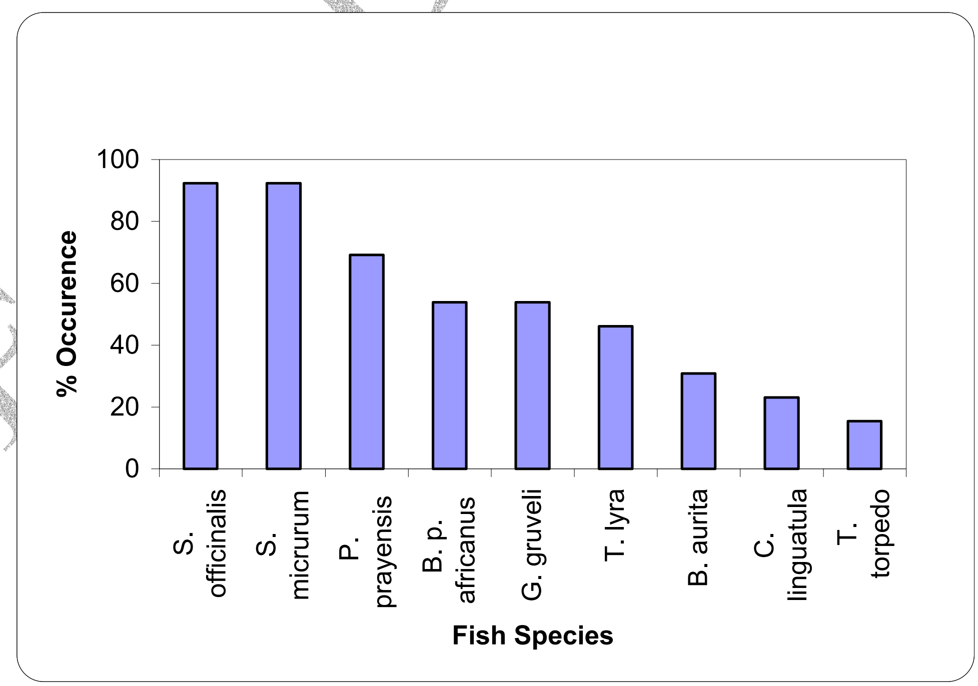


Figure 3.3-45
Occurrence of common species in waters offshore of Ghana.



Five out of the nine dominant fish species found in the entire region were represented offshore Togo. *S. officinalis* was the most dominant species, and *T. torpedo* was the least dominant species (Figure 3.3-46), a pattern similar to that of the entire pipeline.

S. officinalis was again present in most trawl hauls offshore Benin but, unlike the main pipeline, *Pseudopeneus prayensis* was the least dominant (Figure 3.3-47). *Brachydeuterus aurita* was however, not represented. The trawl haul samples offshore Nigeria were different from that of the main pipeline in having *G. gruveli* as the most dominant species and *P. prayensis* the least dominant.

Figure 3.3-46
Occurrence of common species in offshore Togo waters.

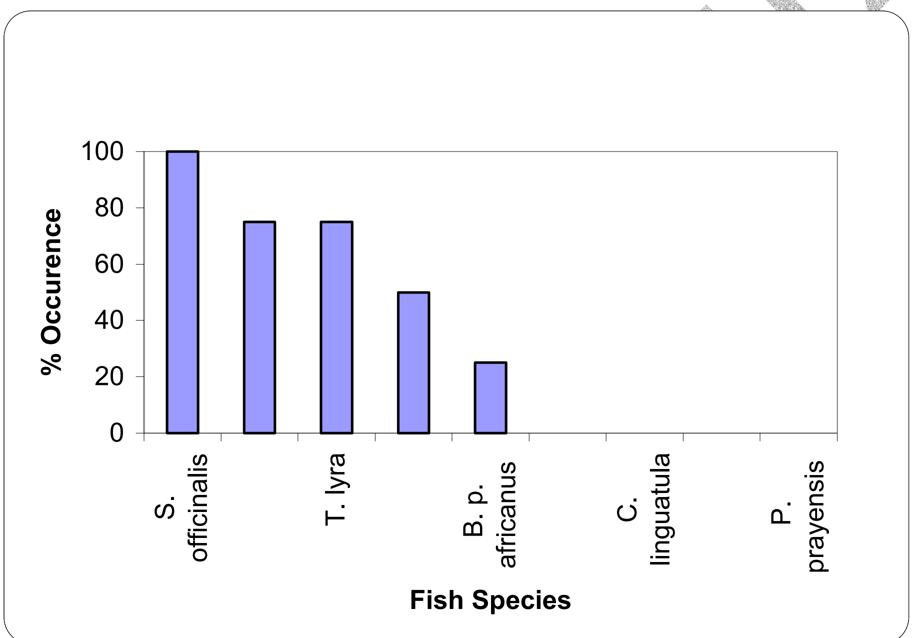


Figure 3.3-47
Occurrence of common species in offshore Benin waters.

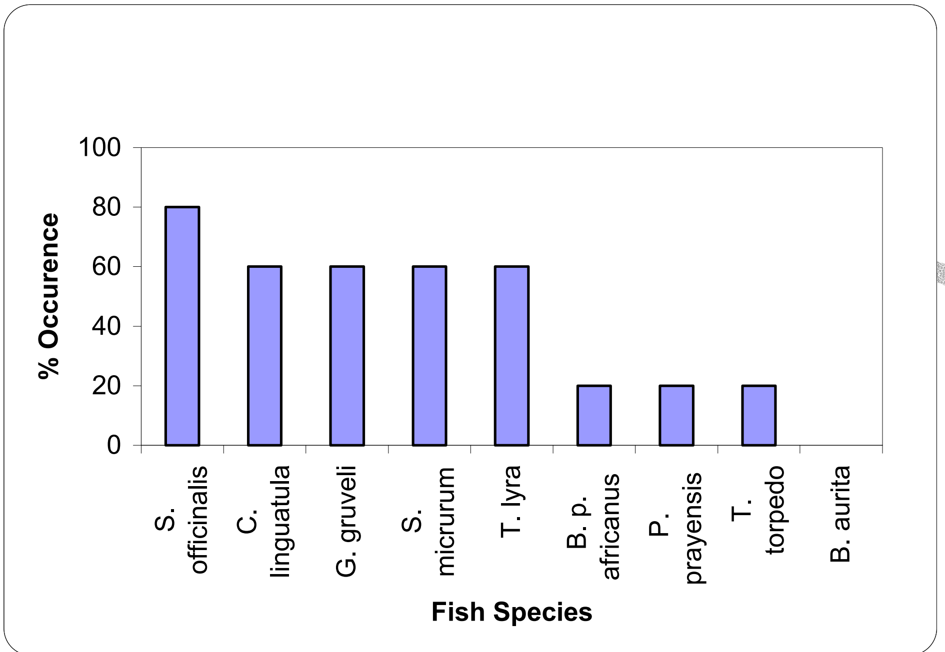
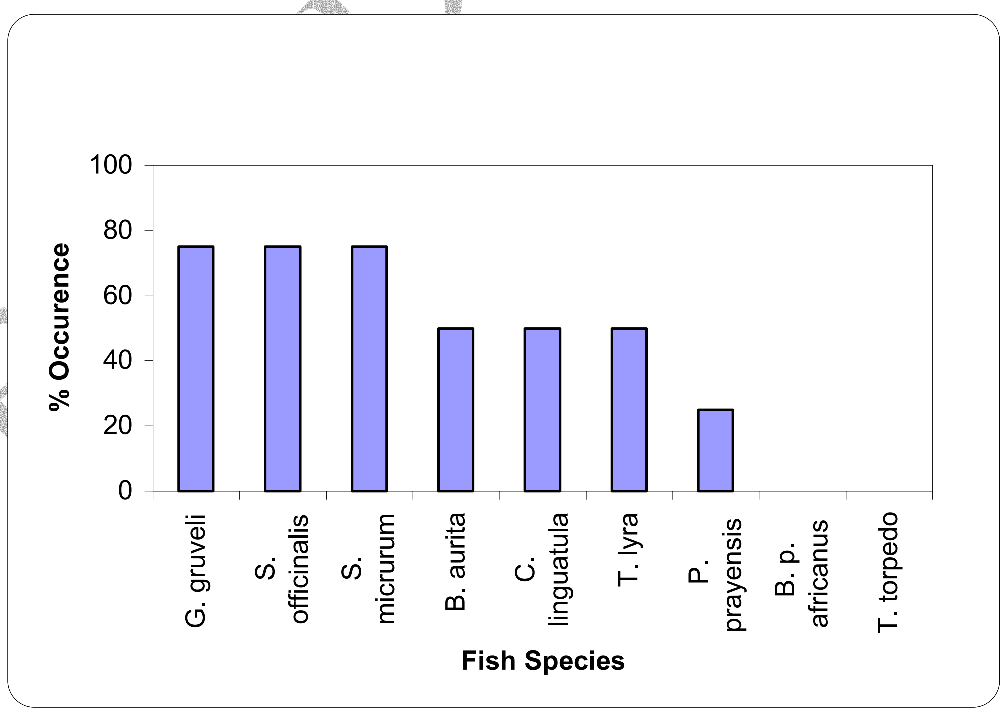


Figure 3.3-48
Occurrence of common species in offshore Nigerian waters.



It is suggested from these results that, at the regional level, five fish species, namely: *S. officinalis, S. micrurum, G. gruveli, T. lyra,* and *P. prayensis* be used as bio-indicators for future monitoring of potential environmental impacts, though country-specific fish species must also be considered.

3.3.4 Marine Birds, Mammals, and Reptiles

During the 1st season fisheries survey, the survey crew recorded several sightings of black terns (*Chlidonias niger*) and royal terns (*Sterna maxima*) as illustrated in Figures 3.3-49 and 3.3-50. (Note: the photographs shown are representative of the species and were not taken during the survey).

Figure 3.3-49
Black Tern

Figure 3.3-50
Royal Tern

On 10 December 2003, at 0745, two humpback whales (*Megaptera novaeangliae*) and a calf were sighted approximately 0.5 miles off the bow of the R/V *GeoExplorer*™ at N5° 41.78’ E0° 53.3216’. See Figures 3.3-51 and 3.3-52 for representative photographs of the species (not taken by survey personnel).

Figure 3.3-51
Humpback Whale

Figure 3.3-52
Humpback Whale Breaching

Table 3.3-37
Marine mammal sightings during the October 2002 geophysical survey.

Date	Number of Individuals	Species
22 October 2002	2	Unidentified Whale
23 October 2002	1	Unidentified Whale
28 October 2002	2	Unidentified Whale

No marine reptiles were observed during the survey.

3.4 METEOROLOGICAL CONDITIONS AND OCEAN CURRENTS

Wind speed and direction, wave height, current direction, and speed were recorded in the GeoExplorer™ bridge log. Water depths at the locations sampled ranged from 15 to approximately 77m. The prevailing wind direction during the survey was from the southwest with wind speeds ranging from zero to approximately 20 knots. Wave heights ranged from zero to approximately 1.3m with the prevailing current from the southwest at 0.5 to 2 knots. Extracts from the bridge log detailing these conditions are listed in Table 3.4-1.

Table 3.4-1
Meteorological and Oceanographic Data from the GeoExplorer™ Bridge Log

Date	Station Number	Time In	Time Out	Wind Speed	Wind Direction	Wave Ht	Water Depth(m)	Doppler Current Direction/Knots
12/13/2002	N01E	7:13	7:18	5-10	SSW	2-3	15.6	S 0.5
12/13/2002	N01C	7:30	8:00	5-10	SSW	2-3	15.6	S 0.5
12/13/2002	N01W	6:42	7:00				15.5	
12/13/2002	N02C	5:12	5:48				38.4	
12/13/2002	N02E	4:59	5:04				38.3	
12/13/2002	N02W	4:40	4:47				38.9	
12/13/2002	N03C	2:54	3:31				76.7	
12/13/2002	N03E	2:39	2:45				77.1	
12/13/2002	N03W	2:18	2:25				74.6	
12/13/2002	N04C	0:48	1:43				63.5	
12/13/2002	N04N	0:34	0:40				59	
12/13/2002	N04S	0:12	0:20				67.5	
12/12/2002	N06C	21:23	22:19				68.5	
12/12/2002	N06N	20:48	20:55				64.5	
12/12/2002	N06S	21:10	21:16				73	
12/12/2002	B01C	18:58	19:34				55	
12/12/2002	B01N	18:35	18:41				50.5	
12/12/2002	B01S	18:17	18:24				58.7	
12/12/2002	B02C	14:46	15:24	12	WSW	2-3	36.5	N 0.5
12/12/2002	B02N	14:34	14:39	12	WSW	2-3	31.2	W 0.5
12/12/2002	B02S	14:10	14:22	10	WSW	2-3	42	W 0.5
12/12/2002	B03C	12:10	12:54	10	WSW	2-3	24.2	W 0.5
12/12/2002	B03N			10	WSW	2-3	22	W 0.5

Date	Station Number	Time In	Time Out	Wind Speed	Wind Direction	Wave Ht	Water Depth(m)	Doppler Current Direction/Knots
12/12/2002	B03S			10-12	WSW	2++	26.9	W 0.5
12/12/2002	B04C	5:02	5:33	12-15	WSW	2-4	39.2	SW 0.5
12/12/2002	B04W	4:49	4:55	10-15	WSW	2-4		SW 0.5
12/12/2002	B04E	4:32	4:38	15	WSW	2-4		SW 0.5
12/12/2005	B05C	6:52	7:24	10-12	WSW	2-3	20	SW 0.5
12/12/2002	B05W	6:41	6:46	12-15	WSW	2-3	19.9	SW 1.0
12/12/2002	B05E	6:23	6:28	12-15	WSW	2-3	20.3	SW 1.0
12/12/2002	B06C	8:18	8:45	10-12	WSW	2-3	15.4	SW 0.5
12/12/2002	B06W	8:06	8:10	10-12	WSW	2-3	18.3	SW 0.5
12/12/2002	B06E	7:49	7:54	10-12	WSW	2-3	16.1	SW 0.5
12/12/2002	B07C	2:51	3:21	15	WSW	2-4	46.9	SW 0.5
12/12/2002	B07N	2:36	2:44	15	SW	2-4	36.7	SW 0.5
12/12/2002	B07S	2:10	2:20	15	SW	2-4	51.3	SW 0.5
12/11/2002	B08S	21:03	21:59	10	SSW	2-3	61.7	SSW 0.5
12/11/2002	B08N	20:47	20:54	10	SSW	2-3	57	SSW 0.5
12/11/2002	B08S	20:29	20:36	10	SSW	2-3	66.7	SSW 0.5
12/11/2002	B09C	18:50	19:35	10	SSW	2-3	57.2	SSW 0.5
12/11/2002	B09N	18:33	18:40	10	SSW	2-3	54	SSW 0.5
12/11/2002	B09S	18:16	18:22	10	SSW	2-3	61	0.5
12/11/2002	B10C	16:35	17:17	10	SSW	2-4	61	0.5
12/11/2002	B10N	16:21	16:27	10	SSW	2-3	57	0.5
12/11/2002	B10S	15:55	16:08	12	SSW	2-3	64	0.5
12/11/2002	T01C	14:45	15:20	10	SW	2-3	50	0.5
12/11/2002	T01N	14:31	14:37	10	SW	2-3	50.8	0.5
12/11/2002	T01S	13:50	14:17	10	SW	2-3	55.6	0.5
12/11/2002	T02C			15	SW	2-3	49.6	0.5

Date	Station Number	Time In	Time Out	Wind Speed	Wind Direction	Wave Ht	Water Depth(m)	Doppler Current Direction/Knots
12/11/2002	T02N			12-15	SW	2-3	47.8	0.5
12/11/2002	T02S			12-15	SW	2-3	52.2	0.5
12/10/2002	T03C	22:34	0:20	10-15	SSW	2-3	48.3	NIL
12/10/2002	T03N	23:20	23:26	10-15	SSW	2	46.7	NIL
12/10/2002	T03S	21:03	21:08	10-15	SSW	2	50.6	NIL
12/10/2002	T04C	18:59	20:04	8-10	SSW	2-3	60	NIL
12/10/2002	T04S	18:19	18:26	8-10	SSW	2-3	68.5	NIL
12/10/2002	T04N	18:39	18:50	8-10	SSW	2-3	47	NIL
12/10/2002	T05C	21:52	22:35	10-12	SSW	2-3	67.2	NIL
12/10/2002	T05E	21:40	21:46	8-10	SSW	2-3	66	NIL
12/10/2002	T05W	21:20	21:26	8-10	SSW	2-3	68	NIL
12/11/2002	T06C	5:41	6:12	8-10	SW	2-3	33.6	0.5
12/11/2002	T06W	5:07	5:16				34	
12/11/2002	T06E	5:26	5:31	10	SW	2-3		0.5
12/11/2002	T07C	7:31	8:00	8-10	SW	2		NIL
11/12/2002	T07E	7:16	7:22	8-10	SW	2		NIL
12/11/2002	T07W	6:58	7:05	8-10	SW	2	15.5	NIL
12/10/2002	T08C	17:24	18:06	8-10	SW	2-3	62.5	NIL
12/10/2002	T08N	17:10	17:16	10-12	SW	2-3	52.5	SW 0.5
12/10/2002	T08S	16:54	16:59	8-10	SSW	2-3	73	NIL
12/10/2002	G01C	14:18	15:02	10-12	SW	2-3	47.5	SW 1.0
12/10/2002	G01N	14:01	14:08	10-12	SW	2-3	46.5	SW 1.0
12/10/2002	G01S	13:42	13:50	10	SW	2-3	49	SW 1.0
12/10/2002	G02C		12:47	10	SW	2-3	20.3	SW 2.0
12/10/2002	G02N			10	SW	2-3	18.4	SW 1.5
12/10/2002	G02S			10-15	SW	2-3	22.3	SW 2.0

Date	Station Number	Time In	Time Out	Wind Speed	Wind Direction	Wave Ht	Water Depth(m)	Doppler Current Direction/Knots
12/10/2002	G03C			10-15	SSW	2-3	15.5	SW 1.5
12/10/2002	G03N			10-15	SSW	2-3	15.4	SW 1.5
12/10/2002	G03S			10-15	SW	2-3	16.6	SW 2.0
12/10/2002	G04C			12-15	WSW	2-4	24.5	SW 0.5
12/10/2002	G04S			10-15	WSW	2-4	25	SW 0.5
12/10/2002	G04N			12-15	WSW	2-4	23.5	SW 0.5
12/10/2002	G05C			10-15	WSW	2-4	41.4	SW 0.5
12/10/2002	G05S			10-15	WSW	2-4	43.2	SW 0.5
12/10/2002	G05N			10-15	WSW	2-4	38.6	SW 0.5
12/9/2002	G06N	5:22	5:45	15	SW	2-4	59	SW 0.5
12/9/2002	G06C	4:43	5:15	15	SW	2-4	67	SW 0.5
12/9/2002	G06S	4:16	4:34	15	SW	2-4	76	SW 0.5
12/9/2002	G07N	2:45	3:04	15	SW	2-4	53	SW 0.5
12/9/2002	G07C	2:00	2:37	10-15	SW	2-4	57	SW 0.5
12/9/2002	G07S	1:31	1:51	10-15	SW	2-4	62	SW 0.5
12/9/2002	G08N	0:04		15-20	SW	2-4	47.5	SW 1.0
12/8/2002	G08C	23:12	23:55	15-20	SW	2-4	51.5	SW 1.0
12/8/2002	G08S	22:45	23:04	15-18	SW	2-3	53	SW 1.0
12/9/2002	G09C	21:45	22:55	10	SW	2-4	64.4	SW 0.5
12/9/2002	G09E	23:10		10-15	SW	2-4	64.3	SW 1.0
12/9/2002	G09W	21:03	21:33	10-12	SW	2-4	64.6	SW 0.5
12/9/2002	G10C	14:38	15:16	14	SW	2-4	32.9	SW 0.5
12/9/2002	G10E	15:25		12	SW	2-4	32.5	SW 0.5
12/9/2002	G10W	14:11	14:26	14	SW	2-4	33.8	SW 0.5
12/9/2003	G11C	12:40	13:17	10-12	SW	2-4	15	SW 0.5
12/9/2002	G11E	12:12	12:29	10-12	SW	2-4	15.8	SW 1.0

Date	Station Number	Time In	Time Out	Wind Speed	Wind Direction	Wave Ht	Water Depth(m)	Doppler Current Direction/Knots
12/9/2002	G11W	13:24	13:36	12	SW	2-4	16.7	SW 0.5
12/8/2002	G12C	20:26	21:17	15-18	SW	2-3	50.5	SW 1.0
12/8/2002	G12N	19:58	20:15	15-18	SW	2-3	49	SW 1.0
12/8/2002	G12S	21:33	22:00	15-18	SW	2-3	51	SW 1.0
12/8/2003	G13C	16:02	16:40	15	SW	3-5	62	SW 1.0
12/8/2002	G13N	16:50	17:07	15-18	SW	2-4	59	SW 1.0
12/8/2002	G13S	15:33	15:55	14	SW	2-3	67	SW 1.0
12/8/2002	G14C	13:19	13:59	10-15	SW	2-3	52.5	SW 1.0
12/8/2002	G14N	14:08	14:27	14	SW	2-3	50.3	SW 1.0
12/8/2002	G14S		13:12	10	W	2-3	54	WSW 1.0
12/8/2002	G15C			7-12	W	2-3	47.9	WSW 1.0
12/8/2002	G15N			5-10	W	2-3	45.6	WSW 1.0
12/8/2002	G15S			7-12	W	2-3	48.9	SW 1.0
12/8/2002	G16C	6:03	6:32	5-10	WNW	2-3	41.7	SW 0.5
12/8/2002	G16N	6:43	7:00	5-10	WNW	2-3	40	SW 0.5
12/8/2002	G16S	5:31	5:53	10	WNW	2-3	43.2	SW 0.5
12/8/2002	G17C	2:49	3:18	15	WSW	2-4	29.7	SW 0.5
12/8/2002	G17N	2:26	2:41	15	WSW	2-4	29.5	SW 0.5
12/8/2002	G17S	3:28	3:44	15	WSW	2-4	31	SW 0.5
12/7/2002	G18C	23:35	0:12	15-20	WSW	2-4	29.5	NIL
12/8/2002	G18N	0:24	0:44	15-20	WSW	2-4	29.7	SW 0.5
12/7/2002	G18S	23:11	23:25	15-20	SW	2-3	29.5	NIL
12/7/2002	G19C	21:38	22:07	15-20	SW	2-3	30	SW 0.5
12/7/2002	G19N	21:10	21:28	15-20	SW	2-3	29.5	NIL
12/7/2002	G19S	22:19	22:34	15-20	SW	2-3	30	NIL
12/7/2002	G20C	17:59	18:52	15-20	SW	2-4	30.8	SW 0.5

Date	Station Number	Time In	Time Out	Wind Speed	Wind Direction	Wave Ht	Water Depth(m)	Doppler Current Direction/Knots
12/7/2002	G20S	16:49	17:43	15-18	SW	3-5	31.8	SW 0.5
12/7/2002	G20N	19:05	19:20	15-20		2-4		NIL
12/7/2002	G21C	3:18	4:02	10	SW	SWELL	30.8	NIL
12/7/2002	G21S	15:13	15:32	15	SW	3-5	31	SW 0.5
12/7/2002	G21N	15:22	15:56	16	SW	2-4		SW 0.5
12/7/2002	G22C	0:06		5-10	W	MILD	29	
12/7/2002	G22N	1:53		5-10	W	MILD		LIGHT
12/7/2002	G22S	1:24		5-10	W	MILD	31	LIGHT
12/6/2002	G23C	6:30		2-5	WNW	SSW 1'	30	W 0.5
12/6/2002	G23N	10:27		2-5	WNW	SSW 1'	27.8	W 0.5
12/6/2003	G23S	11:33		5	WSW	SSW 1-2'	29	0-0
12/6/2002	G24C	21:45	22:43	10-12	W	SW 1'	33	W 0.5
12/6/2002	G24W	22:52	23:07	8-10	W	SW 1'	32	
12/6/2002	G24E	23:20	23:40	5-8	W	LIGHTCHOP	34	
12/6/2002	G24C	18:10	19:00	15-18	SW	SSW 1'	22	
12/6/2002	G25E	19:15	19:43	12-15	SW	SSW 1'	22	
12/6/2002	G25W	20:05	20:40	12-15	SW	SSW 1'	22	
12/6/2002	G26C	1:37	3:42	15	SW	LIGHTCHOP	16	SW 0.5
12/6/2002	G26E			15	SW	LIGHTCHOP	15	SW 0.5
12/6/2002	G26W	16:54	17:15	10-12	SW	LIGHTCHOP	15	SW 0.5

CHAPTER 4
ONSHORE RESULTS – GHANA

The R&M sampling locations for Tema and Takoradi are shown in Figures 4.0-1 and 4.0-2, respectively.

4.1 VEGETATION

4.1.1 The Coastal Strand Vegetation of Tema

The coastal strand of the Tema route is about 40m inland from the beach. It has been greatly disturbed by human activities (mainly farming and shingles collection) to the extent that the typical coastal strand community, dominated by plants such as *Ipomoea pes-caprae, Canavalia rosea, Sporobolus virginicus, Remirea maritima, Cyperus maritimus,* and *Sesuvium portulacastrum*, no longer exists. In its place is a farm re-growth composed of okra (*Abelmoschus esculentus*), grasses such as *Cenchrus echinatus,* and *Dactyloctenium aegyptium*, and forbs such as *Oldenlandia corymbosa, Boerhavia diffusa,* and *Stachytarpheta indica*. In general, the vegetation is less than a meter high in most places. A species list of this area is presented in Appendix D.

4.1.2 The Inland Coastal Scrub and Grassland Vegetation of Tema

The coastal scrub vegetation of the Tema route has also been greatly modified by farming. The typical vegetation (characterized by species such as *Dichrostachys cinerea, Zanthoxylum xanthoxyloides, Carissa edulis, Waltheria indica, Elaeophorbia drupifera, Heteropogon contortus, Vetiveria* sp., *Ctenium* spp., *Andropogon* spp., and *Heteropogon contortus*) has been replaced with a farm-regrowth composed of cassava (*Manihot esculenta*), pepper (*Capsicum* spp.), an admixture of grasses (*Panicum maximum, Cenchrus echinatus,* and *Paspalum orbiculare*) and shrublets, which are herbs with woody bases that mature to less than 1m in height (*Indigofera spicata, Croton lobatus,* and *Byrsocarpus coccineus*). A detailed list of the species encountered in this zone can be found in Appendix D.

4.1.3 The Mangrove Swamp of Tema

The Gao lagoon has a narrow strip (about 4m wide) of mangrove composed of mainly *Avicennia germinans* and *Rhizophora mangle*. *Avicennia germinans* constitutes about 80 percent of the mangrove flora. Some of the mangrove-associated species in the swamp are *Sesuvium portulacastrum* and *Paspalum vaginatum*.

4.1.4 The Coastal Strand Vegetation of Aboadze/Takoradi

The route at Aboadze passes through typical coastal strand vegetation (with the exception of portions that have been converted into coconut, *Cocos nucifera*, plantations). The *Cyperus-Ipomoea* association (characterized by *Cyperus maritimus, Ipomoea pes-caprae, Canavalia rosea,* and *Remirea maritima*) is clearly evident here (Appendix D).

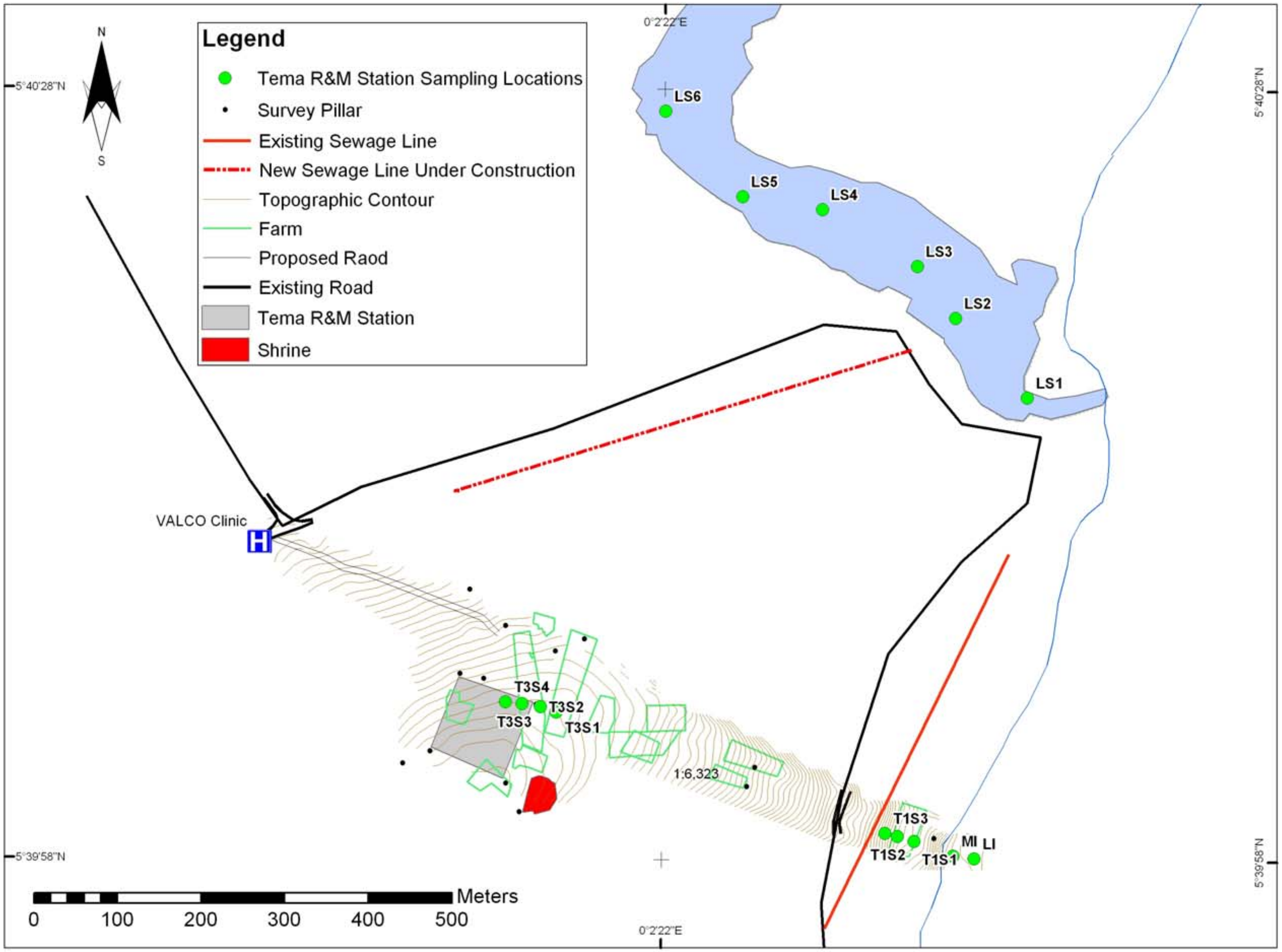


Figure 4.0-1 - Tema R&MStation Sampling Locations

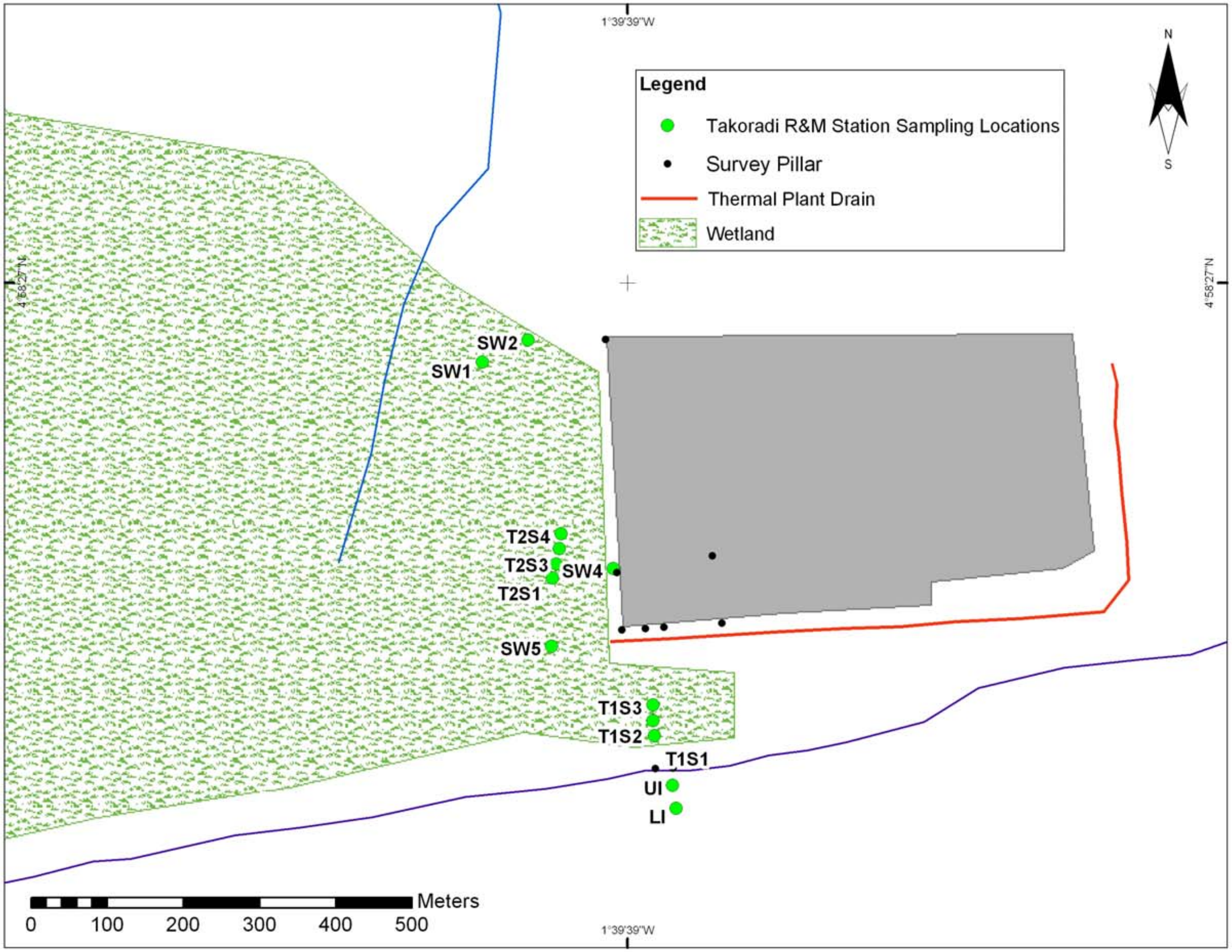


Figure 4.0-2 - Takoradi R&M Station Sampling Locations

4.1.5 The Coastal Scrub Vegetation of Takoradi/Aboadze

The coastal scrub vegetation of the pipeline route at Aboadze has been disturbed by the construction of the thermal generating plant. Rubble from the construction site has made the soil unsuitable for the development of typical coastal scrub vegetation. The vegetation is now composed of grasses (*Pennisetum purpureum, Panicum maximum, Imperata cylindrica,* and *Paspalum conjugata*), low growing shrublets and shrubs (*Abutilon mauritianum, Urena lobata, Croton lobatus, Lantana camara,* and *Chromolaena odorata*). A complete list of the species encountered is presented in Appendix D.

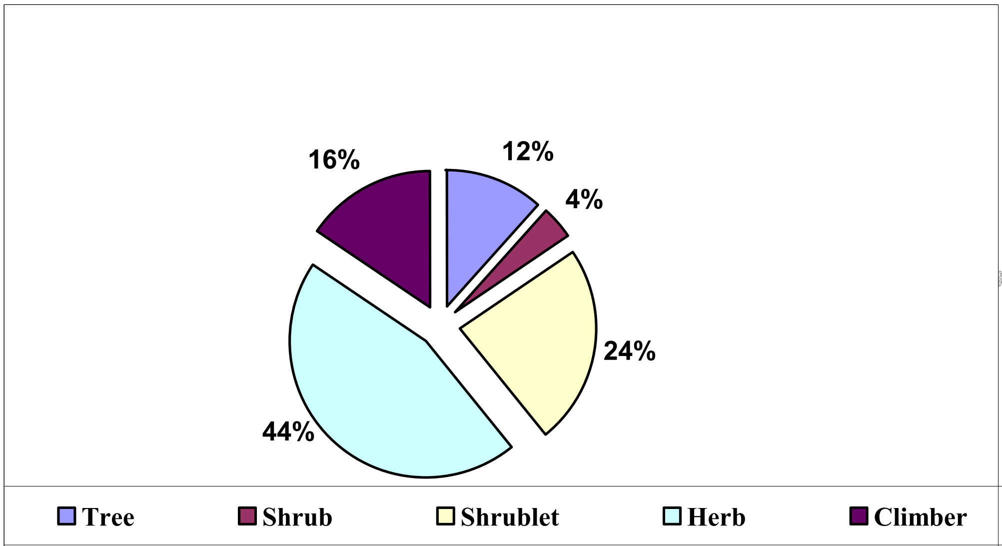
4.1.6 The Freshwater Swamp at Aboadze

The freshwater swamp occupies a depression between the strand vegetation and the scrub or thicket vegetation. It is dominated by *Cyperus articulatus*. The swamp serves as a receptacle for effluents from the thermal generating plant. Some of the species associated with the *C. articulatus* are *Imperata cylindrica*, *Sporobolus virginicus,* and *Ipomoea aquatica.*

4.1.7 Species Composition and Diversity of the Vegetation of the Pipeline Route at Tema

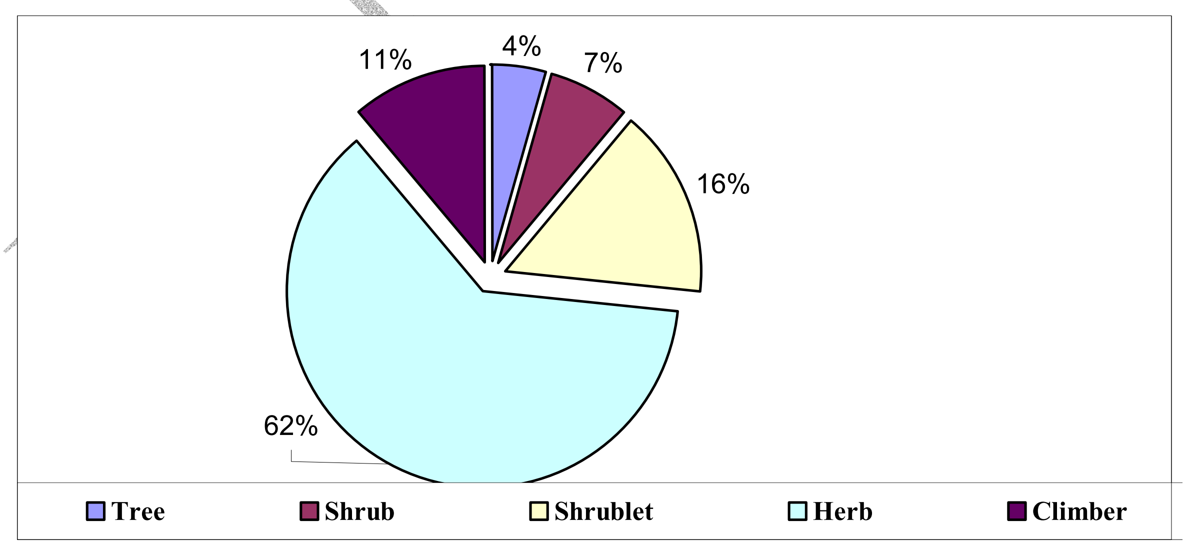
Appendix D shows that 51 species belonging to 49 genera in 29 families were encountered in the coastal strand vegetation at Tema. The Papilionaceae (6), Euphorbiaceae (6) and Graminae (5) are the largest families. The life form composition of the study area is shown in Figure 4.1–1 below. It indicates a clear dominance of the herb and shrub life forms. An intermediate Shannon Diversity Index, H = 2.105 was obtained for the herbs and shrublets. It was not possible to calculate the diversity index for the shrubs and trees since none fell in the areas sampled.

Figure 4.1-1
Life Form Composition of Coastal Strand Vegetation of Tema



With respect to the coastal scrub and grassland vegetation at Tema, 45 species belonging to 41 genera in 23 families were recorded (Appendix D). Again, the largest families were the Papilionaceae (5), Euphorbiaceae (5), and Graminae (11). The life form composition shown in Figure 4.1-2 depicts a dominance of the herb life form (62 percent). The Shannon Diversity Index for herbs and shrublets was again intermediate, H = 2.526.

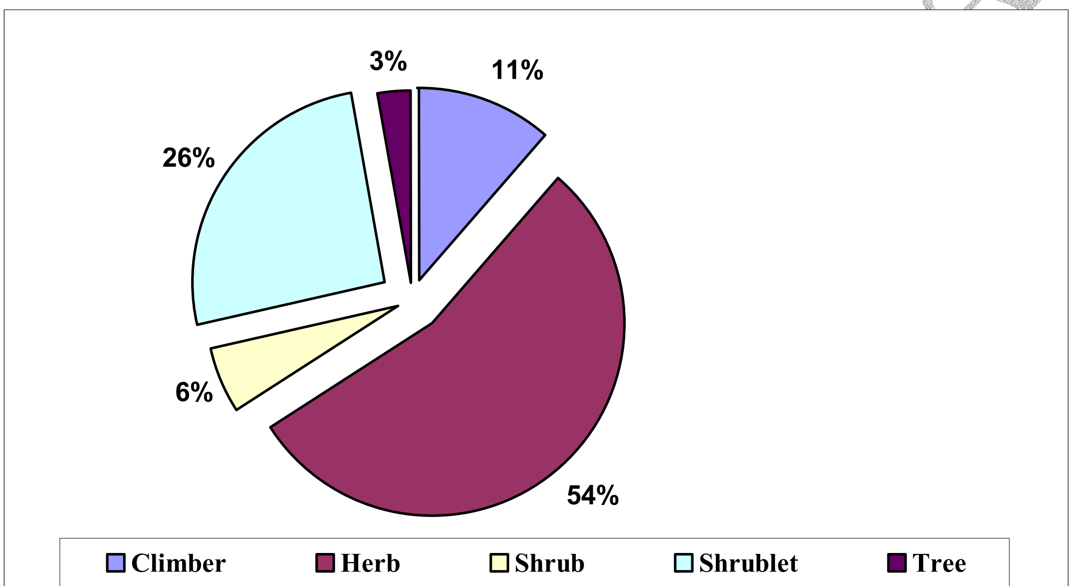
Figure 4.1-2
Life Form Composition of the Coastal Scrub and Grassland Vegetation of Tema



4.1.8 Species Composition and Diversity of the Pipeline Route at Aboadze

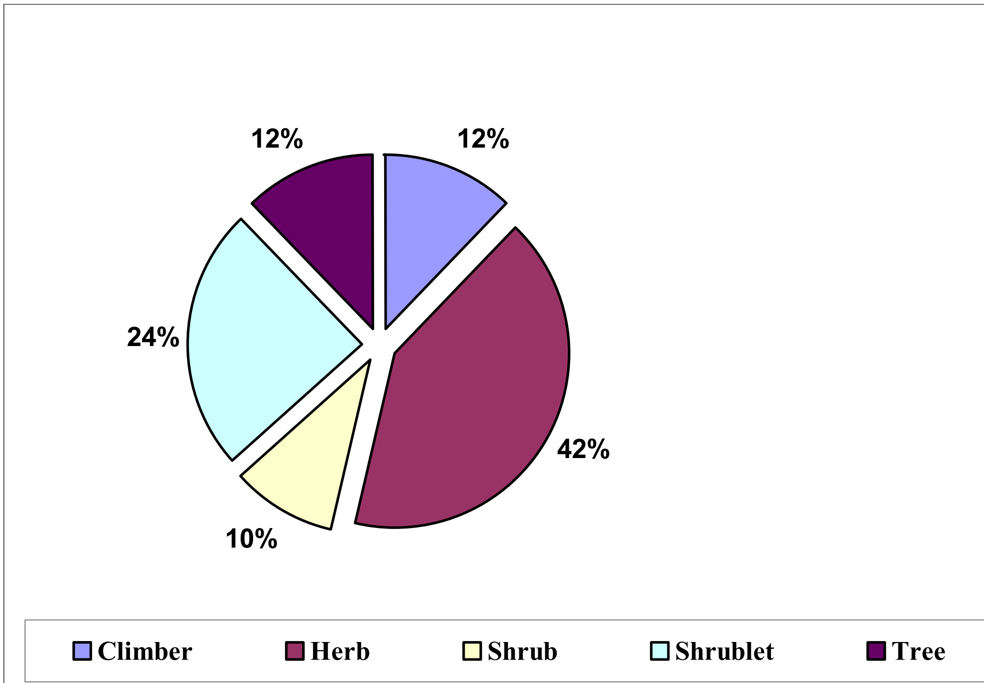
The species composition of the coastal strand vegetation at Aboadze (Appendix D) indicates a total of 35 species in 32 genera belonging to 16 families were recorded, with the dominant ones being the Graminae (7) and the Papilionaceae (7). Figure 4.1-3 shows that the herb life form is dominant, constituting about 53 percent of the records. The Shannon Diversity Index for the herbs and shrublets was H = 1.956.

Figure 4.1-3
Life Form Composition of Coastal Strand Vegetation of Takoradi/Aboadze



The species composition of the coastal scrub and grassland vegetation at Aboadze (Appendix D) shows a total of 41 species in 38 genera belonging to 20 families. The life form composition, (Figure 4.1–4), again shows a dominance of the herb and shrublet life forms (about 42 percent and 24 percent respectively). The Shannon Diversity Index (H) obtained for the herbs and shrublets was 1.664.

Figure 4.1-4
Life Form Composition of Coastal Scrub and Grassland Vegetation of Takoradi/Aboadze



4.1.9 Discussion

The results presented above indicate that the dry season vegetation of the WAGP route at Tema is more diverse than that of the Aboadze route. This is largely because seasonal cropping of the Tema route has created conditions favorable to the growth of herbs and shrubs. The dumping of construction site wastes in the study area at Aboadze accounts for the rather low diversity of the Coastal Scrub vegetation there.

The range of diversity indices obtained (1.664 – 2.526) fall within the expected range of 1.5 to 3.5 (Kent and Coker, 1992) for Shannon's Diversity Index. The flora encountered in both proposed R&M locations (Tema and Aboadze) during the dry season sampling session occur commonly in Ghana and none appear to be on the national or international list of endangered plant species.

4.2 SOIL CHARACTERIZATION

4.2.1 Physical

Results obtained from the physical analysis of onshore soil samples collected from the Tema location are presented in Appendix D.

Soil reaction (pH) from soils taken along Transect A at Tema generally ranged from strongly acidic (5.19-5.49) to very strongly acidic (pH 4.23). Levels of pH along Transect B, further inland, were comparatively lower than those recorded along Transect A. The pH ranged from strongly acidic (pH 6.14 to 5.7) to slightly acidic (pH 6.12 to 6.14).

At the Takoradi/Aboadze locations, the pH levels recorded on the point samples along Transect C ranged from 5.2 to 6.8. This falls within the range of strongly acidic to slightly acidic soils. On Transect D (further away from the sea), the soil pH level ranged from slightly acidic (pH 5.43 to 6.12) to neutral (pH 6.73 to 7.39).

Analysis of the soil particle composition shows that the soils at the Tema location on both Transects A and B were composed largely of sand, ranging between 70 and 85 percent, along all the transect points. This was followed by clay with a percent range of approximately 10 to 20 percent, while silt constituted less than 10 percent in each of the seven-point sample along the two transects. At the Takoradi/Aboadze wetland locations, the proportions of sand in the soils varied from approximately 40 to 95 percent. This was followed by silt constituting about 2 to 38 percent on all seven point locations on the two transects, while the clay component was estimated at 2 to 22 percent.

The total organic carbon (TOC) and total organic matter (TOM) contents of the soils at Tema were generally very low, ranging from 0.2 to 1.1 percent and 0.25 to 1.9 percent, respectively on Transects A and B. Generally, the soils along Transect B, which is located very close to, and partly within the proposed R&M site, had comparatively lower TOC and TOM contents. At the Takoradi/Aboadze locations, the results of the analysed wetland soil samples also yielded very low levels of TOC (0.3 to 1.1 percent) and TOM (1.0 to 1.8 percent). The pH tests for the soils indicated slightly low levels of acidity.

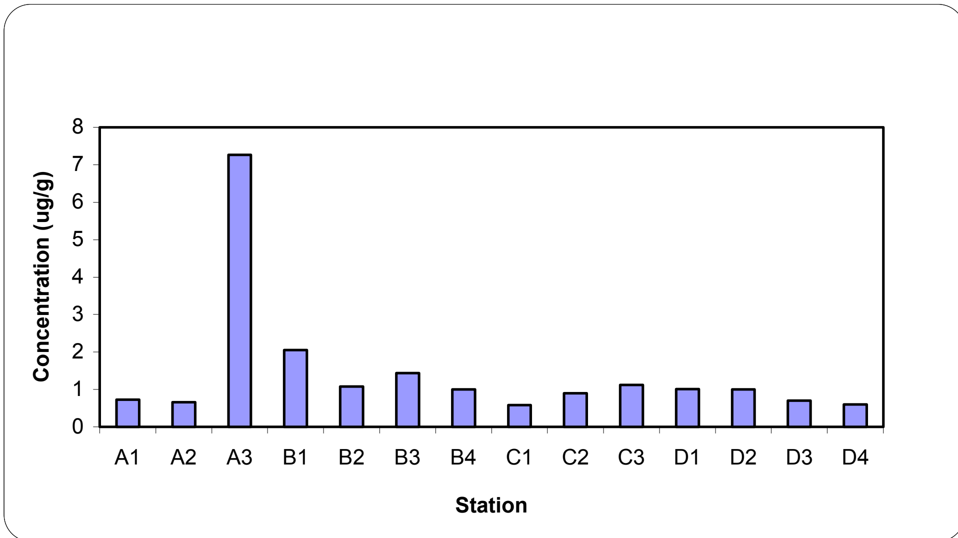
Results of the Total Organic Carbon (TOC) and Total Organic Matter (TOM) for the Tema and Takoradi/Aboadze proposed R&M sampling point samples are presented in Appendix D.

4.2.2 Chemical

Results of the total hydrocarbon content (THC) levels in soils taken from 14 points along four transects, two each in Tema and Takoradi, is presented in Appendix D. The levels of THC in soils along the proposed pipeline are presented as A1 to B4 in Figure 4.2-1. Out of the 7 point-samples taken from the two transects at Tema, 6 points exhibited THC levels within a ranging from 0.75 to 2.00µg/g. The remaining point, A3 however, exhibited a high level of hydrocarbons (7.2µg/g), possibly of petroleum products origin (Figure 4.2-1).

Along the proposed pipeline route in the Aboadze/Takoradi wetlands, all the seven point-samples located on Transects C and D exhibited low THC levels within a narrow ranging between 0.6 and 1.1 µg/g (Figure 4.2-1).

Figure 4.2-1
THC Levels in Soils along the Proposed Pipeline Routes in Tema and Aboadze/Takoradi



Results of trace metal analysis of soil samples taken from the 14 points along the four transects leading to the Tema and Aboadze/Takoradi proposed R&M sites are presented in Appendix D. The Tema location exhibited concentrations of aluminum, iron, and magnesium ranging between 1539 and 6524ppm (parts per million) in soil samples collected from all the seven transect points (Figure 4.2-2). The levels of mercury, cadmium and lead were found to be in low concentrations (<3µg/g) (Figure 4.2-3).

Figure 4.2-2
Trace Metal Levels in Soils along the Tema Pipeline Route (Transects A and B).

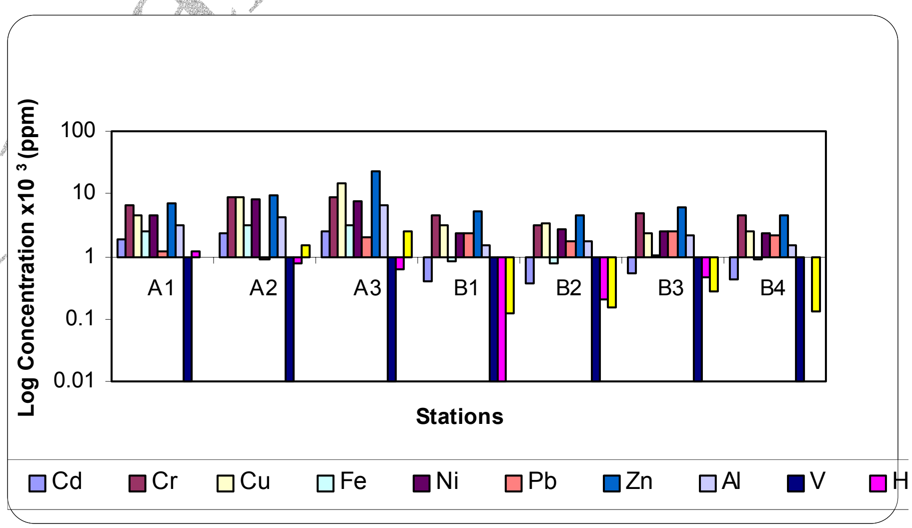
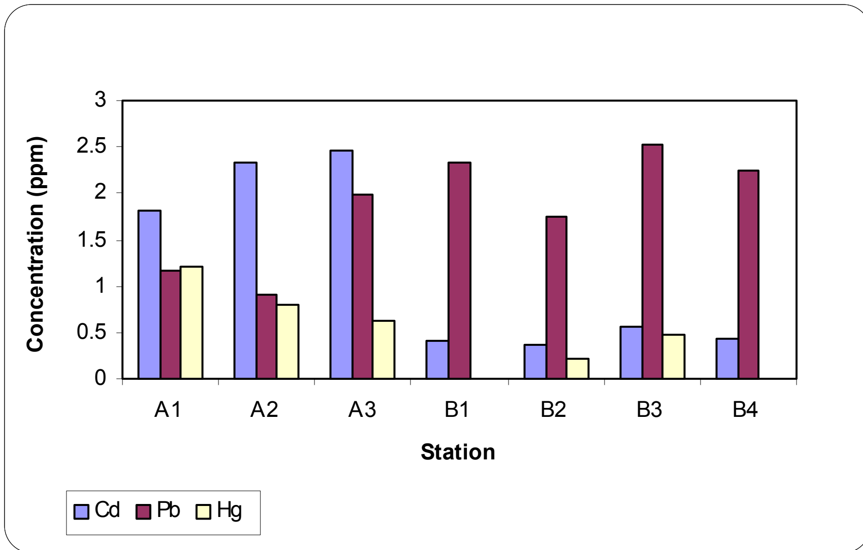


Figure 4.2-3
Levels of Hg, Pb and Cd in Soils at Tema Site.



At the Aboadze/ Takoradi pipeline route locations, the levels of aluminum and iron in the soils were also very high, ranging between 1299 and 2081µg/g along the two transect lines (C and D) (Figure 4.2-4). The level of mercury was observed to be very low and ranged from 1.04 and 1.55µg/g, while cadmium and lead levels ranged from 0.4 to 3.04µg/g (Figure 4.2-5). The concentrations of the remaining elements were within the range of about 2 to 20µg/g.

Figure 4.2-4
Trace Metal Levels in Soils along the Aboadze/Takoradi Pipeline Route (Transects C and D)

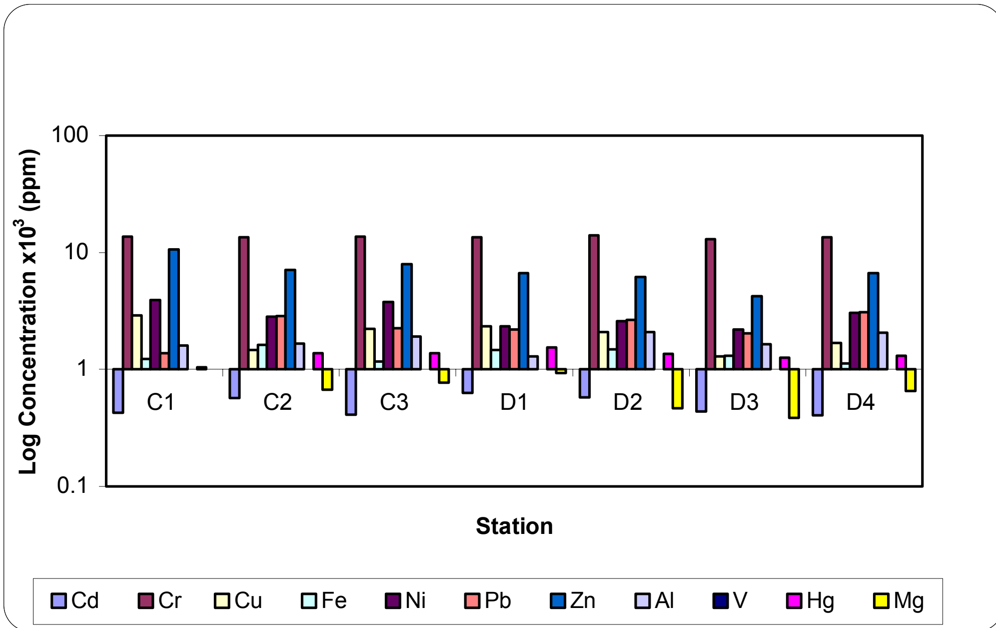
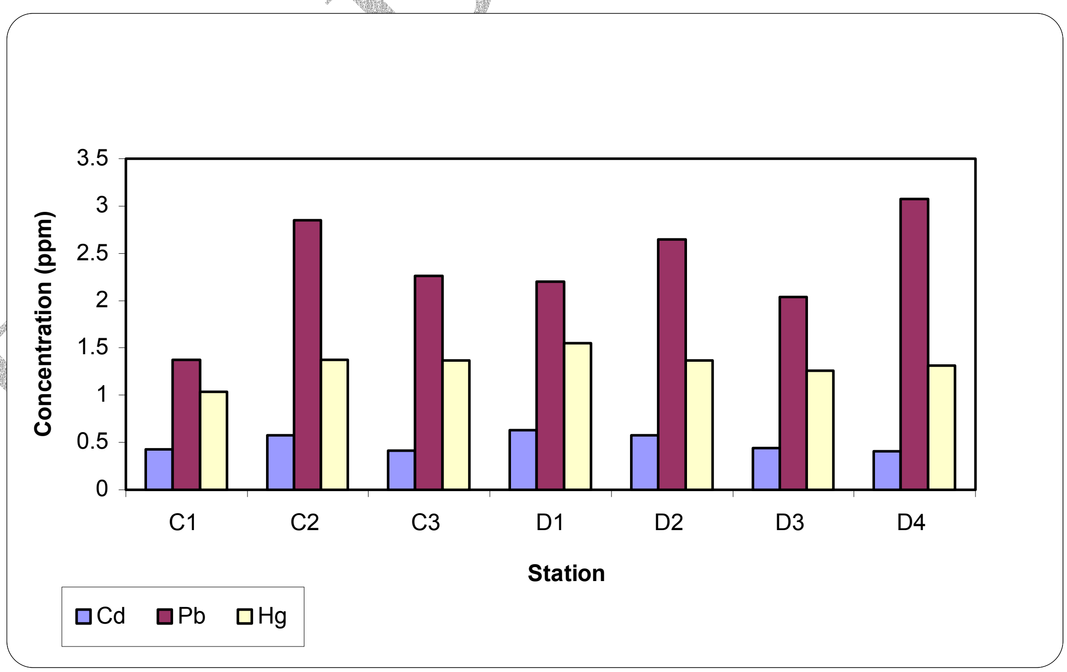
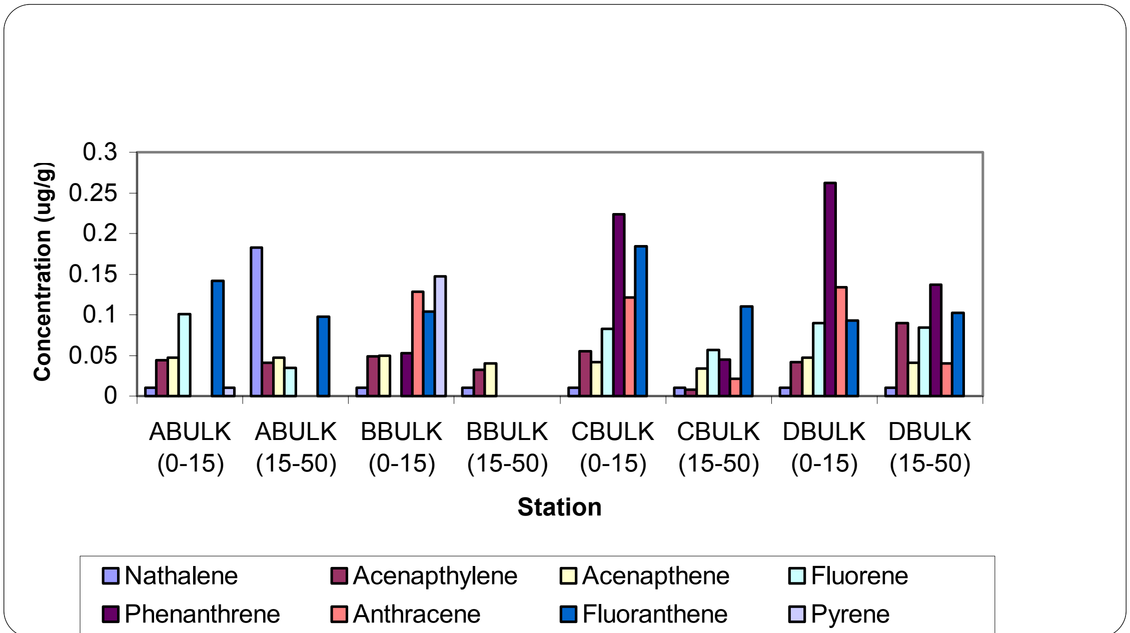


Figure 4.2-5
Levels of Hg, Pb and Cd in Soils at the Aboadze/Takoradi Site



Results of the polyaromatic hydrocarbon (PAH) analysis for the soils at Tema and Aboadze are presented in the Appendix D. The levels of PAH in the composite soils show that phenanthrene levels at Aboadze/Takoradi were very high, ranging from 0.045 to 0.262µg/g (Figure 4.2-6). A striking feature, however, is that all the naphthalene concentrations were below detection limits, with the exception of sample $ABULK_2$ (0.183µg/g) at Tema.

Figure 4.2-6
Levels of PAH in Composite (Bulk) Soils at Tema and Aboadze/Takoradi Locations.



Analysis of rocks in Ghana (Kerbyson and Schandorf, 1966) has shown that Fe_2O_3 composition in the granite is about 2.8 percent. This is the primary source of Fe in this area. The high aluminum level on the other hand might be due to materials used in harbour activities. Lead was also extremely high. Generally, almost all the parameters showed levels higher than background levels.

The high levels of THC in soils observed in the study areas may be a result of industrial activities near the study areas.

An extremely high level of hydrocarbons (7.268µg/g) was observed in the soil point sample A3 (Tema).

The PAH levels recorded at Aboadze may be associated with particulate matter in soot and smoke. The lower molecular weight PAHs (from naphthalene to pyrene) are normally blown by air and settle on the soils, which are located less than 100m away from a thermal plant.

There is little difference in the level of organics between the composite soils taken at Tema locations at the 0 to 15cm (A $Bulk_1$) samples and those of the 15 to 50cm (A $Bulk_2$) depth samples. This may be attributed to the intense plowing activities associated with farming.

At the Takoradi locations, the observed differences between the topsoils and the soils from the 15 to 50cm depths could be associated with emissions from a nearby Thermal Plant.

PAHs with the smallest molecular weights (naphthalene, phenanthrene, biphenyl, etc.) are generally in the gaseous phase (Benner and Gordon, 1989). The larger molecules (more than 5 fused rings) are almost completely associated as solids with the particles.

4.3 SURFACE WATER AND SEDIMENT CHARACTERIZATION

4.3.1 Physical

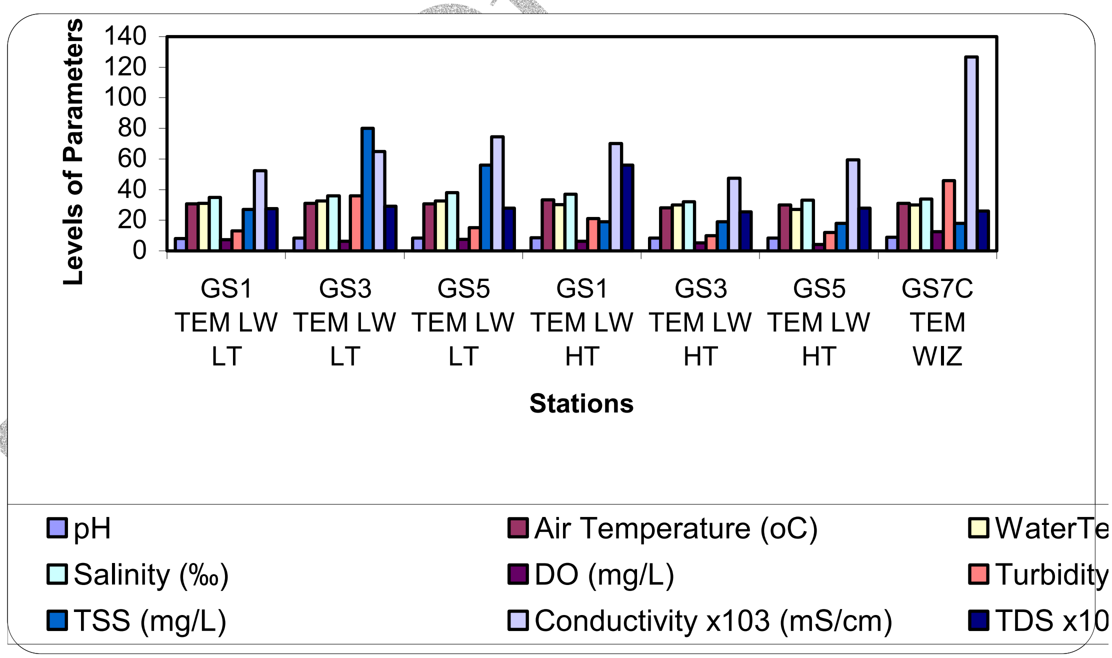
<u>Surface water</u>

Physical parameters measured for the surface waters at Tema and Aboadze included pH, temperature, electrical conductivity (EC), turbidity, dissolved oxygen (DO), total dissolved solids (TDS), and total suspended solids (TSS).

Tema

At Tema, turbidity was lowest at station GS3TEMLW during high tide in the Gao Lagoon at 10 FAU and the highest value was 46 FAU observed at the intertidal station GS3TEMLW. TSS on the other hand showed the highest value of 80mg/L at station GS3 during low tide (Figure 4.3-1). No unusual levels were evident for the other physical parameters.

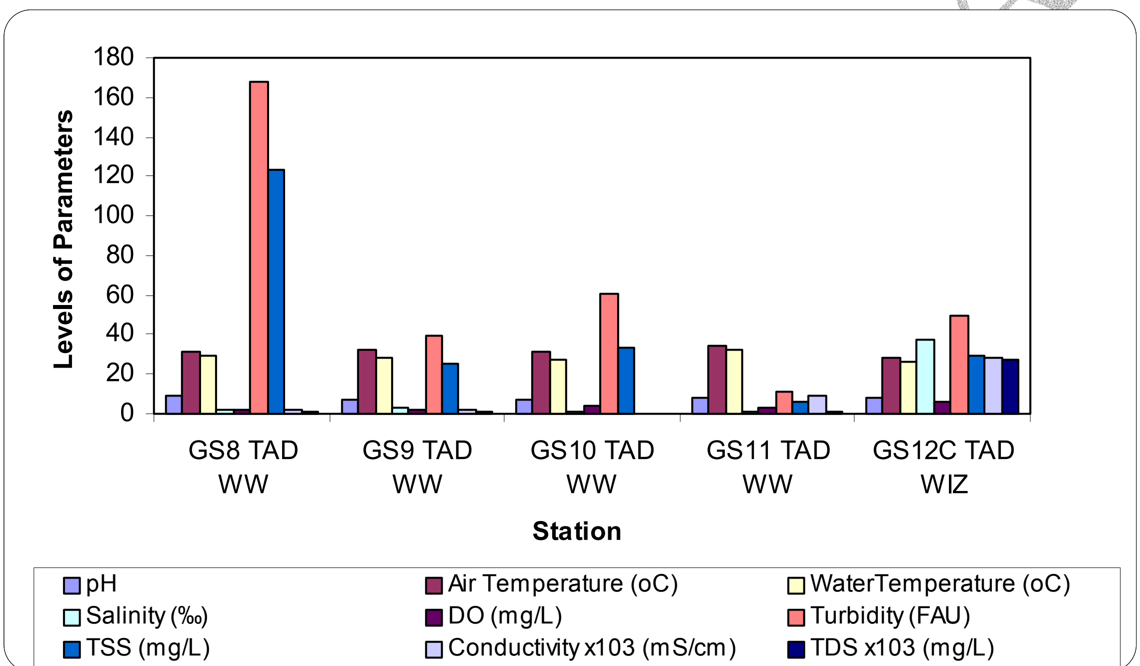
Figure 4.3-1
Levels of physico-chemical parameters of surface water at Tema.



Aboadze/Takoradi

At the Aboadze wetland, sampling station GS8TADWW exhibited the highest TSS level at 123mg/L. This was correspondingly matched with the highest turbidity measurement of 168 FAU (Figure 4.3-2). In all the stations at the Aboadze location, turbidity levels appeared to compare positively with the TSS levels. Water temperature, salinity, and DO levels were within normal ranges and did not show much variation.

Figure 4.3-2
Levels of some physico-chemical parameters of surface water at Aboadze/Takoradi.



Sediment

The sediment parameters measured included temperature, redox potential (RP), total organic carbon (TOC) and grain size.

Tema

Changes in sediment pH and temperature (Figure 4.3-3) were minimal at all the stations. The little variation in temperature reflects the general trend in the tropics, where temperature varies slightly throughout the year. Redox potential showed anoxic conditions in the lagoon sediment and this increased in magnitude as one moved farther away from the mouth of the lagoon. The sediment at the mouth of the lagoon (Station GS1TEMLSED) and the intertidal stations (GS7ATEMLIZ and GS7BTEMUIZ) were oxic however, indicative of low organic matter content (Figure 4.3-4).

Figure 4.3-3
pH and Temperature levels in sediment at Tema and Aboadze/Takoradi.

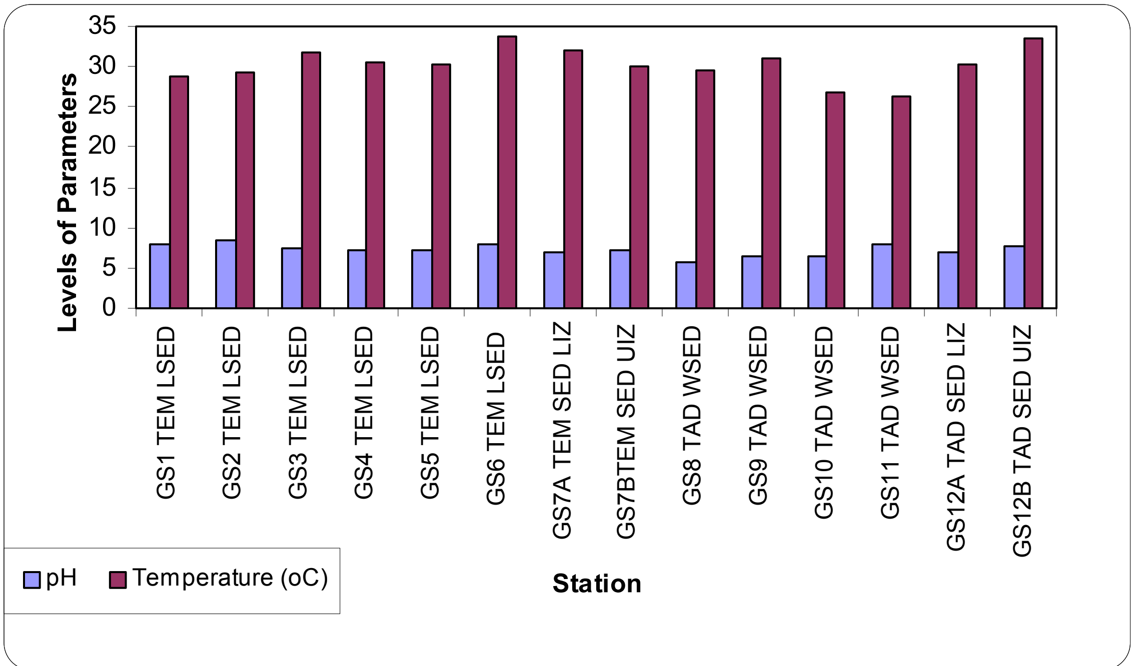
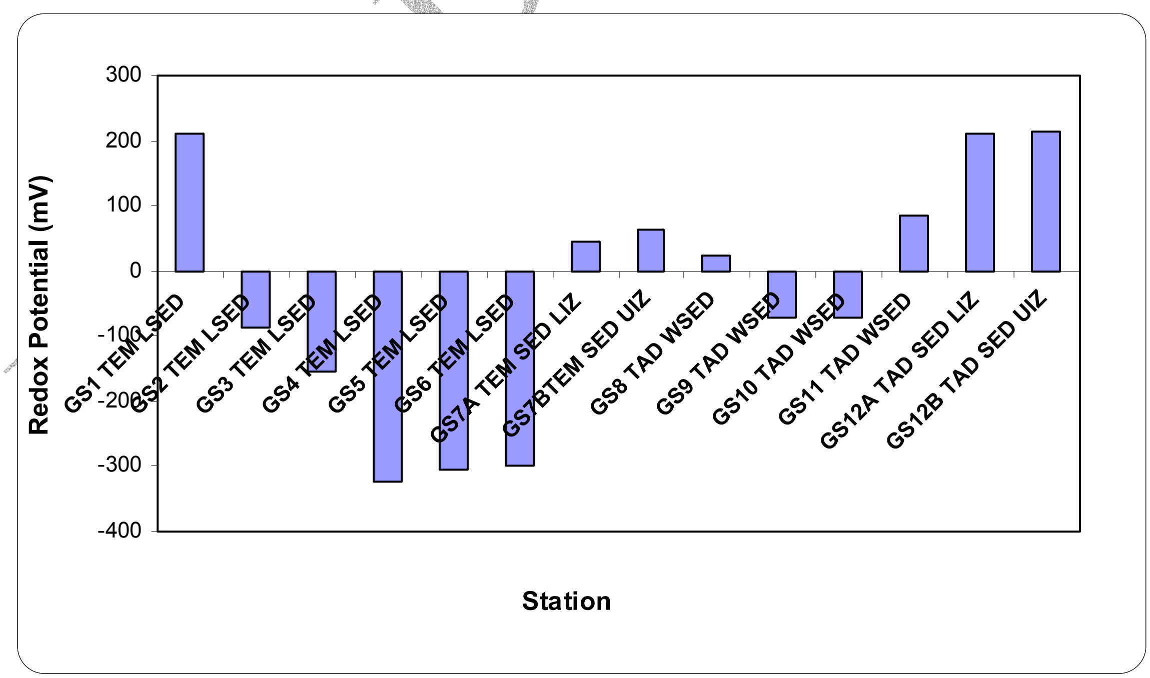


Figure 4.3-4
Redox Potential of Sediments at Tema and Aboadze



Analytical results (Figure 4.3-5) obtained revealed that all sediments from the intertidal zone (LIZ and UIZ), as well as those of the stations (GS1TEMLSED and GS2TEMLSED), which are located close to the mouth of the lagoon, have sandy texture. The rest of the samples from the lagoon sediments were variable in texture, with the clay content being about twice as high as the silt. Levels of TOC in Tema sediment increased from stations located at the intertidal zone to stations farther up in the lagoon (Figure 4.3-6). The intertidal and lagoon mouth station values for TOC ranged between 0.04 and 0.20 percent. The higher values of the main lagoon sediment ranged between 0.91 and 1.84 percent.

Figure 4.3-5
Sediment Grain Size Distribution at Tema

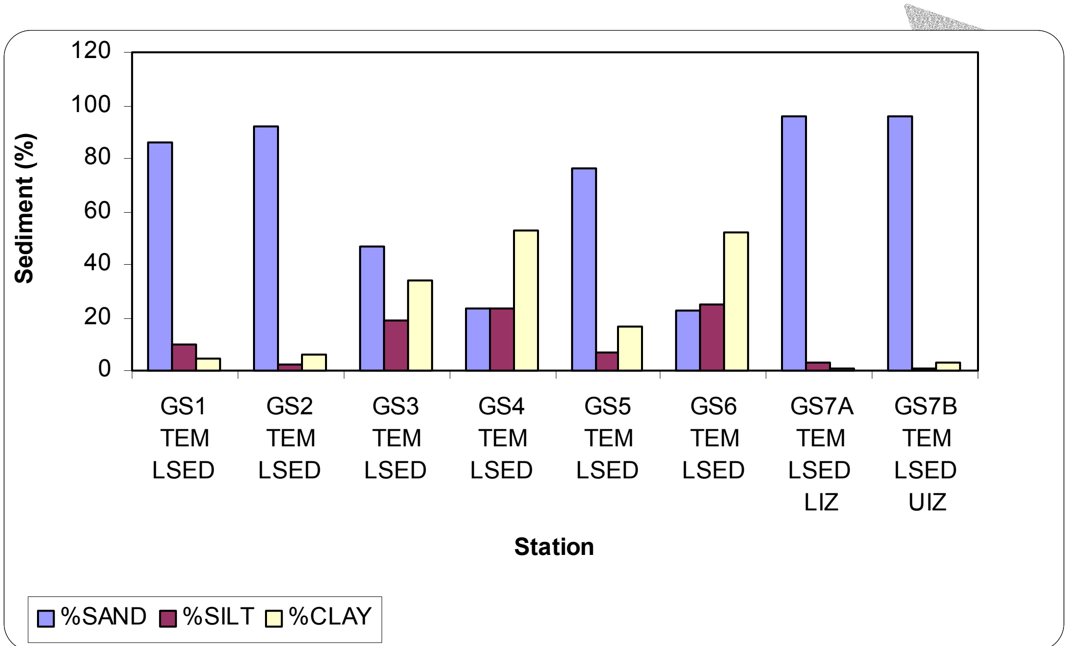
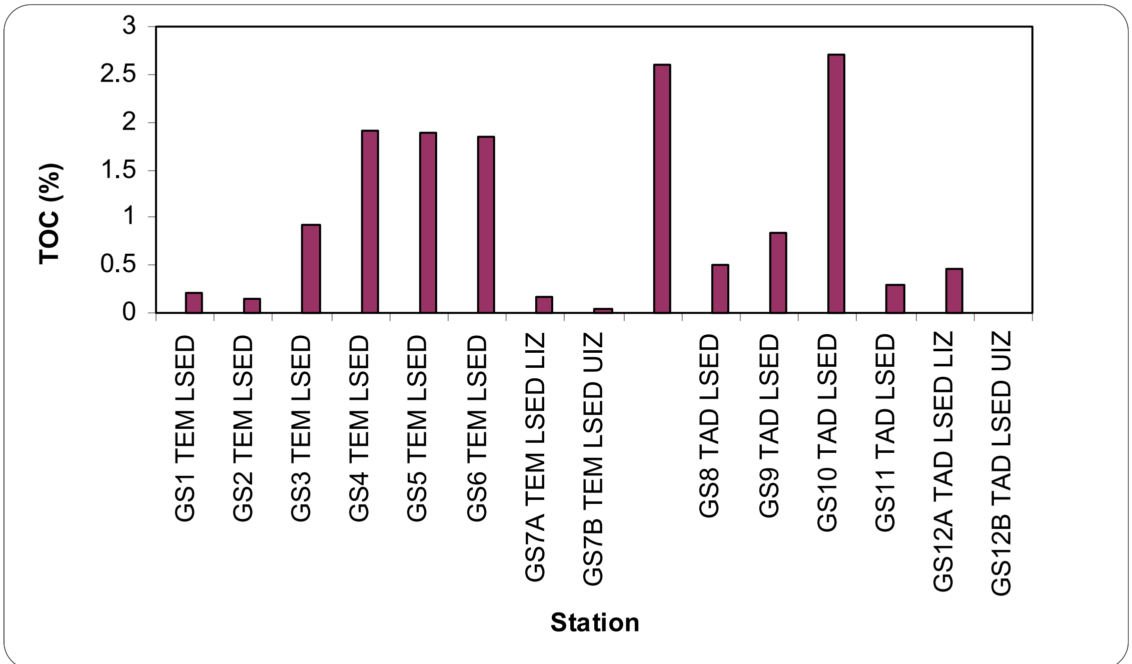


Figure 4.3-6
Total Organic Carbon of Sediment at Tema and Aboadze

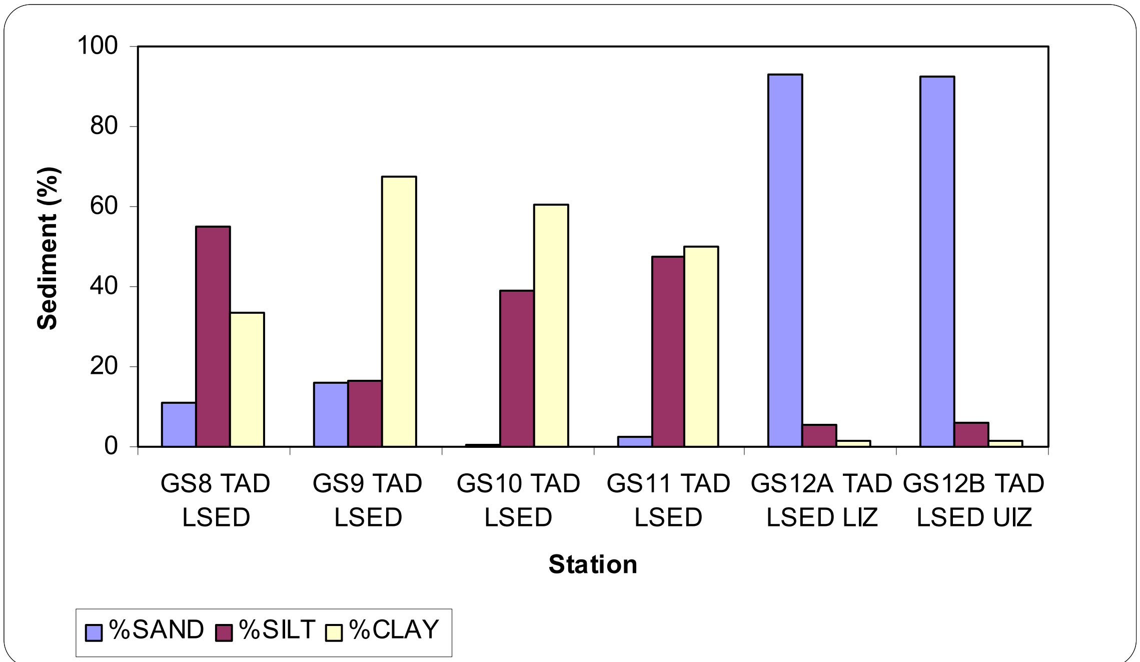


Aboadze/Takoradi

Changes in sediment pH and temperature (Figure 4.3-3) were very minimal at all the stations. Redox potential showed anoxic conditions at two stations (GS9TADWSED and GS10TADWSED) of the wetland. The rest of the wetland stations, as well as the two intertidal stations, were oxic (Figure 4.3-4).

Wetland stations GS9 TAD WW and GS10 TAD WW were both clayey in texture but GS11 TAD WW contained silty clay (Figure 4.3-7). The sediment ranged from loamy sand, sand, sandy clay, sandy loam, to clays.

Figure 4.3-7
Sediment Grain Size Distribution at Aboadze



A critical look at the result (Figure 4.3-6) shows that GS8TADWSED and GS11TADWSED were high in TOC, but GS9TADWSED and GS10 TADWSED exhibited low to very low TOC.

Discussion

Tema

The water physical parameters measured did not show any appreciable variation among the stations at Tema. An elevated level of TSS and reduced turbidity level were found at Station GS3TEMLW of the Gao Lagoon.

Aboadze/Takoradi

All the physical parameters for water at Aboadze were within reasonable levels. As a non-tidal wetland, salinity was very low except for stations near the point of discharge of the perimeter drain of the Thermal Plant. Levels were probably elevated as a result of the use of seawater to cool the plants. Turbidity levels were also comparatively higher at the wetland, probably due to higher concentrations of decaying organic matter.

At Aboadze/Takoradi, redox potential of the sediments was comparatively higher in sediments within the wetland than in the Gao Lagoon sediments. Sediment texture was quite mixed and varied among stations.

TOC is considered to be in very low quantities if it is below 0.6 percent, to be low between 0.60 and 1.26 percent, to be medium within the range of 1.26 to 2.51 percent, to be high from 2.51 to 3.50 percent, and to be very high if it is more than 3.5 percent. The sediments at the two sites thus ranged from very low to high total organic content.

4.3.2 Chemical

<u>Surface water</u>

Chemical parameters determined for the surface water included trace metals, nutrients, alkaline metals, and others. The trace metals were aluminum (Al), cadmium (Cd), copper (Cu), iron (Fe), mercury (Hg), magnesium (Mg), nickel (Ni), lead (Pb), vanadium (V), and zinc (Zn). The nutrients were ammonia-nitrogen (NH_3–N), nitrate nitrogen (NO_3–N), total nitrogen (N), total phosphorus (P), orthophosphate phosphorus (PO_4–P), and sulfate (SO_4). The alkaline metals were sodium (Na), calcium (Ca), and potassium (K). The others category included biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and alkalinity.

Trace metals (Tema)

The levels of aluminum for Tema onshore surface water were high with the highest concentration at lagoon station GS3. Low tide values were extremely high compared to that of the high tide, with station GS1 being an exception (Table 4.3-1). Two of the stations, GS1 and GS5, both in the lagoon, exhibited high levels of lead (0.567 and 0.410ppm, respectively). Vanadium levels were elevated at station GS3. The rest of the metals were higher than the background levels but this is not considered a threat.

Table 4.3-1
Trace metal levels in surface waters of Tema and Aboadze.

Station ID	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Al	V	Hg	Mg
Tema											
GS1 TEM LW LT	0.0895	0.1823	<0.01	<0.01	0.6321	0.5673	0.1295	2.983	2.264	<0.01	147.1
GS3 TEM LW LT	0.0868	0.1108	<0.01	<0.01	0.6156	<0.01	0.1414	14.79	0.857	<0.01	216.8
GS5 TEM LW LT	0.1033	0.1007	<0.01	<0.01	0.5972	<0.01	0.1334	13.26	5.529	<0.01	150.5
GS1 TEM LW HT	0.0975	0.1245	<0.01	<0.01	0.6363	<0.01	0.1343	4.911	0.485	<0.01	231.6
GS3 TEM LW HT	0.1006	0.0838	0.0206	<0.01	0.6312	<0.01	0.1234	0.1441	2.178	<0.01	124.6
GS5 TEM LW HT	0.1068	0.1434	<0.01	0.0081	0.6413	0.4109	0.131	1.639	0.403	<0.01	153.2
GS7C TEM WIZ	0.0752	0.0645	<0.01	<0.01	0.6639	<0.01	0.1354	0.638	<0.01	<0.01	105.2
Aboadze											
Station ID	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Al	V	Hg	Mg
GS8 TAD WW	0.0729	0.1295	<0.01	0.193	0.6925	0.0098	0.157	0.0754	<0.01	<0.01	9.772
GS9 TAD WW	0.0841	0.0634	<0.01	0.1321	0.6454	0.0979	0.1731	<0.01	<0.01	<0.01	2.456
GS10 TAD WW	0.1037	0.0317	<0.01	0.1321	0.5779	<0.01	0.1666	0.3908	<0.01	<0.01	10.88
GS11 TAD WW	0.1091	0.1084	<0.01	0.0476	0.699	0.0685	0.1707	0.3139	<0.01	<0.01	0.9968

GS12C TAD WIZ	0.1218	0.1461	<0.01	0.6194	0.6137	0.1174	0.1397	8.544	0.525	<0.01	120.9

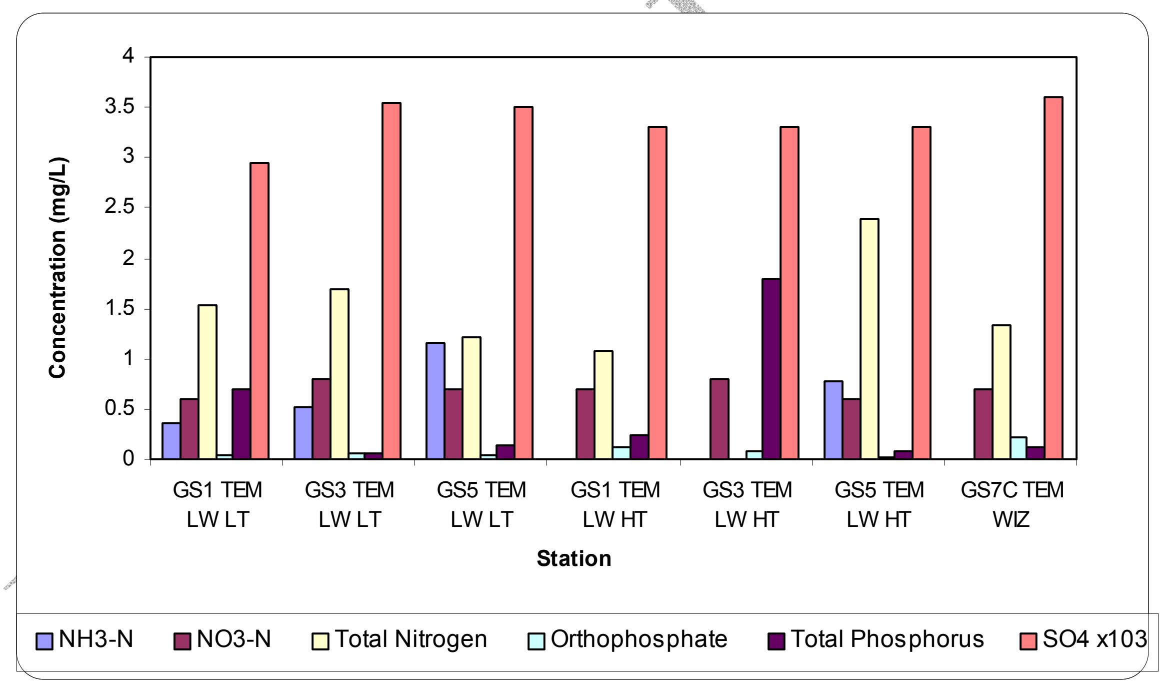
Trace metals (Aboadze)

Unusually high levels of Al (8.544 ppm), Pb (0.1174 ppm), V (0.525 ppm), Fe (0.6194 ppm), and Mg (120.9) were detected at Station GS12C (Table 4.3- 1). This station is close to the outfall of the perimeter drain of the Aboadze Thermal Plant. The rest of the stations in the wetland exhibited much lower values for these metals.

Nutrients (Tema)

Ammonia-nitrogen (NH_3–N) levels generally increased from the intertidal across the lagoon mouth and inland to the higher reaches. The same trend was evident at both high and low tides. Ammonia levels ranged from <0.001 to 1.16 mg/L. Total nitrogen (N) values did not show any appreciable variation except at Station GS3TEMLW, where it was below detectable limits. Nitrate nitrogen (NO_3–N), total phosphorus (P), orthophosphate phosphorus (PO_4–P), and sulfate (SO_4) did not show any definite trends among the stations (Figure 4.3-8).

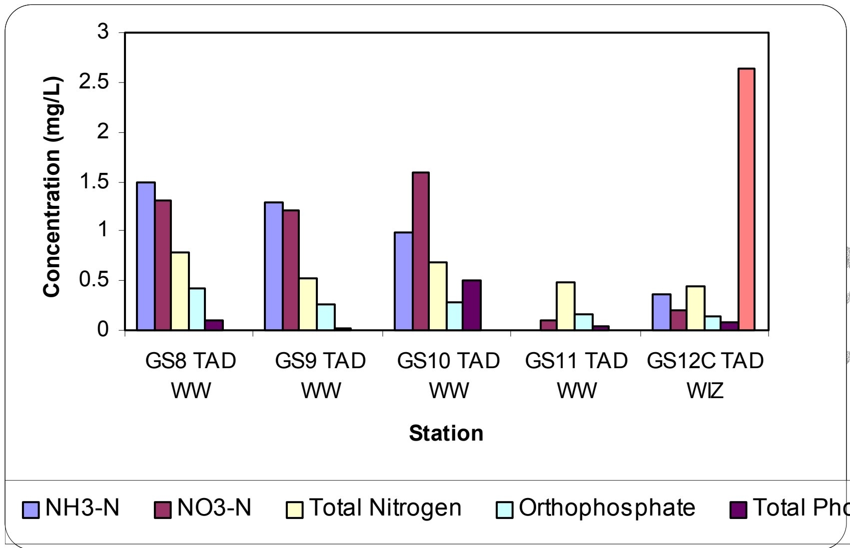
Figure 4.3-8
Nutrient levels at Tema



Nutrients (Aboadze/Takoradi)

The nitrogen and phosphorus nutrients NH_3–N, NO_3–N, N, P, and PO_4–P did not show any appreciable variation among the stations. However SO_4 levels were extremely low in the wetland stations (Figure 4.3-9).

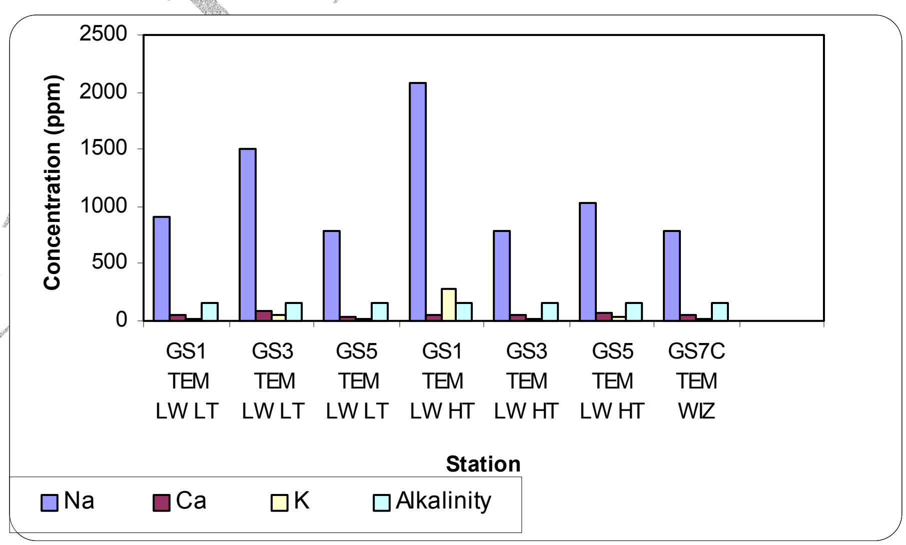
Figure 4.3-9
Nutrient levels at Aboadze/Takoradi



Alkaline metals and alkalinity (Tema)

Generally, the alkaline metals showed elevated levels at high tide. The low tide range for Na was 782 to 1512 mg/L while the high tide range was 791.8 to 2082 mg/L. Alkalinity was more or less uniform and ranged between 150 and 160 mg/L (Figure 4.3-10).

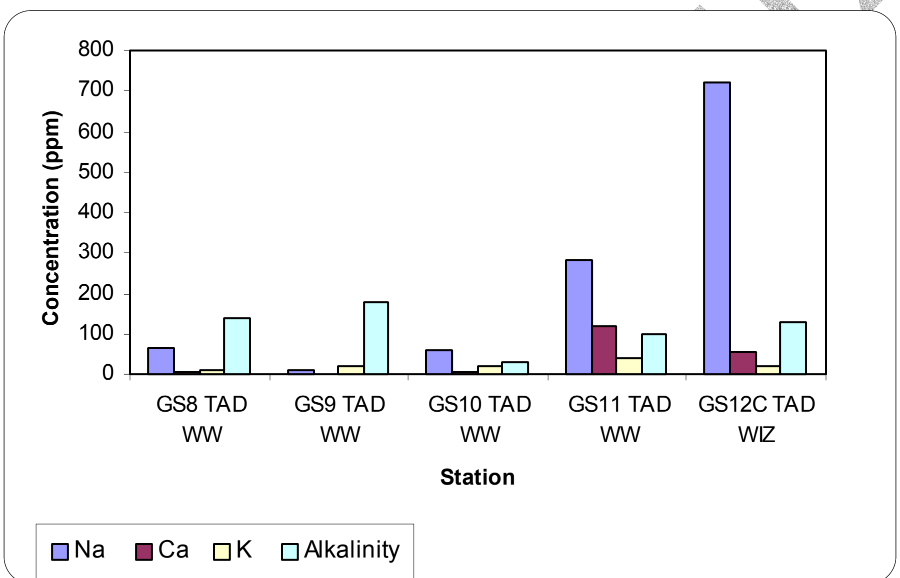
Figure 4.3-10
Alkaline metals and alkalinity levels at Tema



Alkaline metals and alkalinity (Aboadze/Takoradi)

The alkaline metals did not show any appreciable differences among the stations with the exception of Na. As expected Na concentrations were very high in the intertidal areas with a value of 723.3mg/L. The wetland values were lower and ranged from 63.35 to 281mg/L. The highest value for Na in the wetland was recorded at Station GS11TADWW, which is close to the emptying point of the perimeter drain of the existing thermal plant that uses seawater for cooling its systems. No clear trends were observed among the stations for alkalinity (Figure 4.3-11).

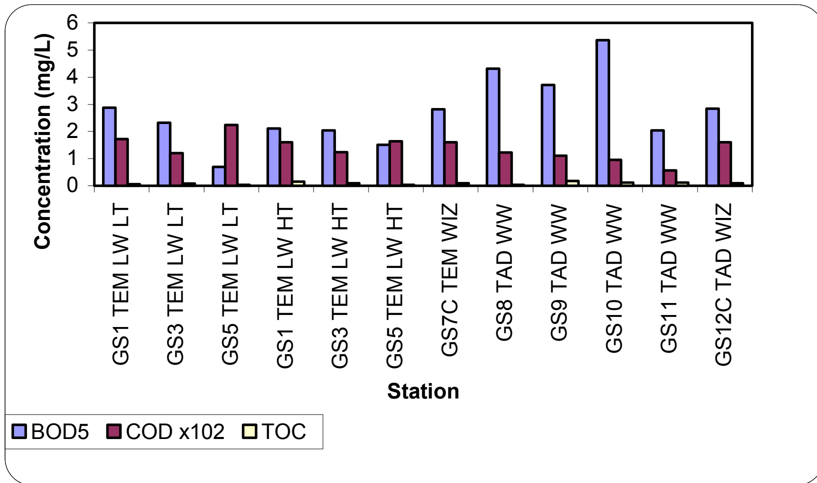
Figure 4.3-11
Alkaline metals and alkalinity levels at Aboadze



BOD, COD, and TOC (Tema)

The BOD ranged from 0.70 to 2.88mg/L and COD from 120 to 224mg/L while TOC varied from 0.03 to 0.1mg/L among the stations. No major differences were observed among the stations for all the parameters. TOC levels were particularly low (Figure 4.3-12).

Figure 4.3-12
BOD, COD and TOC levels at Tema and Aboadze.



BOD, COD, and TOC (Aboadze)

The BOD, COD and TOC levels showed similar trends with Tema. BOD ranged from 2.04 to 5.36mg/L and COD from 56 to 160mg/L while TOC varied from 0.03 to 0.18 mg/L among the stations. No major differences were observed among the stations for all the parameters. TOC levels were particularly low (Figure 4.3-13).

<u>Sediment</u>

Trace metals (Tema)

Values for trace metals, Fe, Cd, Cu, Ni, Pb, Zn, and Cr, were low in the sediments with the exception of Station GS4TEMLSED at Tema. Vanadium levels were very low at the same station (Table 4.3-2), but were extremely high at Station GS3TEMLSED. Patterns could be due to the use of aluminum and iron materials in industrial activities at Tema. Lead was also extremely high at Station GS4TEMLSED in the Gao Lagoon at Tema.

Trace metals (Aboadze)

Trace metals Al and Fe exhibited extremely high values in the sediments of the wetlands (Table 4.3-3). It is conceivable that the wetlands could have been the dumping site of waste materials during the construction of the nearby thermal plant.

Table 4.3-2
Trace metals levels in sediments at Tema and Aboadze (ug/g).

Tema											
Station ID	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**	**Zn**	**Al**	**V**	**Hg**	**Mg**
GS1 TEM LSED	<0.01	3.818	<0.01	<0.01	1.272	0.4059	<0.01	2404	5.385	<0.01	1067
GS2 TEM LSED	<0.01	3.977	<0.01	<0.01	1.339	0.2687	<0.01	2662	6.375	<0.01	1245
GS3 TEM LSED	<0.01	3.934	<0.01	<0.01	1.454	0.863	0.0407	2548	17.29	<0.01	2379
GS4 TEM LSED	2.077	9.983	10.06	3144	6.87	12.34	55.34	1964	<0.01	<0.01	2844
GS5 TEM LSED	<0.01	2.818	<0.01	<0.01	1.416	0.4116	<0.01	2.64	0.346	<0.01	612.6
GS6 TEM LSED	<0.01	3.999	<0.01	<0.01	1.532	0.813	<0.01	3.684	5.003	<0.01	1150
GS7A TEM SED LIZ	<0.01	4.434	<0.01	<0.01	1.293	0.2401	<0.01	3.766	6.593	<0.01	1165
GS7BTEM SED UIZ	<0.01	3.567	<0.01	<0.01	1.306	0.6175	<0.01	5.643	5.984	<0.01	1155
Aboadze/Takoradi											
Station ID	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**	**Zn**	**Al**	**V**	**Hg**	**Mg**
GS8 TAD WSED	0.6201	13.15	1.803	1553	2.324	2.379	4.633	1333	<0.01	1.478	458.2
GS9 TAD WSED	1.18	18.22	1.812	2881	2.356	4.881	4.828	2043	<0.01	1.797	510.6
GS10 TAD WSED	1.664	28.36	5.278	4128	4.809	6.383	28.94	2938	<0.01	3.132	672.9
GS11 TAD WSED	2.285	15.52	10.43	3986	5.679	5.036	66.43	1584	<0.01	0.9237	1204
GS12A TAD SED LIZ	<0.01	13.38	0.4157	<0.01	1.383	0.5749	<0.01	5.787	4.166	1.05	408
GS12B TAD SED UIZ	<0.01	13.4	0.4347	<0.01	1.436	0.6717	<0.01	6.439	6.429	1.017	650

Table 4.3-3
Alkalinity, TOC and nutrient values at Takoradi (mg/L).

Sample ID	Alkalinity as mg/L $CaCO_3$	NH_4-N	Tot. Nitrogen	Tot. PO_4	TOC.
GS8 TAD WW	136	1.5	0.78	0.109	0.03
GS9 TAD WW	180	1.28	0.53	0.021	0.18
GS10 TAD WW	32	0.986	0.68	0.507	0.12
GS11 TAD WW	98	< 0.001	0.49	0.038	0.12
GS12C LT	128	0.37	0.44	0.077	0.09
GS12C HT	134	0.27	0.59	0.022	0.06
Background levels	276	0.3	0.250-0.500	0.070-0.186	-

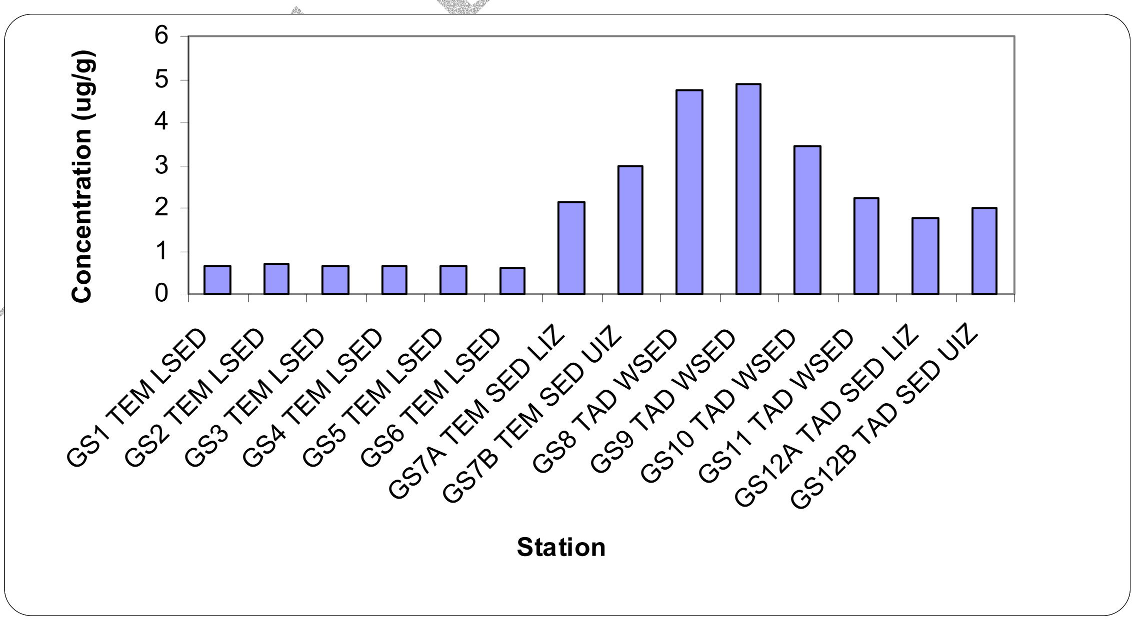
Table 4.3-4
Alkalinity, TOC and Nutrient levels at Tema (mg/L).

Sample ID	Alkalinity as mg/L $CaCO_3$	NH_4-N	Tot. Nitrogen	Tot. Phosphate	TOC
GS1 TEM LW (LT)	126	0.36	1.53	0.7	0.06
GS1 TEM LW (HT)	130	<0.001	1.07	0.23	0.15
GS3 TEM LW (LT)	140	0.51	1.7	0.06	0.08
GS3 TEM LW (HT)	158	< 0.001	< 0.001	1.8	0.1
GS5 TEM LW (LT)	114	1.16	1.21	0.14	0.04
GS5 TEM LW (HT)	142	0.78	2.38	0.07	0.03
GS7C LT	130	< 0.001	1.34	0.12	0.1
GS7C HT	136	< 0.001	1.25	0.08	0.06
Field Blank (acidified)	-	-	0.19	0.06	-
Field Blank (untreated)	8	< 0.001	0.51	0.06	
Background levels	276	0.3	0.250-0.500	0.070-0.186	-

Total hydrocarbons (Tema)

The concentration of total hydrocarbons in the lagoon sediments at Tema was extremely low, less than 1µg/g. For the intertidal samples, it was much higher, between 2 and 3µg/g (Figure 4.3-13).

Figure 4.3-13
Total hydrocarbon concentrations in sediment at Tema and Aboadze.



Total hydrocarbons (Aboadze)

The concentrations of total hydrocarbons in the wetland sediments at Aboadze were high, ranging between 2 and 5µg/g. However, the levels for the wetland were much higher than for the marine intertidal zone (Figure 4.3-13).

Discussion

Tema

The values obtained for the trace metals in the surface water at Tema were all higher than their background levels with the exception of copper, mercury and lead, but probably pose no threat to environment.

In the sediments, vanadium was extremely high at Station GS3TEMLSED. Lead was also extremely high at station GS4 TEMLSED in the Gao Lagoon at Tema. This could be due to the use of aluminum and iron materials in industrial activities at Tema. All the observed values were reasonable.

The high ammonia nitrogen levels obtained for Tema is indicative of the impact of human activities as well as agricultural input from the surrounding vegetable farms. Total nitrogen values were all high at Tema due to human activities in and around the sampling sites. Station GS5TEMLW (HT) exhibited the highest total nitrogen with the rest of the stations having high values during low tide periods.

Sodium (Na), calcium (Ca), and potassium (K) were the three alkali metals that were determined for surface water. These metals did not show any appreciable variations among the stations at Tema. Sodium, as expected, was high in the intertidal water. Alkalinity was almost uniform for stations in the lagoon and for the intertidal station. This might be due to the tidal influence of the sea on the lagoon.

BOD, COD and TOC levels did not vary much among the stations. The values of TOC were low at all the stations at Tema. The values of BOD suggest low organic pollution in the surface waters.

Aboadze/Takoradi

Unusually high levels of Al, Pb, V, Fe, and Mg were detected at the intertidal Station GS12C at Aboadze/Takoradi, near the outfall of a drain from the thermal plant station into the sea. The levels of trace metals in the sediment at Aboadze were higher than that of Tema. Aluminum and Fe exhibited extremely high sediment values in wetlands. Nutrient levels in the wetland stations were lower than those of the Gao Lagoon at Tema.

In the wetland stations at Aboadze/Takoradi, the discharge of saline effluent from the thermal plant into the wetland near Station GS11TADWW, probably influences the high level of Na at this location, compared to the other stations, which are farther away.

At the wetland stations of Aboadze, BOD levels were higher than at the Gao Lagoon in Tema. The higher levels probably result from decomposing vegetation at the Aboadze wetland. The lower values for the Gao Lagoon, are most likely due to the regular tidal flushing of the lagoon.

Total hydrocarbon (THC) levels in sediments were low for all the stations except the wetland stations near the thermal plant at Aboadze/Takoradi.

4.3.3 Biological

The biological components of the surface water and sediments comprise microbiology, phytoplankton productivity and zooplankton of the water bodies as well as the sediment macroinfauna at Tema and Takoradi/Aboadze. The macrofaunal and macroalgal communities at the two localities were also studied.

Microbiology

The microbiological attributes examined include total viable bacteria, total coliform counts, faecal coliforms, hydrocarbon degrading bacteria, moulds, and yeasts (Table 4.3-5).

Table 4.3-5
Results of Microbiological Analyses of Surface Water from Tema and Aboadze/Takoradi

SAMPLE No.	**Total coliform per 100ml**	**Faecal coliform per 100ml**	**Total hetero-trophic count per ml**	***Pseudo-monas* spp. per ml**	***Clostrid-ium* spp. per ml**	***Desulpho-vibrio* spp. per ml**	**Hydro-carbon oxidizers per ml**	**Hydro-carbon decom-posers per ml**	**Moulds per ml**	**Yeasts per ml**
TEMA										
GS1 TEM LW LT	5480	96	242	3.2	78	<1	257	77	128	4
GS1 TEM LW HT	4280	52	72	5.4	8	<1	28	21	35	2
GS3 TEM LW LT	10830	40	125	6.5	42	<1	238	142	93	7
GS3 TEM LW HT	6100	80	275	21.6	35	<1	149	36	72	4
GS5 TEM LW LT	4280	8	264	4.3	73	<1	232	140	60	3
GS5 TEM LW HT	3440	<1	219	3.2	31	<1	297	15	165	7
GS7C TEM LIZ	180	56	51	2.2	8	<1	148	17	16	3
GS7C TEM UIZ	2570	80	126	5.4	96	<1	254	14	54	1
TAKORADI										
GS8 TAD	1800	26	165	5.4	9	<1	138	78	76	6
GS9 TAD	3000	230	380	1.1	6	<1	89	89	108	8
GS10 TAD	3850	48	880	8.6	39	<1	120	110	112	10
GS11 TAD	3600	16	1200	1.1	1	<1	132	98	60	6
GS12C TAD LIZ	4800	<1	160	0.9	<1	<1	42	16	104	4
GS12C TAD UIZ	770	38	84	0.8	<1	<1	38	12	80	2

Tema

Total viable bacteria ranged from 51 to 275 colony forming units (CFU)/ml for the water samples. The *Total coliform* values for the water samples ranged from 180 CFU/100ml for ITZ (LT) to 10830 CFU/100ml for GS3 TEM LW LT. Generally all high tide (HT) values were higher than low tide (LT) values. There was no faecal coliform detected in water sample GS3 TEM LW LT. However, the rest of the water samples ranged from 8 CFU/100ml for GS3 TEM LW LT to 96 CFU/100ml for GS1 TEM LW. All the samples were analyzed for the presence of *Pseudomonas* spp. *Pseudomonas* spp. values for the water samples ranged from 2.2 CFU/ml for ITZ (LT) to 21.6 CFU/ml for GS3 TEM LW LT. *Clostridium* spp. values for the water samples ranged from 8 CFU/ml for GS1 TEM LW HT and ITZ (LT) to 96 CFU/ml for ITZ (HT). *Desulfovibrio* spp. was not detected in any of the samples. Values for oxidizers ranged from 28 CFU/ml for GS1 TEM LW HT to 297 CFU/ml for GS5 TEM LW HT for the water samples. Values for decomposers ranged from 14 CFU/ml for ITZ (HT) to 142 CFU/ml for GS3 TEM LW LT. Moulds and yeasts in the water samples ranged from 16 CFU/ml for ITZ (LT) to 165 CFU/ml for GS5 TEM LW HT, and 1 CFU/ml for ITZ (HT) to 7 CFU/ml for samples from GS3 TEM LW (LT) and GS5 TEM LW (HT), respectively.

Takoradi

Total viable bacteria values ranged from 84 CFU/ml for sample ITZ (HT) to 12 x 10^2 CFU/ml for samples collected from station GS11TADWW. Total coliform bacteria in water samples had values ranging from 770 CFU/100ml for ITZ (HT) to 48 x 10^2 CFU/100ml for ITZ (LT). Faecal coliform bacteria ranged from <1 CFU/100ml for ITZ (LT) to 230 CFU/100ml for samples collected from station GS9TADWW. All the samples exhibited the presence of *Pseudomonas* spp., though the water sample values were very low, ranging from 0.8 CFU/ml for ITZ (HT) to 8.6 CFU/ml for GS11TADWW. *Clostridium* spp. values for water samples ranged from <1 CFU/ml for the ITZ (LT) and ITZ (HT) samples to 39 CFU/ml for the SW4 sample. No *Desulfovibrio* spp. was isolated from the water samples in this study. Values for oxidizers ranged from 38 CFU/ml to 138 CFU/ml for the ITZ (HT) and GS8TADWW samples, respectively. In contrast, decomposers showed values ranging from 12 CFU/ml for ITZ (HT) to 110 CFU/ml for GS10TADWW for the water samples. Moulds in the water samples ranged from 60 CFU/ml for GS11TADWW to 112 CFU/ml for GS10TADWW. Values for yeasts ranged form 2 CFU/ml for ITZ (HT) to 10 CFU/ml for GS10TADWW.

Phytoplankton and Productivity

Phytoplankton diversity, composition and abundance were estimated for surface waters of the Tema and Takoradi sites. In addition, respiration, photosynthesis and productivity were estimated at selected stations for the two sites.

At Tema, phytoplankton species composition and abundance in surface and sub-surface water samples were taken between 0600 and 0630 GMT and 1800-1830 GMT, respectively. Results are presented in Tables 4.3-6a and 4.3-6b. Nine phytoplankton species (2 green algae, 5 diatoms, 2 blue green algae) were recorded in the morning sampling whilst 14 species (4 green algae, 7 diatoms, 3 blue green algae) were recorded in the evening sampling. Populations of all the algae were generally low except for the blue green algae. Diatoms tend to dominate brackish waters, as was the case here. Low nutrient inputs may have also contributed to the low populations in addition to the mixture of seawaters, which dilute the lagoon waters.

Table 4.3-6a
Low Tide Phytoplankton Species and Population at Tema (0600-0630 GMT).

Taxa	**Station and Phytoplankton population in cells/ml**			
	Station 1	**Station 3**	**Station 5**	**Station 3(Replicate)**
Chlorophyta				
(Green Algae)				
Staurastrum	-	-	-	-
Staurodesmus	1	3	1	2
Bacillariophyta				
(Diatoms)				
Cymbella	-	-	1	1
Gyrosigma	-	1	-	-
Navicula	1	1	1	1
Synedra	2	4	1	2
Cyanophyta				
(Blue-green algae)				
	25	50	25	
Anabaena				
Oscillatoria				

Table 4.3-6b
High Tide Phytoplankton Species and Population at Tema (1800-1830 GMT).

Taxa	Station and Phytoplankton population cells/ml							
	Station 1		Station 2		Station 3		Station 3 (Replicate)	
	S	B	S	B	S	B	S	B
Chlorophyta								
(Green Algae)								
Chlorella	-	-	1	-	-	-	-	-
Closterium	-	-	1	-	1	1	1	1
Scenedesmus	1	-	1	1	-	-	-	-
Staurodesmus	-	1	1	1	2	1	1	1
Bacillariophyta								
(Diatoms)								
Diatoma	-	-	1	-	-	-	-	-
Diploneis	-	-	-	-	-	-	1	-
Gyrosigma	-	1	1	-	1	1	-	-
Navicula	1	2	1	1	1	1	1	1
Nitzschia	-	-	-	1	1	1	-	-
Synedra	2	1	2	3	3	2	2	2
Tabellaria	-	-	-	-	-	1	-	
Cyanophyta (Blue-green Algae)								
Anabaena								
Merismopedia	24	-	-	-	-	-	-	-
Oscillatoria	-	-	-	-	-	10	-	24
Total	**25**	**250**	**75**	**50**	**50**	**50**	**25**	**50**

Phytoplankton Respiration, Photosynthesis and Relative Productivity

The results of the concentrations of initial oxygen and oxygen in light and dark bottles in the Gao Lagoon are presented in Table 4.3-7a while those for gross respiration, net photosynthesis and relative productivity are presented in Table 4.3-7b. The magnitudes of respiration, gross and net photosynthesis, and relative productivity decreased from the mouth of the lagoon upstream. The negative results from net photosynthesis could be attributed to high respiratory activity of other organisms (bacteria, microinvertebrates, etc.) as well as oxygen used in the decomposition of organic matter. The long period of 12hrs could also have been an artifact in obtaining high response rates. A six-hour period of incubation would likely have resulted in lower respiratory rates.

Table 4.3-7a
Initial light and dark bottle Oxygen concentrations at the Tema Surface Water Stations.

	Oxygen Concentration in mg/L		
	Initial Oxygen (IB)	Oxygen Light Bottle (LB)	Oxygen Dark Bottle (DB)
GS1TEM LW	17.6	4.67	3.15
GS3TEM LW	14.4	2.74	1.72
GS5TEM LW	23.9	4.27	2.64
GS5TEM LW Replicate	37.1	7.21	3.96

Table 4.3-7b
Respiration, Gross and Net Photosynthesis and Relative Productivity.

Station	Gross Photosynthesis ($mg0_2$/L/hr)	Net Photosynthesis $mg0_2$/L/hr	Respiration $mg0_2$/L/hr	Relative Productivity $mgC/m^3/hr$
1	3.25	-2.49	33.14	84.64
2	1.63	-1.64	22.26	42.45
3	1.02	-0.97	12.68	26.56
3Repl	1.52	-1	14.44	39.58

Phytoplankton (Takoradi/Aboadze)

The phytoplankton species present included: the algal phylum Chlorophyceae (green algae) with a total of 9 species; Cyanophyceae (blue green algae) with 4 species, and Bacillariophyceae (diatoms) with 5 species (Table 4.3-8). There are more photosynthesizing algal species (Chlorophyceae and Cyanophyceae) present than there are non-photosynthesizing algal species (diatoms). The prevalence of green algae and blue green algae may indicate more fresh than brackish or saline conditions of the waters. Finally, apart from the blue green algae, all other algal populations were relatively low. This may indicate relatively harsh conditions associated with the establishment and growth of blue-green algae.

Table 4.3-8
Phytoplankton analysis at Takoradi (Phytoplankton cells/ml).

Taxon	**GS8TAD ww**	**GS9TAD ww**	**GS10TAD ww**	**GS11TAD ww**	**GS12CTAD**
Chlorophyceae/ Green algae					
Ankistrodesmus	-	-	1	-	-
Chlorella	-	22	-	13	-
Closterium	3	-	17	-	-
Coelastrum	-	-	-	14	-
Pediastrum	-	-	-	60	-
Scenedesmus	44	5	22	65	11
Staurastrum	-	-	5	-	-
Tetraedron	-	-	3	3	8
Ulothrix	15	-	-	-	-
Cyanophyaceae/Blue algae					
Anabaena	-	-	21	28	-
Microcystics	-	-	5,475,52	35	-
Merismopedia	70	-	22	69	-
Oscillatoria	164	85	79	552	1035
Bacillariophyceae/ Diatoms					
Gyrosigma	-	-	-	-	3
Melosira	-	-	-	-	8
Navicula	10	-	3	14	6
Synedra	7	10	12	11	45
Tabelaria	-	-	-	-	3

Phytoplankton Respiration, Photosynthesis and Relative Productivity

There were differences in the 6 hr and 9 hr results. The net photosynthesis after nine hours was negative, while it was positive after six hours (Table 4.3-9). The negative results are most likely due to excessive respiration from other microorganisms (bacteria, invertebrates, and zooplankton) as well as oxygen uptake by decomposing organic matter.

Table 4.3-9
Productivity at Takoradi (6 hours and 9 hours duration).

Station No.	Respiration		Net Photosynthesis		Gross Photosynthesis (mgC/m^3/hr	
	6 hours duration	9 hours duration	6 hours duration	9 hours duration	6 hours duration	9 hours duration
GS8 TAD WW	0.2	0.2	1.9	-0.2	72.9	10.4
GS9 TAD WW	0.7	0.6	0	-0.2	10.8	20.8
GS10 TAD WW	0.1	0.1	0.3	0.1	10.8	10.4

Intertidal Macroalgae

There was a high diversity of macrofauna and macroalgae in the rocky intertidal community at both Tema and Takoradi.

Intertidal Macroalgae (Tema)

The intertidal zone of the Tema site comprised a mixed bedrock, boulder, cobble, shingle, and shelly silty sand. The Tema seashore has been described as an extensive shallow – sloping platform with boulders, with a high shore backfacing the open sea but close to the embayment and inlet of The Gao Lagoon. It is largely colonized by ephemeral seaweed, possibly sustained by excessive nutrient inputs derived from the catchment area. The biotope is made of *Sargassum vulgare*, *Ulva fasciata,* littorinids, and *Chthamalus* spp. on mixed substratum.

The algal community includes mainly *Sargassum vulgare* and *Ulva fasciata* but with many other species including *Bachelotia antillarum, Enteromorpha flexuosa, Hypnea musciformis, Hydropuntia dentata, Grateloupia felicina, Centroceras clavulatum, Boodlea composita, Padina durvillei,* and *Chaetomorpha linum.*

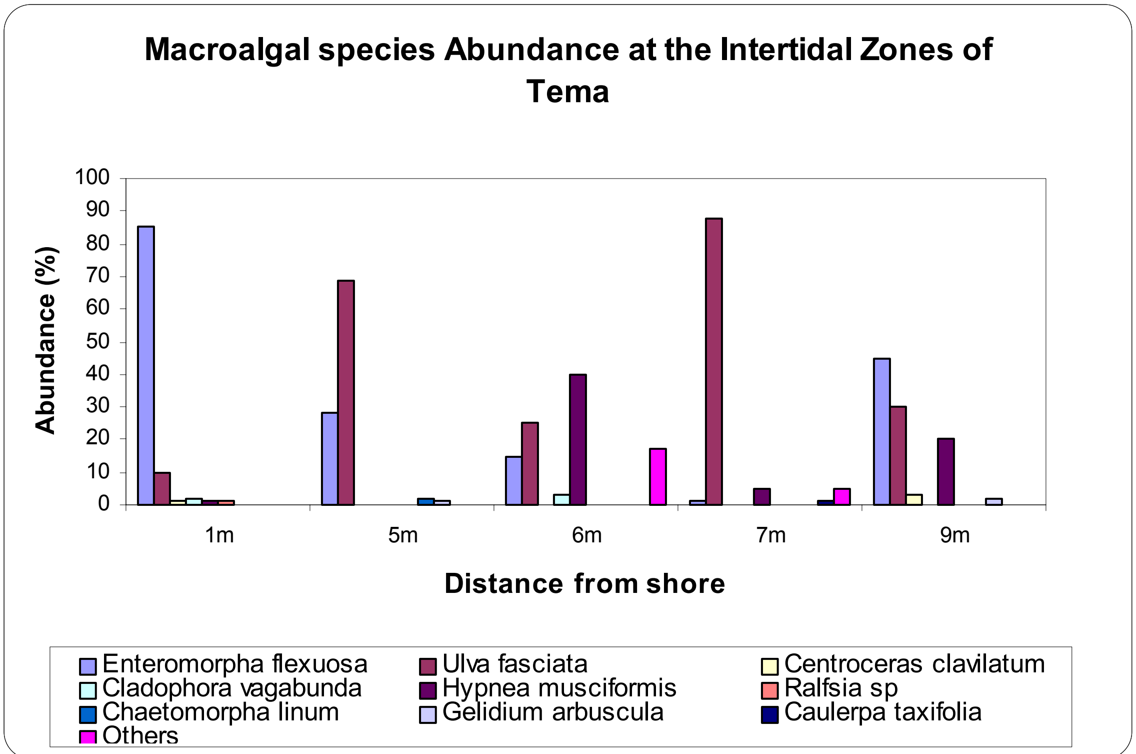
Quadrat Analysis

The macroalgae distribution, composition and abundance within 1m quadrats along a 10m line transect from the low water mark seawards are given in Table 4.3-10. The abundance of algae from between 31-36m from the low watermark, are shown in Figure 4.3-14.

Table 4.3-10
Distribution, species composition and abundance of macroalgae in the Tema intertidal zone.

	SPECIES	ABUNDANCE
Quadrat 1(31m)		
	Sargassum vulgare	85
	Ulva fasciata	10
	Centroceras clavilatum	1
	Cladophora vagabunda	2
	Hypnea musciformis	1
	Ralfsia sp.	1
Quadrat 2 (35m)		
	Ulva fasciata	69
	Sargassum vulgare	28
	Chaetomorpha linum	2
	Gelidium arbuscula	1
Quadrat 3 (36m		
	Hypnea musciformis	40
	Ulva fasciata	25
	Sargassum vulgare	15
	Cladophora vagabunda	3
	Others	17
Quadrat 4 (37m)		
	Ulva fasciata	88
	Hypnea musciformis	5
	Enteromorpha flexuosa	1
	Caulerpa taxifolia	1
	Others	5
Quadrat 5 (39m)		
	Enteromorpha flexuosa	45
	Ulva fasciata	30
	Hypnea musciformis	20
	Gelidium arbuscula	2
	Cladophora vagabunda	3
Nb: Quadrats start with zero (0) mark on 30 metres from the Low Water Mark (00°02´33.0E,0539´57.8N		

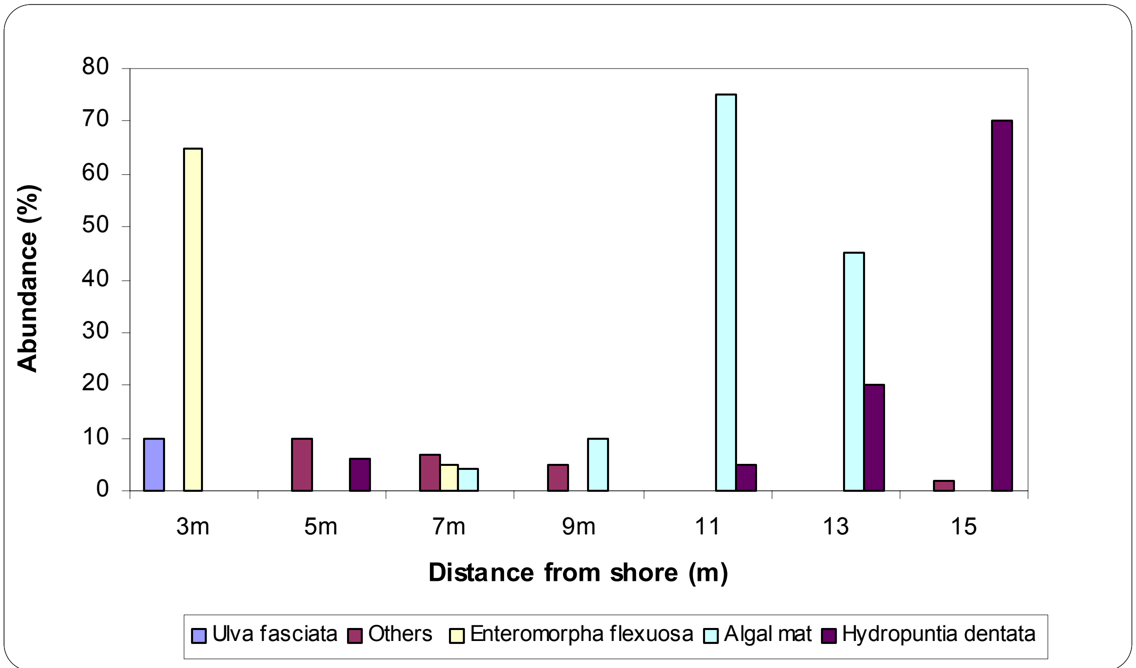
Figure 4.3-14
Abundance of algal species at 10m distance from low water mark.



Intertidal Macroalgae (Takoradi)

The algal community comprises over 15 species, dominated by *Ulva fasciata, Enteromorpha flexuosa, Hydropuntia dentata* and algal mats (Figure 4.3-15).

Figure 4.3-15: Dominance of Macroalgal Species from the Low Water Mark at Takoradi.



Quadrat Analysis

The macroalgae distribution, composition and abundance within 1m quadrats along a 10m line transect from the low water mark seaward are given in Table 4.3-11.

Table 4.3-11
Macroalgae Composition and Distribution in Quadrats at Takoradi.

Distance from Shore	Species	Abundance (%)
Quadrat 1(0m)		
Quadrat 2 (3m)		
	Ulva fasciata	10
	Enteromorpha flexuosa	65
	Bachelotia antillarum	5
	Gelidium arbuscula	1
	Ralfsia expansa	19
Quadrat 3 (5m)		
	Ulva fasciata	40
	Bachelotia antillarum	2
	Gelidium arbuscula	40
	Hydropuntia dentata	6
	Cladophora frolifera	2
	Others	10
Quadrat 4 (7m)		

Distance from Shore	Species	Abundance (%)
	Ulva fasciata	35
	Enteromorphar flexuosa	5
	Ralfsia expansa	4
	Algal mat	4
	Centroceras clavulatum	45
	Others	7
Quadrat 5 (9m)		
	Ulva fasciata	15
	Bachelotia antillarum	50
	Algal mat	10
	Chaetomorpha linum	3
	Hypnea musciformis	2
	Others	5
Quadrat 6 (11M)		
	Ulva fasciata	15
	Ralfsia expansa	1
	Hydropuntia dentata	5
	Algal mat	75
	Chaetomorpha linum	2
	Hypnea musciformis	1
	Padina durvillei	1
Quadrat 7 (13m)		
	Ulva fasciata	6
	Cladophora frolifera	6
	Algal mat	45
	Hydropuntia dentata	20
	Hypnea musciformis	4
	Padina durvillei	5
	Sargassum vulgare	4
	Centroceras clavulatum	10
Quadrat 8 (15m)		
	Hydropuntia dentata	70
	Cladophora frolifera	3
	Sargassum vulgare	5
	Dictyotya ciliolata	4
	Padina durvillei	10
	Hypnea musciformis	2
	Laurerncia majuscula	3
	Centroceras clavulatum	1
	Others	2

Benthic Macrofauna of Tema and Takoradi

A total of 50 species belonging to 4 major taxa were identified at the intertidal zones of Tema and Takoradi.

<u>**Sediment biology**</u>

Macro infauna (Gao Lagoon)

The Gao lagoon at Tema does not appear to support much macrobenthic fauna as very few species were recorded. Polychaetes were the only organisms found in the grab samples. These were at Stations GS2 TEM where a capittelid and a *Nereis* sp. were found and at Station GS4 TEM, which recorded one capittelid and *Notomastus latericeus.* The fiddler crab, *Uca tangerii,* and the gastropod, *Pachymelania* sp. occurred in large numbers within the mangrove vegetation along the Gao lagoon.

Macrofauna (Intertidal)

The total number of species recorded at Tema was 26. This was made up of 8 polychaete species, 4 crustacean species, 9 mollusc species and 5 species placed in ‘others’ category. Table 4.3-12 shows the occurrence and relative abundance for the major taxonomic groups observed in each of the intertidal zones. The most prevalent taxon was represented by an extensive mat of the polychaete worm *Onuphis* sp., followed by *Tharyx dorsobranchialis* (Cirratulidae) and *Capitella capitata* (Capitellidae).

The lower intertidal zone at Tema exhibited the highest number of macrofaunal species (with 25 individuals) (Figure 4.3-16).

Table 4.3-12
Relative abundance of common intertidal benthic macrofauna.

SPECIES	TEMA		TAKORADI/ABOADZE	
	Lower IZ	Upper IZ	Lower IZ	Upper IZ
POLYCHAETA				
Eurythoe complanata	+	-	+	-
Nereis sp.	++	-	+	++
Capitella capitata	+ + +	-	-	-
Onuphis sp.	+ + + + +	-	-	-
Capitellids	+ +	-	-	-
Notomastus latericeus	+	-	+	-
Tharyx dorsobranchialis	+ + + +	-	-	-
Spionid indet	-	-	+	+
Lumbrinereis sp.	+	-	-	-
CRUSTACEA				
Excirolana sp.	+	+	-	+
Amphipods	+ +	-	++	-
Talitrus sp.	-	+ +	-	+ +
Decapod crustaceans	+	+	+	+

SPECIES	TEMA		TAKORADI/ABOADZE	
	Lower IZ	Upper IZ	Lower IZ	Upper IZ
MOLLUSCA				
Thais nodosa	+	-	+	+
Thais haemastoma	+ + +	-	+ + +	+
Patella safiana	+	-	+	+
Siphonaria pectinata	+	+ +	+	+ +
Fissurella nubecula	+	-	+ + +	+
Ceritium sp.	+ +	-	+	-
Littorina punctata	-	+ +	-	+ +
Nerita atrata	-	+	+	+
Chthamalus sp.	-	+ +	-	+ +
Balanus sp.	+	-	+	-
Clibanarius sp.	+	-	-	-
Ostrea tulipa	-	+	-	-
Ocypoda cursor	-	+	-	+
OTHERS				
Eucidaris tribuloides africana	+	+	++	-
Echinometra lucunter	+ +	-	+ +	+
Ophiuroidea	+	-	+	-
Palythoa sp.	-	-	+	-
Zoanthus sp	+	-	+	-
Abundance range: - = 0; + = (0-5); ++ = (6–10); +++ = (11–15); ++++ = (16–20); +++++ (20+)				

Macroinfauna

A total of 24 species, comprising 4 polychaete species, 4 crustacean species, 11 mollusc species, and 5 species placed in ‘others’ category, were found in the intertidal zone of the Aboadze locality. The species placed as ‘others’ category included mainly echinoderms, anthozoans and other decapods.

A higher number of molluscan species was recorded at the Takoradi intertidal zone, which has extensive mats of different species of algae. As most of the molluscs are grazers of algae, food availability could account for the higher abundance of molluscs at Takoradi. Low species counts were observed in the lower intertidal zone for polychaetes and crustaceans at Takoradi (Figure4.3-16). The upper intertidal zone at Takoradi supports quite an appreciable number of fauna (Table 4.3-12). The rock pools at Takoradi also support important fish species including *Microspathodon frontatus* (territorial damselfish), *Rupescartes atlanticus,* and *Pseudoscarus hoefleri.*

Figure 4.3-16
Macrofauna distribution at the Lower intertidal zones of Tema and Takoradi.

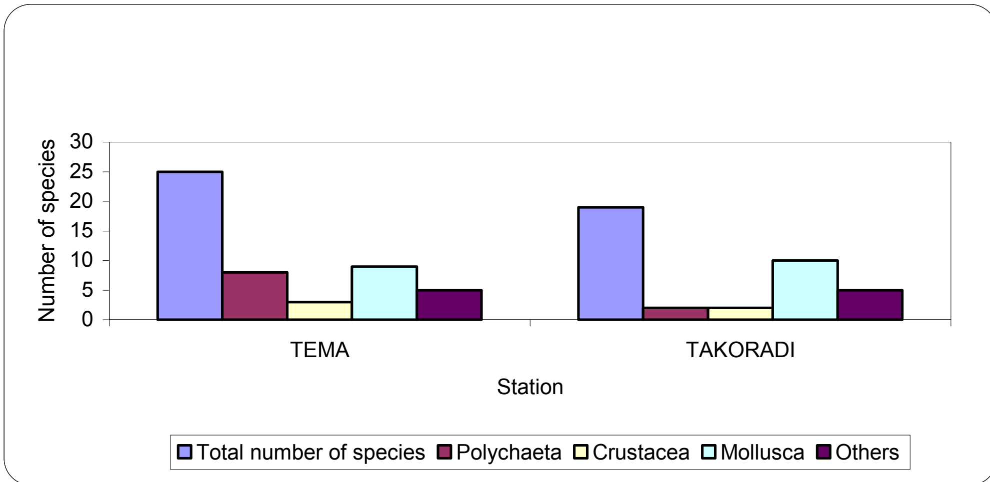
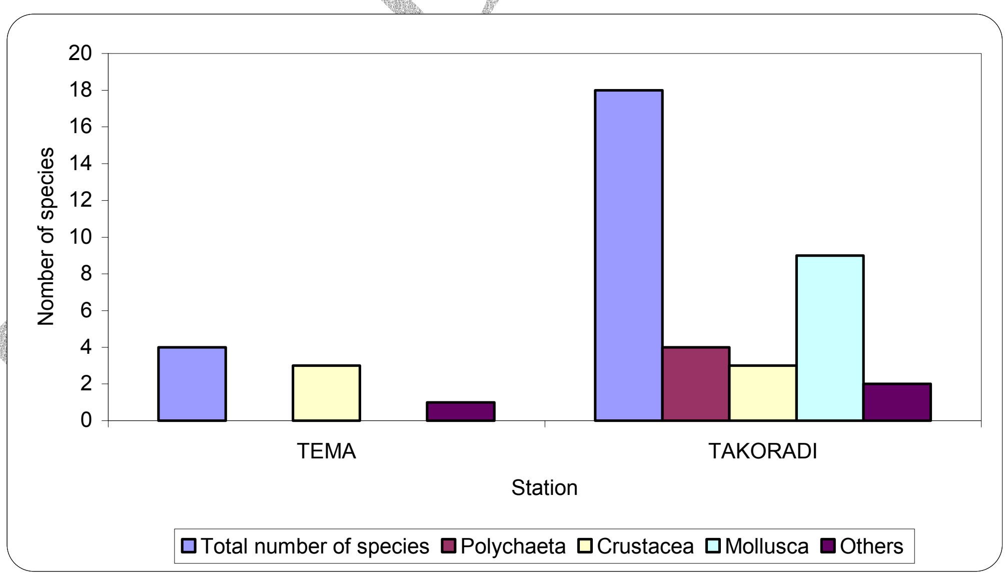


Figure 4.3-17
Macrofauna distribution at the Upper intertidal zones of Tema and Takoradi.



In the upper intertidal zone, a relatively higher number of species was recorded at Takoradi than at Tema, with the dominant taxon being molluscs. A striking feature here was the absence of polychaetes and molluscs at Tema (Figure 4.3-17).

Zooplankton Results

Results of the zooplankton community analysis in the Gao Lagoon at Tema and the adjoining intertidal zone and the Takoradi/Aboadze wetlands and its adjoining intertidal zone are presented in Appendix D. The Gao lagoon as monitored during the high tide period in supported five major zooplankton groups presented in the lagoon. The groups are represented by the copepod community, the copepod developing forms, the decapod larvae, the fish and fish eggs community and the other groups (made up of several smaller group of individuals, including the rotifers). The copepod community, including the calanoid, cyclopoid, and harpacticoid copepods, was the most important group, in terms of numbers in sampling stations GS1TEMLW, GS3TEMLW and GS5TEMLW (replicate). In stations GS1TEMLW and GS2TEMLW (closest to the sea), the decapod larvae, comprising shrimp and crab larvae, were found in large numbers and constituted the second most important group in the plankton community (Figure 4.3-17). At station GS3TEMLW, located midway upstream of the lagoon, fish larvae and fish eggs constituted as much as 46 percent, in terms of numbers. At station GS5TEMLW, the replicate samples did not differ very significantly in terms of the composition of the different communities, from that of the other groups (Figure 4.3-17) At the intertidal zone, the copepod developing forms constituted about 25 percent of the total zooplankton count. The rest of them were represented in approximately equal proportions (Figure 4.3-17).

At the low tide level sampling, fish larvae and fish eggs constituted the most important group at station GS1TTEM LW (LT) (33 percent). This was followed by the copepod crustaceans (25 percent) and the copepod developing forms at 17 percent. The meroplanktonic decapod crustaceans constituted only 9 percent of the total zooplankton count. At station GS3TEMLW, the fish and fish eggs constituted the most important group at 34 percent of the total zooplankton count. The decapod crustacean larvae was the least important group at 8 percent. At station GS5TEMLW, fish larvae and fish eggs made up 23 percent of the total count and was second to the other groups at 27 percent. The smallest group recorded from this station was the copepod developing form at 16 percent. The replicate sample at Station 5, GS5TEMLW (replicate), however, had the fish larvae and the fish eggs community as the dominant group (34 percent) with the decapod crustacean at only 6 percent of the total count as the least important group in that station. At the intertidal zone station GS7C, the copepod developing forms were the largest group and constituted 38 percent of the total zooplankton count. The fish and fish eggs group was the smallest group (7 percent) represented in samples from that station.

In the Takoradi/Aboadze wetlands sampling stations GS8TADWW to GS11TADWW, the zooplankton community was comprised largely of copepods, copepod developmental stages, cladocerans, rotifers, and several other minor groups like the oligochaetes, insect larvae, and hydracarina.

At the sampling station GS8TADWW, the copepods were the most important group at 35 percent of the total zooplankton count. This was followed by the cladocerans at 20 percent and the rotifers at 15 percent, in that order. The meroplankton was not represented in the samples. At station GS9TADWW, GS10TADWW and GS11TADWW, the copepod group continued to be the most important constituting 29 percent, 28 percent, and 30 percent respectively of the total zooplankton counts from those stations. In all these stations, no meroplankton were encountered. The rotifers, cladocerans and the mixed or other groups contributed between 12 percent and 25 percent of the total zooplankton counts in those stations. The fish and fish eggs dominated the zooplankton sample from the intertidal station GS12CTADIZ at 35 percent. This was followed by the copepod developing forms at 19 percent, the copepod crustaceans at 17 percent and the decapod crustacean larvae at 15 percent of the total zooplankton count. The rotifers and the mixed or other groups were represented in the samples at 7 percent respectively.

Discussion

Tema

The levels of total coliform and faecal coliform bacteria encountered in the study areas ranged from 180 CFU/100 ml to 10830 CFU/100 ml and from <1 CFU/100 ml to 96 CFU/100 ml for the total coliform and faecal coliform counts, respectively. A sample from only one site ITZ (LT) with less than 2400 CFU/100 qualifies to be used for primary contact such as swimming.

Microbial counts were relatively low throughout the sampling areas. Of the six water samples, total coliform bacteria, total heterotrophic bacteria, *Pseudomonas*, yeasts and moulds were consistently present in all.

Aboadze/Takoradi

The levels of total coliform and faecal coliform bacteria encountered in the study areas were high, ranging from 770 CFU/100ml to 4800 CFU/100ml and from <1 CFU/100ml to 230 CFU/100 for the total coliform and faecal coliform counts, respectively. Samples from sites GS8 TAD WW and ITZ (HT) that exhibited fewer than 2400 CFU/100 qualify to be used for primary contact such as swimming.

In view of the small numbers of facultative bacteria and absence of sulfate reducers recorded, it is expected that oxidative forms would be extremely scarce.

Tema

Microalgal populations were generally low except for the blue green algae. The dominance of diatoms in the lagoon is indicative of the open nature of the Gao lagoon.

The prevalence of green algae and blue green algae in the Aboadze wetland may indicate more fresh than brackish or saline waters. Finally, apart from the blue green algae, all other algal populations were relatively low. This may indicate conditions favouring the establishment and growth of blue green algae. Primary productivity values obtained suggest reasonably healthy aquatic production systems.

Macrofauna

A total of 50 species belonging to 4 major taxa were identified at the intertidal zones of Tema and Takoradi. In the upper intertidal zone, a relatively higher number of species was recorded at Takoradi than at Tema with the dominant taxon being molluscs. A striking feature here was the low occurrence of polychaetes and molluscs at Tema. This could possibly be due to the steeper slope of the upper intertidal zone, low algal cover as well as a less favorable environment due to the prolonged exposure at low tide.

The polychaete, *Onuphis* sp., occurred in high densities of over 500 individuals/m^2 in the mid-intertidal zone at Tema. This species is a tubiculous scavenger and its high densities may suggest abundant food. It prefers living in sandy sediments and therefore can serve as a biomonitor of sediment change in the intertidal environment.

4.4 WILDLIFE AND ANIMAL RESOURCES

Issues of conservation significance in the onshore and nearshore habitats, Tema and Aboadze, with regard to the WAGP Project in Ghana are presented below where the proposed Regulating and Metering (R&M) stations will be installed. Actual animals observed and recorded for the two locations are presented in Table 4.4-1.

4.4.1 Tema

From previous studies, about 25 species of herpetofauna (including 5 sea turtle species), 46 species of birds, 15 species of mammals, and a variety of fish species are known to occur in the area.

Five herpetofaunal species are of international conservation significance, all of which are listed on CITES Schedule II. Three of these species, *Varanus niloticus,* (Nile monitor), *V. exanthematicus*, (savanna monitor) and *Python regius*, were recorded during the survey (Table 4.4-1). The same three species out of five are of national conservation significance, listed under Schedule II, National Wildlife Conservation Regulations. Five species of sea turtles: *Caretta caretta* (loggerhead turtle), *Chelonia mydas* (green turtle), *Eretmochelys imbricata* (hawksbill turtle), *Lepidochelys olivacea* (olive ridley turtle), and *Dermochelys coriacea* (leatherback turtle) occur in the coastal waters of Ghana. With the exception of the hawksbill, the rest are known to nest in significant numbers on the eastern beaches adjoining the project site at Tema. All five species of sea turtles are listed by CITES and National Wildlife Conservation Regulations under Schedule I. The loggerhead and green turtles are listed by IUCN as endangered (EN) while the hawksbill and leatherback are listed as critically endangered (CR).

Only one of the 46 bird species known to occur in the area, *Falco naumanni* (lesser kestrel), is categorized as vulnerable (VU) on the IUCN Red List. It was, however, not recorded in the survey. Fifteen species of birds are of national conservation significance, with five listed under Schedule I, and 10 under Schedule II. Of these, only two species, *Lonchura cucullata* and *Ploceus cucullatus* were recorded during the survey (Table 4.4-1).

Four of the 15 mammal species are of international conservation significance. Three are categorized in the IUCN Red List, but they were not recorded during the survey. One species is listed on CITES Appendix II, but was not recorded in the survey. There are 10 species of national conservation significance, of which only one species, *Cricetomys gambianus* (giant rat), was recorded (Table 4.4-1) in the survey (Schedule II).

4.4.2 Aboadze/Takoradi

From previous studies, about 20 species of herpetofauna, 50 species of birds, and 19 species of mammals are known to occur in the Aboadze area, along with a limited variety of wetland fish species.

Six herpetofaunal species are of international conservation significance, out of which one species, *Kinixys homeana* (hinged tortoise) is designated data deficient (DD) on the IUCN Red List of Endangered Species. The other five species, *Chamaeleo gracilis* (chameleon), *Varanus niloticus* (Nile monitor), *V. exanthematicus* (savanna monitor), *Python regius* (royal python), and *P. sebae* (African python) are listed in Appendix II by CITES**.** These five species were all recorded in the actual survey (Table 4.4-1). All of these species except the chameleon are also of national conservation significance (listed under Schedule II, National Wildlife Conservation Regulations), as well as *Pelomedusa subrufa* (marsh terrapin), which was also recorded in the actual survey (Table 4.4-1).

None of the 50 bird species known to occur in the Aboadze area is of international conservation significance, but 14 species are of national conservation significance (four are listed on Schedule I, and 10 on Schedule II). Out of the four Schedule I species, *Milvus migrans* (black kite) and *Neophron monachus* (hooded vulture), were recorded in the survey, while two out of the 10 Schedule II species, *Lonchura cucullata* (bronze manikin) and *Ploceus cucullatus* (village weaver) were also recorded (Table 4.4-1).

Six of the 19 mammal species are of international conservation significance. Three of these, *Crocidura oliveri* (white-toothed shrew), *Cephalophus maxwelli* (Maxwell's duiker), and *Neotragus pygmaeus* (royal antelope), categorized VU, Lower Risk (LR) and LR (IUCN Red List) respectively, were recorded during the actual survey (Table 4.4-1). Two species are listed on CITES Appendix II, while 11 species are of national conservation significance (six Schedule I, and five Schedule II).

Table 4.4-1
Fauna Observed at the R&M Sites.

Species	**Common Name**	**Actual Species Recorded**	
		Aboadze	**Tema**
Herpetofauna			
Reptilia			
Chelonia (Tortoises/Terrapins)			
Pelomedusa subrufa	Marsh Terrapin	x	
Squamata: Lacertilia			
Chamaeleo gracilis	Chameleon	x	

Species	Common Name	Actual Species Recorded	
		Aboadze	Tema
Herpetofauna			
Varanus exanthematicus	Savanna Monitor	x	x
V. niloticus	Nile Monitor	x	x
Squamata: Serpentes			
Python regius	Royal Python	x	x
P. sebae	African Python	x	
Aves (Birds)			
Accipitricidae			
Milvus migrans	Black Kite	x	
Neophron monachus	Hooded Vulture	x	
Corvidae			
Corvus albus	Pied Crow		x
Ploceidae			
Lonchura cucullata	Bronze Mannkin	x	x
Ploceus cucullatus	Village Weaver	x	x
Mammalia			
Rodentia			
Cricetomys gambianus	Gambian Giant Pouched Rat		x
Artiodactyla			
Cephalophus maxwelli	Maxwell's Duiker	x	
Neotragus pygmaeus	Royal Antelope	x	

4.5 FISH AND FISHERIES RESOURCES

The artisanal fisheries in Ghana rely on fish from both the inshore and offshore marine environment. The coastal lagoons and estuaries, as a whole, are also very important sources of fish and shellfish in the country. While the contribution of any one lagoon or estuary may be comparatively small, these provide reasonable quantities of fish products for subsistence purposes.

From the EBS dry season survey, it is estimated that about 20 to 30 individuals and small companies fish from the 18.6 Ha Gao Lagoon near the R&M site at Tema. The frequency of fishing is observed to be very irregular but seems to follow some peaks and troughs that are dictated by the nature of the fishing pattern in the marine environment. A 6-day fishing-week is strictly enforced with the 7th day, usually a Tuesday, observed as a fishing holiday in the in the lagoon. During periods of celebration of annual traditional purifications rites, additional fishing holidays may be declared. Besides these periods, there are no restrictions on the number of persons, or regulations on the cultural identities of persons eligible to fish in the lagoon.

Five main types of fishing methods are practiced in the lagoon. These are the cast net, basket traps, hook and line, set nets, and hand-picking for oyster. It must be emphasized that that these fishing methods are practiced at different intensities at different times of the year. The structure of the Gao Lagoon fishery and estimated yields are presented in Table 4.5-1. A description of the fishery of the Gao Lagoon is presented in Appendix D.

Table 4.5-1
Structure of the Gao Lagoon Fishery and Estimated Yields.

Type of Fishing Practice	No. Fishing Days/Wk	Average Yield(Kg)/ Man day	Est. Man days/wk	Yield/wk (Kg)	Yield/ Year (Kg)	Yield/Ha Year(Kg)
Basket Traps (*Callinectes* sp.)	6	1.2	12	14.4	748.8	40.25
Cast net (variety of fish)	6	5.75	12	69	3588	192.9
Set net (variety of fish)	6	3	12	36	1872	100.6
Hook and line (mixed species	6	1.5	12	18	936	50.3
Hand picking (Oysters	6	1	6	36	1872	100.6
Total						484.65

Based on interviews granted by some fishermen and users of the Gao lagoon, as well as direct observations made during the survey, about 14 species of fish and shellfish have been listed as being very common in the Gao Lagoon (Table 4.5-2). About 63 species of fish from the nearshore beach-seine fishery that are most likely to be regular visitors to the lagoon is also compiled and presented in Appendix D.

Table 4.5-2
Fish and Fisheries Resources of the Gao Lagoon

Fish Species	Common Name
Sphyraena sp.	Baracuda
Pomadasys peroteri	Parrot grunt
Chloroscombus chryurus	Atlantic bumper
Galeoides decadactylus	African threadfin
Brachydeuterus auritus	Big-eye grunt
Pseudotolithus senegalensis	Cassava croaker
Mugil cephalus	Flat head grey mullet
Scomberomerus tritor	West African mackerel
Selene dorsalis	African moonfish
Ilisha africana	West African sardine
Sardidella spp.	Sardine
Sarotherodon melanotheron	Black chin tilapia
Penaeus notialis	Pink shrimp
Ostrea spp.	Oyster

Comparative fish yield from 3 lagoons, Sakumo II (in the Greater Accra Region near the Gao lagoon), Fosu Lagoon, and Muni Lagoon, both in the Central Region are presented in Table 4.5-3.

Table 4.5-3
Comparative Fish Yield from Three Coastal Lagoon and Gao Lagoon

Coastal Lagoon	Location/ Region	Est Surface Area (Ha)	Yield Kg/Ha	Reference
Fosu	Central	47	452-664	Blay & Ameyaw-Asabre (1993)
Muni	Central	68.8	125-150	Koranteng et al. (2000)
Sakumono	Gt. Accra	106.3	150	Pauly, 1976
Gao	Gt. Accra	18.6	484.65	ESL, 2003

The size structure of the fisheries of the Gao Lagoon from a day's cast net fishing catch shows that the predominant fish species in the lagoon were the cichlids, represented by the black-chin tilapia, *Sarotherodon melanotheron*, which constituted about 41 percent of the catch by weight. The second most important group were the mugils, represented by *Mugil cephalus,* at 23 percent. Two species of the swimming crab, *Callinectes gladiator (marginatus)* and *C. pallidus* together constituted 16 percent (at 14 percent and 2 percent respectively). The remaining 20 percent was comprised of several juvenile groups of mixed species (Figure 4.5- 1). Within individual groups, results of meristematic measurements indicate that most of the catch was comprised of juveniles. For example, the size range of *Sarotherodon melanotheron* indicated than more that 50 percent of the catch was below 10cm TL, with none of the individual weights exceeding 20g (Figure 4.5-2). Similarly, the *Callinectes* spp. size classes are represented by carapace lengths that fall largely below that of average-size swimming crabs that are harvested from the seas.

Figure 4.5-1
Percent Composition of Cast Net Catch from Gao Lagoon (Dec., 2002)

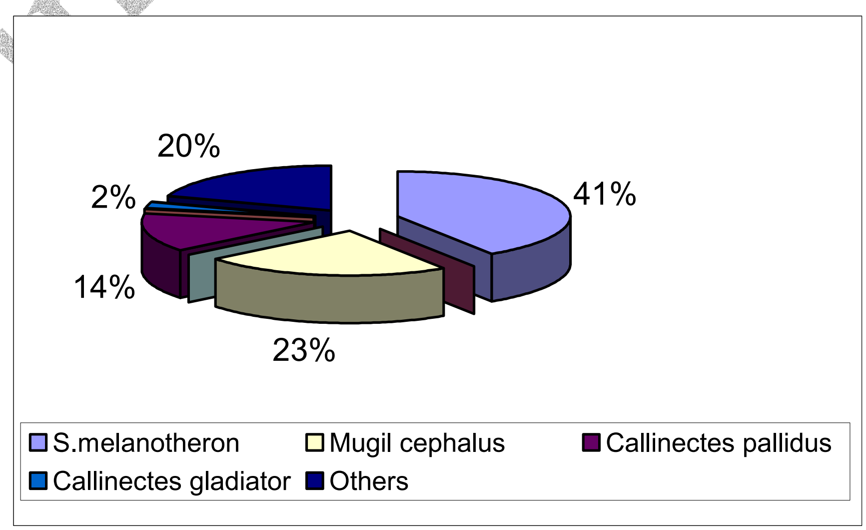
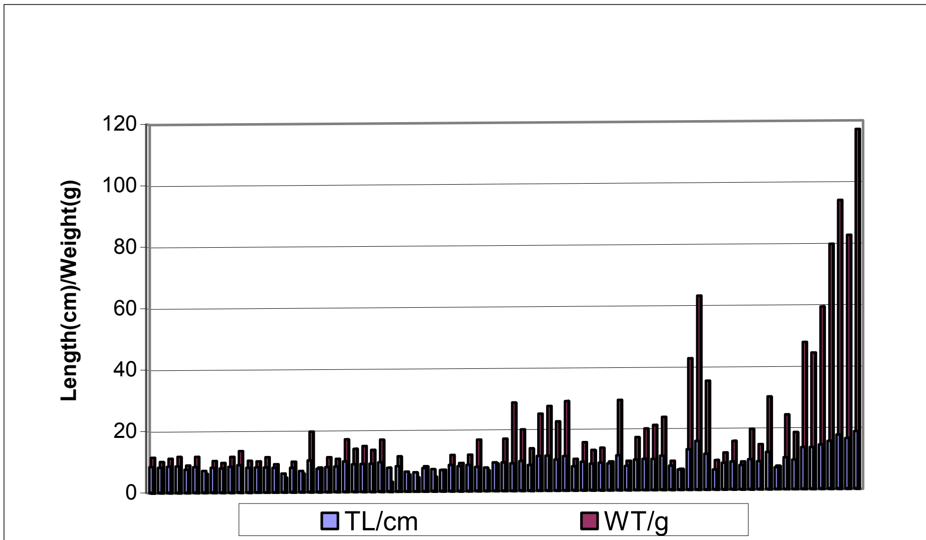


Figure 4.5-2
Size Structure of *Sarotherodon melanotheron* from the Gao Lagoon (Dec., 2002)



The log transformed graphs on fisheries resources (Figures 4.5-3, 4.5-4 and 4.5-5) show the length-weight relationship for *Mugil cephalus, Sarotherodon melanotheron,* and two the crab species of *Callinectes* from the Gao Lagoon. The scatter plot for *M. cephalu*s (Figure 4.5-3) indicates that the fishes caught are on average small in size. Since the mugils are large marine fishes, the fishes caught can be assumed to be juveniles that had entered the lagoon temporarily to forage; thus confirming the lagoon as a nursery ground and foraging grounds for that fish. The length-weight scatter graph for *S. melanotheron,* on the other hand, indicates the presence of more mixed sizes in the lagoon. *S. melanotheron* is a permanent resident of the lagoon, unlike *M. cephalus*, which migrates out to sea.

Figure 4.5-3
Length-Weight Relationship of Mugil cephalus in the Gao Lagoon.

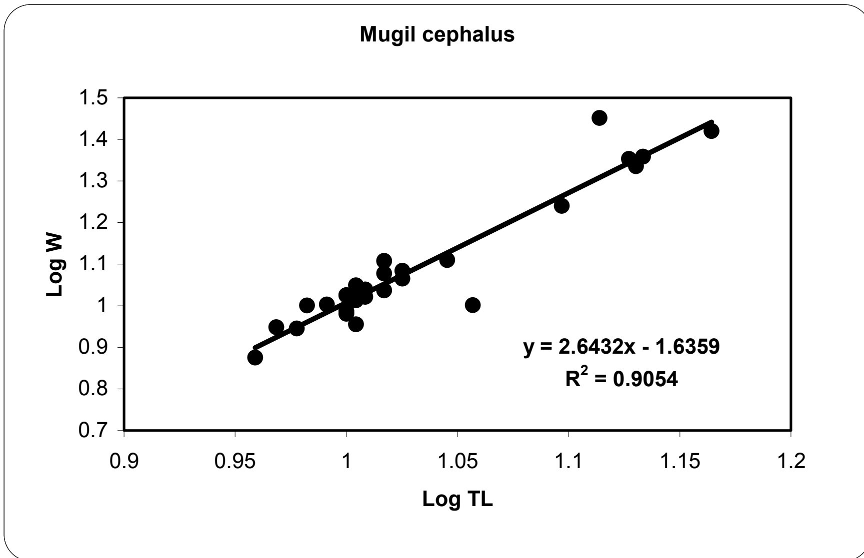


Figure 4.5-4
Length-Weight Relationship of *Sarothrodon melanotheron* in the Gao lagoon.

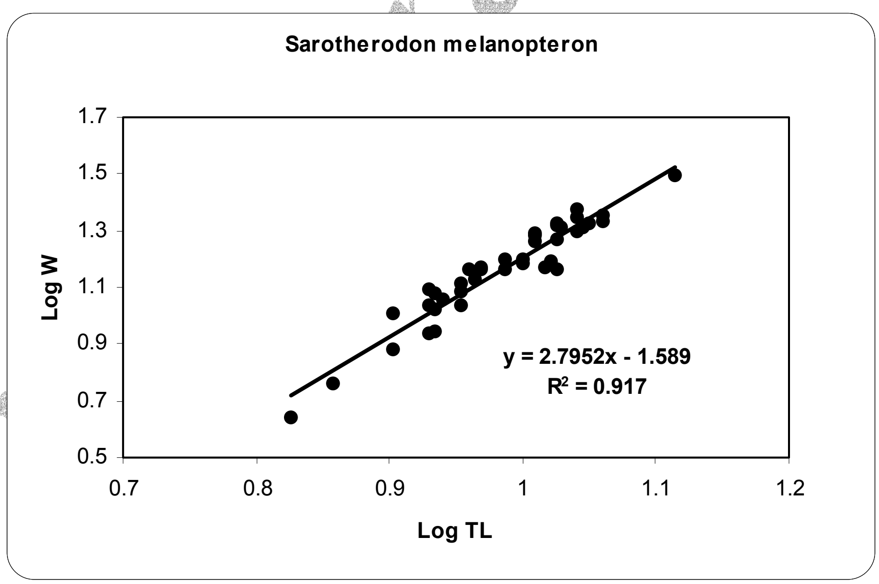
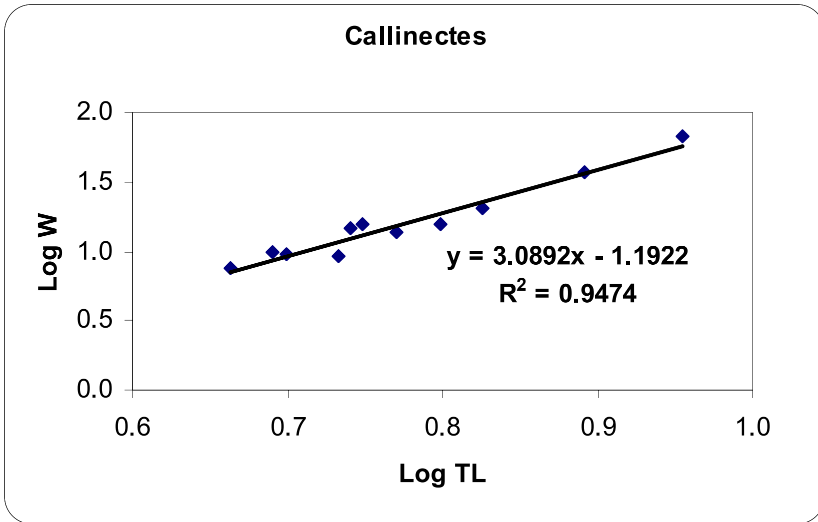


Figure 4.5-5
Length-Weight Relationship of *Callinectes* spp. in the Gao Lagoon



In the wetlands bordering the Aboadze/Takoradi R&M site, fishermen interviewed at the site indicated that fishing is very sparingly done and it is usually restricted to the method of basket fishing. This fishing practice is predominantly applied in the wetlands in the dry season. During the wet season when the entire wetland makes contact with the nearby Anankware Lagoon, the basket trap type of fishing method is augmented with hook and line fishing, both of which are deployed from small dugout or plank canoes. The most common fish species that occur in the wetlands are presented in Table 4.5-4.

Table 4.5-4
Common fish species of the Takoradi/Aboadze Wetlands.

Fish Species	Common Name
Clarias sp.	African Catfish
Heterobranchus sp.	African Catfish
Polypterus sp.	African Bichir
Heterotis niloticus	-
Tilapia spp.	-
Hemichromis fasciatus	-
Hemichromis bimaculatus	-

The structure of the inshore and nearshore fishery around the R&M sites in the Tema and Takoradi/Aboadze sites (Table 4.5-5) were examined and briefly discussed.

Table 4.5-5
Structure of the Inshore and Nearshore Fishery Around the Tema and Takoradi/Aboadze R&M Sites in Ghana.

Fish Village	Landing Beach	Total # Canoes	Total # of Fishermen	Major Fishing season	Minor Fishing season	Fishing Holidays	Annual Catch (MT)
Aboadze	Bronibima	116	1890	Jun- Sept.	Feb - May -	Tuesday	4,200
Aboadze	Akunamu (Aboadze Beach)	40	200	Jun- Sept.	Feb - May -	Tuesday	230
Tema	Canoe Beach Awoudum	193	2650	Jun- Sept.	Feb - May -	Tuesday	6300
Tema	Ashamang (New town)	194	1062	Jun- Sept.	Feb - May -	Tuesday	5000
Kpone	Laa Loi Naa	12	198	Jun- Sept.	Feb - May -	Tuesday	490
Kpone	Odunyama	62	323	Jun- Sept.	Feb - May -	Tuesday	360
Kpone	Sega	83	630	Jun- Sept.	Feb - May -	Tuesday	420

Source: Fisheries Research Unit, Ministry of Food & Agriculture, Tema

Discussion

The traditional artisanal inshore fishery in Ghana is well developed and provides about 70 percent of the total marine production in the country. This type of fishery is usually year-round but shows definite peaks and troughs over the course of the year.

The off-season marine fishery concentrates efforts on shallow nearshore areas, notably estuaries and coastal lagoons. These lagoons are known to be very productive areas functioning both as nursery and foraging grounds for several of the marine fish species. During the off-season fishing in the lagoons, a lot of the spawners and recruits become vulnerable to the kind of fishing practices that are employed. This may affect the secondary productivity and to a limited extent, the fish biodiversity in the area.

At the Tema location, the main water body that supports the finfish and shellfish fisheries is the Gao Lagoon. Preliminary results from this EBS indicate that the lagoon supports a relatively small size fishery, which is exploited largely by the Kpone community on the

Eastern side of the pipeline route. Nonetheless its estimated annual yield of about 9MT per annum makes it a fairly productive lagoon. The estimated annual yield of 464.65Kg/Ha compares very favorably with some of the selected coastal lagoon of like characteristics (Table 4.5-3).

The fisheries situation in the Aboadze site is more complex. The wetlands around the site of the R&M support air-breathing fishes like *Clarias* spp*., Heterobranchus* and *Polypterus* spp. The cichlids, like *Tilapia* spp. and *Hemichromis* spp*.,* are also present in moderate quantities.

The nearshore marine area is important to several coastal fishes by providing a nursery area, rich source of food and a shelter from predation. The area also supports fish and macro-crustaceans that move between offshore and estuarine/lagoonal habitats, in addition to serving as important spawning area as well as a foraging zone for a number of predators. This mobility of organisms introduces variability in both time and space of fish assemblages found in the habitat.

A survey of the catch of two commercial beach seine nets fishing in the nearshore waters of Sakumono near the Tema site between November 1999 and October 2001 provided information on the fish and macro-crustacean assemblage in the coastal waters in and around Tema (Nunoo, 2003). The nearshore assemblage was dominated by a large numbers of juveniles, showed seasonal changes in abundance, and had high species richness. It consisted of 63 fish species from 30 taxonomic families and 14 crustacean species from 5 taxonomic families. Other invertebrates of import in the catch were *Alloteuthis africana* and *Sepia* sp.. Examination of the offshore catch data by all gears that landed in and around Tema and the Aboadze landing beaches from 2000-2002 and documented by the Marine Fisheries Research Division of the Fisheries Directorate Table (4.5-4) showed that more than 80 percent (by number) of fish species found in beach seine catch at Sakumono were recorded in the offshore catch as adults. The structure of the inshore marine fishery also indicates that fishing intensively has exploited in the inshore and nearshore areas. Loss of fishery biodiversity and or abundance in the nearshore locations and the lagoon and estuaries can therefore not be solely attributed to external impacts on those water bodies.

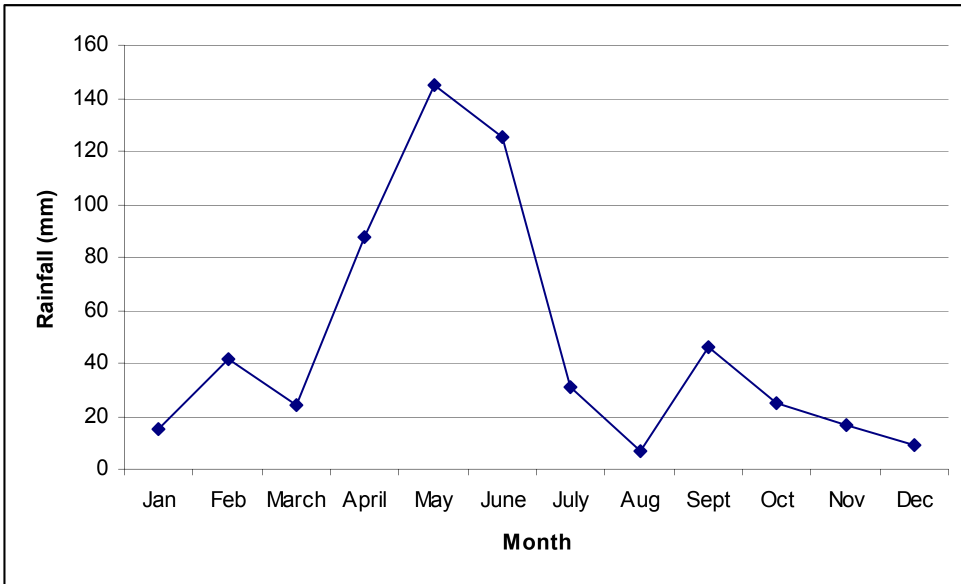
Generally, by the nature of the vegetation, the more coastal areas tend to have lower species diversity and abundance than areas farther inland, where biodiversity may be enhanced by the presence of rare or endemic species, which are more vulnerable to environmental change. Habitat disturbance in coastal areas therefore poses relatively less danger to biodiversity than disturbance in the more inland areas. Furthermore, with the exception of the sea turtles, whose prime nesting sites in Ghana are adjacent to the project site near Tema, the size of the area under the influence of the project at the two localities is quite insignificant in relation to the entire size of the coastal habitats of the country.

4.6 CLIMATE AND METEOROLOGY

4.6.1 Tema

The rainfall pattern in Ghana is generally bimodal; i.e. major and minor rainy seasons. In the Tema area, the major rainy season is normally between March and July while the minor season occurs between August and October. The month of June is usually considered the wettest month with mean rainfall of about 370mm (Figure 4.6-1). Tema is considered one of the driest in the country with mean annual rainfall of about 800 mm. The average monthly duration of solar radiation ranges between 4.4 and 9.3 hours. Monthly relative humidity for 1999 to 2001 was generally high all year round, ranging between 82 and 96 percent.

Figure 4.6-1
Mean monthly rainfall distribution at Tema (mean of 1999 – 2001)



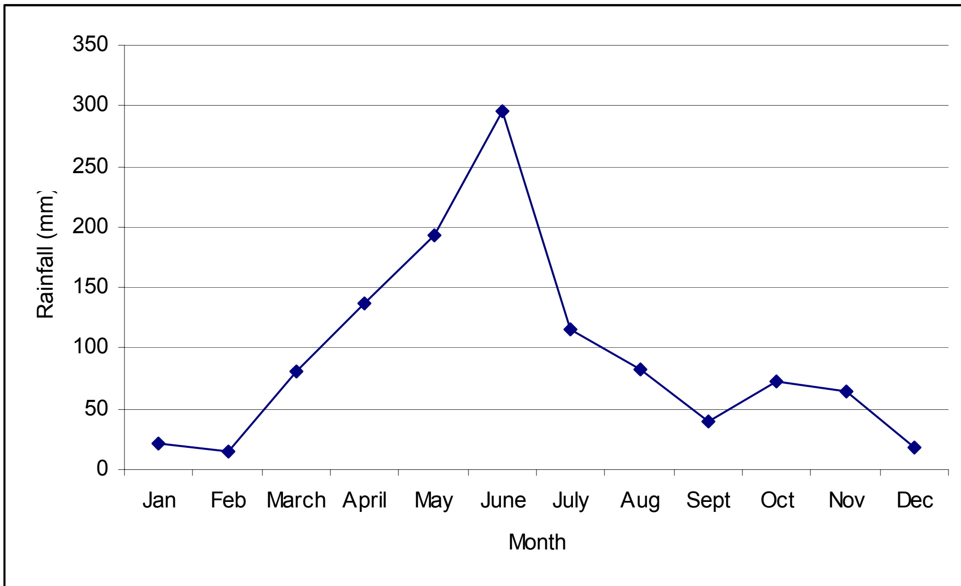
Ambient temperature ranges between 25 to 34°C with very small mean annual variations. The hottest month is normally in April (~34°C), and the coldest month is usually in August (~ 24.7°C).

The prevailing wind is south westerly, with a speed ranging between 3.2 and 6.1m/s at Tema but changes direction on certain occasions. For instance, the wind was recorded as being south easterly in December 1999.

4.6.2 Aboadze/Takoradi

Takoradi has a mean annual rainfall of about 1200 mm. The wettest months are May and June, which usually records more than 250 mm of rain during this period. There is consistent daily variation in relative humidity with night values (95 to 100 percent), slightly higher than daytime values (70 to 80 percent).

Figure 4.6-2
Mean monthly rainfall distribution at Takoradi (mean of 1999 – 2001)



There is little temperature variation during the year. Daily ambient temperature normally ranges between 27^{o}C in July to September and 31^{o}C in November to April. Barometric pressure is highest during night time and lowest during the hottest period of daytime.

The prevailing SW monsoon wind is relatively light but steady throughout the year with distinct diurnal variation relative to the land/sea breeze effect. Average monthly wind speed rarely exceeds 2.3m/s at Takoradi.

CHAPTER 5
ONSHORE RESULTS – TOGO

The Lome R&M station sampling locations are shown in Figure 5.0-1.

5.1 VEGETATION

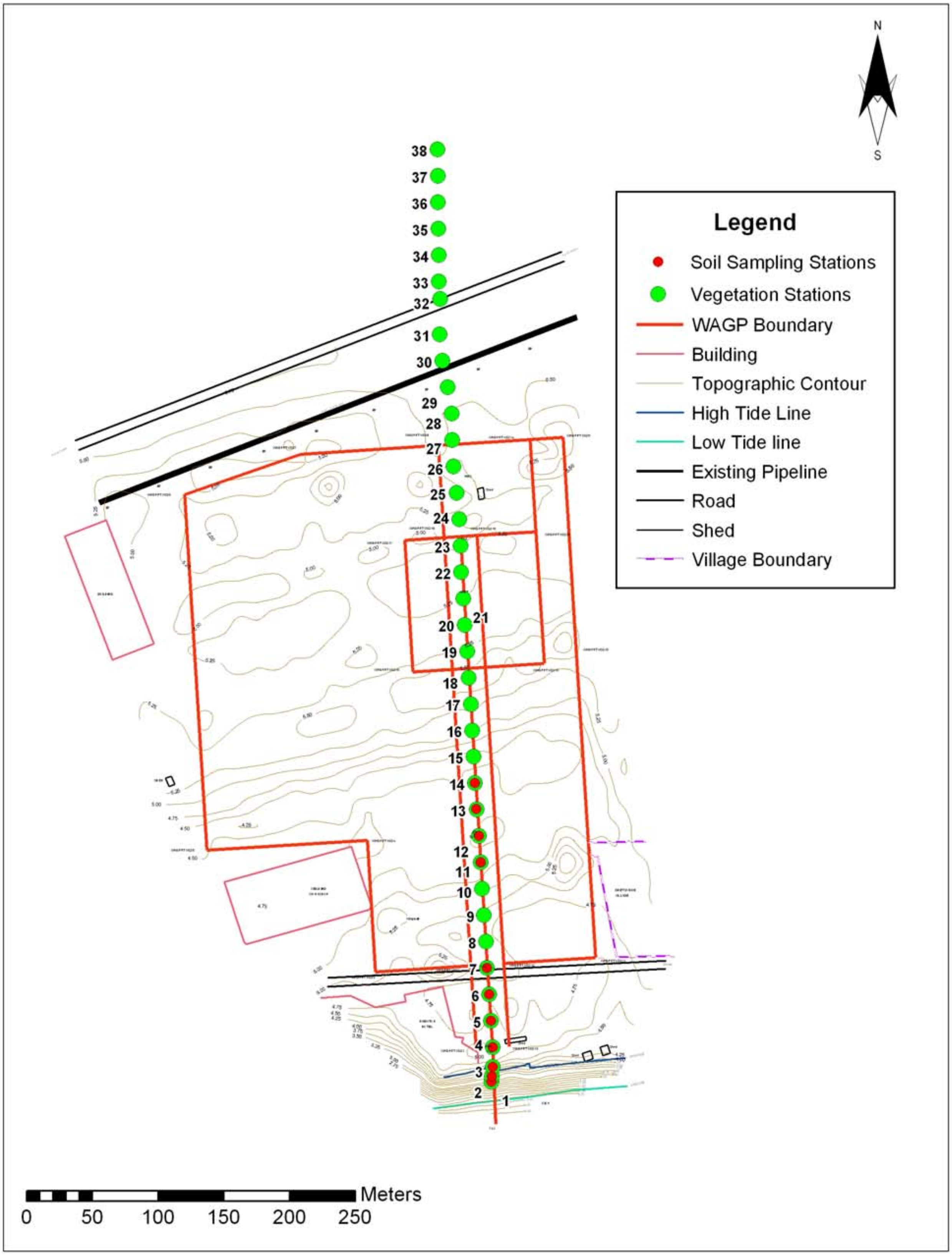
No natural plant communities were found along the transects that were studied. The coastline grasses and the former coconut plantations have given way to fallow land, as well as cultivated small market gardens, a practice that has intensified over the last ten years. A road also intersects the study area. The study transect across the project area in Togo spans three general habitat zones. The beach area consists of bare sand, extending about 30m from the sea (approximately 4 percent of the transect). The second section of the transect corresponds to a coastal fallow area which covers approximately 120m (or 17 percent) of the transect. The third section overlaps the market gardens area, which occupies some 80 percent of the transect.

5.1.1 Floral Resources

Herbaceous species represent 84 percent of the flora at the pipeline installation area. They are also the most widespread. This strong domination of herbaceous species indicates the strong human influence, essentially in the form of market gardens. Species such as *Daucus carota* (carrot), *Allium cepa* (onion), *Capsicum annuum* (pepper), *Ocimum basilicum* (basil), *Corchorus olitorius*, *Corchorus aestuans, Solanum macrocarpum* (African eggplant), *Cucumis melo* var. *agrestis* (melon), *Cucumis sativus* (cucumber), and *Arachis hypogea* (peanut) are the herbaceous species cultivated on the site. Among these, *Daucus carota*, *Allium cepa*, and *Ocimum basilicum* predominate. *Carica papaya* and *Cocos nucifera* are the sole bush and tree species cultivated, respectively. All these cultivated species are in a good phenological state with vigorous plants observed during the field survey.

Among the non-cultivated species, *Trianthema portulacastrum, Tephrosia purpurea, Eragrostis tenella, Euphorbia hyssopifolia, Portulaca oleracea, Amaranthus cruentus,* and *Dactylotenium aegyptium* appear most frequently. They co-exist with the market-garden species and are subjected to systematic weeding. *Dactylotenium aegyptium, Tephrosia purpurea, Boerhavia diffusa, Cleome viscosa, Opuntia dillenii,* and *Indigofera arrecta* are present in the old coastal fallow area. The presence of these and bushes such as *Azadirachta indica*, *Byrsocarpus coccineus*, *Morinda lucida*, and *Dichapetalum madagascariensis* appears to be indicate a relict of the coastal thickets and constitute evidence for the past existence of such thickets on the site. In fact, these species are among the bush species found along the Togolese coast (Batawila, 1997), which are currently experiencing a major decline. Other bushes such as *Leucaena glauca* and *Moringa oleifera* have been introduced onto the site in order to delimit vegetable patches. *Carica papaya* has been planted for its fruits, whereas the presence of *Ricinus communis* seems to be accidental.

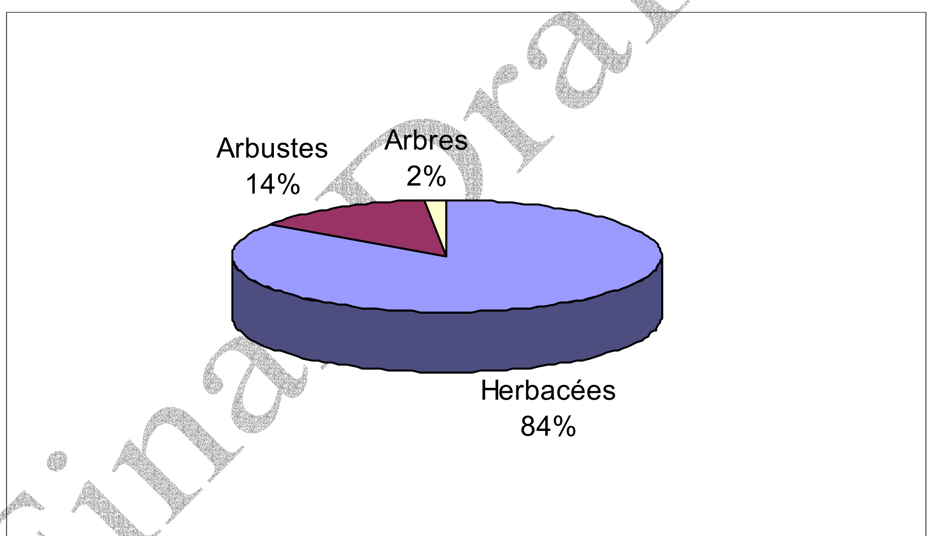
Figure 5.0-1 - Lome R&M Station Sampling Locations



Generally, the species observed on the pipeline route (59 taxa in total) represent only 22 percent of all the species that may be found on the coastal strip. One solitary tree (*Cocos nucifera*) was observed in the transect surveyed. The small number of coconut trees indicates the presence of a former coconut plantation no longer in existence. The paucity of woody species (trees and bushes) is one element of the heavy degradation of the environment in this area. The disappearance may be partly attributed to advancing urbanization but mainly attributed to coastal erosion. According to Akpagana (1992), coastal erosion is one of the main causes of the disappearance of species and psammophile plant communities along the coast, such as *Canavalia rosea, Euphorbia hyssopifolia, Pedalium murex, Cyperus compressus* and *Croton lobatus,* which subsist still with ruderal species in the coastal fallow area.

The lists of the herbaceous species, shrubs, and trees identified are presented in Tables 5.1-1, 5.1-2 and 5.1-3, respectively. Figure 5.1-1 shows the relative composition of the different plant life forms found in the survey.

Figure 5.1-1
Relative composition of the flora by life form of species found in the survey.



As part of the onshore survey, 37 points were sampled resulting in 185 total transects characterized. Assessment and identification revealed 59 species of plants including 50 herbaceous species, 8 shrubs and one tree. This represents 56 genera, grouped into 32 families of six monocotyledons and 26 dicotyledons. The Poaceae, Fabaceae and Euphorbiaceae are the most represented families with at least five genera in each. The Tiliaceae family was represented by three genera. The Amaranthaceae, Nyctagynaceae, Cucurbitaceae, Cyperaceae, Solanaceae and Portulaccaceae each had two genera, whereas the 23 other families were represented only by one genus each.

Table 5.1-1
List of Herbaceous Plants Identified.

Scientific name	**Family**
Allium cepa	Liliaceae
Alysicarpus glumaceus	Fabaceae
Amaranthus cruentus	Amaranthaceae
Anthephora cristata	Poaceae
Arachis hypogaea	Fabaceae
Boerhavia diffusa	Nyctagynaceae
Boerhavia erecta	Nyctagynaceae
Brachiaria deflexa	Poaceae
Canavalia rosea	Fabaceae
Daucus carota	Umbelliferae
Cassia rotundifolia	Caesalpiniaceae
Cenchrus biflorus	Poaceae
Cleome viscose	Capparidaceae
Commelina erecta erecta	Commelinaceae
Corchorus aestuans	Tiliaceae
Corchorus olitorius	Tiliaceae
Crotalaria retusa	Fabaceae
Croton lobatus	Euphorbiaeous
Cucumis melo var.*agrestis*	Cucurbitaceae
Cucumis sp.	Cucurbitaceae
Cyperus compressus	Cyperaceae
Dactyloctenium aegyptium	Poaceae
Digitaria horizontalis	Poaceae
Eleusine indica	Poaceae
Eragrostis tenella	Poaceae
Euphorbia hirta	Euphorbiaceae
Euphorbia hyssopifolia	Euphorbiaceae
Gisekia pharnacioides	Mollugonaceae
Indigofera arrecta	Fabaceae
Mariscus cylindristachyus	Cyperaceae
Molugo nudicaulis	Mollugonaceae
Momordica charantia	Cucurbitaceae
Occimum basilicum	Labiatae
Opuntia dillenii	Cactaceae
Panicum lindleyanum	Poaceae
Passiflora foetida	Passifloraceae
Pedalium murex	Pedalliaceae
Pergularia daemia	Asclepiadaceae
Phyllanthus amarus	Euphorbiaceae
Capsicum annuum	Solanaceae
Portulaca oleracea	Portulaccaceae

Scientific name	Family
Pupalia lappacea	Amaranthaceae
Sida cordifolia	Malvaceae
Solanum macrocarpum	Solanaceaous
Tephrosia purpurea	Fabaceae
Tiliacora funifera	Menispermaceae
Trianthema portulacastrum	Portulaccaceae
Tribulus terrestris	Zygophyllaceae
Triumfetta rhomboidea	Tiliaceae
Vigna sp.	Fabaceae

Table 5.1-2
List of Identified Shrubs.

Scientific name	Family
Azadirachta indica	Meliaceae
Byrsocarpus coccineus	Connaraceae
Dichapetalum madagascariensis	Dichapetalaceae
Leucaena glauca	Mimosaceae
Morinda lucida	Rubiaceae
Moringa oleifera	Moringacese
Ricinus communis	Euphorbiaceae
Carica papaya	Caricaceae

Table 5.1-3
List of Identified Trees.

Scientific name	Family
Cocos nucifera	Arecaceae

5.2 SOIL CHARACTERIZATION

5.2.1 Physical

<u>**Grain Sizing**</u>

Compositional analysis indicates that soils are comprised of mainly coarse and medium grains and that the distribution is quite homogeneous (see graphs in Appendix E). This indicates that sedimentary deposition occurred under very normal conditions. The results are consistent with existing knowledge of the coastal areas that documents that the loose coastal relief is comprised of a well-compacted substratum. Grain size characteristics are homogeneous with a coarse sediment body of 70 to 80 percent on average.

Chemical

The pH values and humidity levels are shown in Table 5.2-1 below. Three ranges of pH values may be distinguished. The first range is that for which pH is greater than or equal to 8.5. The second is the range of pH values between 6.5 and 8.5. The most acidic soil, whose pH = 5.55, is sample T11. Regarding humidity levels, samples T11 and T12 are the most humid. The driest are samples T13 and T14, whose humidity levels are lower than 0.5 percent. Appendix E contains more results from analyses of the soil samples.

Table 5.2-1
Humidity Levels and pH of soil samples.

Sample number	Code	Longitude	Latitude	pH	Humidity (%)
1	T 1 soil	6°09'079''	1°18'154''	8.50	3.6
2	T2 soil	6°09'081''	1°18'153''	8.50	4.2
3	T3 soil	6°09'082''	1°18'153''	8.50	2.0
4	T4 soil	6°09'094''	1°18'152''	8.70	2.6
5	T 5 soil	6°09'108''	1°18'151''	7.34	0.5
6	T6 soil	6°09'118''	1°18'150''	6.40	2.0
7	T7 soil	6°09'130''	1°18'148''	6.87	2.0
8	T11 soil	6°09'174''	1°18'144''	5.55	5.9
9	T12 soil	6°09'187''	1°18'142''	6.80	3.6
10	T13 soil	6°09'197''	1°18'141''	7.20	0.3
11	T14soil	6°09'208''	1°18'140''	6.40	0.3

The results of analyses for organic matter, total hydrocarbons and aromatic polycyclic hydrocarbons are shown in Table 5.2-2.

Table 5.2-2
Levels of Organic Materials, Hydrocarbons, and Polycyclic Aromatic Hydrocarbons.

Sample	TOM (%)	TOC (%)	OMEP (µg/g)	THC (ng/g)	Total PAH (ng/g)
TI 01	0.550	0.220	38	2.612	1.266
TI 02	0.494	0.198	78	4.953	2.562
TI 03	0.298	0.119	27	ND	ND
TI 04	1.142	0.488	37	ND	ND
TI O5	1.166	0.466	109	7.585	3.812
TI 06	1.253	0.501	199	12.673	6.555
TI 07	1.010	0.404	69	5.192	3.080
TI 08	0.883	0.353	325	22.918	12.533
TI 09	1.142	0.457	262	17.926	10.664
TI 10	1.241	0.496	308	21.135	13.592

Sample					
	TOM (%)	TOC (%)	OMEP (µg/g)	THC (ng/g)	Total PAH (ng/g)
TI 11	1.027	0.411	238	15.756	9.191
TII 01	0.495	0.198	38	ND	ND
TII 02	0.366	0.146	90	6.170	3.472
TII 03	0.280	0.112	27	ND	ND
TII 04	0.551	0.222	18	ND	ND
TII 05	1.008	0.403	200	12.998	7.771
TII 06	1.163	0.465	287	18.311	11.057
TII 07	0.500	0.700	105	7.289	4.049
TII 08	0.650	0.260	396	27.343	15.263
TII 09	1.273	0.509	333	22.766	12.852
TII 10	1.401	0.560	327	20.880	12.600
TII 11	0.754	0.302	258	17.617	9.961

TOM: Total organic materials; **OMEP**: Organic materials extractible by pentane;
TOC: Total organic carbon; **THC**: Total Hydrocarbons; **PAH**: Polycyclic aromatic hydrocarbons; **ND:** Not detected.

5.2.2 Biological

<u>Microbiology</u>

The results of the microbiological analysis of the soil samples are tabulated and included in Appendix E.

Upper Soil (0 to 15 cm)

Analysis of microflora in the upper soil depths (0 to 15 cm) indicates that bacteria are present in the soil at all locations. Populations are higher in the composite sample, C4, which is a mixture of soil from Sites 4, 5, 6, and 7. This is followed by composite sample C5, which is a mixture of soil from Sites 11, 12, 13, and 14, and Sites 1, 2, and 3.

Total coliform bacteria, specifically, the enterobacteria, were not detected in soil samples from Sites 1, 2, or 3. Coliform bacteria were present in composite samples C4 and C5 at concentrations of 1.6 x 10^4 and 1.2 x 10^4 per gram of soil, respectively. Enterobacteria were present in composites C4 and C5 at 1.9 x 10^4 and 1.11 x 10^4 per gram of soil, respectively.

Molds were not detected in samples from Sites 1 or 3. They were present in the sample from Site 2 and composites C4 and C5. Concentration was determined to 1 x 10^4 per gram of soil at Site 2, and 9 x 10^3 and 2.2 x 10^4 CFU/g of soil for composites C4 and C5, respectively.

Deeper Soil (15 to 50 cm)

Analysis for total bacteria (30°C) indicates that bacteria are present at various degrees in all the sampling sites. The microflora of composite C5 is the highest in concentration followed by composite C4, Site 3, and Site 2. Coliform bacteria were detected in only composites C4 and C5, and at nearly the same concentration. Only the microflora of composites C4 and C5 contain enterobacteria with a concentration of 1.6×10^4 and 3.2×10^4CFU/g of soil, respectively.

Molds were present in the microflora of Site 3 and composites C4 and C5 with a respective concentration of 1×10^4, 1.3×10^4, and 2×10^4CFU/g of soil. Molds were not present in the samples collected from Sites 1 and 2.

Summary

In summary, microflora in the upper soils consists of total bacteria (30°C) while coliforms and enterobacteria are present only in the flora of composites C4 and C5. Molds were found in site n°2 and composites C4 and C5. The other sites do not contain these bacteria.

In the lower soil depths (15 to 50 cm), total bacteria are found in the flora of all the sites. On the contrary, coliforms and enterobacteria are found only in the samples of composites C4 and C5. The microflora of Sites 1 and 2 do not contain moulds. It is also important to note that none of the soil samples analyzed showed the presence of yeast.

The same categories of bacteria are also found at the two depths analyzed (0 to 15 cm and 15 to 50 cm) and the profile of the microbial flora of the soil samples analyzed revealed the bacteria typically normally found in the soil.

The absence of total coliform bacteria (including enterobacteria) in the flora of Sites 1, 2, and 3 is not surprising, given the proximity to the sea and the fact that these areas have not been subject to human activities, especially defecation and gardening. This is not the case of the second transect (Sites 4, 5, 6, and 7) and the third transect (Sites 11, 12, 13, and 14).

Note that the analysis did not account for sulfur reducing anaerobic bacteria and sporulated bacteria.

<u>Soil Moisture</u>

Any significant variation in soil moisture content could influence the growth of the various categories of bacteria that constitute the microflora in the area near the proposed pipeline.

The results of the analysis for soil moisture are included in Table 5.2-3. In general, the results indicate that for the two depths studied (0 to 15 cm and 15 to 50 cm), the moisture of the soil samples analyzed is in the range of what would be expected for this type of soil (2 to 20 percent). Moreover, this humidity level is compatible with the microflora as revealed by the microbiological analysis.

Entomology

To provide an entomological baseline, ten (10) samples were analyzed for arthropods. The results of this analysis are summarized in Table 5.2-3, which also reports the percent moisture of the samples analyzed.

Table 5.2-3
Entomological Results

Sample	Moisture (%)	Arthropods found
1	3.56	1 Heteropteran
2	4.37	(Nothing)
3	2.92	3 Collemboles, 1 Heteropteran
4	2.94	1 Collembolan, 1 Hymenopteran (Formicidae), 1 Coleopteran
5	2.31	(Nothing)
6	2.47	1 Hymenopteran, 1 Coleopteran
7	1.84	1 Acarine, 1 Hymenopteran, 1 Coleopteran, 1 Dipteran, 1 Heteropteran, 1 Isopteran, 1 undetermined insect larva
8	2.02	1 Heteroptran, 1 Isopteran, 3 Lepidopteran
9	3.13	3 Acarines, 3 Collembolans, 1 Dipteran, 1 Arachnid, 2 Coleopteran
10	2.08	1 Collembolan, 5 Lepidopteran, 1 Thysanopteran, 1 Dipteran, 1 Arachnid, 4 Heteropteran, 1 Coleopteran, 1 Psocopteran, 2 Hymenopteran

In the environment studied, the following arthropods orders are found: Acarines, Collembolans, Coleopterans, Dipterans, Heteropterans, Hymenopterans, Isopterans, Lepidopterans, Psocopterans, Thysanopterans. The representatives of the orders found tend to become more frequent as one gets further away from the sea. This trend can be attributed to the salinity of the areas near the ocean and the higher levels of organic matter in the soil further from the coastline. This is evident when comparing samples 1 to 6 to sites that are further from the seawater and richer in dead plants. This observation can be corroborated by the fact that samples 1 to 6 contain only 4 orders of arthropods as compared to 9 orders in the other samples.

Further analysis and identification of arthropod species might help to determine the relationship of specific factors to diversity and abundance of the species.

5.3 SURFACE WATER AND SEDIMENT CHARACTERIZATION

There are no surface water bodies in the study area and no samples of water or sediment were collected.

5.4 WILDLIFE AND ANIMAL RESOURCES

Descriptions of wildlife and animal resources in the project area are included in tabular format in Appendix E.

Mammals

Seventeen species of mammals (across 16 genera and 6 families) were observed. Seven species are marine, the other 10 are small terrestrial mammals. The marine mammals are migratory and frequent the Togolese coast between August and December (Rapport sur les cétacés au Togo, Direction de Faune et de la Chasse, 2002). Endangered species known to occur in Togo are listed in Appendix E of CITES (Convention sur le commerce international des espèces de faune et de flore menacées de disparition).

Birds

Thirty-four species of birds (across 24 genera and 16 families) were observed near Gbetsogbe. Twenty-four of these species are paleartic migrators. They use European wetlands as breeding grounds and African wetlands as internuptial and hibernating areas. These species are observed on the Togolese coast between November and February.

Reptiles

Eighteen species of reptiles (across 16 genera and 11 families) were observed. Four are marine (marine turtles). Like cetaceans, marine turtles are migratory species and are protected species across the world. They lay eggs on Gbetsogbe beach between September and February. The other 14 species are terrestrial. They are small animals whose habitats have been greatly degraded by market gardening.

Amphibians

Two species (in two genera and two families) are present: *Bufo regularis* and *Rana* sp. Appendix E contains a list of the species in the project area in Togo.

5.5 FISH AND FISHERIES RESOURCES

No fishing is conducted in the study area due to the absence of onshore surface water bodies.

5.6 CLIMATE AND METEOROLOGY

Data relating to climate and meteorology in Togo were not specifically collected during the first season. General information on these aspects was derived from historic records and reference documents. This information is reported in Appendix E.

CHAPTER 6
ONSHORE RESULTS – BENIN

The Cotonou R&M station sampling locations are shown in Figure 6.0-1.

6.1 VEGETATION

The six transects sampled, from Djokpotomegon up to Ahouangagbe near the sea, run through the following plant formations: fallow land, degraded swampy forest, thicket, swampy grassland, mangrove, and coastal coconut grove.

6.1.1 Plant Inventory

The plant inventory identified 171 species, grouped into 136 genera and 55 families (Appendix F). Herbaceous species dominate the vegetation with 117 or 68.42 percent of the species. Shrubs and trees are represented respectively by 34 species (19.88 percent), and 20 species (11.70 percent). The families with the largest representation by species are, in decreasing order: Poaceae with 24 species (14.03 percent), Fabaceae with 21 species (12.28 percent), Cyperaceae with 18 species (10.52 percent), Rubiaceae with 7 species (4.09 percent). Two families possess 5 species each (2.92 percent). The other families are represented by 1, 2, 3, or 4 species.

6.1.2 Characterization of Plant Formations

Abundance parameters and diversity indices are indicated in Table 6.1-1.

<u>**Fallow Land (Transect B1)**</u>

The fallow land habitat derives from the degraded coastal thicket, which results from degraded coastal forest. The structural profile has two strata. One is a shrub stratum, from 1 to 2m in height, with an average cover of 20 percent. The most frequent species are: *Annona senegalensis, Lonchocarpus cyanescens*, *Rauvolfia vomitoria, Clerodendrum capitatum*, *Uvaria chamae, Dalbergia setifera, Trichoscypha oba* and *Psorospermum senegalense*. The other is an herb stratum, from 0 to 1m in height, with an average cover of 75 percent. It is made up of many species, the most dominant are: *Setaria pumila, Cassia rotundifolia, Sporobolus pyramidalis, Perotis indica, Cyperus margaritaceus* and *Schyzachyrium sanguineum*. The No trees (dbh > 7.5cm) are present. The density of shrubs of dbh < 7.5cm with a height greater than 1m is 6700 individuals per hectare. The species richness is 53. The Shannon Diversity Index, calculated for the shrub stratum and herb stratum is 1.54, and 2.88, respectively (Table 6.1-1).

Figure 6.0-1 - Cotonou R&M Station Sampling Locations

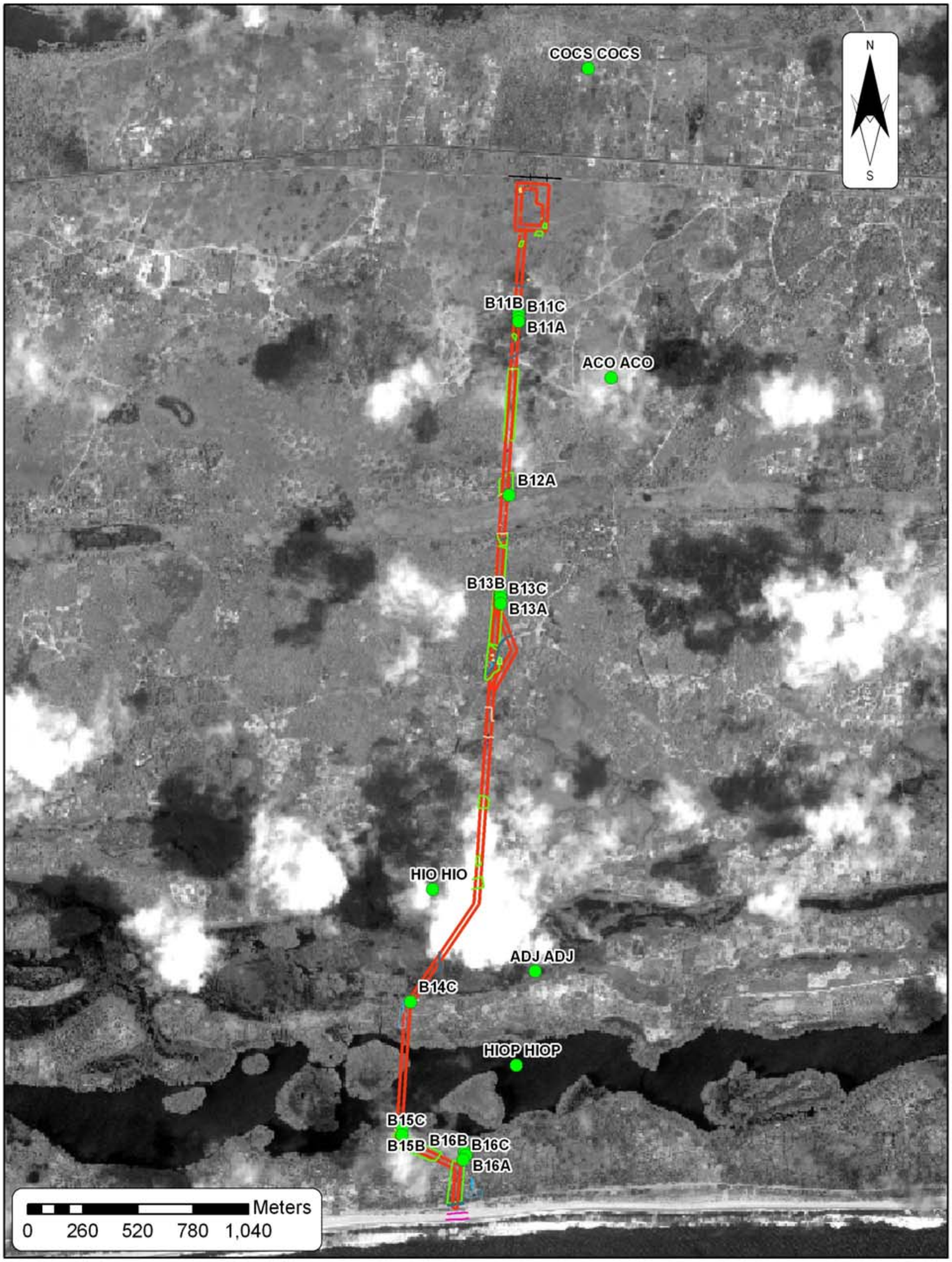


Table 6.1-1
Abundance parameters and diversity indices.

	G (m^2/ha)	D (boles/ha)	R (%)	H_A	H_a	H_h	R_s
Fallow Land	0	6700	75	0	1.54	2.88	53
Degraded Swampy Forest	1.97	4100	63	0.35	0.32	2.34	55
Thicket	0,31	35700	87	0.19	2.27	3.54	78
Swampy Grassland	0	220	73	0	0.22	0.72	19
Mangrove	0.63	17500	92	0.21	0.88	1.51	26
Coastal Coconut Plantation Grove	1.44	3400	50	0.55	0.52	2.42	32
Coastal Grassland	0	0	30	0	0	0.84	3

G, land surface of trees with dbh > 7.5cm;
D, density of shrubs with dbh < 7.5cm and height > 1m;
R, percent cover of woodlands less than 1m high and herbaceous plants;
H_A, Shannon Diversity Index for trees with dbh > 7.5cm;
H_a, Shannon Diversity Index of shrubs with dbh < 7.5cm and height > 1m;
H_h, Shannon Diversity Index of woodlands of less than 1m in height and herbaceous plants;
$R_{s,}$ specific richness.

Degraded Swampy Forest (Transect B2)

The degraded swampy forest habitat has a structural profile of three strata. The tree strata, from 4 to 8m in height, has an average cover of 15 percent. It is characterized by: *Cocos nucifera, Acacia auriculiformis* and *Syzygium guineense* var. *coastale*. The shrub stratum, from 1 to 4m in height, has an average cover of 63 percent. The most predominant species are: *Mussaenda isertiana, Tetracera alnifolia*, *Alchornea cordifolia* and *Syzygium guineense* var. *littorale.* The herb stratum, from 0 to 1m in height, with an average cover of 65 percent, is made up of many species. The most predominant are: *Fuirena umbellata, Eleocharis complanata, Scleria achtenii* and *Leersia hexandra*. The density of shrubs with dbh < 7.5cm and heights greater than 1m is 4100 individuals per hectare. The species richness is 55. The Shannon Diversity Index for the trees, shrubs and herbs is 0.35, 0.32, and 2.34, respectively (Table 6.1-1).

Thicket (Transect B3)

The thicket habitat succeeds oil palm plantation that have not been well maintained and become overgrown with weedy shrub species. There are two distinct strata. The shrub stratum, 1 to 2m in height, has an average cover of 70 percent. The predominant species are: *Uvaria chamae*, *Zanthoxylum zanthoxyloides*, *Cnestis ferruginea*, *Agelaea obliqua*, *Rhaphiostylis beninensis*, *Tetracera alnifolia*, *Rourea coccinea*, *Olax scorpioidea*, *Landolphia owariensis*, *Sorindeia warneckei*, *Dialium guineense*, *Diopyros tricolor*, *Flacourtia flavescens*, *Bridelia ferruginea*, *Carpolobia lutea* and *Lannea nigritania*. The herb stratum, 0 to 1m in height, with an average cover of 87 percent, is made up of many species, most predominantly: *Perotis indica*, *Cassytha filiformis, Pseudovigna argentea* and *Oldenlandia corymbosa*. Some sparsely distributed *Ficus* spp. Trees greater that 7.5cm dbh also are present. The density of shrubs with dbh < 7.5cm and height greater than 1m is 35,700 individuals per hectare. This very high stem density results in a closed shrub canopy. Species richness is 78. The Shannon Diversity Index of trees, shrubs, and herbs is 0.19, 2.27, and 3.54, respectively (Table 6.1-1)

Swampy grassland (Transect B4)

The swampy grassland habitat derives from degraded mangrove habitat. Two distinct strata can be found there. The shrub stratum, which is very open and 1 to 2m in height, has an average cover of 2 percent. The characteristic species are: *Acrostichum aureum* and *Dalbergia ecastaphyllu.* The herb stratum, 0 to 1m in height, has an average cover of 73 percent. The most predominant species include: *Paspalum vaginatum*, *Fuirena umbellata, Centella asiatica* and *Cyperus articulatus*. There are not trees (dbh > 7.5cm). The density of shrubs with dbh < 7.5cm and height greater than 1m is 220 individuals per hectare. The species richness is 19, the dominant species belong to the Cyperaceae and Poaceae families. The dominance of these two families explains the "prairie" nature of this formation. The Shannon Diversity Index for shrubs and herbs is 0.22 and 0.72, respectively (Table 6.1-1).

Mangrove (Transect B5)

Mangrove habitat is situated along the coastal lagoon, inland from the coconut grove habitat. The mangrove has three strata. The woody stratum, with a height of 6m and having a more closed canopy along the lagoon, has an average cover of 60 percent. *Rhizophora racemosa* is the dominant species. *Pterocarpus santalinoides* has been planted along the edges of the mangrove. The shrub stratum, 1 to 2m in height, has an average cover of 20 percent. The most predominant species are: *Rhizophora racemosa* along the lagoon, *Avicennia germinans, Acrostichum aureum, Dalbergia ecastaphyllum, Cassipourea barteri, Phyllanthus reticulatus* and *Syzygium guineense* in the background of the *Rhizophora racemosa* strip. The herb stratum, which is from 0 to 1m in height, has an average cover of 85 percent. The predominant species include: *Pasalum vaginatum, Cyperus polystachyos, Eleocharis mutata, Scoparihasof thelcis, Pentodon pentandrus* and *Fuirena umbellata.* The topography shows that the mangrove habitat is made up of two parallel units: a non-specific plantation for *Rhizophora racemosa* along the lagoon, and a mixed plantation of *Avicennia germinans* and *Acrostichum aureum*, behind the *Rhizophora racemosa* plantation. Mangrove trees with dbh > 7.5cm have been cut for firewood in the production of salt. The density of shrubs with dbh < 7.5cm and height greater than 1m is 17,500 individuals per hectare. The species richness is 26. The Shannon Diversity Index is 0.21 for trees, 0.88 for shrubs, and 1.51 for herbaceous plants (Table 6.1-1). This low diversity is explained by the fact that few species are adapted to live in peaty, brackish conditions.

Coastal Coconut Plantation (Transect B6)

The coastal coconut plantation habitat is the result of an agricultural plantation on the bar between the lagoon and the Gulf. Coconut trees are the only tree species except for rare shoots of *Azadirachta indica* and *Acacia auriculiformis,* which occur in the areas where coconut trees have been cut. The height of coconut trees is, on average, 12m. The shrub stratum, 1 to 2m in height, has an average cover of 30 percent. The predominant species are:

Azadirachta indica and *Uvaria chamae*. The herb stratum, which is less than 1m in height, has a average cover of 50 percent. The predominant species include: *Catharanthus roseus, Tephrosia purpurea*, *Aristida adscensionis, Cassia rotundifolia, Ipomoea stolonifera, cassytha filiformis, Opuntia tuna, Spermacoce stachydea and Croton lobatus*. The density of trees with dbh > 7.5cm is 1.44m^2 per hectare. The density of shrubs with dbh < 7.5cm and heights greater than 1m is 3.400 individuals per hectare. The species richness is 32. The Shannon Diversity Index is 0.55 for trees, 0.52 for shrubs, and 2.42 for herbaceous plants (Table 6.1-1).

Coastal Grassland

The coastal grassland habitat was not been studied along a transect due to its small size. The grassland has an average cover of only 30 percent. Only three species were found there: *Remirea maritima* (the most dominant), *Sporobolus virginicus* and *Cyperus maritimus*. The Shannon Diversity Index is 0.84.

6.2 SOIL CHARACTERIZATION

6.2.1 Physical

In the coastal plain, the sediments in the project area are made up of sands on the dunes, clayey sands in the depressions, and a plateau in the north of the coastal plain. The sands of the plain occupy nearly 10 to 15m in depth before becoming level sandy clay, which are often peaty to a few meters (Oyede, 1991).

Soil Studies/ Structure

Soil studies carried out by Volkoff, (1976); and Agassounon, (2002) elucidate five soils types in the pipeline ROW. These include: the poorly developed mineral soils, on the sub-current and current brown dunes; the often salty, hydromorphic gley, organic lagoon material, which is the preferred area for mangrove; the gley hydromorphous mineral soils on quaternary sea sand (which developed on the grey sand medial dunes and the yellow sands of the internal dunes); the ferralitic, lowly desaturated, poor soils on clayey-sandy sediments of the "Continental Terminal" of the plateau; and the ferralitic, lowly desaturated, poor soils located on eroded material of the surrounding plateau and deposited in the small depressions surrounding the gley hydromorphic, organic and unsalty soils (which are undifferentiated on alluvial material).

The soil description represents a south-north section, starting from the less developed soil of the current dune toward the soils of the Continental Terminal plateau nomenclature used is that of pedological reference (R. P. de Baize and Girard, 1995).

On the current sandy dune along the coast, the soils are less differentiated and developed and on a coarse sandy material. They enable one to see the appearance on the surface of a fairly less humiferous superficial, thin horizon, overlying a mineral horizon. It is a poor soil with a very low cation exchange capacity and a low water retention capacity (due to a lack of clay). These soils are characterized by a predominance of very clean, coarse quartzose sands. The clay content is practically nil. The pH is variable, influenced by the marine environment with a tendency to be basic, while the lagoon environment is lowly acidic. These soils have a low water retention capacity and undergo a very rapid vertical drainage. They have exchangeable base contents between 0.98 and $2.01_{m}E_{q}/100$ g and lack fertility. Organic material content is never high. Total organic carbon is practically nil, corresponding to the near absence of organic material.

The mangrove soils are gley, hydromorphic, organic soils, having developed on lagoon material. They are seasonally salty, which explains the presence of mangrove. The soils are characterised by a homogeneous clayey texture, with a more heterogeneous texture, which is dominantly sandy at some places. The mangrove sediment is characterised by an accumulation of clayey-sandy material, and more particularly at the level of the roots of mangrove trees, sulfurs of iron, mainly pyrite. The latter arises from the reduction of sulfates of seawater in an anaerobic environment under the influence of sulfate-reducing bacteria present in the soil. The dominant factor in the evolution of mangrove soils is the sulfur and the sulfated compounds, and they are often distinguished by acidic sulfate. In the field, the pH is 6 to 7; while after drying, the soil generally appears as much more acidic (with a pH less than 4). The difference between these two pHs is the potential acidity which is higher in the deep horizons, more inundated under the mangroves than on salty soils which are vegetated with grasses (*Paspalum vaginatum*) at the edges. The soils under mangroves present organic carbon contents reaching 8.4 percent and an organic material content of 17 percent (Oyédé, 1983). The C/N ratios give values from 6 to 44. These variations are high and can be explained by the nature and quantity of the organic material. The high values of the C/N (40 – 50) arise, according to Hutchinson (Dussart, 1996) from the allochthonous nature of the organic material. The low C/N ratios explain the influence of the indigenous organic material (plankton), which is richer in protein. The intermediary values found here can explain an environment subjected to the double influence of the two types of organic material.

The somewhat ferruginous mineral soils on quaternary sand are described by Lamouroux (1953) and Volkoff (1976). These ferruginous tropical soils, with sesquioxides of iron leached without concretions, developed on quaternary sands. These soils develop on hills which correspond to ancient internal sandy cordons, formed during the Holocene. The main characteristic feature of these soils is the predominance of fine to average quartzose sands, which are at times very clean. The clay contents are always low, hardly reaching 10 percent at the level of Horizon A, and are slightly humiferous. These soils contain occasional stains or nodules which are rust-coloured with oxidation. pH ranges from 4.5 to 5.9, reflecting the variable acidity of these soils which always have the tendency to be acidic. They are also marked by a low water retention capacity and a fairly rapid vertical drainage. The low cation exchange capacity (CEC = 2 to 5mEq/100g) is the cause of the mediocre fertility of these soils which have exchangeable base contents between 0.98 and 2.05mEq/100g. Total organic carbon is always less than 1 percent. It is only in the surface horizons of forest areas that the TOC can reach 2.2 percent (that is 3.96 percent organic material).

Between the soils of the dunes described, can be found some depressions with gley, organic, hydromorphic, humic soils. These non-salty soils (except on the edges of the lagoon) have developed in decantation basins, in an alluvial floodplain and correspond to the black, clayey soils described by Lamouroux (1953). They are almost always saturated (6 to 8 months per year) and covered by vegetation, which is made up of grasses of shrubby savanna. The water table is generally within 40cm in all seasons.

The soils are very rich in clays (60 to 80 percent), with a totally fine texture, capable of presenting some average coarse sands. The pH in their natural environments ranges from 6 to 6.8 on the surface, becoming more acidic in depth (4.5 to 5). The A Horizon is very rich in organic material (organic carbon 10.5 percent), whereas the lower horizons are very poor, due to the fact that there is a sandy layer present that is less than 2m in depth.

6.2.2 Chemistry

Aside from chromium, aluminium, copper, and zinc for uplands (cultivated savanna, coconut plantation, and barrier island), the concentrations measured were generally low. (Table 6.2-1).

Table 6.2-1
Result of heavy metal analysis of soil.

Sample	Long.	Lat.	Date	Pb	Fe	Cd	Cr	Ni	Al	Cu	Hg	V	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
B1B1	02°15'25.4"	06°22'55.1"	28/12/02	<10.0	<4.0	<0.8	6.1	<4.0	3.5	4.5	<1.0	<0.04	7.8
B1B2	02°15'25.4"	06°22'55.1"	28/12/02	<10.0	<4.0	<0.8	6.1	<4.0	3.2	2	<1.0	<0.04	5.9
B1D	02°15'24.8"	06°22'55.1"	28/12/02	<10.0	<4.0	<0.8	12.1	<4.0	3.2	4.5	<1.0	<0.04	10.3
B1A	02°15'25.4"	06°22'55.7"	28/12/02	<10.0	<4.0	<0.8	7.3	<4.0	1.9	2.9	<1.0	<0.04	5.5
B1C1	02°15'25.4"	06°22'54.4"	28/12/02	<10.0	<4.0	<0.8	8.5	4	2.3	3.7	2.3	<0.04	19.2
B1C2	02°15'25.4"	06°22'54.4"	28/12/02	<10.0	<4.0	<0.8	8.5	<4.0	8.7	2	<1.0	<0.04	10.9
B1E	02°15'26.0"	06°22'55.1"	28/12/02	<10.0	<4.0	<0.8	9.7	<4.0	2.6	2.9	1.3	<0.04	5.9
B3B1	02°15'22.7"	06°22'12.1"	28/12/02	<10.0	<4.0	<0.8	5.6	<4.0	6.8	2	1.3	<0.04	4.3
B3B2	02°15'22.7"	06°22'12.1"	28/12/02	<10.0	<4.0	<0.8	7.3	<4.0	<0.2	2	<1.0	<0.04	4.3
B3D	02°15'22.1''	06°22'12.1"	28/12/02	<10.0	<4.0	<0.8	6.7	<4.0	2.3	<2.0	<1.0	<0.04	5.2
B3A	02°15'22.7"	06°22'12.7"	28/12/02	<10.0	<4.0	<0.8	8.5	<4.0	2.6	3.7	3.3	<0.04	<2.0
B3C1	02°15'22.7"	06°22'11.3"	28/12/02	<10.0	<4.0	<0.8	13.8	5.5	6.8	4.5	4.1	<0.04	9.7
B3C2	02°15'22.7"	06°22'11.3"	28/12/02	<10.0	12.2	<0.8	6.1	<4.0	1.8	2.1	1.3	<0.04	4.3
B3E	02°15'23.3"	06°22'12.1"	28/12/02	<10.0	<4.0	<0.8	7.9	<4.0	3.5	3.7	2.5	<0.04	3.9
B6B1	02°15'17.5"	06°20'46.8"	28/12/02	<10.0	<4.0	<0.8	6.7	<4.0	1.8	2.9	<1.0	<0.04	3.6
B6B2	02°15'17.5"	06°20'46.8"	28/12/02	<10.0	<4.0	<0.8	13.8	4	6.5	3.7	12	<0.04	11.3
B6D	02°15'17.0"	06°20'46.8"	28/12/02	13.4	8.7	<0.8	16.1	5.5	3.8	4.5	1.5	<0.04	1.6
B6A	02°15'17.3"	06°20'47.3"	28/12/02	<10.0	9.7	<0.8	7.9	<4.0	3	3.7	<1.0	<0.04	11.9
B6C	02°15'17.1"	06°20'46.1"	28/12/02	12.1	7.7	<0.8	22.1	6.3	3	7.7	<1.0	<0.04	18.5
B6E	02°15'17.9"	06°20'46.8"	28/12/02	<10.0	17.8	<0.8	9.6	<4.0	3.8	3.7	<1.0	<0.04	8.1

6.2.3 Biological

Macrobiology

Table 6.2-2 shows the results of the soil macrobiology investigation. The beach, Transect 6, was dominated by molluscs, including *Arca afra, Cardita tankervillei, Dreissena africana, Tellina nymphalis,* and *Diplodonta diaphana.* Transects 1 and 3 were dominated by Hymenoptera, including Myrmicidae and Formicidae.

Table 6.2-2
Results of soil macrobiology investigation.

Transect 1

	B1B1	B1B2	B1A.	B1C1	B1C2	B1E	B1D
Longitude	**02°15’25.4“**	**02°15’25.4“**	**02°15’25.4”**	**02°15’25.4**	**02°15’25.4**	**02°15’26.0“**	**02°15’24.8“**
Latitude	**06°22’55.1“**	**06°22’55.1“**	**06°22’55.7”**	**06°22’54.4”**	**06°22’54.4”**	**06°22’55.1“**	**06°22’55.1“**
MALLOPHAGES							
Haematomyzidae	X				X		
HYMENOPTERA							
Formicidae	X	X	X	X	X		X
Myrmicidae	X	X	X			X	X
Dorylidae							X
HETEROPTERA							
Plesiocoris sp.						X	
Capside					X		
ORTHOPTERA							
Acridoidea					X		
Tettigonioidea	X			X			
COLEOPTERA							
Hydrophilidae					X		
ANNELIDA							
Achètes	X	X					
ARACHNIDA					X		

Transect 3

	B3B1	B3B2	B3A.	B3C1	B3C2	B3E	B3D
Longitude	**02°15’22.7’’**	**02°15’22.7’’**	**02°15’22.7”**	**02°15’22.7”**	**02°15’22.7”**	**02°15’23.3’’**	**02°15’22.1’’**
Latitude	**06°22’12.1’’**	**06°22’12.1’’**	**06°22’12.7”**	**06°22’11.3”**	**06°22’11.3”**	**06°22’12.1’’**	**06°22’12.1’’**
HYMENOPTERA							
Formicidae		X		X			
Myrmicidae	X	X	X	X	X	X	X
Dorylidae				X			
ORTHOPTERA							
Acridoidea							X
Tettigonioidea	X						
COLEOPTERA							
Dermestidae			X				
LEPIDOPTERA							
Papilionidae							X
ANNELIDA							
Achètes	X				X		
ARACHNIDA						X	

Transect 6

	B6B1	B6B2	B6A	B6C	B6E	B6D
Longitude	**02°15’17,5’’**	**02°15’17,5’’**	**02°15’17,3”**	**02°15’17,1”**	**02°15’17,9’’**	**02°15’17,0’’**
Latitude	**06°20’46,8’’**	**06°20’46,8’’**	**06°20’47,3”**	**06°20’46,1”**	**06°20’46,8’’**	**06°20’46,8’’**
MOLLUSKS						
Arca afra		X			X	X
Cardita tankervillei						X
Dreissena africana		X				X
Tellina nymphalis				X		X
Donax pulchellus				X		
Veneridae						
Pitaria tumens	X					
Ungulinidae						
Diplodonta diaphana	X			X		
HYMENOPTERA						
Formicidae			X			
ORTHOPTERA						
Acridoidea			X			
COLEOPTERA						
Silphidae			X			
CRUSTACEA						

Portunidae					X	
Ocypoda africana				X		
ARACHNIDA					X	

6.2.4 Microbiology

Table 6.2-3 shows the results of the soil microbiology investigation. The microbial communities of the beach (Transect 3) have a relatively high abundance coliform bacteria as a result of human activity in these areas.

Table 6.2-3
Results of soil microbiology investigation.

N°	Sample number	Longitude	Latitude	Total Count	Yeast and Molds	Coliforms	Sulfite Reducing Bacteria
						(*E.Coli* + fecal)	
1	B1A	**02°15'25.4"**	**06°22'55.7"**	$15.6 \cdot 10^3$	$30.8 \cdot 10^2$		
2	B1A	**02°15'25.4"**	**06°22'55.7"**	$7 \cdot 10^3$			
3	B1B1	**02°15'25.4"**	**06°22'55.1"**	$7.8 \cdot 10^3$			
4	B1B2	**02°15'25.4"**	**06°22'55.1"**	$23 \cdot 10^3$	$58.5 \cdot 10^2$	160	36
5	B1C1	**02°15'25.4"**	**06°22'54.4"**	$17.6 \cdot 10^3$			
6	B1C2	**02°15'25.4"**	**06°22'54.4"**	$7.2 \cdot 10^3$			
7	B1D	**02°15'24.8"**	**06°22'55.1"**	$15 \cdot 10^3$	$12 \cdot 10^2$	197	45
8	B1E	**02°15'26.0"**	**06°22'55.1"**	$16 \cdot 10^3$	$76 \cdot 10^2$	240	39
1	B3A	**02°15'22.7"**	**06°22'12.7"**	$18.1 \cdot 10^3$	$14 \cdot 10^2$		
2	B3A	**02°15'22.7"**	**06°22'12.7"**	$5.5 \cdot 10^3$	$16.16 \cdot 10^2$	280	50
3	B3B1	**02°15'22.7''**	**06°22'12.1''**	$17.3 \cdot 10^3$	$16 \cdot 10^2$		
4	B3B2	**02°15'22.7''**	**06°22'12.1''**	$5.8 \cdot 10^3$			
5	B3C2	**02°15'22.7"**	**06°22'11.3"**	$15 \cdot 10^3$			
6	B3D	**02°15'22.1''**	**06°22'12.1''**	$14. \cdot 10^3$	$12 \cdot 10^2$		
7	B3E	**02°15'23.3''**	**06°22'12.1''**	$12 \cdot 10^3$			
8	B3E	**02°15'23.3''**	**06°22'12.1''**	$9.2 \cdot 10^3$			
1	B6B1	**02°15'17.5''**	**06°20'46.8''**	$15.8 \cdot 10^3$	$25 \cdot 10^2$	120	52
2	B6C	**02°15'17.1"**	**06°20'46.1"**	$12 \cdot 10^3$			
3	B6D	**02°15'17.0''**	**06°20'46.8''**	$13 \cdot 10^3$	$70 \cdot 10^2$	191	29

N°	Sample number	Longitude	Latitude	Total Count	Yeast and Molds	Coliforms	Sulfite Reducing Bacteria
						(*E.Coli* + fecal)	
4	B6E	**02°15'17.9''**	**06°20'46.8''**	$7 \cdot 10^3$			
5	B6E	**02°15'17.9''**	**06°20'46.8''**	$15 \cdot 10^3$			

6.3 SURFACE WATER AND SEDIMENT CHARACTERIZATION

6.3.1 Physical

Table 6.3-1 presents the result of the surface water analysis. The freshwater marsh was somewhat more acidic than the salt marsh or the lagoon. Because of the shallow depth of the water in the salt marsh, the water temperature was rather high (30-36°C), whereas it remained between 28-31°C in the two other mediums. The total dissolved matter conductivity and concentration (TDS) were higher in the salt marsh and lagoon than in the freshwater marsh, proportional to the salinities of the water in the respective habitats.

The freshwater marsh was more turbid, followed by the salt marsh, whereas the biological oxygen demand was higher in the lagoon than the freshwater marsh. Primary production and total organic carbon (TOC) covaried, with higher values in the salt marsh than the coastal lagoon. These variations correspond to nitrate variations in the various mediums.

Table 6.3-1
Surface water physical analysis results.

Sample	Longitude	Latitude	pH	T° (°C)	Condu (µS/cm)	Salinity (°/oo)	TDS (mg/L)	Turbidity secchi (m)	Absorbance (FAN)
Transect 2									
B2C1	2°15'39.9"	6°22'45.9"	6.24	28.1	800	0.2	331	0.20	0.02
B2C2	2°15'39.7"	6°22'45.9"	6.51	28.2	787	0.2	313	0.20	0.04
B2E1	2°15'37.4"	6°22'46.8"	6.22	28.8	721	0.1	336	0.25	0.03
B2E2	2°15'37.4"	6°22'46.8"	6.3	28.1	686	0.1	322	0.25	0.03
B2W1	2°15'40.2"	6°22'45.9"	6.18	28.1	764	0.1	300	0.30	0.20
B2W2	2°15'40.2"	6°22'45.9"	6.16	28.1	741	0.1	300	0.30	0.12
B2W3	2°15'40.6"	6°22'45.9"	6.31	31.2	343	0	227	0.40	0.02
B2W4	2°15'40.6"	6°22'45.9"	6.49	30.8	838	0.2	313	0.40	0.06
Transect 4									
B4S1	2°15'27.5''	6°21'14''	8.03	32.6	21000	12.8	5018	0.40	0.02
B4S2	2°15'27.5''	6°21'14''	7.78	33.5	18930	11.3	5386	0.40	0.04

Sample	Longitude	Latitude	pH	T° (°C)	Condu (µS/cm)	Salinity (°/oo)	TDS (mg/L)	Turbidity secchi (m)	Absorbance (FAN)
B4S3	2°15’27.5’’	6°21’13.8’’	7.78	32.7	19980	11.9	5077	0.60	0.03
B4S4	2°15’27.5’’	6°21’13.8’’	7.8	30.1	19860	11.9	5690	0.50	0.08
B4S5	2°15’27.5’’	6°21’13.6’’	7.79	30.5	19930	11.9	5268	0.60	0.10
B4C1	2°15’28.2’’	6°21’15’’	8.02	33.3	19970	11.9	4913	0.20	0.08
B4C2	2°15’28.1’’	6°21’15’’	7.81	31.7	20000	11.9	5377	0.20	0.11
B4N	2°15’28.2’’	6°21’14.6’’	8.01	36.1	26900	16.5	5763	0.20	0.08
Transect 5									
B5.1	2°15’12.4”	6°20’87.5’’	8.23	28.6	15050	8.8	3531	0.55	0.09
B5.2	2°15’12.4”	6°20’87.1’’	8.06	28.7	14860	8.7	4190	0.25	0.11
B5.3	2°15’12.4”	6°20’86.7’’	8.13	28.8	14830	8.8	3259	0.30	0.09
B5.4	2°15’12.4”	6°20’86.3’’	8.15	28.7	14820	8.7	4059	0.80	0.06
B5.5	2°15’12.4”	6°20’85.9’’	8.15	28.5	14790	8.6	3763	0.75	0.13
B5.6	2°15’12.4”	6°20’85.5’’	8.23	28.6	14790	8.7	3240	0.80	0.04
B5.7	2°15’12.4”	6°20’85.1’’	8.24	28.5	14810	8.7	3354	1.00	0.04
B5.8	2°15’12.4”	6°20’84.7’’	8.27	28.7	14940	8.7	3568	0.80	0.04

6.3.2 Chemical

Table 6.3-2 shows the surface water chemical analysis results for nutrients present. Table 6.3-3 presents the data on surface water chemistry in terms of primary production, TOC and BOD. Results for trace metals present can be found in Appendix F. Aside from chromium, aluminium, copper, and zinc for uplands (cultivated savanna, coconut plantation, and barrier island), and magnesium and zinc for the wetlands (freshwater marsh, salt marsh, and coastal lagoon), the various sampling sites were homogeneous in heavy metal concentrations. The concentrations were higher in soil than in water. Results of surface water sediment analyses for organics can be found in Appendix F.

Table 6.3-2
Surface water chemical analysis results for nutrients.

Sites		Parameters						
		Coordinates.	NO_2^- (mg/l)	NO_3^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	TSS (mg/l)	DO (mgO_2/l)
Coastal Lagoon (LC)	LC1	N 6°20’87.5" E 002°15’12.4"	0.04	1.83	18.43	0.095	12.50	436
	LC2		0.05	1.81	19.01	1.10	15.00	410
	LC3		0.05	1.85	18.3	1.10	10.00	397
	LC4		0.07	2.04	21.2	1.40	7.50	431
	LC5		0.071	1.93	20.97	1.40	17.50	448
	LC6		0.069	1.87	20.5	1.30	21.25	426
	LC7		0.03	1.79	17.02	0.09	3.75	379
	LC8		0.032	0.97	18.2	0.087	10.75	362
	LC9		0.029	1.01	17.3	0.083	7.50	376
	MAR1.1		0.39	1.49	15.8	0.96	22.50	633

Sites		Parameters						
		Coordinates.	NO_2^- (mg/l)	NO_3^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	TSS (mg/l)	DO (mgO_2/l)
Salt Marsh (MAR1)	MAR1.2	N 6°22'45.9" E 002°15'39.9"	0.37	1.52	16.02	1.13	27.50	607
	MAR1.3		0.37	1.47	16.11	0.91	24.25	614
	MAR1.4		0.41	1.50	15.9	0.91	20.25	589
	MAR1.5		0.40	1.52	15.8	0.89	25.50	640
Freshwater Marsh (MAR2)	MAR2.1	N 6°20'87.8" E 002°15'18.4"	0.45	2.96	22.01	0.087	33.00	570.1
	MAR2.2		0.48	3.01	21.96	0.091	31.75	569.0
	MAR2.3		0.39	3.0	22.00	0.10	32.50	570.3
	MAR2.4		0.44	2.95	20.98	0.13	31.00	568.9
	MAR2.5		0.46	3.04	22.06	0.11	37.75	569.2

Table 6.3-3

Surface Water Chemical Analysis Results Primary Production, TOC, and BOD.

Sample Number	Longitude	Latitude	Primary Production		TOC	BOD5
			($mgO_2m^{-2}J^{-1}$)	($gC.m^{-2}.J^{-1}$)	mg $C.m^{-3}$	(mg/l)
Freshwater Marsh						
B2C1	2°15'39.9"	6°22'45.9"	391.50	0.12	4.70	23.48
B2C2	2°15'39.7"	6°22'45.9"	587.25	0.18	7.05	78.26
B2E1	2°15'37.4"	6°22'46.8"	244.69	0.07	2.94	40.00
B2E2	2°15'37.4"	6°22'46.8"	489.38	0.15	5.88	5.21
B2W1	2°15'40.2"	6°22'45.9"	880.88	0.26	10.58	107.83
B2W2	2°15'40.2"	6°22'45.9"	880.88	0.26	10.58	38.26
B2W3	2°15'40.6"	6°22'45.9"	783.00	0.24	9.41	106.95
B2W4	2°15'40.6"	6°22'45.9"	1174.50	0.35	14.11	137.39
Average			**679.01**	**0.20**	**8.16**	**67.17**
Salt marsh						
B4S1	2°15'27.5''	6°21'14''	1174.50	0.35	14.11	59.78
B4S2	2°15'27.5''	6°21'14''	1174.50	0.35	14.11	33.69
B4S3	2°15'27.5''	6°21'13.8''	1761.75	0.53	21.16	13.04
B4S4	2°15'27.5''	6°21'13.8''	978.75	0.29	11.76	9.78
B4S5	2°15'27.5''	6°21'13.6''	2349.00	0.71	28.22	5.43
B4C1	2°15'28.2''	6°21'15''	783.00	0.24	9.41	44.56
B4C2	2°15'28.1''	6°21'15''	587.25	0.18	7.05	16.30
B4N	2°15'28.2''	6°21'14.6''	587.25	0.18	7.05	50.00
Average			**1174.50**	**0.35**	**14.11**	**29.07**

Coastal Lagoon						
Sample Number			**Primary Production**		**TOC**	**BOD5**
			($mgO_2m^{-2}J^{-1}$)	**($gC.m^{-2}.J^{-1}$)**	**mg $C.m^{-3}$**	**(mg/l)**
B5.1	2°15'12.4"	6°20'87.5''	1076.63	0.32	12.93	88.80
B5.2	2°15'12.4"	6°20'87.1''	489.38	0.15	5.88	105.60
B5.3	2°15'12.4"	6°20'86.7''	587.25	0.18	7.05	56.40
B5.4	2°15'12.4"	6°20'86.3''	1566.00	0.47	18.81	62.40
B5.5	2°15'12.4"	6°20'85.9''	1468.13	0.44	17.64	30.00
B5.6	2°15'12.4"	6°20'85.5''	1566.00	0.47	18.81	61.20
B5.7	2°15'12.4"	6°20'85.1''	978.75	0.29	11.76	72.00
B5.8	2°15'12.4"	6°20'84.7''	783.00	0.24	9.41	165.60
Average			**1064.39**	**0.32**	**12.79**	**80.25**

Table 6.3-4
Surface Water Chemical Analysis Results for Trace Metals

Sample Number			Date of Sampling		Fe	Mg	Cd	Cr	Ni	Al	Cu	Hg	V	Zn
	Lon	Lat			µg/g	mg/L	µg/g	µg/g	µg/g	mg/g	µg/g	µg/L	µg/g	µg/g
B2C1	2°15’39,9”	6°22’45,9”	28/12/02	<10.0	<4.0	37.2	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	4.9
B2C2	2°15’39,7”	6°22’45,9”	28/12/02	<10.0	<4.0	12.0	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	2.4
B2E1	2°15’37,4”	6°22’46,8”	28/12/02	<10.0	<4.0	12.0	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B2W1	2°15’40,2”	6°22’45,9”	28/12/02	<10.0	<4.0	21.6	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	3.0
B2W3	2°15’40,6”	6°22’45,9”	28/12/02	<10.0	<4.0	26.4	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	6.2
B2W4	2°15’40,6”	6°22’45,9”	28/12/02	<10.0	<4.0	34.8	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B4C	2°15’28,2’’	6°21’15’’	28/12/02	10.7	<4.0	446.4	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	8.4
B4N	2°15’28,2’’	6°21’14,6’’	28/12/02	<10.0	<4.0	421.2	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B4S1	2°15’27,5’’	6°21’14’’	28/12/02	<10.0	<4.0	459.6	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B4S2	2°15’27,5’’	6°21’14’’	28/12/02	10.7	<4.0	436.8	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B4S3	2°15’27,5’’	6°21’13,8’’	28/12/02	<10.0	<4.0	427.2	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B4S4	2°15’27,5’’	6°21’13,8’’	28/12/02	12.1		480.0	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	2.4
					<4.0									
B5-1 surf	2°15’12,4”	6°20’87,5’’	28/12/02	<10.0	<4.0	319.2	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B5-1 prf	2°15’12,4”	6°20’87,5’’	28/12/02	<10.0	<4.0	326.4	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B5-2	2°15’12,4”	6°20’87,1’’	28/12/02	<10.0	<4.0	278.4	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B5-3	2°15’12,4”	6°20’86,7’’	28/12/02	<10.0	<4.0	324.4	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0
B5-4 surf	2°15’12,4”	6°20’86,3’’	28/12/02	12.1	<4.0	314.4	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	3.3
B5-4 prof	2°15’12,4”	6°20’86,3’’	28/12/02	10.7		316.8	<0.8	<4.0	<4.0	<0.2	<2.0	<1.0	<0.04	<2.0

6.3.3 Macroinvertebrates

Molluscs dominated the macroinvertebrate community in the beach habitat while hymenopterans dominated the upland habitats.

Benthos

Data from the macroinvertebrate survey can be found in Appendix F. The freshwater marsh had higher species richness that the salt marsh and lagoon. The latter two habitats were dominated by molluscs and annelids. In the lagoon, *Mytilus perna, Pitaria tumens, Diplodonta diaphana, Tellina nymphalis, Turritella ligar* and *Turritella torulosa* were dominant species. Crustaceans, such as those from the families Corophidae and Haustoridae were also present.

The molluscs recorded in the marsh of salty water were dominated by *Littorina* sp., *Turritella ligar,* and *Turritella torulosa.*

Microbiology

Results of surface water microbiology canb be found in Appendix F. The microbial communities of the marshes and part of the lagoon were dominated by fecal coliform bateria. This profusion of bacteria and fungus reflects the fact that the area is used for dumping animal and human waste, as well as household refuse.

Zooplankton

Results for surface water zooplankton survey can be found in Appendix F. The salt marsh and the lagoon exhibited the same species richness of zooplankton. Both were dominated by the copepods. The zooplankton of the freshwater marsh consisted of rotifers, cladocerans, and copepods. The abundance was higher in the freshwater marsh than in either the salt marsh or the lagoon.

Phytoplankton

The species richness of phytoplankton was higher in the freshwater marsh (40), than the salt marsh (27). The dominant species in the freshwater marsh are, by order of importance: *Closterium aciculare*, *Cyclotella* sp., *Synedra* sp., *Microcystis* sp., *Fragilaria* sp., *Oscillatoria* sp., and *Synechocystis aquatilis*. Those that dominate the salt marsh are: *Microcystis* sp., *Nitzschia* sp., *Closterium* sp., *Merismopedia* sp., *Microcoleus* sp., *Oscillatoria* sp.. The lagoon is dominated by the following phytoplanktonic species: *Cyclotella* sp., *Stephanodiscus* sp., *Melosira* sp., *Microcystis* sp., and *Oscillatoria* sp..

6.4 WILDLIFE AND ANIMAL RESOURCES

6.4.1 An Overview the Wildlife Habitat

Many botanical studies have been conducted on the coastal area of Benin: Adjanohoun (1965, 1966), Guinko (1974), Adjakidjè (1984), Profizi (1982), Akoegninou (1999).

However, wildlife studies are scanty and take into account only some zoological groups. Documentation is available mainly on fisheries and birds. This report will focus on amphibians, reptiles, and mammals living in the plant formations of the study area.

Coastal Grassland

This habitat is a stretch of grass along the sea vegetated with *Remirea maritima* (Cyperaceae) and *Sporobolus virginicus* (Poaceae). It has been reported that sea turtles belonging to the *Erectmochelys*, *Chelonia*, and *Lepidochelys* families visit the area to lay eggs.

Coastal Coconut Plantation

In this habitat, which stretches along the seashore on the sand bar are very few animals. Most have dispersed because of the urbanisation in Cococodji. Formerly, this habitat supported squirrels, rats, and other animals that used the coconut trees as habitat.

Mangrove

The mangrove provides habitat for a variety of animal populations. The most common reptiles in this formation are *Python regis*, *Python sebae*, *Varanus niloticus*, *Naja nigricollis*, and *Crocodilus niloticus*. Mammals are represented by *Potamochoerus porcus* (a threatened species) and formerly many monkey species that have been extirpated. This habitat continues to support populations of the red-bellied monkey, *Cercopithecus erythrogaster.*

Other Habitats

There are a number of degraded habitats (i.e., abandonded from former human use) stretching from the north of Adjahindji through Vinaura to Akadjame. These include up to 10 small patches of thickets dominated by *Chrysobalanus* sp., *Dalbergia* sp., *Azadirachta indica*, and *Zanthoxylum* sp. of vegetation of The patches are scattered over a vast area covered with fine sand and crossed by small streams where people used to catch fresh water turtles (e.g., *Pelusios subniger*). It is a favourite habitat for rats, squirrels, monkeys, grass snakes, land turtles (*Kinixy belliana*), and amphibians. Species present are listed in Table 6.4-1.

Table 6.4-1
Wildlife Census Results

Local Common Name	Scientific Name	Number (abundance)	Comments /Notes
AMPHIBIANS			
Crapaud	*Bufo regularis*	+++	
Grenouille	*Dicroglossus occipitalis*	+++	
Rainette	*Hyla* sp.	++	
Ptychadena	*Ptychadena* spp.	++	
REPTILES			

Local Common Name	Scientific Name	Number (abundance)	Comments /Notes
Python royal	*Python regius*	+	
Python de Seba ou faux boa	*Python sebae*	+	
Vipère	*Causus rhombeatus*	+	
Naja	*Naja nigricolis*	+	
Mamba	*Dendrospis viridis*	+	
Couleuvre	*Philotamnus heteropidotus*	+++	
Lézard	*Varanus niloticus*	++	
Crocodile	*Crocodilus niloticus*	+	
Tortue terrestre	*Kinixys belliana*	++	
Tortue d'eau douce	*Pelusios subniger*	++	
Tortue luth (marine)	*Dermochelys coriacea*	+	
Tortue imbriquée (marine)	*Erectmochelys imbricata*	+	
Tortue verte (marine)	*Chelonia mydas*	+	
Cameléon	*Chameleon* sp.	++	
MAMMALS			
Sitatunga	*Tragelaphus spekei*	+	
Potamochère	*Potamochoerus porcus*	++	
Porc-épic	*Hystrix cristata*	+	
Guib harnaché	*Tragelaphus scriptus*	+	
Ecureuil (arbre)		++	
Ecureuil (sol)	*Xerus erythropus*	++	
Rat de Gambie	*Cricetomys gambianus*	+++	
Aulacode	*Tryonomis swinderianus*	++	
Lièvre	*Lepus crawshay*	D	
Vervet	*Cercopithecus aethiops*	+	
Singe à ventre rouge	*Cercopithecus erythrogaster*	D	

[b]for example: in tree tops, flying, moving through, on ground, in water, feeding, etc.
+: Rare
+++: Abundant
++ : Present
D: extinct or endangered

Other degraded habitat types in the area include palm groves and cashew plantations that are generally not well maintained. They provide habitat for squirrels, ground squirrels, monkeys, grass snakes, cobras, porcupines, and other animals. Furrows, fields, and market gardens, also in the area, provide habitat for rats, grass snakes, pythons (*P. regis*), and some amphibians.

<u>Wildlife Census</u>

Wildlife census data from the study area, in particular, Adjahindji, Hio Houta, Vinawa, and Akadjamè villages, is shown in Tables 6.4-2, through 6.4-5.

Table 6.4-2
Results of the Bird Census in the Coconut Plantation and on the Sand Bar

Local Common Name	Scientific Name	Number
Héron crabier	*Ardeola ralloides*	2
Héron garde-bœuf	*Ardeola ibis*	8
Milan noir	*Milvus migrans*	4
Buse unibande	*Kaupifalco monogrammicus*	1
Emerauldine à bec rouge	*Turtur afer*	1
Tourterelle vineuse	*Streptopelia vinacea*	2
Tourterelle maillée	*Streptopelia senegalensis*	11
Coucal du sénégal	*Centropus senegalensis*	3
Martin-chasseur à tête grise	*Halcyon leucocephala*	4
Martin-chasseur du Sénégal	*Halcyon senegalensis*	2
Moqueur	*Phoeniculus purpureus*	2
Pic à dos vert	*Campethera cailliautii*	2
Pic gris	*Mesopicos goertae*	4
Alouette sentinelle	*Macronyx croceus*	2
Bulbul à bec grêle	*Andropadus gracilirostris*	1
Bulbul commun	*Pycnonotus barbatus*	35
Grive kurrichane	*Turdus pelios*	2
Camaroptère à dos gris	*Camaroptera brachyura*	1
Gobemouche caronculé à collier	*Platysteira cyanea*	1
Soui-manga à poitrine rouge	*Nectarinia senegalensis*	1
Soui-manga brun	*Anthreptes gabonicus*	1
Soui-manga à ventre jaune	*Nectarinia venusta*	1
Soui-manga à ventre olive	*Nectarinia chloropygia*	2
Soui-manga cuivré	*Nectarinia cuprea*	3
Soui-manga éclatant	*Nectarinia coccinigaster*	2
Corvinelle	*Corvinella corniva*	6
Téléphone tchagra	*Tchagra senegala*	2
Gonolek de barbarie	*Laniarius barbarus*	5
Piac – piac	*Ptilostomus afer*	6
Moineau gris	*Passer griseus*	1
Tisserin gendarme	*Ploceus cucullatus*	32
Amarante commun	*Lagonosticta senegala*	5

Local Common Name	Scientific Name	Number
Joues oranges	*Estrilda melpoda*	1

Table 6.4-3
Results of the Bird Census in the Wet Meadows

Local Common Name	Scientific name	Number
Cormoran africain	*Phalacrocorax africanus*	3
Héron crabier	*Ardeola ralloides*	9
Héron garde-bœuf	*Ardeola ibis*	29
Héron à dos vert	*Butorides striatus*	1
Héron pourpré	*Ardea purpurea*	4
Héron cendré	*Ardea cinerea*	2
Aigrette dimorphe	*Egretta gularis*	3
Aigrette garzette	*Egretta garzetta*	17
Grande aigrette	*Egretta alba*	6
Aigrette intermédiaire	*Egretta intermedia*	1
Dendrocygne veuf	*Dendrocygna viduata*	3
Elanion blanc	*Elanus caeruleus*	1
Milan noir	*Milvus migrans*	2
Busard des roseaux	*Circus aeruginosus*	2
Balbuzard pêcheur	*Pandion haliaetus*	1
Hibou des marais africain	*Asio capensis*	1
Râle noir	*Limnocorax flavirostra*	2
Poule d'Allen	*Porphyrio alleni*	1
Poule sultane	*Porphyrio porphyrio*	6
Petite poule d'eau africaine	*Gallinula angulata*	1
Jacana	*Actophilornis africana*	11
Echasse blanche	*Himantopus himantopus*	4
Oedicnème du Sénégal	*Burhinus senegalensis*	2
Grand gravelot	*Charadrius hiaticula*	1
Chevalier aboyeur	*Tringa nebularia*	4
Chevalier sylvain	*Tringa glareola*	4
Chevalier guignette	*Actitis hypoleucos*	6
Emerauldine à bec rouge	*Turtur afer*	3
Tourterelle maillée	*Streptopelia senegalensis*	1
Martinet des palmes	*Cypsiurus parvus*	8
Martin-chasseur à tête grise	*Halcyon leucocephala*	2
Martin-chasseur du Sénégal	*Halcyon senegalensis*	1
Martin pêcheur pie	*Ceryle rudis*	10
Petit martin-pêcheur huppé	*Alcedo cristata*	1
Guêpier nain	*Merops pusillus*	2

Local Common Name	**Scientific name**	**Number**
Guêpier à gorge blanche	*Merops albicollis*	7
Rollier varié	*Coracias naevia*	2
Rolle africain	*Eurystomus glaucurus*	4
Hirondelle de rivage	*Riparia riparia*	2
Hirondelle à ventre roux	*Hirundo semirufa*	14
Alouette sentinelle	*Macronyx croceus*	2
Bulbul à bec grêle	*Andropadus gracilirostris*	2
Bulbul commun	*Pycnonotus barbatus*	4
Cisticole roussâtre	*Cisticola galactotes*	2
Cisticole à tête rousse	*Cisticola ruficeps*	3
Camaroptère à dos gris	*Camaroptera brachyura*	2
Gobemouche caronculé à collier	*Platysteira cyanea*	2
Pie-grièche fiscale	Lanius collaris	1
Téléphone tchagra	*Tchagra senegala*	1
Spermète nonnette	*Lonchura cucullata*	10

Table 6.4-4
Results of the Bird Census in the Crop Fields on Sandy Soil

Local Common name	**Biological name**	**Number**
Héron garde-bœuf	*Ardeola ibis*	15
Elanion blanc	*Elanus caeruleus*	2
Milan noir	*Milvus migrans*	3
Emerauldine à bec rouge	*Turtur afer*	3
Tourterelle maillée	*Streptopelia senegalensis*	5
Coucou de levaillant	*Clamator levaillantii*	1
Coucal du sénégal	*Centropus senegalensis*	6
Martin-chasseur à tête grise	*Halcyon leucocephala*	5
Martin-chasseur du Sénégal	*Halcyon senegalensis*	3
Bulbul commun	*Pycnonotus barbatus*	15
Soui-manga brun	*Anthreptes gabonicus*	1
Pie-grièche fiscale	*Lanius collaris*	4
Corvinelle	*Corvinella corniva*	8
Téléphone tchagra	*Tchagra senegala*	1
Gonolek de barbarie	*Laniarius barbarus*	2
Spermète nonnette	*Lonchura cucullata*	32
Merle métallique à œil blanc	*Lamprotornis splendidus*	4
Moineau gris	*Passer griseus*	2
Moineau – tisserin	*Plocepasser superciliosus*	5
Tisserin gendarme	*Ploceus cucullatus*	100

Local Common name	**Biological name**	**Number**
Tisserin noir de vieillot	*Ploceus nigerrimus*	2
Travailleur à bec rouge	*Quelea quelea*	1
Amarante commun	*Lagonosticta senegala*	5
Joues oranges	*Estrilda melpoda*	5
Spermète pie	*Lonchura fringilloides*	13

Table 6.4-5
Results of the Bird Census in the Swamp

Local Common Name	**Scientific Name**	**Number**
Cormoran africain	*Phalacrocorax africanus*	1
Héron crabier	*Ardeola ralloides*	7
Héron garde-bœuf	*Ardeola ibis*	25
Héron à dos vert	*Butorides striatus*	1
Héron pourpré	*Ardea purpurea*	1
Héron cendré	*Ardea cinerea*	3
Aigrette garzette	*Egretta garzetta*	3
Dendrocygne veuf	*Dendrocygna viduata*	8
Sarcelle à oreillons	*Nettapus auritus*	10
Elanion blanc	*Elanus caeruleus*	1
Milan noir	*Milvus migrans*	5
Busard des roseaux	*Circus aeruginosus*	1
Jacana	*Actophilornis africana*	26
Chevalier sylvain	*Tringa glareola*	3
Vanneau terne	***Vanellus lugubris***	24
Emerauldine à bec rouge	*Turtur afer*	2
Tourterelle maillée	*Streptopelia senegalensis*	5
Coucou de levaillant	*Clamator levaillantii*	1
Coucal du sénégal	*Centropus senegalensis*	3
Martinet des palmes	*Cypsiurus parvus*	9
Martin-chasseur à tête grise	*Halcyon leucocephala*	8
Martin-chasseur du Sénégal	*Halcyon senegalensis*	4
Martin pêcheur pie	*Ceryle rudis*	7
Petit martin-pêcheur huppé	*Alcedo cristata*	1
Guêpier nain	*Merops pusillus*	13
Guêpier à gorge blanche	*Merops albicollis*	6
Hirondelle à ventre roux	*Hirundo semirufa*	6
Bulbul à bec grêle	*Andropadus gracilirostris*	2
Bulbul commun	*Pycnonotus barbatus*	5
Soui-manga brun	*Anthreptes gabonicus*	1
Pie-grièche fiscale	*Lanius collaris*	2

Local Common Name	Scientific Name	Number
Spermète nonnette	*Lonchura cucullata*	32
Spermète pie	*Lonchura fringilloides*	13

Table 6.4-5
Results of the Bird Census in the Crop Field on a Poorly Developed Soil.

Local Common Name	Scientific name	Number
Héron garde-bœuf	*Ardeola ibis*	11
Elanion blanc	*Elanus caeruleus*	1
Milan noir	*Milvus migrans*	1
Epervier shikra	*Accipiter badius*	3
Buse unibande	*Kaupifalco monogrammicus*	1
Crecerelle	*Flco tinnunculus*	1
Francolin commun	*Francolinus bicalcaratus*	4
Vanneau terne	*Vanellus lugubris*	16
Emerauldine à bec rouge	*Turtur afer*	2
Tourterelle à collier	*Streptopelia semitorquata*	1
Tourterelle maillée	*Streptopelia senegalensis*	8
Inséparable à tête rouge	*Agapornis pullaria*	2
Touraco gris	*Crinifer piscator*	1
Coucou de levaillant	*Clamator levaillantii*	1
Coucal du sénégal	*Centropus senegalensis*	8
Martin-chasseur à tête grise	*Halcyon leucocephala*	6
Martin-chasseur du Sénégal	*Halcyon senegalensis*	4
Petit barbu de vieillot	*Lybius vieilloti*	1
Pic à dos vert	*Campethera cailliautii*	2
Pic gris	*Mesopicos goertae*	2
Bulbul commun	*Pycnonotus barbatus*	29
Grive kurrichane	*Turdus pelios*	1
Gobemouche caronculé à collier	*Platysteira cyanea*	1
Soui-manga à poitrine rouge	*Nectarinia senegalensis*	1
Soui-manga brun	*Anthreptes gabonicus*	1
Soui-manga à ventre jaune	*Nectarinia venusta*	1
Soui-manga à ventre olive	*Nectarinia chloropygia*	1
Soui-manga cuivré	*Nectarinia cuprea*	2
Soui-manga éclatant	*Nectarinia coccinigaster*	2
Pie-grièche fiscale	*Lanius collaris*	1
Corvinelle	*Corvinella corniva*	8
Téléphone tchagra	*Tchagra senegala*	1
Gonolek de barbarie	*Laniarius barbarus*	6

Local Common Name	Scientific name	Number
Corbeau pie	*Corvus albus*	2
Merle métallique à œil blanc	*Lamprotornis splendidus*	4
Moineau gris	*Passer griseus*	2
Moineau – tisserin	*Plocepasser superciliosus*	5
Tisserin gendarme	*Ploceus cucullatus*	50
Tisserin noir de vieillot	*Ploceus nigerrimus*	2
Travailleur à bec rouge	*Quelea quelea*	2
Amarante commun	*Lagonosticta senegala*	9
Joues oranges	*Estrilda melpoda*	2
Veuve dominicaine	*Vidua macroura*	2

6.5 FISH AND FISHERIES RESOURCES

Overall, 7894 individual fishes comprising 51 species and belonging to 26 families were collected from March 2000 to September 2001**.** The most speciose families were Eleotridae (7 species), Cichlidae (5 species) and Mugilidae (5 species). The families Eleotridae, Cichlidae, Mugilidae, Cyprinotontidae, Gerreidae and Clupeidae numerically dominated the sample and accounted for 92.96 percent. In terms of species, six dominated the sample and accounted for 80.27 percent: *Kribia nana*, *Sarotherodon melanotheron*, *Gerres melanopterus*, *Ethmalosa fimbriata*, *Hemichromis fasciatus*, and *Aplocheilichthys spilauchen*. *Sarotherodon melanotheron,* alone, constituted 28.98 percent of the total sample followed by *Kribia nana* (15.19 percent), *Aplocheilichthys spilauchen* (13.71 percent), *Gerres melanopterus* (12.90 percent), *Ethmalosa fimbriata* (4.84 percent) and *Hemichromis fasciatus* (4.65 percent). The remaining (19.73 percent), was shared by 45 species and none of them had an individual relative abundance more than 2.65 percent. In term of biomass, the 7894 fishes collected weighed 95106.7g. *Sarotherodon melanotheron, Kribia nana*, *Aplocheilichthys spilauchen*, *Gerres melanopterus*, *Ethmalosa fimbriata* and *Hemichromis fasciatus* constituted 79.11 percent of the total biomass. *Sarotherodon melanotheron,* alone, constituted 46.66 percent of the total biomass. The remaining 20.89 percent, was shared by 43 species, none of which had a biomass of more than 3.62 percent (Table 6.5-1).

The Shannon-Wiener Diversity Index at the mangrove sites ranged from 0.108 to 2.206 (mean=1.444). Diversity was lower at degraded sites (Sites 5, 6 and 7), and higher at less degraded sites (Sites 1 and 2)**.** A restored mangrove site (Site 8) had a high species diversity of 2.087 and species richness (37). In terms of season, species diversity during the wet, transitional and dry seasons was 1.931, 1.655, and 1.870, respectively (Table 6.5-2). Permanent water dynamic (flux and reflux from freshwater and saltwater) may act to maintain approximately constant the species richness and species diversity from one season to another.

Of a total of 51 fish species gathered from the coastal zone, only 11 species (20 percent) originated from the inland water and the remaining (80 percent), originated from the marine or estuarine environment. Consequently, fish composition tends to be greatly dominated by marine-estuarine fishes whereas the number of inland (rivers) fish species was lower. This situation is due to the relatively new water quality and hydrological regimes caused by the construction of the hydroelectrical dam of the Mono River.

Data from combined samples from cast net, seine, gill net and cross-lake fish trapping provide information on fish species composition, abundance, size, and weight of the mangrove fishes in the Benin coastal zone.

Table 6.5-1
Fish Catch Data from Multiple Methods of Fishing, Coastal Benin.

Species families	Total Num.	SL range (mm)	SL mean (mm)	Weight range (g)	Weight mean (g)	Total weight (g)
Belonidae						
Strongylura senegalensis	**6**	**242-275**	**257.3**	**25-33**	**28.5**	**171**
Bothidae						
Citharichthys stampflii	**86**	**30-130**	**79.7**	**0.5-50**	**10.8**	**933**
Carangidae						
Caranx hippos	**88**	**50-82**	**64.6**	**2-50**	**7.6**	**671**
Cichlidae						
Sarotherodon melanotheron	**2288**	**8-189**	**72.1**	**0.1-220**	**19.3**	**44375**
Tilapia zillii	**109**	**47-175**	**83.1**	**4-250**	**31.5**	**3440**
Tilapia guineensis	**180**	**13-220**	**56.6**	**0.25-455**	**12.1**	**2182**
Hemichromis fasciatus	**367**	**15-158**	**74.1**	**0.1-150**	**16.5**	**6088**
Hemichromis bimaculatus	**102**	**21-67**	**36.3**	**0.3-15**	**2.5**	**253**
Clariidae						
Clarias gariepinus	**5**	**215-440**	**279**	**65-520**	**203.6**	**1018**
Claroteidae						
Chrysichthys nigrodigitatus	**107**	**62-275**	**118.7**	**4-420**	**41.5**	**4446**

Clupeidae						
Ethmalosa fimbriata	**382**	**49-130**	**76.8**	**2-48**	**10**	**3832**
Pellonula sp	**209**	**29-95**	**71**	**0.15-10**	**5**	**1061**
Cynoglossidae						
Cynoglossus senegalensis	**2**	**313-315**	**314**	**86-94**	**90**	**180**
Cyprinotontidae						
Aplocheilichthys spilauchen	**1082**	**14-83**	**31.4**	**0.1-5**	**1**	**1068**
***Epiplatys* sp.**	**2**	**19-26**	**22.5**	**0.1-0.1**	**0.1**	**0.2**
Eleotridae						
Kriba nana	**1199**	**19-80**	**51.8**	**0.2-13**	**3.8**	**4650**
Dormitator lebretonis	**39**	**21-65**	**35**	**0.3-9**	**1.4**	**56**
Dormitator pleurops	**1**	**30-30**	**30**	**0.8-0.8**	**0.8**	**0.8**
Eleotris daganensis	**2**	**93-93**	**93**	**21-25**	**23**	**46**
Eleotris vitatta	**7**	**78-155**	**97.8**	**9-100**	**54.5**	**205**
Eleotris senegalensis	**6**	**29-105**	**48.6**	**0.3-34**	**7**	**42**
***Eleotris* sp.**	**77**	**30-180**	**85.8**	**0.5-190**	**24.2**	**1867**
Elopidae						
Elops lacerta	**36**	**100-190**	**136.7**	**10-90**	**30.5**	**1101**
Elops senegalensis	**5**	**131-176**	**155.2**	**24-50**	**37.2**	**186**
Gerreidae						
Gerres melanopterus	**1018**	**7-118**	**59.8**	**0.1-30**	**6.2**	**6388**
Gerres nigri	**2**	**74-89**	**81.5**	**9-17**	**13**	**26**
Gobiidae						
Oxyurichthys occidentalis	**87**	**43-130**	**95.2**	**2-31**	**12.5**	**1091**
Progobius schlegeli	**25**	**40-99**	**72.5**	**1-22**	**9.1**	**228**
Lutjanidae						
Lutjanus goriensis	**11**	**30-118**	**62.4**	**3-70**	**14.7**	**162**
Lutjanus agennes	**4**	**48-72**	**57.7**	**4-13**	**6.5**	**26**
Lutjanus sp	**4**	**60-114**	**83.5**	**5-144**	**20.3**	**81**

Mochokidae						
Synodontis sp	**1**	**93-93**	**93**	**14-14**	**14**	**14**
Monodactylidae						
Psettia sebae	**9**	**27-55**	**41.6**	**2-15**	**9**	**81**
Mugilidae						
Liza falcipinnis	**179**	**23-195**	**100.1**	**0.4-135**	**27.8**	**4979**
Mugil curema	**62**	**52-160**	**101.8**	**3-92**	**24.5**	**1521**
Mugil bananensis	**2**	**102-255**	**178.5**	**21-240**	**130.5**	**261**
Mugil cephalus	**1**	**163-163**	**63**	**92-92**	**92**	**92**
Mugil sp	**25**	**77-162**	**102.7**	**9-76**	**24.5**	**612.5**
Liza sp	**22**	**15-29**	**22.4**	**0.2-0.4**	**0.28**	**6.2**
Ophichthyidae						
Myrophis plumbeus	**1**	**395-395**	**395**	**46-46**	**46**	**46**
Dalophiss sp	**1**	**475-475**	**475**	**32-32**	**32**	**32**
Ophiocephalidae						
Parachana obscura	**1**	**240-240**	**240**	**220-220**	**220**	**220**
Polynemidae						
Galeoides decadactylus	**2**	**50-78**	**64**	**3-10**	**6.5**	**13**
Pomadasydae						
Pomadasys jubelini	**4**	**84-145**	**116**	**12-80**	**50**	**200**
Pomadasys peroteti	**1**	**92-92**	**92**	**13-13**	**13**	**13**
Pomadasys sp	**11**	**57-113**	**83.4**	**6-40**	**16.1**	**117**
Protopteridae						
Protopterus annectens	**1**	**340-340**	**340**	**165-165**	**165**	**165**
Scombridae						
Cybium sp	**14**	**88-120**	**108.2**	**8-20**	**14.8**	**208**

Serranidae							
Epinephelus aeneus	**2**	**145-250**	**197.5**	**68-340**	**204**	**408**	
Syngnathidae							
Microphis brachyurus							
Aculeatus		**5**	**100-116**	**108.2**	**0.5-3**	**1**	**5**
Sphyraenidae							
Sphyraena guachancho	**12**	**60-98**	**80**	**7-34**	**19.9**	**239**	
Total number of families	**26**						
Total number of species	**51**						
Total number of individuals	**7894**						

Species richness and species diversity for the mangrove fish, caught from March 2000 to September 2001, in the Benin estuarine/coastal zone. Site 1 = Aido; Site 2=Djondji; Site 3=Djegbame; Site 4=Grand-Popo; Site 5=Onkuiwe; Site 6=Hio; Site 7=Togbin; Site 8=Djegbadji.

Table 6.5-2
Diversity Indices for Fish Data by Site

Attributes	Site1	Site2	Site3	Site4	Site5*	Site6*	Site7*	Site8**
Species richness	**15**	**27**	**14**	**16**	**15**	**8**	**2**	**37**
Species evenness	**0.77**	**0.59**	**0.58**	**0.49**	**0.44**	**0.54**	**0.16**	**0.61**
Species diversity	**2.09**	**1.91**	**1.54**	**1.37**	**1.18**	**1.12**	**0.11**	**2.21**

Distribution of the Fishes in the Habitats

The species richness for the four habitat categories: adjacent open water, mangrove fringe, channel, and adjacent marginal vegetation; were 38, 30, 16, and 19, respectively. Within the mangrove fringe, the families such as Cichlidae, Mugilidae, Elopidae, Cyprinotontidae, Claroteidae, Cynoglossidae, and Clariidae were best represented, while Cichlidae, Gerreidae, Eleotridae, Bagridae, Clupeidae, Belonidae, Carangidae, and Gobiidae were most prevalent in adjacent open water. The cichlid, *Hemichromis bimaculatus*, occurred in the shallow environments including the vegetation, channel, and mangrove roots system where water could become turbid. Though occurring in the four habitats, *Hemichromis fasciatus* and *Aplocheilichthys spilauchen* tend to be more abundant at the mangrove fringe. Relatively to the total number of fish caught, *Sarotherodon melanotheron* is always abundant in all habitats. This species occurs abundantly in most of the brackish water of Benin such as Lake Nokoue, the lagoon of Porto-Novo, and Lake Aheme where *Sarotherodon melanotheron* is always the first dominant species (Van Thielen et al., 1987). According to Gbaguidi and Pfeiffer (1988), *Sarotherodon melanotheron* accounts for about 30 percent of the annual total catches. The species *Kribia nana, Ethmalosa fimbriata, Gerres melanopterus*, though present at all site, were more abundant in the adjacent open water. In particular, *Kribia nana* occurred mostly in open water during flooding. During both the dry and wet seasons, this species inhabits muddy, vegetated environments and mangrove root systems; where flooding brings them to the open water. The relatively high abundance of *Hemichromis fasciatus* at the mangrove fringe compared to the other habitats, may indicate a relatively high predation in/or around the mangrove forest. Primarily a freshwater resident, *Pellonula* sp. mostly occurred in the Mono River mouth where salinities where always low.

Appendix F contains data on the species composition and abundance by habitat in the mangrove zone. Adjacent open water and mangrove habitat exhibited higher species abundance and species richness than the channel and adjacent marginal vegetation, where mangrove has been destroyed.

Trophic structure of fish composition

The mangrove fish community was numerically dominated by detritivores (39.4 percent) and planktonivores/microcarnivores (45.6 percent). Though not numerically important, the intermediate carnivores (4.7 percent) and the top-predators (6.6 percent) comprised a relatively high species number, 15 and 15, respectively. Herbivore species (*Tilapia guineensis, Tilapia zillii*) comprised 3.67 percent. In terms of biomass, detritivores dominated the sample (63.3 percent of the total biomass) due to the predominance of *Sarotherodon melanotheron*, which constituted 46.66 percent of the total biomass. The intermediate carnivores and the top-predators, despite their number (30 species), had a relatively low biomass proportion (5.5 percent and 10.4 percent, respectively). Relative to economic value of the fish species, fish were classified into three categories according to their commercial value: (1) fishes of high commercial value (HC), (2) fishes of moderate commercial value (MC), and (3) fishes with no commercial value, including those not utilized as food nor sold in the fish market (NV). From the fish sampled, about 74 percent had a high economic value, from which 74 percent were juveniles and adults. Only three species (*Aplocheilichthys spilauchen, Epyplatys* sp., and *Mycrophis brachyurus aculeatus)* of small sizes had no commercial value. This indicates that the mangrove zone is a multi-species fishery where about 94 percent of the fish species are exploited.

Table 6.5-3 lists the trophic categories, relative abundance and fisheries importance of the fish caught on the Benin estuarine/coastal zone. Detritivores and planktonivores dominated the sample.

Table 6.5-3
Trophic and Commercial Characteristics of Estuarine Fish in Benin
(J: Juvenile; A: adult; HC: highly commercial; MC: moderately commercial; NV: no value.)

Trophic Category / Species	Relative Abundance (%)	% of Total Weight	Life History Stage	Fisheries Importance
Detritivores				
Chrysichthys nigrodigitatus	**1.35**	**4.66**	**J/A**	**HC**
Dormitator lebretonis	**0.49**	**0.06**	**J**	**MC**
Dormitator pleurops	**0.01**	**0.0008**	**J**	**MD**
Ethmalosa fimbriata	**4.84**	**4.03**	**J/A**	**HC**
Liza falcipinnis	**2.27**	**5.23**	**J/A**	**HC**
Liza sp	**0.29**	**0.007**	**J**	**HC**
Mugil curema	**0.79**	**1.60**	**J/A**	**HC**
Mugil bananensis	**0.02**	**0.27**	**A**	**HC**
Mugil cephalus	**0.01**	**0.1**	**A**	**HC**
***Mugil* sp.**	**0.32**	**0.64**	**J/A**	**HC**
Sarotherodon melanotheron	**28.98**	**46.66**	**J/A**	**HC**
***Synodontis* sp.**	**0.01**	**0.01**	**A**	**MC**
Planktonovores/microcarnivores				
Aplocheilichthys spilauchen	**13.71**	**1.12**	**J/A**	**NV**
***Epiplatys* sp.**	**0.02**	**0.0002**	**J**	**ND**
Gerres melanopterus	**12.90**	**6.12**	**J/A**	**HC**
Gerres nigri	**0.02**	**0.03**	**A**	**HC**
Kriba nana	**15.19**	**4.89**	**J/A**	**HC**
Oxyurichthys occidentalis	**1.10**	**1.12**	**J/A**	**HC**
***Pellonula* sp.**	**2.65**	**1.12**	**J/A**	**MC**
Herbivores				
Tilapia guineensis	**2.28**	**2.29**	**J/A**	**HC**
Tilapia zillii	**1.38**	**3.62**	**J/A**	**HC**
Intermediate carnivores				
Caranx hippos	**1.11**	**0.71**	**J/A**	**HC**
Citharichthys stampflii	**1.09**	**0.98**	**J/A**	**MD**
Clarias gariepinus	**0.06**	**1.07**	**A**	**HC**
Cynoglossus senegalensis	**0.02**	**0.19**	**A**	**MC**
***Dalophis* sp.**	**0.01**	**0.03**	**A**	**MC**
Elops lacerta	**0.46**	**1.16**	**A**	**HC**
Elops senegalensis	**0.06**	**0.20**	**A**	**HC**
Hemichromis bimaculatus	**1.29**	**0.27**	**J/A**	**MC**
Microphis brachyurus Aculeatus	**0.06**	**0.005**	**A**	**NV**
Myrophis plumbeus	**0.01**	**0.05**	**A**	**MC**
Pomadasys jubelini	**0.05**	**0.2**	**J/A**	**HC**
Pomadasys peroteti	**0.01**	**0.01**	**J/A**	**HC**
***Pomadsys* sp.**	**0.14**	**0.12**	**A**	**HC**

Protopterus annectens	**0.01**	**0.17**	**A**	**MC**
Progobius schlegeli	**0.32**	**0.24**	**J/A**	**HC**
Predators				
Cybium **sp.**	**0.18**	**0.22**	**J/A**	**HC**
Eleotris daganensis	**0.02**	**0.05**	**A**	**MC**
Eleotris senegalensis	**0.08**	**0.04**	**J/A**	**MC**
Eleotris **sp.**	**0.98**	**1.96**	**J/A**	**MC**
Eleotris vitatta	**0.09**	**0.22**	**J/A**	**MC**
Epinephelus aeneus	**0.02**	**0.43**	**J/A**	**MC**
Hemichromis fasciatus	**4.65**	**6.40**	**J/A**	**HC**
Galeoides decadactylus	**0.02**	**0.01**	**J**	**MC**
Lutjanus agennes	**0.05**	**0.03**	**J/A**	**HC**
Lutjanus goriensis	**0.14**	**0.17**	**J/A**	**HC**
Lutjanus **sp.**	**0.05**	**0.09**	**J/A**	**HC**
Parachana obscura	**0.01**	**0.23**	**A**	**MC**
Psettia sebae	**0.11**	**0.09**	**J/A**	**MC**
Strongylura senegalensis	**0.08**	**0.18**	**A**	**MC**
Sphyraena guachancho	**0.15**	**0.25**	**J/A**	**MC**
TOTAL INDIVIDUALS	**7894**			

<u>Size Structure</u>

Overall, fish size (total length) in the mangrove zone ranged from 7mm (*Gerres melanopterus*) to 440mm (*Clarias gariepinus*) with corresponding weights of 0.1g and 525g, respectively. Larger fish were found in the adjacent open water and at the mangrove fringe. Larger sizes were found among Cichlidae, Mugilidae, Clariidae, Elopidae, Belonidae, Bagridae and Cynoglossidae. Smaller fish (*Aplocheilichthys spilauchen*, *Kribia nana*, *Epyplatys* sp.) and *Pellonula* sp. were found in the channel and vegetation. In Particular, trends of size by habitat type for dominant species are as follow: smaller sizes of *Sarotherodon melanotheron* were found in vegetation, mangrove and open water; while larger sizes tended to be associated with colonization of the mangrove fringe. Smaller sized *Kribia nana* occurred in vegetation, whereas larger individuals were prevalent in open water. *Gerres melanopterus* and *Ethmalosa fimbriata* occurred in open water regardless of size. Smaller sized individuals of *Hemichromis fasciatus* occurred in channels and vegetation whereas larger individuals were found in mangrove. *Aplocheilichthys spilauchen* were found in all habitats regardless of size. Dominant species, *Kribia nana*, *Sarotherodon melanotheron*, *Gerres melanopterus*, *Ethmalosa fimbriata*, *Hemichromis fasciatus*, and *Aplocheilichthys spilauchen* showed unimodal size distributions**.** In general, small individuals inhabit calm and shallow environments to avoid strong currents. As we would expect, fish sizes are generally relatively small in the Benin mangrove-lined estuary due to high fishing effort and overexploitation.

6.6 CLIMATE AND METEOROLOGY

Tables 6.6-1 through 6.6-7 represent meteorological conditions as they were measured from 1952 to 2002 at the Cotonou Airport (6°2 N, 2°0 E).

Table 6.6-1
Relative Humidity (%)

Maximum	Minimum	Average
99.5	70	93

Table 6.6-2a
Daily insolation (hour/day)

Maximum	Minimum	Average
12	0.2	6.9

Table 6.6-2b
Average monthly insolation (hour/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.82	7	7.04	6.2	7.44	5.2	4.2	5.2	5.6	6.1	8.0	8

Table 6.6-3a
Wind Speed (m/s)

Maximum	Minimum	Average
10.1	1.11	4.28

Table 6.6-3b
Average monthly Wind Speed (m/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3	4.9	5.7	4.5	3.6	4.2	5.3	5.6	5.1	4.4	3.8	3.8

Table 6.6-4a
Average Temperature (°C)

Maximum	Minimum	Average
34	25	30

Table 6.6-4b
Average Monthly Temperature (°C)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24.1	29.4	29.9	29.20	26	17.15	26.7	26.4	26.3	27.20	28.8	28.6

Table 6.6-5a
Annual Precipitation (mm)

Maximum	Minimum	Average
2350	970	1366

Table 6.6-5b
Annual Monthly Precipitation (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24.1	Traces	29.9	126.1	71.1	438.8	78.6	34.9	59.8	255.7	26.	0.2

Table 6.6-6
Number of Days of Rain (per year)

Maximum	Minimum	Average
125	68	102

Table 6.6-7
Average Monthly Vapor Pressure (%)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
89.7	31.20	68.9	69.23	66.4	71.3	76	75	74.8	72.3	67.3	58.5

CHAPTER 7
ONSHORE RESULTS – NIGERIA

The R&M station sampling locations in Nigeria are shown in Figure 7.0-1, while those at Badagry Creek are shown in Figure 7.0-2. Figure 7.0-3 illustrates the vegetative cover classification map.

7.1 VEGETATION

The vegetation in the study area falls into two categories, inland and coastal/nearshore.

7.1.1 Coastal Area Habitats

Four habitat types were noted in the coastal zone, which lies between the Atlantic Ocean and the Lagos Lagoon, they are discussed below.

<u>Strandline</u>

This habitat is located between the extreme high water mark and the coconut groves. Creeping plants (mainly rhizomatous and stoloniferous) above the shoreline characterize the area (Figure 7.1-1 and Table 7.1-1). The most common species include: *Commelina erecta* var. *maritima, Kylingia peruviana,* and *Ipomoea pes-caprae* (Table 7.1-1). The strandline plants are mainly creepers, which are fully exposed to full sunlight. They are scattered in terms of spatial distribution along the shoreline. The biomass of the plants is 48±13g/m^2.

Table 7.1-1
Plant species composition within the strandline zone.

Scientific Name	Common name	Habit
Brachilaria sp.		Creeper
Cassytha filiformis		Twinner
Chromolaena odorata	Siam weed	Shrub
Chrysobalanus icaco		Shrub
Cocos nucifera	Coconut	Tree
Commelina erecta var. *maritime*	Wandering Jews	Creeper
Ipomoea pes caprae	Seaside goat foot	Stoloniferous creeper
Kylingia peruviana		Herb
Manihot esculenta	Cassava	Shrub
Melanthera scandens	Haemorhage plant	Herb
Panicum maximum	Guinea grass	Herb
Pennisetum purpureum	Elephant grass	Herb
Philoxerus vermicularis		Creeper

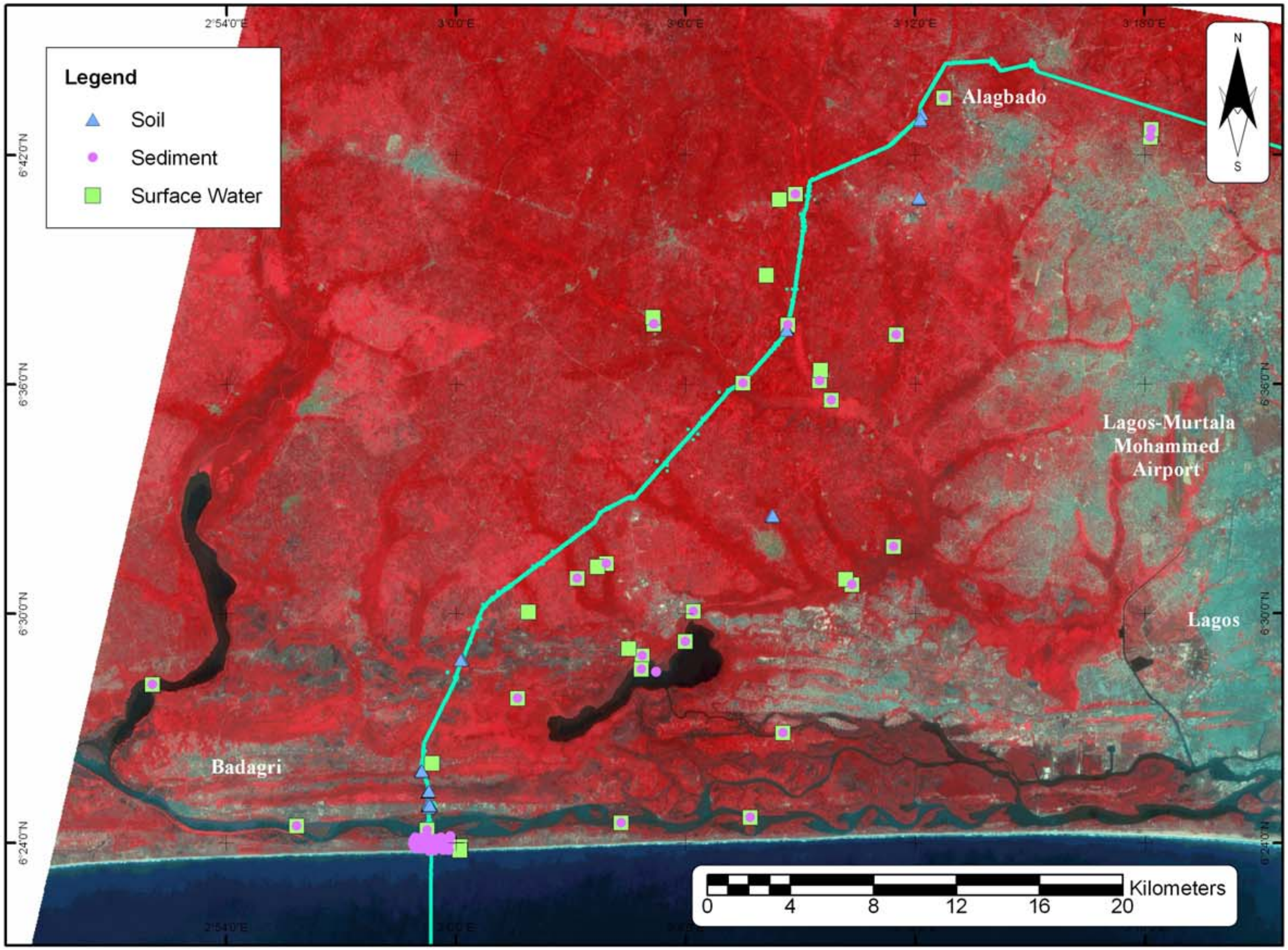


Figure 7.0-1 - Nigeria Onshore Sampling Locations

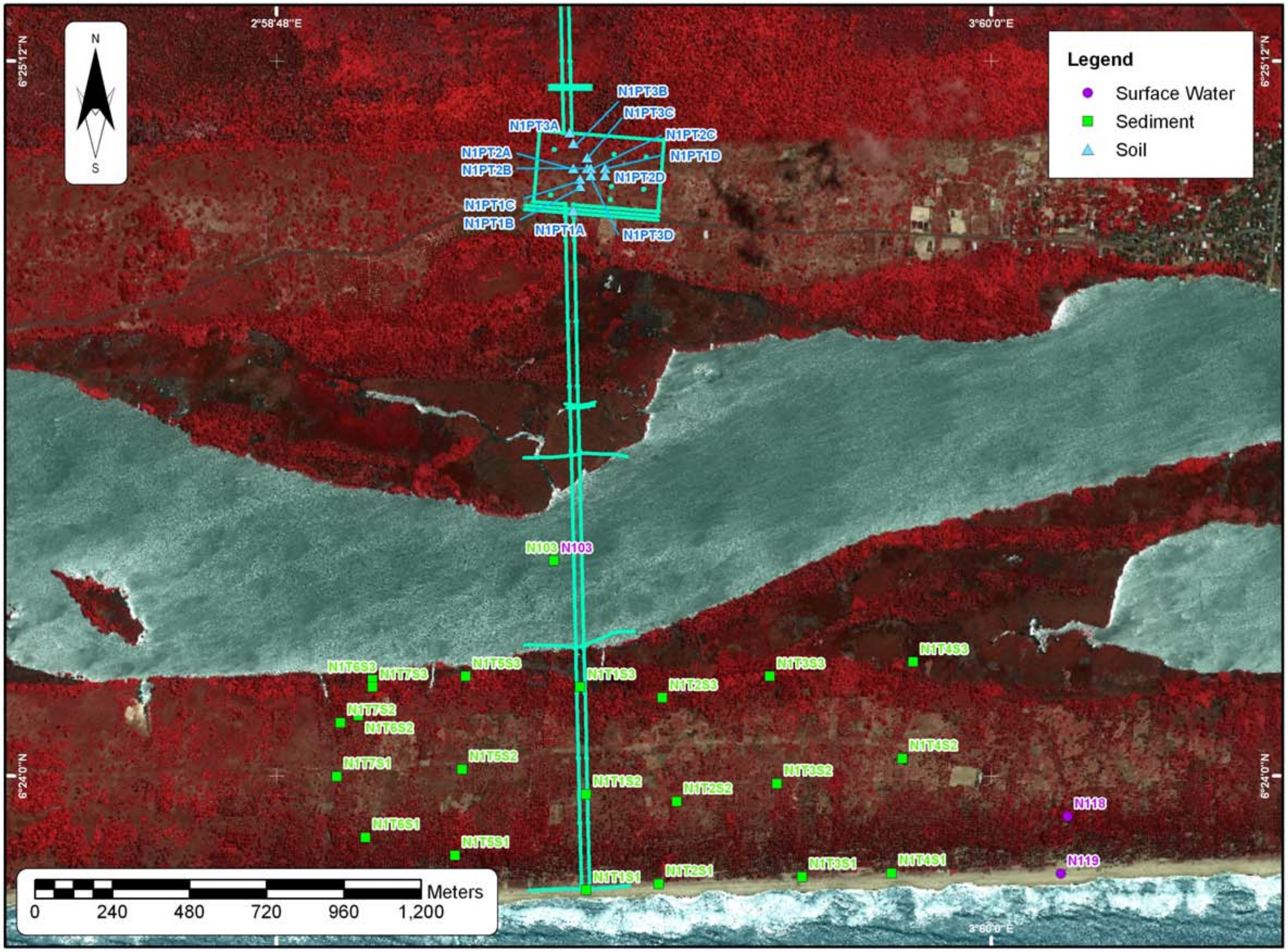


Figure 7.0-2 - Badagri Creek Sampling Stations

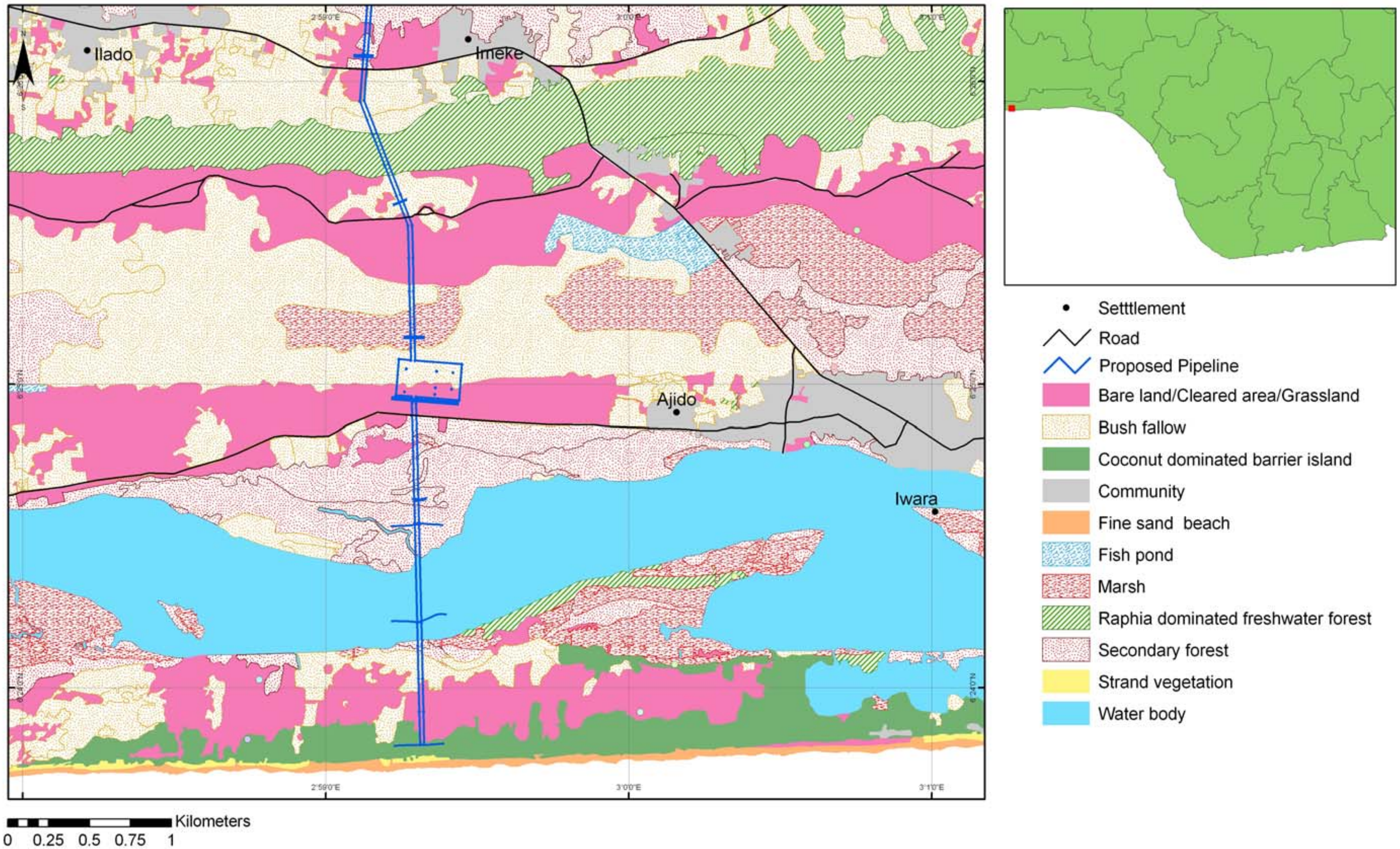


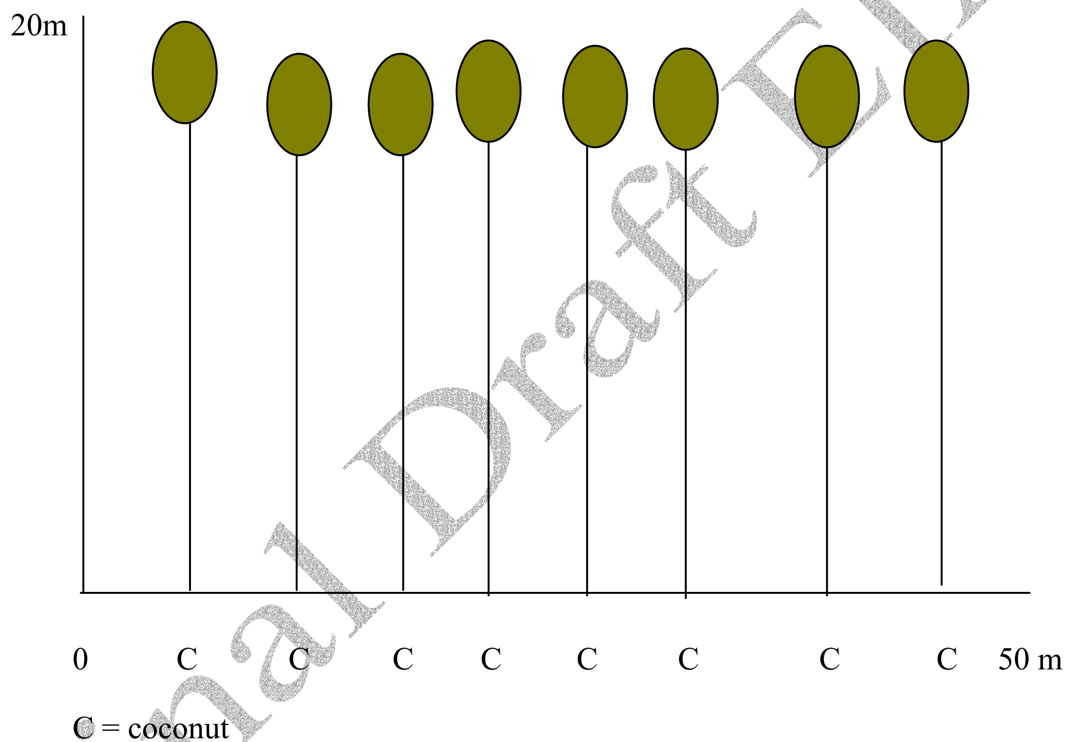
Figure 7.0-3 Vegetative Cover Classification Map

Figure 7.1-1
Part of the Atlantic shoreline showing strand vegetation.

Coconut-Dominated Barrier Island

The second habitat is the main barrier island area where a lot of agricultural activities take place. Extensive groves of coconut occur within this area (Figure 7.1-2). A few weeds occur under the canopy of the coconut. The coconut groves have a close canopy and have an average height of about 20m. The vertical and spatial structure of the coconut belt is shown in Figure 7.1-2. The coconut tree has a mean density of 400 plants per hectare. Most of the coconut trees were chlorotic at the time of the survey. The biomass value for the herb layer is 36±12g/m^2.

Figure 7.1-2
Profile diagram of a typical coconut palm grove along the coastline.

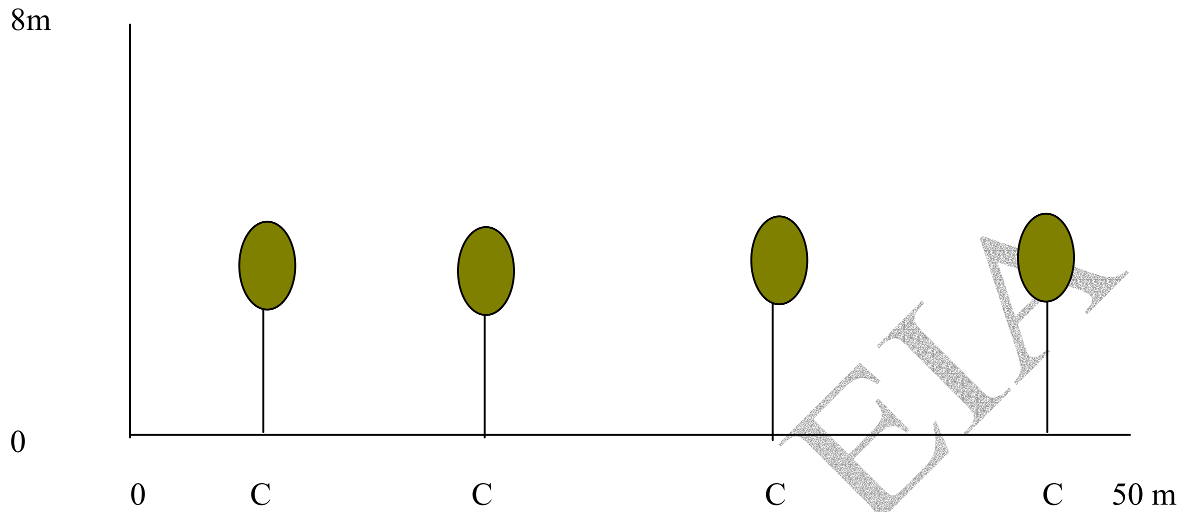


Bare Ground/Farms/Grassland Mosaic

The third habitat consists of a mosaic of bare ground, cassava farms and grassland. Young populations of coconut also occur here (Figure 7.1-3 and 7.1-4). The grasses include *Imperata cylindrica* (spear grass), *Cynodon dactylon,* and *Andropogon gayanus.* There are also scattered populations of *Vitex doniana* (black plum). The mosaic of bare ground, cassava farms and grassland, which occupy the middle part of the barrier island, is physiognomically dominated by young coconut palms (Figure 7.1-3). The canopy height is about 8m.

Figure 7.1-3
Young coconut trees and grasses at the middle of the barrier island.

Figure 7.1-4
Profile diagram of the vegetation structure in the middle part of the barrier island.



C = Coconut

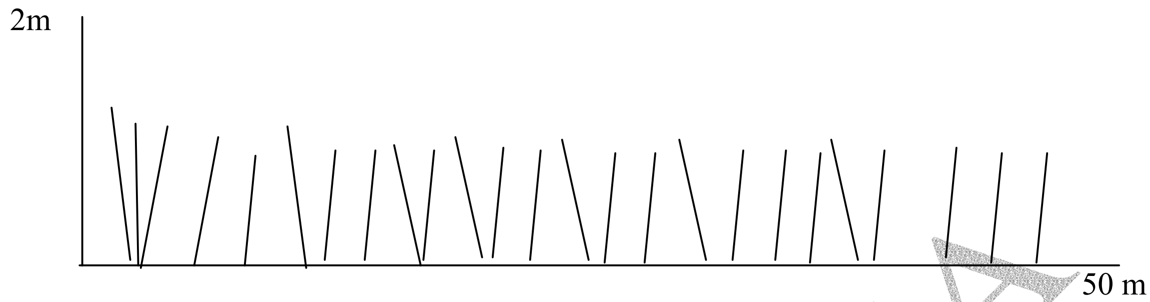
Marsh/Swamp

The fourth habitat consists of a narrow belt of marshy area at the fringe of Badagry Lagoon. This is dominated by extensive mats of *Cyperus articulatus* and scattered stands of coconut and flood-tolerant trees and shrubs. This zone is in turn fringed by aquatic macrophytes such as water hyacinth, *Polygonium africanum*, and *Pistia stratiotes*. A consolidated list of the plants is presented in Table 7.1-2. The canopy of the vegetation is open (Figure 7.1-5). The biomass for the herb layer is 136±15g/m^2.

Table 7.1-2
Plant species composition within the marsh/swamp habitat.

Scientific name	Common name	Habit
Cyperus articulatus	Bizzy-bizzy	Rhizomatous sedge
Eichhornea crassipes	Water hycainth	Free floating
Ludwigia repens		Erect herb
Machaerium lunatus		Shrub
Paspalum sp.		Herb
Pistia stratiotes	Water lettuce	Free floating
Polygonium africana	Smartweed	Emergent
Saccharium officinarium	Sugarcane	Erect grass
Typha domingensis	Reed	Emergent macrophyte

Figure 7.1-5
Profile diagram of the marsh/swamp area dominated by *Cyperus articulatus.*



7.1.2 Inland Habitats

Four habitat types were observed in the inland areas, which spans from Alagbado to Badagry and continue westward, almost paralleling the barrier island. They are discussed below.

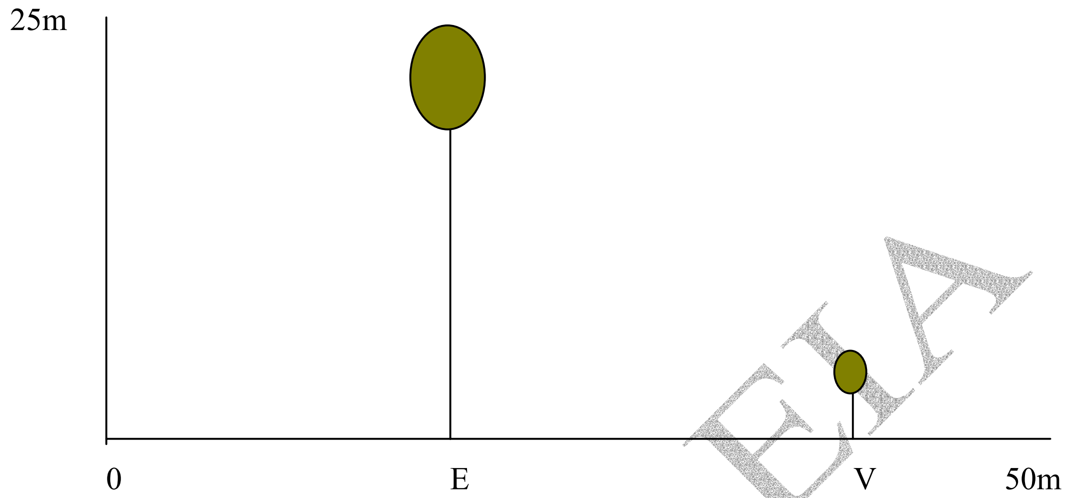
Coastal Savanna

The coastal savanna occurs in parallel belts. They are grazed by cattle and subjected to burning annually. There are scattered shrubs and trees within the large expanse of grasses (Table 7.1-3). The vegetation canopy is open and is characterized by isolated emergent trees between extensive grassland (Figure 7.1-6). The coastal savanna had recently been burnt at the time of the survey, largely killing the herbaceous layer. The process of regeneration had just begun. Herds of cattle were seen grazing within the area during the study.

Table 7.1-3
Plant species composition in the coastal savanna habitat.

Scientific name	Common name	Habit
Elaeis guineensis	Oil palm	Tree
Imperata cylindrical	Spear grass	Rhizomatous grass
Panicum maximum	Guinea grass	Erect grass
Pennisetum purpureum	Elephant grass	Erect grass
Vitex doniana	Black plum	Tree
Zanthozyllum sp.		Tree

Figure 7.1-6
Profile diagram of the vegetation of the coastal savanna.



E=*Elaeis guineensis*; V=*Vitex doniana*

<u>Raphia Palm-Dominated Freshwater Swamp Forest</u>

The swamp forest is dominated by raphia palm (*Raphia hookeri)*, which, in places, forms a more or less homogenous belt. A few flood tolerant plants are associated with the raphia palm (Table 7.1-4). The raphia is also subjected to burning (e.g. near the proposed compressor station), which killed the herbaceous layer. The raphia-palm dominated swamp, in some places, has also recently been burnt. The swamp vegetation has a canopy height of about 20m. Herbaceous species (e.g. water lily) and seedlings of raphia palm dominate the understory (Figure 7.1-7). Raphia palm (*Raphia hookeri*) has a mean population density of 600 plants per hectare while the lowest population density of 5 plants per hectare was recorded for *Piptadenisatrum* sp.. The biomass value for the herb layer is $163 \pm 4 g/m^2$.

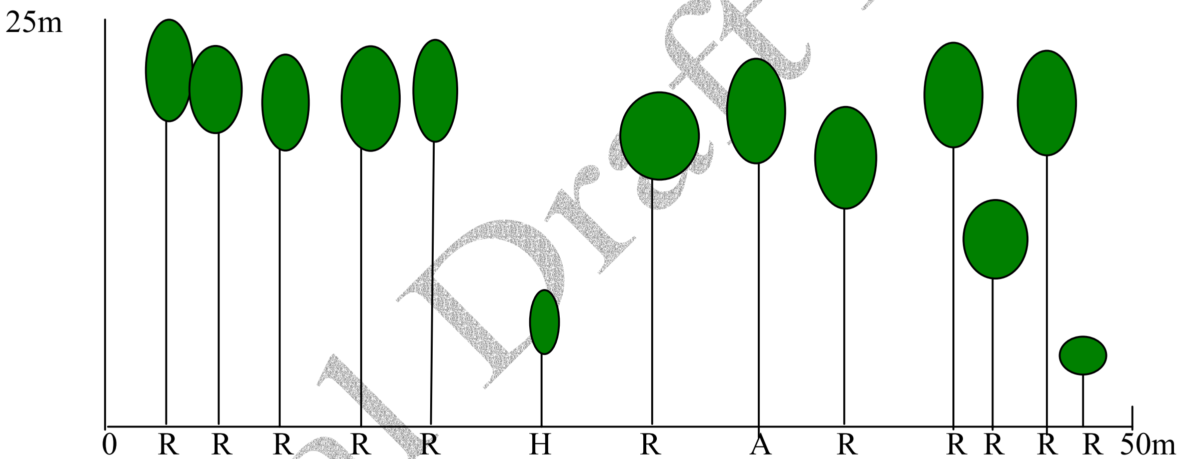
Raphia Palm-Dominated Freshwater Swamp Forest

This habitat is commonly associated with either healthy raphia and or stressed/degraded raphia (Figure 7.2-5) palms. By degraded, it is meant that the raphia palms were stressed either due to annual bush fire or due to changes in local hydrology. The healthy raphia palms are those showing luxuriant growth with virtually no evidence of physiological stress. Except in a few areas where very few stands of Plantain and Banana were growing at the fringes of the swamp, this habitat was essentially uncultivable for arable cropping. In a number of places however, tapping of the raphia palms for wine was clearly noticeable.

Table 7.1-4
Plant species composition in the Raphia palm-dominated swamp.

Scientific name	Common name	Habit
Alstonia boonei	Stool wood	Tree
Anchomanes difformis		Erect herb
Anthostema aubryanum		Tree
Cyrtosperma senegalense		Emergent macrophyte
Ficus sp.	Fig tree	Tree
Hallea ciliata	Abura	Tree
Nephrolepis biserrata		Epiphytic fern
Nymphaea lotus	Water lily	Floating –leaved
Scleria pterota	Razor grass	Erect grass

Figure 7.1-7
Profile diagram of Raphia palm-dominated swamp.



R=*Raphia hookeri;* A=*Alstonia boonei;* H=*Hallea ciliata.*

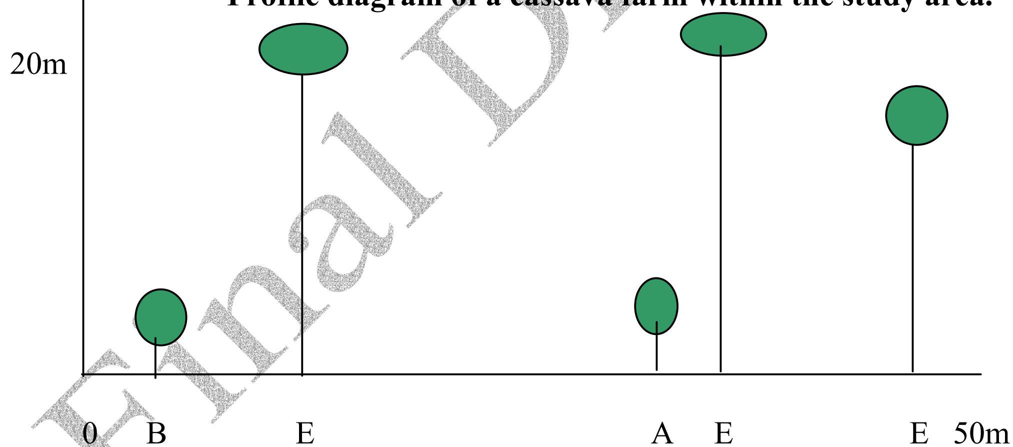
<u>Farm/Bush Fallow Mosaic</u>

The farm-bush fallow mosaic consists of scattered plots of farms within a matrix of fallow areas. Cassava is the dominant crop. Fast growing plant species typical of the early stages of secondary succession are common in the fallow areas. These include *Musanga cecropioides*, *Baphia nitida,* and *Elaeis guineesis*. A comprehensive list of the plants within the farms and fallow areas is presented in Table 7.1-5. The height of the vegetation within the bush fallow was variable. The tallest trees were the preserved economic species whose average height was 20m. The crowns of these trees formed a discontinuous canopy (Figure 7.1-8). Grasses, shrubs, forbs and remnants of agricultural crops such as cassava, occupy the gaps between the trees. The crop plants on the farms, which are dominated by cassava, have an average height of two meters. The highest plant population density (1350 plants per hectare) was recorded for *Manihot esculenta.* The growth of some cassava was also affected by competition from weeds. Cassavas that were overtaken by weeds showed symptoms of nutrient deficiency. The biomass of the herb layer within farms is 63±5g/m^{2-} while that of the bush fallow is 250±3g/m^2.

Table 7.1-5
Plant species composition in the farms/bush fallows.

Scientific name	Common name	Habit
Ageratum conizoides	Goat weed	Erect herb
Albizia zygia		Tree
Alchornea cordifolia		Shrub
Anthonotha macrophylla		Shrub
Baphia nitida	Cam wood	Tree
Chromolaena odorata	Siam weed	shrub
Elusine indica	Bull grass	Erect grass
Ficus exasperata	Sandpaper tree	Tree
Imperata cylindrica	Spear grass	Rhizomatous herb
Mannihot esculenta	Cassava	Shrub
Panicum maximum	Guinea grass	Erect herb
Pennisetum purpureum	Elephant grass	Erect herb
Rauuwolfia vomitoria		Tree
Spondias mombin	Hog plum	Tree

Figure 7.1-8
Profile diagram of a cassava farm within the study area.



B=*Baphia* sp; E=*Elaeis guineensis;* A=*Alchornea cordifolia*

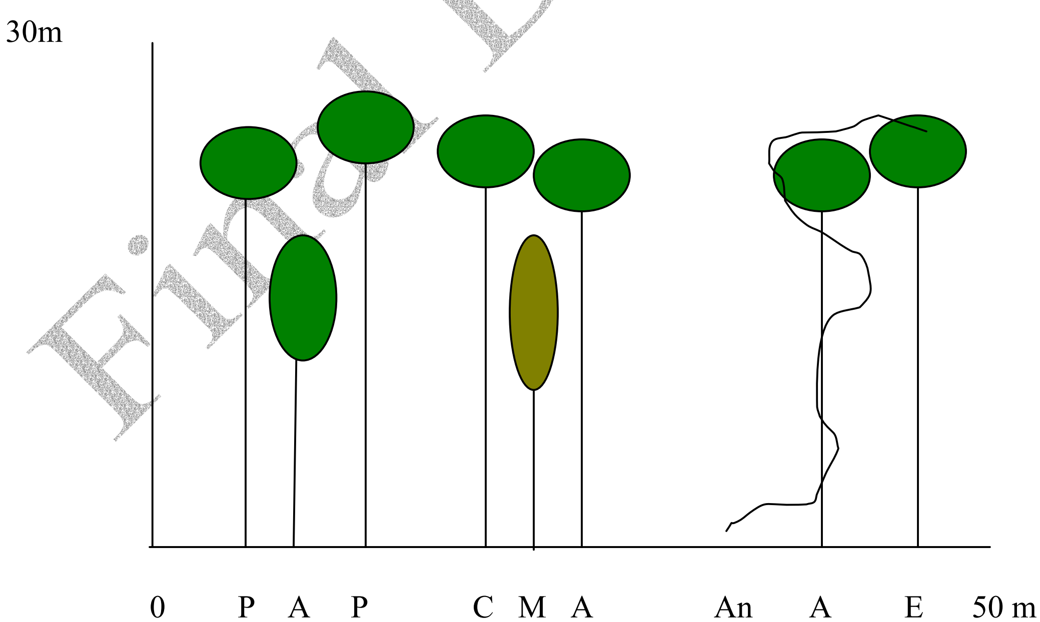
<u>Secondary Forest</u>

Secondary forests occur in the area, although none coincided with the transects in this survey. For informational purposes, a description of the habitat is provided here. Soils of this habitat were collected but not analyzed. The floristic composition of the vegetation within this habitat is presented in Table 7.1-6. It consists of an association of many plants organized into strata: trees, shrubs, herbs and climbers (Figure 7.1-9). This habitat has a well-developed structure and is rich floristically. It has a nearly complete canopy cover. The tallest trees include silk cotton tree, *Bombas buonoposense,* and *Artoarpus communis*, which are about 30m in height. Other species forming the canopy layer are: *Spondias mombin, Antholeista vogelii, Musanga* sp.*, Alstonia boonei,* and *Piptadeniastrum afrianum.* The canopy layer reaches about 20m in height. Plants such as *Smilas kraussiana* and other lianas form dense tangles around the trees. *Anhomanes difformis, Nephrolepis* sp.*, Palisota hirsuta, Costus spetabilis,* and *Icacnia tricantha* are found at the herb layer. The presence of oil palm attests to the secondary nature of the forest. The biomass value for the herb layer is $234 \pm 12 g/m^2$.

Table 7.1-6
Plant species composition within the secondary forest area.

Scientific name	Common name	Habit
Anchomanes difformis		Erect herb
Costus spectabilis	Bush cane	Erect herb
Musanga cecropioides	Rain tree	Tree
Piptadenistrum africanum		Tree
Spondias mombin	Hog plum	Tree
Anthoscleista vogelii	Cabbage tree	Tree
Palisota hirsute		Erect herb
Nephrolepis biserrata		Epiphytic fern
Artocarpus communis	Bread fruit	Tree

Figure 7.1-9
Profile diagram of a typical secondary forest.



P=*Piptadeniastrum africanum*; A=*Artocarpus* sp.; An=*Anchomanes difformis*; E=*Elaeis guineensis*; M=*Musing cecropioides*

Table 7.1-7
Population density of the major economic plants in the study area.

Scientific name	Common name	Density (No/ha)
Saccharum officinarum	Sugar cane	700±50
Cocos nucifera	Coconut	400±25
Elaeis guineensis	Oil palm	17±5
Hallea ciliata	Abura	9±4
Artocarpus communis	Bread fruit	10±3
Piptadeniatrum africanum		5±2
Manihot esculentum	Cassava	1350±120
Cola nitida	Cola nut	70±12
Raphia hookeri	Wine palm	600±50
Borassus aethiopum	Borrassus palm	30±8
Cyperus articulatus		20±12*

7.2 SOIL CHARACTERIZATION AND LAND-USE

7.2.1 Physical Properties of the Soils

This section of the report contains information on the physical characteristics of soil samples collected during the field campaign within each habitat, both in the inland and coastal area.

Coastal Area Soils

This is the land area between the Atlantic Ocean and the Badagry Lagoon. In width, the land area covered extends from about 500m to 720m. Generally, in this land area, on the basis of the vegetation/land-use pattern, the main habitat types and associated soils that were encountered, mapped, and characterized, consisted of the following:

Strandline Sand

This bare beach sand is commonly fringed by strand vegetation. In most places, the deep, medium-grained, loose beach sand is exposed (bare) with numerous thatched huts dotting the habitat (Figure 7.2-1). The beach sand is highly leached and is almost devoid of humified organic remains other than the shells of sea organisms brought onto the beach by wave actions. The physical characteristics of representative soil samples from within this habitat are indicated in Table 7.2-1.

Figure 7.2-1
Thatched houses along the barrier island.

Table 7.2-1
Mean particle size distribution of soils from the different habitats within the barrier island (coastal area).

Sampling coordinates		Habitat Type	Sand Fraction					Soil Separate			
Latitude (^oN)	**Longitude (^oE)**		**VCS**	**CS**	**MS**	**FS**	**VFS**	**TS**	**Silt**	**Clay**	**Texture**
			(percent)								
06^o 23.81	**002^o 59.32**	**Strandline Sand**	**4**	**29**	**53**	**7**	**0.00**	**93**	**1.00**	**6.00**	**Sand**
06^o 23.97	**002^o 59.32**	**Bare Ground /Farms / Grassland**	**3**	**34**	**47**	**7**	**0.00**	**91**	**2**	**7**	**Sand**
06^o 24.15	**002^o 59.31**	**Marsh/ Swamp**	**1**	**5**	**11**	**11**	**2**	**30**	**28**	**42**	**Clay**
VCS = Very coarse sand; CS = coarse sand; MS = medium sand; FS = fine sand; VFS = very fine sand; TS = total sand											

Table 7.2-1 shows that the sandy soils of the beach are predominantly medium (53 percent) to coarse (29 percent) sand, with virtually little or no silt and clay. The predominance of medium to coarse sand predisposes the soils to high infiltration, low moisture holding capacity, and good aeration regime.

On the field, there were no observable genetic horizons, which suggests that the beach sand is essentially sedimentary material (USDA Soil Taxonomy, 1998) that were possibly worked out of the area. They are therefore regarded as parent material, which may later transform into soil.

Coconut-Dominated Barrier Island

This is a very highly homogenous habitat type and is quite extensive in the study area. The habitat is characterized by very loose, medium to fine sand, with tall grasses and few scattered shrub species. In texture, the sandy soils become finer with distance away from the shoreline. This habitat, close to the shoreline, supports tall coconut palms that are more closely spaced (i.e. of high density) compared to the scattered stands of the palms in places farther away from the coastline. Within the first 200m distance away from the coastline area, there are settlements with mostly thatched roof houses (Figure 7.2-2). In terms of the physical characteristics, soils in this habitat are not significantly different from those of the beach sand (Table 7.2-1). As indicated for the bare beach sand, soils in this habitat are also very highly porous, well aerated, with very rapid infiltration rate but low moisture holding capacity.

The soils are considered to have medium to high permeability since they are loose, unconsolidated, single-grained, medium sand. Apart from the weakly developed A-horizon, no other visible genetic horizon was observed which suggests that they are recently formed soils, or Inceptisols of the USDA Soil Taxonomy (1998), and are Cambisols by the FAO/UNESCO (1996) system of soil classification. On the basis of their particle size distribution (i.e. texture), they are loamy fine sand and coarser, and this, coupled with the high annual rainfall in the area, will group the soils as Dystrudepts (Great Group of Soil Taxonomy) and Humic Psammentic Dystrudepts (Subgroup of Soil Taxonomy) (USDA Soil Taxonomy, 1998). This classification shows that the soils are recently formed, with very sandy texture located in a region of high annual rainfall.

The soils are not prone to water erosion in view of the high infiltration and their high intrinsic permeability; hence they are not easily erodible. The influence of wind erosion is likely to be minimal because the loose sand grains are medium to coarse which makes them a little 'heavy' for transport by wind, since the silt content is considerably low. Virtually all the clay particles have been translocated, i.e. eluviated, by percolating water. The translocation is possibly enhanced by the predominance of medium to coarse sand particles with large pore spaces in a region that has heavy annual precipitation.

Figure 7.2-2
Thatched hut established in coconut dominated barrier islands.

Bare Ground/Farms/Grassland

This habitat is characterized by a mosaic of bare land with cleared areas, seasonally burnt plots and a few patches of scattered, unburnt grassland. Cassava plots (Figure 7.2-3) within the very scattered stands of young coconut palms and mango trees are common features.

Physically, the soils are deep, loose, friable, fine to medium sand. The physical properties of representative soil samples from within the habitat are indicated in Table 7.2-1. From the table, medium (47 percent) to coarse (34 percent) sand fractions predominate. In view of the sandy texture, the soils' ability to retain moisture is low, but the soils are well aerated. On the basis of morphological and physical characteristics, the soils are not significantly different from those of coconut palm dominated area, and will classify as the same.

Marsh/Swamp

This habitat is dominated by *Cyperus* sp. (Figure 7.2-4), an aquatic plant that is used locally in making mats. The plant is considered to have great economic value by the people in the area. Crops observed in some parts of this habitat include coconut palm, sugarcane, oil palm and plantain. However, because of the poor drainage condition in the area and difficulty of accessibility, a large portion of this habitat has not been opened up.

Typical particle size distribution of soils within this habitat is shown in Table 7.2-1 above. From the table, it is observed that soils in this habitat have almost equal amounts of sand (30 percent) and silt (28 percent) and about 42 percent clay. The high content of silt and clay can be due to deposition of materials in suspension brought down by lagoon water in addition to overland flow from the surrounding higher physiographic land area.

Texturally, the soils are clayey, very poorly drained, poorly aerated and generally contain partly decomposed and un-decomposed organic materials, possibly occasioned by low rate of decomposition due to high moisture, and a poor aeration regime. At the time of field investigations (January 2003), the soils were still water-logged to swampy. The soils are muddy, massive in structure, and dark gray to black at the surface.

Figure 7.2-3
Cassava farm close to the study area.

Figure 7.2-4
Part of the marshland at the fringe of Badagry Creek

The soils in the habitat are characterized with aquic soil moisture regime (i.e., a reducing regime) in a soil that is virtually free of dissolved oxygen in the water that saturates it (USDA Soil Taxonomy 1998) in all the horizons. The texture is clay, and the soils are slightly sticky, plastic wet, and firm moist. They have hue of 2.5Y or yellower, chroma of 3 or less, and distinct redox colorations. These characteristics will group the soils as Aquents, i.e. recently formed poorly drained soils.

In view of the low relief characteristic of the habitat and the presence of sufficient vegetation cover, water erosion is not considered to be severe in the habitat.

<u>**Inland Area Soils**</u>

In this part of the study area, the various habitat types identified, mapped and soils characterized were as follows:

Coastal Savanna

In the inland areas, tall grasses, scattered shrubs, and few trees characterize this habitat. At the time of the field study, most of the grasses were burnt, and cattle heavily grazed those that were not burnt.

Soils in this habitat are loose, generally non-coherent and sandy. Table 7.2-2 shows the particle size distribution of representative soil samples from within the habitat. The soils have about 88 percent sand, dominated by fine (27 percent) and medium (43 percent) sand fractions. Morphologically and physically, the soils in this habitat are essentially the same as those similarly mapped and characterized within the barrier (nearshore) island area. Since the soils are predominantly fine to medium sand in texture and the sand fraction is dominated by quartz coupled with good internal drainage, good aeration regime and low moisture holding ability, they are not expected to be aggressive in reaction to buried metals. The soils are thus classified as a Psammentic (sandy) member of recently/weakly developed soils (Inceptisols).

Table 7.2-2
Mean particle size distribution of soils from the different habitats within the Inland Area.

Sampling coordinates		Habitat Type	Sand Fraction					Soil Separate			
Latitude (^oN)	**Longitude (^oE)**		**VCS**	**CS**	**MS**	**FS**	**VFS**	**TS**	**Silt**	**Clay**	**Texture**
			(percent)								
06^o 25.88	**002^o 59.14**	**Raphia Palm-Dominated Freshwater Swamp Forest**	**0.0**	**2**	**4**	**1**	**0.0**	**7**	**22**	**71**	**Clay**
06^o 25.00	**002^o 59.30**	**Coastal Savanna**	**1**	**16**	**43**	**27**	**1**	**88**	**3**	**9**	**Sand**
06^o 28.83	**002^o 00.18**	**Farm/Bush Fallow Area**	**1**	**10**	**20**	**29**	**15**	**75**	**8**	**17**	**Sandy Loam**
VCS = Very coarse sand; CS = coarse sand; MS = medium sand; FS = fine sand; VFS = very fine sand; TS = total sand											

The soils in this swampy habitat are generally poorly drained, very poorly aerated (due to water-logging), massive in structure, contain a high content of partly decomposed to almost un-decomposed organic materials, and were all deeply flooded at the time of field investigations (January, 2003). Table 7.2-2 shows the particle size distributions and texture of representative soils from the habitat. The soils are clayey in texture with very high content of clay – about 71 percent, and 22 percent silt.

In all the observation points within this habitat, there is sufficient vegetation cover and the relief is generally low. Erosion susceptibility of the swampy soils is therefore low but the soils can easily be compacted, puddled and degraded if worked when wet. The soils are classified as Aquents.

Figure 7.2-5
Degraded Raphia.

Farm/Bush Fallow Area

This habitat type is generally widespread in the inland area, especially close to big towns along the proposed pipeline right of way (ROW). In this habitat, the proposed pipeline route passes, sometimes, very close to settlements, across tarred and earth roads, farmlands and fallow plots. For instance:

- **Observation point 6 (PT 6)** i.e. 06° 28.83N and 003° 00.18E is a mosaic of fallow, farmland and light forest (possibly 3-4 yr fallow) area. The main cultivated crops include cocoyam, cassava, pawpaw and kola nut, all within 60m radius of the observation point, and
- **Observation point 7 (PT 7)** i.e. 06° 42'54"N and 003° 12'08"E is a mixture of farmland (with mostly cassava), fallow-land (1½-2yrs) and secondary forest (or a fallow plot of about 3-5 years)

Soils in this habitat are typical of upland, well drained, humic brownish to yellowish red, granular to crumb, slightly sticky, plastic wet, firm moist, sandy loam surface soils, with distinctly brownish red, sub-angular blocky, mottled – free, friable moist sub-soils. The absence of mottles and uniform subsoil colour up to 100cm soil depth indicate that the groundwater table is definitely beyond this depth of investigation. Within this depth of the soils, gaseous exchange between the soils and the atmosphere will not be adversely affected by seasonal changes throughout the year. Table 7.2-2 gives the particle size distribution of representative soil samples taken from the habitat. Although the sand content accounts for about 75 percent of the total soil separates, nevertheless, the sand is mainly very fine (15 percent), fine (29 percent), and medium (20 percent) sand fractions.

The soils were classified as ultisols (Amusan and Ashaye, 1989), meaning low base-status forest soils. The relief is generally undulating and this can predispose the soils to water erosion.

Secondary Forest

7.2.2 Chemical Properties of the Soils

<u>**Coastal Area Soils**</u>

The selected chemical properties of representative soils characterized within the different habitats mapped in the nearshore (coastal area) are given in Table 7.2-3. The various habitat types and the chemical properties of their associated soils are as follows:

Strandline Sand

The average pH of representative samples of the beach sand is 6.9. The near neutral pH is likely due to sea-spray because of the proximity of the beach to the ocean. The total organic matter (TOC) content is low, averaging 0.47 percent, with total hydrocarbon content (THC) of 12.09µg/g. The low TOC and high pH indicate that the sandy material may not be chemically corrosive to buried metals/pipelines. The level of THC is significantly below the 50ppm (50µg/g) critical level (i.e. a limit that should not be exceeded) specified for land locations by the Department of Petroleum Resources (DPR) in its Environmental Guidelines for oil and gas industry (DPR, 2002).

Coconut-Dominated Barrier Island

Physico-chemically, soils in this habitat are essentially the same as those in the cleared/bare/grassy habitat i.e. texture, content and distribution of soil separates, ability to hold moisture, internal soil drainage, pH, TOC and THC. Overall, soils in this habitat are homogenous.

Bare Ground/Farms/Grassland

The soils are slightly acid with average pH of 6.5. At this pH however, mobilization (i.e. solubilization) of heavy metals in soil solution is not envisaged more so that the soils are well drained (due to sandy texture), and well aerated with low moisture holding capacity. The mean TOC is 0.98 percent and is considered to be very low in enhancing soil corrosion. The THC value of 13.2µg/g (Table 7.2-3) in the soil is also considered as being very low when compared with the 50µg/g DPR limit for land locations. Moreover, PAH were detected at low levels, ranging from 2.23 to 6.39µg/g, being higher in the topsoil than the sub soil (Table 7.2-4). While iron was high (291.3mg/kg) and manganese was low (6.94mg/kg) the other heavy metals occurred in traces (<0.1mg/kg) (see Table 7.2-5).

Marsh/Swamp

The soils in this habitat are strongly acid with an average pH of 4.9 due mainly to poor drainage and poor aeration regimes occasioned by the clay texture of the soils. Mobilization of heavy metals in the soils is a likely process if metals are present in the soils. The TOC content of the soils is high, with an average of 37.05 percent, due probably to low rate of organic matter decomposition as engendered by flooding conditions in the soils. The average THC content of representative soil samples from within the habitat is about 6.42µg/g and this is considered to be very low as a baseline value.

Table 7.2-3
The average chemical characteristics of soils in the different habitats within the barrier island (coastal area).

Sampling coordinates		Habitat Type	pH	TOC (percent)	THC (µg/g)	Salinity (ppm)
Latitude (°N)	**Longitude (°E)**					
06° 23.81	**002° 59.32**	**Strandline Sand**	**6.9**	**0.47**	**12.09**	**ND**
06° 23.97	**002° 59.32**	**Bare Ground/Farms/Grassland**	**6.5**	**0.98**	**13.12**	**ND**
06° 24.15	**002° 00.31**	**Marsh / Swamp**	**4.9**	**37.05**	**6.42**	**35.45**

Table 7.2-4
PAH of selected soil samples from the study area.

Sample codes	Habitat	PAH, mg/kg
T1S2 (0-15)	Coastal savanna	6.19
T1S2 (15-50)		2.23
PT2 (C0-15)	Bare Ground/Farms/Grassland	0.88
PT2 (C15-50)		0.93
PT4(C 0-15)		2.63
PT4(C 15-50)		2.09
PT5(C 0-15)	Raphia Palm-dominated freshwater swamp forest	2.27
PT6(B 0-15)	Farm/Bush fallow	1.88
PT6(B 15-50)		1.56

Table 7.2-5
The average heavy metal concentrations of soils in the different habitats within the barrier island (coastal area).

Sampling coordinates		Habitat Type	Cadmium	Chromium	Manganese	Zinc	Lead	Copper	Nickel	Iron
Latitude (°N)	**Longitude (°E)**									
06° 23.81	**002° 59.32**	**Strandline Sand**	0.04	<0.001	6.94	<0.001	<0.001	<0.001	0.12	291.3
06° 23.97	**002° 59.32**	**Bare Ground/Farms/Grassland**	0.06	<0.001	13.8	0.28	0.78	<0.001	0.32	338.44
06° 24.15	**002° 00.31**	**Marsh / Swamp**	0.12	0.2	9.84	6.16	<0.001	0.34	3.72	2020.42

Inland Area Soils

Three main habitat types were mapped and characterized for this portion of the project area. The chemical properties of representative soil samples in the various habitats are presented in Table 7.2-6. The habitat types and the chemical characteristics of the associated soils follow.

Coastal Savanna

Soils here are moderately acidic with an average pH of 6.0 and generally low TOC, about 0.70 percent (Table 7.2-6). At pH of 6.0 and above, mobilization of heavy metals into soil solutions from soil solids is not expected (Amusan and Ashaye, 1989; Ashaye, 1967). Furthermore, the soils are sandy in texture, well drained, highly porous, with low capacity to retain moisture. The level of THC in the soils appears to be moderately high though it is still below the DPR limit of 50µg/g. The average THC content of the soils is 27.26µg/g, whereas the PAH was considerably lower, ranging from 0.88 to 2.63µg/g. Heavy metal analysis revealed that the levels of iron were high, manganese medium, while lead and zinc were relatively low, and the other metals occurred in traces (see Table 7.2-7).

Raphia Palm-Dominated Freshwater Swamp Forest

The pH of soils in this habitat is about 5.0 (strongly acidic) with high TOC, about 18.36 percent (Table 7.2-6). The PAH and THC content of the soils is low, with an average of about 9.44 and 2.27µg/g respectively (Tables 7.2-4 and 7.2-6). Iron was high in this habitat, copper was relatively lower, while levels of nickel, zinc and manganese were medium; the other heavy metals analyzed occurred in traces (Table 7.2-7).

Table 7.2-6
The average chemical characteristics of soils in the different habitats within the Inland Area.

Sampling coordinates		Habitat Type	pH	TOC (%)	THC (µg/g)	Salinity (ppm)
Latitude (°N)	**Longitude (°E)**					
06° 25.88	**002° 59.14**	**Raphia palm-dominated freshwater swamp forest**	**5.0**	**18.36**	**9.44**	**200.88**
06° 25.00	**002° 59.30**	**Bare Ground/Farms/Grassland**	**6.0**	**0.70**	**27.26**	**199.41**
06° 28.83	**002° 00.18**	**Farm/Bush fallow**	**5.9**	**2.96**	**30.32**	**94.53**

Table 7.2-7
The heavy metal concentrations of soils in the different habitats within the Inland Area.

Sampling coordinates		Habitat Type	**Cadmium**	**Chromium**	**Manganese**	**Zinc**	**Lead**	**Copper**	**Nickel**	**Iron**
Latitude (°N)	**Longitude (°E)**									
06° 25.88	**002° 59.14**	**Raphia palm-dominated freshwater swamp forest**	0.08	0.83	14.09	16.75	0.98	8.27	14.23	5779.82
06° 25.00	**002° 59.30**	**Bare Ground/Farms/Grassland**	0.12	0.13	39.83	2.19	1.30	0.07	0.41	1682.95
06° 28.83	**002° 00.18**	**Farm/Bush fallow**	<0.001	0.04	12.85	4.04	2.4	<0.001	1.8	2503.72

Farm/Bush Fallow Mosiac

Morphologically, soils here are highly ferruginized with an average pH of 5.9 and low TOC of 2.96 percent (Table 7.2-6). The accumulation of iron (in Fe^{3+} form) in the soils is evidence of good internal drainage and aeration. The average THC content of the soils is 30.32µg/g, whereas PAH was below 2.0µg/g.

7.2.3 Biological

Soil Microbiology

The results of the microbial analysis of the soil samples from the inland habitats are as shown in Table 7.2-8. Total heterotrophic bacteria seems to exhibit little variation in the different habitats surveyed as their populations ranged in orders of magnitude of 10^5 to 10^6 CFU/g, while fungal densities were lower, ranging 10^2 to 10^3 CFU/g. Hydrocarbon degrading bacterial counts of the soils were high, on the order of 10^3 to 10^4 CFU/g, accounting for over 10 percent of the total heterotrophic population. This high proportion of HDB may either suggest that the area was previously exposed to hydrocarbons or confirms the ubiquity of hydrocarbon degraders. In contrast, hydrocarbon degrading fungi were observed to be low varying from 0 to 70 CFU/g. Sulphate reducing bacterial (SRB) were generally low in abundance in the entire study area, but seem to be relatively higher in the (seasonally) flooded areas such as the raphia-dominated swamp, coastal savanna and grassy areas, whereas they are almost non-existent in the drier, well ventilated soils such as those found in the farmlands and bush fallows. This is quite understandable since SRB are strict anaerobes and are therefore expected to be more prevalent in swamps/flooded areas and less prevalent in more oxygenated areas such as farm land (Ohimain, personal observation). Tilling and other agricultural activities, which encourage soil ventilation may inhibit the growth of SRB, hence the observed low population in this habitat.

The high population of SRB in the flooded areas tends to suggest that these areas are anoxic. In all the habitats studied, 15 bacteria and 11 fungi species were identified from the entire area. The bacterial isolates include: *Bacillus subtilis, Bacillus polymyxa, Streptomyces* spp., *Aeromonas* spp., *Arthrobacter* spp., *Sarcinia* spp., *Proteus mirabilis, Corynebacterium* spp., *Pseudomonas aeruginosa, Klebsiella pneumoniae, Micrococcus luteum, Desulfotomaculum* spp., *Bacillus cereus, Pseudomonas fluorescens,* and *Flavobacterium* spp.; while the fungal isolates include the following: *Microsporium audovinii, Microsporium gypseum, Aspergillus flavus, Aspergillus niger, Cladosporium* spp., *Trichoderma* spp., *Daldenia* spp., *Scopulariopsis brevicaulis, Penicillium notatum,* and *Rhodotorula* spp..

Table 7.2-8
Average microbial densities of soil samples from inland area of WAGP EIA project (dry season).

Sample code	THB (cfu/g)	HDB (cfu/g)	SRB (cells/g)	THF (cfu/g)	HDF (cfu/g)
Bare Ground/Farms/Grassland					
PT2A	**7.8×10^5**	**8.3×10^4**	**10^2**	**3.7×10^2**	**08**
PT2B	**2.0×10^5**	**4.0×10^3**	**Nil**	**4.0×10^2**	**Nil**
PT2C	**1.0×10^6**	**4.3×10^4**	**10^2**	**6.2×10^3**	**21**
PT2D	**4.8×10^5**	**5.2×10^4**	**10^1**	**1.6×10^3**	**42**
Coastal savanna					
PT4A	**1.2×10^6**	**2.3×10^4**	**Nil**	**2.1×10^3**	**23**
PT4B	**3.3×10^5**	**3.8×10^3**	**Nil**	**2.6×10^3**	**70**
PT4C	**4.0×10^6**	**5.1×10^4**	**10^1**	**4.0×10^3**	**40**
PT4D	**2.3×10^6**	**2.9×10^3**	**10^2**	**2.4×10^3**	**40**
Raphia Palm-Dominated Freshwater Swamp Forest					
PT5A	**8.7×10^5**	**7.3×10^3**	**10^2**	**4.6×10^2**	**08**
PT5B	**1.6×10^6**	**3.6×10^4**	**10^3**	**5.0×10^2**	**50**
PT5C	**7.1×10^5**	**1.1×10^4**	**Nil**	**7.0×10^2**	**42**
PT5D	**1.3×10^6**	**3.5×10^4**	**Nil**	**2.0×10^2**	**46**
Bare Ground/Farms/Grassland					
PT6A	**7.0×10^5**	**6.7×10^3**	**Nil**	**1.5×10^3**	**20**
PT6B	**4.6×10^5**	**5.4×10^4**	**Nil**	**3.0×10^2**	**Nil**
PT6C	**1.4×10^5**	**4.1×10^3**	**Nil**	**7.0×10^2**	**Nil**
PT6D	**4.8×10^5**	**4.4×10^3**	**10^1**	**7.0×10^3**	**30**
Keys: THB - Total heterotrophic bacteria; HDB - Hydrocarbon degrading bacteria; SRB – Sulphate reducing bacteria; THF – Total heterotrophic fungi; HDF – Hydrocarbon degrading fungi.					

The results of the microbial analysis of the soil samples from the coastal areas/beach transects are shown in Table 7.2-9. The population of microbial species appears to be identical in all the habitats sampled. Total heterotrophic bacterial counts ranged between 1.6 $\times 10^6$ and 2.8 $\times 10^6$ CFU/g, while fungal densities were relatively lower, being on the order 10^2 to 10^3 CFU/g. Hydrocarbon degrading bacteria counts of the soils varied on the order 10^2 to 10^4 CFU/g, while fungi varied between 0 and 25 CFU/g. Very low populations of SRB (10^1 cells/g) were recorded for the marshy/swamp area/habitat. The soil physical properties (loose/unconsolidated, non-humified sand; see Section 7.2.1) may have prevented the growth of SRB.

Thirteen bacteria and twelve fungi species were identified from the soil/sediment samples, and these include the following bacteria: *Desulfotomaculum* spp., *Arthrobacter* spp., *Corynebacterium* spp., *Pseudomonas aeruginosa, Proteus vulgaris, Pseudomonas pseudomallei, Streptomyces* spp., *Aeromonas* spp., *Bacillus cereus, Bacillus subtilis, Pseudomonas fluorescens, Bacillus polymyxa,* and *Flavobacterium* spp.. The fungi species include *Rhodotorula* spp., *Penicillium* spp., *Aspergillus flavus, Cladosporium* spp., *Trichoderma* spp., *Scopulariospsis brevicaulis, Microsporium gypseum, Cunninghamella* spp., *Botrytis* spp., *Microsporium audovinii, Neurospora* spp., and *Pullularia* spp..

Table 7.2-9
Average microbial densities of soil samples from a beach transect of WAGP EIA project (dry season).

Sample code	Habitat	THB (cfu/g)	HDB (cfu/g)	SRB (cells/g)	THF (cfu/g)	HDF (cfu/g)
T1S1	**Strandline**	**2.8 × 10^6**	**4.5 × 10^2**	**Nil**	**1.5 × 10^3**	**25**
T1S2	**Bare Ground/Farms/Grassland**	**1.6 × 10^6**	**3.2 × 10^2**	**Nil**	**3.4 × 10^3**	**20**
T1S3	**Marsh/Swamp**	**2.8 × 10^6**	**4.4 × 10^4**	**10^1**	**3.0 × 10^2**	**Nil**
Keys: **THB - Total heterotrophic bacteria; HDB - Hydrocarbon degrading bacteria; SRB – Sulphate reducing bacteria; THF – Total heterotrophic fungi; HDF – Hydrocarbon degrading fungi.**						

<u>Soil Microarthropods</u>

Soil microarthropods are normal soil fauna, which are good indicators of soil health, and their densities are sometimes a reflection of the habitat disturbances resulting from agricultural and industrial activities (Badejo and Lasebikan, 1988; Badejo, 1998). The most abundant taxonomic group of soil microarthropods in the study area is Acarina. This extremely diverse group, which is represented by more than fifty genera in the southwestern region of Nigeria (Badejo, 1999), is poorly represented in the area investigated (Table 7.2-10). This is not unexpected because sampling took place during the dry season when soil microarthropods are normally not very abundant (Badejo, 1990).

The most abundant acarine species are *Scheloribates mochlosimilaris* and *Galumnella sonpona*. These pterogasterine mites have been shown to be the most abundant in forest and cultivated soils of other locations in the southwestern zone of Nigeria. They were abundant at Ewupe and Onipanu where the vegetation is close to the original undisturbed forest conditions. Their low densities at locations near the beach suggest that sparse vegetation is not conducive for the growth of their populations.

Table 7.2-10
Mean numbers of soil microarthropods extracted from the soil in different habitat types. (Mean is based on four sampling units).

Microarthropod Group	Grass near beach	Coconut + Raphia near beach	Re-growth Forest near beach	Cassava/ Forest Mosaic (EWUPE)	Cassava farm (ONIPANU)	Raphia swamp (IGBESA)
Acarina						
***Mesoplophora* sp.**						
***Mixacarus* sp.**	**0**	**0**	**0**	**0**	**5**	**0**
Bicyrthermannia nigeriana	**0**	**5**	**0**	**0**	**0**	**0**
***Epilohmania* sp.**	**9**	**9**	**0**	**4**	**7**	**1**
Nothrus lasebikani	**0**	**14**	**0**	**0**	**0**	**0**
***Carabodes* sp.**	**0**	**1**	**0**	**0**	**0**	**0**
Muliercula inexpectata	**1**	**0**	**0**	**0**	**0**	**0**
Scheloribates mochlosimilaris	**6**	**0**	**0**	**0**	**0**	**0**
Galumnella sonpona	**6**	**1**	**0**	**10**	**40**	**4**
***Pergalumna* sp.**						
***Teleiolides* sp.**						
Belbidae	**0**	**1**	**0**	**45**	**25**	**1**
Liacaridae	**0**	**0**	**0**	**0**	**3**	**1**
Polyaspidae	**0**	**3**	**0**	**0**	**0**	**1**
Parasitidae	**3**	**0**	**0**	**4**	**0**	**0**
	0	**0**	**0**	**0**	**2**	**0**
	0	**0**	**0**	**0**	**3**	**0**
	0	**1**	**0**	**2**	**0**	**0**
Symphylla	**1**	**0**	**0**	**0**	**0**	**0**
Pseudoscorpionida	**0**	**2**	**0**	**0**	**0**	**0**
Chilopoda (Centipedes)	**0**	**0**	**0**	**2**	**2**	**2**
Collembola (springtails)	**0**	**0**	**0**	**0**	**0**	**1**
Isoptera (Termites)	**0**	**0**	**0**	**0**	**2**	**0**
Homoptera	**3**	**8**	**3**	**7**	**0**	**1**
Coleoptera (Beetles)	**2**	**2**	**2**	**3**	**3**	**3**
Formicoidea (Ants)	**0**	**1**	**0**	**0**	**17**	**0**

7.3 SURFACE WATER AND SEDIMENT CHARACTERIZATION

7.3.1 Physical Characterization

Water Physical Characterization

Detailed records of the measured physical parameters of water at the investigated stations are presented in Table 7.3-1 and summarized in Tables 7.3-2 and 7.3-3. The surface water bodies (both tidal and non-tidal) were generally brownish in colour (as viewed against the general background), ranging from greenish brown through light brown (for Badagry Creek) to dark brown (for Ologe Lagoon and River Owo's tributaries). The generally brown coloration of the surface waters could be attributed to their relatively high organic matter content resulting from the decomposition of the dense swamp forest vegetation in the environment.

The dark brown coloration of Ologe Lagoon and the non-tidal rivers is probably due to the fact that they are heavily shaded by dense plant cover from which senescent leaves drop directly into the water course. At various stages of decomposition, these dead leaves release by products such as humic and fluvic acids which impart such water bodies with characteristic brown coloration. Unlike the surface water sources, the ground water sources in the study area were generally clear and colourless, having filtered through the ground into the aquifer.

Secchi disc transparency was generally less than 1m into the water column. For waterbodies less than 1m in depth, light visibility extended directly to the water bottom. The proportion of Secchi disc transparency to total water depth (i.e. Secchi disc/depth x 100) was inversely related to depth; for instance, it was 25 percent in Badagry Creek at 2.8m depth, 21 percent at 4.0m and 8 percent at 6.8m. On average, the Secchi disc transparency for the tidal water bodies was 0.71 ± 0.12m while transparency extended directly to the bottom in the non-tidal waterbodies (Table 7.3-2).

In general, waterbodies in the study area were characterized by low total suspended solids (TSS). The measured values occurred in the range of 2 to 8 mg/L with mean values of 6.0 ± 1.7mg/L for tidal waters and 4.3 ± 2.9mg/L for subsurface water (hand-dug wells).

The diel pattern, as well as the relationship between ambient air temperature and water temperature, in the study area is depicted in Figure 7.3-1 for the three investigated types of water bodies (tidal, non-tidal and well waters). Both ambient air and water temperature followed essentially the same diel pattern, which is characterized by a gradual rise through the morning to a peak in the afternoon and thereafter a gradual fall through evening. From mid-morning through early evening, air temperature was usually slightly higher than water temperature. In contrast, the data suggests that from late evening through mid-morning (7pm to 9am), water temperature was slightly higher than air temperature. The difference between air temperature and water temperature was more pronounced for non-tidal waters, followed by hand-dug wells, and least in the open tidal waterbodies. In general, the air temperature exhibits a significant direct correlation with water temperature over the period mid morning to evening (Figure 7.3-2).

Table 7.3-1
Physical characteristics of water in the study area (January 2003).

S/N	Depth (m)	Temperature		Transparency (m)	Colour	TSS mgl^{-1}
		Air	Water			
1	4.0	29.4	28.3	0.85	Dark brown	3.0
2	6.8	31.4	29.6	0.54	Light brown	6.0
3	6.8	31.4	29.5	0.54	"	6.0
4	3.3	32.0	31.1	0.82	Greenish brown	7.0

S/N	Depth (m)	Temperature		Transparency (m)	Colour	TSS mgl^{-1}
		Air	Water			
5	3.3	32.0	30.1	0.82	"	9.0
6	2.8	31.8	30.5	0.69	Dark brown	6.0
7	2.8	31.8	30.4	0.69	"	5.0
8	ca. 10	30.8	30.0	>2	Light green	6.0
9	3.7	32.0	29.8	NA	Clear colourless	8.0
10	9.0	33.8	29.0	NA	Clear colourless	1.0
11	-	29.4	28.4	TB	Dark brown	4.0
12	0.4	24.0	25.5	TB	Brownish green	2.0
13	-	26.0	25.0	TB	Dark brown	4.0
14	5.8	26.5	28.0	NA	Clear colourless	4.0
15	0.3	29.0	28.0	TB	Light green	2.0
NA = Not applicable; TB = Transparent to bottom; n = number of samples						

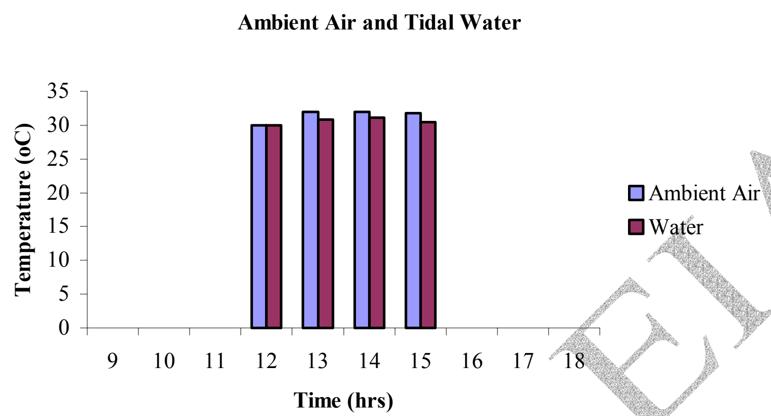
Table 7.3-2
Summary of physical characteristics of water in the study area (January 2003).

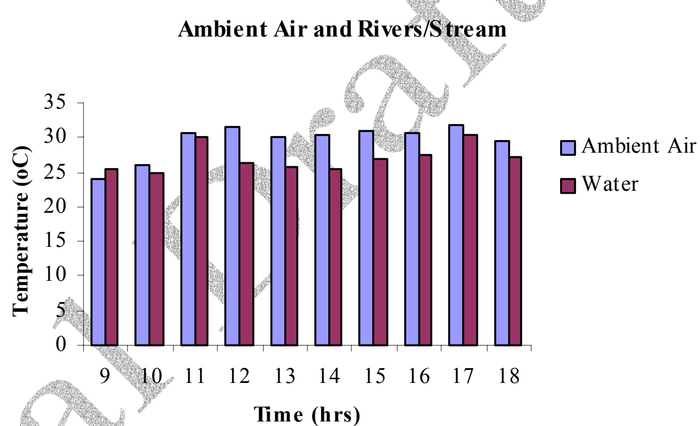
Parameter	Tidal Rivers (n=8)	Non-tidal Rivers (n=4)	Hand dug wells(n=3)
Depth (m)	4.36 ± 1.65	0.35 ± 0.05	6.17 ± 2.18
Air Temp (°C)	31.4 ± 0.85	27.1 ± 2.22	30.77 ± 3.11
Water temp (°C)	29.9 ± 0.84	26.73 ± 1.49	28.93 ± 0.74
Transparency (m)	0.7 ± 0.12	TB	NA
Colour (visual)	Brown	Dark brown	Clear colourless
TSS (mg/l)	6.0 ± 1.69	3.0 ± 1.00	4.33 ± 2.87
NA = Not applicable; TB = Transparent to bottom; n = number of samples			

Table 7.3-3
Descriptive statistics of water temperature in the study area (morning and afternoon).

Time of day	Statistics	Water body		
		Tidal waters	Non-tidalwaters	Hand dug wells
Morning	n	3	5	4
	min	26.2	25.0	27.6
	max	30.5	30.0	29.2
	range	4.3	5.0	1.6
	mean	28.2	26.8	28.5
	s.d.	2.1	1.8	0.7
	%c.v	7.4	6.6	2.4
Afternoon	n	5	9	6
	min	30.0	25.5	28.0
	max	31.8	30.4	30.0
	range	1.8	4.9	2.0
	mean	30.8	27.6	29.1
	s.d	0.6	1.5	0.7
	%c.v	1.9	5.3	2.2

Figure 7.3-1
Diurnal variation in ambient air and tidal water temperature in the project area





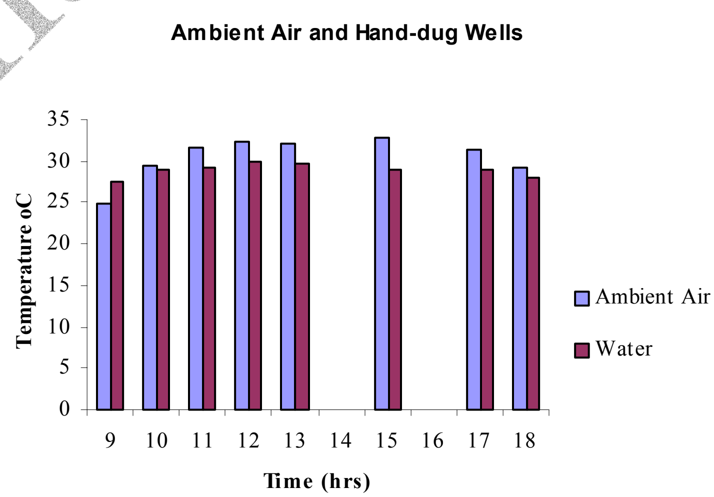
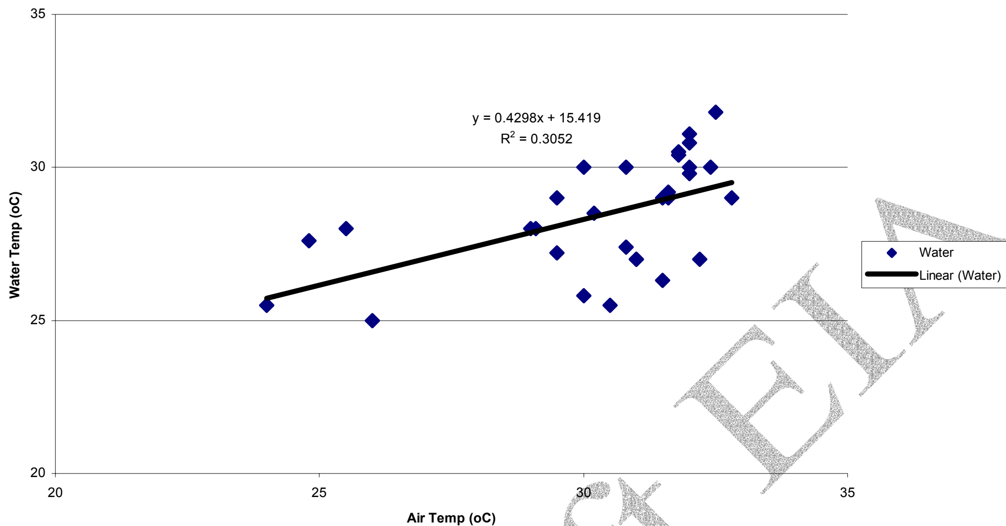


Figure 7.3-2
The relationship between air temperature on water temperature in the study area.



Sediment Physical Characterization

Information on the particle size distribution and textural classification of bottom sediments from waterbodies in the project area is presented in Table 7.3-4. Sediments from the investigated area of Badagry Creek are essentially sandy, ranging from sandy silt (at Topo Island), through clayey sand (at the ROW), to sand eastward of the ROW. The sand comprises mostly medium fraction (MS), the contribution of which increases steadily from west to east along the creek. For instance, the contribution of medium sand fraction increased from 5.5 percent at Topo Island (06^o 24.464N, 002^o 55.063'E) to 35.0 percent at the ROW, to 37.7 percent at Tofa village, to 51.3 percent at Ibode/Orufo (06^o 24.690'N; 003^o 07.693'E). The relative contribution of both silt and clay follow an inverse pattern, decreasing from Topo Island to Ibode/Orufo village. Sediments from the main sector are essentially silty clay in nature, with little or no sand fraction content.

Sediments from the non-tidal waterbodies generally have a total sand fraction in the range of 71 to 92 percent. The Imede River is comprised predominantly of coarse sand fraction at the upper reach to a fine sand fraction at the lower reach, while silt and clay fractions each contribute less than 8 percent to the sediment.

Table 7.3-4
Physical characteristics of sediments from waterbodies in the project area.

Water body	Sampling site and location		% Sand Fraction						% Silt	% Clay	Texture
	Lat (N)	Long (E)	VCS	CS	MS	FS	VFS	Total			
Yewa River	06° 28.155’	002° 52.091’	0.00	0.00	0.00	0.00	0.00	0.00	33.0	67.0	Silty clay
Badagry Creek	06° 24.464’	002° 55.863’	0.59	1.37	5.52	17.18	7.34	32.0	54.0	14.0	Sandy silt
Badagry Creek	06° 24.326’	002° 59.266’	0.37	7.34	35.04	39.35	3.90	86.0	2.0	11.0	Claye sand
Badagry Creek	06° 24.546’	003° 04.325’	0.09	5.34	37.65	42.60	4.32	90.0	2.0	8.0	Sand
Badagry Creek	06° 24.690’	003° 07.693’	1.20	15.44	51.29	20.33	0.74	89.0	30.0	9.0	Sand
Ologe lagoon	06° 29.283’	003° 05.996’	0.30	0.92	2.78	4.62	0.62	9.0	39.0	61.0	Silty clay
Ologe lagoon	06° 28.492’	003° 05.239’	0.00	0.00	0.00	0.00	0.00	0.00	22.0	61.0	Silty clay
Ologe lagoon	06° 28.555’	003° 04.484’	0.00	0.00	0.00	0.00	0.00	0.00	2.0	78.0	Silty clay
Ologe lagoon	06° 26.897’	003° 08.542	8.60	15.70	26.77	40.56	0.37	92.0	2.0	6.0	Sand
Imede River	06° 28.907’	003° 04.872’	1.40	4.95	12.50	28.2	40.05	88.0	7.0	5.0	Sand
Imede River	06° 30.929’	003° 03.171’	19.70	45.50	25.35	1.40	0.00	92.0	2.0	6.0	Sand
Ijile River	06° 27.799’	003° 01.618’	0.81	4.28	9.33	42.30	14.25	14.25	10.0	19.	Clayey sand

7.3.2 Chemical Characterization

<u>Water Chemical Characterization</u>

The data obtained for major ions and salinity parameters (pH, salinity and conductivity) of the investigated water bodies are presented in Tables 7.3-5 and 7.3-6. Water pH varied over a wide range of values (4.63 to 8.14) i.e. from very acidic to moderately alkaline. On average, the sea water was slightly alkaline (8.1); while the tidal waters were near neutral, (7.22 ± 0.66), the non-tidal waters were moderately acidic (6.42 ± 0.23) and hand dug well waters were acidic (5.73 ± 1.33). The values of the salinity parameters (pH, conductivity and salinity) in the area are all close to those of the “mean sea values.” The tidal waters are essentially oligohaline brackish in nature while the non-tidal and hand-dug well waters are relatively fresh and dilute in salinity.

Water salinity along Badagry Creek (at both surface and bottom levels) gradually increases towards the direction of the Lagos Harbour. Conversely, it decreases westward in the direction of Yewa River. Salinity, TDS and conductivity were generally higher at the bottom than at surface water level.

The concentrations of dissolved oxygen in water varied from 3.2 mg/L to 7.0 mg/L corresponding to 39.5 percent and 87.0 percent saturation, respectively. On average, the concentration and percent saturation of dissolved oxygen were higher in the tidal waters (66.3 ± 8.8 percent) than non-tidal waters (62.7 ± 16.8 percent) and lowest in well waters

(60.9 percent). The concentrations of BOD_5 were generally low, most of them being less than 4 .0mg/L. On average, BOD_5 was highest in the non-tidal waters (5.6 ± 2.6mg/L) followed by the tidal waters (1.7 ± 0.9mg/L). The relatively high values for the non-tidal rivers may be due to their demand for decomposition of organic matter resulting from dead plant matter.

COD values were generally lower than their corresponding BOD values, especially for non-tidal and well waters. Inorganic nitrogen occurred mainly as nitrate-nitrogen (NO_3–N), then ammonium nitrogen (NH_4^-N), and nitrite nitrogen (NO_2–N), which occurred mainly in traces. Total inorganic nitrogen in the samples occurred in the range of 1.73 – 9.34 mg/L (mean ± s.d. = 2.0 ± 1.79 mg/L) comprising of 84 ±1, 8 percent NO_3–N, 14.5 ± 7.7 percent NH_4–N, and 0.7 ± 0.5 percent NO_2-N. The concentration and proportion in which the various species of nitrogen occurred are indicative of a healthy aquatic environment.

Total phosphate-phosphorus and available phosphate-phosphorus occurred in the range of 0.06 – 0.13mg/L PO_4–P and 0.04 – 0.11mg/L PO_4–P, respectively. Average values were slightly higher in the tidal waters than in the non-tidal and hand-dug well water.

The variations in the heavy metal concentrations in the investigated waterbodies are shown in Tables 7.3-9 and 7.3-10. Except for Zinc (Zn) and Lead (Pb), most of the heavy metals varied over a narrow range of values. The metals could be grouped with regard to their mean/median mass values into four categories:

<0.01 mg/L = Cr>Cr

0.01– 0.1 mg/L, Zn>Cd>Pb

0.1 –1.0 mg/L Mn>Ni

1.1 – 10.0 mg/L = Fe

With regard to the tidal water, most of the metals had slightly higher values at high tide than at low tide (P>0.05) as well as at bottom level than at surface level (P>0.05).

Table 7.3-5
Parameters and major ions in the investigated waterbodies.

S/N	PH	Conductivity	Sal ‰	TDS	HCO_3	SO_4
1	7.14	251	0.1	126	37.82	12.5
2	7.27	431	0.2	207	50.02	16.9
3	7.00	435	0.2	210	50.02	16.3
4	7.53	1106	0.5	544	52.46	20.0
5	7.31	1523	0.8	757	53.68	24.6
6	7.20	329	0.2	156	23.18	18.8
7	7.13	341	0.2	165	23.18	19.2
8	8.14	51100	33.5	32300	136.64	2772
9	7.60	187.5	0.1	89.9	13.42	15.3
10	4.96	462.0	0.2	223.0	0	12.2

S/N	PH	Conductivity	Sal ‰	TDS	HCO_3	SO_4
11	6.06	27.5	0.0	12.5	7.32	3.9
12	6.59	54.4	0.0	25.5	12.2	5.5
13	6.63	67.5	0.0	31.6	18.3	5.2
14	4.63	212.0	0.1	101.6	0	3.1
15	6.41	56.3	0.0	26.5	18.3	4.4

Table 7.3-6
Salinity parameters and the major ions of the major water studies in the study area.

Parameter	Ocean (n=1)	Tidal Rivers (n=7)	Non-tidal Rivers (n=4)	Hand-dug wells (n=3)
PH	8.14	7.22 ± 0.16	6.42 ± 0.23	5.73 ± 1.33
Conductivity (μScm^{-1})	51000	630.6±450.49	51.42 ± 14.69	287.2 ± 124.03
Salinity (‰)	33.5	0.31 ± 0.23	0.02 ± 0.08	0.13 ± 0.047
TDS (mgl^{-1})	32200	309.3 ± 224.81	24.03 ± 7.04	138.2 ± 60.18
HCO_3 (mgl^{-1})	136.64	41.48 ± 12.53	14.03 ± 4.61	4.47 ± 6.33
SO_4 (mgl^{-1})	2772	18.33 ± 3.45	4.75 ± 0.63	10.2 ± 5.18

Table 7.3-7
Oxygen and nutrients compounds in waterbodies in the study area.

S/N	DO	DO Sat	BOD	COD	TOC	NO_2-N	NO_3^-N	NH_4^-N	T-N	PO_4 (Total)	PO_4 (Avail)
1	5.2	67	3.0	58.7	60	0.02	2.51	0.39	2.92	0.13	0.10
2	6.0	79	3.2	89.8	90	0.02	1.82	0.45	2.29	0.11	0.07
3	5.2	67	3.0	121.0	120	0.03	1.85	0.46	2.34	0.09	0.07
4	5.8	78	2.6	58.7	60	0.03	1.88	0.50	2.41	0.13	0.07
5	4.6	61	2.8	58.7	60	0.04	1.79	0.59	2.42	0.12	0.07
6	4.2	56	2.0	121.0	120	0.03	3.06	0.74	3.83	0.06	0.05
7	4.2	56	1.8	121.0	120	<0.01	2.05	0.74	2.79	0.05	0.04
8	5.8	77	3.6	614.1	600	0.01	3.67	5.66	9.34	0.11	0.11
9	4.4	58.3	1.4	58.7	60	0.04	2.57	0.62	3.23	0.06	0.04
10	3.6	47.1	0.8	27.6	30	0.02	2.80	0.32	3.15	0.06	<0.04
11	4.8	62.3	4.2	89.8	90	<0.01	1.93	0.01	1.94	0.06	<0.04
12	7.0	87.0	10.3	27.6	30	<0.01	1.62	0.20	1.82	0.07	<0.04
13	3.2	39.5	4.8	58.7	60	<0.01	1.62	0.11	1.73	0.04	<0.04
14	6.0	77.4	3.0	27.6	30	<0.01	2.69	0.07	2.76	0.09	<0.04
15	4.8	61.9	3.0	BDL	BDL	0.01	1.70	0.19	1.90	0.13	<0.04

Table 7.3-8
Oxygen and nutrient compounds in major waterbodies in the study area.

Parameters	Ocean (n=1)	Tidal Rivers (n=7)	Non-tidal Rivers (n=4)	Hand-dug wells (n=3)
DO (mgl^{-1})	5.8	5.03 ± 0.67	4.95 ± 1.35	4.67 ± 0.998
DO Sat (%)	77	66.29 ± 8.78	62.68 ± 16.80	60.93 ± 12.51
BOD (mgl^{-1})	3.6	2.63 ± 0.49	5.60 ± 2.60	1.73 ± 0.93
COD (mgl^{-1})	614.1	89.86±28.84	58.7 ± 25.39	37.97 ± 14.66
TOC (mgl^{-1})	600	90.0 ±27.77	60.0 ± 24.49	40.0 ± 14.14
NO_2^-N (mgl^{-1})	0.01	0.03 ± 0.009	0.033 ± 0.039	0.023 ± 0.012
NO_3^-N (mgl^{-1})	3.67	2.14 ± 0.44	1.718 ± 0.127	2.69 ± 0.094
NH_4^-N	5.66	0.55 ± 0.13	0.128 ± 0.076	0.337 ± 0.225
T-N	9.34	2.71 ± 0.51	1.85 ± 0.080	3.05 ± 0.21
PO_4^-P	0.11	0.10 ± 0.03	0.075 ± 0.034	0.07 ± 0.014
PO_4^-P	0.11	0.07 ± 0.03	0.040 ± 0.000	0.04 ± 0.000

Table 7.3-9
Descriptive statistics of heavy metal content of the investigated waterbodies

Parameter (mgl^{-1})	n	Descriptive Statistics (mgl^{-1})					
		min	Max	Median	mean	s.d	%C.V
Cadmium (Cd)	10	0.018	0.023	0.0225	0.0215	0.0019	8.8
Chromium (Cr)	10	<0.001	<0.001	<0.001	<0.001	0.000	0.00
Manganese (Mn)	10	<0.07	0.211	0.1075	0.1159	0.0435	37.6
Zinc (Zn)	10	<0.001	0.048	<0.001	0.0073	0.0150	204.8
Lead (Pb)	10	<0.001	0.067	<0.001	0.023	0.0291	126.4
Copper (Cu)	10	<0.001	<0.001	<0.001	<0.001	0.00	0.00
Nickel (Ni)	10	0.053	0.088	0.071	0.0696	0.0122	17.5
Iron (Fe)	10	0.803	3.105	1.705	1.633	1.100	67.4

Table 7.3-10
Heavy metal contents of some waterbodies in the study area (January 2003)

Waterbody	Cd (mg/l)	Cr (mg/l)	Mn (mg/l)	Zn (mg/l)	Pb (mg/l)	Cu (mg/l)	Ni (mg/l)	Fe (mg/l)
R. Yewa (LT)	0.023	<0.001	0.086	<0.001	<0.001	<0.001	0.053	0.808
Badagry Creek (LT)	0.023	<0.001	0.111	<0.001	<0.001	<0.001	0.075	2.435
Badagry Creek (HT)	0.023	<0.001	0.211	0.015	0.067	<0.001	0.083	3.105
Badagry Creek (LT)	0.022	<0.001	0.105	<0.001	<0.001	<0.001	0.08	2.492
Badagry Creek (HT)	0.023	<0.001	0.117	<0.001	0.043	<0.001	0.088	2.733
Ologe lagoon (S)	0.02	<0.001	0.091	<0.001	0.052	<0.001	0.059	0.975
Ologe lagoon (B)	0.018	<0.001	0.11	<0.001	0.062	<0.001	0.069	1.06
Sea at Jegeme	0.019	<0.001	0.07	<0.001	<0.001	<0.001	0.055	0.212
Imede River	0.021	<0.001	0.085	0.003	<0.001	<0.001	0.061	2.349
Well water	0.023	<0.001	0.173	0.048	<0.001	<0.001	0.073	0.163

Sediment Chemical Characterization

Information on the sediment characteristics of waterbodies in the project area is presented in Table 7.3-11 to 7.3-14. Sediment pH varied over a wide range of 3.42-8.15, i.e. from extremely acidic to moderately alkaline with values in the range of 5.42 – 5.09 (mean ± s.d = 4.32 ± 0.69). pH at Ologe Lagoon was extremely acidic to strongly acidic. Sediment was also extremely acidic at Yewa River. At the non-tidal rivers (Imede and Ijile Rivers), values range from moderately acidic to neutral. Along Badagry Creek, values increase steadily from neutral to moderately alkaline east of the ROW.

The values of total organic carbon (TOC) in the sediment samples varied widely from 0.002 percent to 16.97 percent with an overall mean ± s.d. of 5.14 ± 6.6 percent. The mean values for Yewa River and Ologe Lagoon were much higher than for Badagry Creek and the non-tidal rivers (Table 7.3-12). TOC values decreased steadily from north to south (16.97 percent - 14.82 percent - 7.22 percent -0.04 percent) along Ologe Lagoon. Similarly, values decreased along Badagry Creek, with increase in salinity, i.e. from east to west. Sediment total hydrocarbon (THC) also varied over a wide range (0.39 –68.48mg/kg), with a mean value of 14.9 ± 12.9mg/kg values, which were lowest in Badagry Creek.

As visible from Table 7.3-13, sediment heavy metals content in the study area varied widely. Broadly the metals can be classified into five categories as follows:

<0.1mg/kg: Cd>Cr

0.1-1.0mg/kg: Pb>Cu

1.1-10mg/kg: Zn>Ni

10.1 – 100mg/kg: Mn

>1000mg/kg: Fe

Compared to values obtained from Lagos Lagoon (Okoye *et al*. 1991) and African waters (Calamari and Naere, 1994), the values obtained in the study area are generally low (Table 7.3-13). On average, the concentration of these heavy metals were lowest in the Imede River (Table 7.3-14). The concentrations of Cu, Ni, Fe, Mn and Cr were relatively high in the tidal waters compared to the non-tidal waters. In constrast, the values of Cd and Pb were higher in the non-tidal waters than the tidal waters.

Table 7.3-11
Descriptive statistics of the concentration of pH, TOC and THC in sediments from waterbodies in the project area.

Parameters	Descriptive statistics of concentrations						
	n	min	max	median	mean	s.d.	% C.V
PH	12	3.42	8.15	5.80	5.80	1.48	25.5
TOC (%)	12	0.02	16.97	2.16	5.14	6.6	128.8
THC ($mgkg^{-1}$)	12	0.39	68.48	24.28	32.46	22.8	70.3

Table 7.3-12
The mean concentrations of sediment pH, TOC and THC in waterbodies in the project area.

Parameters	Waterbody				
	Yewa River	Badagry Creek (n=4)	Ologe lagoon (n=4)	Imede River (n=2)	Ijile River
PH	4.49	7.45 ± 0.62	4.32 ± 0.69	5.99 ± 054	5.99
TOC (%)	9.75	1.40 ± 2.38	10.51 ± 8.83	1.30 ± 1.8	1.75
THC ($mgkg^{-1}$)	68.5	014.9 ± 12.9	33.9 ± 20.8	33.9 ± 26	58.0

Table 7.3-13
Sediment heavy metal concentration at the project area compared with other African environment.

Parameter (n=12)	WAGP Project Area					Lagos lagoon	African waters			
							Inland		Coastal	
	min	max	med	Mean	s.d.		Range	Mean	Range	mean
Cd	0.0	0.26	0.06	0.0768	0.0802	4.1	0.1-1.0	0.37	2.0-4.1	27.8
Cr	<0.001	0.36	0.001	0.0723	0.1343	-	ND	ND	ND	ND
Mn	1.34	108.3	25.75	30.9667	29.488	-	ND	ND	ND	ND
Zn	1.1	16.98	6.94	8.2867	6.112	147	2.54-140	82.5	130-448	92
Pb	<0.001	7.28	0.001	0.9773	2.116	178.9	7.3-6.3	23.2	48-68	57.8
Cu	<0.001	1.5	0.0135	0.3993	0.572	15.0	0.96-4.1	26.3	10.5-2900	12.77
Ni	0.44	5.44	1.07	2.2983	1.899	-	ND	ND	ND	ND
Fe	110.3	9494.52	2122.92	3199.13	3024.63	36380	460-69000	ND	1100-52000	ND

Table 7.3-14
Heavy metal concentrations in water sediments from the project area.

Parameters	Waterbody				
	Yewa River	Badagry Creek	Ologe lagoon	Imede River	Ijile River
Cd	0.001	0.0209 ± 0.0281	0.11 ± 0.0476	0.07 ± 0.05	0.26
Cr	0.34	0.0908 ± 0.1795	0.0405 ± 0.056	0.001 ± 0.0	0.001
Mn	51.68	57.38 ± 34.06	17.59 ± 10.58	6.1 ± 4.76	7.86
Zn	15.84	5.73 ± 5.37	11.05 ± 7.096	3.06 ± 0.44	10.38
Pb	0.001	0.2108 ± 0.4195	0.5808 ± 1.1595	0.6405 ± 0.6395	7.28
Ca	1.5	0.3108 ± 0.6195	0.466 ± 0.5237	0.001 □1 0.0	0.18
Ni	5.44	1.47 ± 1.614	3.315 ± 1.825	0.88 ± 0.0	1.24
Fe	9494.52	2826 ± 1605.5	4094.3 □1 2945.6	39.02 ± 143.3	432.06

7.3.3 Biological Characterization

Hydrobiological Characterization

Highlights of the results obtained are presented in Tables 7.3-15 and 7.3-16. On the whole, total chlorophyll content varied over a narrow range of 1.15 to 20.68µg/L with mean of 8.63 ± 6.33µg/L. The mean chlorophyll crop comprised chlorophyll *a*, chlorophyll *b* and chlorophyll *c* in the ratio of 3:3:4 respectively. On average, the phaeophytin crop was 3.95 ±

5.36µg/L, i.e. about 46 percent mean total chlorophyll crop. This suggests that most of the recorded chlorophyll crop occurred in live form, i.e. undecomposed form.

As one can see in Table 7.3-16, the non-tidal waterbodies were richer in mean total chlorophyll content (mean± s.d = 15.5 ± 3.62µg/L) than the tidal water bodies (4.70 ± 3.62µg/L). Also, the low tide water regime was much richer both in chlorophyll *a* and total chlorophyll content than high tide water (this was based on measurements on Badagry Creek). Based on the mean concentrations of chlorophyll *a* of the different water bodies in the area (2.49 ± 2.26µg/L) the trophic status of the investigated water bodies can be classified as mesotrophic (i.e. moderately nutrient rich) following the classification of McColl (1972). The much richer levels of chlorophyll *c* in the non-tidal waters (9.34 ± 0.79µg/L) compared to the tidal water (0.16 ± 0.38µg/L) as well as in high tide waters 0.55 ± 0.55µg/L) compared to low tide waters (<0.1 ± 0.1µg/L) suggest that algae of the division Chrysophyta (i.e. golden algae) and Phaeophyta (brown algae) were the dominant primary producers in those richer waterbodies. Similarly, the preponderance of chlorophyll *b* in non-tidal waters and low-tide tidal water suggest that Chlorophyta (i.e. green algae) were the dominant primary producers in those waters.

Table 7.3-15
The concentrations of photosynthetic pigments in the investigated watebodies.

Statistics	Chl.a	Chl.b	Chl. c	Total Chl	Phaeophytin
n	10	9	5	10	6
min	0.65	0.19	1.09	1.15	2.03
max	8.70	8.06	10.40	20.69	15.38
range	8.70	8.00	10.40	20.68	15.38
median	2.05	2.80	0.00	8.89	2.03
mean	2.49	2.64	3.49	8.63	3.95
s.d.	2.26	2.57	4.45	6.33	5.36
%c.v	92	97	128	73	136

Table 7.3-16
Variation in photosynthetic pigments in relation to tide regime in the study area.

Parameter µgl^{-1})	Tidal Regime			
	Tidal water	Non-tidal water	Low tide	High Tide
Chlorophyll a	2.33 ± 2.73	2.95 ± 0.82	5.44 ± 3.26	1.35 ± 0.70
Chlorophyll b	2.31 ± 2.76	3.22 ± 2.09	4.13 ± 3.94	3.45 ± 0.65
Chlorophyll c	0.16 ± 0.38	9.34 ± 0.79	0.00 ± 0.00	0.55 ± 0.55
Total Chlorophyll	4.70 ± 3.62	15.50 ± 3.62	9.56 ± 0.67	5.34 ± 0.60
Phaeophytin	3.08 ± 5.20	5.47 ± 5.31	7.69 ± 7.69	1.66 ± 1.66

The tentative analysis of the plankton communities indicates that the phytoplankton flora were dominated by diatoms (Chrysophyta), green algae (Chlorophyta), and dinoflagellates (Pyrrophyta). Also recorded were members of the blue-green algae (Cyanophyta) and the brown algae (Phaetophyta) in order of decreasing taxa richness and abundance. The diatoms were comprised mostly of centric members (Class Centrales) with species of the following genera: *Melosira, Coscinodiscus, Chaetoceros,* and *Bidduphia*, were the most common. Among the penate diatoms (Penales) *Surrirella, Asterinella,* and *Navicula* spp. as the most common. The most commonly occurring dinoflagellates were members of the two genera, *Peridinium* and *Ceratium,* while *Microcystis* and *Anabaena* were the most common blue-green algae. The green algae were mostly Chlorocacaea members but with a few desmids also occurring.

The zooplankton fauna comprised rotifers and copepod crustaceans. Whereas copepods (especially cyclopoid copepods) predominate in the tidal waters, the rotifers and cladocerans tend to predominate in the non-tidal freshwater bodies. The rotifers were dominated by members of the families Brachionidae and Lecanidae. Other represented families are Trichocercidae, Synchaetedae, Asplanchnidae, Testudinellidae, in decreasing order of importance.

Perhaps because of the generally low-lying and swampy nature of the study area, the surface waterbodies are infested by a wide range of aquatic macrophytes (Figure 7.3-3). The occurrence and distribution of these weeds are indicated in Table 7.3-17. The flora comprise both floating and submerged forms in the open water, while rooted forms predominate along the shoreline and littoral zones. In the tidal waters, especially on the Badagry Creek and Ologe Lagoon, water hyacinth (*Eichhornia crassipes*) is by far the most common floating weed. On those waters, it forms extensive mats incorporating other weeds, mostly *Ceratophyllum, Nymphia* spp., *Salvinia nymphellula*, and *Azolla africana*. These mats were frequently visited by a wide range of waterfowl and serve as a rich source of macroinvertebrate fauna, too. The occurrence of water hyacinth is greatly reduced outside the tidal waters, occurring only occasionally at the lower reach of the Owo River. Rooted vegetation, most of which stretches into the watercourse from the shoreline, predominates in the non-tidal waterbodies. Notable among these are: *Commelina* spp., *Luduwiga* spp., *Ipomea aquatica*, and the fern, *Nephrolepsis* sp..

Information on the taxonomic composition and distribution pattern of macro invertebrate animals associated with macrophytes in the investigated waterbodies is presented in Table 7.3-18. A lot of animal phyla are represented in the assemblage. The macroinvertebrate communities comprise of 40 genera belonging to five phyla, viz: Amphibia, Annelida, Crustacea, Insecta, and Mollusca. The number of species recorded per station ranged from 5 to 18. Members of the phylum Insecta were by far the most common, accounting for about 65 percent of the fauna qualitatively. On the whole, the most widely occurring species include the insect *Clinotanypus maculata* (Diptera). The recorded crustacean species (*Gamarus fasciatus, Potamalpteops mondi*, and *Ligia gracilipes*) were all limited to the tidal waters while the beetles (Coleoptera) were limited to the non-tidal waterbodies. Qualitatively, the Owo River and the Iju River had the richest representation of the macrofauna while the Imede River and the Ore River had the lowest.

Figure 7.3-3
Water hyacinth bordering a mangrove swamp.

Table 7.3-17
The occurrence of aquatic macrophytes in the study area.

Taxa		Waterbodies in the study area						
Species	Family	Yewa River	Badagry Creek	Ologe lagoon	Owo River	Ore River	Iju River	Imede River
Pistia stratiotes	Araceae	+	-	-	+	+	+	+
Azolla african	Azollaceae	-	+	-	+	-	+	+
Ipomea aquatica	Convoluvulaceae	-	-	-	-	+	-	+
Eichhornia crassipes	Eichhorniaceae	+++	+++	+++	+	-	-	-
Lewna spp.	Lamnaceae	-	+	+	+	-	-	+
Ceratophylum demersun	Nymphaeaceae	+	+	+	+	+	+	+
Nymphia lotus	Nymphaeaceae	-	+	-	+	+	-	+
Commelina spp.	Onagraceae	+	+	-	+	+	-	+
Ludwigia sp.	Onagraceae	-	-	-	+	+	+	+
Nephrolepsis spp.	Thelypteridaceae	+	-	+	+	+	+	-
Salvinia nymphellula	Salviniaceae	-	+	-	-	+	+	+

A total of 496 specimens of macro invertebrate animals (belonging to 20 species) were recorded from the 20 sediment samples analyzed. A summary of the occurrence is given in Table 7.3-19 while the original data is presented in Appendix G. Three groups of organisms, namely mollusks, dipteran larvae, and oligochaete worms, formed the bulk of the fauna accounting for 56.45 percent, 23.59 percent and 18.75 percent, and respectively. The remaining 1.21 percent of the fauna comprised polychaetes, decapods, neuroptera species. The mollusks, particularly *Egeria paradoxa* (bivalve) and *Pachymelania aurita* (gastropoda), occurred in significantly large numbers in the stations located along Badagry Creek (S2, S3, S4, S5) and Yewa River (S1). Larvae and oligochaete worms were more in the slow running forest streams of the study area. The chironomids were more abundant at stations S12, S15, S29 and S37, while *Tubifex tubifex,* an oligochaete worm, occurred in large number also at S37. Another oligochaete that was in fairly large number was *Nais communis*. Sampling stations S1, S2, S3, S4, S5, S12, S15, S29, and S37 had the highest number of macrobenthic fauna in the area. The oligochaetes and chironomidae (which are amongst the well known organic pollution-tolerant macrobenthic fauna) formed the bulk of the macrobenthic fauna in the slow running forest streams in the study area.

The number of species per station ranged from 1 (in station S4) to 7 (in station S37). Species diversity was generally low. Margalef's index of species richness (D) was in the range of 0.00 – 2.06 and Shannon-Weiner Index of general diversity, between 0.00 and 1.55. Eveness index also ranged between 0 and 0.96. Station S4 generally had the lowest diversity while the station with the highest diversity was S33. Analysis of variance (ANOVA) revealed that stations S1, S2, S3, S4, S5, S15, and S37 had significantly ($P<0.05$) higher populations than other stations (most of these stations were located in Badagry Creek). As revealed in Table 7.3-18, the macrobenthic sediment fauna of non-tidal waters was less abundant but by far more diverse than those of tidal waterbodies. With regard to taxon number (S), species richness (D) and Shannon-Weiner Index (H') of the non tidal waterbodies were, on average are at least twice as great as the tidal waters.

As expected, the benthic communities in the sediment and those associated with the water weeds in the aquatic system in the study area are admixtures of fresh and brackish water species. The well known brackish water forms include the errant polychaetes *Neanthes limnicola*, mollusc *Pachymelania aurita*, *Potamopyqus ciliatus*, *Egeria paradoxa*, *Iphigenia rostrata, Mytillus perna,* and *Tellina senegambiensis*, while the freshwater forms include the developing stages of most insects, the oligochaete worms, and freshwater molluscs. In the sediment, fauna was on average low in abundance. However, in the roots of aquatic weeds there was a large variety and abundance of different stages of insects, leeches and other invertebrates, thus providing a very conducive habitat for detritivorous and omnivorous fish to thrive if other environmental conditions are right. The whole array of common and rare benthic fauna on the roots of the aquatic weeds and the sediment therefore provides an economic and practical utility in fish culture practices.

Table 7.3-18
The occurrence of macro-invertebrate animals associated with aquatic weeds in the investigated waterbodies.

Taxon	**Waterbodies in the study area**						
	Badagry Creek	**Ologe lagoon**	**Owo River**	**Imede River**	**Iju River**	**Ore River**	**Oruku River**
Amphibia tadpoles	-	-	+	-	+	-	-
Annelida (Oligochaeta)							
***Branchiodrilus* sp.**	-	-	+	-	+	-	-
Chaetogaster diastrophus	-	-	-	-	+	-	-
Nais communis	-	+	+	-	+	-	-
Tubifex tubifex	-	-	-	-	+	-	-
Annelida (Hirudinea)							
***Glossiphonia* sp.**	+	-	-	-	-	-	-
Helobdella punotata	-	-	+	-	-	-	-
Haemopsis marmorata	-	-	+	-	-	-	-
Crustacea (Amphipoda)							
Gamarus fasciatus	+	+	-	-	-	-	-
Crustacea (Decapoda)							
Potamalpheops monody	+	+	-	-	-	-	-
Crustacea (Isopoda)							
Ligia gracilipes	+	+	-	-	-	-	-
Insecta (Coleoptera)							
***Copelatus* sp.**	-	-	+	+	+	+	-
***Hydrocanthus* sp.**	-	-	-	-	-	-	+
***Hydrophilus* sp.**	-	-	-	-	-	-	+
***Hydroporus* sp.**	-	-	+	-	-	-	-
***Philhydrus* sp.**	-	-	-	-	+	-	-
Insecta (Dipteria*)*							
***Chaoborus* sp.**	-	-	+	-	-	-	-
Chironomus fractilobus	-	-	-	+	+	-	+
Chironomus transvaalesis	-	-	-	+	+	-	-
Clinatanypus maculates	+	+	+	+	+	-	-
***Corynoneura* sp.**	-	-	-	+	+	-	-
***Cricotopus* sp.**	-	+	-	-	+	-	-
Insecta (Ephemeroptera)							
***Adenophlebiodes* sp.**	+	-	-	-	-	-	-
***Baetis* sp.**	+	-	+	-	+	-	-
Cloeon cylindroculum	-	-	+	-	-	-	-
***Pseudocloeon* sp.**	-	+	-	-	-	-	-
Insecta (Hemptera)							
***Lothocerus* sp.**	-	-	-	-	+	+	-
Pelocoris femoratus	-	-	-	+	-	-	-
Insecta (Anisoptera)							
***Cordulid* sp.**	+	-	-	-	-	-	+
***Erythemis* sp.**	-	-	-	-	-	+	-
***Ophiogomphus* sp.**	-	+	-	-	-	-	-
Oxygaster curtisii	-	-	-	-	+	-	-
***Plathemis* sp.**	-	-	+	-	-	-	-
Insecta (Zygoptera)							
Coenagrion scitulum	+	-	-	-	-	-	-
Lestes dryas	-	-	-	-	+	-	-
Mollusca (Bivalvia)							
Psidium pirothi	-	-	-	+	-	-	-
Mollusca (Gastropoda)							
***Hydrobia* sp.**	-	+	-	-	-	-	-
Lanistes libycus	-	-	+	-	-	-	-
Potamopygus ciliatus	-	+	-	-	-	-	-
Species number	**10**	**10**	**13**	**8**	**18**	**5**	**5**
+ = present - = absent							

Table 7.3-19
Summary of species richness, abundance, diversity and distribution of the major groups of macrobenthic fauna in the sediment at the study area.

MAJOR GROUPS	S	WAGP EIA ONSHORE SAMPLING STATIONS																				TOTAL	%
		S1	S2	S3	S4	S5	S6	S8	S9	S10	S11	S12	S13	S15	S16	S23	S24	S29	S33	S36	S37		
ANNELIDA																							
OLIGOCHAETA	**6**	0	0	0	0	0	7	2	3	2	2	4	2	2	5	3	2	0	5	**0**	**54**	**93**	**18.75**
POLYCHAETA	**1**	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	**2**	**0.40**
DECAPODA	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	**0**	0	**2**	**0.40**
DIPTERA	**6**	0	0	0	0	0	2	0	0	0	0	23	2	33	7	3	3	17	2	**0**	**25**	**117**	**23.59**
MOLLUSCA																							
BIVALVIA	**4**	8	53	51	58	65	0	0	0	0	1	0	0	0	0	0	0	0	0	**0**	**0**	**236**	**47.58**
GASTROPODA	**1**	35						3	2	4												**44**	**8.87**
NEUROPTERA	**1**						1													1		**2**	**0.40**
Abundance(N)		**45**	**53**	**51**	**58**	**65**	**10**	**5**	**5**	**6**	**3**	**27**	**4**	**35**	**13**	**6**	**5**	**18**	**7**	**1**	**79**	**496**	
Diversity																							
I. Taxa number(S)	**20**	**3**	**2**	**2**	**1**	**3**	**5**	**3**	**3**	**2**	**2**	**5**	**3**	**5**	**5**	**4**	**3**	**4**	**5**	**1**	**7**		
II. Species Richness(D)		**0.525**	**0.252**	**0.254**	**0.000**	**0.479**	**1.737**	**1.243**	**1.243**	**0.558**	**0.910**	**1.214**	**1.443**	**1.125**	**1.559**	**1.674**	**1.243**	**1.038**	**2.056**		**1.373**		
III. Shannon-Weiner index (H,)		**0.641**	**0.094**	**0.097**	**0.000**	**0.266**	**1.471**	**0.950**	**1.055**	**0.637**	**0.637**	**1.390**	**1.040**	**0.897**	**1.327**	**1.330**	**1.055**	**0.926**	**1.550**	**0.000**	**1.317**		
IV. Evenness index (E)		**0.583**	**0.135**	**0.139**		**0.242**	**0.914**	**0.865**	**0.960**	**0.918**	**0.918**	**0.864**	**0.946**	**0.558**	**0.824**	**0.959**	**0.960**	**0.668**	**0.963**		**0.677**		

Table 7.3-20
Diversity of macro invertebrate sediment fauna of the investigated waterbodies in relation to tidal regime.

Diversity Index	Tidal waters						Non-tidal waters					
	min	max	med	mean	s.d.	%C.V	Min	max	med	mean	s.d.	%C.V
Abundance	3	65	48	35.8	24.67	69	1	79	8.5	17.5	20.95	120
Taxa number (s)	1	3	2	2.25	0.66	29	1	7	4.5	4.17	1.46	35
Species Richness (D)	0.00	1.243	0.502	0.528	0.369	70	1.038	2.056	1.308	1.309	0.483	37
Shannon-Weiner Index (H')	0.00	0.950	0.637	0.415	0.323	78	0.000	1.897	1.186	1.077	0.371	34
Evenness Index (E)	0.00	0.960	0.413	0.480	0.371	77	0.558	0.963	0.889	0.774	0.269	35

Water Microbiology

Result of the microbial analysis of water samples from the study area revealed the presence of appreciable quantities of heterotrophic bacteria and fungi communities. Also, the distribution of hydrocarbon degraders, coliform bacteria, and sulphate reducing bacteria was observed to vary extensively as shown in Table 7.3-21. Total heterotrophic bacterial count was observed to range in the order of 10^2 and 10^4 CFU/mL. Total fungal densities were generally lower than that of bacteria and ranged between 20 and several magnitudes of the order of 10^2 CFU/mL. Hydrocarbon degrading bacteria count varied from 1.0×10^2 to 2.4×10^4 CFU/mL while their fungal counterpart was observed to vary between 0 and 70 CFU/mL. Sulphate reducing bacteria was absent in most of the sample locations but varied between 0 and 10^2 cells/ml. Coliform bacterial densities suggest that all the water samples are not potable as counts in the range of 5.8 and 1760 cells/100 ml were observed. In two cases (WS13S and WS14), the indicator of fecal contamination, *Escherichia coli* was observed (Table 7.3-21).

Bacteria isolates identified in this location include *Escherichia coli, Pseudomonas aeruginosa, Acinetobacter* spp., *Azotobacter* spp., *Micrococcus luteum, Serratia marcescens, Desulfurvibrio* spp., *Aeromonas* spp., *Enterobacter* spp., *Klebsiella pneumoniae, Alcaligenes feacalis, Proteus vulgaris, Bacillus cereus,* and *Bacillus subtilis.* The fungal species isolated include *Microsporium audininii, Cephalosporium* spp., *Cunnighamella* spp., *Pullularia pullularis, Cladosporium* spp., *Penicillium camenberti, Alternaria* spp., *Rhizopus oryzae, Fusarium* spp., *Penicillium italicum,* and *Rhodotorula* spp.

Table 7.3-21
Average microbial densities of water samples from WAGP EIA project.

Sample code	TBC (cfu/ml)	HDB (cfu/ml)	SRB (cells/ml)	THF (cfu/ml)	HDF (cfu/ml)	Coliform (cells/100ml)
WS1	**6.0×10^3**	**2.0×10^3**	**Nil**	**1.5×10^2**	**25**	**736**
WS2S	**1.1×10^4**	**8.3×10^3**	**Nil**	**90**	**10**	**24**
WS2B	**2.4×10^4**	**6.9×10^3**	**10^2**	**3.3×10^2**	**43**	**68.8**
WS3S	**2.4×10^2**	**1.1×10^2**	**Nil**	**1.2×10^2**	**23**	**24**
WS3B	**2.0×10^2**	**1.2×10^2**	**10^2**	**1.2×10^2**	**44**	**24**
WS11S	**3.2×10^4**	**1.1×10^4**	**10^2**	**4.0×10^2**	**55**	**62.4**
WS11B	**3.2×10^2**	**1.2×10^2**	**10^2**	**1.0×10^2**	**24**	**148.8**
WS26	**2.8×10^4**	**1.8×10^4**	**10^2**	**3.2×10^2**	**54**	**14.6**
WS29	**2.2×10^4**	**2.2×10^4**	**Nil**	**20**	**Nil**	**84.8**
WS31	**2.6×10^4**	**6.6×10^3**	**Nil**	**1.6×10^2**	**32**	**240**
WS33	**1.7×10^4**	**8.5×10^3**	**10^2**	**20**	**07**	**336**
WS34	**3.7×10^4**	**1.7×10^4**	**Nil**	**1.2×10^2**	**44**	**36.8**
WS36	**1.5×10^4**	**5.7×10^3**	**Nil**	**1.4×10^2**	**13**	**57.6**

Keys:
*** Presence of *E. coli* suggestive of possibility of fecal contamination**
THB **- Total heterotrophic bacteria;** HDB **- Hydrocarbon degrading bacteria;** SRB **– Sulphate reducing bacteria;** THF **– Total heterotrophic fungi;** HDF **– Hydrocarbon degrading fungi.**

Sediment samples from the area were observed to be rich in different microbial communities as shown in Table 7.3-22. The results of the microbial densities of the sediment samples revealed that average total heterotrophic bacterial count ranged between 2.7×10^5 and 2.8×10^6CFU/g. Average total fungal densities varied from 3.0×10^2 to 3.6×10^3CFU/g. Hydrocarbon degrading bacterial population ranged between 1.1×10^4 and 1.2×10^6CFU/g, while their fungal counterpart range from 0 to 3.1×10^3CFU/g. Sulphate reducing bacteria population varied between 0 and 10^3CFU/g.

The bacteria species isolated from the sediment include *Proteus vulgaris, Desulfuvibrio* spp., *Pseudomonas pseudomallei, Sarcinia* spp., *Corynebacterium* spp., *Pseudomonas aeruginosa, Arthrobacter* spp., *Klebsiella pneumoniae, Micrococcus luteum, Streptomyces* spp., *Staphylococcus aureus, Aeromonas* spp., *Bacillus cereus, Bacillus subtilis, Pseudomonas fluorescence, Proteus mirabilis, Bacillus polymyxa*, and *Flavobacterium* spp. The isolated fungal species include *Daldenia* spp., *Aspergillus niger, Cladosporium* spp., *Trichoderma* spp., *Rhodotorula* spp., *Aspergillus flavus, Botrytis* spp., *Scopulariospsis brevicaulis, Pullularia* spp., *Microsporium gypseum, Cunninghamella* spp., *Penicillium notatum, Rhodotorula* spp., *Neurospora* spp., and *Microsporium audovinii*.

Table 7.3-22
Average microbial densities of sediment samples from WAGP EIA.

S/N	Sample code	THB (cfu/g)	HDB (cfu/g)	SRB (cells/g)	THF (cfu/g)	HDF (cfu/g)
1	**SE1**	1.8×10^6	1.5×10^5	10^3	2.0×10^3	1.2×10^2
2	**SE2-TO**	1.1×10^6	1.1×10^4	10^3	1.7×10^3	41
3	**SE3-ROW**	2.1×10^6	1.2×10^6	10^1	8.0×10^2	32
4	**SE4**	8.8×10^5	6.5×10^5	Nil	1.1×10^3	1.4×10^2
5	**SE5**	1.1×10^6	6.3×10^4	Nil	1.3×10^3	50
6	**SE6**	2.8×10^6	4.4×10^4	Nil	1.4×10^3	33
7	**SE8**	1.1×10^6	5.3×10^5	10^3	3.0×10^2	12
8	**SE9**	1.5×10^6	7.9×10^3	10^2	6.0×10^2	35
9	**SE10**	6.9×10^5	1.5×10^5	10^1	3.0×10^2	21
10	**SE11**	1.3×10^6	7.7×10^3	10^3	1.9×10^3	2.1×10^2
11	**SE16**	1.2×10^6	2.3×10^4	10^2	9.0×10^2	52
12	**SE21**	4.9×10^5	1.1×10^5	10^2	1.8×10^2	23
13	**SE23**	1.6×10^6	4.8×10^4	Nil	5.0×10^2	15
14	**SE24**	3.5×10^5	3.5×10^4	Nil	3.6×10^3	3.1×10^2
15	**SE31**	2.8×10^5	7.9×10^3	Nil	1.0×10^3	47
16	**SE33**	6.5×10^5	1.3×10^5	10^2	4.0×10^2	24
17	**SE34**	5.3×10^5	4.7×10^4	10^2	4.0×10^2	Nil
18	**SE36**	2.7×10^5	6.5×10^4	10^3	6.0×10^2	15
19	**SE37**	6.2×10^5	3.6×10^4	Nil	1.1×10^3	1.7×10^2
Keys: THB - **Total heterotrophic bacteria;** HDB - **Hydrocarbon degrading bacteria;** SRB – **Sulphate reducing bacteria;** THF – **Total heterotrophic fungi;** HDF – **Hydrocarbon degrading fungi.**						

7.4 SOIL AND GROUNDWATER CHARACTERIZATION (COMPRESSOR STATION)

7.4.1 Borehole Lithology and Hydrogeology

Table 7.4-1 shows the result of the vertical electric soundings (VES) survey. There is a 5-layered subsurface with resistivity values and thicknesses. There are two water-bearing horizons; the first is encountered from a depth of about 5-30m, except at locations 5 and 6 where this occurs at a depth of about 2-4m, and the second is separated from the first by a dry sand layer varying in thickness from about 4 to 35m. From the results, the water table is assumed to be at about 10m below the ground surface. The VES diagrams are presented in Appendix G while the borehole logs are shown in Figure 7.4-1.

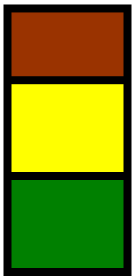
Table 7.4-1
Summary of the hydrogeophysical characteristics at the six VES Stations.

VES Location	Number of layers	Resistivity (Ohm-m)	Thickness (m)	Depth (m)	Comments
1	1	8248.2	0.1	0.1	Topsoil
	2	26941.4	4.8	4.9	Dry sand
	3	2848.7	17.4	22.3	Wet sand
	4	25892.2	12.5	34.8	Dry sand
	5	280.8	Infinity	Infinity	Wet sand
2	1	23572.4	4.9	4.9	Topsoil
	2	4852.0	0.1	5.0	Dry sand
	3	4565.7	24.9	29.9	Wet sand
	4	12646.1	20.5	50.4	Dry sand
	5	338.9	Infinity	Infinity	Wet sand
3	1	26010.7	1.7	1.7	Topsoil
	2	18718.6	6.3	8.0	Dry sand
	3	1453.58	7.6	15.7	Wet sand
	4	8747.7	34.5	50.2	Dry sand
	5	701.1	Infinity	Infinity	Wet sand
4	1	26649.5	1.2	1.2	Topsoil
	2	19099.7	5.3	6.5	Dry sand
	3	3128.6	19.1	25.6	Wet sand
	4	10223.1	24.0	49.6	Dry sand
	5	593.6	Infinity	Infinity	Wet sand
5	1	3811.2	0.2	0.2	Topsoil
	2	33941.8	2.0	2.2	Mottled Clay
	3	2861.2	1.8	4.0	Wet sand
	4	6214.7	20.6	24.6	Dry sand
	5	1295.0	Infinity	Infinity	Wet sand
6	1	10915.7	0.7	0.7	Topsoil
	2	41428.1	1.4	2.1	Mottled Clay
	3	1206.6	1.4	3.5	Wet sand
	4	75080.6	4.8	8.3	Dry sand
	5	3145.1	Infinity	Infinity	Wet sand

Based on the above interpretation of the data of the VES survey, three monitor boreholes were drilled in the proposed compressor station location. The borehole lithologic logs are presented along with other pertinent data (see Figure 7.4-1), while the groundwater flow direction is shown in Figure 7.4-2.

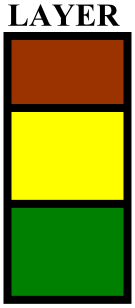
Figure 7.4-1
Borehole lithology.

BOREHOLE 1: COORDINATES: 06°24’59”N; 002°59’21”E
DEPTH TO WATER: 7m



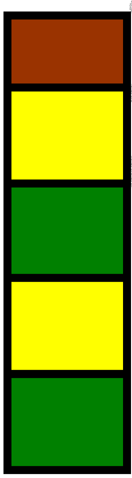
LAYER	DESCRIPTION	Thickness (m)	Depth (m)
-	TOPSOIL	0.1	0.1
-	DRY SAND	4.8	4.9
-	WET SAND	17.4	22.3

BOREHOLE 2: COORDINATES: 06°25’00”; 002°59’20”E
DEPTH TO WATER: 6m



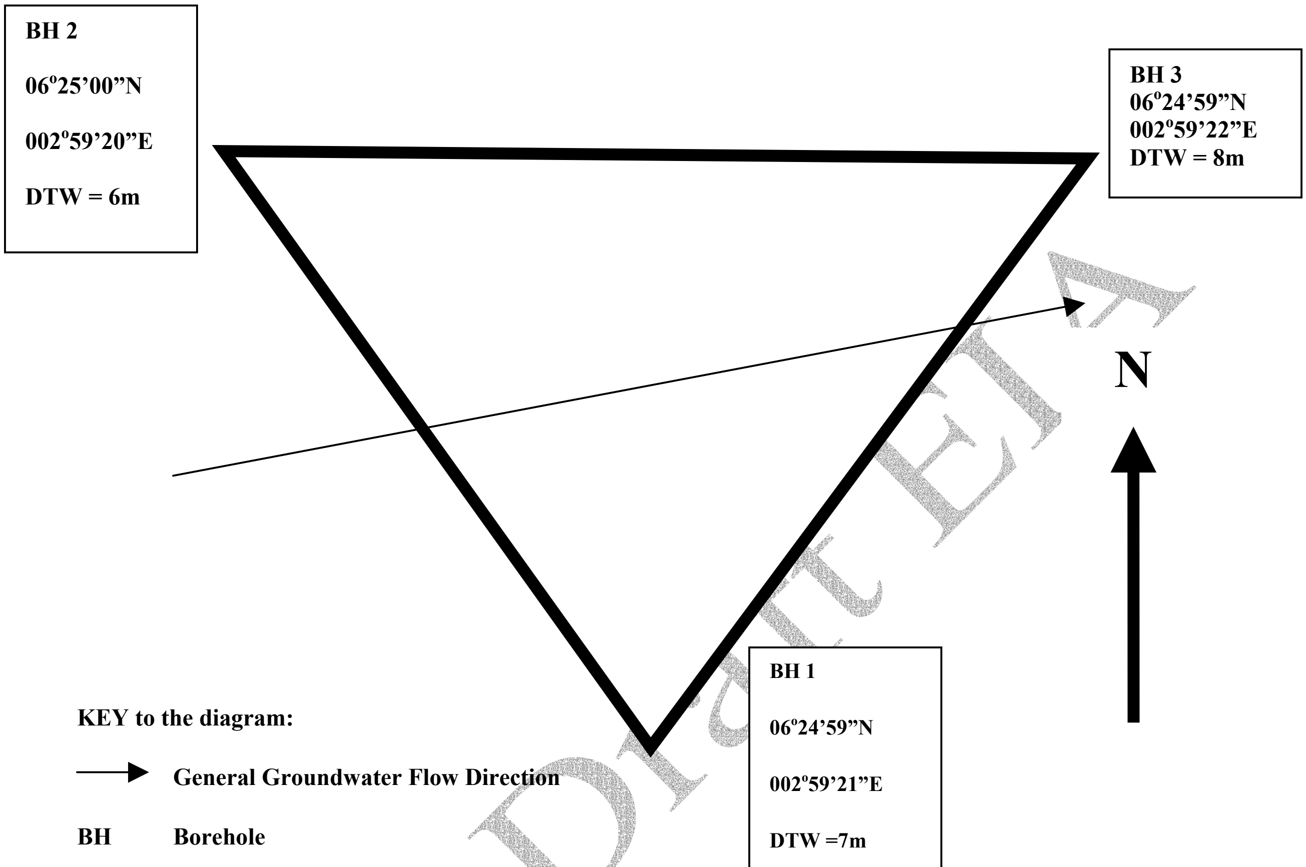
LAYER	DESCRIPTION	Thickness (m)	Depth (m)
-	TOPSOIL	1.7	1.7
-	DRY SAND	6.3	8.0
-	WET SAND	7.6	15.6

BOREHOLE 3: COORDINATES: 06°24’59”N; 002°59’22”E
DEPTH TO WATER: 8m.



LAYER	DESCRIPTION	Thickness (m)	Depth (m)
-	TOPSOIL	0.7	0.7
-	MOTTLED CLAY	1.4	2.1
-	WET SAND	1.4	3.5
-	DRY SAND	4.8	8.3
-	WET SAND	Infinity	Infinity

Figure 7.4-2
Direction of groundwater flow



KEY to the diagram:

→ **General Groundwater Flow Direction**

BH **Borehole**

DTW **Depth to Water**

7.4.2 Groundwater Quality

Laboratory analysis of the groundwater samples revealed that the water is potable, on the basis of non-detection (to trace levels) of heavy metals and PAH (see Tables 7.4-2 and 7.4-3).

Table 7.4-2
Groundwater Trace Metals Concentration.

Samples	Cd(mg/L)	Cr(mg/L)	Mn(mg/L)	Zn(mg/L)	Pb(mg/L)	Cu(mg/L)	Ni(mg/L)	Fe(mg/L)
BH1	0.015	<0.001	0.041	<0.001	<0.001	<0.001	0.028	0.085
BH2	0.014	<0.001	0.041	<0.001	<0.001	<0.001	0.059	1.063
BH3	0.012	<0.001	0.051	0.024	0.041	<0.001	0.061	1.502

Table 7.4-3
Polycyclic Aromatic Hydrocarbon Content (mg/L) of the groundwater at the proposed compressor station site.

COMPONENT	BH1	BH2	BH3
Naphthalene	0.000	0.000	0.000
2-Methyl Naphthalene	0.030	0.021	0.019
Acenaphthalene	0.025	0.017	0.014
Acenaphthene	0.000	0.000	0.000
Florene	0.000	0.000	0.000
Phenathrene	0.055	0.073	0.047
Anthracene	0.068	0.082	0.092
Fluoranthene	0.079	0.112	0.107
Pyrene	0.000	0.000	0.000
Benzo(a)anthracene	0.000	0.000	0.000
Crysene	0.000	0.000	0.000
Benzo(b)fluoranthrene	0.000	0.000	0.000
Benzo(a)pyrene	0.000	0.000	0.000
Benzo(k)fluoranthrene	0.000	0.000	0.000
Indeno(1,2,3) perylene	0.000	0.000	0.000
Dibenzo(a,h)anthracene	0.000	0.000	0.000
Benzo(g,h,i) perylene	0.000	0.000	0.000
Total (mg/l)	0.257	0.306	0.280

7.5 WILDLIFE AND ANIMAL RESOURCES

7.5.1 Diversity and Distribution

Mammals

Mammals known to be present in the area, from a combination of literature and field sources, (Table 7.5-1) include Bosman's Potto, *Perodicticus potto*, Dwarf Galago, *Galagoides demidovii*, Mona Monkey, *Cercopithecus mona*, Bushpig, *Potamochoerus porcus*, Sitatunga, *Tragelaphus spekei*, Bushbuck, *Tragelaphus scriptus*, Maxwell's Duiker, *Cephalophus maxwelli*, Tree Pangolin, *Manis tricuspis*, Long-tailed Pangolin, *M. tetradactyla*, Brush-tailed Porcupine, *Atherurus africanus*, Grasscutter, *Thryonomys swinderianus*, and Crawshay's Hare, Lepus crawshayi. Others included the African Civet, *Viverra civetta*, Palm Civet, *Nandinia binotata*, Cape Clawless Otter, *Aonyx capensis*, Spotted-necked Otter, *Lutra maculicollis*, Cusimanse Mongoose, *Crossarchus obscurus*, Marsh Mongoose, *Atilax paludinosus*, the Gambian Mongoose, *Mungos gambianus*, and genets, presumably the Large-spotted Forest Genet, *Genetta poensis.*

Birds

As shown in Table 7.5-2, the study area contains quite a few birds of the waterside and an abundance of species commonly associated with gardens, farmlands, fallows with scattered trees, and dense secondary growth. These include the Grey Heron, *Ardea cinerea* (Fig. 7.5-1), Village Weaver, *Ploceus cuculatus* (Figure 7.5-2), Cattle Egret, *Bulbulcus ibis*, Black-shouldered Kite, *Elanus caeruleus*, Black Kite, *Milvus migrans*, Grey Kestrel, *Falco ardosiaceus*, Senegal Thick-knee, *Burhinus senegalensis*, African Green Pigeon, *Treron calva*, Red-billed Wood Dove, *Turtur afer*, Senegal Coucal, *Centropus senegalensis*, Pied Kingfisher, *Ceryl rudis,* and the African Pied Hornbill, *Tockus fasciatus.*

Reptiles

The reptilian fauna is made up of crocodiles, turtles, tortoises, snakes and lizards (Table 7.5-3). The Monitor Lizard, *Varanus niloticus*, the Nile Crocodile, *Crocodylus niloticus,* and the Dwarf Crocodile ("Alligator"), *Osteolaemus tetraspis* are hunted for food. Several species of snakes are said to occur in the area including the Black Cobra, *Naja melanoleuca*, Spitting Cobra, *Naja nigicollis*, Night Adder, *Causus maculatus*, African Beauty Snake *Psammorphis sibilans*, Royal Python, *Python regius*, and the Rock Python, *Python sebae*. Sea turtles that nest annually on the sandy shores of Badagry and nearby Takwa Bay include the Green Turtle, *Chelonia mydas*, Olive Ridley Turtle, *Lepidochelys olivacea*, Hawksbill Turtle, *Eretmochelys imbricata*, and Loggerhead Turtle, *Caretta caretta.*

Figure 7.5-1
Grey Heron found in the study area.

Figure 7.5-2
A colony of weaver birds in the study area.

Amphibians

Species recorded in the area include: *Bufo regularis* (common toad), ranid frogs: *Dicroglossus occipitalis* (Bullfrog), *Ptychadena oxyrhinchus*, *P. aequplicata, P. taenioscelis, Aubria subsigilata,* and *Phrynobatrachs albolabris;* treefrogs: *Afrixalus dorsalis, Hyperolius fusciventris, H. guttulatus,* and *H. concolor,* and a Clawed toad, *Xenopus tropicalis*, (Table 7.5-4).

7.5.2 Species of Conservation Concern

It is important to point out that some of the animals found in the study area, e.g., the Bushpig, Sitatunga, Bushbuck, and all primates are locally endangered. Seven of them are listed in the IUCN Red List of Endangered Species of 1996 (see Tables 7.5-1 and 7.5-3), while others, like pangolins, the Brush-tailed Porcupine, river otters, civets, genets, mongooses, crocodiles, Nile Monitor Lizard, all kites, the francolin (bushfowl), etc., are protected by the Endangered Species (Control of International Trade and Traffic) Decree No. 11 of 1985, which is Nigeria's version of the Convention on International Trade and Traffic in Endangered Species (CITES). The hunting, capture of, or trade in those species listed in Schedule I of this Decree, is absolutely prohibited.

Table 7.5-1
The Mammals in the vicinity of the proposed pipeline ROW.

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Primates				
Bosman's Potto	*Perodicticus potto*	1	2	Endangered
Demidov's Galago	*Galago demidovii*	1	2	Common
Mona Monkey	*Cercopethicus mona*	2	2	Vulnerable
Pholidota (Pangolins)				
Tree Pangolin	*Manis tricuspis*		1	Vulnerable
Long-tailed Pangolin	*Manis tetradactyla*		1	Vulnerable
Lagomorpha (Hares and Rabbits)				
Crawshay's Hare	*Lepus crawshayi*			Common
Rodentia (Rodents)				
Giant Forest Squirrel	*Protoxerus stangeri*			Vulnerable
Red-legged Sun-squirrel	*Heliosciurus rufobrachium*			Common
Fraser's Flying Squirrel	*Anomalurus derbianus*			Endangered
Giant Rat ("Rabbit")	*Cricetomys gambianus*			Common
Cane Rat or Grasscutter	*Thryonomys swinderianus*			Common
Brush-tailed Porcupine	*Atherurus africanus*		1	Common
Carnivora (Carnivores)				
Cape Clawless Otter	*Aonyx capensis*		1	Vulnerable
African Civet	*Viverra civetta*		2	Vulnerable
Two-spotted Palm Civet	*Nandinia binotata*		2	Uncommon
Large-spotted Forest Genet	*Genetta poensis*		2	Vulnerable
Cusimanse Mongoose	*Crossarchus obscurus*		2	Common
Gambian Mongoose	*Mungos gambianus*		2	Vulnerable
Marsh Mongoose ('Fox')	*Atilax paludinosus*		2	Endangered
Hyracoidea (Hyraxes)				
Tree Hyrax ("Bush dog")	*Dendrohyrax dorsalis*		2	Common
Artiodactyla				
Bushpig	*Potamochoerus porcus*			Very rare
Maxwell's Duiker	*Cephalophus maxwelli*		2	Common
Bushbuck	*Tragelaphus scriptus*		2	Uncommon
Sitatunga ("Water Deer")	*Tragelaphus spekei*	1	1	Endangered

Table 7.5-2
Birds seen or heard in the vicinity of the proposed pipeline ROW.

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Ardeidae (Herons and Egrets)				
Cattle Egret	*Bubulcus ibis*		2	Uncommon
Grey Heron	*Ardea cinerea*		2	Common

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Accipitridae (Vultures, Hawks, Kites, Eagles, etc.)				
Black-shouldered Kite	*Elanus caeruleus*		1	Common
Shikra	*Accipiter badius*		1	Common
Lizard Buzzard	*Kaupifalco monogrammicus*		1	Common
Black Kite	*Milvus migrans*		1	Abundant
Falconidae (Kestrels, falcons)				
Common Kestrel	*Falco tinnunculus*		1	Common
Grey Kestrel	*Falco ardosiaceus*		1	Common
Phasianidae (Francolins and Guinea Fowls**)**				
Double-spurred Francolin	*Francolinus bicalcaratus*		2	Common
Burhinidae (Thick-knees or Stone Curlews)				
Senegal Thick-knee	*Burhinus senegalensis*			Uncommon
Columbidae (Pigeons and Doves)				
Red-eyed Dove	*Streptopelia semitorquata*			Common
Laughing Dove	*Streptopelia senegalensis*			Common
Vinaceous Dove	*Streptopelia vinacea*			Uncommon
Red-billed Wood Dove	*Turtur afer*			Common
Tambourine Dove	*Turtur tympanistria*			Common
African Green Pigeon	*Treron calva*			Uncommon
Cuculidae (Cuckoos and Coucals)				
Senegal Coucal	*Centropus senegalensis*			Common
Alcedinidae (Kingfishers)				
Woodland Kingfisher	*Halcyon senegalensis*			Common
Grey-headed Kingfisher	*Halcyon leucocephala*			Uncommon
Shining-blue Kingfisher	*Alcedo quadribrachys*			Uncommon
Malachite Kingfisher	*Corythornis cristata*			Common
Pied Kingfisher	*Ceryl rudis*			Unommon
Meropidae (Bee-eaters)				
White-throated Bee-eater	*Merops albicollis*			Uncommon
Little Bee-eater	*Merops pusillus*			Rare
Bucerotidae (Hornbills)				
African Pied Hornbill	*Tockus fasciatus*			Common
Capitonidae (Barbets)				
Speckled Tinkerbird	*Pogoniulus scolopaceus*			Common
Hirundinidae (Swallows)				
Ethiopian Swallow	*Hirundo aethiopicus*			Common
Motacillidae (Wagtails, Pipits, Longclaws)				
African Pied Wagtail	*Motacilla aguimp*			Rare
Pycnonotidae (Bulbuls)				
Common Garden Bulbul	*Pycnonotus barbetus*			Common
Sylviidae (Warblers)				
Grey-backed Camaroptera	*Camaroptera brevicaudata*			Common
Nectariniidae (Sunbirds)				
Olive-bellied Sunbird	*Nectarinia chloropygia*			Common

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Collared Sunbird	*Anthreptis collaris*			Common
Corvidae (Crows, Magpies, etc)				
Pied Crow	*Corvus alba*			Common
Passeridae (Sparrows)				
Grey-headed Sparrow	*Passer griseus*			Common
Ploceidae (Weavers)				
Village Weaver	*Ploceus cucullatus*			Common
Estrildidae (Finches, Waxbills, Mannikins)				
Bronze Mannikin	*Lonchura cucullata*			Abundant
Red-billed Fire-Finch	*Lagonosticta senegala*			Uncommon
Viduidae (Whydahs, Indigo Birds)				
Pin-tailed Whydah	*Vidua macroura*			Uncommon

Table 7.5-3
Reptiles reported to occur in the vicinity of the proposed pipeline ROW.

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Crocodylidae (Crocodiles)				
Nile Crocodile	*Crocodylus niloticus*		1	Common
Short-snouted Crocodile ("Alligator")	*Osteolaemus tetraspis*	Endangered	1	Common
Pelomedusidae (Swamp terrapins)				
West African Mud Turtle	*Pelusios castaneus*			Uncommon
Testudinidae (Tortoises)				
Serrate Hinge-backed Tortoise	*Kininxys erosa*			Common
Home's Hinge-backed Tortoise	*Kinixys homeana*			Uncommon
Bell's Hinged Tortoise	*Kinixys belliana*			Common
Varanidae (Monitor Lizards)				
Nile Monitor Lizard	*Varanus niloticus*		1	Common
Boidae (Pythons)				
Royal Python	*Python regius*		1	Uncommon
African Python	*Python sebae*		1	Uncommon
Elapidae (Cobras and Mambas)				
Spitting Cobra	*Naja nigricollis*			Common
Black Cobra	*Naja melanoleuca*			Common
Viperidae (Vipers)				
Night Adder	*Causus maculatus*			Common

Table 7.5-4
Amphibians recorded in the vicinity of the proposed pipeline ROW.

COMMON NAME	SPECIES	CONSERVATION STATUS

		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Hyperolidae (Treefrogs)				
	Afrixalus dorsalis			Common
	Hyperolius fusciventris			Common
	Hyperolius guttulatus			Common
	Hyperolius concolor			Common
Ranidae (Frogs)				
	Ptychadena taenioscelis			Common
	Ptychadena oxyrhinchus			Common
	Ptychadena aequiplicata			Common
	Aubria subsigilata			Common
	Phrynobactrachus albolabris			Common
Bullfrog	*Dicroglossus occipitalis*			Common
Bufonidae (Toads)				
Common Toad	*Bufo regularis*			Common
Forest Toad	*Bufo maculatus*			Common
Pipidae (Clawed Toads)				
	Xenopus tropicalis			Common
NB. Decree No. 11 refers to the Endangered Species (Control of International Trade and Traffic) Decree of 1985. By virtue of this decree, the hunting, capture of, or international trade in animals listed in Schedule 1 is absolutely forbidden, while trade in animals listed in Schedule 2 may only be conducted under licence from the Federal Ministry of Agriculture and Natural Resources.				

7.6 FISH AND FISHERY RESOURCES

As in many other riverine and coastal areas of Nigeria, fishing is a major occupation of the local people of the WAGP Project area in Nigeria. It also holds an attraction for a number of non-indigenes that have migrated to the area from the hinterland. There is evidence from oral interviews that some of the existing communities in the area originally started off or were founded as fishing settlements. However, fishing still exists largely at artisanal level in the area, engaged in subsistence mostly by the local fisherfolks using traditional facilities and gears (Figure 7.6-1). The major facility required is a boat, usually a dug-out canoe which can be propelled by paddling. This is the usual sight in the non-tidal rivers. Canoes with outboard engines occur more in the tidal waterbodies notable on Badagry Creek, Ologe lagoon and the lower reach of Owo River where water is deep enough for their use. Both men and women, and to some extent children too, are involved in fishing.

A wide range of fishing gears are employed in the study area. The most common are nets (gill nets, lift nets and cast nets), traps (usually made into baskets), hooks on line etc. Although finfish is the main target of exploitation, shellfish are also sought after (Figure 7.6-2). The latter include crabs, prawns, shrimps and molluscs (notably gastropods and bivalves and cephalopods). The finfish fauna reflects the mixed nature of the water environment comprising marine, brackish and freshwater species.

Thus the fauna is quite rich but of entirely bony fishes. The distribution record of the recorded fish species during the fieldwork is shown in Table 7.6-1. Detailed analysis of the fauna is delayed until the completion of the second season fieldwork.

Figure 7.6-1
Gears used by the local fishermen.

Figure 7.6-2
Fish caught during the study.

Table 7.6-1
The distribution of the recorded fish species in the study area

Species	Family	Occurrence	
		Tidal waters	Non-tidal waters
Bagrus bayad	**Bagridae**	+	+
***Bagrus* sp.**	"	+	+
Chrysicthys auratus	"	+	+
Tilapia guineensis	**Cichlidae**	+	-
***Tilapia* sp.**	"	+	+
Oreochromis niloticus	"	-	+
Hemichromis fasciatus	"	-	+
***Clarias* sp.**	**Claridae**	+	+
***Pellonula* sp.**	**Clupeidae**	+	+
Ilisha africana	"	+	-
Sardinella aurita	"	+	_
Gymnarchus niloticus	**Gymnarchidae**	-	+
Malapterurs electricus	**Malapteruridae**	-	+
***Synodontis* spp.**	**Mochocidae**	+	+
***Liza* spp.**	**Mugilidae**	+	-
***Mugil* sp.**	"	+	-
Periophthalnus papillio	**Periophthalidae**	+	-
***Pseudolithus* sp.**	**Scianidae**	+	-
***Sphyraena* sp.**	**Sphyraenidae**	+	-
***Ephippion* sp.**	**Tetraodontidae**	+	-
Hespetus odeo	**Hespetinidae**		+

7.7 CLIMATE, METEOROLOGY, AND AIR QUALITY

Information on the meteorology and climate of the study area was obtained from a literature review and is presented in Section 1.7.2. Notwithstanding, additional data were collected during the dry season study to update the existing database. This section of the report presents the results of the dry season field measurements (March) for the determination of ambient meteorology and air quality studies with emphasis on pollutant gases.

7.7.1 Ambient Meteorology

Meteorological parameters measured at the compressor site during the study included average wind speed, air temperature, wind chill, humidity, heat index and dew point. The results obtained from the field investigations of these parameters are summarized in Table 7.7-1. Detailed daily recordings are provided in Appendix G.

Table 7.7-1
Summary Values of Meteorological Parameters at the Compressor Site (Feb, 2003)

S/NO	Day	Sampling Station	Parameters (8-hr mean daily values)					
			Average Wind Speed (m/s)	Temp. (^{0}C)	Wind Chill (^{0}C)	Humidity (%)	Heat Index (^{0}C)	Dew Point (^{0}C)
1.	1	AQS1	1.938	31.775	32.213	69.325	34.788	26.263
2.		AQS2	1.363	31.025	31.813	67.350	39.050	26.763
3.		AQS3	1.900	31.438	32.963	68.013	40.325	27.538
4.	2	AQS1	1.663	30.825	31.550	71.000	35.625	26.588
5.		AQS2	1.638	31.988	32.288	69.200	41.225	26.925
6.		AQS3	1.075	30.463	30.713	77.838	37.125	27.125
7.	3	AQS1	1.163	33.025	33.988	62.450	42.100	25.875
8.		AQS2	0.925	32.338	32.750	42.275	26.163	26.300
9.		AQS3	0.700	31.838	32.063	73.875	40.738	25.950
10.	4	AQS1	0.688	31.338	31.450	76.888	39.300	25.925
11.		AQS2	0.763	31.700	32.100	77.250	39.925	26.663
12.		AQS3	0.813	31.938	32.288	40.088	40.088	26.825
13.	5	AQS1	0.875	31.700	32.075	73.013	41.225	26.188
14.		AQS2	0.975	31.938	32.213	73.750	40.663	26.100
15.		AQS3	0.913	31.963	32.213	72.250	40.263	25.925
Mean			1.172	31.686	32.699	67.638	38.574	26.464

Mean daytime ambient air temperature ranged narrowly from 30^{0}C to 33^{0}C with a five-day average of 31^{0}C suggesting a more or less equable temperature over the sampling period. Similarly, Wind Chill and Dew Point ranged from 31^{0}C to 33^{0}C and 25^{0}C to 26 ^{0}C respectively. Mean diurnal Humidity and Heat Index ranged from 40^{0}C to 76^{0}C and 26^{0}C to 41^{0}C respectively. Wind speed averaged 1.17m/s. The recorded values are largely in consonance with existing historical data from synoptic stations in Lagos.

As expected, variations of the investigated meteorological parameters with the sampling stations were marginal, with the Southwesterly monsoon winds appearing to be predominant at the time of sampling.

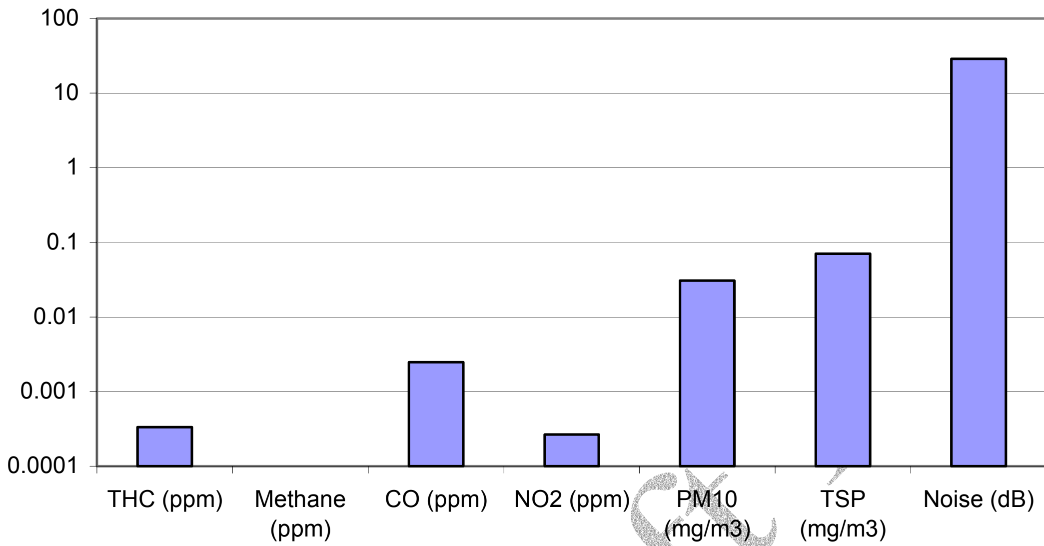
7.7.2 Pollutant Gases and Noise

Pollutant gases that were investigated include total hydrocarbons (THC), methane, carbon monoxide, nitrogen dioxide and particulates (total and inhalable). The overall summary results obtained from the investigations are presented in Table 7.7-2 and Figure 7.7-1. These parameters were chosen based on existing knowledge of potential pollutants of concern from a compressor facility. Sulphur oxides were not investigated since the WAGP gas supply is known to be very low in sulphur.

Table 7.7-2
Summary Results of Ambient Pollutant Gases and Noise Levels obtained at the Compressor Site (Feb, 2003).

S/NO	Day	Sampling Station	Parameters (8-hr mean daily values)						
			THC (ppm)	Methane (ppm)	CO (ppm)	NO_2 (ppm)	PM_{10} (mg/m^3)	TSP (mg/m^3)	Noise (dB)
1.	1	AQS1	0.001	0.000	0.000	0.000	0.059	0.125	27.750
2.		AQS2	0.001	0.000	0.000	0.000	0.017	0.118	28.000
3.		AQS3	0.000	0.000	0.000	0.000	0.018	0.050	27.125
4.	2	AQS1	0.001	0.000	0.003	0.001	0.011	0.045	27.750
5.		AQS2	0.001	0.000	0.000	0.000	0.014	0.090	29.750
6.		AQS3	0.000	0.000	0.000	0.000	0.024	0.039	29.000
7.	3	AQS1	0.000	0.000	0.003	0.000	0.005	0.011	29.500
8.		AQS2	0.000	0.000	0.002	0.000	0.004	0.013	28.250
9.		AQS3	0.000	0.000	0.006	0.001	0.033	0.070	29.250
10.	4	AQS1	0.000	0.000	0.002	0.000	0.080	0.064	29.250
11.		AQS2	0.001	0.000	0.005	0.000	0.034	0.068	29.250
12.		AQS3	0.000	0.000	0.009	0.001	0.036	0.088	29.250
13.	5	AQS1	0.000	0.000	0.002	0.000	0.041	0.089	28.250
14.		AQS2	0.000	0.000	0.001	0.000	0.044	0.083	28.625
15.		AQS3	0.000	0.000	0.004	0.001	0.043	0.104	30.750

Figure 7.7-1
Overall Mean Values of Pollutant Gases and Noise Levels obtained at the Compressor Site.



Generally, obtained results indicate that the investigated parameters exist at background levels in the compressor station site area, at the time of study. For example, methane (atropospheric ozone-depletion precursor) concentrations were not detected above the equipment detection limits of 0.0001ppm while hydrocarbons and nitrogen dioxide both recorded an overall mean value of 0.0003ppm each. Carbon monoxide concentrations had overall mean value of 0.002ppm. For Particulates, Total Suspended Particles (TSP) and inhalable particles (PM_{10}[1]) recorded overall mean values of 0.03mg/m^3 and 0.07mg/m^3 respectively at the time of study while noise levels averaged 28.78 decibels.

These values do not indicate any form of pollution of the ambient air at the compressor station during the period of this study. The impact of vehicular emissions on the obtained results is minimal since traffic density at the time of study was very low as very few vehicles were plying the road by the compressor station. The concentration levels obtained for the investigated parameters are therefore likely to be from natural sources.

[1] Inhalable particulates are generally regarded as those particles with a size of 10 microns or less.

CHAPTER 8
PROGRAM AND DATA QUALITY OBJECTIVES

This section evaluates the type, quality, and quantity of EBS data to determine whether program objectives identified in Section 1.1 were met. This was done through an evaluation of the study design, including variability, sampling density and replication. Data quality and adherence to quality control objectives are also discussed.

8.1 EVALUATION OF STUDY DESIGN

8.1.1 Within Station Variability

During the offshore survey, replicate sediment samples were collected at five locations: G04, G12, T04, B03, and N04. The samples were analyzed in duplicate as an assessment of field variability (within stations) as well as laboratory precision. The results of the analysis for metals indicates generally low variability (<30% relative percent difference - RPD) for many key elements: Pb, Fe, Mg, Cr, Ni, Cu, V. Some higher than desired variability was observed in others, such as Hg and Zn. Upon review, this was determined to be due to interference in the laboratory analysis and not to within station variability. Review of a limited number of results for physicochemical parameters and organic parameters (hydrocarbons) indicated generally low within station variability.

Replicate water samples were also collected at select stations. A summary of the water quality results is included as Table 8.1-2. Variability was generally low for these parameters with the exception of total nitrogen and total phosphorus which both exhibited higher RPD likely due to the analysis technique used (a field test kit). Spurious high RPD values were also reported. Replicate results for metals were in good agreement (Appendix A) with the exception of iron (Fe), which showed relatively high variability.

For analysis of offshore sediment samples for biological parameters, replicate samples were collected at each station. In the case of the main pipeline, two replicates per station were collected; for the laterals, four replicate samples were collected. As a screening measure, the three images from each center station were closely inspected to see if there was within-station variance. The results of this were used to designate stations where benthic replicate samples should be analyzed to better characterize the location. This analysis involved assessment to determine if the following parameters were similar:

1. Grain size major mode similar? (yes or no)

2. RPD depth similar (within 0.5 cm)? (yes or no)

3. Infaunal successional stage similar? (yes or no)

The results of this screening were used to designate eight locations for additional replicates analysis. In other words, variation was sufficiently low at 84 percent of the sample stations.

Table 8.1-1
Summary of Metals Results for Field Duplicates

		Comparison of Field Duplicates (Relative Percent Difference)										
Numéro de l'échantillon	Date de prélèvement	Plomb Pb %RPD	Fer Fe %RPD	Magnésium Mg %RPD	Cadmium Cd %RPD	Chrome Cr %RPD	Nickel Ni %RPD	Aluminum Al %RPD	Cuivre Cu %RPD	Mercure Hg %RPD	Vanadium V %RPD	Zinc Zn %RPD
G12CSed	12/12/2002	14%	31%	19%	NC(2)	29%	32%	158%	16%	NC(1)	NC(2)	154%
B03CSed	12/11/2002	NC(2)	13%	33%	NC(2)	24%	NC(2)	19%	NC(1)	119%	NC(2)	10%
T04CSed	12/10/2002	7%	9%	8%	NC(2)	0%	9%	30%	10%	NC(1)	22%	34%
N04CSed	12/13/2002	4%	1%	2%	NC(2)	6%	6%	53%	9%	NC(2)	0%	137%
G04CSed01	12/10/2002	3%	21%	3%	NC(2)	NC(1)	13%	36%	12%	NC(2)	22%	26%

Table 8.1-2
Summary of Water Quality Results for Field Duplicates

		Relative Percent Difference									
CODE	QC Code	Sulfate (mg/L)	Alkalinity (ppm)	COD (mg/L)	Ammonia Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)	Calcium (ppm)	Potassium (ppm)	Magnesium (ppm)	Sodium (ppm)
B03cwat 01	D	2%	0%	11%	67%	75%	195%	5%	12%	4%	6%
B03cwat 02	D	0%	0%	3%	0%	73%	NC	2%	1%	1%	0%
G02cwat 01	D	0%	7%	4%	50%	25%	NC	28%	3%	2%	4%
G02cwat 02	D	2%	0%	4%	0%	0%	18%	7%	7%	3%	1%
G03cwat 01	S	0%	7%	10%	NC	0%	NC	58%	10%	21%	7%
G03cwat 02	S	2%	7%	28%	NC	13%	NC	6%	4%	3%	3%
G13cwat 01	D	5%	0%	7%	22%	15%	29%	101%	18%	4%	9%
G13cwat 02	D	2%	0%	15%	120%	40%	29%	1%	1%	0%	0%
N04cwat 01	D	5%	7%	20%	86%	15%	188%	2%	7%	15%	0%
N04cwat 02	D	9%	0%	3%	67%	15%	25%	42%	32%	13%	2%
T04cwat 01	D	5%	7%	3%	NC	15%	50%	16%	170%	11%	6%
T04cwat 02	D	4%	0%	3%	0%	31%	NC	3%	2%	2%	0%
Average %RPD		**3%**	**3%**	**9%**	**46%**	**27%**	**76%**	**23%**	**22%**	**7%**	**3%**

8.1.2 Overall Variability

The sampling plan design included assessment of stations along the main route of the proposed pipeline (center stations) and of stations 1km to each side of the center station (side stations). The SPI camera collected images at each of the stations (center and two sides) and the results were used to determine whether the grab samples that were taken at the center station were representative of the larger area in the vicinity of the route. If the grab samples, as indicated by SPI, were not representative, then additional grab samples were collected and analyzed at that side stations. This screening was conducted during the offshore survey and resulted in identification of five additional sediment grabs. In other words, 90% of the center stations were determined to be representative of the local area. This percentage implies low overall local variability.

8.1.3 Quality Assurance and Quality Control

Laboratory Audits

Laboratories and organizations participating in the data acquisition for the EBS were audited before the onset of the field work and during the final stages of the laboratory and report preparation period. These initial audits were conducted in Fall 2002 on-site using a standardized checklist which guided review of the laboratory's systems for:

- Sample custody and tracking mechanisms
- Facilities and equipment
- Staff capabilities and experience
- Analytical capabilities and procedures
- Sample preparation procedures
- Weekly capacity for preparation and analysis of inorganic and organic parameters
- QA/QC procedures
- Document control and chain-of-custody systems
- Data management
- Data package preparation
- Recent results of performance evaluation samples

Audits conducted during the period when laboratory work was being completed (April 2003) were also conducted on-site but were focused on more specific review of the work conducted on behalf of the project. As such, bench records, documentation, and final data were reviewed for completeness and accuracy. Sample storage and custody procedures were also reviewed.

Participating laboratories were determined to have conducted the work in accordance with the project instructions and data quality objectives. Select instances where deficiencies were noted were followed-up with plans for either immediate or long term corrective action.

Quality Control

Participating laboratories were required to have implemented and maintained a system which included quality control samples that are required by the respective reference methods. That this was followed and documented was verified during on-site laboratory audits. Any quality control data that was reported by the participating laboratories is included in the respective appendices.

Field Blanks and Equipment Blanks

Field blanks and equipment blanks were analyzed for a variety of parameters and the results are included in the report appendix. No abnormal levels of targeted parameters were identified.

8.2 METHOD COMPARISONS, VERIFICATION, CONFIRMATION

Both West African and United States analytical laboratories analyzed a select number of samples from the offshore environment. This was done primarily as a quality assurance measure but also to fulfill a secondary objective of the EBS to exchange scientific expertise between the participating scientists and organizations with the goal of building in-region capabilities and capacity.

8.2.1 Comparisons

Analytical results for samples collected during the offshore survey were compared internally for consistency and against that which would be expected in the marine environment using independent data sources. This did not involve a statistical evaluation. This analysis indicated that values for PAH and aliphatic components in sediment sample may be reported as false positive as discussed in the respective results section. It also indicated that mercury results might be influenced and biased high due to method interferences. This is also discussed in the respective results sections.

8.2.2 Independent Verification

At two offshore stations, replicate samples were collected for independent analysis by a Ghanian laboratory as verification of analyses conducted by other participating organizations. The full results were not available at the time of this report.

8.2.3 Confirmatory Analyses

Both West African and United States analytical laboratories analyzed a select number of sediment samples from the offshore environment. This was done primarily as a quality assurance measure but also to fulfill a secondary objective of the EBS to exchange scientific expertise between the participating scientists and organizations with the goal of building in region capabilities and capacity. Results of these analyses are included in Appendix A. The comparison of the actual data is discussed in the respective report sections (Offshore Sediment Chemistry). With respect to in-region capacity building, the result of this process is the identification of the need for broader confirmatory analysis in future rounds of baseline data collection as method interferences were readily identified. In addition, it revealed a need to conduct further method-specific capability development in-region, in particular in methods for determining trace levels of contaminants in marine sediments.

CHAPTER 9
REFERENCES, ACRONYMS AND AUTHORS

9.1 REFERENCES

Adam, K. S (1986) Man's impact on the geomorphological evolution of the coastal plain in the Gulf of Benin. *in* Thalassas, University of Santiago, Spain.

Adam, K. S. & N. Devine (1993) Quantification of risk to Benin from an Accelerated Sea Level Rise. International Sea-Level Rise Studies Project, Rutgers University New Jersey, USA.

Adam, K. S. (1991) The Gulf of Benin: Present environment and future Sea-Level Rise. International SLR Studies Project. Institute of Marine and Coastal Sciences. The State University of New Jersey. USA.

Adam, K. S. (1996) Towards Integrated Coastal Zone Management in the Gulf of Guinea / Vers une gestionn intégrée de la zone côtière dans lle Golfe de Guinée, Editions du Flamboyant. 200 pp.

Adejuwon (1974)

Adeniyi (1991)

Adité A. (2002) Diversity and management of mangrove fishes in the coastal zone. Research Project Funded by the International Foundation for Science (IFS) under Research Grant IFS No. A/2913-1.

Adjakidjè V. (1984) Contribution à l'étude botanique des savanes guinéennes de la République Populaire du Bénin. Thèse 3ème Cycle. Univ. Bordeaux III. 301 p.

Adjakpa, J. B. (1999) Etude de la faune aviaire des zones humides du Bénin: Inventaire faunique, habitats et cycles migratoires. CEROE/CPU Benin.

Adjakpa, J. B., Coubeou, Th. P., Hagemeijer, J. M. W. (1996) Inventaire de la faune aviaire des zones humides du Sud-Bénin. PAZH, Ambassade Royale des Pays Bas, Cotonou, 70 pp.

Adjakpa, J. B., Tchabi, A. & Ogouvide, F. T. (2002) Oiseaux utilisés en pharmacopée traditionnelle au Bénin. Malimbus 24:1-24.

Adjanohoun E. (1965) Comparaison entre les savanes côtières de la Côte d'Ivoire et du Dahomey. Ann. Univ. Abidjan, t.1, pp. 1-60.

Adjanohoun E. (1966) Existence au Dahomey de savanes côtières analogues à celle de la Côte d'Ivoire. Etude Dahoméenne, 6-7, pp. 48-7.

Adjanohoun E. (1968) Le Dahomey. (Cons. Vég. Afr. South of the Sahara, Symp. AET FAT, Acta phyt. Suecica, 54:86-91.

Adokpo S., Fanou T. (1992) Rapport sur l'inventaire et l'analyse de la législation environnementale au Bénin. MEHU, 1992, Cotonou, 108 pp.

Adomeko and Armale (1981)

Afoakwa, S.N., Agbodaze, D. and Abrahams, C.A. (1988) Microbiological quality of the coastal waters of Ghana: a bacteriological appraisal. Accra: GNC/IOC Seminar on the Conservation and Utilisation of Marine Resources.

Agassounon L. C. (2002) Evolution pédosédimentaire du géosystème margino-littoral de l'Ouémé-Sô au cours de l'holocène (Bénin-Afrique de l'Ouest) Thèse de Doctorat en Sciences de la Terre et de l'Environnement. 425 pp.

Agbo-zegue (2002)

Ajaji (1994) The Status of marine Fishery Resources of the Gulf of Guinea: In: Proc. 10th Session FAO, CECAF, Accra, Ghana, 10-13 October.

Ajavon A. L (2000) . Stratégie nationale de la lutte contre la pollution atmosphérique en République du Bénin. MEHU, 70 pp.

Ajavon A. L., Amegankpoé A. (1998) Contribution à l'évaluation de la pollution de l'air à Cotonou.

Akintola (1986)

Akoègninou A. (1984) Contribution à l'étude botanique des îlots de forêts denses humides semi-décidues en République Populaire du Bénin. Thèse 3ème cycle. Univ. Bordeaux III. 250 pp.

Akoègninou A. (1999) Rapport final des travaux du groupe Mangrove Bénin. 34 pp.

Akoègninou A., Oyede L. M. & Toffi M. (1993) La mangrove du Benin: Environment physique, vegetation, et essais de gestion. Document technique no2. FAST-UNB.

Akpagana, K. & Bouchet, P. (1997) Les espèces en voie de disparition et leur utilisation en thérapeutique. In Les phytomédicaments éthiques. Les Presses de l'UB, pp. 63-70.

Akpagana, K. (1992) Quelques espèces rares ou menacées de disparition sur le cordon littoral du Togo. ral. Ann. Univ. Bénin Togo, sect. sci., 10, p. 33-36.

Akpati, B. N. (1975) Source and dispersal of Holocene sediments on the continental shelf of Ghana, West Africa., p.44. Accra: Research report of UNESCO. Contract SC/RP600.874.

Akpiti S., Clauer, N., Houessou A., Lang J. and Tisserand D. (1985) Datation isotopique K-Ar d'un niveau de sable glauconieux à la limite Paléocène- Eocène dans le bassin côtier béninois (Afrique de l'Ouest) Journal of African Earth Sciences. 3(4): 487-490.

Alassane M. A., (2000) .Contribution à l'étude hydrochimique de l'aquifère du Continental Terminal du plateau de Sakété dans le bassin sédimentaire côtier du Bénin. Mémoire de DEA. UCAD. Dakar, Sénégal.

Albatet J-J & Diouf P. S. (1994) Diversité des poissons des lagunes et des estuaires Ouest-africains. Ann. Mus. r. Afr. Centr. Zool. 275: 165-177.

Alidou S. et Oyede L. M. (1984) Quaternaire du Bénin. ASEQUA, Bull. Liaison, no. 72-73, 42-43. Dakar.

Alidou S., Boukari M., Oyede L. M., Gaye C. B., Faye A., Gelinas P., Isabel D. et Locat J., (1994) Rapport technique final du projet "hydrogéologie du Quaternaire du Sud-Bénin", phase 2. CRDI 3-P-89-1017. Tomes I, II, III et IV. Univ. Nat. Bénin, Univ. CA. Diop, Dakar, Univ. Laval Québec.

Allen and Wells (1962)

Allersma, E. and Tilmans, W. M. K. (1993) Coastal conditions in West Africa: a review. Ocean and Coastal Management 19, p. 199-240.

Amusan and Ashaye (1989)

Anderson, D.M., Anderson, P., Bricelj, V.M., Cullen, J.J. and Rensel, J.E. (2001) Monitoring and management strategies for harmful algal blooms in coastal waters, APEC #201 – MR-01.1, Asia Pacific Economic Program, Singapore, and Intergovernmental Oceanographic Commission Technical Series No. 59, Paris.

Aravomo (1991)

Archambault J. (1953) Les eaux souterraines de l'Afrique Occidentale, BURGEAP-BCEOM, Paris.

Archambault J. (1960) . Etudes hydrogéologiques pour l'alimentation en eau des divers centres urbains du Dahomey. BURGEAP, Paris.

Armah, A. K. and Amlalo, D. S. (1998) Coastal zone profile of Ghana. In Gulf of Guinea Large Marine Ecosystem Project, pp. vii + 111. Accra: Ministry of Environment, Science and Technology.

Armah, A.K., Darpaah, G.A., Wiafe, G., Adomako, J.K. and Fiagbedzi, S. (1997a) Save sea turtles: a primer on sea turtle conservation for coastal communities in Ghana. Accra: Royal Crown Press Ltd.

Armah, A.K., Darpaah, G.A., Wiafe, G., Adomako, J.K., Quartey, S.Q., Abotchie, C., Ansah, F. and Fiagbedzi, S. (1997b) Traditional and modern perspectives of marine turtle conservation in Ghana. In Biodiversity Conservation: traditional knowledge and modern concepts. (ed. Amlalo D.S., L. D. Atsiatorme and C. Fiati), EPA/MAB/UNESCO, pp. 80-87.

Ashaye (1967)

Association de Climatologie du Québec (1997) Les défis des changements environnementaux à l'échelle planétaire. Actes du colloque du 63 ème congrès de l'ACFAS, Québec, 212 pp.

Asubre (1993)

Awosika, L.F., and Ibe, A.C. (1994) Geomorphic features of the Gulf of Guinea shelf and littoral drift dynamics. In Proc. International symposium on the results of the first IOCEA cruise in the Gulf of Guinea, May 1994, p. 17-20.

Awosika, L.F., Ibe, A.C., and Ibe, C.E. (1993) Anthropogenic Activities affecting sediment load balance along the West Africa Coastline. In Coastlines of western Africa, Coastlines of the world series. Pub. American Society of Civil Engineers N.Y., 1993, pp. 26-35.

Azontonde A. (2000) Dynamique de la matière organique et de l'azote dans le système Mucuna-Maïs sur un sol ferralitique (terre de barre) au Sud-Bénin. Thèse de Doctorat ENSAM-Université de Montpellier, Montpellier, 235 pp.

Baba-Moussa A. (1994) Etude de la pollution bactériologique de la nappe phréatique à partir d'une latrine en Afrique subtropicale. Thèse de Doctorat ès Sciences Techniques. Ecole Polytechnique Fédérale de Lausane.EPFL. 252 pp.

Badejo (1990)

Badejo (1999)

Badejo M.A. and Lasebikan, B.A (1988) Comparative studies of the acarine populations of a secondary regrowth forest and a cassava plantation in Ile-Ife, Nigeria. Pedobiologia, 32:111-116.

Badejo, M.A. (1998) Introduction to the General Classification of Crustaceans of Wetlands, Freshwaters and Coastal Regions in Nigeria. College Press, Ibadan & Enproct Consultants Lagos. 45pp. Badejo.

Badejo, M.A., Tian, G., and Okoh, I.O. (in press) Litter transformers as ecosystem engineers in sustainable agroecosystems. In: Badejo M.A. and Togun A.O. (eds) Strategies and Tactics of Sustainable Agriculture in the tropics. Volume 2. College Press & Enproct Consultants.

Bainbridge, V. (1972) The zooplankton of the Gulf of Guinea. Bulletin of Marine Ecology 8:61-97.

Baize D. et Girard, M.-C. (1995) Référence pédologique. AFES, Paris, 332 pp.

Bassindale, R. (1961) On the marine fauna of Ghana. Proceedings of the Zoological Society of London 137, pp. 481-510.

Batawila, K., (1997) Recherches sur les formations dégradées et jachères de la plaine côtière du sud Togo. Mém. DEA. Biol. Dév. Univ. Lomé. 65 pp.

Belfield (1956)

BURGEAP (1985) Préparation d'un programme d'hydraulique villageoise dans lesprovinces de l'Atlantique et de l'Ouémé. DH. Cotonou Bénin.

Benner, B. A., Gordon, G. E. and Wise, S.A. (1989) Mobile sources of atmospheric polycyclic aromatic hydrocarbons: a roadway tunnel study, Environ Sci Technol., 23:1269-1278.

Bernacsek, G. M. (1986) Profile of the Marine Resources of Ghana. CECAF/TECH/86/71. CECAF Program. FAO, Dakar, Senegal.

Bijker E. W., Radu, M. (1981) Sur l'application de l'analogie entre l'équation de la chaleur et celle développée par Pelnard-Considère à l'étude d'un littoral. XIX ème Congrès AIHR New Delhi, India.

Binet, D., Marchal, E. and Pezennec, O. (1991) Sardinella aurita de Cote d'Ivoire et du Ghana: fluctuations halientiques et changements climatiques. In Pecheries Ouest Africaines: varibilite, instabilite et changement. (ed. P. Cury and C. Roy) ORSTOM.

Biney, C.A. (1986) The state of pollution of the west and central African marine environment: aspects of the Ghanaian situation., 24pp. Accra: Institute of Aquatic Biology.

BOAD (2001) Etude sur l'impact du transport urbain par les véhicules à deux roues et perspectives de développement dans les pays de l'UEMOA (Bénin, Niger, Togo) Rapport de synthèse provisoire.

BOAD. (2001) :. Etude sur l'impact du transport urbain par les véhicules à deux roues et perspectives de développement dans les pays de l'UEMOA (bénin, Niger, Togo) Rapport de synthèse provisoire.

Boko M. (1975) . La plaine côtière du Dahomey à l'Ouest de Cotonou. Thèse de Doctorat de 3ème cycle. Géographie tropicale. Univ. de Dijon, 225 p.

Boko M. (1975) La plaine côtière du Dahomey à l'Ouest de Cotonou. Thèse de Doctorat de 3ème cycle. Géographie tropicale. Univ. de Dijon, 225 pp.

Bokonon-Ganta E. (1987) Les climats de la région du Golfe du Bénin. Thèse de 3ème cycle. Univ. de Paris IV. Sorbone. 248 pp.

Boukari Boukari M., (1998) . Fonctionnement du système aquifère exploité pour l'approvisionnement en eau de la ville de Cotonou sur le littoral béninois. Impact du développement urbain sur la qualité des ressources. Thése de Doctorat d'Etat ès Sciences. UCAD. Dakar, Sénégal.

Boukari M., (1984) Rapport de synthèse sur les connaissances géologiques et hydrogéologiques du bassin sédimentaire côtier de la République Populaire du Bénin. Université Nationale du Bénin. FAST, Cotonou. Bénin.

Boukari M., (1996) Caractérisation hydrodynamique et hydrochimique du système aquifère du panneau d'Allada dans le bassin sédimentaire côtier du Bénin. Africa Groundwater Resources '96. Résumé. 7.

Boukari M., Alidou S., Oyede L,. M. Gaye C.B, et Maliki R., (1995) Identification des aquifères de la zone littorale du Bénin (Afrique de l'Ouest) hyrdynamique, hydrochimie et problèmes d'alimentation en eau de la ville de Cotonou. African Geoscience Review, Paris France. Vol. 2(1):139-157.

Boukari M., Gaye C. B., Faye A. et Faye S., (1996) The impact of urban development on coastal aquifers near Cotonou, Benin. Journal of African Earth Sciences. 22(4)

Bourgeois M. (1978) Carte de planification des ressources en eau: Côte-d'Ivoire, Ghana, Togo et Bénin. CIEH, Ouagadougou, Burkina Faso.

Bourrelly P. (1981) Les Algues d'eau douce: Initiation à la systématique Tome II Les Algues jaunes et brunes. 517 pp.

Bourrelly P. (1985) Les Algues d'eau douce: Initiation à la systématique Tome III: Les Algues bleues et rouges. 606 pp.

Bourrelly P. (1990) Les Algues d'eau douce: Initiation à la systématique Tome I: Les Algues Vertes. 572 pp.

Bouzid M. (1967) Données hydrogéologiques sur le bassin sédimentaire côtier du Dahomey. Projet DAH3, FAO, Rome.

Bowessidjaou E. J., Fretey J., Formia A., Segniagbeto H., (2002) Observations biométriques et ethnozoologies préliminaires sur les tortues marines au Togo, 2e journées scientifiques internationales de l'Université de Lomé, 6 pp. (non-publié)

Brl/gersar-Beture (1995) Alimentation en eau potable: Plan d'investissementdans les villes de Cotonou, Porto-Novo et Djougou ; Tome 1: Cotonou. SBEE. Cotonou.

Brunel, J.F., Scholz, H. & Hiepko, P. (1984) Flore analytique du TOGO. Phanérogames. GTZ, Eschorn, 751 pp.

Buchanan JB and Anderson M.M. (1955) Additional records to the marine molluscan fauna of the Gold Coast. J.West Afr..Sci. Ass. 3(2):10-11.

Buchanan, J.B. (1957) Benthic fauna of the continental edge off Accra, Ghana. Nature 179:634-635.

Buchanan, J.B. (1958) The bottom fauna communities across the continental shelf off Accra, Ghana (Gold Coast) Proceedings of the Zoological Society of London 130(Part 1):1-56.

BURGEAP- GEOHYDRAULIQUE, (1988) Projet d'hydraulique villageoise BOAD-Atlantique. DH, Cotonou, Bénin. Paris, France.

Burton M., (1978) Reptiles et amphibiens . Edition Atlas S.a.r.l ; Paris. pp 44-45.

Butcher et al. (1971)

Calamari & Naere (1994)

Chapman, P. J., Edwards, A.C., Reynolds, B., Cresser, M.S. and Neal, C. (1998) The nitrogen content of rivers in upland Britain: The significance of organic nitrogen. Hydrology, Water Resources and Ecology in Headwaters. 248:443-450.

Cheke R. A. & Walsh J.F.. (1996) The birds of Togo. British Ornithologists Union, BOU Check List No. 14. pp.63-80.

Chelboldaeff M. et Trichet J. (1990) The Continental Terminal in West Africa. Journal of African Earth Sciences, 10(1/2):79-99.

Chippaux J.P. (2001) Les serpents d'Afrique Occidentale et Centrale. Edition de l'IRD (Ex ORSTOM) 292 p.

Church Harrison, R.J. (1980) West Africa. London, Longman.

Clarke, K. R., and R. M. Warwick. (1994) Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Plymouth Marine Laboratory, Plymouth.

Clason, E.W.H., Tellegen, B.D.H., Friijlink, H.C., Thijsse, J.Th., Jansen, P.Ph., and Schijf, J.B. (1954) Report on the Western Niger Delta by the Netherlands Engineering Consultants to the Government of Nigeria.Lagos: The Hague; NEDECO. 143 pp.

CMS/CMS. Technical Series Publication No. 5. Abidjan-Côte d'Ivoire, Mai (1999) Mesures de conservation pour les Tortues Marines de la côte atlantique de l'Afrique.

Colleuil B. (1984) Un modèle d'environnement lagunaire soumis aux conditions de climat équatorial tempéré: le lac Nokoué (République Populaire du Bénin) Thèse de l'Univ. de Bordeaux 1. no.158, 135 pp.

Colombani, (1967) Premiers résultats des mesures de qualité de l'eau au Togo et au Dahomey. Cahiers ORSTOM. Série hydrologie (Fr.), 4(2):3-25.

Crosnier and Berritt (1966)

Darboux-Afouda R., Locat J. et Gelinas P. (1997) Localisation géoélectrique des biseaux salés dans la région côtière au Bénin: Exemple de terrain. Bulletin de l'Assoc. Intern. De Géol. De l'Ingénieur. 55:83-97.

Day, J. H. (1967) A Monograph on the Polychaete of Southern Africa. Part 1 & 2. Errantia & Sedentaria. Trustees of the British Museum (Natural History), London.

de Baize & Girard (1995)

De Foucault, B., Akpagana, K., Batawila, K. et Bouchet, P. (2000) Contribution à une étude phytosociologique du littoral sableux du Togo. Acta Bot. Gallica. 147(4):333-344.

DFC Togo/OMPO (2002) Suivi des oiseaux migrateurs et des oiseaux d'eau du Togo, cahier de la formation Lomé (Togo).

DFC(MERF)/ DEP(MAEP) PNUE/CMS. Marine Education Research, Projet WAFCET-3 GHANA-TOGO, Etude d'exploitation, de distribution et d'histoire naturelle des cétacés au Togo.

DFC/MERF, (2002) Les zones humides les plus importantes du Togo. Rapport provisoire.

DFC/OMPO (2001)

Direction de l'Environnement/MEHU (2001) Communication nationale initiale du Bénin, Cotonou, 92 pp.

Dorst J., (1985) Qui mange qui, la lutte pour la vie dans le monde animal. p. 639.

Dossou-Bodrenou, J., Hoekert,W.E.J., Fretey. (2000) Atelier international de formation sur les techniques de conservation des tortues marines et évaluation du programme de sauvegarde des tortues marines au Bénin. Rapport intérimaire No. 2, p. 8.

Doty & Oguni (1957)

DPR (2002)

Durand J. R. & Levêque C. (1980) Flore et faune aquatique de l'Afrique sahélo-soudanienne. Ed. de l'ORSTOM. Paris, 389 pp.

Dussart (1996)

Dussart B. (1966) Limnologie. Etude des eaux continentales. Géologie – Ecologie – Aménagement. Paris, 676 pp.

Edmunds, J. (1978) Sea shells and other mollusks found on West African Coast and Estuaries. Ghana Universities Press. 164 pp.

Edwards, R.A., Whitmarsh, R.B., and Scrutton, R.A. (1997) Synthesis of the crustal structure of the transform continental margin off Ghana, northern Gulf of Guinea. Geophysical Marine Letters 17:12-20.

Ekundayo (1977)

Elgood et al. (1994)

Elster (1965)

Ern, H. (1979) Die Vegetation Togos. Gliederrung, Gefährdung, Erhaltung. Willdenowia 9:295-312.

Evans, S.M., Gill, M.E., Hardy, F.G., and Seku, F.O.K. (1993) Evidence of change in some rocky shore communities on the coast of Ghana. Journal of Experimental Marine Biology and Ecology 172:129-141.

Faggianelli J.D., Faggianelli E. (1984) Pêche maritime artisanale au Togo: Caractéristiques générales et résultats statistiques pour la saison p. 80.

Fiogbe (2000)

Fischer et al. (1981)

FishBase (2000)

Fontaine, B., Janicot, S., and Roucou, P. (1999) Coupled ocean-atmosphere surface variability and its climate in the tropical Atlantic region. Climate Dynamics 15:451-473.

Foster, S., Huettle, M. and Ziebis, W. (1996) Impact of boundary layer flow velocity on oxygen utilisation in coastal sediments. Marine Ecology Progress Series. 143:173-185.

Fretey J. (1998) Marine Turtles of the Atlantic Coast of Africa / Tortues Marines de la façade Atlantique de l'Afrique. UNEP Technical Publication No. 1.

Fretey J. (2001) Biogeography and conservation of marines turtles of the Altlantic coast of Africa / Biogéographie et conservation des tortues marines de la cote Atlantique de l'Afrique. CMS Technical Série Publication No. 6 pp. 209-207.

Gaillard M. et M., Lang J. et Lucas J. (1982) Etude des milieux de mangrove du Bénin occidental (Afrique de l'Ouest) Océanologica Acta. no. sp., 129-137

Garzoli, S.L. and Katz, E.J. (1983) The forced annual reversal of the Atlantic North Equatorial Counter Current. Journal of Physical Oceanography 13:2082.

Gbaguidi & Pfeiffer (1998)

GEOHYDRAULIQUE. (1985) Note explicative de la carte hydrogéologique à 1/200 000 du bassin sédimentaire côtier du Bénin. MET. DH. FED. 23 pp.

GEOHYDRAULIQUE-BURGEAP (1988) Projet d' hydraulique villageoise BOAD: Provinces de l'Atlantique et du Sud du Zou, Rapport final.DH, Cotonou, Bénin.

GIGG ou IGIP - GKW- GRAS (1989) Plans directeurs et étude d'ingénierie pour l'alimentation en eau potable et l'évacuation des eaux pluviales, des eaux usées et déchets solides. Ville de Cotonou. SBEE. Cotonou, Bénin. 90 pp.

GIGG ou IGIP-GKW-GRAS (1983) Plan directeur alimentation en eau potable ville de Cotonou. Les ressources en eau. Ministère de l'Industrie des Mines et de l'Energie- SBEE. Vol. 2 .

GIGG ou IGIP-GKW-GRAS (1987) Plans directeurs et étude d'ingénierie pour l'alimentation en eau potable et évacuation des eaux pluviales, des eaux usées et des déchets solides, ville de Cotonou. Tome 1, les ressources en eau.

Girard O. (1998) Echassiers, Canards et limicoles de l'Ouest-africain. p. 136.

Gnaha E.F.C. & Adjadji Ch. A. (2001) Evolution quantitative et qualitative des eaux souterraines captées dans le périmètre de pompage intensif de Godomey: impact sur l'approvisionnement en eau potable de l'agglomération de Cotonou . UAC ; Cotonou. Bénin.

Guedegge B. (1999) Programme de Gestion de la faune non aviaire dans les zones humides du littoral du Bénin. Rapport provisoire-PAZH, 39 p.

Guendéhou S. (2001) Résultats des inventaires des gaz à effet de serre au Bénin. In actes de l'atelier des journées de restitution de l'atelier régional sur les inventaires des gaz à effet de serre, Accra. 11 pp.

Guilcher A. (1959) La région côtière du bas-Dahomey occidental. Bull. IFAN, XXI (3/4), pp. 357-424.

Guinko S. (1974) Contribution à l'étude des savanes marécageuses du Bas-Dahomey. Thèse 3ème cycle, Fac. Sc. Abidjan, p. 142.

HACEMEIJER, W., POOT, M. & ADJAKPA, J. B. 2000. Suivi des oiseaux d'eau dans les zones humides du Sud-Bénin 1996-1997, CEROE & SOVON, 70 pp.

Halliday I. A., & Young W.R. 1996. Density, biomass and species composition of fish in a subtropical Rhizophora stylosa Mangrove forest. Mar. Freshwater Res., 47:609-15.

Hansel (1965)

Harris, G.P. (1986) Phytoplankton ecology: structure, function, and fluctuation, p. ix, 384. New York: Chapman and Hall.

Hill, M.B. and Webb, J.E. (1958a) The Ecology of Lagos lagoon. 1.The lagoon of the Guinea coast. Philosophical transactions of the Royal Society of London. 241:308-319.

Hill, M.B. and Webb, J.E. (1958b) The ecology of Lagos Lagoon, topography and physical features of Lagos Harbour and the Lagos lagoon. Phil. Trans. Roy. Soc. London. Ser. B. 241:319-333.

Houghton, R.W. (1983) Seasonal variations of the subsurface thermal structure in the Gulf of Guinea. Journal of Physical Oceanography 13:2070-2081.

Houndénou C. (1999) Variabilité climatique et maïsiculture en milieu tropical humide. Thèse pour le Doctorat d'Université: Option géographie Spécialité: Climatologie. Centre de Recherches de Climatologie. UMR 5080 du CNRS « Climatologie de l'Espace Tropical ». Université de Bourgogne, Dijon, 390 pp.

Houndénou C. et ABE (2002) Tableau de bord du kiosque informations et produits du SISEI-Bénin: indicateurs environnementaux et statistiques (compendia) ABE pour l'environnement, 236 pp.

Huettel, M., W. Ziebis, and S. Forster. (1996) Flow-induced uptake of particulate matter in permeable sediments. Limnol. Oceanogr. 41:309-322.

Hutchinson, J. and Dalziel, L.M (1954-1972) Flora of West Tropical Africa. 2nd ed., revised by Keay and Hepper, 3 vol.

Ibadan (1979)

ICF (2003a) Benin Preliminary Draft West African Gas Pipeline Environmental Impact Assessment Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by the Centre pour l'Environnement, le Dèveloppement et l'Amènagement durables, CEDA Consult (Benin) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.0.

ICF (2003b) Ghana Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Environmental Solutions (ESL), LTD (Ghana) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

ICF (2003c) Nigeria Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Environmental Resources Managers Limited (ERML, Nigeria) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

ICF (2003d) Regional Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Adote Blivi, University de Lome (Togo); Centre pour l'Environnement, le Dèveloppement et l'Amènagement durables, CEDA Consult (Benin); Environmental Resources Managers Limited (ERML, Nigeria); Environmental Solutions (ESL), LTD (Ghana); and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

ICF (2003e) Togo Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Adote Blivi, University de Lome (Togo) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

IGIP (1984) Adduction d'eau dans 13 chefs-lieux de district. Ministère de l'Industrie des Mines et de l'Energie - SBEE Rapport de fin de travaux.

IGIP (1987) Rapport final sur les forages F8 et F19 à Godomey et le forage FAC à Abomey-Calavi. SBEE.

Ihenyen, A.E. (1998) Appraisal of heavy metal concentrations in bottom sediments of the Gulf of Guinea. In Nearshore dynamics and sedimentology of the Gulf of Guinea (ed. Ibe, A.C., Awosika, L.F. and Aka, A.), p. 93-98. Cotonou: IOC-UNESCO/UNIDO.

Imevbore, A. et al. (1993) Environmental Impact Assessment of the Activities of Shell Petroleum Development Company Ltd. in the South Forcados Development Area. Institute of Ecology, Obafemi Awolowo University, Ile-Ife, Nigeria.

INSAE. (2000) Résultats provisoires du recensement de la population et de l’habitat.

IRB, (1987) Etude de cartographie géologique et prospection minièrede reconnaissance au Sud du 9ème parallèle. Rap. Istituto Recerche Breda. FED- OBEMINES. 80 pp.

Iverson (1972)

Janicot S. (1990) Variabilité des précipitations en Afrique de l’ouest et circulations quasi-stationnaires durant une phase de transition climatique. Thèse de Doctorat d’Etat, Paris, 178 pp.

Janicot S. (1990) Variabilité des précipitations en Afrique de l’ouest et circulations.

Jefferson, T.A., Leatherwood, J. & Weber M.A. (1993) Marine mammals of the word. FAO Species identification guide, p. 319.

John, D.M. and Lawson, G.W. (1997) Seaweed biodiversity in West Africa: a criterion for designating marine protected areas. In The coastal zone of West Africa: problems and management. (ed. S. M. Evans, C. J. Vanderpuye and A. K. Armah), London: Penshaw Press, pp. 111-123.

John, D.M., Lawson G.W. & Ameka G.K. (2001) Seaweeds of the Tropical West Africa Sub-region, Identification manual. Marine Biodiversity capacity Building in the West African-Region, 161 pp.

Joiris, C.R., Otchere, F.A., Azokwu, M.I. and Ali, I.B. (1997) Total and organic mercury, and organochlorides in a bivalve from Ghana and Nigeria in the coastal zone of West Africa: problems and management (ed. Evans, S.M., Vanderpuye, C.J., and Armah, A.K.), pp. 89-92.

Jones & Hockey (1964)

Keay (1959)

Kent, N and Coker, P. (1992) Vegetation Description and Analysis. Wiley, Chichester.

Kerbyson, J. D. and Schandorf, J.R.H. (1966) Chemical Analysis of Ghana Rocks, Ores and Minerals, 1945-1965, Geological Survey Bulletin 42: Accra, Ghana.

Kirkegaard, J. B. (1988) The Polychaeta of West Africa. Part 2. Errantia species. In: J. Knudsen and T. Wolff (eds.) Atlantide Report 14. E.J. Brill/ Scandinavian Science Press Ltd.

Kogbe C. A. (1978) Revision of Continental terminal concept in Africa. 2nd Working Conference IGCP-IUGS Project 127. Occasional Publ., no. 7, Ahmadou Bello University, Zaria, Nigeria.

Kokou, K. et. al. (1999) Les ilôts forestiers au Sud du Togo : Dynamique et relation avec les végétations périphériques. Rev. Ecol. (Terre Vie), 54:301-314.

Koranteng, K.A. (2001) Structure and Dynamics of Dermersal Assemblages on the Continental Shelf and Upper Slope off Ghana, West Africa. Mar-Ecol-Prog-Ser. 2001 Sep 27. 220:1-12.

Laboratoire de delft: Port de Cotonou. (1977) Influence d'un épi d'arrêt et d'un barrage sur la côte. p.1241.

Laegdsgaard P. & Johnson C.R. (1995) Mangrove habitats as nurseries: unique assemblages of juvenile fish in subtropical mangroves in eastern Australia. Mar. ecol – Prog ser. 126:67-81.

Lamouroux m. (1953) Etude pédologique de la vallée de l'Ouémé, rive droite de la Sô. Rapport ORSTOM, Paris, 32 pp.

Lang J. and Paradis G, (1977) Un exemple d'environnement sédimentaire, biodétritique, non carbonaté, marin et continental, holocène en climat intertropical: le domaine margino-littoral du Bénin (ex. Dahomey) Rev. Géogr. Phys. Géol. Dynam. (2), XIX, fasc. 3:295-312.

Lang J. and Paradis G, (1984) Le quaternaire margino-littoral béninois (Afrique de l'Ouest); synthèse des datations au carbone 14. Paleoecology of Africa. Ed. J.A. Coetze et E. M. Van Zinderen Baker - A.A. Balkema Publ., Rotterdam, Pays- Bas.

Lang J., Kogbe C., Alidou S., Alzouma K., Dubois D., Houessou A. et Trichet J. (1986) Le Sidérolithique du Tertiaire ouest africain et le concept de Continental terminal. Bull. Soc. Géol. Fr., 8(4, II):605-622.

Lang J., Paradis G. and Oyede, L. M. (1988) Le domaine margino-littoral du Bénin (Golfe de Guinée, Afrique de l'Ouest) Age holocène et mise en place marine des "Sables jaunes". Journal of African Earth Sciences, Vol. 7(5/6):829-833.

Lang, J Kogbe C. A Alidou S Alzouma K. Bellion C. Dubois D., Durand A., Guiraud R, Houessou A. Klasz I. Roman E., Salard- Lang J. et Oyede L. M. (1991) Discontinuities in the recent and quaternary margino-littoral sedimentation of Benin (humid tropical zone) Journal of African Harth Sciences. 12(1/2):217-228.

Le Barbe l., Ale G., Millet B., Borel Y. et Gualde R. (1993) Les ressources en eau superficielles de la République du Bénin. ORSTOM Editions, Paris.

Le Barbe l., Ale G., Millet B., Borel Y. et Gualde R. (1993) Les ressources en eau superficielles de la République du Bénin. ORSTOM Editions, Paris.

Leveque C., Paugy D. & Teugels G. G. (1990a) Faunes des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 1. Editions ORTOM/MDRAC, Paris.

Leveque C., Paugy D. & Teugels G. G. (1990b) Faunes des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 2. Editions ORTOM/MDRAC, Paris.

Levi C., Cotillon P. (1990) Campagne Biocal: Environnement bathyal actuel et récent aux abords de la Nouvelle Calédonie. In Tour du Monde (Jean Charcot), Ocean. Act., 10:163-171.

LIFAD/ABE. (2000) Inventaire et diagnostic pour la préparation du SDAL. Cotonou

Longhurst, A.R. (1962) A review of the oceanography of the Gulf of Guinea. Bulletin d'Institute franc Africain noire, 24:633-663.

Longhurst, E.R & D. Pauly (1987) Ecology of Tropical Ocean. Academic Press Inc. Harcourt Brace Jovanovich Publishers, San Diego. 407 pp.

Lund (1958)

Magurran A. (1991) Ecological Diversity and its measurement. London,Chapman and Hall.

Maliki R., (1993) Etude hydrogéologique du littoral béninois dans la région de Cotonou (A.O.) Thèse de Doctorat de 3ème cycle. Version provisoire. UCAD; Dakar, Sénégal. 162 pp.

Marche-Marchad J. (1969) Le monde animal en Afrique intertropicale. pp. 514-519.

Maslin J. L. (1983) Les mollusques bentiques d'une lagune du Sud-Bénin, le lac Ahémé: les facteurs de leur répartition, dynamique de population et estimation de la production de Corbula trigona. Thèse doct. 3ème cycle, Univ. de Lyon, 152 pp.

McColl (1972)

McCune B. and Mefford M. J. (1995) Multivariate analysis of ecological data. Version 2.0. MJM Software design, Gleneden Beach, Oregon, USA.

MEHU/GTZ (2001) Pollution atmosphérique urbaine au Bénin. Tractebel (2000) Etude sur la qualité de l'air en milieu urbain: cas de Cotonou. 49 pp.

Mensah, M.A. (1991) The influence of climatic changes on the coastal oceanography of Ghana. In Pecheries ouest Africaines: variabilite, instabilite et changement (ed. C. Phillipe and C. Roy), pp. 67-79.

Merle, J. and Arnault, S. (1985) Seasonal variability of the surface dynamic topography in the Tropical Atlantic Ocean. Journal of Marine Research 43:267-288.

Miller & Tiller (1971)

Mondjanagni A. (1969) Contribution à l'étude des paysages végétaux du Bas-Dahomey. Ann. Univ. Abidjan. t. 1, fasc.. 2:191.

Moore, D.W., Hisard, P., McCreary, J.P., Merle, J., O'Brien, J.J., Picaut, J., Verstraete, J.M., and Wunsch, C. (1978) Equatorial adjustment in the eastern Atlantic ocean. Geophysical Research Letters 5:637-640.

Morton R. M. (1990) Community structure, density, and standing crop of fishes in a subtropical Australian mangrove area. Marine Biology. 105:385-394.

Moss (1957)

Nason, A. (1992) Discovering Birds: An Introduction to the Birds of Nigeria. Pisces Publications, the Nature Conservation Bureau Ltd., UK.

Nations Unies (1979) Seminaire-Atelier sur les problèmes de l'érosion Gouvernements du Togodes côtes du Togo et du Bénin. Lomé.

NEDECO/HASKONING (1984) Complément de formation de l'unité hydrographique Laboratoire de Delft. Evaluation et Interprétation des données morpho.

NEDECO/HASKONING Port Autonome de Cotonou. (1983) Etude du littoral. Laboratoire de Delft.

NEDECO: République togolaise. Etude détaillée de l'érosion.

Nelson & Sommers (1982)

NISSAKU Co. LTD. (1994) Projet pour l'exploitation des eaux souterraines du Bénin, phase III. Rapport final. 204 pp.

Northridge S.P. (1985) Etude des interactions entre les mammifères marins et les pêches au niveau mondial. FAO. pp. 60-78.

NU. (1987) Plan directeur d'utilisation des ressources en eau: la plaine côtière du Bénin, une reconnaissance hydrochimique. Rapport informel UN/DTCP No. 1. Projet BEN 85/004, Cotonou, Bénin. 12 pp.

Nunoo, F. K. E. (2003) Biotic, abiotic and anthropogenic controls of nearshore marine fish assemblage caught in beach seines in Sakumono, Ghana, and their management implications. Ph.D. Dissertation. University of Ghana, Legon. 142 pp.

Nwankwo (1990a)

Nwankwo (1990b)

Nyarko, E. and Evans, S.M. (1997) Impacts of tributyltin pollution and human food gathering on populations of gastropods Thais haemastoma and Thais nodosa along the Ghana coast. *In* The coastal zone of West Africa: problems and management (Eds., Evans, S.M., Vanderpuye, C.J. and Armah, A.K.), London: Penshaw Press, pp. 93-101.

Odeyemi, O.O., et al. (1994) The effect of drill slot on aquatic life in Belema field in the eastern operational area of the Shell Petroleum Company of Nigeria Limited. Environmental Pollution Studies and Technology Team, Dept of Microbiology, Obafemi Awolowo University, Ile-Ife, Nigeria. 154 pp.

Okoye et al. (1991)

Olaniyan (1961)

Olaniyan (1975)

OMI/UNNEP : Rapport de mission concernant l'élaboration d'un projet de plan d'intervention d'urgence en cas de situation critique pour l'environnement marin et côtier, République Populaire du Bénin.

Omori, M. and Ikeda, T. (1984) Methods in marine plankton ecology, pp. xiii, 332. New York: Wiley.

Onudi. (1999) Organisation des Nations Unies pour le Dévéloppement et l'Industrie. Rapport.

Oteng-Yeboah, A.A. (1994) Biodiversity in three traditional groves in Guinea savannah,Ghana, in L. J.G. Van deer Maesen et al.(eds.) The Biodiversity of African plants , Kluwer AcademicPublishers, Dordrecht. pp. 188-197.

Owre, H. B. and Foyo, M. (1967) Copepods of the Florida Current. In Fauna Caribaea. No.1 Crustacea, Part1: Copepoda. Miami: University of Miami. 137 pp.

Oyede L. M. (1983) Un exemple de sédimentation biodétritique quaternaire dans le domaine margino-littoral en climat tropical humide: le « lac » Ahémé (Bénin – Afrique de l'Ouest) Thèse Doctorat 3ème cycle, Université Nationale du énin – Université de Bourgogne, Dijon, 171 p.Oyede L.M., Kaki C. & Yessoufou S. (2001) Reconnaissance géologique d'un site de décharge et de valorisation des véhicules hors d'usage: étude d'impact environnemental sur le milieu physique. DST/UNB, 17 p.

Oyede L. M. (1991) Dynamique sédimentaire actuelle et messages enregistrés dans les séquences quaternaires et néogènes du domaine margino-littoral du Bénin (Afrique de l'Ouest) Thèse de Doctorat. Univ. de Bourgogne et Univ. Nat. du Bénin. 302 pp.

Oyede L. M., Lang. J. and Carbonnel G. (1986) Phénomènes biosédimentaires actuels et subactuels dans le domaine margino-littoral sud-béninois (Bénin, Afrique de l'Ouest) Workshop projet no. 210. PICG. Jos, Nigeria. pp. 47-48.

Oyede L. M., Lang. J. and Tsawlassou. (1988) - Un exemple de sédimentation biodétrique holocène en climat tropical humide: le lac Ahémé (Bénin, Afrique de l'Ouest) Journal of African Earth Sciences, 7(5/6):835-855.

Oyede L. M., Prichonnet G., Alidou S. and Preda M. (1987) Les minéraux lourds et argileux dans la stratigraphie du Quaternaire littoral du Bénin (Afrique de l'Ouest) XIIème Congrès INQUA. Montréal., 237 pp.

P.N.U.E. (1985) Erosion Côtière en Afrique de l'Ouest et du Centre, (avec la collaboration des Nations Unies et de l'UNESCO) Paris.

Page et al. (1987)

Pallas P. (1988) Contribution à l'étude des ressources en eau souterraine du bassin côtier du Bénin. Confrontation ressources-besoins. (Projet PNUD) 29 pp.

Papadakis (1965)

Paradis G. & Adjanohoun E. (1974) L'impact de la fabrication de sel sur la végétation de mangrove et la géomorphologie dans le Bas-Dahomey. Univ. Abidjan, Sér. E, Ecologie, VII, 1.

Paradis G. (1975) Physionomie, composition floristique et dynamisme des formations végétales d'une partie de la basse vallée de l'Ouémé (Dahomey) Ann. Univ. Abidjan, Sér. C, Sc., t.XI, p. 35-101.

Paradis G., (1976) Recherches sur le Quaternaire récent du Sud de la République du Bénin. Thèse 3ème cycle. Univ. Paris Sud. Orsay, 174 pp.

Pelnard Considère, R. (1956) Essai de théorie de l'évolution des formes de rivage en plages de sables et de galets. Ves journées de l'hydraulique. Paris.

Per Roed, J. (1989) Coastal erosion in the Bight of Benin; national and regional aspects. Commission of the European Community, p. 381.

Pereira J. J. (1978) Le Crétacé dans le bassin sédimentaire côtier du Bénin (Afique de l'Ouest) 6ème Réun. Ann. Sci. Terre. Orsay. 305.

Pliya J.1980. La pêche dans le Sud-Ouest du Bénin, ACCT,1980, 296 pp.

PNAE/MERF, (2002) Monographie nationale sur la diversité biologique. Document préliminaire, p. 191.

PNUD (1987) Plan directeur d'utilisation des ressources en eau du Bénin. Projet UN/DTCD BEN 85/004. DH. Cotonou, Bénin.

Port Autonome de Cotonou- Direction du bureau d'études: Erosion Côtière. Etude et suivi de l'évolution de la côte béninoise (phase 1) Rapport de l'étude.

Prichonnet G., Oyede L. M. et al., (1987) Les bas niveaux marins du Pleistocène supérieur au Sud du Bénin et dans les zones adjascentes de l'Afrique de l'Ouest.

Profizi J. P. (1982) Essai de quantification du dynamisme d'une mosaïque forêt-savane du savane Sud-Bénin par photo-interprétation. Ann. Univ. Abidjan, Sér. E., E. (Ecol.), t. XV, pp. 95-101.

Purser B.H. (1980) Sédimentation et diagenèse des carbones néritiques récents. Technip., Paris, 366 pp.

Ramsar Convention on Wetlands (2000) Workplan.

Richardson, P.L. (1984) Moored current meter measurements in the Atlantic North Equatorial Counter Current during 1983. Geophysical Research Letters 11, pp. 749-752.

Rijavec, L. (1980) A survey of the demersal fish resources of Ghana. CECAF/TECH/80/25.

Roberston A. I. & Duke N.C. (1987) Mangrove as a nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. Marine Biology. 96: 193-206.

S.G.I., (1983) Etude de la nappe aquifère de Godomey. Rapport complémentaire sur les piézomètres. Société Générale pour l'Industrie. Banque Africaine de Développement, Abidjan, Côte d'Ivoire. SBEE, Cotonou. Genève, Suisse.

Sagbo O. M. (2000) Pollution des nappes alimentant la ville de Cotonou en eau de consommation: vulnérabilité et urgence des mesures de protection des aquifères. UAC, Cotonou, Bénin.

SBEE (1995) - Adduction d'eau des villes de Cotonou et Porto-Novo. Rapport final.S.G.I., (1981) Etude de la nappe aquifère de Godomey. Société Générale pour l'Industrie Banque Africaine de Développement-SBEE. Cotonou.

Schneider (1990)

SERHAU-BURGEAP (1987) Expérimentation sur l'assainissement à Cotonou: potentialité d'infiltration dans le sol. FAC, France, MET, Bénin.

Serle W. & Morek G. J. (1993) Les oiseaux de l'Ouest-africain ; Guide du naturaliste.

SERRES G. (1987) Coupe hydrogéologique à travers le Nord-Ouest du plateau d'Allada. DH. Cotonou. Inédit.

Sitarz, ( ) Côtes africaines, études des profils d'équilibre de plages. Travaux du Centre d'Etudes.

Slansky M. (1968) Contibution à l'étude géologique du bassin sédimentaire côtier du Dahomey et du Togo. Thèse . Univ. Nancy, série 59, n° 165 et 1962, Mém. BRGM, No. 11, 170 pp.

Sogreah (1990) Etude sur modèle mathématique de l'évolution du littoral béninois entre la frontière togolaise et l'est de l'embouchure du fleuve Mono.

Sogreah (1991) Etude des problèmes sédimentologiques et programmation des campagnes de dragages du chenal d'accès et du bassin portuaire.

Sogreah, and Delft (1983) Travaux de Protection de la Zone de « la Crique » à Cotonou. Pièce annexe au dossier d'Appel d'Offres (Projet) Mémoire justificatif des ouvrages.

Sogreah, and Delft (1989) Instiut danois d'Hydraulique Expertise Régionale pour le Projet Pilote Régional de Lutte contre l'Erosion en Afrique de l'Ouest et du Centre.

Sogreah/SCET-Tunisie, (1997) Etude de la stratégie nationale de gestion des ressources en eau du Bénin. Rapports R1 à R7. Cotonou, Bénin.

Steentoft, M. (1986) Flowering plants in West Africa. In: (G.W. Lawson, Ed.) Plant Ecology in West Africa, Systems and processes. Chichester. John Wiley.

Syreyjol, P (1964) Communication sur la construction du port de Cotonou (Dahomey) Coastal Engieneering Conference, Lisbon.

Syreyjol, P. (1964) Communication sur la construction du port de Cotonou (Dahomey) Coastal Engieneering Conference, Lisbon.

T&T Associates Ltd. (1991)

Tastet J. P. (1981) Morphologie des littoraux sédimentaires liés aux variations du niveau de la mer: exemple du Golfe de Guinée. Océanis, 7, Fasc. 4:455-472.

TEE Associates Environmental Consultants (1991)

Thayer G. W., Colby D. R. & Hettler W.F. Jr. (1987) Utilization of the red mangrove prop root habitat by fishes in south Florida. Marine Ecology Progress Series. 35:25-38.

Thiriot, A. (1977) Zooplankton in the upwelling zones of the African Atlantic littoral. Document Scientifique Centre Recherche Oceanographique (ORSTOM) 8:1-72.

Thomas (1959)

Tomas, C. R. (1997) Identifying Marine Phytoplankton. San Diego: Academic Press. 858 pp.

TROADEC and Coll. (1979)

Tsidzi, K. E. N., Akoto, M. A. and Iddrisu, Y. (1995) Geological hazards mitigation in Ghana: the state of the art. Ghana Mining Journal 1.

TurkPak International-SCET -Tunisie, (1991) Inventaire des ressources en eaux souterraines au Bénin. Rapport final. V.1 284 p. + Annexes.UN, (1987) La plaine côtière du Bénin: une reconnaissance hydrochimique. Rapport informel No. 1. Projet BEN 85/OO4 PNUD, Cotonou, Bénin.

UN, (1990) Plan directeur d'utilisation des ressources en eau du Bénin. Projet BEN 85/OO4 PNUD, Cotonou, Bénin.

UNB-UQAM (1987) Aquifère du Quaternaire côtier du Bénin. Projet CRDI (1ère phase) n° 3-P-84-1056-03..

UNEP Tzeng W-N. & Wang Y.T. (1992) Structure, composition and seasonal dynamics of the larval and juvenile fish community in the mangrove estuary of Tanshui River, Taiwan. Marine Biology. 113:481-490.

UNESCO/UN (DIESA) (1984) Projet Erosion Côtière en Afrique Centrale et de l'Ouest. WACAF/3. Réunion au B.R.G.M. Orléans.

Van Thielen R. , Hounkpe C., Agon G. & Dagba L. (1987) Guide de détermination des poissons et crustacés des lagunes et lacs du Bas Benin. Deutsche Gesellschaft Fur Technische Zusammenarbeit (GTZ)GMBH & Direction des Pêches, Cotonou.

Vance D. J., Haywood M.D.E., Heales D.S., Kenyon R.A. & Loneragan N.R. (1990) How far prawns and fish move into mangroves? Distribution of juvenile banana praws Penaeus merguiensis and fish in a tropical mangrove forest in northern Australia. Marine Ecology Progress Series. 131:115-124.

Vanden Bossche, J.P. and Bernaesek, G.M. (1990) Source book for the inland Fishery resources of Africa. CIFA Technical Paper 18/2 Rome, 240 pp.

Van-Thielen et al (1987)

Vinje, J.J. et W.M.K. Tilmans ( ) Expertise sur l'Erosion Côtière et les Techniques de Protection du Littoral de la République du Togo.

VOLKOFF B. (1976) Carte pédologique de reconnaissance de la République Populaire du Bénin. ORSTOM, Paris, Inédit.

Waerbeek, K. V. and Ofori-Danson, P. K. (1999) Exploratory survey of cetaceans and their interactions with fisheries in Ghana and Togo, the Gulf of Guinea. Chicago Zoological Society and Leopold III Fonds Voor Natuuronderzoek en Natuurbehoud. 15 pp.

Webb (1958)

Welcomme, R. L. 1971. A description of certain indigenous fishing methods from Southern Dahomey. Afr.J.Trop.Hydrobiol.Fish., 1: 129-40.

Wetzel & Likens (1990)

Wiafe G. & Frid C.L.J. (2001) Marine zooplankton of West African. Marine Biodiversity capacity Building in the West African-Region, 120 p., Recherches Océanographiques. Vol. 3, fasc. 4.1960 Construction, No 9, 1967 XIIème. Congrès INQUA. Montréal. Résumé. 245. 80, 125-160.

Wiafe G. and Quist, M. (2002) Nutrient Pollution in Ghana., p. 31. Accra: UNIDO Thematic Area Paper For Stocktaking Meeting (PDF-B).

Wiafe, G. (2002) Spatial and temporal dynamics of plankton communities in the Gulf of Guinea ecosystem. In: Oceanography and Fisheries, pp. 188. Legon: University of Ghana.

Wiafe, G. and Frid, C. L. J. (2001) Marine plankton of West Africa, pp. 120. with CD-ROM Published by Darwin Initiative, U.K.

Williams, F. (1968) Report on the Guinean Trawling Survey, Organisation Of African Unity Scientific and Technical Research Commission (99)

Yankson and Kendall (2001)

Zar (1984)

Ziebis, W., M. Huettel, and S. Forster (1996) Impact of biogenic sediment topography on oxygen fluxes in permeable seabeds. Mar. Ecol. Prog. Ser. 140: 227-2.

9.2 ACRONYMS

Abbreviation	Meaning
AASHTO	American Association of Highway and Transportation Officials
ABE	Benin Environmental Agency
ABS	American Bureau of Shipping
AC	Alternating Current
ACI	American Concrete Institute
AES	Engineering Company
AID	Agency for International Development
AIDS	Acquired Immune Deficiency Syndrome

Abbreviation	**Meaning**
AISC	American Institute of Steel Construction
AIT	Auto Ignition Temperature
AIW	Antarctic Intermediate Water
Al	Aluminum
ALARP	As Low As Reasonably Practical
AML	Approved Manufacturers List
ANSI	American National Standard Institute
API	American Petroleum Institute
ASCE	American Society for Civil Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society of Non-Destructive Testing
ASTM	American Society for Testing and Materials
atm	Atmosphere
AVR	Automatic Voltage Regulation
AWS	American Welding Society
B	Boron
Ba	Barium
BA	Breathing Air
BAT	Best Available Technology
Bbl	API Barrel
BDV	Blowdown Valve
BHP	Break Horse Power
BOD	Biochemical oxygen Demand
BPT	Best Practicable Control Technology
Br	Bromine
BS	British Standard
BS EN	British Standard Euro-Norm
C	Celsius
Ca	Calcium
$CaCO_3$	Calcium Carbonate
CADD	Computer Aided Design and Drafting
CAE	Computer Aided Engineering
CAPEX	Capital Expenditure
CBD	Convention of Biological Diversity
CCR	Central Control Room
CCTV	Closed Circuit Television

Abbreviation	**Meaning**
Cd	Cadmium
CDC	Centralized Dispatch Center
CDM	Clean Development Mechanism (Kyoto protocols – Greenhouse Gas Reduction)
CEDA	Center for Environment and Development in Africa
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CH_4	Methane
CII	Construction Industry Institute
Cl^-	Chloride
CLT	Cross–Lake Fish Trap
Cm	Centimeter
CMMS	Computerized Maintenance Management System
CMS	Consortium Electric Power
CMT	Consortium Management Team
CN	Cast Net
CNL	Chevron Nigeria Limited
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CoC	Chain of Custody
COD	Chemical Oxygen Demand
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
CP	Cathodic Protection
CPDEP	ChevronTexaco Project Development and Execution Plan
CPI	Chemical Process Industries
CPT	Cone Penetration Test
CPU	Central Processor Unit
CPUE	Catch per Unit Effort
Cr	Chromium
CR	Critically endangered
CRA	Corrosion Resistant Alloy
CRT	Cathode Ray Tube
CSC	Convention on the Continental Shelf
CTD	Conductivity, Temperature and Depth
Cu	Copper
CWAG	Chevron West African Gas

Abbreviation	**Meaning**
D	Normal Outside Diameter
dB	Decibels
dB (A)	decibels weighted to 'A' scale
dbh	diameter at breast height
DC	Direct Current
DCS	Distributed Control System
DD	Due Diligence
DD	Data Deficient
DGPS	Digital Global Positioning System
DIN	Deutche Industrie-Norm (German Industrial Standard)
DNV	Det Norske Veritas
DO	Dissolved Oxygen
DOI	Declaration of Isolation
DP	Dynamic Positioning
DPR	Department of Petroleum Resources
DSC	Decision Support Center
E	East
EBS	Environmental Baseline Survey
EC	Electrical Conductivity
ECC	Equatorial Counter Current
ECOWAS	Economic Community of West African States
EEMUA	Engineering Equipment and Materials Users Association
EFD	Engineering Flow Diagram
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industry in Nigeria
EG&S	Environmental Guidelines and Standards
EIA	Environmental Impact Assessment
EIS	Environmental Impact Study
EJMA	Expansion Joint Manufacturers Association
ELP	Escravos – Lagos Pipeline
EMC	Electromagnetic Compatibility
EMS	Environmental Management System
EN	Euronorm
EN	Endangered
EPA	U.S. Environmental Protection Agency
EPC	Engineering, Procurement, Construction
ER	Emergency Response

Abbreviation	Meaning
ERML	Environmental Resources Managers Limited
ERP	Emergency Response Plan
ERT	Emergency Response Team
ESD	Emergency Shutdown
ESDV	Emergency Shutdown Valve
ESI	Environmental Sensitivity Index
ESL	Environmental Solutions, Ltd.
ESS	Emergency Support System
Et al.	Et alli (and others)
ETZ	Eastern Tropical Zone
F	Fahrenheit
F&G	Fire and Gas
F&S	Fire and Smoke
FAT	Factory Acceptance Testing
FBE	Fusion Bonded Epoxy
FC	Fail Closed
FCA	Failure Characteristic Analysis
Fe	Iron
FEED	Front End Engineering Design
FEL	Front End Loading
FEPA	Federal Environmental Protection Agency
FIN	Facilities Information Network
FMEA	Failure Mode and Effect Analysis
FMEnv	Federal Ministry of the Environment
FMOE	Federal Minister of the Environment
FO	Fail Open
FOB	Free on board
FOS	Federal Office of Statistics
FRP	Fiber Reinforced Plastic
ft	Feet
g	Gramme
G&A	Germano & Associates
GC	Guinea Current
Ghacem	Ghana Cement
GDP	Gross Domestic Product
GEF	Global Environment Fund

Abbreviation	Meaning
GEPA	Ghana Environmental Protection Agency
Gg	Gigagramme
GHG	Greenhouse Gas
GIEC	International Group of Experts on the Climate
GIS	Geographic Information System
GNPC	Ghana National Petroleum Corporation
GPHA	Ghana Ports and Harbour Authority
GRE	Glass Reinforced Epoxy
GRP	Glass Reinforced Plastic
GTA	Gas Transportation Agreement
GTG	Gas Turbine Generator
H	Hour
hr	Hour
H_2CO_3	Carbonic Acid
H_2S	Hydrogen Sulfide
Ha	Hectare
HAT	Highest Astronomical Tide
HAZAN	Hazard Analysis - (A formal procedure used to identify hazards, quantify their impact, and analyze problems associated with a given process)
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study – (A formal procedure used to identify hazards and operability problems associated with a given process)
HAZOPS	Hazardous Operations
HCO_3	Hydrogen Carbonate
HDD	Horizontal Directoinal Drill
He	Helium
HES	Health, Environment, Safety
HFE	Human Factors Engineering
HFIP	Human Factors Implementation Plan
Hg	Mercury
HIC	Hydrogen Induced Cracking
HIPP	High Integrity Pressure Protection
HIPPS	High Integrity Pressure Protection System
HIPS	High Integrity Protection System
HIV	Human Immunodeficiency Virus
HMI	Human Machine Interface

Abbreviation	Meaning
HOA	Heads of Agreement
HOCNS	Harmonized Chemical Offshore Notification Scheme
HOCl	Hypochlorous Acid
HP	High pressure
HP	High Power
hp	Horsepower
HR	Human Resources
HRc	Hardness Rockwell (C Scale)
HSE	Health, Safety, and Environmental
HT	High Tide
HV	High Voltage
HVAC	Heating Ventilation Air Conditioning
I/C	Interconnect
I/O	Input and Output
IC	Institute of Corrosion
ICEA	Insulated Cable Engineers Association, Inc.
ICF	ICF Consulting
ICP/MS	Inductively Coupled Plasma/Mass Spectrometer
ID	Inside Diameter
IEC	International Electrotechnical Council
IEEE	Institute of Electrical and Electronics Engineers
IESNA	Illuminating Engineering Society of America
IFA	Issued for Approval
IFD	Issued for Design
IFH	Issued for HAZOP
IFO	Incident Free Operations
IGA	Inter Government Agency
IGN	National Geographic Institute
IITA	International Institute for Tropical Agriculture
IM	Information Management
IME	Integration Management Entity
in	Inch
IOPCFUND	International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage
IPCC	Intergovernmental Panel on Climate Change
IRI	Industrial Risk Insurers

Abbreviation	Meaning
IRR	Internal Rate of Return
IS	Intrinsically Safe
ISA	Instrument Society of America
ISO	International Organization for Standardization
ISSER	Institute of Statistical, Social, and Economic Research
IT	Information Technology
ITB	Invitation to Bid
ITCZ	Inter-Tropical Convergence Zone
ITD	Inter-tropical Discontinuity
ITF	Inter-tropical Front
IZ	Intertidal Zone
JHA	Job Hazard Analysis
JVA	Joint Venture Agreement
K	Potassium
kg	Kilogramme
khz	Kilohertz
km	Kilometer
KO	Knock Out
KP	Kilometer Post
kW	Kilowatt
L	Litre
LAN	Local Area Network
LAT	Lowest Astronomical Tide
LC_{50}	Lethal Concentration, 50 Percent
LCN	Local Country Nationals
LCR	Local Control Room
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit.
LGAs	Local Government Areas
Li	Lithium
LME	Large Marine Ecosystem
LOI	Letter of Intent
LP	Low pressure
LPP	Low Point of Paving
LR	Lower Risk
LT	Low Tide

Abbreviation	Meaning
LV	Low Voltage
m	Meter
m/s	Meter per second
MAC	Manual Alarm Call
MARPOL	Marine Pollution Convention
MAOP	Maximum Allowable Operating Pressure
MC	Metal Clad
MCC	Motor Control Center
MCR	Main Control Room
MDAs	Ministries, Departments and Agencies
MDT	Mean Down Time
MEHU	Ministry of the Environment, Housing, and Town Planning
mEq	Milliequivalent
Mg	Magnesium
mg	Milligramme
MIS	Management Information System
mm	Millimeter
MM	Million when used in the context of gas flow or heating value. Thus MMBtu implies million Btus.
MMm^3D	Million Meters Cubed Per Day
MMS	Maintenance Management System
MMscf	Million Standard Cubic Feet per Day
MMscfd	Million Standard Cubic Feet per Day
MMTPA	Million Metric Tonnes per Annum
Mn	Magnesium
MOC	Management of Change
MOU	Memorandum of Understanding
MP	Medium Pressure
Ms	Millisecond
MS	Medium Fraction
MSC	Ministerial Steering Committee
MSDS	Material Safety Data Sheet
MSL	Mean Sea Level
MTBF	Mean Time Between Failure
Mtpa	Million Tonnes per Annum
MTTR	Mean Time To Repair

Abbreviation	Meaning
MV	Medium Voltage
MVAR	Mega Volt Amps Regulation
MW	Mega Watts
N	Nitrogen
N	North
N	Newton
N°2	Main Coastal Road in Togo
Na	Sodium
NACE	National Association of Corrosion Engineers.
NADW	North Atlantic Deep Water
NAPCA	National Association of Pipe Coating Applicators
NB	Nominal Bore
NDT	Non destructive testing
NE	North East
NEC	National Electric Code
NEMA	National Engineering Manufacturers Association
NEPA	Nigeria Energy and Power Authority
NFPA	National Fire Protection Association
NGC	Nigerian Gas Corporation
NGO	Non-Government Organizations
Ni	Nickel
NISER	Nigerian Institute of Social and Economic Research
nm	Nanometer
NNPC	Nigerian National Petroleum Corporation
NO_2	Nitrite
NO_3	Nitrate
NOx	Nitrous Oxides
NOEC	No Observable Effect Concentration
NPDES	National Pollution Discharge Elimination System
NPS	Nominal Pipe Size
NPV	Net Present Value
NTU	Nephelometric Turbidity Units
NW	North West
O & M	Operations and Maintenance
OCl-	Hypochlorite Ion

Abbreviation	Meaning
OEM	Original Equipment Manufacturer
OILPOL	International Convention for the Prevention of Pollution of the Sea by Oil
OJT	On-the-Job-Training
OPEX	Operating Expenditure
ORP	Oxidation Reduction Potential
OSI	Organism-Sediment Index
OSHA	Occupational Safety and Health Administration
OSPARCOM	Commissions of Oslo and Paris
OTC	Overhead Traveling Crane
P	Phosphorus
P&ID	Piping and Instrumentation Diagrams
PAGA	Public Address/General Alarm
PAH	Polycyclic Aromatic Hydrocarbons
PALL	Pressure Alarm Low Low
PAR	Pre-assembled Piperack
PAS	Process Automation System
Pb	Lead
PCBs	Poly Chlorinated Biphenyls
PEP	Project Execution Plan
PES	Project Execution Strategy
PFD	Process Flow Diagrams
PFP	Passive Fire Protection
PHA	Process Hazards Analysis
PI	Profitability Index
PIC	Project Implementation Committee
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PLE	German Engineering Company – Feasibility study
PM	Particulate Matter
PM_{10}	Less than or equal to 10 micro meters
PO_4	Phosphate
POB	People on Board
POP	Persistent Organic Pollutants
PP&E	Protecting People and the Environment – CT Policy 530
ppb	Parts per Billion
PPE	Personal Protective Equipment

Abbreviation	Meaning
ppm	Parts per Million
PSIA	Pounds per Square Inch Absolute
PSIG	Pounds per Square Inch Gauge
PSS	Plant Safeguarding System
PSV	Pressure Safety Valve
PVC	Polyvinylchloride
PWHT	Post Weld Heat Treatment
QA	Quality Assurance
QC	Quality Control
QRA	Quantified Risk Assessment
R	River
R&M	regulating and metering
R.O.W.	Right of Way
RAM	Reliability, Availability, and Maintenance
RBI	Risk Based Inspection
RCM	Reliability Centered Maintenance
Redox	Reduction/Oxidation
RF	Raised Face
RFQ	Request for Quotation
ROV	Remotely Operated Vehicle
ROW	Right Of Way
RP	Recommended Practice
RPD	Redox Potential Discontinuity
RTD	Resistance Temperature Device
RTJ	Ring Type Joint
RV	Relief Valve
RVP	Reid Vapor Pressure
S	South
s	Seconds
SACW	South Atlantic Central Water
SAFE	Safety Analysis Function Evaluation Chart
SBC	Structured Breakdown of Costs
SCADA	Supervisory Control and Data Acquisition
SDV	Shut Down Valve
SE	South East
SHE	Safety, Health and Environment

Abbreviation	**Meaning**
Si	Silicon
SID	Safety In Design
SIL	Safety Integrity Level
SIMOPS	Simultaneous Operations
SiO_2	Silicon Dioxide
SIS	Safety Instrumented System
SIT	Systems Integration Test
SMC	Sponsor Management Committee
SN	Seine
SNGL	Shell Nigeria Gas Limited
SO_2	Sulfer Dioxide
SO_4	Sulfate
SOBEGAZ	Societe Beninoise de Gaz S.A.
SOE	Sequence of Events
SOLAS PROT	Protocol Relating to the International Regulations for the Safety of Life at Sea
SOP	Standard Operating Procedure
SOTOGAZ	Societe Togolaise de Gaz S.A.
So_x	oxides of sulfur
SPDC	Shell Petroleum Development Company
SPI	Sediment Profiling Imagery
SPM	Single Point Mooring
SPPM	Safe Practices and Procedures Manual
Sr	Strontium
SRB	Sulphate Reducing Bacteria
SST	Sea Surface Temperature
SSW	South-southwest
STDs	Sexually Transmitted Diseases
STWC	Standards of Training Certification and Watch-keeping for the Seafarer
SW	South West
TBA	To Be Advised
TBD	To Be Determined
TCA	Total Corrosion Allowance
TCN	Third Country Nationals
TDS	Total Dissolved Solids
TEG	Tri-ethylene Glycol
TEMA	Tubular Exchanger Manufacturers Association, Inc.

Abbreviation	Meaning
THC	Total Hydrocarbon Content
TLV	Threshold Limit Value
TMA	Tema Municipal Authority
tn	Tonne
TOC	Total Organic Carbon
TOM	Total Organic Matter
TOR	Tema Oil Refinery
TPH	Total Petroleum Hydrocarbons
TQM	Total Quality Management
TSP	Total Suspended Particulate
TSS	Total Suspended Solids
TSW	Tropical Surface Water
TVP	True Vapor Pressure
μ	microgramme
μg/g	Micrograms/gram
μgm^{-3}	Micrograms per cubic meter
μS/cm	Micrograms per cubic meter
UBC	Uniform Building Code
UES	Uniform Effluent Standards
UJV	Unincorporated Joint Venture
UL	Underwriters Laboratory
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UPS	Uninterruptable Power Supply
USEPA	US Environment Protection Agency
V	Vanadium
VAC	Volts Alternating Current
VALCO	Volta Aluminium Company
VDC	Volts Direct Current
VDU	Video Display Unit
VES	Vertical Electrical Sounding
VIP	Value Improvement Practices
VOC	Volatile Organic Compound
VRA	Volta River Authority
VSAT	Very Small Aperture Terminal

Abbreviation	Meaning
VSDS	Variable Speed Drive System
VU	Vulnerable
W	West
WAGP	West African Gas Pipeline
WAPCo	West African Pipeline Company
WD	Water Depth
WHRU	Waste Heat Recovery Unit
WHO	World Health Organization
WT	Wall Thickness
yr	Year
ZH	Hydrographical Zero
Zn	Zinc

9.3 AUTHORS AND CONTRIBUTORS

Each of the teams was asked to provide a listing of authors and major contributors to the EBS field, laboratory, and report work.

Benin

Adam, K. Sikirou	General Editing And Geological Setting
Adjakpa	Birds
Akoegninou Akpovi	Vegetation
Boko, Michel	Climate and Meteorology
Boukari, Moussa	Surface Water and Groundwater
Dimon, B. Fidèle	Chemical
Fiogbe, Emile	Biology, Benthos Plankton
Gnonlonfin, Lazare	Physical Oceanography
Houndenou Constant	Climate and Meteorology
Oyede, Marc	Soil, Sediment, Geological Setting
Sakiti	Wildlife and Animal Resources
Soclo, Henri	Chemical

Ghana

A.K. Armah
G. A. Darpaah
G. Wiafe
J. K. Adomako
S. Addo
S. D. Ababio
E. Lamptey
J. A. Ampofo

K.A. Koranteng
S. Quaatey
O. Ansa-Asare
J.K.K de-Graft Johnson
D. K. Allotey
D. K. Attuquayefio
M. A. Cobblah

Nigeria

Albert Ikolo
Victor Ohioze Imevbore
Adeolu Ojo

Togo

Pr. Adoté Blivi	Coordonnateur De L'eie Also GIS, Database, GPS, Géographe
Melle Abla Lucie Kwassi	GIS, Database, GPS, Géographe
Mr. Dieu-Donné P. Adjoussi	GIS, Database, GPS, Géographe
Pr. Koffi Akpagana	Botaniste
Dr. Kouami Kokou	Botaniste
Dr. Komlan Batawila	Botaniste
Pr. Yaya Boukari	Chimiste
Pr. Moctar Bawa	Chimiste
Pr. Gbandi Djaneye-Boundjou	Chimiste
Mr. Komi Doni	Chimiste, Technicien Supérieur
Mr. Phinté Nambo	Chimiste, Technicien Supérieur
Mr. Amah Hunlede,	Chimiste, Technicien Supérieur
Mr. Massabalo Aya	Chimiste, Ingénieur Stagiaire
Mr. Sogoyou Nimon	Chimiste, Géologue
Mr. Vincent Towanou	Chimiste, Technicien
Mr. Kangni Kpodar,	Chimiste, Technicien
Mr. Ganiou Soulemane Abdoul	Chimiste, Elève Ingénieur Stagiaire
Mr. Ibrahim Kpekpassi	Chimiste, Elève Ingénieur Stagiaire
Mr. Midassirou Bebou,	Chimiste, Elève Ingénieur Stagiaire
Pr. Adoté Blivi	Grain Size Team, Géographe
Mr. Etsè Gatogo	Grain Size Team, Géographe
Dr. Yaovi Nuto	Biologiste, Entomology
Dr. Komina Amevoin	Biologiste, Entomology
Mr. Banibea Sambena	Technician, Entomology
Mr. Komi Konou	Technician, Entomology
Dr. Kofi Agbeko	Soil Pedology
Pr. Comlan De Souza	Biologiste, Microbiology
Dr. Yaovi Ameapoh	Biologiste, Microbiology
Mr. Kossi Soncy	Technicien, Microbiology
Mr. Kodjo Anani	Technicien, Microbiology
Pr. Théré Edorh	Biologiste, Plankton

Dr. Takouda Kpatcha	Biologiste, Plankton
Mr. Gabriel H. Segniagbeto	Biologiste, Fauna
Mr. Kokouvi F. Akpamou	Biologiste, Fauna

United States

Chad Brown
Henry Camp
Marlene Cole
Theodore Coogan
Linos Costapas
James Gardiner
Joe Germano
Will Gibson
Dean Gouveia
Erin Healy
Johanna Kollar
Frank Querzoli
Craig Reid
Kathy Thrun

Appendix 5-B

Second Season

Environmental Baseline Surveys

West African Gas Pipeline

Benin
West African Gas Pipeline
Environmental Baseline Survey
Second Season

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the West African Gas Pipeline (WAGP) Joint Venture

12 November 2003

Centre pour l’Environnement, le Dèveloppement et l’Amènagement durables,
CEDA Consult
Cotonou, Benin

TABLE OF CONTENTS

Executive Summary 1

Chapter 1 Introduction and Background 1-1

Chapter 2 Onshore Field Methods..2-1

2.1 Vegetation Sampling..2-1
2.2 Soil Sampling..2-2
2.2.1 Taking on Continent 2-2
2.2.2 Taking in Water Plans..2-2
2.3 Surface Water and Sediment Quality and Hydrobiology 2-2
2.3.1.1 Sampling Water for the Primary Production 2-2
2.3.1.2 The Sampling of the Plankton..2-2
2.3.1.3 Sampling of Sediments and Harvest of the Benthiques Macro Invertebrates..2-2
2.3.1.4 Harvest Bodies of Grounds..2-3
2.4 In-Situ Methods..2-3
2.4.1 Mesures in situ des paramètres physico-chimiques 2-3
2.5 Wildlife and Animal Resources 2-3
2.6 Fish and Fisheries Resources..2-4
2.7 Sample Tracking, Storage, and Shipping 2-4

Chapter 3 Analytical Methods..3-1

3.1 Physical Laboratory Methods 3-1
3.1.1 Measure of pH..3-1
3.1.2 Granulometry 3-1
3.1.2.1 Preparatory Treatments..3-1
3.1.2.2 Splitting up Technique..3-1
3.1.2.3 Modes of Graphic Representation 3-1
3.1.2.4 Nomenclature used to Characterise the Supplies............................3-2
3.1.2.5 Granulometric Parameters 3-2
3.2 Chemical Laboratory Methods..3-3
3.2.1 DBO5's Measure..3-3
3.2.2 Primary Production and TOC 3-3
3.2.3 Protocol of Measure..3-4
3.2.3.1 Chlorophyllous Pigments Measurement..3-4
3.2.3.2 Conversion in Total Organic Carbon (TOC) 3-4
3.2.4 Primary Production..3-5
3.2.5 Observation, Identification, and Counting of Planktonic Types.........3-6
3.2.5.1 The Phytoplankton..3-6
3.2.5.2 The Zooplankton..3-6
3.2.5.3 Sorting of the Benthic Bodies..3-7
3.2.5.4 Determination of the Benthic Bodies..3-7

TABLE OF CONTENTS

3.2.6 Microbiology of Waters, Sediments and Grounds....3-8
3.2.6.1 Material and Methods....3-8
3.3 Biological Laboratory Methods....3-10
3.3.1 Vegetation....3-10
Chapter 4 Results....4-1
4.1 Vegetation....4-1
4.1.1 R&M Station to the Sea....4-2
4.1.1.1 Floristic Inventory....4-2
4.1.1.2 Characterisation of Plants Formation....4-3
4.1.1.3 Seasons' Effects on the Flora and Vegetation....4-6
4.1.1.4 Structural Modification....4-7
4.1.1.5 Floristic Modification....4-7
4.1.2 R&M Station to Maria Gleta....4-9
4.1.2.1 Floristic Inventory....4-9
4.1.2.2 Characterisation of Plan Formations....4-9
4.1.3 Programme of ecological accompaniment....4-11
4.1.4 Conclusion....4-12
4.2 Soil Characterization....4-12
4.2.1 Physical....4-12
4.2.1.1 General Pedological Data....4-12
4.2.1.2 On the Plateau....4-12
4.2.1.3 The Characteristics of the Studied Grounds....4-16
4.2.1.4 Grounds Developed on Yellow Sand....4-16
4.2.1.5 Grounds Developed on Grey Sand....4-16
4.2.1.6 Grounds of the Current and Subactual Cordon....4-17
4.2.1.7 The Plateau Grounds....4-17
4.2.1.8 Chemical Analysis of the Grounds and some Sediments....4-18
4.2.2 Chemical....4-20
4.2.2.1 Akadjame (Transect B2)....4-20
4.2.2.2 Station of Cococodji Treatment Gas (Transect B1) - Takings in Five Various Points....4-22
4.2.2.3 Cococodji (Transect B7)....4-23
4.2.2.4 Hio's Coastal Lagoon (Transect B5)....4-24
4.2.2.5 Adjahindji-Hio (Transect B4)....4-26
4.2.2.6 Hevie (Transect B8)....4-28
4.2.2.7 Sodo (Transect B9)....4-31
4.2.2.8 Maria-Gleta Ground (Transect B10)....4-34
4.2.2.9 Maria-Gelta Station (Transect B11)....4-35
4.2.2.10 The Hio Beach (Transect B6)....4-36

TABLE OF CONTENTS

4.2.3 Biological 4-37
4.2.3.1 Macro Ecology 4-37
4.2.3.2 Microbiology 4-38
4.3 Surface Water and Sediment Characterization 4-38
4.3.1 Physical 4-38
4.3.1.1 Grain Size 4-38
4.3.2 Chemical 4-40
4.3.2.1 Physics – Chemistry 4-40
4.3.2.2 Physics – chemistry of water 4-48
4.3.3 Biological 4-52
4.3.3.1 Benthos 4-52
4.3.3.2 Plankton 4-54
4.4 The lagoons and marshes habitats 4-63
4.4.1 Coastal Lagoon (Transect B5) 4-63
4.4.1.1 Physico-Chemical Characteristics of the Water 4-63
4.4.1.2 Vegetation 4-63
4.4.1.3 The Soil 4-64
4.4.2 Marsh of Adjahindji (Transect B4) 4-65
4.4.2.1 Physic and Chemical Characteristics of Water 4-65
4.4.2.2 Vegetation 4-65
4.4.2.3 The Soil 4-66
4.4.3 The Akadjamè Marsh (Transect B2) 4-66
4.4.3.1 Physico-Chemical Charasteristic of Water 4-66
4.4.3.2 Vegetation 4-66
4.4.4 The Hêvié Marsh 4-67
4.4.4.1 Physico-Chemical Characteristic of Water 4-67
4.4.4.2 Vegetation 4-67
4.5 Wildlife and Animal Resources 4-68
4.5.1 The Fauna 4-68
4.5.1.1 The Non fowl fauna 4-69
4.5.1.2 The Fowl Fauna 4-71
4.5.2 Turtles Survey 4-72
4.5.2.1 Methodology 4-72
4.5.2.2 Characteristic 4-72
4.5.2.3 Threat for Sea Turtles Life 4-74
4.5.2.4 The Clutch Sites 4-75
4.5.3 Conclusion 4-75
4.6 Fish and Fisheries Resources 4-75
4.6.1 The Area of Study Presentation: The Coastal Lagoon Avlekete – Hio4-75

4.6.2 The Fishermen Population 4-76
4.6.3 The Used Engines 4-77
4.6.4 The Species Caught....................4-77
4.6.5 Main Fishing Season....................4-84
4.6.6 Organisation of the Fishing Products Trade 4-84
4.6.7 Conclusion 4-85
4.7 Climate, Meteorology, and Air Quality 4-85
4.7.1 Average Rainfall Regime of the Margino-littoral Area in Benin 4-86
4.7.2 Hygrometry in the Margino-littoral Area in Benin....................4-86
4.7.3 Average Thermometrical Regime of the Margino-littoral Area.......4-86
4.7.4 Winds in the Margino-littoral Area in Benin....................4-86
4.7.5 The Link of Seasons in the Margino-littoral Area in Benin 4-87
4.7.6 Sunstroke....................4-93
4.7.6.1 The Variation of Temperatures....................4-93
4.7.6.2 Vapour Pressure 4-93
4.7.7 Conclusion 4-94
4.7.8 Air Quality 4-94
4.7.8.1 Causes and Demonstrations of the Air Pollution on the Coastal Plain4-94
4.7.8.2 Facts and Environmental Indicators of the Air Quality on the Coastal Plain of Benin 4-95
4.7.8.3 Quantification and Assessment of the Air Pollution....................4-95
4.7.8.4 Consequences of the degradation of the air quality and enfeeblement measures4-100
Chapter 5 Conclusion 5-1
5.1 VEGETATION 5-1
5.2 Soils 5-1
5.2.1 On The Coastal Plain 5-1
5.2.2 On The Plateau....................5-2
5.3 The Environmental Impact Assessment 5-3
Chapter 6 References 6-1

List of Figures

Table 2.7-1 Transects and Sampling Locations....................2-5

Figure 4.2-1 Variation of the Number of Bodies in Deep Surface 4-37

Figure4.2-2 Specific Relation Variety and the Total Number of Bodies on the Transects Grounds of 4-38

TABLE OF CONTENTS

Figure 4.3-8 Comparison of Temperature on Surfaces and in Depth (hurt 1 and 2 = transect B2 , 3 and 4 = transect 5 , 7 and 8 = transect 9)..4-49

Figure 4.3-9 Comparison of Average Temperature in Depth between Dry and Raining Season (hurt 1 = transect B2 , 2 = transect 4 and 3 = transect 5)...4-49

Figure 4.3-10 Comparison between Dissolved Oxygen on Surfaces and in Depth (points1 and 2 = transect B2,3 and 4 = transect 4 , 5 and 6 = transect 5 , 7 and 8 = transect 8 and 9 = transect 9)..4-50

Figure 4.3-11 Relation between the Salinity, the TDS, and the Conductivity Read One the B2 , B4 , B5, B8 and B9 Transects (Hurt 1,2,3 and 4 = transect B2 , 5 , 6, 7 and 8 = transect 4 , 9 , 10, 11 and 12 = transect 5 , 13 , 14, 15 and 16 = transect 8 and 17 and 18 = transect 9)..4-51

Figure 4.3-12 Variation du DBO5 en surface et en profondeur et d'un transecte à un autre (points 1 et 2 = transecte B2, 3 et 4 = transecte 4, 5 et 6 = transecte 5, 7et 8 = transecte 8 et 9 = transecte 9)..4-51

Figure 4.3-12 Variation du DBO5 en surface et en profondeur et d'un transecte à un autre (points 1 et 2 = transecte B2, 3 et 4 = transecte 4, 5 et 6 = transecte 5, 7et 8 = transecte 8 et 9 = transecte 9)..4-52

Figure 4.3-13 Variety (Number of Sorts) and Abundance of Benthics Bodies..................4-53

Figure 4.3-14 Primary Productivity on each transect in Grams/year.................................4-57

Table 4.3-2 Species found in each sampling point of each transect. 4-58

Figure 4.7-1 Evaluation of the CP1 Tendency on the Benin Environment Monsoon Deason in (1961-1990) by Mann-Kendall Method. (The direct curve is in fined line, the curve degrades is represented in fat; the threshold of 95 % is in dotted lines; the threshold of 99 % is in a point - hyphen.) (Houndénou, on 1999)..4-89

Figure 4.7-2 The Evaluation of the CP1 Tendency on the of the Beninese Small Dry Season in the Environment (1961-1990) By Mann-Kendall Method. (The direct curve is in fined line, the curve degrades is represented in fat, the threshold of 95 % is in dotted lines, the threshold of 99 % is achieved with a point - hyphen.) (Houndénou, on 1999) 4-90

Figure 4.7-3 Evaluation of the CP1 Tendency on the of the Second Season of Cultivation in the Benenese Environment (1961-1990) by Mann-Kendall Method. (The direct curve is in full line; the curve degrades is represented in fat; the threshold at the beginning of 95% is in dotted lines, the threshold at the beginning of 99% is achieved with a point-hyphen) 4-90

Figure 4.7-4 Full Low Season , Evaluation of the CP1 Tendency at the Threshold of Annual Time in Benin Environment from the Test of Mann-Kendall. (The direct curve is in fined line; the curve degrades is represented in fat; the threshold at the beginning of 95 % is in dotted lines; the threshold at the beginning of 99 % is achieved with a point accompanied with a hyphen) 4-91

Figure 4.7-5 Variation in the Number of the Rainy Days in the South of Benin 4-92

Figure 4.7-6 Variability of the Water Vapour Pressure in Cotonou 4-93

Figure 4.7-8 Concentration des divers de polluants dans l'air das la plaine côtièree 4-96

Figure 4.7-9 Temporal Variation of CO_2 / ht emissions ; from 1993 to 2010 (Source: Houndénou and al.: on 2002)........ 4-97

Figure 4.7-10 Temporal Variation of CH_4 / ht emissions; in Benin from 1993 to 2010 4-97

Figure 4.7-11 Evolution des émissions de NOx 4-98

Figure 4.7-12 Secteurs de transport 4-99

Figure 4.7-13 taux des infactions respiratoires aigües dues à la dgrdatio de la qualité de l'ir à Cotonou........ 4-100

List of Tables

Table 4.1-1 Different prospected habitats and their geographical coordinated. 4-1

Table 4.1-2 Structural Parameters and Diversity Signs 4-3

Table 4.1-3 Signs and Structural Parameters for the Two Seasons Diversity 4-6

Table 4.1-4 Evolution of the Specific Richness in Term of Seasons........ 4-8

Table 4.1-5 Diversity Signs and Structural Parameters 4-10

Table 4.2-1 European Standards of Concentrations of Grounds in some Heavy Metals and Elements Tracks........ 4-18

Table 4.2-2 Physico-chemical Data on the Samples of Akadjamè Swamp Surface Water N°1 4-20

Table 4.2-3 Organic charges and contents in hydrocarbons of the Akadjamè swamp sediments samples N°1 4-21

Table 4.2-4 Organic Charges and Contents in Hydrocarbons of the Ground Sample at the Cococodji Gas Treatment Station (Transect B1) 4-22

Table 4.2-5 Organic charges and contents in hydrocarbons the Cococodji samples ground (Transect B7's) 4-23

Table 4.2-6 Physico-chemical Data on the samples of the Hio coastal lagoon surface water 4-24

Table 4.2-7 Organic charges and contents in hydrocarbons of the Hio coastal lagoon sediments samples 4-25

Table 4.2-8 Physico-chemical Data on the samples of the swamp surface water from Adjahindji to Hio (Transect B4) N°2 4-26

Table 4.2-9 Organic charges and contents in hydrocarbons of the swamp sediments samples from Adjahindji to Hio (Transect B4) N°2 4-27

Table 4.2-10 Physico-chemical Data on the Hêvié Samples Swamp Surface Water (Transect B8's) N°3 4-28

Table 4.2-11 Organic charges and contents in hydrocarbons of the Hêvié sediments swamp samples (Transect B8's) N°3 4-29

Table 4.2-12 Physico-chemical Data on the Hêvié samples ground (Transect B8) 4-30

Table 4.2-13 Physico-chemical Data on the Sodo swamp surface water samples (Transect B9) N°4 4-31

Table 4.2-14 Organic charges and contents in hydrocarbons of the Sodo swamp sediments samples (Transect B9) N°4 4-32

Table 4.2-15 Physico-chemical Data on the Sodo grounds samples (Transect B9) 4-33

Table 4.2-16 Physico-chemical Data on the Maria - Gléta samples ground station 4-34

Table 4.2-17 Physico-chemical Data on the Maria - Gléta Ground Samples Station 4-35

Table 4.2-18 Physico-chemical Data on the Hio Beach Ground Samples (Transect B6) .. 4-36

Figure 4.3-1 Comparison of Temperature Read on Surface and in Depth (points 1 and 2 = transect B2, 3 and 4 = transect 5, 7 and 8 = transect 9) 4-40

Figure 4.3-2 Comparison of Average Temperature Read in Depth between Dry and Raining Season (points 1= transect B2, 2 = transect 4 and 3 = transect 5) 4-42

Figure 4.3-3 Comparison between Dissolved Oxygen Rate on Surface and in Depth (points1 and 2 = transect B2,3 and 4 = transect 4, 5 and 6 = transect 5, 7 and 8 = transect 8 and 9 = transect 9) 4-43

Figure 4.3-4 Relation between the Salinity, the TDS and the Conductivity Read on the B2, B4, B5, B8 and B9 Transects (points 1,2,3 and 4 = transect B2; 5, 6, 7 and 8 = transect

B4; 9, 10, 11 and 12 = transect B5; 13, 14, 15 and 16 = transect B8; and 17 and 18 = transect B9) 4-44

Figure 4.3-5 DB05 Variation on Surface and in Depth and from One Transect to Another (point 1and 2 = transect B2, 3 and 4 = transect 4, 5 and 6 = transect 5, 7 and 8 = transect 8 and 9 = transect 9) 4-45

Figure 4.3-6 Relation between Specific Diversity and Benthos Bodies Total Numbers of Wet Zones Transects 4-46

Figure 4.3-7 Relation between Specific Diversity and Total Number of Transect Soils Bodies 4-47

Table 4.3-13 Variety and Specific Abundance of the Zooplankton Great Groups 4-54

Table 4.5-1 Average Number of the Sea Turtles Caught during the Last Clutch Period according to Species and per Zone 4-75

Table 4.6-1 Fish Species Composition, Abundance, Size Range, and Mean, Weight Range, Weight Mean, and Total Weight of the Mangrove Fishes in the Benin Coastal Zone. Data are from Combined Samples from Cast Net, Seine, Gill Net, and Cross-Lake Fish Trap. 4-79

Table 4.6-2 Fish Production (in tonnes) from the West Complex Main Lakes (data of 1997)4-85

Executive Summary

The Gas Pipeline route crosses the coastal plain from Hio-Houta (06°20’46,8’’ N, 02°15’17,5’’ S) to Cococodji (6°22’93.3 " N, 02°15’42.8" E) on around 4,800km, through sandy costal ridges, lagoon, swamps (salted and unsalted), and clay-sandy glacis.

GEOLOGICAL AND GEOMORPHOGICAL SETTING

Geological evolution of the Benin sedimentary shore has been mainly conditioned by sea-level fluctuations, and secondly, by local tectonic movements (the hypothetical Togbin, Godomey and Krake faults, as defined by LANG & PARADIS (1977). The sedimentological indices reported by different authors (ASSEMIEN et al., 1970) enable us to explain the evolution of the Benin coastal plain.

Coastal Geology

Trapezoidal in shape and cornered in the Gulf of Guinea, the beninois continental plateau covers a surface area slightly more than 2,800km^2 between isobaths 10 and 100m, but reaching 3,000km^2 at a depth of 200m according to the estimates of COPACE (TROADEC and Coll. 1979). Extending over about 110km of coastline, its width varies between 22 and 24km in the west up to Ouidah and reaches 31.50km at the Benin-Nigerian border in the east.

At a depth of approximately 35m from Agoué to Ouidah-Beach, and between 35 and 45m from Godomey-Beach to Sèmè-Beach, a slight break in the slope marks the end of the shelf at a coral reef located at an average depth of 55m. From this barrier to around the talus, one observes numerous scattered rocky outcrops that greatly limit demersal trawling in these zones.

Waves break obliquely on the Benin shore and transport sediments generally toward the east. The shoreline segment where the pipeline is proposed to cross, between Djègbadji and Adounko-Plage, is generally a stable area, although some areas (near Togbin, for example) are susceptible to erosion.

Dredging operations carried out during the ″OMBANGO″ campaigns of 1963 revealed the existence of four types of bottoms arranged in parallel bands following isobaths 10 to 100m (Crosnier and Berrit 1966). These four types of sediments are described below.

- Hard bottoms (two categories)
    - Gorgonian bottoms
    - Coral bottoms
- Muddy sand bottoms**.**
- Sand bottoms
- Sandy mud and muddy bottoms

Onshore Geology

Grey and brown sands are found along lagoon depressions. Mainly quartzous, they are average, coarse-grained sands with increasing clay content near the depressions. Clay content varies between 5 and 25%. Yellow sands are average to fine-grained sands that contain small amounts of clay, i.e., less than 10%. In sand quarries, they appear in bulk without sedimentary formations and fossils. A bar is a clay and sand formation made up of lateritic clays that result from the destruction of old soils. Bars are characterized by well-pronounced sedimentology. There can also be soil formation on the bars as a result of organic matter deposition. The pipeline ROW crosses three generations of cordons separated by depressions. From south to north, they are as follows:

- A narrow, brown sandbar that stretches parallel to the sea. Its plane morphology shows intertwining ripples and butts at the local level;
- A first depression that results in lagoons such as the one south of Togbin and Adounko villages;
- A grey sandbar, 2 to 4m high, such as that which lies between the Wegba depression in the north and the coastal lagoon in the south. The edge of the lagoon is made up of wetlands and sandy spits. The whole area is mostly flooded during the wet seasons;
- A second depression named Wegba, such as that between Godomey and Dekoungbe. This depression is connected to Lake Nokoue;
- A “yellow sandbar” such as that which lies between Ouidah and Cotonou. Its height varies from 5 to 6m, with some ridges reaching up to 7m high;
- A third depression, which is about 400m wide, stretches along the south edge of the plateau. This is the west-east oriented Djonou depression from Cococodji to Godomey. It has nearly permanently flowing water, contributed by Towo, Todouba, and Date Rivers. These rivers drain the tablelands en route to Lake Nokoue; and
- A bar plateau with altitudes reaching 40 to 50m in the southern part of Abomey–Calavi.

Geomorphology

Sandy beach dunes resulting from the longshore drift (W-E) closed the rias and gave rise to coastal lagoons and marshes that can be flooded from Grand-Popo to Cocotomey. The lagoons are generally 1 metre deep, reaching up to 3 or 4 metres in depth in the outlets channels of the Sazue, Mono and N’Gbaga rivers. In the flooded areas and low valleys of the Oueme, Couffo, and Mono rivers, we can observe many lagoon and river deposits dating from the ***Nouakchottian*** to the present. These fine grained and heterometric sized deposits (sand, mud and clay) can reach thickness of 47 metres at Ghezin.

The Sandy beach ridges were formed during glacio-eustatic Holocene marine fluctuations (from around 5,000 years B.P.): they have an average width of 2.5km and separate the lagoons from the ocean. They are strictly parallel and oriented W-E. Relatively narrow from

Grand-Popo to Cocotomey, where coastal lagoons cut it, the shore is wider and subdivided into many ridges from Godomey onwards. Both the granulometric and morphoscopic characteristics of the dune sand point to its marine origin. It was spread under homogeneous hydrodynamic conditions.

In the study area, two types of ridge generation can be distinguished:

- The oldest ridges (around 5,000 years B.P.), formed by white sand appear along the clay-sandy glacis.

- The recent ridges, of reddish-brown sand, spread around 2,500 years B.P. (first ridges) and 1,490 years B.P. (second ridges)

Since the formation of the last ridges, minor transgressions have taken place up to 500 years B. P., the last dunes forming close to present day ones. The last transgression was rapid and brought sea level down below present-day Zero. In the last century or so, the sea is once again rising to initial zero, thus causing a dangerous evolution of the shore.

METEOROLOGY

The climate of the Gulf of Benin is classified as “beninian” (subequatorial) with two rainy seasons (mid-March to July and September to November) and two dry seasons. The average rainfall is 1.2m per year, decreasing toward the west (1,400mm per year in Sémè and 850mm per year in Lomè); the decrease is due to the configuration of the coast in relation to the marine winds. The temperature is constantly high (yearly average is 27°C) with the average maximum in March (33°C) and the average minimum in August (25°C) when temperatures can fall to 22.5°C. The months of January, February and March record high thermal amplitudes (12°C). These variations are reduced during the rainy season.

The predominant direction of the wind is from the southwest with average speeds of 4 to 6m/s^{-1} (3 Beaufort). The winds from the south-southeast sector are infrequent and they blow in April and May. Because of the relatively even relief, the pattern of winds does not vary much according to seasons. In the dry season, the wind strength is weak-to-moderate (2 to 5m/s^{-1}) in the morning. It is stronger during the day (5 to 7m/s^{-1}) and becomes moderate in the evening and at night (4 to 6m/s). During the rainy season, a moderate wind blows (4-6m/s^{-1}) in the morning, which becomes stronger in the afternoon (6 to 8m/s^{-1}) and remains constantly moderate-to-strong (5-8m/s^{-1}) in the evening and at night. The peak speeds are reached during the passage of rain lines (east to west direction) with an average speed of 15m/s^{-1} and accompanied by harsh winds and rainstorms.

PHYSICAL AND CHEMICAL OCEANOGRAPHY

The Benin coast is part of the Gulf of Guinea, which is subject to two main currents: the Guinea Current (GC), or equatorial current, and the Equatorial Counter Current, which is sub-marine. The GC is on the surface and persists throughout the year. Its speed varies between 1.5m/s^{-1} to 0.5m/s^{-1}. It moves from west to east along the Benin coast. From June to December, driven by northeast winds, the speed of the current is at its maximum. Between July and August, the GC moves from the east to the west and is slower.

Long swells of distant origin, whose wavelengths may vary between 160 and 220m, are typical along the Benin coast. These swells break on the bar at 150 to 200m away from the shore. The height of the swell observed in Cotonou varies between 1.0 and 2.0m.

Weak swells whose mean range varies between 0.9 and 1.3m occur between December and March, and those whose mean range varies between 1.6 and 1.9m occur between June and August Larger swells, as high as 4.5m, can be observed between June and September.

BIOLOGICAL SETTING

Phytoplankton

The presence of diatoms, dinoflagellates, various microscopic alga, and nannoplankton (coccolithes) is reported on the Beninese continental plateau of the Atlantic ocean. (Fiogbé, 2000, John et al., 2001).

Zooplankton

For aminiferans, radiolarians, copepods (with higher biomass than all other animals), small shellfishes, amphipods, isopods, decapods, ostracods, which constitute the link between primary plant productivity and species exploited are adequately represented in the Atlantic Ocean at the southern border of Benin (Wiafe et al., 2001). The major species have been listed by Wiafe et al. (2001) in the Gulf of Guinea including Benin.

Benthic Organisms

The major groups of benthic macro-invertebrate species harvested in West Africa by Yankson and Kendall (2001) are sufficiently represented in Benin.

Marine Tortoises

According to Fischer et al. (1981) the marine tortoises of the center-East Atlantic are grouped into two families, five genera and 6 species (*Caretta caretta caretta, Chelonia mydas mydas, Eretmochelys imbricata, Lepidochelys kempii, Lepidochelys olivacea, Dermochelys coriacea coriacea*). The two families: *Chelonidae* and *Dermochelidae* are often fished accidentally on the coast of Benin. Capturing of tortoise is prohibited in Benin as in most Gulf of Guinea countries, due to population depletion.

Whales and Dolphins

Humpback or “Jubarte” whales *(Megaptera novaeangliae)* have been very recently observed on the Beninese continental plateau at depths generally varying between 13 and 35m, with less frequent observations between 27 and 600m depth. The whale species identified are of *Jubarte generus (Megaptera novaeangliae).* The different fins (caudal of certain subjects) have white and black stains. Others are black on the upper face and white on the lower face. Bottlenose dolphins *(Tursiops truncates)* have also been observed at a depth of approximately 31m.

Marine Fishes

To date, 449 marine fish species have been recorded on the coasts of Benin (out of the 25,000 species known worldwide). These 449 species, identified from about 1000 collections of the Fisheries Department and the Department of Zoology/FAST/UNB, were caught at various habitats of the Atlantic Ocean at the southern border of Benin. They include benthic or demersal fishes, open sea or pelagic fishes and abyssal fishes from great depths. Based on the taxonomical group, FishBase (2000) has reported a total of 3 classes containing 37 orders. In these orders, 129 families have been identified, involving 294 genera and 449 species.

Details on species found on the coasts of Benin are presented in Appendix X. According to Vanden Bossche and Bernacsek (1990), among these identified fish species 373 are marine, 76 marine and brakish water; 261 are recognized as having potential for commercial fishing, 4 have aquaculture potential (*Megalops atlanticus*, *Ethmalosa fimbriata*, *Epinephelus aeneus, and Mugil curema*), 16 have potential for live export; 77 for sport fishing; 15 are said to be endangered fishes *(Serranidae, Rhincodontidae, Scombridae, Xiphiidae,* etc), 2 potentially protected (*Dalatias licha, Hippocampus hippocampus*); and 34 are recognized as endangered (including *Epinephelus itajara, Xiphias gladius, Carcharias taurus*, *Pristis microdon, Pristis pectinata*, etc.

VEGETATION

Vegetation (trees, shrubs, and understory) composition, abundance, and diversity was sampled during the First Season EBS at 18 samples points arranged along five transects. The transects sampled, from Djokpotomegon up to Ahouangagbe near the sea, represented the following plant community types: fallow land, degraded swampy forest, thicket, swampy grassland, mangrove, and coastal coconut grove, and are described in more detail below.

Plants identified included 171 species in 136 genera and 55 families. Herbaceous species dominate the vegetation with 117 (68.42%) of the species. Shrubs and trees are represented by 34 species (19.88%) and 20 species (11.70%), respectively. The families with the largest representation by species are, in decreasing order: Poaceae with 24 species (14.03%), Fabaceae with 21 species (12.28%), Cyperaceae with 18 species (10.52%), and Rubiaceae with 7 species (4.09%). Two families possess 5 species each (2.92%). Abundance parameters and diversity indices are provided in the First Season EBS Report.

LAND USE

Small scale agriculture is common in the study area. However, productivity of farms is limited by arid conditions and poor soil. Cultivation on the barrier islands consists predominately of large-scale coconut plantations. Nearly 3% of the total national agriculture value is practiced on approximately 9,000ha below an elevation of 2.0m (240ha of this is in the intertidal zone). These plantations are associated with private land ownership. They provide relatively substantial incomes to the landlords, most of whom are absent, or else devote their time to fishing in the lagoons or sea. Along the inland margins of lagoons, vegetables, grains, and pulses (e.g., cassava, maize, and cowpeas) are grown.

CULTURAL RESOURCES

People in the study area rely on the plants for medical care. Appendix 5-A presents a summary of information gathered during the First Season WAGP EBS on local use of medicinal plants. Twenty-two plant species are used to treat 23 diseases out of a total of 171 species.

CHAPTER 1
INTRODUCTION AND BACKGROUND

The second phase of the study of the main gas passage zone onshore in Benin consists in starting again in rainy season, various works made on the same zone in dry season (Nov.-December, 2002). The works of the ground known as sampling earth ground, in lagoons and swampy zones, the technics of analysis (vegetation, granulometry, microphone-granulometry, measure of pH, Biology, Hydrogeology) were described during the first report. In the description of the physical environment, we will insist on the portion of the main gas plan which was not taken into account during the first phase, namely the plateau, the ground, the bar zone in the North of the yellow sand bar.

The overall project area in Benin with the proposed pipeline right-of-way (ROW) is shown in Chapter 5 of the EIA. More specifically, as one walks from the open water end of the project area and travels inland, one will traverse a number of distinct areas. The onshore area begins in the intertidal zone, which is about 20m wide and is comprised of sands of average coarseness and shell fragments smaller than 10cm. Next comes a sandy beige-colored beach with patchy grasses and coconut trees. Located along the crest of the beach is a road that runs from Cotonou to Ouidah, commonly called the “fishermen’s road.” Inland from road, is the beginning of a coconut plantation that is approximately 400m wide and has an herbaceous layer. The land slopes downward from here toward the lagoon. Between the coconut plantation and the mangrove area, which runs along the edge of the lagoon, are wetlands that are used to grow market vegetables. The sandbar area between the sea and the lagoon is approximately 100m wide. The lagoon is about 800m wide. Opposite the lagoon, the sandy substrate slopes gently upward and is vegetated by coconuts and understory plants. This is a narrow strip of land that farther inland becomes a brackish marsh, about 1km wide, vegetated by *Paspalum vaginatum*, with occassional islands of mangroves. Next one encounters the last of the onshore sandbars, which is about 1km wide. It is comprised of fine gray-colored sands and supports shrubby savanna vegetation and oil plam trees. This topographic unit ends in a freshwater marsh, about 100m wide, vegetated by *Fuirena umbellata* and *Eleocharis complanata*. Rising inland from this marsh one enters a glacially formed upland that has a yellow sand substrate and is vegetated by shrubby savanna (with *Annona senegalensi* and *Rauvolfia vomitoria*), interspersed with patches of cultivated crops. It is on this upland area, bordered by the Interstate Cotonou-Lome railway, that the R&M station will be built. Approximately 50m inland from the railway is the plantation of Mrs. Adjovi. From this plantation to Maria-Gleta, the route continues along the edge of a marsh that lies adjacent to the southernmost edge of the Allada plate, which has a red clayey sand substrate. In this most inland portion of the route there is a marshy forest that also has patches of oil palm groves. These have recently been planted. When the route encounters the high voltage electrical transmission lines it bends south and runs parellel to the transmission corridor until it reaches the future CEB station at Maria-Gleta.

CHAPTER 2
ONSHORE FIELD METHODS

Location and numbering seem important as far as it is not necessary to confuse the samples of this campaign with those of the first while being able to move closer and compare samples taken at the same level during two campaigns.

- Location is made for the G.P.S. "Garmin e trex Summit" as in the first campaign.

- For the numbering of samples, the same numbers were kept: B1a1, B1a2, … B6a1, B6a2, preceded in figure 2 (to express the second campaign). We thon have: 2B1a1, 2B1a2, 2Ba4; 2B2a1, 2B2a2, …, 2B2a4; 2B6a1, 2B6a2 … , 2B6a4 to indicate the various horizons of pédological pits B1, B2, …. B6 made at the level of the six transects during the first campaign and which were summarized for the sampling of the second campaign. The cuttings of 2B1 in to 2B6 (B1 into B6 of the first campaign) extend thus over the littoral zone with its bars and wet zones. Then, the composite samples were sharply distinguished and analyzed. They are numbered 2B1cp1 and 2B1cp2 for the cutting 2B1, …. 2B6cp1, and 2B6cp2 for the cutting 2B6.

- For the numbering of the new transects samples the plateau of the ground and the bar, the same system was held from the North of bars towards the plateau. We distinguished there five pedological pits, of 2B7 into 2B11. So, we indicate by 2B7a1, the superficial horizon of the cutting 2B7, 2B7a2, the included horizon between 0 and 15cm , 2B7a3 that included between 15 and 30cm, 2B7a4, the horizon included between 30 and 50cm of the same cutting.

2.1 VEGETATION SAMPLING

The different types of plants formation are identified during the land recognition. A transect of 60m long is installed inside each plant formation. The position of transects, along the forest track, is chosen by impredictable drawing lots. Three points of statement, 20m far from one another, are defined on each of the transect. At each point, two concentric circular places of 10m and 15m ray are installed. Then, five square places, of 1m each side, with one in the center of the circles and four at the ends of the two diameters 10m ray slanting to the circle. In those 10m ray circular places, the diameter of a man size (dbh) some trees higher than 7.50m are measured. Withing the 5m ray circular places, shrubs and yellow trees of dbh<7.50m can also be counted in order to determine their density. Finally, the square places of 1m side allowed to count some ligneous of less than a meter high and the herbaceous. The collection of each specy is visually appreciated following the scale of 1 to 10, recommended in the terms of reference (annexe 1).

The principle of “timed meader search” is used to collect the non inventoriated species in the places (term of reference of WAGP). That method allows to appreciate the specific richness of each type of plant group. The non-identified species on the ground are reaped and numbered. They are determined by Hutchinson and Dalziel flora (1954) and also by comparison with Herbier National of Benin specimen. The fertile samples are sent up and deposited to the Herbier. The adopted list is that of Lebrun and Stock (1991;1992; 1995; and 1997).

2.2 SOIL SAMPLING

2.2.1 Taking on Continent

On the ground, trenches were realized by means of tools as hoe, machete, pickaxe and shovel. The required depth is 50cm with takings made as above indicated. The composite samples are made with mixture of two levels (0 and 0-15cms: 2Bncp1, 15-30cm, and 30-50cms: 2Bncp2), Bn indicating the pedological pit with moving from 1 to 11.

2.2.2 Taking in Water Plans

The sampling sediment in water plans is made by means of Birge-Ekman's truck. It is the device which serves for making punctual takings. It is used for the soft sediments of our lagoons. The non-disturbance of the sample in the ascent and the moderated penetration in the mud return this very practical sampling for the study of the superficial collection sediments in water plans of plans of water.

2.3 SURFACE WATER AND SEDIMENT QUALITY AND HYDROBIOLOGY

2.3.1.1 Sampling Water for the Primary Production

It takes place on surface and in depth at the level of every no sampling zone. Bottles of 1 liter filled directly surfaces and kept in the darkness (packaging with the aluminium foil) until the laboratory. The water taking of depth was possible due to a bottle of Van dom. Once in the laboratory, the samples of water (4 by station) are maintained in the darkness and kept in the refrigerator in 4°C.

2.3.1.2 The Sampling of the Plankton

It is made on 8 points of sampling defined at the level of every studied station. In every no sampling of swamps (Stations B2 and B4) and in shallow places of the lagoon (station B5), a volume of 40 liters of water is taken with of a bucket and is concentrated in a jar of 250ml by means of a net with plankton of 55µm of stitches, provided with funnel of 40cm diameter (Hydro-bios Kiel, 55µm Cat. No. 438040). In the deep places the lagoon (depth>1m), the net with plankton is dragged over 10m. The protocol of collection and concentration of the very plankton is described by Bourrelly (1960). The concentrated samples are directly fixed to the formalin in 5%.

2.3.1.3 Sampling of Sediments and Harvest of the Benthiques Macro Invertebrates

The objective of this work is to know the variety of macro invertebrates in 5 various stations (B2, B4, B5, B8, and B9) defined within the framework of the study. 5 samplings were made in every station. The sites of samplings were chosen so as to cover all the station and to sample in all the biotopes.

Let us note that by definition, the benthiques macro-invertebrates waters indicate bodies such as Mollusks, Insects, Annelides, etc. which size at the end of embryonic development or in the imaginal stage is superior to 500µm.

In every station, they collected macro-invertebrates with a net of type Troubleau. It is made of a circular metal frame 25cm of diameter to which it is fixed a net of opening stitch 500µm and 30cm of the pocket. This frame is deep supported by one sleeve light of 1.5m long which allows to move the set of Troubleau in the water and to harvest the benthos in the first centimeters of the sediment.

So, the frame deposited in the heart of the water is slightly pushed in the sediments and by a regular movement, they scrape this sediment over about 1m. The sample returned on surface is put down on a sieve of 500µm and cleared the sheets, grits and mud by rinsing in the water.

Meditative bodies are poured in a bottle and fixed with the formalin 4%. They will be sorted out in the laboratory.

2.3.1.4 Harvest Bodies of Grounds

The various sites of sampling being defined in a station, they dig in every site with a hoe holes of 50cms in deep. A quantity of 2kg of sand is taken there and put sieving on a column of 2 sieves of stitch 200µm and 500µm. The sand as well as the meditative bodies are directly poured in small bottles, then fixed to the formalin 4%.

2.4 IN-SITU METHODS

2.4.1 Mesures in situ des paramètres physico-chimiques

The physico-chemical parameters of the water were measured in situ in the various sites of sampling. Temperature and dissolved oxygen were measured with an Oxythermomètre WTW Oxi 197/set of respective precision 0.1°C and 0.01mg. L-1 whose probe is plunged in 10cm deep in the water. Measures of pH were made with a pH-metre WTW pH 330/SET-0 of precision 0.01 unity of pH plunged in 10cm deep in the water.

Salinity (°/oo), specific conductivity (µS/cm), the TDS (MG/L) was measured with a conductimetre mark WTW LF 340/SET.

The depth was measured with Secchi's.

2.5 WILDLIFE AND ANIMAL RESOURCES

The adopted method comprises an inquire phase from the populations of the localities crossed by the gas pipeline and a prospecting phase for the physical characteristic study of the area and for the biological resources inventory sensitive to be influenced by the ecological parameters effects attached to the gas pipeline installation.

The inquiry that lasted three (3) days, has been carried out in the villages close to gas pipeline line and has been directed to various possible aspects of the impacts on the area. We have kept some data related to the fowl fauna (birds) and non fowl (Amphibians, Reptiles and Mammalians).

The prospecting also lasted five (05) days:

- Two days to appreciate the biotop characteristics

- Three days for the biological resources inventory and their identification.

The matter is almost an itinerant prospecting on foot for the last two. The birds identification and inventory have be achieved with the binoculars and telescope for the distant specimen and to the view for the close specimen.

The non fowl fauna inventory has been performed by a direct inventory for the animals that are seen during the prospetings and by an indirect inventory for the unseen animals whose presence in the zone is proved by their footprints (traces, scabs, phareries…) and the animals whose existence in the zone has been noticed by the populations.

The co-ordinates of the landmarks have been recorded with GPS.

2.6 FISH AND FISHERIES RESOURCES

The Team led three actions to the methodological plan:

1. A documentary study relating inter alia to the documents relating to inshore and maritime fishing;
2. A qualitative investigation near the structures had a presentiment of to hold the data of fishing concerning the zone of study;
3. A qualitative investigation near the Stakeholder people (fishermen).
4. The sampling procedure used for the individual interviews and the investigation into the living resources is the Simple Random Sampling (SRS)

2.7 SAMPLE TRACKING, STORAGE, AND SHIPPING

include sample listing

Simple ground and composite ground were sampled separately according to the work plan, with hoe and shovel. Samples for microbiology were put in sterilized bottles in the field. They were then transported to the laboratory where the ones for microbiology analysis were cooled in 4°C, and those for macroecology were stored in formalin 5%.

Sediment samples were collected with troubleau net for benthos determination and with pèle for microbiology analysis. Those for benthos determination were stored in formalin 5% and those for microbiology were stored in sterilized bottles and cooled in 4°C.

Water samples for microbiology analysis were collected directly in the field with sterilized bottles and those for physicochemical analysis and phytoplankton biomass analysis were stored in 2 litters bottles. All water samples were cooled in laboratory at 4°C.

Table 2.7-1 Transects and Sampling Locations

Transect	Simple ground	Composite ground	Longitude	Latitude	Sediment	Longitude	Latitude	Water	Longitude	Latitude
B1	2B1a1	2B1 cp1	6°22'56,2''	2°15'25,4''						
	2B1a2	2B1 cp2	6°22'56,2''	2°15'25,4''						
	2B1a3		6°22'56,2''	2°15'25,4''						
	2B1a4		6°22'56,2''	2°15'25,4''						
B2	2B2a1	2B2 cp1	6°22'28,5''	2°15'23,8''	2B2 s1	6°22'26,8	2°15'23,6	2B2 ps1	6°22'26,8	2°15'23,6
	2B2a2	2B2 cp2	6°22'28,5''	2°15'23,8''	2B2 s2	6°22'26,9	2°15'23,7	2B2 pf1	6°22'26,8	2°15'23,6
	2B2a3		6°22'28,5''	2°15'23,8''	2B2 s3	6°22'26,9	2°15'23,4	2B2 ps2	6°22'26,8	2°15'39,7
	2B2a4		6°22'28,5''	2°15'23,8''	2B2 s4	6°22'27,1	2°15'23,7	2B2 pf2		
					2B2 s5	6°22'27,6	2°15'23,8			
B3	2B3a1	2B3 cp1	6°22'7,3''	2°15'23,9''						
	2B3a2	2B3 cp2	6°22'7,3''	2°15'23,9''						
	2B3a3		6°22'7,3''	2°15'23,9''						
	2B3a4		6°22'7,3''	2°15'23,9''						
B4	2B4a1	2B4 cp1	6°21'9,5''	2°15'9,0''	2B4 s1	6°21'10,3	2°15'9,6	2B4 ps1	6°21'10,3	2°15'9,6
	2B4a2	2B4 cp2	6°21'9,5''	2°15'9,0''	2B4 s2	6°21'10,4	2°15'8,5	2B4 pf1	6°21'10,3	2°15'9,6
	2B4a3		6°21'9,5''	2°15'9,0''	2B4 s3	6°21'10,1	2°15'7,9	2B4 ps2	6°21'9,9	2°14'58,8
	2B4a4		6°21'9,5''	2°15'9,0''	2B4 s4	6°21'9,7	2°15'4,5	2B4 pf2	6°21'9,9	2°14'58,8
					2B4 s5	6°21'9,9	2°14'58,8			
	2B5a1	2B5 cp1	6°20'49,9''	2°15'7,7''	2B5 s1	6°20'52,3	2°15'7,5	2B5 ps1	6°20'52,3	2°15'7,5

Transect	Simple ground	Composite ground	Longitude	Latitude	Sediment	Longitude	Latitude	Water	Longitude	Latitude
	2B5a1	2B5 cp1	6°20’49,9’’	2°15’7,7’’	2B5 s1	6°20’52,3	2°15’7,5	2B5 ps1	6°20’52,3	2°15’7,5
B5	2B5a2 2B5a3	2B5 cp2	6°20’49,9’’	2°15’7,7’’	2B5 s2 2B5 s3	6°20’54,7 6°20’55,7	2°15’7,7 2°15’8,7	2B5 pf1 2B5 ps2	6°20’52,3 6°20’59,8	2°15’7,5 2°15’8,4
	2B5a4		6°20’49,9’’	2°15’7,7’’	2B5 s4	6°20’57,8	2°15’9,4	2B5 pf2	6°20’59,8	2°15’8,4
					2B5 s5	6°20’59,8	2°15’8,4			
	2B6a1	2B6 cp1	6°20’46,2	2°15’17,3						
B6	2B6a2	2B6 cp2	6°20’46,2	2°15’17,3						
	2B6a3		6°20’46,2	2°15’17,3						
	2B7a1	2B7 cp1	6°23’37,4’’	2°15’40,2’’						
	2B7a2	2B7 cp2	6°23’37,4’’	2°15’40,2’’						
B7	2B7a3		6°23’37,4’’	2°15’40,2’’						
	2B7a4		6°23’37,4’’	2°15’40,2’’						
	2B8a1	2B8 cp1	6°23’45,3’’	2°16’25,0’’	2B8 s1	6°23’45,2	2°16’26,1	2B8 ps1	6°23’45,2	2°16’26,1
	2B8a2	2B8 cp2	6°23’45,3’’	2°16’25,0’’	2B8 s2	6°23’45,9	2°16’25,4	2B8 pf1	6°23’45,2	2°16’26,1
B8	2B8a3		6°23’45,3’’	2°16’25,0’’	2B8 s3	6°23’46,3	2°16’25,4	2B8 ps2	6°23’45,9	2°16’25,4
	2B8a4		6°23’45,3’’	2°16’25,0’’	2B8 s4	6°23’46,6	2°16’25,3	2B8 pf2	6°23’45,9	2°16’25,4
					2B8 s5	6°23’44,5	2°16’25,8			
	2B9a1	2B9 cp1	6°24’22,3	2°16’55,4	2B9 s1	6°24’22,0	2°16’54,7	2B9 ps1	6°24’22,0	2°16’54,7
	2B9a2	2B9 cp2	6°24’22,3	2°16’55,4	2B9 s2	6°24’22,3	2°16’54,9	2B9 pf1	6°24’22,0	2°16’54,7
	2B9a3		6°24’22,3	2°16’55,4	2B9 s3	6°24’22,4	2°16’54,8			

Transect	Simple ground	Composite ground	Longitude	Latitude	Sediment	Longitude	Latitude	Water	Longitude	Latitude
	2B9a4		6°24'22,3	2°16'55,4	2B9 s4	6°24'22,7	2°16'54,9			
					2B9 s5	6°24'23,1	2°16'54,3			
B10	2B10a1	2B10 cp1	6°26'3,1''	2°17'43,6''						
	2B10a2	2B10 cp2	6°26'3,1''	2°17'43,6''						
	2B10a3		6°26'3,1''	2°17'43,6''						
	2B10a4		6°26'3,1''	2°17'43,6''						
B11	2B11a1	2B11 cp1	6°25'24,7''	2°18'23,1''						
	2B11a2	2B11 cp2	6°25'24,7''	2°18'23,1''						
	2B11a3		6°25'24,7''	2°18'23,1''						
	2B11a3		6°25'24,7''	2°18'23,1''						
TOTAL	**43**	**22**			**25**			**18**		
Conservation	Réfrigérés à 4°C pour la microbiologie Formolé à 4 % pour la macroécologie	Cooled in 4°C for the microbiology Formolé in 4 % for the macroecology Formolé à 4 % pour la macroécologie			Cooled in 4°C for the microbiology Formolé in 4 % for the macroecology			Cooled in 4°C for the microbiology		

CHAPTER 3
ANALYTICAL METHODS

3.1 PHYSICAL LABORATORY METHODS

3.1.1 Measure of pH

It was made in situ to allow to see the real state of the sediments ground samples sourness in the environment.

It takes 20g of sediments to which it is added 50ml of distilled water. The mixture is shaken hanging about ten minutes to homogenize, then left with the rest, during about fifteen minutes, so that the solid particles really settle at the bottom. We then proceed to the measurement of pH on the surface of the sediment. This one was made with an electronic pH-metre for direct posting.

3.1.2 Granulometry

3.1.2.1 Preparatory Treatments

Most of the samples are sandy-clayey. 150 to 200 grammas have been treated for the granulometry. The samples that have plant remains have been attached by peroxide (H_2O_2, 220 volumes) before the taking of the 150 grammas. After the washing or the square mesh sieve of 0.050mm edges, the inferior fraction to 0.050mm obtained in the Erlenmeyer has been concentrated then dehydrated in the small dish in a steam room. The percentages related to the two fractions have been calculated.

3.1.2.2 Splitting up Technique

For the study of granulometry supply, the samples have undergone a sifting. The superior fraction to 0.050mm is divided by a series of sieves (2; 1; 0.50; 0.250; 0.125; 0.063; 0.050mm). The sifting is performed by an apparatus of Rotap type ducting 15mn. Each of the fraction is weighted to the hundredth of grammas and the respective percentages are calculated compared with the totality of the treated sediment.

3.1.2.3 Modes of Graphic Representation

The supply of the heights is the subject of diverse representations. Those that have been used here are the cumulative curves at ordinate of probability, which have been drawn by hand. They highlight the gaps of supply compared with the gaussian curve and enable to adapt to individual circumstances granulometric stocks. They have enable to measure the value of the median (height of the particles for cumulated mass of 50% sediment) as well as to calculate graphically various parameters of supply.

3.1.2.4 Nomenclature used to Characterise the Supplies

The nomenclature used is the one Chamley, 1987 repeated in 2000. The supplies observed in all our takings show that the samples are entirely devoid of superior height particles to 2mn. We distinguish four granulometric classes:

- coarse sands (diameter included between 0.50 and 2mn), 1 to –1
- medium sands (0.250 and 0.50mm) 2 to 1
- thin sands (0.063 and 0.25mm) 4 to 2
- the silts and clay (inferior diameter to 0.063)

3.1.2.5 Granulometric Parameters

The different parameters seek to characterise the granulometric supplies. They have been determined graphically. The formulas used are those of FOLK and WARD (1957 and repeated partly by Chamley, 1987 and 2000).

- the mode is the granulometric class for which the frequency is maximal Mo
- the median represents the diameter of the corresponding particles to 50% of the cumulative curve. M_d
- the average of the medium grain gives an idea of the medium granulometric fan of a given sample

In a symmetrical supply, the mode, the median and the average are confounded.

- classification (sorting or deviation standard) shows the dispersal of the heights compared with the average of the sample.

$\mu = \phi16 + \phi\ 5O + \phi84$

In the symmetrical supply, the mode the median and the average are confounded.

- Classification (sorting or deviation standard) shows the dispersal of the heights compared with the average of the sample.

$0<\phi\ i<0.35$: very well classified sediment; $0.35<\phi i<0.50$: well classified;

$0.50<\phi i<0.71$: well classified enough; $0.71<\phi i<1.0$: fairly classified;$1.0<\phi i<2$; poorly classified; $2<\phi i<4$: very mineral classified

- asymmetry (Skewness sk_i) shows the predominance or not of thin particles (positive values) or coarse (negative values), compared with the samples average.

+ 1.0>ski>+0.30: strong symmetry towards the small height; +0.30>ski>+0.10: asymmetry towards the small height; +0.10>ski>-0.10: granulometric symmetry of the sample; -0.10>ski>-0.30: asymmetry towards the big heights; -0.30>ski>-1.0: very strong asymmetry towards the great heights.

3.2 CHEMICAL LABORATORY METHODS

3.2.1 DBO5's Measure

The dissolved oxygen is first moderate and after 5 days of incubation in 20°C by an Oxythermometre WTW Oxi 197/set and respective precision of 0.01 mg. L-1. Every sample is kept in the darkness (packed in the aluminium foil). Difference considered in mg O2/liter represents the DBO5 as quantity of oxygen consumed in 5 days.

The test of DBO5 allows an estimation of the organic charge from the quantity of oxygen which will have been consumed for its partial oxidation in 5 days. In the present study, this polluting load charge is measured with a typical DBOMÈTRE OXITOP "single measuring system". The principle of this method consists in brooding a definite volume of water (that is 250ml) of every sample in the OxiTop's dark bottle of 20°C. This bottle is closed hermetically with a neck containing a jar in which is deposited 2 tablets of soda. The electronic neck automatically registers every day a value or a digit. The digit posted{*shown*} after 5 days by incubation is multiplied by a factor indicated in a corresponding table delivered with the instrument. Factor corresponding to the volume of 250ml is 5. Digits obtained here after 5 days from incubation are multiplied by 5 to obtain DBO5's values, as organic charge or polluting charge in 1 liter of water in the environment.

3.2.2 Primary Production and TOC

The study of the primary production consists in estimating the capacity of a system to be transformed in external energy (light and chemical substances) in consistant organic which will serve to superior trophiques levels feed. Photosynthesis, as well as chimio-autotrophes processes, are then the essential phenomena of the primary production.

A first approach of the productivity of a system allows to estimate biomass (" status crop ") with primary producers. However, it is not necessary to lose sight that processes in question are dynamic, and that a biomass (in other words, a quantity of organic matter present at the given moment) is only the result of the difference between processes of production (raw assimilation of carbon) and processes of disappearance (breath, mortality, grazing, dilution …). We can write:

DB / dt = (P-D) B

Where B = Biomass in g C m^{-2} or in g C m-3
P = Term of production (rate of primary production), in j-1
D = Sum terms of disappearance, in j-1

A population or a community of bodies can so remain only if P>D. It is then necessary, to estimate the primary production of the studied stations, to measure the rate of production P, as well as the biomass which assures the assimilation of the carbon in these stations.

Let us add besides that the study of the primary production implies the follow-up of the parameters which directly influence it: light (on surface and in the column of water), temperature, stream of the nourishing elements (CO2, N, P, …).

The present study was realized on 5 stations of soft and brackish waters of the South Benin. At the level of every station, 4 samples of water are taken.

3.2.3 Protocol of Measure

3.2.3.1 Chlorophyllous Pigments Measurement

We filter 0.5l of every sample by means of a vacuum pump (KNF NEUBERGER, type N 022 AT. 18). Pigments are extracted from some plankton collected on a filter GF/C, 90 Ø, placed in a glass tube, by a solvent established with a mixture acetone 90 methanol 5/1 (5 ml). The origin makes in warmly by investment of tubes in a bath marries (Fisher, T ° max: 100°C) in 65°C within 2 minutes. The absorbence confronts the spectrophotomètre in 665mn before (Db) and after (Da) acidification in the HCL 0.1N (Lorenzen, on 1967). Concentration in chlorophyll as "active" and is calculated according to the general equation based on the decrease of the absorbance of the acidified extract (Pechar, in 1987). Equation is the following one:

Chla (µg / l) = (Db - Da) * 2,439 * 11,89 * v / (V*l)

With:

V = Volume of filtered sample (l)
V = Volume of the solvent (ml);
L = Thickness of the washbasin of spectrum (cm);
Db = D.O. before acidification;
Da = D.O. after acidification

3.2.3.2 Conversion in Total Organic Carbon (TOC)

The report Carbon/chlorophyll can vary to a large extent according to the acclimatization in the light, the nutritional state and the age of the algales populations. It is then necessary to determine ideally the carbon organic report: chlorophyll of the phytoplankton, by measures in COP (organic carbon particules) and some chlorophyll on the same samples. However the usual range of the report C:Chla is situated between 30 and 50, where it often adopts the mean value of 40. In other words:

C] = [Chl.a] * 40

3.2.4 Primary Production

The methods of measurement of the primary planktonic production aim to estimate the daily production of carbon by the phytoplankton, in g C.m^{-2}.j-1. For a sufficient sampling in time, we can estimate annual production. This generally expresses in raw production, either added up over the year (g C.m^{-2}.a-1), or averaged (g C.m^{-2}.j-1). The estimation of the primary production of the studied stations is based on the method of calculation simplified by Talling (1957):

In (mg C or mg O2 m^{-2} j-1) = nPmax / k Ln (2Io / Ik) T 0,9

Where:

N biomass phytoplanktonic (mg chla m-3) is
Pmax the photosynthetic capacity of the phytoplancton (in mg C or mg O2.mgChla-1.h-1)
K the extinction coefficient (in m-1)
Io the average luminous intensity of the day (in µE m^{-2} S-1)
Ik intensity at the beginning of the satisfaction (in µE m^{-2} S-1)
? T the average duration of the day

In other words, production on a column of water (A) depends on the phytoplanktonic biomass (n), on the coefficient of extinction (k), of the photosynthetic activity in saturating light (Pmax) and Io/Ik.

Pmax's values, influenced by the temperature, are more raised in tropical lakes and estimated in about 25±5mg O2.mg Chla-1.h-1 (Descy, in 2002).

Ln's (2Io/Ik) values vary a bit in time, generally speaking of the given adaptation of alga to the brilliant climate. In tropical region, we often find very constant values (between 2 and 3), for example 2.6 for the lakes in East Africa (Talling, in 1965). We then used the mean value of 2.5.

T the average duration of a day, is constant in intertropical environment and estimated at 12 hr within the measures.

The light extinction coefficient is estimated from the depth of secchi (sd). Indeed, according to Descy (2002), k=2/sd.

Phytoplanktonic Biomass (n), strongly controlled by the availability in nutriments, is with the extinction coefficient (k), only variable parameters. This biomass is determined by the concentration in chla of the environment.

In other words, the used formula is:

?? In (mg O2 m^{-2} j-1) = 25*n / k * 27

To find the value of the production in mg C m^{-2} j-1, we divide the value in to mg O2 m^{-2} j-1 by 3,33 (3,33 g produced D'O2/molecule of assimilated carbon).

3.2.5 Observation, Identification, and Counting of Planktonic Types

3.2.5.1 The Phytoplankton

The concentrated samples are observed in the laboratory. No special preparation is made for the observation of alga. A dozen preparations, equivalent to 1ml of every sample is examined to allow the inventory big majority of alga existing in the circles (Iltis, in 1980) and to estimate their abundance. Observation is made by with a photonic microscope (L II ooB). Objectives 10, 40, and sometimes 100 (in dumping) are used with the ocular WF 10x.

The used guides of identification are:

- The Sahélo-soudanian Africa Flora and aquatic Fauna (During and Levêque, in 1980);
- The Alga of fresh water: yellow and brown Algae (Bourrelly, in 1981);
- The Alga of fresh water: blue and red Alga (Bourrelly, in 1985);
- The Alga of fresh water: green Alga (Bourrelly, in 1990);
- Initiation into the systematics of Diatomées of soft water for the practical use of an indication diatomic generic (Rumeau and Coste, in 1988);
- Seaweeds of the Tropical West Africa Sub-region (John and al. in 2001).

3.2.5.2 The Zooplankton

As regards the quantitative study of the zooplankton (Rotifères, Copépodes and Cladocères), the adopted methodology is based on the counting in Dollfus cell, (NIVAL, in 1967). Dollfus cell is an oblong tub divided into 200 compartments (10 compartments by row of vertical line x 20 rows) of 0.5cm aside, separated some of the others by mouldings of 1mm height. The plankton to be studied, once poured into the cell, becomes a sediment, and can be counted compartment by compartment. When it moves the cell under the binocular magnifying glass during the counting, the mouldings prevent the bodies from moving from a compartment to the other. According to this method, we had analyzed 5ml of every well shaken sample. Considering the available keys, the identification of cladocères and copépodes was not able to continue until the level of sorts as to rotifers.

The used keys are:

- Flora and aquatic Fauna of the Sahélo-soudanian Africa (During and C. Levêque, in 1980)
- Marine zooplankton of west Africa (Wiafe and Frid, in 2001).
- Introduction to the study of the South Benin plankton (Gominan, in 2000).

3.2.5.3 Sorting of the Benthic Bodies

In the laboratory, the first rinsed sample is washed in a column of 6 sieves of 20cm diameters each and an opening stitch from 4mm to 500µm. Fragments are spread and the bodies of every sieve are transferred in tubs of sorting. They are sorted out at sight and classified roughly speaking according to the big taxinomic groups then kept in pilulars containing the formalin 4%.

3.2.5.4 Determination of the Benthic Bodies

The determination of these macroinvertebrates made with binocular magnifying glass Pierron (x10, x25, x35) and different keys of the macroinvertebrates identification, of soft and brackish waters. We used in certain cases of common binocular microscope (10x10; 10x40) with the aim of observing indispensable structures to the precision of the definite body status.

The determined macroinvertebrates are classified with sample of pilulars containing the formalin 4%.

List used keys of determination

- Atachi P., in 1983. Insects classification key. Collection of practical boards works, Agro 3, FSA Benin.
- Brown D.S. and Kristensen T.K. in 1993. On the field drive to African freshwater snails. 1. West African species. Danish Bilharziasis Laboratory. 55p.
- Fischer, W. (Ed). in 1973. Rome, FAO, pag. The Var. Do{*throw*} FAO of the identification sorts for the necessities of the peach. The Mediterranean Sea and Black Sea (Zone of peach) 37. Volume 2
- Fischer, W. (Ed). in 1981. Rome, FAO, pag. The Var. FAO of the identification sorts for the necessities of the peach. Zone of pêche34 , 47 (partially). Volumes 3 and 4.
- Maslin J.-L. in 1985. Populatings mollusks benthiques of a lagoon of the South-Benin (the lake Ahémé): factors of their distribution and impact of the variations of the conditions of the environment{*middle*}. Verh. Boarding school. Verein. Limnol. 22. Pp. 3300-3305.
- Micha J-C and Noiset J-L, in 1982. Biologic evaluation of the pollution of brooks and rivers by the aquatic invertebrates. SEEN AGAIN{*REVISED*} PROBIO, quarterly publication flight{*theft*} 5 n°1. 143 p.
- Nicklès M on 1953. Scaphodes and Lamellibranches harvested in the African West. 94-237.
- Nicklès M, in 1950. The Occidental rib shellfishes maritime Mollusks of Africa. 269p.

- Tachet H., Bournaud M and Richoux P., in 1980. Introduction to the study of the macroinvertebrates soft waters (elementary Systematics and ecological outline). Limnologie's French association. 151p.

3.2.6 Microbiology of Waters, Sediments and Grounds

Analysis made in these samples of grounds, sediments and water can amount in detecting, the enumeration and the identification of microbodies parasites, which they contain.

3.2.6.1 Material and Methods

Material

The used material is composed with glass factory and instruments collectively met in the microbiology laboratories.

The glass factory is composed with:

- The test tubes of 16 x 160mm and of 20 x 200mm
- The erlen meyers of 250ml, 500ml and 1000ml
- Pipettes with a total drainage increased with 1ml, 2ml, 5ml, and 10ml with a precision of 1/10
- Them limp of MOLDED with diameter 90mm
- Layer
- Tubes of hemolyse
- Durham bells

The Instruments are:

- Carded cotton
- Handle of platinum
- Beak Bunsen + gas
- Plastic, holder wooden and in metal
- Washing bottle of alcohol and distilled water
- Aluminium foil
- Marker pens

- Bacteriological leading MEMMERT steam room with a maximal reach of 70° ±1°C
- Leading SANOCLAN autoclave
- Leading CONCORD refrigerator
- Maximal oven of reach 70°C
- Precision balance 0.001mg

Cultural circles and reagent:

- Dabbed peptoned water to make main suspension
- Simple peptoned water to make dilutions
- Agar standard to enumerate (PCA)
- Red-purple bile agar
- Agar baird Parker (BP)
- Bacto-Sulfite Agar (BSA)
- Blue Eosine of the Methyl alcohol (EMB)
- Bile Esculine Azide Agar (BEA)
- Oxytetracycline Glucose Agar (OGA)
- Malt Extract Agar (MEA)
- Rothe broth
- Broth in the Brilliant Green (BLBVB)
- Reagent of Kovacks
- Egg yolk emulsion of the potassium tellusite
- Solution of tetracycline of 0.10%
- Solution of the ammoniacal citrate iron
- Sterile distilled water

Methods

The methodology used for all the microbiologic analysis are relative to the capacities of 'International Standard Organization (ISO)'.

So, as far as the analysis of grounds, the procedures are the following:

- General directives for the preparation of dilutions with the aim of the microbiologic examing ISO/D15/6887
- Total flora: ISO/D15/4833
- Coliformes: ISO/D15/4832
- Coliformes sulfito-reducers: ISO/D15/7937
- Yeasts and molds: ISO/D15/7954
- Pathogenic staphylococci: ISO/D15/6888

As for the water analysis, the methods concern:

- The colimetry: technics of the Most likely Number (NPP) and Test of Mackerzie
- Coliforme in 30°C: ISO 4831
- Coliformes thermotolerants in 44°C: ISO 4832
- Escherichia coli presumed: ISO 7251
- ENTÉROCOQUES ISO 7899
- Spores of sulfito-reducing Clostridium: 7937
- Aerobic flora total mesophile in 30°C: ISO/D15/4833

The confirmations of the enterocoque presence in the water samples consist in isolating agar Muse Fisculine Azide Rothe's tubes which present a confusion.

3.3 BIOLOGICAL LABORATORY METHODS

3.3.1 Vegetation

The land surfaces of trees of different typify of vegetation is given by the formulated: G=£D (with G=expressed land surface in m2/ha and D the diameter of trees of man hight). It is calculated for trees of dbh>7.5cm.

The populating density is the number of the stem by hectare. It is calculated for trees and shrubs having has dbh<7.5cm.

The specific diversity of format is interpreted with help of specific richness and the diversity sign of Shannon (Legendre& Legendre on 1984; Frontter& Pichod-Vitale, on 1991). That indication is established from the formulated: A hour=-£pilnpi (with pi=importance related to the species i). Total The specific richness (Rs) is the number of species in the studied community.

CHAPTER 4
RESULTS

4.1 VEGETATION

In total eleven (11) transects, with six (6) between Atlantic Ocean and the R&M Station and 5 of the R&M Station at Maria Gléta are installed (Picture 1). The different prospected environments and their geographical coordinated are summarised in Table 4.1-1.

Table 4.1-1
Different prospected habitats and their geographical coordinated.

Housing	Code	Points	Geographical coordinated			
		Sampled	Dry seasons		Rainy seasons	
			Latitud (DD)	Longitud (DD)	Latitud (DD)	Longitud (DD)
STATION R&M BEACH						
		B1-1	06.38200°N	02.25702°E	06.38223°N	02.25707°E
Fallow	B1	B1-2	06.38195°N	02.25707°E	06.38187°N	02.25703°E
		B1-3	06.38179°N	02.25707°E	06.38179°N	02.25702°E
Forest		B2-1	06.37446°N	02.25665°E	06.37446°N	02.25670°E
Swampy	B2	B2-2	06.37431°N	02.25669°E	06.37430°N	02.25670°E
Graduated		B2-3	06.37415°N	02.25669°E	06.37415°N	02.25669°E
		B3-1	06.36982°N	02.25631°E	06.36985°N	02.25634°E
Thicket	B3	B3-2	06.37002°N	02.25633°E	06.37007°N	02.25629°E
		B3-3	06.37013°N	02.25631°E	06.37020°N	02.25636°E
Grassland		B4-1	06.35283°N	02.25250°E	06.35292°N	02.25244°E
Swampy	B4	B4-2	06.35306°N	02.25256°E	06.35310°N	02.25247°E
		B4-3	06.35321°N	02.25247°E	06.35329°N	02.25247°E
		B5-1	06.34780°N	02.25208°E	06.34760°N	02.25222°E
Mangrove	B5	B5-2	06.34749°N	02.25213°E	06.34745°N	02.25210°E
		B5-3	06.34729°N	02.25215°E	06.34730°N	02.25210°E
Coconut palm plantation		B6-1	06.34652°N	02.25474°E	06.34649°N	02.25481°E
Littoral	B6	B6-2	06.34627°N	02.25477°E	06.34634°N	02.254779°E

Housing	Code	Points	Geographical coordinated			
		Sampled	Dry seasons		Rainy seasons	
			Latitud (DD)	Longitud (DD)	Latitud (DD)	Longitud (DD)
		B6-3	06.34615°N	02.25477°E	06.34616°N	02.25483°E
R&M STATION MARIA GLETA						
		B7-1			06.39237°N	02.25925°E
Coconut palm plantation	B7	B7-2			06 .39227°N	02.25918°E
		B7-3			06.39206°N	02.25917°E
		B8-1			06.39373°N	02.26125°E
Fallow	B8	B8-2			06.39375°N	02.26146°E
		B8-3			06.39371°N	02.26163°E
		B9-1			06.39598°N	02.27374°E
Grassland	B9	B9-2			06.39403°N	02.27383°E
Swampy		B9-3			06.39410°N	02.27392°E
		B10-1			06.40629°N	02.28212°E
Field	B10	B10-2			06.40642°N	02.28225°E
		B10-3			06.40666°N	02.28232°E
		B11-1			06.43417°N	02.29555°E
Thicket	B11	B11-2			06.43403°N	02.29538°E
		B11-3			06.43393°N	02.29518°E

4.1.1 R&M Station to the Sea

4.1.1.1 Floristic Inventory

The counted flora in rainiy season, are 222 species, grouped in 166 types and 61 families (annexe 2). It is clearly dominated by herbaceous species that are 150 in number, about 67.57% of the whole collected taxous. The shrubs and the tree are respectively represented by 47 species, means 21.17% and 26 species, about 11.71%. The most represented families with regard to the number of species in descending order are: Poaceae: 36 species, or 16.22%; Fabceae 24 species, or 10.81%; Cyperaceae: 22species or 09.91%; Rubiaceae: 15 species that is to say 06.76%; Euphorbiaceae: 09 species, that is to say 04.05%; Mimosaceae: 07 species, that is to say 03.15% and Commelinaceae: 6 species or 2.70%. The other families count from 1 to 4 species.

4.1.1.2 Characterisation of Plants Formation

The structural parameter and the diversity sign of the different families are recorded in Table 4.1-2.

Fallow (Transect B1)

It is grassy fallow studied with variable thicket surface. The herbaceous cover from 0 to 1m high and 90% collection is composed with several species whose most important are: Setaria pumila, Cassia rotimdifolia, sporobolus pyramidalis, perotis indica, cyperus margaritaceus and schyzachyrium sanguineum.

The thickets have between 0.5 and 1.5m high. The total covering is estimated to 20%. The most frequent species are: Annona Senegalensis, Lonchocarpus cyanescens, Rauvolfia vomitoria, Clerodendrum capitatum,Uvaria chamae,Dalbergia setifera, Trichoscypha oba and Psorospermum glaberrimum.

The land surface is nil; this can be explained by the total absence of tree of dbh>7.5cm. The density of shrubs of dbh<7.5cm and higher than 1m is 4774 1168 stems by hectare. The specific richness is 74 species. The Shannon diversity index is 0.1.59±0.17 for the shrubs and 3.04±0.37 bits for the herbaceous. The herbaceous stratum is thus the most diversified (Table 4.1-2). The differences are relatively narrow. These testify a regular spatial repartition of the individuals in that habitat.

Table 4.1-2
Structural Parameters and Diversity Signs

	G(m2/ha)	D(stems/ha)	R(%)	HA(bits)	Ha(bits)	Hh(bits)	Rs(bits)
Fallow	0	4794±1168	90	0	1.59±0.17	3.04±0.37	74
Gradated swampy forest	3.00±4.24	59.40±8400	78	0.25±0.35	0.46±0.65	2.25±0.98	65
Thicket	0.12±0.16	33431±8404	26	0	2.48±0.12	3.51±0.13	87
Swmpy grassland	0	0	70	0	0	0.77±0.76	17
Mangrove	0.63±0.89	1103±999	80	0	0.44±0.32	1.00±0.22	25
Coastal cocnut palm	2.55±3.60	4497±1680	25	0.55±0.40	0.73±0.38	2.91±0.16	56

G: Trees burrows surface of dbh>7.5cm; shrub density of dbh<7.5cm and height>1m:R: collection of ligneous below 1m high and fo herbaceous; Ha: diversity sign of Shannon trees for dbh>7.5cm; Ha: diversity sign of Shannon for shrub dbh<7.5cm and hight>1m; Hh: diversity sign of Shannon for for ligneous below 1m high and herbaceous; Rs: specific richness.

Gradated Swampy Forest (Transect B2)

Degradation is so deep. Structural profile comprises three stratums. Covered stratum, forum 4 to 8m high and a collection of 25% comprises only a characteristic *specy Syzygium guineense var*. Coastal zone covered with Acacia *Auriculiformis* and *cocos nucifera* that are transgressive taxons of a well drained zone.

The shrubby stratum from 1 to 4m high, has an average collection of 63%. The most representative species are*: Mussaenda isertiana, Tertracera alnifolia, Alchornea cordifolia and Syzygium guineense*.

Finally the herbaceous stratum from 1 to 1m high and a collection of 78% is constituted of numerous species whose most abundant are: *Fuirena umbrellata, Eleocharis complanata, Scleria achtenii* and *Leersia hexandra*.

The burrow surface is 3.00±4.24m2/ha. That low value can be explained by the so advanced state of that habitat defacement whose greenery stratum is only represented by some plants of cocs nucifera. These latter are observed on one list and on edge. This explains the strong value of difference–type which shows the large difference between the land surface of the three range of samples points of this habitat. The shrubs density of dbh<7.5cm and the hight above 1m is 5940±8400 stems/ha. The high value of the difference–type, compared with that of the average density shows that the shrubs density tremendously varies from one point of the list to another. The swampy forest degradation has also reached the shrub stratum whose structure is very heterogeneous. The specific richness is 65 species. The diversity sign of Shannon is 0.35±0.09 bits for the trees, 0.46±0.12 bits for the shrub and 2.25+ - 0.98 bits for the herbaceous. The herbaceous stratum has the strongest sign; it is thus the most diversified (Table 4.1-2).

Thicket (Transect B3)

It is a thicket at an advanced stage of reconstruction in a badly kept palm plantation. Two tratums can be distinguished:

- The shrubby stratum from 1 to 2m high has an average collection of 80%. The dominant species are: *Uvaria chamae, Zanthoxylum Zanthoxyloides*, *Gnestis ferruginea*, *Agelaea oblique*, *Rhaphiostylis beninensis*, *Tetracera almifolia*, *Rourea coccinea*, *Olax scorpioidea*, *Landolphia owariensis, Sorindeia wareckei*, *Dialium guineesnse*, *Diopyros tricolor*, *Flacourtia flavescens, Bridelia ferruginea*, *Carpolobia lutea* and *Lannea nigritana*;
- herbaceous stratum from 0 to 1m high and 30% of collection is less dense. It is composed with numerous species whose most frequent are: *Perotis indica*, *Cassytha filiformis*, *Pseudovigna argentea* and *Oldenlandia corymbosa.*

The burrow surface s very weak (0.12±0.16m2/ha). It can interpreted by a single plant of Mangifera indica of dbh>7.5cm. The shrubs density of dbh<7.5cm and above 1m is 33431±8404 stems per ha. That very high density demonstrates a shrubby thicket so cluttered. It constitutes the richest formation with 87 species. The density sign of Shannon is

0 bit for the trees, 2.48±0.12 bits for the shrubs and 3.51±0.13 bits for the herbaceous. Contrary to other formation, the shrubby stratum shows itself as well diversified as the herbaceous stratum (Table 1).

Swampy Grassland (Transect B4)

It is characterized by a single stratum, the herbaceous stratum from 0 to 1m high has 73% of covering. The most representative species are *Paspalum Vaginatum, Fuirena umbrellata, Centella asiatica* and *Cyperus articulatus*. The specific richness is 17 species and the diversity sign of Shannon is O.77±0.76 bits. That formation in its whole is very less diversified with regard to the previous ones (table1). It is located in the brackish area less favourable to many species. The high difference-type can be explained by the influence of the edge (floadable part) that is relatively more diversified with the wet zone companions species. The dominant species belong to Cyperaceae and Poaceae families.

Mangrove (Transect B5)

Mangrove is the best structured formation we met. It is situated by the coastal lagoon side, at the background of the coconut palm. It contains three stratums:

- Trees planted stratum of 6m high very closed with 60% of an average collection; it is completely dominated by *Rhizophora racemosa*;

- Shrubby stratum from 1 to 2m high with 5% of an average coverng. The most represented species are: *Rhizophora recemosa* at the waterside, *Aricennia germinans, Acrostichum Aureum, Dalbergia ecastaphyllum, Cassipourea barteri, Phyllanthus* reticulates and Syzyg*ium guineense* at the background of the bunch at *Rhizophora racemosa*

- Herbaceous stratum from 0 to 1m high with 75% of covering is diversified on the edge of the species like: *Pasalum vaginatum, Pycerus polystachyos, Eleocharis mutala, Scopiria dulcis, Pentodon pentandrus* and *Fuirena umbrellat*a.

In fact, mangrove is composed of two units (groups) juxtaposed parallel to the water plan:

- Amonospecific group at *Rhizophora racemosa* at the lagoonside.

- A group at Avicennia germinans and Acrostichum aureum at the background of the previous unit

The burrow surface about 0.63±0.89m2/ha is relatively low and its differnce-type is higher because the tree planted stratum is only present in only one list. That little value is due to the cutting of big mangrove of dbh<7.5cm whose wood is used to produce salt. The shrubs density of dbh<7.5cm with more than 1m is 1103± 999 stems per ha. The specific richness is 25 species. The value of the diversity sign of Shannon are all low. They are 0.44±0.32 bit for the shrubs and 1.00±0.22 for the herbaceous (table1). That low diversity can be explained through the difficult edaphic conditions (presence of salt) for the non adapted species.

Coastal Coconut Palm (Transect B6)

The coastal coconut palm covers a great part of the recent offshore bar. On the lagoon side, it is partly destroyed for tomatoes and corn culture.

The coconut palm with about 2m high constitutes the only individual tree planted stratum, apart from some rare plants of *Azadirachta indica* and *Acacia auriculiformis.*

In the bushy stratum, 1 to 2m high and 30% average covering the most frequent species are: *Azadirachta indica* and *Uvaria chamae*. The herbaceous stratum with less than 1m high and 50% recorvering is constituted of corn (*Zea mays*) to which can be added many species such as: *Catharanthus roseus, Tephrosia purpurea, Aristida adscensionis, Cassia rotundifolia, Ipomoea stolonifera, Cassitha filiformis, Opuntia tuna, Spermacoce stachydea* and *Croton lobatus.*

The burrow surface is 2.55±3.60m2/ha for the individual of dbh>7.5cm. The shrubs density of dbh<7.5cm and more than 1m high is 4497±1680 stems/ha. The specific richness is 56 species. The diversity density of Shannon is 0.55±0.40 bit for the trees, 0.73±0.38 bit for the shrubs and 2.91±0.16 bits for the herbaceous. The lowest values of the sign, observed at the trees and shrubs level can be explained by the plantation monospecificity (Table 4.1-2).

4.1.1.3 Seasons' Effects on the Flora and Vegetation

The seasonal study has shown modifications at the level of the structure and the flora of different formation. Table 4.1-3 summarises the different calculated variables.

Table 4.1-3
Signs and Structural Parameters for the Two Seasons Diversity

	G(m2/ha)	D(stems/ha)	R(%)	HA(bits)	Ha(bits)	Hh(bits)	Rs
Fallow dry season	0	6700	75	0	1.54	2.88	53
Fallow rainy season	0	4794 ±1168	98	0	1.59 ± 0.17	3.04±0.47	74
FM – dry season	1.97	4100	63	0.35	0.32	2.34	55
FM- rainy season	3.00± 4.24	5940±8400	78	0.25±0.35	0.46±0.65	2.25±0.98	65
Thicket – dry season	0.31	35700	87	0.19	2.27	2.34	78
Thicket rainy season	0.12±0.16	33431±8404	26	0	2.48±0.12	3.51±0.13	87
Grassland dry season	0	220	73	0	0.22	0.72	19
Grassland rainy season	0	0	70	0	0	0.77±0.76	17

	G(m2/ha)	D(stems/ha)	R(%)	HA(bits)	Ha(bits)	Hh(bits)	Rs
Mangrove dry season	0.63	17500	92	0.21	0.88	1.51	26
Mangrove rainy season	0.63±0.89	1103±999	80	0	0.44±0.32	1.00±0.22	25
Coconut palm – dry season	1.44	3400	50	0.55	0.52	2.42	32
Coconut palm – rainy season	2.55±3.60	4497±1680	35	0.55±0.40	0.73±0.38	2.91±0.16	56

G: Trees burrows surface of dbh>7.5cm; shrub density of dbh<7.5cm and hight >1m:R: collection of ligneous below 1m high and fo herbaceous; Ha: diversity sign of Shannon trees for dbh>7.5cm; Ha: diversity sign of Shannon for shrub dbh<7.5cm and hight>1m; Hh: diversity sign of Shannon for for ligneous below 1m high and herbaceous; Rs: specific richness.

4.1.1.4 Structural Modification

The fallow and the marshy forest have known the herbaceous covering rate growth, this can be explained by the individuals numbers and specific richness increase. In the thicket, the grassland, the mangrove and the coastal coconut palm, the rate has rather decreased; this is due to the improvement of high stratum covering at the thickets level, to the therophytes with great wreath disappearance by the end of the cycle in the grassland, coconut palm and the mangrove where the water level has increased (Table 4.1-3).

Apart from the fallow and the coastal coconut palm where the shrub density has known a substantial increase, this one has decreased in all the other formation because of the man high pressure who seeks for fire wood. In the thicket, the two feet of *Ficus spp* observed in the dry season are cut so that the diversity sign of Shannon of that formation has become nil and the burrow surface has passed from 0.31m^2/ha in the dry season to 0.12m^2/ha in rainy season. Also in the mangrove, many shrubs of *Avicennia germinaus* of *Rhizophora racemosa* and of *Acacia auriculoformis* observed in dry season are dead in rainy season. Their density then passed from17500 to 1103 stems/ha.

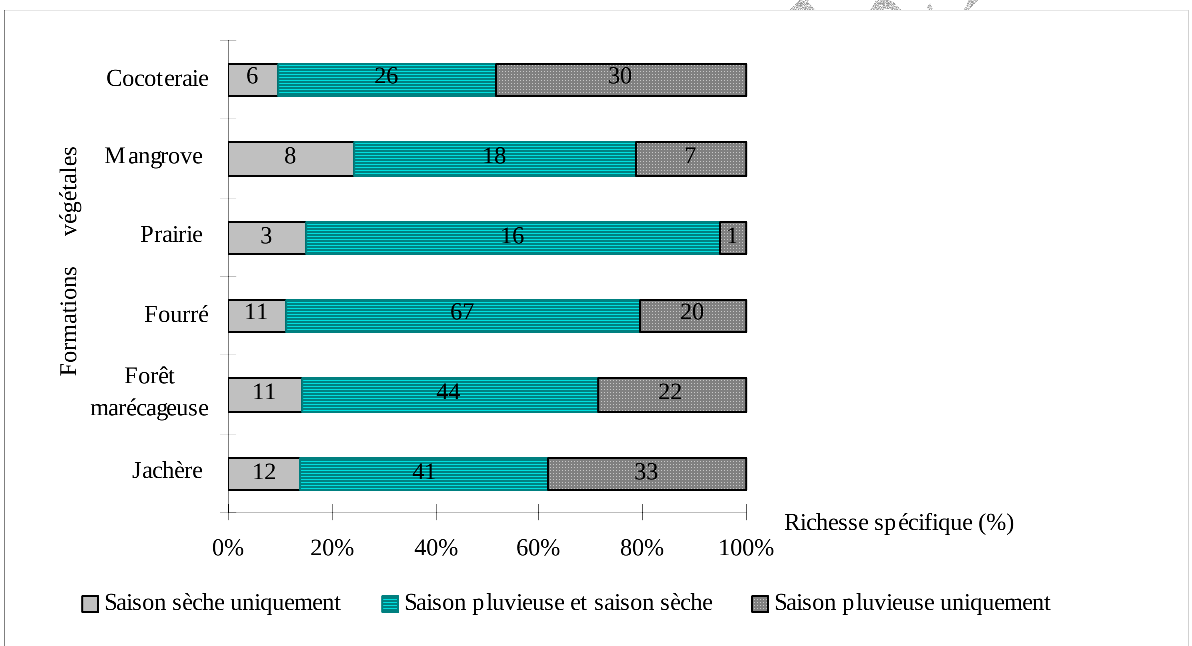
4.1.1.5 Floristic Modification

At the flora level, we notice the appearance of new herbaceous species, what led to the specific richness increase at the plants formations except grassland and mangrove (Table 4.1-4).

In the fallow the specific richness has passed from 53 to 74 species, that is to say an increase rate of 39.62%. In the total 86 species have been recorded within the two seasons in that formation. Among them 2 are exclusively for dry season and 33 for rainy season. The remaing 41 species are common for the two seasons. The increase of the specific richness can be explained by the appearance of many therophytes species with rainy seasons' favour. At the thickets level, the specific richness has passed from 78 species in dry season to 87 species in rainy season, that is to say an increase of 9 species with an increase rate of 11.54%. The total number of species for the two seasons is 98 with 11species exclusively in dry season, 20 exclusively in rainy season and 67 for both seasons. The thicket being formed of shrubby species, its seasonal variation is less sensitive on the floristic plan.

If the coastal coconut palm, the number of species has passed from 32 to 56 respectively for dry season and rainy season; the increase rate is then 75%. Sixty-two (62) species are recorded within both seasons with 6 exclusively in dry season, 30 in rainy season and 26 for both seasons. The high rate of increase can be explained by the development of many therophytes in rainy season.

Table 4.1-4
Evolution of the Specific Richness in Term of Seasons



In the marshy degraded forest, the specific richness has passed from 55 to 66 species with 20% of increase rate. The floristic record of both seasons give 77 species with 11 exclusively in dry season, 22 in rainy season and 44 for both seasons. The increase rate of the floristic richness can be explained by the appearance of many therophytes herbaceous species and suffrutex with the rainy season's influence.

The increase of specific richness in those different formations in rainy season has inferred the diversity sign increase of Shannon at the herbaceous level and/or the shrubs of dbh<7.5cm and height>1m. However, in the marshy grassland and mangrove, the consequence of the rainy season is the reduction of the species number and the diminishing of Shannon diversity sign. The increase of water level has led the disappearance of certain individuals and certain species (8 for mangrove and 3 for grassland).

4.1.2 R&M Station to Maria Gleta

The 5 transects installed at Maria Gleta run across the following plants formations: the coconut palm, fallow, marshy grassland, farm and thicket.

4.1.2.1 Floristic Inventory

The recorded flora in rainy season counts 195 species, grouped in 171 genders and 61 families (annexe 2). It is clearly dominated by the herbaceous species which are 109, that is to say 55.33% of the total. The shrubs and the trees are respectively represented by 59 species, that is to say 29.95% and 29 species, that is to say 14.72%.

The most represented families in the term of species number, by descending order are Poaceae: 21 species or 11%; Fabaceae: 19 species or 10%; Rubiceae: 13 species or 0.7%. Cyperaceae: 11 species or 0.6%; Euphorbiaceae: 11 species, or 0.6%.

4.1.2.2 Characterisation of Plan Formations

The diversity sign and structural parameter are found in Table 4.1-4.

Coconut Palm (Transect B7)

It is in fact a mixt formation constituted of coconut palm and cashew plantation overgrown by a reconstitution thickets. Three stratum are distinguished.

- Tree planted stratum, of 4 to 8m high with 5% of covering. It is dominated by C*ocos nucifera and Anacardium occidentale*.

- The shrubby stratum of 1 to 2m high with 70% of average covering. The frequent species are: *Uvaria chamae, Zanthoxylum zanthoxyloides, Rourea coccinea, Opilia celtidifolia, Annona senegalensis, Ranvolfia vomitoria and Psorospermum.*

Herbceous stratum of 0 to 1m high and 73% covering, is constituted of many species whose most frequent are: *Sporobolus pyramidalis, pandiaka involucrate, Ipomoea involucrate, Setaria pumila and Triumfetta rhomboidea*, etc.

The burrow surface relatively high is 6.98±5.46m2/ha. That value is due to the individual frequency of *Cocos nucifera* of 16cm<dbh<22cm and of *Anacardium occidentale* of 8cm<dbh<26cm. The shrubs density of dbh<7.5cm and of height above 1m is 14297±7545 stems/ha. The very high density can be explained by the development of a shrubby thickets that is formed under the coconut palm. The specific richness is 73 species. The Shannon diversity signs, calculated for trees, shrubs and grass are respectively 0.27±17; 1.82±0.35 and 33.3±0.21 bits. The most diversified are the herbaceous and shrubby stratums (Table 4.1-4).

Table 4.1-5
Diversity Signs and Structural Parameters

	G (m^2/ha)	D (tiges/ha)	R (%)	H_A (bits)	H_a (bits)	H_h (bits)	R_s
Coconut palm	6,98 ± 5,46	14297 ± 7545	73	0,27 ± 17	1,82 ± 0,35	3,33 ± 0,21	**73**
Fallow	0,27 ± 0,38	1909 ± 2101	63	0	1,14 ± 0,92	3,02 ± 0,17	**82**
Marshy grassland	0	255 ± 208	92	0	0,42 ± 0,30	0,84 ± 0,11	**25**
Farm Farm	0	127 ± 104	47	0	0	2,35 ± 1,68	**69**
Thicket	12,84 ± 8,17	22613 ± 15321	43	0,66 ± 0,46	1,74 ± 0,90	3,30 ± 0,19	**103**

Fallow (Transect B8)

It is a recent fallow. The structural profile is completely constituted of two stratums:

- The shrubby stratum of 1 to 2m high with about 12% of an average covering. The most frequent species are: *Rhaphiostylis beninensis, Zanthoxylum zanthosiloides, Clerodendrum thyrsoideum, Urania chamae, Abizia ferruginea and Macrosphyra longistyla.*

- The herbaceous stratum of 0 to 1m high and 63% covering is composed with many species whose most important are: Imperata cylindrical, Dolichos argenteus, Commelina erecta, Impmoea involucrate and Sporobolus pyramydalis. The burrow surface is 0.27±0.38m2/ha. The dbh<7.5cm shrubs density and above 1m high is 1909± 2101 stems per hectare. The specific richness is 82 species. The Shanno diversity signs calculated for the trees, shrubs and grassland are respectively of 0; 1.14±0.92 and 3.02± 0.17 bits. The most diversified seems the herbaceous stratum.

Marshy Grassland (Transect B9)

It is the ultimate stage of the marshy forest degradationwhere we have observed some rare cuts of Berlinia grandiflora. Two stratums can be distinguished:

- The shrubby stratum, well covered of 1 to 2m high with 1% of an average covering. The characteristic species are: Berlinia grandiflora (rejects), Phoenix reclinata and Alchornea cordifolia.

- The herbaceous stratum of 0 to 1m high with 92% covering. The most representative species are: Cyclosorus striatus, Typha australi, Leersia hexandra and Cyrtosperma senegalense.

The shrubs surface is nil and it can be justified by the dbh>7.5cm individual absence. The dbh<7.5cm shrubs density and above 1m high is 255±208 stems per hectare. The specific richness is low only 25 species. The Shannon diversity signs calculated for trees, shrubs and grass are respectively 0; 0.42±0.30 and 0.84±0.11 bits. The formation in its whole is less diversified comparing with the previous (Table 4.1-5).

Farm (transect B10)

It is a corn farm (Zea mays) badly kept and overgrown by the herbaceous whose most frequent are: Imperat cylindrical, Talinum triangulare, Rottbellia exaltat, Diditaria horizontalis and Phyllanthus amarus. The hrubby stratum is noticed through some young feet of Elaeis guineensis.

The burrow surface and the shrubs and trees Shannon sign are nil. The dbh<7.5cm shrub density and above 1m high is 127±104 stems/ha. The specific richness is 69 species. The herbaceous stratum Shannon diversity sign is 2.35±1.68 bits.

Thicket (transect B11)

It is preforested thicket. The presence of Angylocalyx oligophillus, characteristic species of forested gaps (Sokpon 1995 is an indicator. Three stratums are distinguished:

- Tree planted stratum of 4 to 8m high with 15% covering. It’s composed with Dialius guineense, Acacia auriculiformis, Elaeis guineensis, Perseaa Americana and Cassia siamed.

- The shrubby stratum of 1 to 2m high with an average 60% covering. The dominant species are: Dialium guineense, Bridelia furruginea, Rauvolfia vomitoria, Rourea coccinea, Millettia barteri, Agelae oblique, Raphiostylis beninensis, Sorendeia warneckei, Zanthoxylum zanthoxyloides, Leconiodiscus cupanuoides, Angylocalyx olygophyluus and Uvaria chamae.

- The berbceous stratum of 0 to 1m high with 43% covering is composed with many species whose most frequent are: Chassalia kolly, Mariscus alternifolius, Gnistis ferruginea, Rourea coccinea, Ipomoea involucrate, Oldenlandia offinis and Paullinia pinnata.

The burrow surface is relatively high: 0.31±8.17m2/ha. It is interpreted by the presence of some rare individuals of Dialium guineens, acacia auriculiformis, Elaeis guineensis, Persea Americana and Cassia simea of dbh>7.5cm. The shrubs density of dbh<7.5cm and above 1m high is 22613±15321 stems per hectare. That high density very high shows a closed shrubby thicket. With 103 species it is the richest formation. The Shannon sign calculated for trees, shrubs and grass are respectively 0.66±0.46; 1.74±0.90 and 3.30±0.19 bits. The herbaceous stratum is known as the most diversified with a diversity of about the double of that of the shrubby stratum (Table 4.1-5).

4.1.3 Programme of ecological accompaniment

The project launching and operation phase will cause the vegetation destruction on an extent of 25m wide and 10.2km long. The pipeline project would develop that area with the herbaceous plants. That work could be given to the botanic laboratory of Abomey-Calavi University for the proposition of plant species and their planting out.

Apart from that land on which the plant cover will be inevitably destroyed, project will be engaged to respect the plant cover in time of access to the works sites.

4.1.4 Conclusion

The pipeline impact over vegetation and flora of the concerned zone will certainly lead to the destruction of the different recorded formations and individuals loss of various recorded species. Because of the so reduced width of the land, we can deduce that the damages will not be enormous. The different recorded species find themselves elsewhere and no rare species has been identified.

4.2 SOIL CHARACTERIZATION

4.2.1 Physical

4.2.1.1 General Pedological Data

The Volkoff pedological Studies of (1976) and the Agassounon (2002) put in evidence five units of grounds in the ground part which is crossing the main gas; they are:

- Ferralitic Grounds, weakly desatured impoverished in sediments furnish argilo-sandy of " Continental Terminal " trays;

- Grounds ferralitiques désaturés impoverished on building material affected with trays surrounding and deposited in small depressions of surrounding grounds, hydromorphes organic in gley and salty, undifferentiated on the alluvial building material.

- The little evolved raw mineral grounds, developed on the subactual and current bar of brown sands;

- Hydromorphes Grounds, organic in gley often salty with the material lagoon: it is the preference domain of the mangrove swamp;

- The hydromorphes mineral soils in gley with quaternary maritime sand, developed in medical cords of grey sand and the internal cords of yellow sands.

Pedological description is made according to a North-south cutting, by beginning with the Continental Terminal plateau soils towards the evolved grounds in the current cordon. Used naming is that of pédological repository (R. Baize and Girard's P., 1995).

4.2.1.2 On the Plateau

On the plateau of Continental Terminal and of the Bar which overhangs the coastal plain develops some soils that Volkoff (1976) had qualified of ferrallitics. Detailed, recent studies distinguish fersialsoils on Earth of Bar, on the plateau summits of trays and argilo-sandy fersiallitic colluviosoils on the valleys border in the slopes which lead in the heart of swampy depressions (Blaize and Girard's naming, 1995).

Has 1. Fersialsoils

They are the grounds that are developped on the summits of plateau from the forming of Earth bar.

** Texture and mineralogy*

They are grounds of red colour to brunette. The granulometric analysis show surfaces with more sandy building material that become argilo-sandy in depth. The nature of the constituents is generally quartz, kaolinite, but we can also meet the hematite and the goethite.

** pH*

This fersialsoils present a certain sourness with values of pH measured in situ (on the ground) included between 4.9 and 5.49 (samples 2B11A). These values could be as a result of the frequently bush fires practised by the populations in dry season.

** Organic matter*

The rate of organic matter is variable. Except the superficial horizon humifère, this rate is weak but depends on the presence or not of a natural plant place setting culture.

Has 2. Colluviosoils fersiallitic argilo-sandy colluviosoils

They characterize the edges of the trays of Continental terminal often found by erosion of the Earth Bar. One often distinguishe in the profile pedological unrefined, extracted upstream and reshaped. Elements these grounds keep well the great features of fersialsoils first described on the plateau. The argilo-sandy original building material and sometimes gritty is reshaped as a result of the successive collusionments.

** Texture and mineralogy*

These grounds are characterized by the abundance well marked unrefined grains of sand at the as well as that of fine fractions (silts and clays).

** pH*

pH remains always acid (4.06-6.16 in 2B9A and 2B10A) because of the reasons evoked first of fall.

The Coastal Plain

The three units of grounds revealed at the coastal plain are:

- -The raw mineral grounds, developed on the subactual cordon and brown sands;
- Hydromorphes grounds, organic in gley often salted on the lagoon material: it is the zone by excellency of the mangrove swamp;

- -The more or less ferruginous mineral grounds on quaternary maritime sand, developed on the medical cords of grey sand and the internal cords of yellow sands.

The raw mineral grounds

On the current sandy cordon along side the coast, the grounds are a bit differentiated and developed on an unrefined sandy material. They let appear in surface a superficial humifere horizon, weak thickness on a more or less altered mineral horizon. It is a poor ground with very weak capacity of exchange and with feable water keeping back power because of their poverty in clays.

** Texture and mineralogy*

The characteristic of these grounds is a very rough appropriate average quartz sands ascendancy a no clay.

** pH and exchangeable bases*

The pH is variable, influenced in the basic maritime and slightly acid in the lagoon. These grounds have a weak capacity of keeping back water and undergo a very fast vertical drainage.

These grounds which have exchangeable bases are included among 0.98 and 2.01méq/100g lack of fertility.

** Content in organic material*

It is never important. The total organic carbon is practically nothing, what gives evidence of the almost absence of the organic material.

Hydromorphes grounds, organic in gley, more or less salted

They are grounds developed on the lagoon material; they are seasonally salted, which showed the presence of mangrove swamp.

** Texture and mineralogy*

The grounds are characterized by a homogeneous clayey texture with, in places, a more diverse texture with sandy dominant.

The sediment of mangrove swamp is characterized by the accumulation within an argilo-sandy material, more particularly their roots, iron sulphides, mainly pyrite. It causes the reduction of the sea water sulfates in anaeroby area under the influence of the present sulfato-reducing bacteria on the ground.

The dominant factor of the evolution of the mangrove swamp grounds is the sulfur and the compound sulphurated where the term of treated acid with copper sulphate grounds usually tried to distinguish them.

** pH and potential sourness*

On the ground, pH is slightly acid (6-7); after drying, the ground generally presents a much more acid pH (lower than 4). The difference between these two pH is the higher potential sourness of the deep horizons, flooded under mangrove swamp than on the salted grounds in grasses bordered with grass.

** Content of the organic material and nitrogen*

Grounds under mangrove swamp present contents of organic achieving carbon 8.4% with a rate of organic material of 17% (Oyédé, in 1983).

Report C/N gives values from 6 to 44. These variations are important and can explain themselves by the nature and the quantity of the organic material. The high values of the C/N (40-50) result according to Hutchinson (Dussart, in 1996) from the allochtone nature of some organic material. The weak report C/N shows an influence of the autochtonous organic matter (plankton), richer in protein (C). Intermediate values found here would indicate an environment subjected to the double influence of the two types of organic material.

The more or less ferruginous mineral grounds on quaternary sand

Theu are grounds described by Lamouroux (1953) and Volkoff (1976) under the term of tropical ferruginous grounds in sesquioxydes of iron, washed, without concretions on quaternary sands. These grounds develop on more or less lengthened mounds corresponding to the former internal sandy cords, organized during the holocène transgressive phase.

** Texture and mineralogy*

The main characteristic of these grounds is the very appropriate fine quartzy sands ascendancy. Contents in clays are always weak, rarely reaching 10% on the horizon A, slightly humifère. These grounds present sporadically spots or nodules make rusty of oxidation.

** pH and exchangeable bases*

The moderate pH evolves between 4.5 and 5.9; they reflect the variable sourness of these grounds with always an acid tendency. They are also marked by a weak water capacity of keeping back and a rather fast vertical drainage.

The weak capacity of the cationic exchange (CEC=2-5méq/100g) causes an inferior fertility of these grounds which have contents of exchangeable bases included between 0.98 and 2.05 méq/100g.

** Contents of the organic material*

The rate of total organic carbon is always lower than 1%. It is only on the superficial surfaces of the forests zones that this rate can reach 2.2% (that is 3.96% of the organic material).

4.2.1.3 The Characteristics of the Studied Grounds

4.2.1.4 Grounds Developed on Yellow Sand

* Curves and Granulometrical Parameters

We distinguish from the height downward horizons 2B1a1, 2B1a2, 2B1a3, and 2B1a4 which is already the rock. In these horizons, we have:

- Mode in 2f (that is 0, 250mm): classify average grounds
- Average Mz: 1.86<f<2, 16: average grain.
- The classification (sorting or standard abnormality) is approximately equal to 0.80f: averagely classified sediment.
- Asymmetry is variable (0.03-0.20) but always indicates positive values, that is ascendancy of the fine sands.

Y Interpretation

The samples analyzed at the level of trenches 2B1 belong to the same geologic forming: the yellow sands. The proportion of sand (fraction superior to 0.063mm) is always superior to 90%. It is then sand and not of clayey sand as some people tend to call it. The curves of unimodal frequency as well as the histograms, indicate that we are dealing with the population of the same origin. They are sands homometrical indicating a certain constancy in the conditions of the deposit. Median, close or equal to the average, around 0.250mm indicates average sands, rather than a fined deposit.

4.2.1.5 Grounds Developed on Grey Sand

They are samples of trenches 2B3. Here also, we distinguish several horizons a1, a2, a3, and a4.

* *Curves and Parameters Granulometrical*

- Mode is 2f: classify average grains
- Average Mz: 1.13-1.15: unrefined average grains
- The classification 0.48<fi<0.52: well enough classified sediment
- Asymmetry (skewness) aiming towards 0 (0.009-0.86) expresses the presence of fined and unrefined grains.

*	*Interpretation*

It is a very sandy sediment, the proportion of the diameter particles superior to 0.063mm always overtakes 95% of the sample. Granulometrical parameters indicate more unrefined sands than the previous: we can speak about average unrefined sediments. The wlole group evokes a deposit of an environment shaken by variable currents.

4.2.1.6 Grounds of the Current and Subactual Cordon

They are samples of trenches 2B6. On this cord, the differentiation of the ground is not very net. We can distinguish there the top 2B6a1, slightly tanned with organic fragments and pure cords sand (2B6a2, 2B6a3).

*	*Curves and Granulometrical Parameters*

- These curves are always unimodal of the class 0.0250mm.
- The average: rather constant in 1.31: unrefined grains with means.
- The classification: 0.51<fi<0.58: well enough classified sediment.
- Negative asymmetry (-0.035-0.007) indicates a light ascendancy of the unrefined particles.

*	*Interpretation*

The curves of the trenches samples 2B6 are very high. The group of granulometrical characteristics indicates a sediment in which a winnowing extended enough with the fined particles (silto-clayey) that occurred. It is a mature sediment, resulting from an active action and constant hydrodynamics.

4.2.1.7 The Plateau Grounds

They are samples of trenches 2B8, 2B9, 2B10, and 2B11.

*	*Curves and granulometrical parameters*

Four levels in each of the trenches were distinguished:

A1 (in 0cms), a2 (enter 0 and 15cm), a3 (between 15 and 30cms), a4 (between 30 and 50cms).

- In all the trenches and in all the levels, the mode is 2f (that is 0, 250mm), and grounds with average grains.
- Average, once calculated is close to 2f (1.73-2.23), whereas the median is equal 2f in 2B9 and generally lower in 2B10 and 2B11.
- Distributions, although unimodal are not always symmetric.

- The classification fi was not able to be calculated because it hasn't reached 95% of grains in the cumulative layer of the microgranulometry.

** Y Interpretation*

The grounds of the bar are generally badly classified.

4.2.1.8 Chemical Analysis of the Grounds and some Sediments

The elements tracks or heavy metals looked for in the samples of grounds and sediments of the two campaigns of takings (in December, 2002 and July, 2003) are the lead shot (Pb), the iron (Fe), the cadmium (Cd), the chromium (Cr), the nickel (Or), the aluminium (Al), the copper (Cu), the vanadium (V) and the zinc (Zn). The mercury (Hg) analyzed in December samples was not that of July (to see tables of results).

The comment of concentrations in heavy metals of a ground depends on what we wants to make of the ground. The laboratory of analysis, not having supplied any standard of these elements, our brief comment will be anxious to see, with regard to the grounds of culture and to the European standards, if the part of the national territory crossed with the main gas presents grounds very favorable to cultures or polluted grounds.

We know that certain elements tracks favor the growth and development of rooty plants, the others allow resistance diseases and fruiting. In brief, the content of a ground in heavy metals allows to determine mobilizable maximal concentration, that is, accessible part to vegetables. And in some concentrations, these elements are going to meet themselves in vegetables (vegetables and fruits) and dangerous for the future.

The enclosed tables present concentrations of heavy metals of the grounds in the zone of passage of the main gas (Table 4.2-2 through Table 4.2-18). European Standards (Table 4.2-1) for gleaned grounds in the documentation (MEHU-ABE, 2003-picture) allow to make some analysis as if to speak about the fertility of grounds.

Table 4.2-1
European Standards of Concentrations of Grounds in some Heavy Metals and Elements Tracks

Elements	Lead (Pb)	iron (Fe)	Cadmium (Cd)	Chrome (Cr)	Nickel (Ni)	Aluminium (Al)	Mercury (Hg)	Copper (Cu)	Zinc (Zn)	Vanadium (V)
Europeans standars (ppm)	300	250-600	3	-	-	-	1,5	140	300	-

The Measures of December, 2002

The concentration of the elements found in Bene are lower than those shown accepted by the European Standards, with one exception. The mercury concentration found at stations B1 and

B3 (caostal cord grounds) are 2.3 and 4.1ppm respectively, where the value for the European Standards is 1.5 ppm.

All the elements, except for mercury, are found at levels below the allowed values of the European Community. The lower concentration levels partiall explain the poor cultivation of the soil found in the area

The Measures of July, 2003

The same observations are made that for the results of the analysis of December, 2002 with regards to concentrations of the heavy metals in the ground. The laboratory of analysis did not proceed this time to the determination of the contents in mercury (Hg).

Comparison between the two Series of Measure

Although very weak values in two campaigns, some differences are clear with some elements from one campaign to the other:

- The Chromium (Cr): concentrations seem higher in July, 2003 than in December, 2002.
- The nickel (Or), of concentrations generally lower than 4.0 in December, 2002 show values being able to reach 16 in July, 2003.
- The zinc (Zn): the values between 3.9 and 18.5 in December, 2002 grow between 5 and 37 in July, 2003.

Generally speaking , some elements show stronger values in July with regard to previous December. Would not it be linked to the rains of the first season which would have provoked migration and concentration of these elements?

4.2.2 Chemical

4.2.2.1 Akadjame (Transect B2)

Table 4.2-2
Physico-chemical Data on the Samples of Akadjamè Swamp Surface Water N°1

Transect	Samples N°	Longitude	Latitude	NO_3^- (mg/l)	NO_2^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)	TSS (mg/l)	DCO (mgO_2/l)	rH
B2 Akadjamè	M1.1	N6°22’27,2’’	E2°15’23,8 ‘’	15,32	0,47	18,03	0,190	98,7	37,15	540	18
	M1.2	N6°22’27,3’’	E2°15’25,5 ‘’	17,01	0,53	21,60	0,076	101,2	34,92	610	17
	M1.3	N6°22’27,2’’	E2°15’23,7 ‘’	17,22	0,45	23,10	0,110	107,6	36,67	495	17
	M1.4	N6°22’27,4’’	E2°15’24,0 ‘’	19,91	0,61	23,41	0,180	101,18	33,87	487	16
	M1.5	N6°22’24,4’’	E2°15’24,3 ‘’	21,16	0,46	19,13	0,082	101	36,11	515	19

Table 4.2-3
Organic charges and contents in hydrocarbons of the Akadjamè swamp sediments samples N°1

Transect	Sample N°	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)	rH
B2 Akadjamè	M1.1	N6°22’27,2’’	E2°15’23,8 ‘’	4,45	0,123	0,006	67,38	50,13	13
	M1.2	N6°22’27,3’’	E2°15’25,5 ‘’	5,08	0,099	0,005	80,00	48,02	12
	M1.3	N6°22’27,2’’	E2°15’23,7 ‘’	4,56	0,134	0,008	79,15	36,16	12
	M1.4	N6°22’27,4’’	E2°15’24,0 ‘’	5,24	0,142	0,013	82,23	58,00	11
	M1.5	N6°22’24,4’’	E2°15’24,3 ‘’	3,95	0,130	0,004	65,64	43,00	14

Reports:

- Soft waters with higher levels due to the bodies of water as a result of the seasonal rains;
- Drinking place for the oxen;
- Nauseous smells
- Important organic charges contributions due to the activities of the anthropic origin (nearness of houses, agricultural activities on banks, …) owed to the streamings during the rainy period);
- Contributions of waters of streamings from regions amont.

4.2.2.2 Station of Cococodji Treatment Gas (Transect B1) - Takings in Five Various Points

Table 4.2-4
Organic Charges and Contents in Hydrocarbons of the Ground Sample at the Cococodji Gas Treatment Station (Transect B1)

Transect	N° Sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B1	ST1 Simple ground1)	6°22’52,8 "	2°15’25,5"	1,350	0,050	0,008	30	28
	ST2 (Simple ground 2)	6°22’53,1 "	2°15’25,0"	0,917	0,040	0,000	ND	ND
	ST3 (Simple ground 3)	6°22’53,6"	2°15’25,4"	1,070	0,040	0,006	6	4,5
	ST4 (Simple ground 4)	6°22’53,0 "	2°15’26,3"	0,760	0,035	0,001	ND	ND
	ST5 (Simple ground 5)	6°22’53,0 "	2°15’25,9"	1,019	0,028	0,003	ND	ND

Reports:

- Sandy soil (weak rate of organic material)
- In ST1 and ST3 presence of some wooden residues after combustion under the ground: that would explain TPH's presence dominated by the HAP of origin pyrolytical (report TPH / PAH close to 1) in these two points

4.2.2.3 Cococodji (Transect B7)

Table 4.2-5
Organic charges and contents in hydrocarbons the Cococodji samples ground (Transect B7's)

Transect	Sample N°	Longitude	Latitude	TOC %)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B7	S1 (Simple ground 1)	6°23’37,4 "	2°15’40,2"	1,150	0,071	0,009	ND	ND
	S2 (Simple ground 2)	6°23’37,4 "	2°15’40,2"	0,832	0,059	0,000	ND	ND
	S3 (Simple ground 3)	6°23’37,4 "	2°15’40,2"	1,172	0,070	0,004	ND	ND
	S4 (Simple ground 4)	6°23’37,4 "	2°15’40,2"	0,800	0,056	0,003	ND	ND
	S5 (Composite ground 1)	6°23’37,4 "	2°15’40,2"	0,950	0,065	0,005	ND	ND
	S6 ST4 (Composite ground 2)	6°23’37,4 "	2°15’40,2"	0,975	0,045	0,005	ND	ND

Reports:

- Sandy soil;
- Weak rate of organic material;
- No particular contagion

4.2.2.4 Hio's Coastal Lagoon (Transect B5)

Table 4.2-6
Physico-chemical Data on the samples of the Hio coastal lagoon surface water

Transect	Sample N°	Longitude	Latitude	NO_3^- (mg/l)	NO_2^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)	TSS (mg/l)	DCO (mgO_2/l)	rH
B5 (lagune côtière)	L1	N6°20'52,5''	E2°15'07,6 ''	13,20	0,163	26,03	0,23	180,2	11,83	456	15
	L2	N6°20'52,5''	E2°15'07,7 ''	11,42	0,143	29,41	0,46	175,5	10,93	448	12
	L3	N6°20'52,5''	E2°15'07,8 ''	11,56	0,161	24,58	0,31	172,8	13,07	435	14
	L4	N6°20'55,2''	E2°15'08,2 ''	16,08	0,097	27,11	1,93	159,1	9,15	376	13
	L5	N6°20'55,2''	E2°15'08,3 ''	15,64	0,088	31,08	2,10	162,7	9,67	368	14
	L6	N6°20'55,4''	E2°15'08,3 ''	14,97	0,132	30,67	2,31	167,4	8,97	427	14
	L7	N6°20'59,8''	E2°15'08,1 ''	9,72	0,109	24,83	1,47	163,1	6,58	315	14
	L8	N6°20'59,9''	E2°15'08,2 ''	10,11	0,078	25,07	1,68	170,3	6,74	295	13
	L9	N6°20'59,9''	E2°15'08,2 ''	9,83	0,078	25,20	0,910	167,4	7,10	329	14

Table 4.2-7
Organic charges and contents in hydrocarbons of the Hio coastal lagoon sediments samples

Transect	Sample N°	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)	rH
B5 (coastal lagoon)	L1	N6°20’52,5’’	E2°15’07,6 ‘’	6,04	0,231	0,091	81,00	58,25	10
	L2	N6°20’52,5’’	E2°15’07,7 ‘’	5,67	0,210	0,073	63,87	34,92	7
	L3	N6°20’52,5’’	E2°15’07,8 ‘’	5,88	0,249	0,088	97,00	53,00	9
	L4	N6°20’55,2’’	E2°15’08,2 ‘’	4,95	0,230	0,083	74,15	61,22	8
	L5	N6°20’55,2’’	E2°15’08,3 ‘’	4,77	0,198	0,075	63,25	48,17	9
	L6	N6°20’55,4’’	E2°15’08,3 ‘’	5,18	0,176	0,065	41,23	37,08	9
	L7	N6°20’59,8’’	E2°15’08,1 ‘’	5,80	0,202	0,090	60,00	46,30	9
	L8	N6°20’59,9’’	E2°15’08,2 ‘’	4,98	0,170	0,078	49,15	29,90	8
	L9	N6°20’59,9’’	E2°15’08,2 ‘’	5,59	0,200	0,O85	56,27	23,14	9

Reports:

- Deposits of plant fragments (sheets and boughs of mangrove in this particular case)
- Organic Pollution
- Very reducing Circles (many contributions of regions amont) by streamings
- Domestic discharges
- Ramblings of domestic animals (pigs) in the immediate neighborhoods of the site
- Report TPH / PAH close to 1 indicates contributions of pyrolytical origin (use of charcoal, bush fires, etc.)

4.2.2.5 Adjahindji-Hio (Transect B4)

Table 4.2-8
Physico-chemical Data on the samples of the swamp surface water from Adjahindji to Hio (Transect B4) N°2

Transect	Sample N°	Longitude	Latitude	NO_3^- (mg/l)	NO_2^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)	TSS (mg/l)	DCO (mgO_2/l)	rH
B4 Adjahindji/ Hio	M2.1	N6°21’10,8’’	E2°15’09,3 ‘’	20,14	0,61	24,50	1,46	179	31,05	564	16
	M2.2	N6°21’11,6’’	E2°15’09,0 ‘’	18,16	0,56	26,08	0,97	148	29,14	487	14
	M2.3	N6°21’10,5’’	E2°15’09,0 ‘’	21,01	0,49	23,87	1,53	153	30,26	495	14
	M2.4	N6°21’10,8’’	E2°15’08,6 ‘’	17,48	0,55	24,44	1,24	182	29,33	610	15
	M2.5	N6°21’11,9’’	E2°15’08,8 ‘’	21,07	0,53	25,06	1,56	169	30,18	538	16

Table 4.2-9
Organic charges and contents in hydrocarbons of the swamp sediments samples from Adjahindji to Hio (Transect B4) N°2

Transect	N° Sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B4 Adjahindji/ Hio	M2.1	N6°21’10,8’’	E2°15’09,3 ‘’	7,50	0,201	0,053	54,29	39,15
	M2.2	N6°21’11,6’’	E2°15’09,0 ‘’	7,26	0,187	0,041	81,40	58,12
	M2.3	N6°21’10,5’’	E2°15’09,0 ‘’	6,95	0,168	0,029	90,83	49,20
	M2.4	N6°21’10,8’’	E2°15’08,6 ‘’	5,57	0,180	0,032	65,35	47,00
	M2.5	N6°21’11,9’’	E2°15’08,8 ‘’	6,28	0,170	0,040	78,73	61,80

4.2.2.6 Hevie (Transect B8)

Table 4.2-10
Physico-chemical Data on the Hêvié Samples Swamp Surface Water (Transect B8's) N°3

Transect	Sample N°	Longitude	Latitude	NO_3^- (mg/l)	NO_2^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)	TSS (mg/l)	DCO (mgO$_2$/l)	rH
B8 Hêvié	M3.1	N6°23'45,2''	E2°16'26,1 ''	46,10	0,63	29,50	1,69	83,71	36,14	469	13
	M3.2	N6°23'45,3''	E2°16'25,4 ''	44,92	0,67	28,76	2,00	81,56	33,78	468	11
	M3.3	N6°23'45,9''	E2°16'25,4 ''	51,02	0,74	33,58	3,11	92,03	42,24	465	12
	M3.4	N6°23'46,6''	E2°16'25,3 ''	52,14	0,71	35,11	3,08	95,11	46,03	465	12
	M3.5	N6°23'44,5''	E2°16'25,8 ''	No sample of water							

Table 4.2-11
Organic charges and contents in hydrocarbons of the Hêvié sediments swamp samples (Transect B8's) N°3

Transect	Sample N°	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B8 Hevie	M3.1	N6°23’45,2’’	E2°16’26,1 ‘’	6,18	0,149	0,043	73	58,00
	M3.2	N6°23’45,3’’	E2°16’25,4 ‘’	5,15	0,125	0,029	33	29,27
	M3.3	N6°23’45,9’’	E2°16’25,4 ‘’	5,58	0,142	0,032	41	35,18
	M3.4	N6°23’46,6’’	E2°16’25,3 ‘’	6,00	0,137	0,044	53	42,80
	M3.5	N6°23’44,5’’	E2°16’25,8 ‘’	4,97	0,140	0,040	62	47,20

Reports:

- Strong rates of organic material (presence of aquatic plant);
- Very reducing Circles because of the decomposition of the dead vegetables and the important contributions of the streamings in villages situated upstream; favorable conditions to the accumulation of the HAP.

Table 4.2-12
Physico-chemical Data on the Hêvié samples ground (Transect B8)

Transect	N° sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B8	Simple ground 1	6°23’45,3’’	2°16’25,0’’	1,380	0,070	0,001	ND	ND
	Simple ground 2	6°23’45,3’’	2°16’25,0’’	1,088	0,078	0,001	ND	ND
	Simple ground 3	6°23’45,3’’	2°16’25,0’’	1,260	0,075	0,001	ND	ND
	Simple ground 4	6°23’45,3’’	2°16’25,0’’	1,000	0,068	0,000	ND	ND
	Composite ground 1	6°23’45,3’’	2°16’25,0’’	1,270	0,068	0,001	ND	ND
	Composite ground 2	6°23’45,3’’	2°16’25,0’’	1,150	0,071	0,000	ND	ND

Reports: no particular ground contagion

4.2.2.7 Sodo (Transect B9)

Table 4.2-13
Physico-chemical Data on the Sodo swamp surface water samples (Transect B9) N°4

Transect	Sample N°	Longitude	Latitude	NO_3^- (mg/l)	NO_2^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3-} (mg/l)	SO_4^{2-} (mg/l)	TSS (mg/l)	DCO (mgO_2/l)	rH
B9	M 4.1	N6°24’22,0’’	E2°16’54,7 ‘’	63,41	0,98	47,86	2,56	189	31,12	548	11
	M4.2	N6°24’22,3’’	E2°16’54,9 ‘’	63,22	0,95	46,79	2,74	165	33,26	549	10
	M4.3	N6°24’22,4’’	E2°16’54,8 ‘’	No water sample							
	M4.4	N6°24’22,7’’	E2°16’54,9 ‘’								
	M4.5	N6°24’23,1’’	E2°16’54,3 ‘’								

Table 4.2-14
Organic charges and contents in hydrocarbons of the Sodo swamp sediments samples (Transect B9) N°4

Transect	Sample N°	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B9 Sodo	M 4.1	N6°24'22,0''	E2°16'54,7 ''	7,57	0,232	0,084	117,2	83,0
	M4.2	N6°24'22,3''	E2°16'54,9 ''	6,82	0,162	0,071	72,84	49,10
	M4.3	N6°24'22,4''	E2°16'54,8 ''	5,15	0,145	0,059	ND	ND
	M4.4	N6°24'22,7''	E2°16'54,9 ''	4,78	0,130	0 ;065	ND	ND
	M4.5	N6°24'23,1''	E2°16'54,3 ''	5,56	0,138	0,088	ND	ND

Reports:

- Very reduced or reducing Circles;
- Strong rates of organic material in sediments;
- Important Contributions of organic charges by streamings coming from regions;
- Nearness of houses everything around the swamps where are poured the biggest part of the domestic waste (waste water, borders serving of places of ease for the local residents,);
- Presence of a heap of garbage near M4.1 with residues of charcoal and some ashes; what would partially explain relatively high rates by PAH in sediments; streamings would also sources of TPH's contributions in the circles.

Table 4.2-15
Physico-chemical Data on the Sodo grounds samples (Transect B9)

Transect	N° Sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B9 Sodo	Simple ground 1	6°24’22,3’’	2°16’25,0’’	1,30	0,090	0,002	ND	ND
	Simple ground 2	6°24’22,3’’	2°16’25,0’’	1,34	0,100	0,002	ND	ND
	Simple ground 3	6°24’22,3’’	2°16’25,0’’	1,32	0,096	0,003	ND	ND
	Simple ground 4	6°24’22,3’’	2°16’25,0’’	1,23	0,113	0,002	ND	ND
	Composite ground1	6°24’22,3’’	2°16’25,0’’	1,30	0,097	0,002	ND	ND
	Composite ground 2	6°24’22,3’’	2°16’25,0’’	1,29	0,100	0,003	ND	ND

ND: not discovered (limit of detection 0,01 ng / g)
O.M. : Organic material

4.2.2.8 Maria-Gleta Ground (Transect B10)

Table 4.2-16
Physico-chemical Data on the Maria - Gléta samples ground station

Transect	N° Sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B 10 Maria-gléta	Simple ground 1	6°26’03,1’’	2°17’43,6’’	1,26	0,100	0,004	ND	ND
	Simple ground 2	6°26’03,1’’	2°17’43,6’’	1,15	0,116	0,004	ND	ND
	Simple ground 3	6°26’03,1’’	2°17’43,6’’	1,12	0,107	0,003	ND	ND
	Simple ground 4	6°26’03,1’’	2°17’43,6’’	1,20	0,120	0,002	ND	ND
	Composite ground1	6°26’03,1’’	2°17’43,6’’	1,21	0,114	0,004	ND	ND
	Composite ground 2	6°26’03,1’’	2°17’43,6’’	1,18	0,114	0,002	ND	ND

ND: not discovered (limit of detection 0,01 ng / g)

4.2.2.9 Maria-Gelta Station (Transect B11)

Table 4.2-17
Physico-chemical Data on the Maria - Gléta Ground Samples Station

Transect	N° Sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B 11 Maria-gléta Station	Simple ground 1	6°25’24,7’’	2°18’23,1’’	1,36	0,110	0,003	ND	ND
	Simple ground 2	6°25’24,7’’	2°18’23,1’’	1,30	0,115	0,004	ND	ND
	Simple ground 3	6°25’24,7’’	2°18’23,1’’	1,32	0,097	0,002	ND	ND
	Simple ground 4	6°25’24,7’’	2°18’23,1’’	1,30	0,125	0,002	ND	ND
	Composite ground1	6°25’24,7’’	2°18’23,1’’	1,32	0,111	0,003	ND	ND
	Composite ground 2	6°25’24,7’’	2°18’23,1’’	1,290	0,107	0,002	ND	ND

MOEH: Organic extractible material by the hexane ND: not discovered (limit of detection 0,01 ng / g) O.M.: Organic material

4.2.2.10 The Hio Beach (Transect B6)

Table 4.2-18
Physico-chemical Data on the Hio Beach Ground Samples (Transect B6)

Transect	N° Sample	Longitude	Latitude	TOC (%)	N (%)	P (%)	TPH (ng/g)	PAH (ng/g)
B6	Simple ground 1	6°20’46,7’’	2°15’17,4’’	0,218	0,007	0,000	ND	ND
	Simple ground 2	6°20’46,0’’	2°15’17,4’’	0,220	0,003	0,000	ND	ND
	Simple ground 3	6°20’46,0’’	2°15’18,4’’	0,270	0,005	0.000	ND	ND
	Simple ground 4	6°20’46,4’’	2°15’18,0’’	8,341	0,710	0,011	105,64	22,80
	Composite ground1	6°20’46,6’’	2°15’18,6’’	15,320	1,020	0,023	172,50	38,32
	Composite ground 2							

ND: not discovered

Reports:

- Sandy soil
- Not so organic material, with the exception of the grounds 4 and 5 the strong rate of organic material which would give evidence of some pollution;
- The high rates of TPH and PAH with ratios TPH / PAH widely superior to 1 would indicate a pollution of oil origin; this pollution results from coal nuts of tar which fall on beaches folbecause of the discharges of oil dumpings of the vessels which follow the coasts; residues of these coal nuts were found in samples 4 and 5 analyzed.

4.2.3 Biological

4.2.3.1 Macro Ecology

Analysis revealed a more important variety of bodies in the superficial coats of the sampled grounds. This specific variety considerably decreases as we moves on the deep coats, and nullifies at the level of some transects, notably the beach and the grounds near the wet zones. As for the dry season, Hymenopteries are represented on all the transects by Formicidae and\or Myrmicidae. Towards Annelides were found only on the grounds of the wet zones of fresh water (B2, B8, and B9).

The exam of the variety and the total number of bodies by transect, leads us to notice that the transect 2B7 has a higher specific variety (16) follow-up of the transecte 2B8 (14) and transect 2B1 (13). The transect 2B8 (70) has however the most high number of the follow-up bodies of the transect 2B9 41 and 2B10 (40). The grounds of transect 2B3 2, 2B4 4, 2B5 6, 2B10 5, and 2B11 (5) present critical states due to their specific variety.

Figure 4.2-1
Variation of the Number of Bodies in Deep Surface

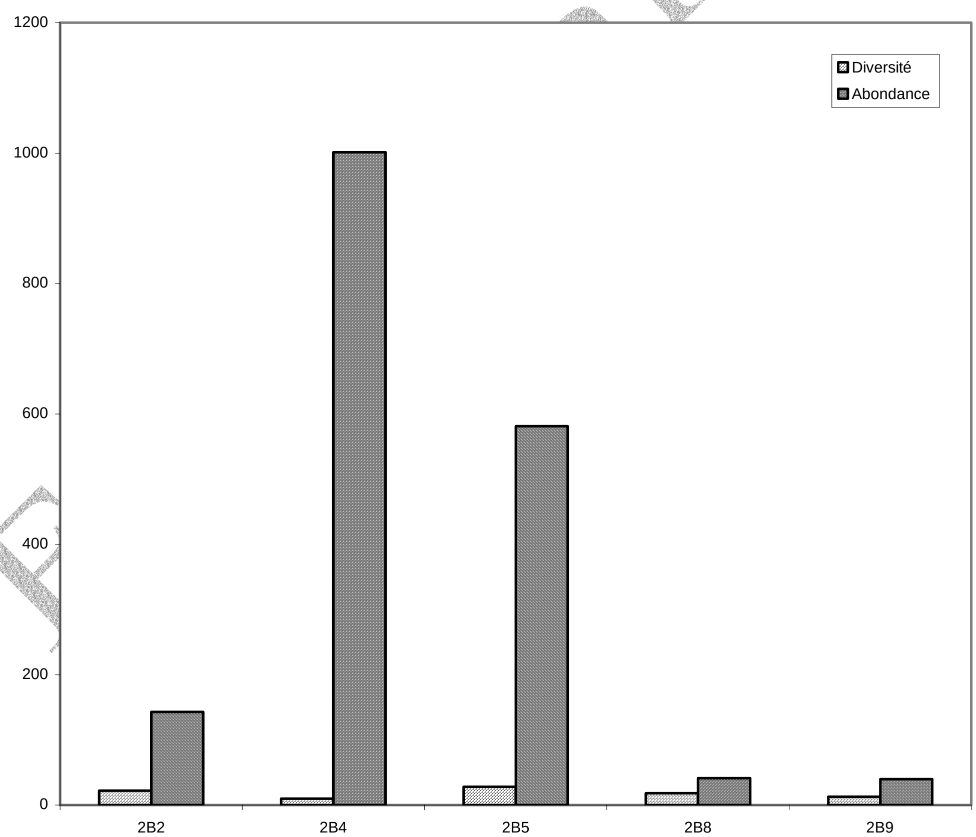
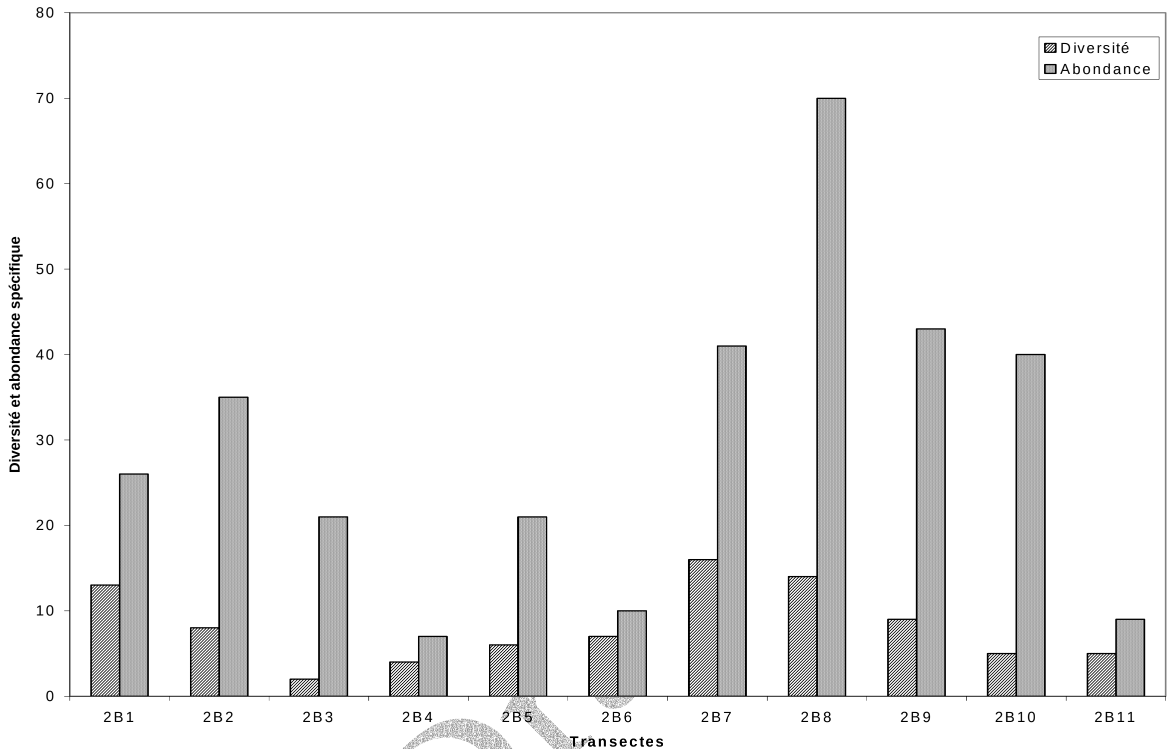


Figure4.2-2
Specific Relation Variety and the Total Number of Bodies on the Transects Grounds of



4.2.3.2 Microbiology

As far as grounds, are concerned it is necessary to note that all are contaminated with Bacillus spp, 66.15% contain coliformes (43 on 65), 43.08% contain spores of sulfito-reducing Clostridium (28 to 65), none of the grounds shelters pathogenic Staphylococci. It is necessary to note that 88.53% of grounds contain yeasts and molds the dominance of which is found among zygomycetes and Sacharomyces.

The various aerobic microbial quanta remained all lower for 106/g and express a pauci -microbial character generally seen in the nature of the takings.

As for the dry season, the profusion of bacteria and mushrooms observed in the various samples indicates that the various transects serve as garbage dumps of animal and human excrement and domestic garbage.

4.3 SURFACE WATER AND SEDIMENT CHARACTERIZATION

4.3.1 Physical

4.3.1.1 Grain Size

Preparatory treatments

Most of the samples are sandy-clayey. 150 to 200 grammas have been treated for the granulometry. The samples that have plant remains have been attached by peroxide (H2O2, 220 volumes) before the taking of the 150 grammas. After the washing or the square mesh sieve of 0.050mm edges, the inferior fraction to 0.050mm obtained in the Erlenmeyer has been concentrated then dehydrated in the small dish in a steam room. The percentages related to the two fractions have been calculated.

Splitting up technique

For the study of granulometry supply, the samples have undergone a sifting. The superior fraction to 0.050mm is divided by a series of sieves (2; 1; 0.50; 0.250; 0.125; 0.063; 0.050mm). The sifting is performed by an apparatus of Rotap type ducting 15mn. Each of the fraction is weighted to the hundredth of grammas and the respective percentages are calculated compared with the totality of the treated sediment.

Modes of graphic representation

The supply of the heights is the subject of diverse representations. Those that have been used here are the cumulative curves at ordinate of probability, which have been drawn by hand. They highlight the gaps of supply compared with the gaussian curve and enable to adapt to individual circumstances granulometric stocks. They have enable to measure the value of the median (height of the particles for cumulated mass of 50% sediment) as well as to calculate graphically various parameters of supply.

Nomenclature used to characterise the supplies

The nomenclature used is the one Chamley, 1987 repeated in 2000. The supplies observed in all our takings show that the samples are entirely devoid of superior height particles to 2mn. We distinguish four granulometric classes:

- coarse sands (diameter included between 0.50 and 2mn), 1 to –1
- medium sands (0.250 and 0.50mm) 2 to 1
- thin sands (0.063 and 0.25mm) 4 to 2
- the silts and clay (inferior diameter to 0.063).

Granulometric parameters

The different parameters seek to characterise the granulometric supplies. They have been determined graphically. The formulas used are those of FOLK and WARD (1957 and repeated partly by Chamley, 1987 and 2000).

- the mode is the granulometric class for which the frequency is maximal Mo
- the median represents the diameter of the corresponding particles to 50% of the cumulative curve. M_d

- the average of the medium grain gives an idea of the medium granulometric fan of a given sample

In a symmetrical supply, the mode, the median and the average are confounded.

- classification (sorting or deviation standard) shows the dispersal of the heights compared with the average of the sample

$$\mu = \phi 16 + \phi\, 5O + \phi 84$$

In the symmetrical supply, the mode the median and the average are confounded.

- Classification (sorting or deviation standard) shows the dispersal of the heights compared with the average of the sample.

$0<\phi\, i<0.35$: very well classified sediment; $0.35<\phi i<0.50$: well classified;

$0.50<\phi i<0.71$: well classified enough; $0.71<\phi i<1.0$: fairly classified;$1.0<\phi i<2$; poorly classified; $2<\phi i<4$: very mineral classified.

- asymmetry (Skewness sk_i) shows the predominance or not of thin particles (positive values) or coarse (negative values), compared with the samples average.

+ 1.0>ski>+0.30 : strong symmetry towards the small height; +0.30>ski>+0.10: asymmetry towards the small height; +0.10>ski>-0.10: granulometric symmetry of the sample; -0.10>ski>-0.30: asymmetry towards the big heights; -0.30>ski>-1.0: very strong asymmetry towards the great heights.

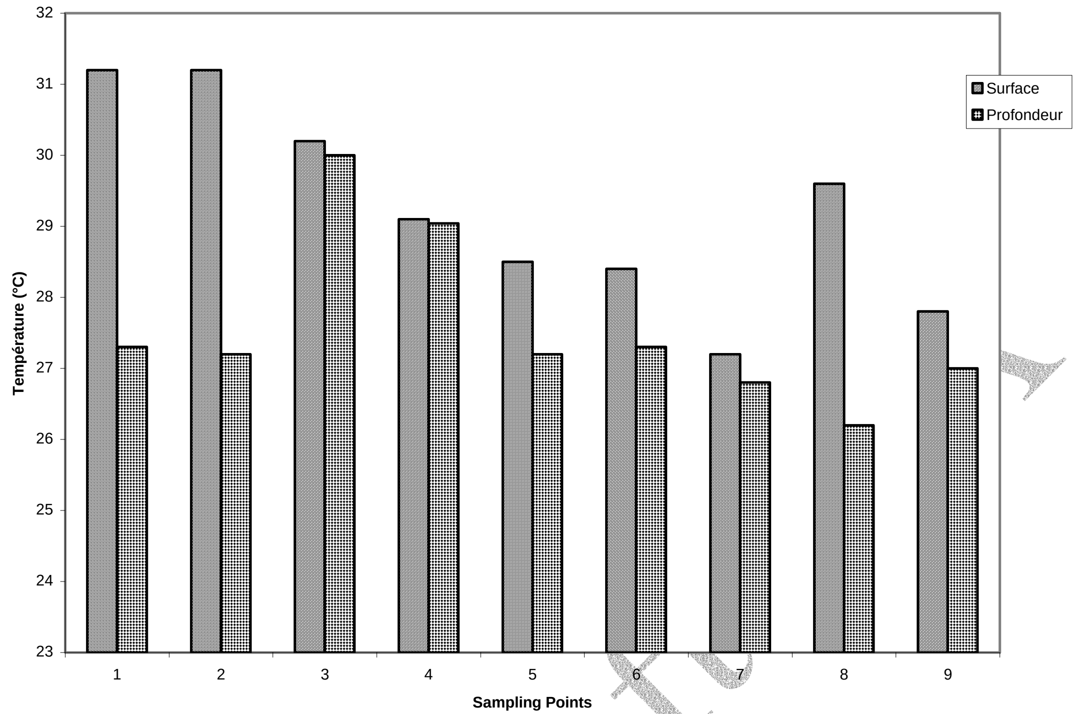
4.3.2 Chemical

4.3.2.1 Physics – Chemistry

Temperature

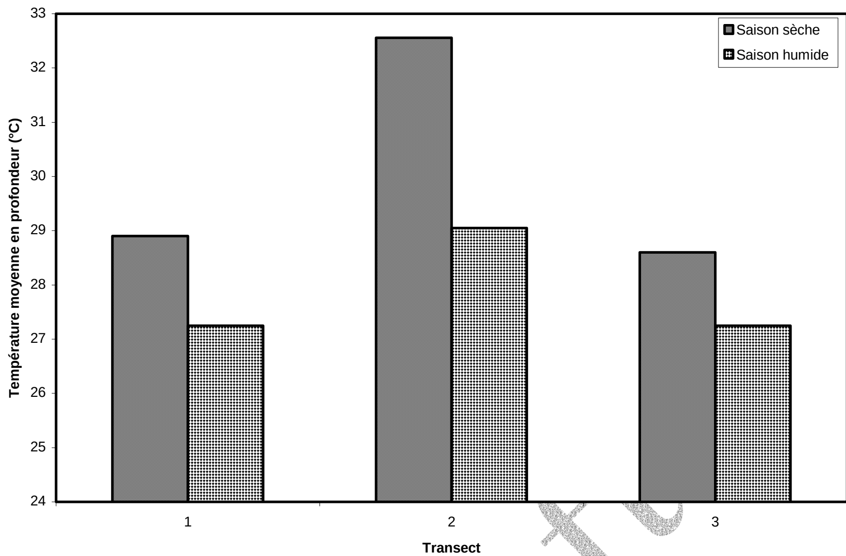
It is generally higher on surface (Figure 4.3-1) than in depth (Figure 4.3-2) and perfectly remained in the acceptable range by most of the tropical species (20–32°C) especially fish. The average temperature noticed during the dry season is higher than the one during raining season. Critical points from 33.3°C to 36°C have been noticed during dry season at the of salty water swamps level (transect B4) that was drained in places.

Figure 4.3-1
Comparison of Temperature Read on Surface and in Depth
(points 1 and 2 = transect B2, 3 and 4 = transect 5, 7 and 8 = transect 9)



32
31
30
29
28
27
26
25
24
23
Température (°C)
Surface
Profondeur
1
2
3
4
5
6
7
8
9
Sampling Points

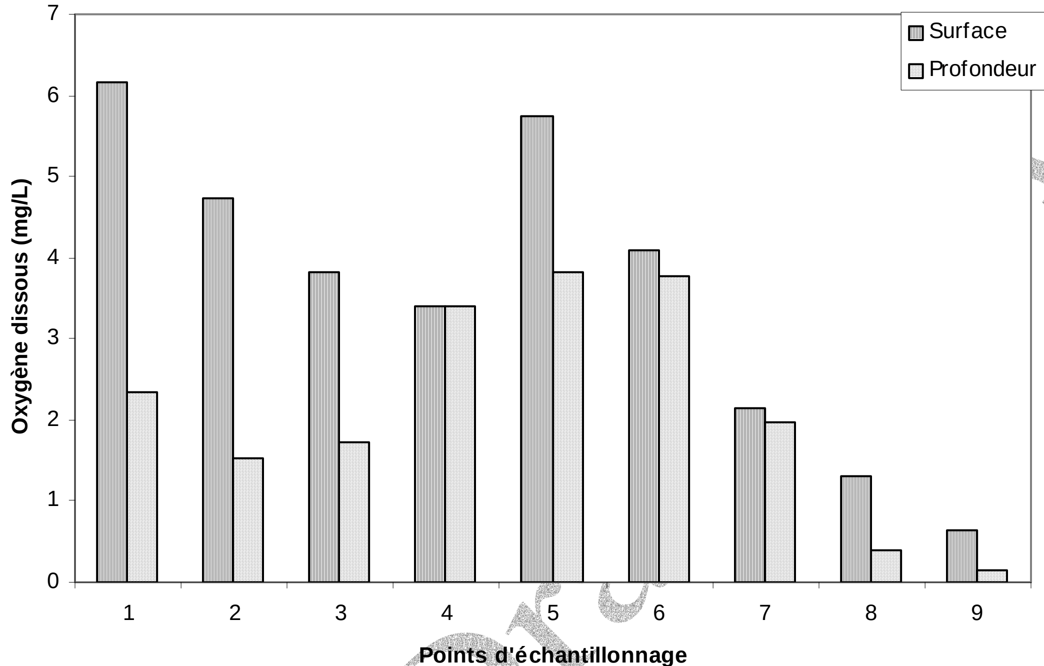
Figure 4.3-2
Comparison of Average Temperature Read in Depth between Dry and Raining Season (points 1= transect B2, 2 = transect 4 and 3 = transect 5)



Dissolved Oxygen

As for the temperature with which it often has a strong correlation, the oxygen rate on surface is clearly higher than the one read in depth (Figure 4.3-3). That can be understood by the strongest photosynthesis on surface and by a re-airing favoured by the air and water contact.

Figure 4.3-3
Comparison between Dissolved Oxygen Rate on Surface and in Depth
(points1 and 2 = transect B2,3 and 4 = transect 4, 5 and 6 = transect 5, 7 and 8 = transect 8 and 9 = transect 9)



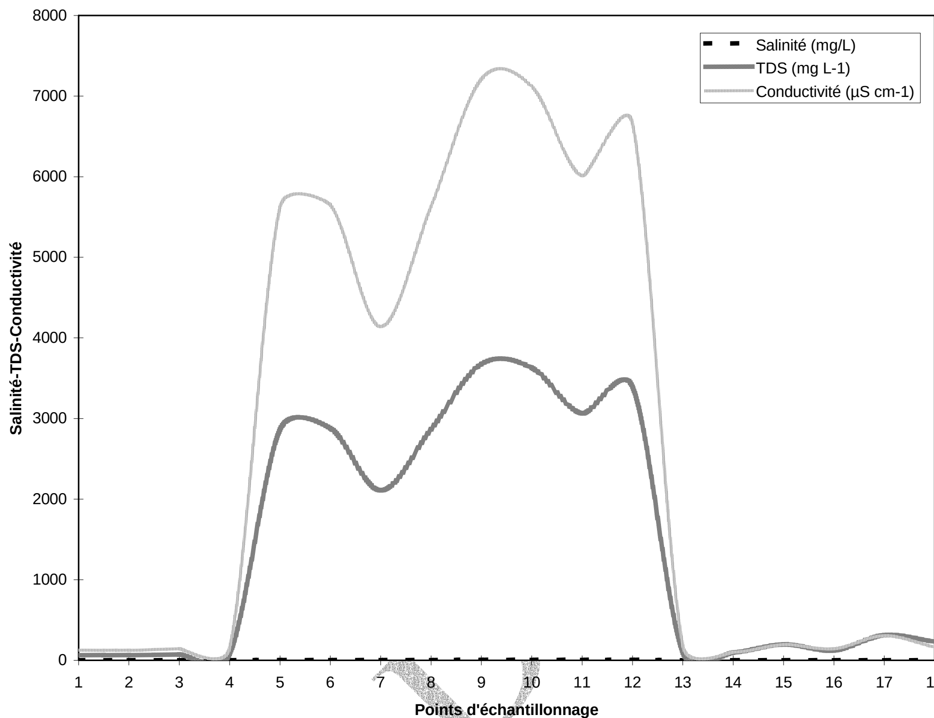
pH

Apart from the (transect B5) lagoon where the ph is lightly basic, we read at every swamps level an acid ph. That acidity is well emphasised on the last transects (B8and B9) (4.91-5.30), probably because of they contained peat.

Salinity, Conductivity, TDS

The salinity that was higher at the briny water swamp level during dry season, is now higher in the lagoon. It remains nil in the other swamps equally to seasons. It is highly correlated with the TDS and the conductivity (Figure 4.3-4).

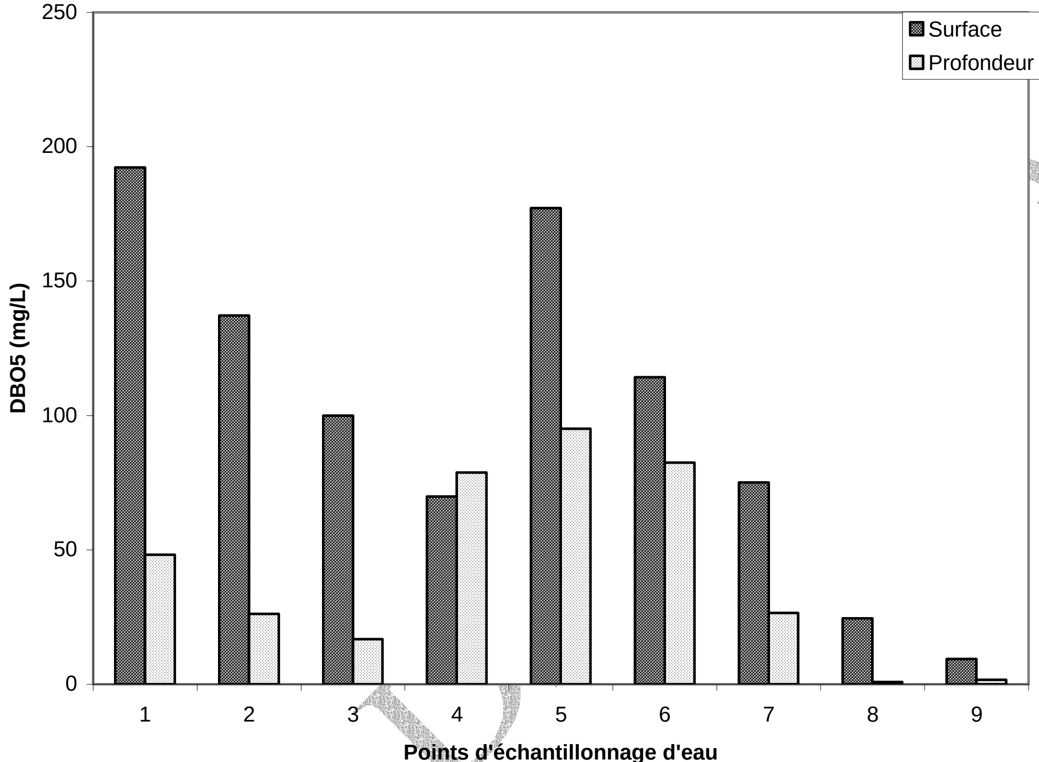
Figure 4.3-4
Relation between the Salinity, the TDS and the Conductivity Read on the B2, B4, B5, B8 and B9 Transects
(points 1,2,3 and 4 = transect B2; 5, 6, 7 and 8 = transect B4; 9, 10, 11 and 12 = transect B5; 13, 14, 15 and 16 = transect B8; and 17 and 18 = transect B9)



DB05

The biologic need in DD05 oxygen is generally higher on surface than in depth probably because of plankton abundance (phytoplankton and zooplankton) and the macro-invertebrate larva’s photophile that filled up the sampled water on surface (Figure 4.3-5). The only case in which the DB05 on surface is inferior to the one noticed in depth corresponds to a total transparency (transparency=depth). Critical values are noticed at transect 2 soft water’s swamps (137.14 and 192.24mg/L) and at transect 5 lagoon level (114.29 and 177.14).

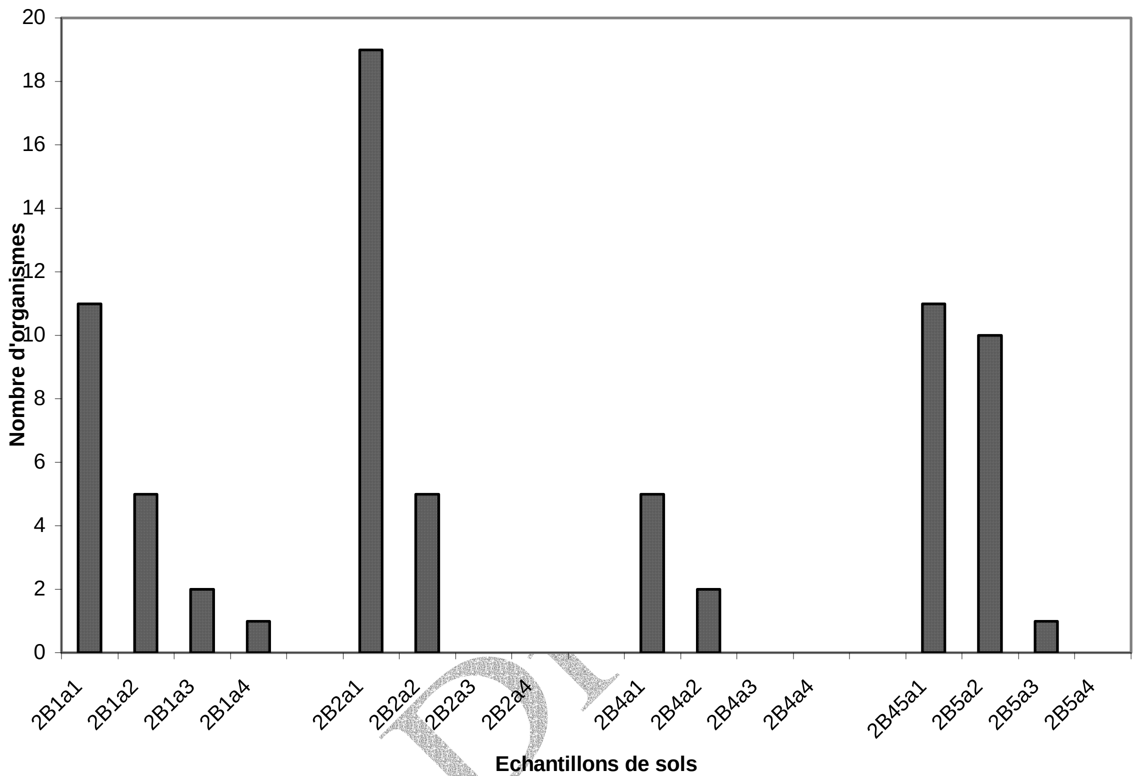
Figure 4.3-5
DB05 Variation on Surface and in Depth and from One Transect to Another
(point 1and 2 = transect B2, 3 and 4 = transect 4, 5 and 6 = transect 5, 7 and 8 = transect 8 and 9 = transect 9)



Macro ecology

Analyses revealed a more important diversity of bodies in the sampled soils superficial strata (Figure 4.3-6). That specific diversity decrease considerably as one advance towards deep strata and become nil at some transect levels especially on beach and soils near wet zones. As in the case of dry season, Hymenopterans are represented on all of the transects by the Formicidae and/or by the Myrmicidae. The worms with ring are only found on the soft water of wet zones soils (B2, B8 and B9)... *Perna, Pitaria tumens, Diplodonta diaphana, Tellina nymphalis, Turritella ligar* and *Turritella torulosa*. Nevertheless, we notice a nearly total absence of shellfish in the lagoon. Shellfish registered in the salty water swamp are dominated by *Littorina sp., Turritella ligar, Turritella torulosa*.

Figure 4.3-6
Relation between Specific Diversity and Benthos Bodies Total Numbers of Wet Zones Transects



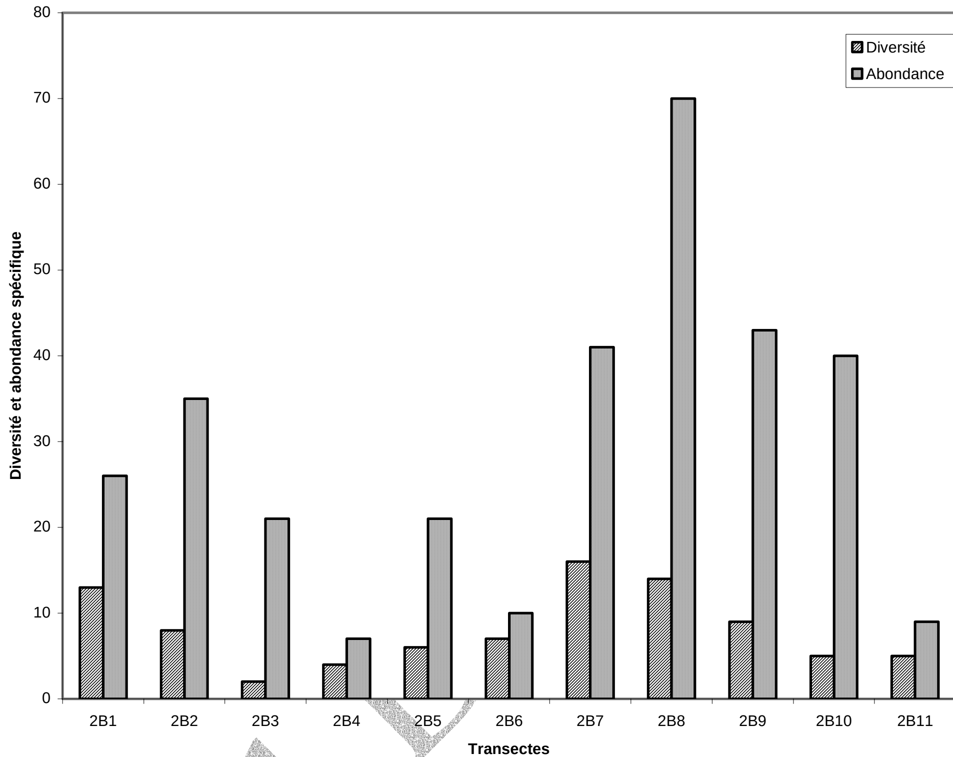
Microbiology

The different results are presented in appendix on the table entitled "results o microbiologic analyses of soils, sediments and sampled water during raining season". In all, 18 water samples and 65 soils samples and 25 benthos samples have been analysed on microbiological plan. The general remarks that get out are the following: as far as analysed waters are concerned, 83.30% (15 over 18) of the samples are contaminated by the thermo-tolerant coliforms, whereas 27.78% (5 over 18) contain *Escherichia coli*. Only 5 samples contain *Streptococcus* D. and 7 samples contain *Clostridium* sulphite-reducers. The presence of a thermo tolerant testifies a recent faeces contamination (pollution by human or animals faeces evacuation). On the other hand, the *Streptococcus* presence reports an old faeces contamination (water from phreatic lake originally restful on a soil of alluvial or sedimentary structure). The *Clostridium* spores are also indicators of faeces pollution.

As far as soils are concerned, we have to know that all of them are contaminated by *Bacillus spp*, 66.15% contain coliform (43 over 65), 43.08% contain *Clostridium* reducers-reducers larva (28 over 65), none of the soils shelters pathogenus *Staphylococcus*. It is important to notice that 88.53% of soils contain yeasts and molds whose dominance talking of molds is found among the zygomycets and the *Sacharomyces* for the yeasts.

The different aerobic quanta microbial are all inferior to 10/g and explain a pauci-microbian characteristic generally when taking into account the samples nature (Figure 4.3-7).

Figure 4.3-7
Relation between Specific Diversity and Total Number of Transect Soils Bodies



Benthos

The results obtained here are perfectly suitable to the state of the different sampled wet zones. Therefore, one can notice that the briny water swamp shelters very few macro-benthos species (10) are perfectly adapted to that biotope, that justify their abundance clearly superior to the one in the other zones (1001). On the other hand, the 2B9 and 2B8 transects that are zones filled of peat with slight water are not diversified or abundant in macro-benthos species. On the other hand, the lagoon with abundant water appears quite balanced in specific diversity (28) and in body number (581). It is followed by the 2B2 soft water swamp which is also balanced in specific diversity and abundance.

As in the case of the dry season, the B2 soft water swamp has preserved its specific diversity that remains clearly superior to the one of the salty water swamp. On the other hand, the lagoon is more abundant in bodies than during dry season with shellfish and ring worms in abundance. Lagoon shellfish are also surpassed by Mytilus.

The test of the diversity and of the total number of bodies per transect allows us to notice that the 2B7 transect has a higher specific diversity (16) followed by 2B8 (14) transect and 2B1

(13) transect. However, the 2B8 (70) transect has the highest number of bodies followed by 2B9 (41) and 2B10 (40) transect. The 2B3 (2), 2B4 (4), 2B5 (6), 2B10 (5) and 2B11 (5) transects soils show critical aspects according to their specific diversity. The test of the diversity and of the total number of bodies per transect allows us to notice that the 2B7 transect has a higher specific diversity (16) followed by 2B8 (14) transect and 2B1 (13) transect. However, the 2B8 (70) transect has the highest number of bodies followed by 2B9 (41) and 2B10 (40) transect. The 2B3 (2), 2B4 (4), 2B5 (6), 2B10 (5) and 2B11 (5) transects soils show critical aspects according to their specific diversity.

As in the case of the dry season, bacteria and mushrooms profusion noticed in the different samples shows that the various transects stand for animals and human faeces and domestic garbage dumping grounds.

Zooplankton

As in the case of the dry season, the salty water swamp and the lagoon (transect 4 and 5) shelter the same specific diversity of plankton dominated by the cladoceros and the copepods. The B4 transect whose salt content has significantly decreased because of raining water, is very poor in zooplankton. However, soft water swamps are filled with zooplanktons clearly superior to the one of the 4 and 5 transects, with a specific exceptional high rotifer content.

Phytoplankton

As noticed during the dry season, phytoplankton specific diversity is clearly superior at the soft water swamps level followed by the one of the salty water swamp. The dominant species in the soft water transects during the raining season remain *Cyclotella* spp., *Closterium aciculare*, *Synedra* sp., *Mycrocystis* spp., *Fragilaria* sp., *Oscillatoria* spp. and *Synechocystis aquatilis* with particular abundance of *Cyclotella* spp. The one that dominate in the transect 4 are: *Cyclotella* spp., *Microcystis* spp., *Nitzschia* sp., *Closterium* sp., *Merismopedia sp.*, *Microcoleus* sp., *Oscillatoria* sp. The lagoon is dominated by the following phytoplankton species: *Cyclotella* sp., *Stephanodiscus* sp., *Melosira* spp., *Microcystis* spp. and *Oscillatoria* spp.

4.3.2.2 Physics – chemistry of water

Temperature

The temperature is generally higher at the surface as opposed to at depth (Figure 4.3-8), but the water is warm enough to allow for tropical species (20-32°C) to exist in the region. The critical range, from 33.3 to 36°C, has been observed during the dry season at the salt water swamp (transect B4), which has been drained in some places (Figure 4.3-9).

Figure 4.3-8
Comparison of Temperature on Surfaces and in Depth
(hurt 1 and 2 = transect B2 , 3 and 4 = transect 5 , 7 and 8 = transect 9)

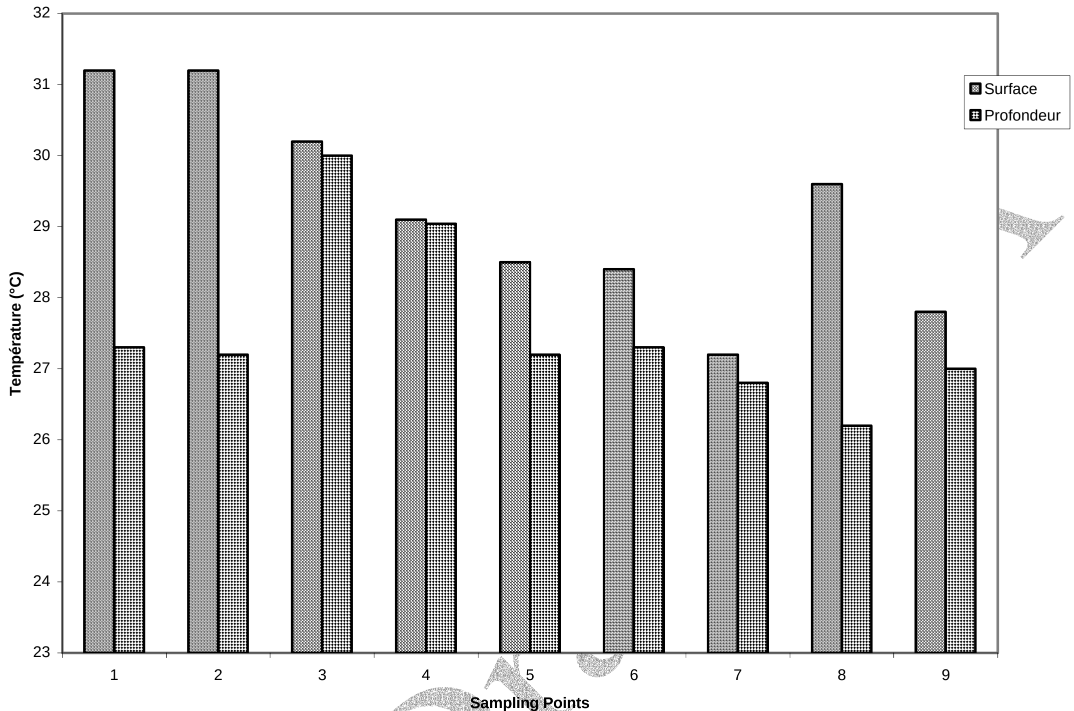
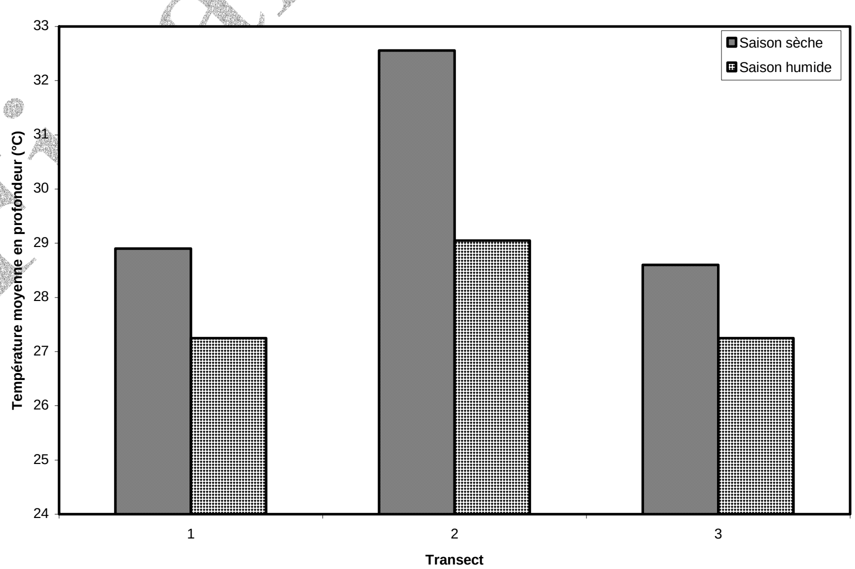


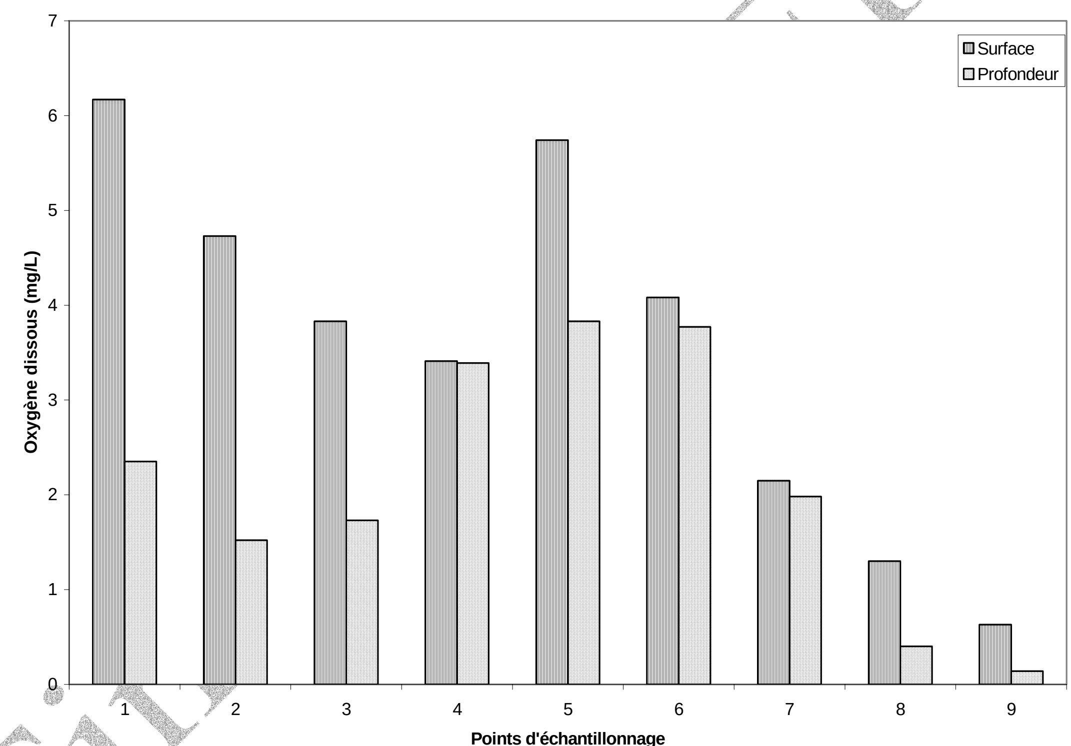
Figure 4.3-9
Comparison of Average Temperature in Depth between Dry and Raining Season
(hurt 1 = transect B2 , 2 = transect 4 and 3 = transect 5)



Dissolved oxygen

Have for the temperature with which it often has strong correlation, the oxygen (Figure 4.3-10) spleen one surfaces is clearly higher than the one read in depth (bank 3). That can be understood by the strongest photosynthesis one surfaces and by has re-airing favoured by the air and water contact.

Figure 4.3-10
Comparison between Dissolved Oxygen on Surfaces and in Depth (points1 and 2 = transect B2,3 and 4 = transect 4 , 5 and 6 = transect 5 , 7 and 8 = transect 8 and 9 = transect 9)



pH

Apart from the (transect B5) lagoon where the ph is lightly BASIC, we read at every swamps level a year acid pH. That acidity is well emphasised one the last transects (B8 and B9) (4.91-5.30), probably because of they contained peat.

Salinity, Conductivity, and TDS

The salinity that was higher at the briny water swamp level during dry season, is now higher in the lagoon. It remains the Nile in the other swamps equally to seasons. It is highly correlated with the TDS and the conductivity (bank 4) (Figure 4.3-11).

Figure 4.3-11
Relation between the Salinity, the TDS, and the Conductivity Read One the B2 , B4 , B5, B8 and B9 Transects
(Hurt 1,2,3 and 4 = transect B2 , 5 , 6, 7 and 8 = transect 4 , 9 , 10, 11 and 12 = transect 5 , 13 , 14, 15 and 16 = transect 8 and 17 and 18 = transect 9)

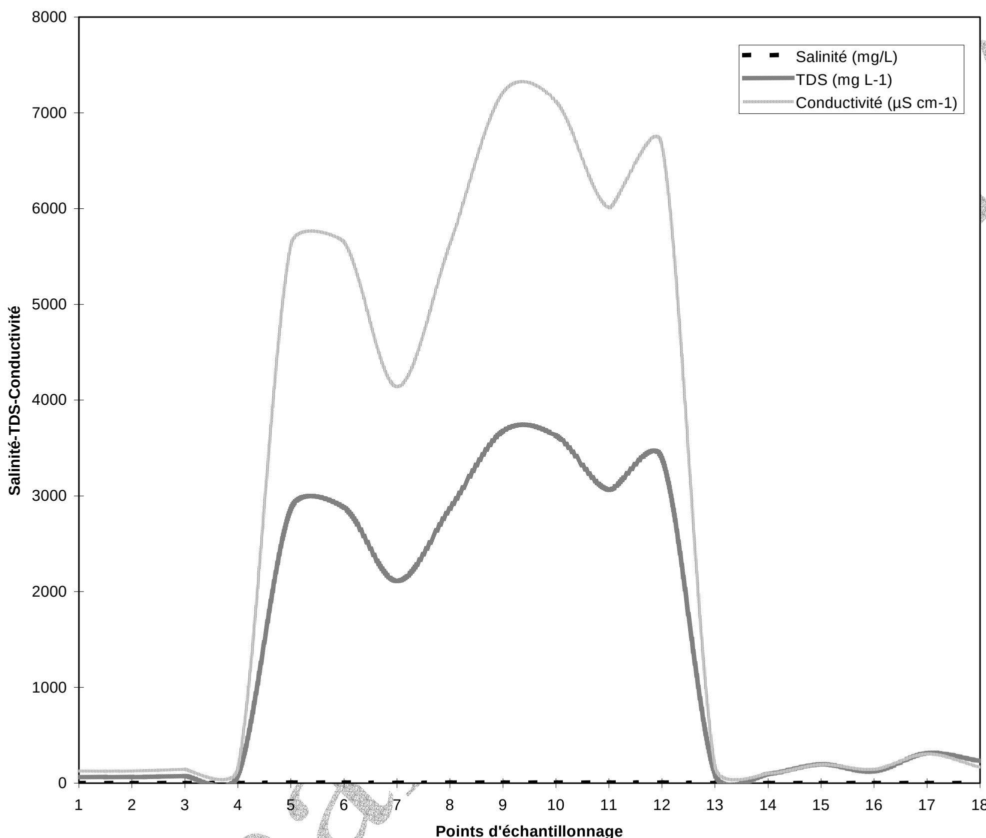
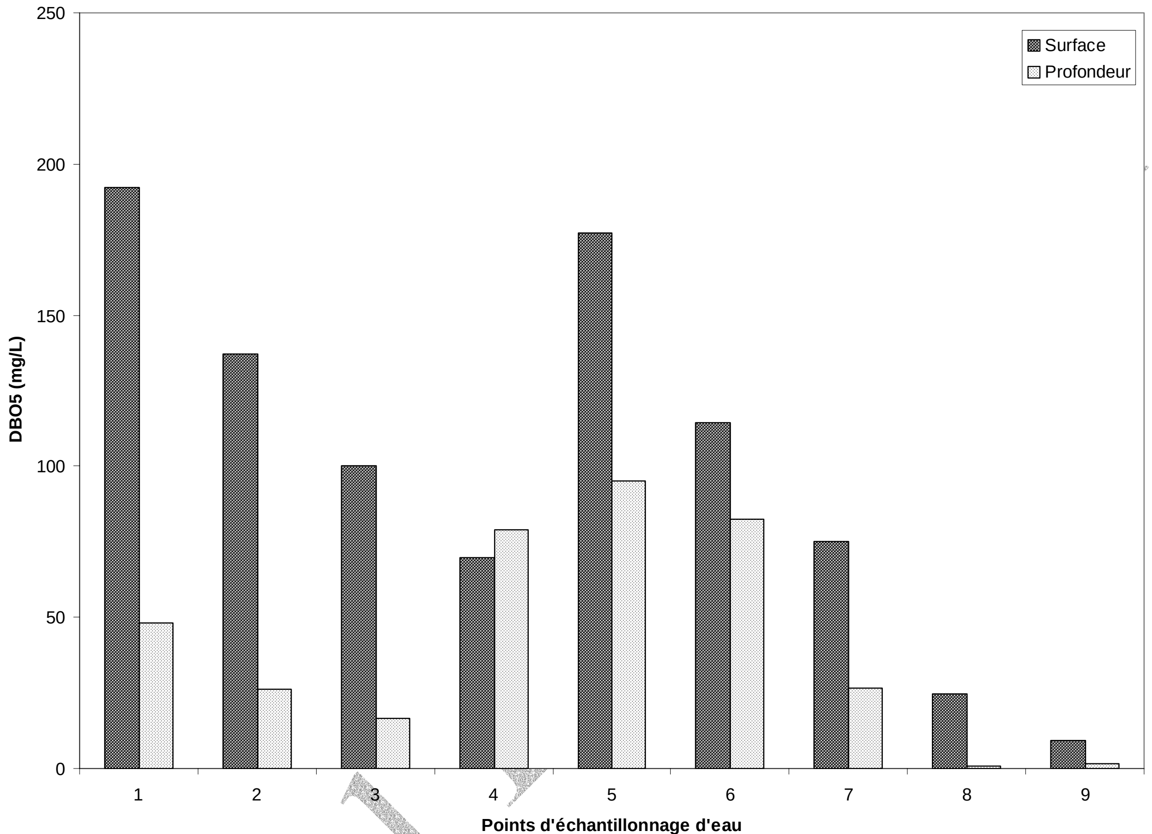


Figure 4.3-12
Variation du DBO5 en surface et en profondeur et d'un transecte à un autre (points 1 et 2 = transecte B2, 3 et 4 = transecte 4, 5 et 6 = transecte 5, 7et 8 = transecte 8 et 9 = transecte 9)



4.3.3 Biological

4.3.3.1 Benthos

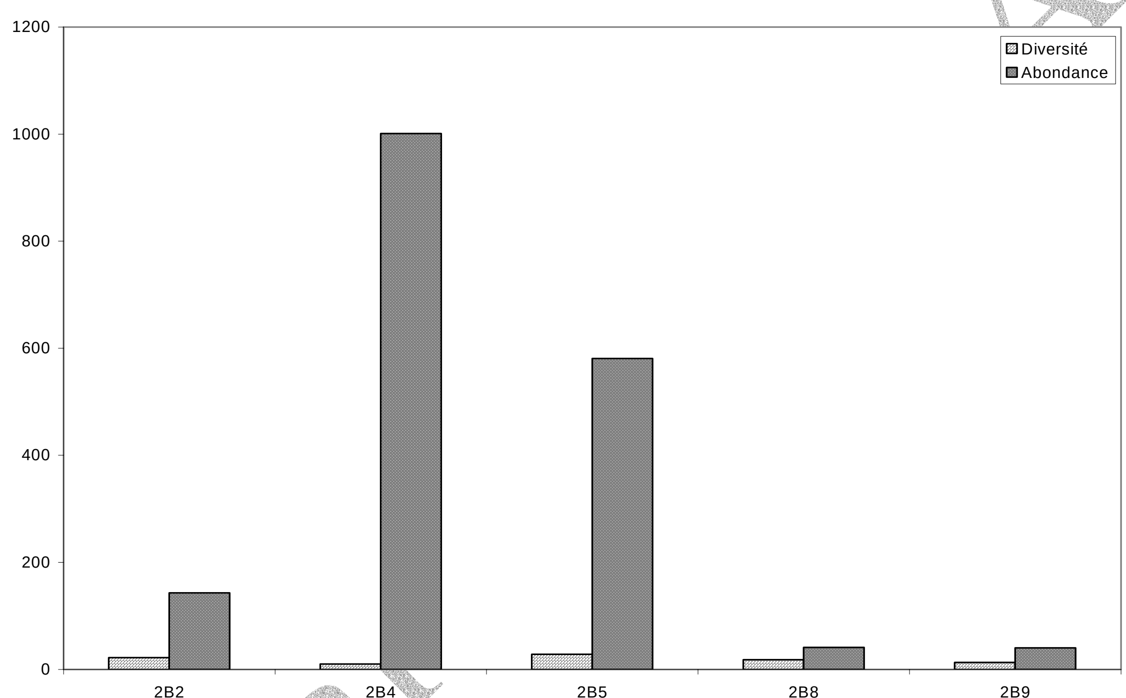
The results obtained here are in perfect equivalence with the state of the various sampled wet zones. So, we can notice that the swamp of brackish water shelter very few sorts of macrobenthics (10) perfectly adapted to this biotope, which proves their abundance sharply superior to those of the other circles (1001). Besides, the transects 2B9 and 2B8 which are curry in fined film of water, is neither diversified, nor plentiful in macrobenthics cash. On the other hand, the lagoon in important water body seems balanced enough in specific variety (28) and in number of bodies (581). It is followed by the swamp of fresh water 2B2 which is also well-balanced in variety and specific abundance.

As for the dry season, the swamp of fresh water B2 kept its specific variety which remained sharply superior to those of the swamp of salt water. The lagoon on the other hand is more plentiful in bodies than in dry season, with a dominance in mollusks and towards Annélides.

The mollusks of the lagoon are still dominated by *Mytilus perna, Pitaria tumens, Diplodonta diaphana, Tellina nymphalis, Turritella ligar* and *Turritella torulosa*. We however note the almost total absence of shellfishes in the lagoon.

Mollusks registered in the swamp of salt water are dominated by *Littorina sp. Turritella ligar*, *Turritella torulosa*. Figure 4.3-12 shows the numbers of individuals collected.

Figure 4.3-13
Variety (Number of Sorts) and Abundance of Benthics Bodies



Microbiology

The various results are presented in Appendix on the entitled table "results of the microbiologic analysis of grounds, sediments and water sampled during the rainy season. On the whole, 18 samples of water and 65 samples of ground and 25 samples of benthos were analyzed in the microbiologic plan. The general remarks which come out are the following: as far as the analyzed waters, 83.30% (15 to 18) samples are contaminated with coliformes thermotolérants, while 27.78% (5 to 18) contain Eschérichia coli. Only 5 samples contain Streptococci D.et 7 samples contain the spores of sulfito-reducing Clostridium. The presence of thermotolérants gives evidence of a recent faecal contagion (pollution by the human or animal excrement). On the other hand, the presence of the Streptococci of the group D testifies a former faecal contagion (water emanating from a groundwater basing originally on a ground with alluvionary sedimentary structure). The spores of Clostridium are also indicators of faecal pollution.

4.3.3.2 Plankton

Zooplankton

As for the dry season, the swamp of salt water and the lagoon (transects 4 and 5) shelter the same specific varieties of zooplankton dominated with cladocères and copépodes. The transect B4 content in salt which seems significantly because of rainy waters, is very poor in zooplankton. However, the swamps of fresh water have an abundance of zooplankton sharply superior to those of the transects 4 and 5, with an exceptional specific wealth in rotiferies. Table 4.3-1 shows the abundance of zooplankton at each collection point on the transects.

Table 4.3-13
Variety and Specific Abundance of the Zooplankton Great Groups

	Rotifères		Cladocères		Copépodes		Ostracodes	
Stations	Species	N/ml	Species	N/ml	Species	N/ml	Species	N/ml
2B2 ps1	*Lecane leontina*	2.67	*Daphnia sp*	2.00	*Cyclops sp*	2.00	*Ostracodes*	15.0
	Lecane monostyla	2.00	*Simocephalus sp*	0.33	*Nauplii*	3.33		
	Polyarthra vulgaris	5.00	*Ceriodaphnia sp*	3.67				
	Hexarthra sp	0.33	*Macrothrix sp*	2.00				
	Mytilina sp	0.67	*Moina brachiata*	0.67				
	Epiphanes brachionus	0.33						
	Keratella quadrata	0.67						
	Anuraepsis fissa	0.33						
2B2 pf1	*Polyarthra vulgaris*	4.67	*Diaphanosoma brachyurum*	0.67	*Cyclops sp*	1.67	*Ostracodes*	22.0
	Lecane monostyla	4.00			*Nauplii*	4.33		
	Trichocera capucina	1.33						
	Keratella quadrata	1.00						
	Lecane leontina	1.67						
	Trichocera chattoni	0.33						
	Chomogaster sp	0.33						
2B2 ps2	*Mytilina sp*	5.67	*Bosmina sp*	3.33	*Cyclops sp*	3.00	*Ostracodes*	12.7
	Lecane leontina	3.00	*Daphnia sp*	1.67	*Nauplii*	13.33		
	Polyarthra vulgaris	3.33	*Ceriodaphnia sp*	2.33				

	Euchlanis sp	0.33	*Macrothrix sp*	3.67				
	Brachionus patulus	0.33	*Moina sp*	0.33				
	Keratella quadrata	0.33	*Simocephalus sp*	0.33				
	Dicranophorus prionacis	5.00	*Moina brachiata*	1.00				
	Lecane monostyla	17.33	*Chydorus sp*	0.33				
	Trichocera capucina	0.33	*Leptodora kindtii*	0.33				
	Keratella tropica	0.33						
	Synchaeta longipes	0.33						
	Brachionus quadridentatus	0.33						
2B2 pf2	*Lecane leontina*	2.33	*Diaphanosoma brachyurum*	1.33	*Cyclops sp*	3.00	*Ostracodes*	17.33
	Lecane monostyla	5.00	*Ceriodaphnia sp*	2.00	*Nauplii*	7.00		
	Mytilina sp	2.33	*Bosmina sp*	1.00				
	Monommata naculata	1.00	*Moina sp*	0.33				
	Conochilus sp	0.67	*Simocephalus sp*	0.33				
	Trichocera capucina	0.67	*Latona sp*	0.33				
	Polyarthra vulgaris	3.00						
	Dicranophorus prionacis	5.00						
	Keratella falcatus	0.67						
	Ascomorpha sp	0.33						
	Brachionus quadridentatus	0.33						
	Trichocera pusilla	0.33						
2B4 ps1	*Keratella quadrata*	0.33	*Daphnia sp*	3.00	*Cyclops sp*	0.33		
			Bosmina sp	0.33	*Nauplii*	59.00		
			Chydorus sp	0.33				
2B4 pf1	*Trichocera capucina*	0.33	*Daphnia sp*	2.33	*Cyclops sp*	4.33		
			Latona sp	1.00	*Nauplii*	17.33		
2B4 ps2	*Monommata sp*	0.33	*Sida sp*	0.33	*Cyclops sp*	2.33		
	Euchlanis sp	0.33		0.00	*Calanoïde*	0.67		

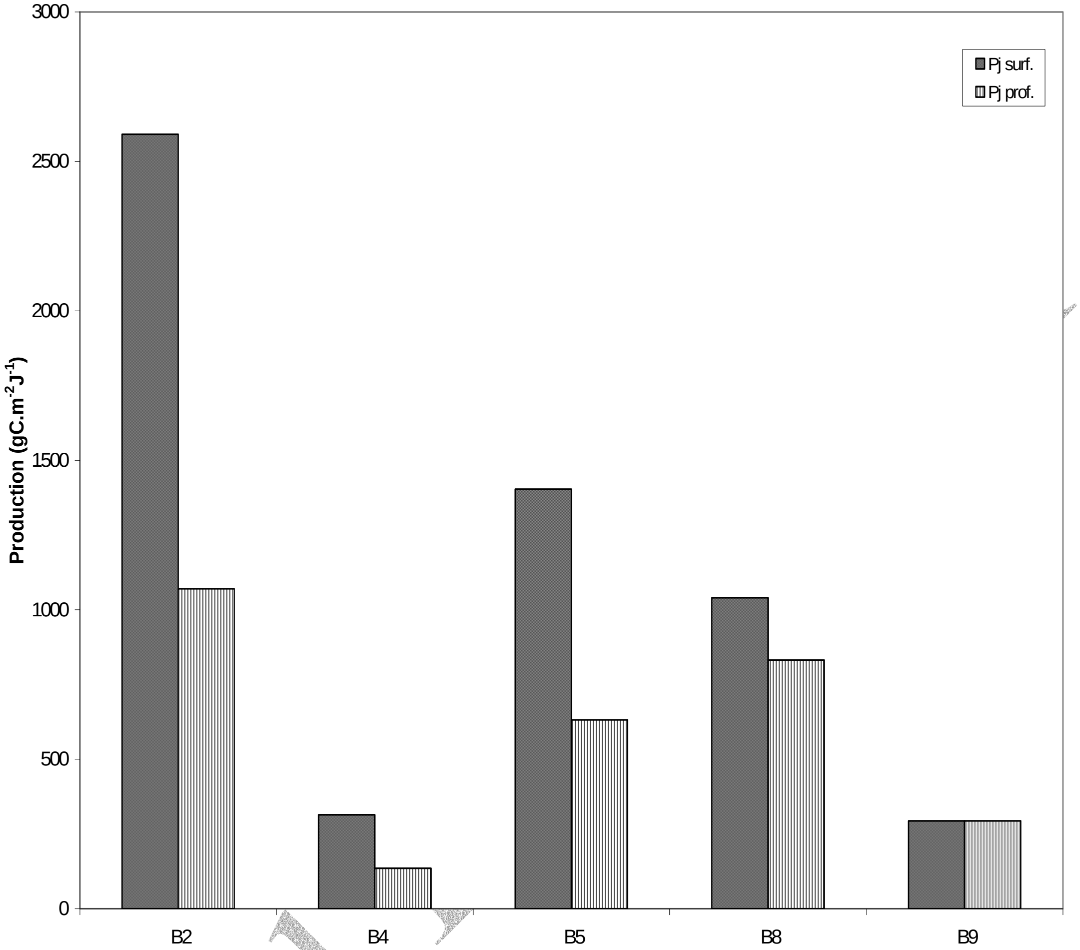
				0.00	*Nauplii*	36.33		
2B4 pf2			*Simocephalus sp*	0.33	*Cyclops sp*	3.33		
					Canthocamptus sp	0.33		
					Nauplii	17.33		
2B5 ps1					*Nauplii*	0.67		
2B5 pf1					*Nauplii*	4.00		
2B5 ps2	*Filina sp*	0.33			*Nauplii*	8.33		
2B5 pf2	*Keratella quadrata*	1.00	*Latona sp*	0.67	*Cyclops sp*	0.67		
	Synchaeta longipes	3.00	*Sida sp*	0.33	*Nauplii*	5.33		
2B8 ps1	*Brachionus falcatus*	0.33	*Bosmina sp*	1.33	*Cyclops*	6.33	*Ostracodes*	16.0
	Dicranophorus prionacis	6.00	*Eurycenus sp*	2.33	*Nauplii*	15.00		
	Platyias sp	0.33	*Ceriodaphnia*	1.00	*Calanoides*	4.33		
	Ascomorpha sp	0.67	*Sida sp*	0.33				
	Mytilina sp	0.33	*Alona costata*	4.33				
	Lecane monostyla	2.33						
	lecane leontina	0.67						
	Brachionus patulus	1.00						
2B8 pf1	*Dicranophorus prionacis*	3.00	*Alona costata*	11.00	*Cyclops*	4.67	*Ostracodes*	5.67
	lecane leontina	1.67	*Ceriodaphnia*	0.67	*Nauplii*	7.33		
	Lecane monostyla	2.00	*Sida sp*	0.33	*Calanoides*	1.67		
			Eurycenus sp	5.33				
			Bosmina sp	0.33				
2B8 ps2	*Lecane leontina*	1.67	*Daphnia sp*	0.33	*Cyclops*	3.00	*Ostracodes*	5.00
	Lecane monostyla	1.67	*Ceriodaphnia sp*	0.67	*Nauplii*	4.33		
	Brachionus patulus	0.33	*Sida sp*	0.67	*Calanoides*	9.00		
	Dicranophorus prionacis	0.33	*Bosmina sp*	0.67				
			Latona setifera	0.33				
			Alona costata	3.33				
			Eurycenus sp	7.67				

2B8 pf2	*Lecane monostyla*	0.67	*Macrothrix laticornis*	0.33	*Cyclops*	0.33	*Ostracodes*	3.67
	Dicranophorus prionacis	0.67	*Macrothrix rosea*	0.33	*Nauplii*	0.67		
			Eurycenus sp	5.67	*Calanoides*	0.33		
			Ceriodaphnia	1.00				
			Alona costata	4.33				
SB9 ps1	*lecane leontina*	1.67	*Ceriodaphnia*	19.67	*Cyclops*	3.00	*Ostracodes*	14.0
	Lecane monostyla	2.00	*Bosmina sp*	8.33	*Nauplii*	6.33		
	Brachionus patulus	0.33	*Eurycenus sp*	4.67	*Calanoides*	0.67		
			Macrothrix sp	6.00				
			Simocephalus sp	11.33				
			Daphnia sp	3.33				
			Chydorus sp	10.33				
			Sida sp	3.67				
			Polyphemus sp	4.67				
			Moina sp	4.67				
2B9 pf1	*Dicranophorus prionacis*	0.33	*Ceriodaphnia*	13.00	*Nauplii*	1.67		
	Lecane monostyla	0.67	*Macrothrix sp*	3.33			*Ostracodes*	11.3
	lecane leontina	1.00	*Chydorus sp*	7.33				
			Bosmina sp	4.67				
			Sida sp	2.33				
			Moina sp	2.67				
			Polyphemus sp	2.00				
			Simocephalus sp	10.67				

Primary Production

It is generally higher on surface than in depth at the all the sampled wet transect level, with a remarkable dominance of the transect 2B2 which water is more transparent (>1m) and probably more loaded in available nutriments for the phytoplancton responsible for this primary production.

Figure 4.3-14 Primary Productivity on each transect in Grams/year



Phytoplankton

As observed during the dry season, the specific variety of the phytoplankton is sharply superior at the swamps of fresh water level followed by that of the swamp of salt water. The dominant sorts in the transects of fresh water during the rainy season remain Cyclotella spp, Closterium aciculare, Synedra sp, Microcystis spp, Fragilaria sp, Oscillatoria spp and Synechocystis aquatilis with a particular abundance of Cyclotella spp. Those that dominate in the transect 4 are: Cyclotella spp, Microcystis spp, Nitzschia sp, Closterium sp, Merismopedia sp, Microcoleus sp, Oscillatoria sp. The lagoon is dominated by sorts phytoplanctoniques following: Cyclotella sp, Stephanodiscus sp, Melosira spp, Microcystis spp and Oscillatoria spp.

Table 4.3-2 Species found in each sampling point of each transect.

	Transec t B2	Transec t B4	Transec t B5

Sorts	2B 2 ps1	2B 2ps f1	2B 2ps 2	2B 2pf 2	2B 4ps 1	2B 4pf 1	2B 4ps 2	2B 4pf 2	2B 5ps 1	2B 5pf 1	2B 5ps 2	2B 5pf 2
Amphora ovalis							13	2				
Anabaena flos-aquae							4					
Anabaena sphaerica											7	
Botryococcus braunii							3					
Calothrix sp			1									
Closterium aciculare	5	3	1		1	2	3		4			
Closterium lanceolatum	3	2	2									
Closterium navicula							6					
Closterium sp			6	4								
Cocconeis placentula							17	10				
Cocconeis sp				6								
Coelastrum microporum			3	1			2					
Coelosphaerium confertum	1								3	9		
Cyclotella sp	340	212	137	223	234	216	95	27	269	30	79	69
Cymatopleura solea				1		4		3				3
Cymbella sp							8					
Diatoma sp		1		1				15		6	3	
Gomphosphaerium aponina									2			6
Melosira sp					1	2	4					
Micrasterias radians			1									
Micrasterias tropica			21	1								

Microcystis delicatissima								57	12	14	9	17
Microcystis sp		10		20	13		54	82	20	24	18	12
Mougeotia floridana			2							1	2	
Navicula cryptocephala	3				8	2	25	14	4		4	
Navicula pigmaea		8						13				
Navicula sp	2	11	6	9	3	1	12	8				
Nitzschia acicularis					8	13						
Nitzschia sigma		1					33	16	9		6	
Nitzschia sp	3		2	5			46	23				
Nostoc entophytum						3	20					
Oscillatoria boryana			7	6					1	1	3	2
Oscillatoria sp	10	4	4	4	4	4	18	5	6	5	77	39
Phacus orbicularis								3				
Pinnularia cardinalis			3									
Pleurotaenium trabecula			11	3	1	2			4			
Raphidiopsis curvata								7				
Scenedesmus quadricauda												6
Sphaerocystis schroeleri				1								
Spharoeca volvox							1					
Spirogyra gracilis			2									
Spirulina sp							1	3				
Stephanodiscus sp	6	1			23					3		1
Surirella capronii				1				1			2	1

Synechococcus aeruginosus							6	9				
Synechocystis aquatilis							8	12	58			
Synedra ulna	8	7	7	5		4	27					
Tabellaria sp						2	6					
Tetraedron gracile			2									
Tetraedron sp		1										2
Ulothrix zonata			3									
Volvox aureus			2									
# of species observed	**10**	**12**	**20**	**16**	**10**	**12**	**23**	**19**	**12**	**9**	**11**	**11**
number of seaweed (seagrasses)/mL of the sample	**381**	**261**	**223**	**291**	**296**	**255**	**412**	**310**	**392**	**93**	**210**	**158**
# of seagrasses/mL of the environment	**0.30**	**0.12**	**0.44**	**1.28**	**0.31**	**0.31**	**0.47**	**0.44**	**0.22**	**0.03**	**0.12**	**0.08**
Abundance (% of types(Species))	**19.2**	**23.1**	**38.5**	**30.8**	**19.2**	**23.1**	**44.2**	**36.5**	**23.1**	**17.3**	**21.2**	**21.2**

	Transect B8				Transect B9	
Espèces	2B8ps1	2B8pf1	2B8ps2	2B8pf2	2B9ps1	2B9pf1
Anabaena sp			8			
Closterium aciculare	11	4	31	18	12	60
Closterium lanceolatum	1		32	57		2
Closterium parvulum	2					
Closterium sp	3					14
Coelasterium microporum	2		2			

Cyclotella sp	5	4		5		3
Cymatopleura solea	6	1				
Gonatozygon monotaenium	1		38	10	5	
Micrasterias radians			8			
Micrasterias truncate	1					
Microcystis delicatissima			17			
Microcystis elachista			13			
Microcystis sp	7	3	4	6	4	
Mougeotia floridana					2	
Navicula cryptocephala		14	3		7	19
Navicula cuspidate	30	16				
Navicula sp	7	3		8	5	12
Nitzschia sp	5					6
Oscillatoria boryana	49	13	3		16	12
Oscillatoria sp	5	3	4			
Oxilallatoria boryana				3		
Oxillatoria sp				45	13	
Pinnularia cardinalis	11	10	1	5		3
Pledorina sphaerica			3			
Pleurotaenia sp	1					
Pleurotaenium trabecula					6	
Spirogyra sp (2 à 3plastes)	13	2	213	32	1	
Spirulina sp	396	54	5			
Stauroneis phoenicenteron	15	6				10
Ulothrix zonata						2
# of species observed	**20**	**13**	**16**	**10**	**10**	**11**
number of seagrasses/mL of the sample	**571**	**133**	**385**	**189**	**71**	**143**
# of seagrasses/mL	**0.5**	**0.2**	**5.6**	**2.2**	**1.1**	**2.4**

of the environment						
Abundance (% of types(Species))	**64.5**	**41.9**	**51.6**	**32.3**	**32.3**	**35.5**

4.4 THE LAGOONS AND MARSHES HABITATS

The lagoon and marshy zones crossed by the pipeline on the Benin territory are represented by the coastal lagonn (at Hio) and a series of marshes of heights more or less important situated between the village of Adjahindji (near the lagoon) and the district Maria-Gléta at Godomey, farther in the North (place of stockage and of gaz supply). They are sensitive zones on the ecological plans as well as socio-economic which is important to know the natural huts and/or species.

4.4.1 Coastal Lagoon (Transect B5)

4.4.1.1 Physico-Chemical Characteristics of the Water

- In dry season (December 2002 to January 2003)
- Temperature: 28.6°C 30.30°C (average: 29.47°C)
- Salinity: 10.2% to 10.70% (average 10.37%)
- Ph: 5.25 to 8.50 (average: 7.49)
- Dissolved oxygen: 3.00mg/l to 7.55 mg/L (average: 4.58mg/L)
- Water's height: 0.45m to 2m (average: 1.31m)
- NO2: 0.029mg/L to 0.071mg/L (average: 0.049mg/L)
- NO3: 0.97mg/L to 2.04mg/L (average: 1.67mg/L)
- NO4: 17.3mg/L to 20.97mg/L (average:18.99mg/L)
- PO4: 3.75mg/L to 21.25mg/L (average: 11.75mg/L)

- In rainy season (june-july 2003)
- Temperature: 28.2°C to 28.6°C (average: 28.4°C)
- Salinity: 0.3% to 1.7% (average:0.66%)
- Ph: 6.70 to 6.92 (average: 6.82)
- Dissolved oxygen: 1.01mg/L to 2.58mg/L (average: 2.22mg/L)
- Water's height:
- NO2: 0.78mg/L to 0.163mg/L (average: 0.117mg/L)
- NO3 : 9.72mg/L to 16.08mg/L (average: 12.50mg/L)
- NO4: 24.58mg/L to 31.08mg/L (average: 27.12mg/L)
- PO4: 0.23mg/L to 2.31mg/L (average: 1.27mg/L)

4.4.1.2 Vegetation

The coastal lagoon is occupied by fragment of mangrove and grassland to *Paspalum vaginatum*. The mangrove is constituted of two parallel units following the topography.

In the lagoon edge where the flood is very prolonged, one note the mono-specific ground to *Rhizophora racemosa*. This grouping of a 6m high has an average covering of 60%. The temporal flood zone in the background of the above grouping to *Avicenia germinans* and *Acrostichum aureum*. It is structured in two stratums: the bushy stratum of 6m high is very opened with 15% covering. The herbaceous stratum, more dense contains a lot of species whose most frequent are: *Pasalum vaginatum,Pycreus polystachyos, Eleocharis mutala,Scqaria dular,Pentadon pentadrus* and *Fuira umbrella.*

The grassland of *Paspalum vaginatum* characterises the places where the mangrove is entirely destroyed. It constitutes a formation the most extended of the lagoon. One notes some isolated feet of *Avicennia germinans, Acrostichum aureum* and herbaceous companions species such as: *Pycreus polystachyos, Fimbristylis ferruginea, Kyllinga erecta, Torenia thouwarsii, S permacoce ocimoides, Fuirena umbrellata, Eleocharis mutata*, etc.

4.4.1.3 The Soil

They are hydromorphs organic soils with gley more or less salty. They are developed on the lagoon materials; they are seasonally salty which which shows the presence of mangrove.

These soils are characterized by a homogeneous clayey texture with in places a texture more heterogeneous with sandy chief characteristic.

The mangrove sediment is characterized by the accumulation within the clay-sandy material more particularly at the level of mangroves' roots, iron pyrites, mainly pyrite. This one comes from the reduction of sea water sulfates in anaerobic environment under the influence of the sulphato-reducing bacteria present in the soil. The dominant factors of the mangrove soils evolution is the sulphur and the compound sulphured where the term of soils acid sulphated is currently used to distinguish them.

Remark: We must particularly note that the lagoon ecosystem constitute the very rich biotopes on ecological view point as a result of the rotated influence of marine waters and soft waters. However thanks to their stilt roots, mangrove constitute for fish some particularly calm spawns and the predator's shelter. Therein the coastal lagoon, the fish, crabs and shrimps of commercial importance and frequently encountered belong to the following families and genders:

- Cichlidae: *Sarotherodon, Tilapia, Hemichromis*;
- Clupeidae: *Ethmalosa, Pellonula*;
- Mugilidae : *Liza, Mugil*;
- Dasyatidae : *Dasyatis*;
- Clarotidae : *Chrisichthys*;
- Carangidae : *Caranz*;
- Portunidae : *Callinectes*; and
- Peneidae : *Penaeus*

4.4.2 Marsh of Adjahindji (Transect B4)

4.4.2.1 Physic and Chemical Characteristics of Water

- In dry season (December 2002 to January 2003)
- Water height:
- NO^-_2: 0.39mg/L to 0.48mg/L (average: 0.44mg/L)
- NO^-_3: 2.95mg/L to 3.O4mg/L (average: 2.99mg/L)
- NO^-_4: 20.98mg/L to 22.06mg/L (average: 21.80mg/L)
- PO3-$_4$: 0.087mg/L to 0.13mg/L (average: 0.103mg/L)
- Because of the rains (june – july 2003)
- Temperature: 29.6°C to 3.16°C (average: 30.74°C)
- Saltiness: 4.95% to 5.40% (average: 5.30%)
- Ph: 6.27 to 6.37 (average: 6.32)
- Dissolved oxygen: 1.87mg/L to 2.35mg/L (average: 2.10mg/L)
- Water height: 110-120cm
- NO2 : 0.49mg/L to 0.61mg/L (average: 0.54mg/L)
- N03: 17.48mg/L to 21.07mg/L (average: 19.57mg/L)
- NO4: 23.87mg/L to 26.08mg/L (average: 24.79mg/L)
- PO4: 0.97mg/L to 1.56mg/L (average: 1.35mg/L)

4.4.2.2 Vegetation

The Adjahindji marsh, of about 400m wide, is covered by some mangrove scraps and grassland from the mangrove degradation.

The permanent clogging zone is occupied by mangrove and grassland. The monospecific mangrove is constituted of *Rhyzophora racemosa* reaching 8m height. The grassland is greatly dominated by *Cyperus articulatus* associated to some rare yellow feet of *Rhizophora racemosa*. It is 1.5m height and covers the biggest part of the marsh (about 380m wide).

The area with temporally flood of 10m height contains also two types of plant formation: mangrove of *Avicenia germinans* and grassland of *Paspalum vaginatum*. Mangrove of *Avicenans germunatum* is observed in places less degraded. It is presented in two stratums. The tree planted stratum is very opened and dominated by *Pasplum vaginatum*. The low grassland of *Pasplum* characterises the area where the mangrove is completely destroyed. It constitutes the most spread formation in the zone of temporary flood. We can note there some isolated feet of *Avicenia germinans*, *Acrostichum aureum* and companion herbaceous species such as: *Pycreus polystachyos*, *Fimbristylis ferruginea*, *Kyllinga erecta*, *Toremia thouwarsii*, *Permacoce ocimoides*, *Fuirena umbrella*, *Eleocharis mutala*, etc.

At the level of exonde zones, some small islands of coastal thickets and fallows can be observed. The thickets comprise many species whose most important are: *Dalbergia acastaphyllum*, *Chrisobalanus icaco*, *Zanthoxylum zanthoxyloides*, *Anona senegalensis*, etc...The fallows are largely dominated by *Aristida adscensionis* followed *with Schyzachyrium sanguineum and Spermacoce verticillata.*

However, the Adjahindji marsh possesses a filled up branch called Dagbétomè marsh with about 10 to 12m wide. That branch is occupied by grassland presenting three floristic composition grouping of *Vetiveria nigritana*; the zone with prolonged flood is covered by the grouping of *Eleocharis complanata* and the grouping of *Eleocharis dulcis.*

4.4.2.3 The Soil

The drilling in the hollows (marsh) during the different works of Oyede (1988,1991) shows that the lowest part is always sandy, surmounted by a hydromorph of gley, of variable depth and so much important that we approach the hollow axis. Some marsh hollows were old channels of abandoned river. The sediments are clayed.

4.4.3 The Akadjamè Marsh (Transect B2)

4.4.3.1 Physico-Chemical Charasteristic of Water

On account of dry season (December 2002 to January 2003)

- NO_2: 0.37mg/L to 0.41mg/L (average: 0.388mg/L)
- NO_3 : 1.47mg/L to 1.52mg/L (average: 1.50mg/L)
- NH_4: 15.8mg/L to 16.11mg/L (average: 15.92mg/L)
- PO_4: 0.89mg/L to 1.13mg/L (average:0.96mg/L)
- On account of rains (june-july 2003)
- Temperature: 28.4°C to 28.7°C (average:28.57)
- Saltiness: 0%
- Ph: 6.62 to 7.86 (average:7.05)
- Dissolved oxygen: 1.93mg/L to 3.32mg/L (average: 2.31)
- Water height: 30cm to 50cm on the edge; 1.20m centerwarding great water
- NO_2: 0.45mg/L to 0.61mg/L (average: 0.50mg/L)
- NO_3: 15.32mg/L to 21.16mg/L (average: 18.12mg/L)
- NO_4: 18.03mg/L to 23.41mg/L (average: 21.05mg/L)
- PO_3: 0.076mg/L to 0.18mg/L (average:0.12mg/L)

4.4.3.2 Vegetation

The Akadjamè marsh is covers by vegetation whose appearance and floristic composition vary in terms of hydromorphy degree. The marsh central zone with a permanent clogging is occupy by small islands of grasslands whose floristic composition and extent are in term of the filling up level. Thus, the low filling up parts are covered with water where we can observe some grouping of *Eleocharis complanata* or of *Cyperus articulatus* of about 1m ray and some floating grassland of *Nymphaea* or of *Utricularia spp*. However, in the most important filling up grasslands we note a grouping of *Typha austalis* and *Scirpus cubensis* strewed of small water puddles spangled with herbaceous like *Nymphara* lotus and *Ipomoea aquatica.*

The marsh floodable edge in time of flood is occupied of grassland and some small islands of degraded marshy forest. The grassland is dominated by *Fuirena umbrellata*. That species is associated with many other less importance taxous like: *Leersia hexandra, Cypirus distans, Toenia thouwarsii, Pycreus polystachyos, Clappertomia ficifolia*, etc. The small island of marshy forest are very reduced about 1m wide. The characteristic species are represented by shrubs and herbaceous whose most important are: *Mussaenda isertiana, Isora brochypoda, Alchornea cordifolia, Vitex grandiflora, Phoenix reclinata, Tetracer alnifolia, Dissotis segregata and Scleria naummanniana*. That floodable zone is used in parts for the production of tomatoes, pepper and corn.

The exonded zone of the marsh is characterised by a fallow mosaic of palm trees and coconut palm. The most frequent species encountered in those formations are: *Vetiveria nigritana, Dolichos argenteus, Hyptis lanceolata, Scoparia dulcis*, etc.

4.4.4 The Hêvié Marsh

It is a big marsh spreading over about 5km long and over a modest 500m wide in average.

The first part of that marsh is bordered by the pipeline of the zone from the bridge on Hêvié road and a bit beyond. Then, the pipeline passes through the second part of the marsh (transect B8) before coming out to run along (transect B9) over a great distance and ends at Maria-Gléta (gas storage and distribution site).

4.4.4.1 Physico-Chemical Characteristic of Water

- On account of the rains (June – July 2003)
- Temperature: 26.2°C to 29.6°C (average: 27.43°C)
- Saltiness: 0%
- Ph: 4.91 to 5.30 (average: 5.17)
- Dissolved oxygen: 0.14mg/L to 2.15mg/L (average:1.1mg/L)
- Water height: 0.60m to 1.5m
- NO2: 0.63mg/L to 0.98mg/L (average: 0.78mg/L)
- NO3: 44.92mg/L to 63.41mg/L (average: 53.47mg/L)
- NO4: 28.76mg/L to 47.86mg/L (average: 39.93mg/L)
- PO3: 1.69mg/L to 3.11mg/L (average: 2.53mg/L)

4.4.4.2 Vegetation

The fist part of the bordered marsh by the pipeline presents a hollow constituted of a degraded marshy forest mosaic and of grassland according to the clogging degree and the degradation level. The zone of permanent flood contains the grouping of *Raphia hookeri* and *Cyrtosperma senegalense*. It is structured in to two stratums. The shrubby stratum of 6m height and 30% covering comprises only *Raphia hookeri*. The herbaceous stratum is denser. It is largely dominated by the *Cyrtosperma senegalense.*

The peripheral grasslands of the mars where the clogging is temporary, are occupied by the grouping of *Ficus congensis* and *Leersia hexandra* constitute of two stratums. The shrubby stratum, very opened, contains species such as: *Ficus congensis, Psychotria articulata,* *Alchornea cordifolia, Ixora brachypoda* and *Symphonia globilifera*. The low stratum, very dense with 95% covering and 1m height.

The largely dominant species is *Leersia hexandra* associated with many other species like: *Rhynchospora corymbosa, Cyclosorus striatus, Clappertonia ficifolia,* etc.

The areas completely degraded of the marsh are occupied by a vegetation whose appearance varies in terms of constitutive plant species. Thus, we can observe the grouping of *Typha australis* and *Nymphaea lotus*, the grouping of *Cyclosorus striatus*, the grouping of *Vossia cuspidate* and the grouping of *Thalia welwitschii* which is a species often grown for its leaves.

The exonded zone of the marsh comprises fallows, other cultures and palm tree plantations and *Artocarpus communis.*

For the second part of the marsh crossed by the pipeline, the zone with permanent flood contains a homogeneous vegetation. It is a grassland of *Typha australis and Cyclosorus striatus* (greatly dominant) *Cyrtosperma senegalense, Lecrsia hexandra* etc... Some rare plants of shrubs emerge. They are *Berlinia grandiflora* and *Anthocleista vogelii* in the marsh depth.

The marsh floodable zone is constituted of inter-seasonal culture and fallows whose common species are: *Torenia thouwarsii, Fuirena umbrellata, Lycopodium cernuum, Emilia sonchifolia, Pycreus polystchyos,* etc.

The aquatic grassland of the marsh are occupied by the fallos and palm-trees plantations and Artocarpus communis. As far as the third part of the marsh bordered by the pipeline is concerned, its zone with permanent clogging contains a degraded marshy forest with a shrubby stratum and a herbaceous stratum. The shrubby stratum, with 1 to 3m height is very opened. It covering is only 30%. It is greatly dominated by *Anthocleista vogelii* followed by *Lycopodium cernuum, Psychotria articulata and Raphia hookeri*. The herbaceous stratum is very closed with 80% covering. The most abundant species are: *Cyclosorus striatus, Thalia welwitschii, Cyperus distants, Anthocleista vogelii, Lycopodium cernuum.*

The marsh floodable edge in time of flood is occupied by a grassland dominated by *Leersia hexandra*. That latter is associated with many other species which are: *Cyclosorus striatus*, *Fuirena umbrellata, Dissotis segregata, Ludwigia stenorraphe, Kyllinga perruviana, Mussaenda isertiana* etc... That floodable zone is used in parts for the cultivation of Thalia *welwitschii.*

The submerged slopes of the marsh contain a mosaic of fallow, market gardening, thicket and palm groves.

4.5 WILDLIFE AND ANIMAL RESOURCES

4.5.1 The Fauna

The fauna study contains two sections: the fowl fauna and the non fowl fauna.

4.5.1.1 The Non fowl fauna

That section takes into account the mammalians , respilian and amphibian fauna.

The Mammalians

The day itinerant prospecting that we completed did not show any direct observation of big and middle mammalians. Nevertheless, the small and very small ones are relatively more represented.

Among the middle ongulated mammalians, the existence of *Sitatunga* (*Tragelaphus spekei* and *harnessed Guib*, *Tragelaphus scriptus*) has been noticed in the Southern sector.

But those animals footsprints research is not conclusive. No antilope has been in the Northern sector. The only ongulate whose presence is certain is the Potamocher (Potamochoerus porcus) that the population called boar. A night prospecting could allow to see some specimen on the marshes edges.

The small mammalians like:

a) The Aulacode improperly called “agouti” (*Thryonomys swinderianus*) live in the thicket small islands and in Savannahs. A specimen has been observed in the Northern sector but the scabs can been everywhere.

b) The Gambia Rat (*Cycetomys gambianus*) has not been observed, but its porches have been located mostly in the Northern sector.

c) The Burrowing squirrel (*Xerus erythropus*) lives in the Savannah in a bit deep burrow. Two specimen have been observed and their numerous burrows.

d) *Funissciurus* sp: live on the trees and like the palm grove, the coconut palms… Many specimen have been observed in the Northern Sector.

e) Have that seems to be absent in the southern sector can be seen in abundance in the Northern sector where we have flushed some specimen out by the farms edges

The very small mammals like reddish rat (*Arvicanthis niloticus*), the black Rat (*Rattus rattus*) anthropophiles live in the habitations neighbourhood.

The Crocidures or shews (*Crocidura* spp*)* are noticed through their unpleasant small. They live near the habitation and often attack the chicks. The populations distroy them with poisons made from insecticides.

The hedgehog with white underbelly (*Stelerix albiventris*) is easily observed in the vegetation clump in wet parts and lives in both sectors. The population give the name of Porcupine to the hedgehog (*Hystrix cristata*). The true Porcupine (*Hystrix critata*) is a much bigger animal, with long thornies. It can likely be met in the zone.

Two species of *Cercopithee* have been observed.

They are green Monkeys (*Cercopithecus aethiop*), very common, liking the thickets and the plantations and the Red monkeys or Patas (*Erythrocelus patas*), visible in the plantations. It prefers the high places than the ground.

The Galago of Senegal is a small primate of the arboricole lemurian group. The population consider it as a squirrel variety. It lives in the wooded formations of the marshes banks. It has been observed in the Northern sector.

The Reptiles

Almost all the respiles groups are represented in the study zone.

The Crocodiles

The specie recognized by the populations of both sectors in the study zone is the dwarf Crocodile (*Osteolaemus tetraspis*) that lives in the marshy waters.

The brackis of the coastal lagoon is not convenient for it at all. The Nile Crocodile has been mentioned, but we have impression that it is the previous species, because the Nile Crocodile (Crocodilus niloticus) is not found in the marshes but in the outskirt of the rivers month, because that specie essentially lives in the water course of a certain importance.

The Tortoises

The tortoises living in soft water, observed in marshy water are: *Pelusios subniger* and *Cyclanorbis sp* and the land Tortoises *Kinixys belliana* live in the Savannah. The specimen have been observed in the Northern sector. We didn't encounter the marine Tortoises at the beach. But the luth Tortoise, the nested Tortoise and the green Tortoise, all marine have been pointed out.

The Snakes

The snakes exist in the zone. The most common are pythons. The royal Python (*Python regius*) and the Python of Seba (*Python Sebae*) also called Africa boa or false boa. Those two species are taboo to most of the Fon people and are protected. The Vipers such as Common Viper (*Causus rhombeatus*), the contrasting viper (*Bitis arietans*), as well as the Gabon Viper (Bitis gabonica) pointed out by the population, live in the Northern sector too. The grass snake like *Chlorophis hetenodermus* and *Psammophis Elapidates* like the black Mzanba (*Dendroaspis polylepsis*) and the green Manba (*Dendroaspis viridis*) have been observed in the same sector.

Amphibians

The Amphibians also exist in the zone of study. The most frequent species are Frog (*Rana occiptalis*), Toad (*Bufo regularis*), the reddish Frog (*Rana temporaria*).

The tree frogs like *Hyla* and *Hyoriolus livant* in the grass and the shrubs have been observed.

4.5.1.2 The Fowl Fauna

That inventory takes into account all the birds species observed in the two sector Northern and Southern of the zone of study. The birds are well represented and more visible than the mammals, the respiles and the batracians.

The reputed habitants by the fauna are described below (cf.2.2). The recapitulative list of the recorded birds species is in annexe (see Birds File).

Specific richness

In total 92 species of birds have been recorded in rainy season.

Specific composition of the Area's birds

That Fowl fauna is composed in its whole of species linked to wet ecosystem (19 species of water birds), in Savannahs and in degraded forest areas.

Origin of the species

We distinguish:

- African resident species which are generally observed the whole year in the zone of study (*African Cormoran*, heron with green back, *Sparrowhawk shira*, black rail, *Turtledove*, *Cuckoo didric*, *Coucals*, *King fisher*, *Crow*, *Soui-Mangas*, *Corvinal*, *buzzard uniband*…)
- The Afrotropical species and as well as paleartic that use the two great faunistic regions in the world: ethiopian and palearctic (Cow Keeper heron, greyed heron, aigrette gazette, White Spawn, rattle…)
- The palearctic migrating species (Crabby heron, crimson heron, Sylvain sand piper, guignette sand piper).

Status of the Study Area

From our knowledge, a part of study area is a Site Ramsar 1017, a protected zone by the Ramsar Convention. However, that area of study is in full urbanisation and the fauna is so threatened.

4.5.2 Turtles Survey

4.5.2.1 Methodology

The adopted methodology is based on participative approach, on population experiences acquired through Nature tropical NGO that are working on the question of turtles protection in the zone. We have been able to see images at the coast wardens who watch somehow over the offenses. The adopted method is based on Simple random Sampling (SSS).

4.5.2.2 Characteristic

The most typical characteristic of a tortoise is the hard shell that covers all its body. That shell is composed above of a layer bone and a cornea layer outside; often but not always, the latter shows a geometric layout of sliver or plates.

All the species must go back to the land after a regular space during reproduction season when they lay eggs in a den dug in the sand (Table 4.5-1). After a period of incubation relatively long (generally 45 days to two months and half) the newborn ones get back to sea.

Chelonidae: shell, head and fins covered with cornea slivers (plates); corned beak never in form of W when seen from front, fins with one or two claws.

Chelonia mydas: green tortoise: oval, flat shell, its width is about 88% of the shell length. Small head (about 20% of the shell length), with only one pair of prefrontal plates; the border of the inferior gum roughly indented, the one of the Superior gum equips with strong combs on the internal face. Four pairs of lateral plates on the shell, the front pair touching not the precentral plate; four pairs of inframarginale plates on the shirt front; only one claw at each fin.

Colouring; upper face olive-brown, shell plates brillant with radial yellow green and black stains; pale-yellows, cream or whitish below. Spheric eggs, about 4.5cm of diameter.

Size: shell length (distance in straight line); up to 105cm maximum; common up to 90cm. Maximum weight up to 140kg; 80Kg common.

Adult; she is herbivore, lives on many zoosters species. The coupling takes place in July and the clutch from July to November; incubation duration varies according to 45 to 60 days latitude.

Lepidochelys Kempii: ridley tortoise: circular, flat shell, its midth is about 95% of its length. Small head (about 20% of the shell length) with two pairs of prefrontal plates and a corned beak that can be thinly indented.

Five pairs of lateral plates on the shell, the front pair touching the precentral plate; with pairs of infra-marginal plates, each one cut with a pore towards its back boarder adultes with only one claw to each fin.

Colouring: upper face grey in predominance; below pale-yellow.

White, spheric eggs about 4cm of diameter and 32g of weight size: shell length (distance in straight line, up to 73cm maximum; common up to 42Kg; the youngers are frequently caught.

We often find them in shrimps holes. The coupling takes place from March to April and the clutch from April to July; the incubation lastes from 45 to 60 days. They live on crabs, shrimps, jellyfish and fish.

Eretmochelys imbricata imbricata: overlapping turtle, oval, flat shell, its width is about 75% of its length.

Average size head (about 27% of the shell length, with two pairs of prefrontal plates and a strong corned beak overlapping plates (overlapped each other) on the shell at all the specimen except whenthey're too old where they are justaposed; 4 pairs of lateral plates on the she the front pair touching not the precentral plate; 4 pairs of intra-marginal plates on the shirt front; 2 claws to each fin.

Colouring: upper face dark brown, with yellow and redisk skates on the plates, bellow plae-yellow.

Eggs: white, spheric 3.5cm of diameter and 28g weight.

Size: the shell length (distance in straight line): maximum up to 90cm; common up to 80cm. Maximum weight up to 120kg; common up to 60Kg. It is an omnivorous.

The mating takes place in August and the clutch from September to February; the incubation duration is from 45 to 60 days.

Lepidochelys olivacea: olive greenish tortoise: shell with circular, flat contour, its midth is about 90% of its length. Small head (about 22% of the shell length) with 2 pairs of prefrontal plates and a corned beak that can be thinly indented. Generally, more than 5 pairs of infra-marginal plates; each one cut by a pore towards its back boarder; adults with only one claw to each fin.

Eggs: white, spheric about 3.9cm of diameter and 33g of weight.

Size shell length (distance in traight line) maximum up to 76cm common up to 72cm, weight: maximum up to 50kg; common up to 40Kg.

The clutch takes place in August to December; the incubation lastes from 45 to 65 days according to the latitude.

Dermochelys coracea: Luth Turtles: Flat body recovered with a smooth corned body without slivers or plates. Small head ended by a corned beak with a well defined cap at each side of the upper gum and a cap on the lower gum (w form of beak when seen from front) lengthways seven combs (including the outside or lateral pair) on the shell and 5 on the shirt front. Very big fins without claws.

Colouring: upper face, dark brown almost black; whitish stains on the neck, in rising number on the stomach and caudal regions.

Size: white, spheric, normally about 5.5cm of diameter; one can often find non fertilized eggs.

Size: shell length (distance in straight line) maximum up to 180cm, common up to 140cm maximum weight up to 725Kg; common up 150kg.

The clutch takes place in September to Frbruary; the incubation lastes from 50 to 70 days.

4.5.2.3 Threat for Sea Turtles Life

- Fishing in upper sea.
- Tortoise catch on the bank when coming out of water for clutch.
- Eggs and next born tortoises collection
- Capture of pregnanted female on the bank by the resident population.
- Vegetation defacement along the bank.
- waters pollution by hydrocarbon.
- Phosphate wastes.
- Pollutions by plastic metals and by the cut nets abndonned in the sea.
- Coastal erosion.
- Exploitation of sand quarries.
- Artificial light along the banks.
- Habitation and tourist facilities on the beach

Enquiries on the field through questions to the fishermen and by tortoises shells observation at the residents allowed this gathering statistic in the table below.

Table 4.5-1
Average Number of the Sea Turtles Caught during the Last Clutch Period according to Species and per Zone

Average number	**Species**					
Zones	Tuth Tortoise	Green Tortoise	Olivish Tortoise	Caouane Tortoise	Kempi Tortoise	Overlapping Tortoise
Seme	6	12	?	?	?	?
Cotonou	7	10	1	?	?	?
Ouidah	1	15	4	?	?	1
Grand-Popo	3	20	3	?	1 ?	?
Total	17	57	8	?	1	1

Source : Inquiry results (nature tropical)

During our inquiries, the tortoise especially luth grease is used in traditional medicine under a wrong designation of cod liver or « *Hwadjo* » in local language. It serves to fight certain diseases such as different malaria crisis, vomiting, indigestion etc.

Because of the above reasons, tortoises hunt constitutes an activity that brings about income to the resident populations.

4.5.2.4 The Clutch Sites

According to information collected from the resident population and the eggs shells collected, more than 60% of beninese beach serve as clutch place for sea tortoises.

Many clutch sites have been identified and deserved to be protected in collaboration with the local population (cf. plate).

4.5.3 Conclusion

Permanent efforts are carried on for the resident populations sensitising on the use of those sea species preservation and generally of the biodiversity. The public power also must be more involved according to the different agreements signed on biodiversity preservation.

4.6 FISH AND FISHERIES RESOURCES

The Avlekete–Hio zone is located in the sourthen part of Pahou accross the coastal lagoon. The people of that area are interested in lagoon as well as in coastal fishing and in agriculrure. On the lagoon, near Ouidah, a section of about 1Km “*yehoueto*” where fishing is prohibited, is a place of fish reproduction par excellence where one can find lamalins (Pagre, 1965).

4.6.1 The Area of Study Presentation: The Coastal Lagoon Avlekete – Hio

The coastal lagoon named “Djessin” (or salty lagoon) is constituted of two entities (imperfectly distinct) Ouidah and Grand-Popo lagoons. It covers an average surface of 1.200ha, extended on 50Km along the bank. Its average length is 200m but at some areas it reaches 800m. Its depth is very short, and varies from 0.30m in time of low waters to 3m during rising. The lake is subdivided into many branches separated by islands especially between Mêko and Avlekete. The coastal lagoon waters are alternatively sweet and briny; during rainy season, the sweet water from Mono river and in lower quantity from a complex Couffo–Aheme–Aho invade the lagoon and the salinity rate becomes lower nil for some weeks according to the rising importance. On the other hand, the lagoon is isolated from the sea by a sandbank of 500m average midth laid out for coconut plantations and at the same time maintained with a communication through the king's mouth. The morphody-namic configuration of that ecosystem has many consequences on the hydrologic rate and especially on the lagoon water salination. Thus for instance, the salinity diminishes from Djondji to Togbin.

In dry season, the salinity is constant and high (more than 25‰) from Djondji up to Djegbadji. At Hio, located at about 20Km to the mouth, the salinity decreases quickly and is no more than 5%.

The water drops of Nangbeto dam tends to modify the physico-chemical parameters of that area. At Djegbadji, the water analysis revealed the presence of copper in potentially toxic concentration with pratically no dissolved oxygen.

Waters temperature varies from 22°C to 35°C. the bottom of the lagoon is in sandy, sandy-muddy or really muddly places. The marsh areas along the lagoon cover about 6000ha and an important biologic role in its productivity.

Along the coastal lagoon is where one can find the most numerous mangroves of Benin.

4.6.2 The Fishermen Population

Fishing is the residents' main activity. In 1966, they have counted 2658 fishermen who are Plah, Pedah and Fon. They live in community in many villages along the lagoon. Women of that zone devote themselves to collection and the breeding of oysters and to crabs catching.

The lagoon fishermen participate to sea fishing, if possible, they specialize and buy their small boats and nets from "Keta".

Those mixed fishermen who catch in lagoon as well as in the sea have many activities, they have inherited the drop in the level of waters farming lands, close to the lagoons or they have bought them. They are also engaged into agriculture, participated willingly to the coconut palms exploitation during slack season. Their women not only sell fish but also agricultural products, make coconut oil from the nuts picked on the spot. Many acquire plantations or build cement houses in their village of origin.

The Pedah from the lagoon area show a noticeable flexibility of adaptation because of their contact with the Fon farmers and traders.

4.6.3 The Used Engines

The engines and the fishing procedures are the same with the ones in the sourthen part of Benin. It is a matter of casting nets, stiching nets, palangres, lines, crab scales, dams with fish traps, canal with fish traps, "*Amedjrotin*".

Channels occupy the first place in fishing technic scale used on the lagoon. They are very activily operated from April to August and from October to December. Their output becomes almost nil because of the low waters way draining and of the installations overhelming during rising.

The functioning is the same as the one on the Nokoue – Porto-Novo lagoon complex Lake. But, the Aheme lake installations are not lighted in the night by lanterns to attract shrimps.

- Parks with branches
- The functioning is the same as on the Nokoue Lake.

The channel with fish traps "*Don*" are rivulets of 1 to 36 meters midth dug in the plains liable to the blocked by the fence made of vegetable material, fixed up with orifice where fish traps are located to catch fish that penetrate the water way made for that purpose.

- The dams with fish traps and the acadja parks are prohibited because of the numerous conflicts they have caused and of their contribution to the lake depopulation.
- Casting net used in the two technics: "*Dassa*" when the net is thrown and hauled in from the canoe where it was thrown and the "*Djètowlé*" or in pejorative term "Comlonko" that, when throwing, the fisherman must take the plunge to search the covered part of the mud to collect with his hand all the fish sticked to the bottom.

According to their stitching, those nets are used to capture *Ethmalose*, *Cichlidaes* and *Mugilidae*. They are respectively called "*Tchiki*", "*Akpakpo*", "*Guessoudo*" and are especially used in the Aho channel.

During risings, Mono waters facilitate fish entering in the lagoons, the lakes and the swamps; they contribute to the species scattering when a high level is maintained for a long time.

4.6.4 The Species Caught

Generally the standard size of the fish becomes more and more small because of the over exploitation of fishermen. In fact, all the species are threatened; this constitutes a direct consequence of marshes disappearance; marshes that are species zone reproduction par excellence.

From statistics and inquiries led on the field, it results that 10 species of fish and other products are more exploited than the others.

It is a question of:

- *Cichlidae* (*Sarotherodon melanotheron*, *Tilapia guineensis*, *Hemichromis fasciatus*. It constitutes the catch of the main part of different engines (stitches, casting nets, fish traps, etc.)

- Clupeidae whose representatives are Ethmalosa fimbriata and Pellonula afzeliusi. Those species are especially caught with the Medokpokonou net in the Nokoué lake and chiki net in the coastal lagoon and in Aheme lake.

- Penaeidae (penaeus notialis, P. monodon and P. Kerathurus)

- Portunidal (crabs, callinectes amnicola and Portunus validus)

Sometimes we can meet other lagoon and sea species that are not as numerous as the ones such as Pomadasyidae, Lutjanidae Polynemidae, cf. table below.

The average outputs of captures varies according to the fishing engines and the species caught:

Baskets for crabs (calinectes sp)	1.18Kg
Stitching net (many species)	5.25Kg
Casting net (many species)	3Kg
Line (many species)	1Kg
Line palangre (many species)	1.5Kg

These output vary according to the different periods of the year.

We meet sometimes other lagoon and marine species, which are not so numerous than other species like *Pomadasyidae*, *Lutjanidae Polynemidae*, See Table below.

Table 4.6-1
Fish Species Composition, Abundance, Size Range, and Mean, Weight Range, Weight Mean, and Total Weight of the Mangrove Fishes in the Benin Coastal Zone. Data are from Combined Samples from Cast Net, Seine, Gill Net, and Cross-Lake Fish Trap.

Species families	Total Num.	SL range (mm)	SL mean (mm)	Weight range (g)	Weight mean (g)	Total weight (g)
Belonidae						
Strongylura senegalensis	6	242-275	257.3	25-33	28.5	171
Bothidae						
Citharichthys stampflii	86	30-130	79.7	0.5-50	10.8	933
Carangidae						
Caranx hippos	88	50-82	64.6	2-50	7.6	671
Cichlidae						
Sarotherodon melanotheron	2288	8-189	72.1	0.1-220	19.3	44375
Tilapia zillii	109	47-175	83.1	4-250	31.5	3440
Tilapia guineensis	180	13-220	56.6	0.25-455	12.1	2182
Hemichromis fasciatus	367	15-158	74.1	0.1-150	16.5	6088
Hemichromis bimaculatus	102	21-67	36.3	0.3-15	2.5	253
Clariidae						
Clarias gariepinus	5	215-440	279	65-520	203.6	1018
Claroteidae						
Chrysichthys nigrodigitatus	107	62-275	118.7	4-420	41.5	4446
Clupeidae						
Ethmalosa fimbriata	382	49-130	76.8	2-48	10	3832
Pellonula sp	209	29-95	71	0.15-10	5	1061

Species families	Total Num.	SL range (mm)	SL mean (mm)	Weight range (g)	Weight mean (g)	Total weight (g)
Cynoglossidae						
Cynoglossus senegalensis	2	313-315	314	86-94	90	180
Cyprinotontidae						
Aplocheilichthys spilauchen	1082	14-83	31.4	0.1-5	1	1068
Epiplatys sp	2	19-26	22.5	0.1-0.1	0.1	0.2
Eleotridae						
Kriba nana	1199	19-80	51.8	0.2-13	3.8	4650
Dormitator lebretonis	39	21-65	35	0.3-9	1.4	56
Dormitator pleurops	1	30-30	30	0.8-0.8	0.8	0.8
Eleotris daganensis	2	93-93	93	21-25	23	46
Eleotris vitatta	7	78-155	97.8	9-100	54.5	205
Eleotris senegalensis	6	29-105	48.6	0.3-34	7	42
Eleotris sp	77	30-180	85.8	0.5-190	24.2	1867
Elopidae						
Elops lacerta	36	100-190	136.7	10-90	30.5	1101
Elops senegalensis	5	131-176	155.2	24-50	37.2	186
Gerreidae						
Gerres melanopterus	1018	7-118	59.8	0.1-30	6.2	6388
Gerres nigri	2	74-89	81.5	9-17	13	26
Gobiidae						
Oxyurichthys occidentalis	87	43-130	95.2	2-31	12.5	1091
Progobius schlegeli	25	40-99	72.5	1-22	9.1	228

Species families	Total Num.	SL range (mm)	SL mean (mm)	Weight range (g)	Weight mean (g)	Total weight (g)
Lutjanidae						
Lutjanus goriensis	11	30-118	62.4	3-70	14.7	162
Lutjanus agennes	4	48-72	57.7	4-13	6.5	26
Lutjanus sp	4	60-114	83.5	5-144	20.3	81
Mochokidae						
Synodontis sp	1	93-93	93	14-14	14	14
Monodactylidae						
Psettia sebae	9	27-55	41.6	2-15	9	81
Mugilidae						
Liza falcipinnis	179	23-195	100.1	0.4-135	27.8	4979
Mugil curema	62	52-160	101.8	3-92	24.5	1521
Mugil bananensis	2	102-255	178.5	21-240	130.5	261
Mugil cephalus	1	163-163	63	92-92	92	92
Mugil sp	25	77-162	102.7	9-76	24.5	612.5
Liza sp	22	15-29	22.4	0.2-0.4	0.28	6.2
Ophichthyidae						
Myrophis plumbeus	1	395-395	395	46-46	46	46
Dalophiss sp	1	475-475	475	32-32	32	32
Ophiocephalidae						
Parachana obscura	1	240-240	240	220-220	220	220
Polynemidae						
Galeoides decadactylus	2	50-78	64	3-10	6.5	13

Species families	Total Num.	SL range (mm)	SL mean (mm)	Weight range (g)	Weight mean (g)	Total weight (g)
Pomadasydae						
Pomadasys jubelini	4	84-145	116	12-80	50	200
Pomadasys peroteti	1	92-92	92	13-13	13	13
Pomadasys sp	11	57-113	83.4	6-40	16.1	117
Protopteridae						
Protopterus annectens	1	340-340	340	165-165	165	165
Scombrida*e*						
Cybium sp	14	88-120	108.2	8-20	14.8	208
Serranidae						
Epinephelus aeneus	2	145-250	197.5	68-340	204	408
Syngnathidae						
Microphis brachyurus Aculeatus	5	100-116	108.2	0.5-3	1	5
Sphyraenidae						
Sphyraena guachancho	12	60-98	80	7-34	19.9	239
Total number of families	26					
Total number of species	51					
Total number of individuals	7894					

Source: *A. Adité IFS Report*

The average yield of catches vary according to the fishery engines and the caught species
Crabs baskets 1.18 kg/man/day
Fishing net (many species) 5.25 Kg/Man/day

Filet épervier (plusieurs espèces) – 3 kg/homme jour
Ligne (plusieurs espèces) – 1kg/homme jour
Ligne palangre (plusieurs espèces) – 1,5kg/homme jour
These yield vary according the different periods of the year.

4.6.5 Main Fishing Season

Precipitation has an effect on fishing production because of the waters coolners that allow fishes to move freely. Thus water rising due to rain favoures fish reproduction such as *Mugils*, *Liza falcipinus*, *Ethmalosa finbriata*, *Lutjanidae, pomadasyidae* which swin up from the sea the Aho channel to Aheme lake and then regain swamps grass. Therefore, fishermen catch fish during their migration due to rising or to sea water invasion–April to July.

The fishing output is quite during the small rainy season–October to November and during the longer rainy season–April to July.

Shrimps are numerous from marsh to August and in December and we notice a perceptible drop between January and February. The bigger shrimps are caught after the rains.

The strong rains disturb fishing, extend abnormally the season and only allow smaller shrimps catching.

In fact, we notice that continental fishing output varies from a month to another and from a year to another.

4.6.6 Organisation of the Fishing Products Trade

The main species marketed are *Tilapia*, *Ethmaloses*, *Silures* and Mullets. Fresh fish is sold to fishermen's wives and to sellers who are around the lake banks. In that locality, the operation takes place early in the morning, when they get back from night fishing or in the afternoon at the wharf and ends up in the night. Fresh fish constitutes an object of immediate transactions between fishermen wives, professional fish merchants and the possible buyers in the closest markets. Those women from the coastal lagoon–Avlekete and Hio–sell their fish in Pahou market located in the North side every five days market. The upset price is high, and after the bargaining that is usual, the initial price is finally reduced to about 1/3.

In case of good catch, fish are sold in retail or in small cuts. The price varies according to the size, the quantity and the quality. At the producers the tilapia average price, according to the cut nowadays is 500F CFA/Kg, sardines 300F CFA/Kg. The most expensive fish are the ones of bigger size as mullets, carangues, captains whose average price per kilogram is 600F CFA.

Generally, fish average price per kilo is proportional to the size.

The lagoon catch between Djegbadji and Togbin offeres no more sufficient resources as before the convoy in the sub-region. It brings essentially a small just right for the local consumption and a little to Pahou market in case of good catch.

The caught shrimps are sent to Cotonou to be sold to processing companies for export at 1200F CFA the kilogram.

Table 4.6-2
Fish Production (in tonnes) from the West Complex Main Lakes (data of 1997)

Lakes and Lagoons Soecies	Lake Aheme	Coastal lagoon	Sazoué	Lake Toho	Lake Togbadji	Lake Doukon
Cichlidae	1686,675	145,880	59,934	687,723	107,793	7,783
Ethmaloses	49,810	117,000	0,088	0,318	0,093	0,000
Chrysichthys	395,051	93,880	2,674	0,000	0,000	0,000
Mugilidae	496,803	141,530	15,709	0,120	0,000	0,000
Gerrinidae	22,255	5,580	0,000	0,000	0,000	0,000
Elops	149,948	13,240	0,039	0,000	0,000	0,000
Carangidae	3,113	22,620	0,000	0,000	0,000	0,000
Gobiidae	221,790	4,050	0,000	0,000	0,000	0,000
Penaeidae	128,754	27,490	0,000	0,000	0,000	0,000
Crabe	680,505	159,830	6,113	0,000	0,000	0,000
Clariidae	0,672	0,130	38,075	5,285	3,515	0,088
Parachama	0,156	0,000	0,000	6,579	11,647	0,054
Mormyridae	0,691	0,000	0,000	0,000	0,000	0,000
Synodontis	7,538	0,000	0,051	15,514	0,000	0,022
Protpterus	0,000	0,000	0,000	0,422	0,000	0,027
Schilbeidae	0,000	0,000	0,000	0,000	0,000	0,000
Heterotis	0,030	0,000	12,834	0,849	9,625	0,078
Machrobrachium	0,098	0,000	0,000	0,000	0,000	0,000
Other fresh water	0,000	0,020	0,000	0,000	0,390	0,000
Other salty water	6,697	53,190	0,861	0,000	0,150	0,000
Total Production	3850,48	784,440 *	136,378	716,811	133,214	8,051
Number of canoes	9191	1351	176	1030	147	65
Number of fishermen	8491	2658	307	1031	188	76

4.6.7 Conclusion

It results from this study that the continental catch in that region becomes more and more the people secondary activity because the different species caught and their size dwindle. That is why various activities that bring about income projects are encouraged in the area. Moreover, people are also devoted to sea fishing and to agriculture. Despite the various methods of regulations suggested by the Fishing management of course with the population help, fishermen didn't change anything in their ancestral practices of lakes exploitation.

4.7 CLIMATE, METEOROLOGY, AND AIR QUALITY

The margino-littoral area in Benin where the West African main gas has to pass by the Atlantic monsoon and does not really know season devoid of precipitation. This climatological situation is linked to the two passages of FACTS, in May-June and in October -November. It is this balance of FACTS, associated with the ascent of the thermocline, which creates on one hand a reduction of the volume of the monsoon rains in August, and on the other hand determines bimodal regime and four rainfall seasons in the margino-littoral area.

4.7.1 Average Rainfall Regime of the Margino-littoral Area in Benin

The regime is pluvial, bimodal, with two maxima subjected to a strong variability during 1931-1990. Generally speaking the diagnosis of the rainfall plan shows that it is raining all year long.

January is the least sprayed, with precipitation included between 3 and 10mm. In February, rainfallings heights are superior to those of January and are situated between 10 and 70mm according to the post rainfall. In March, we notice a net increase of rainfallings heights with regard to those of February in all the stations. March can be considered as the month of rainfallings transition The threshold rainfalling of 100mm is exceeded and the monthly rains are included between 100 and 250mm from April to July. On the coastside, rainy heights vary between 200 and 300mm. From July, we register a decrease of precipitation. August, in all the littoral stations, is characterized by a momentary regression of rains in full monsoon when establishing Beninese upwellings. The decrease of the total average pluviometric is more stressed in the southwest and the heights are generally lower than 50mm; this decrease is very net and the total pluviometric in August is lower than 25mm, like in Grand-Popo, the southwest. Porto Novo, in the southeast, registers 51mm (appear 1) In September or in October, in all the stations, we register a second maximum. From November till December rains sharply decrease and the averages are generally lower than 50mm. As a matter of fact, the study of the average pluviometric regime shows that the climate of the margino-littoral area in Benin is characterized by a decrease of the precipitation in the West, and the absence of an absolute aridity.

4.7.2 Hygrometry in the Margino-littoral Area in Benin

Several elements explain the high hygrometric degree of the air (80 to 90%) in this area. The first source is of oceanic origin. The Atlantic Ocean constitutes unmistakably the closet source of humidity because we find it in the Southern natural limit of Benin. The Indian Ocean can be considered as a distant source. The second source which explains a strong relative humidity in the South of Benin is the continental one. They are steams recycled by the vegetation (evapoperspiration) and over "lakes" (Toho, Ahémé, Nokoué), lagoons (Djassin, Grand-Popo, Cotonou, Porto Novo), rivers (Gbaga in the southwest, Sazué etc.).

4.7.3 Average Thermometrical Regime of the Margino-littoral Area

On the thermometrical plan, the general temperatures are high and a bit variable according to the months and seasons. The maxima are fixed around 32°C in full dry season (in February-March), and the minima wave between 22 and 24°C in August, in the middle of the pluviometric recession. The annual thermic amplitude is weak, lower to 8°C. The effects caused by the alternation of the continental wind with vector (harmattan) and the oceanic stream of vector SW (monsoon) determine to the South of Benin an alternation of four seasons of uneven duration.

4.7.4 Winds in the Margino-littoral Area in Benin

Generally speaking the winds take the direction SW with an annual frequency of 45%. The winds blowing of the West and the southwest are frequent in June, in July and August. They are generally violent and overloaded by mists and humidity. On the other hand from December till February, the margino-coast is under the influence of the trade wind of the northeast strengthened by the breezes of the earth and sea.

Indeed, on coast the breezes of the earth and sea blow all year. They are often merged with the streams of the SW (monsoon and that of the Northeast according to seasons). They contribute to the thermal regulation of the climatic atmosphere by modulating the variations of the relative humidity and the precipitable potential.

4.7.5 The Link of Seasons in the Margino-littoral Area in Benin

The beninese so called climate or liberio-Guinean is characterized by four seasons. The first maximum takes place in June and corresponds with the full season of summer monsoon boreal. The second maximum occurs in September or October according to the years.

The big rainy season (season of summer monsoon boreal) extends from April till July and begins with thunderstorms on the Low-full-hearted with wet winds of direction SW in April and speed included between 15 and 25m/s, in an increasing way of the coast towards the inner plateau. It is almost raining all year long in most of the stations. The rainfall of the big rainy season is linked to the frequency of disturbances within the stream of monsoon and the obstinacy of the ZCIT activity in the Southern and central Benin. From the second decade of July, we observe a decrease of precipitation, with a sensitive decline of the sea surface temperatures. They pass from 25.26°C to 21.23°C with the appearance of the first mists announcing the small dry season.

The small dry seasons: the temporary rains, progress with the physical mechanisms. The small dry season corresponds with the pluviometric recession in August which is characterized by a rough decrease of the pluviometry (around 75 %) on the coast. The fundamental characteristic of this season in Benin is that it generally begins without transition, for some days, without disturbances in the general traffic regime, whereas the moisture content always remains high (89%).

The climatic atmosphere during this season is characterized by frequent fogs of advection. The sky remains covered with clouds of the cumulus type (8 octas in average), with a limited pluviogen power. Sometimes, the presence of stratocumulus explains the precipitation which intervene under the drizzle shape. Generally, the wind speed on earth is reduced.

The decrease of this season pluviometry is linked to the subsidence of the Hadley south cell, the cold maritime winds and the seaward cavity of the littoral lands of Benin which favors difference and subsidence.

On the coast, the minimum pluviometric of this season is comprised between 0 and 125mm. The small dry season in the margino-littoral area in Benin is not that of "pluviometric break" and a real aridity. At the beginning of October the rains become important again. It is the small rainy season.

The small rainy season is the consequence of the slow descent towards the South of the 8-th parallel and the decline of the beninese upwelling. It lasts from October till November, The temperatures of the oceanic surface become higher in September, reaching 28°C. Generally speaking the precipitations are turbulent, diurnal, and linked to the passages of the NE-SW career grains lines. However, the weakness of the stream in subsident drainage prevents the forming of big clouds and we note the demonstration of the first pushes of harmattan, announcing the dry season.

The big dry season in the margino-littoral beninese area is the consequence of the retirement from the Guinea bay coast. It lasts from December till March and is characterized by the weakness of precipitation on all the coastal plain, with 7% of an annual average precipitation within 1931-1990.

The big dry season is especially marked by the breeze harmattan stream phenomena resulting from the Libya anticyclone. At that moment of the year, accelerations and turbulences in the low layers characterize the African West atmosphere. On the coast, the winds speed is weak, around 5 knots.

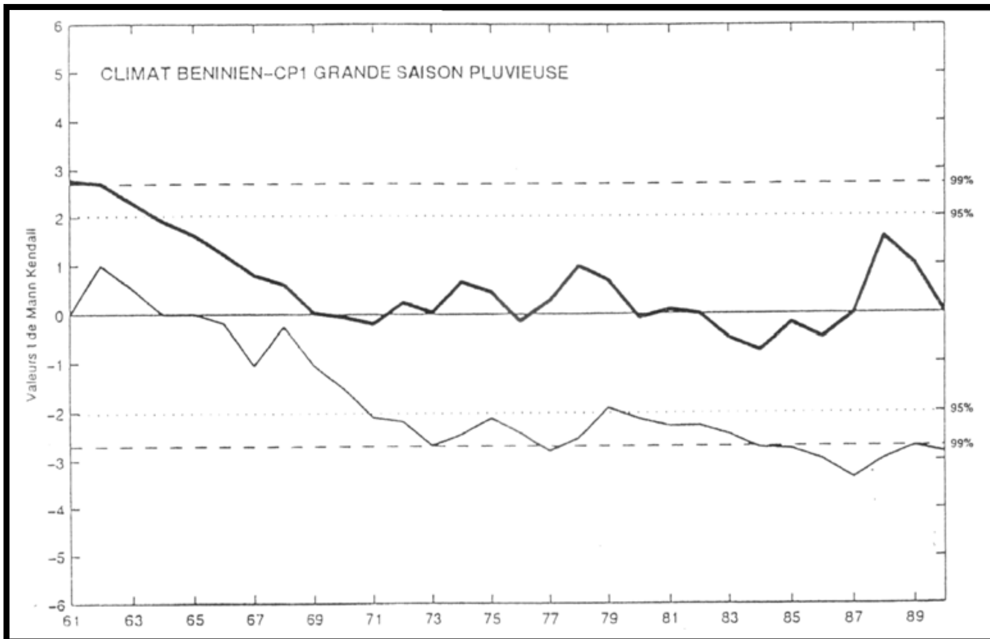
The harmattan, appears on the coast between end November and end February, with little easting fogs, in the morning. The big dry season is characterized by the great daily thermic amplitudes, around 10°C. The sea surface temperatures remain high (28-29°C) and the air temperature under shelter reached 20°C, in the sinking in the dead night or the daybreak. This thermic regime favors the forming of the first cumuliformes clouds in the sea at the end of the night in February-March, whereas the sky remains clear on the coast. Due to the sea breezes, the margino-littoral area is permanently under the influence of the maritime air, with a hygrometric degree of the air constantly high, around 85 to 95%. Turbulent demonstrations and strong cloudiness of the end of March and the beginning of April mark the end of this dry season and the beginning of big rainy season.

On the coast, the annual total means pluviométriques oscillate between 920 and 1,491mm during period 1931-1990. On the other hand, on the normal 1931-1960, they are understood{*included*} between 868 and 1,600mm. The results of the test of Student in 58 degrees of freedom show that there is no significant difference at the beginning of 5% between the total means of the normal 1931-1960 and l961-1990, so as Grand-Popo.

The variability of the annual accumulation of precipitation is understood{*included*} between 23 and 25% for period 1931-1960. On the other hand, she{*it*} is understood{*included*} between 33 in 38% for period 1961-1990. This difference is significant at the beginning of 5% (test of Fisher Snedecor) In the step of the annual time, important significant increases of the variability marked the evolution of the littoral climate. During big rainy season, variability increased in a positive way at the beginning of 5% on the rib{*coast*}. During period 1961-1990, small dry season in Southern Benin is characterized by an increase of totals pluviométriques.

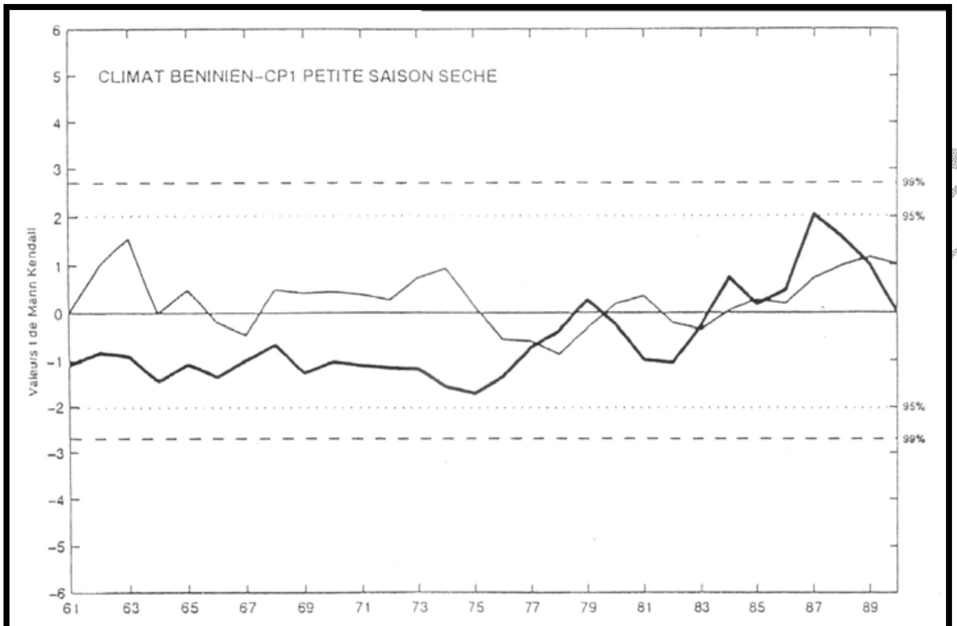
The tendencies of the temporal evolution of precipitation. The big rainy season of summer monsoon knows a falling trend of the pluviometry after records pluviométriques of 1963. Altogether, the decrease of the pluviometry took place in a progressive way because temporal evolution is not marked by a break of stationnarité. Since 1971 until our days, this decrease remained significant at the beginning of 95% (Figure 4.6.5-1).

Figure 4.7-1
Evaluation of the CP1 Tendency on the Benin Environment Monsoon Deason in (1961-1990) by Mann-Kendall Method. (The direct curve is in fined line, the curve degrades is represented in fat; the threshold of 95 % is in dotted lines; the threshold of 99 % is in a point - hyphen.) (Houndénou, on 1999).



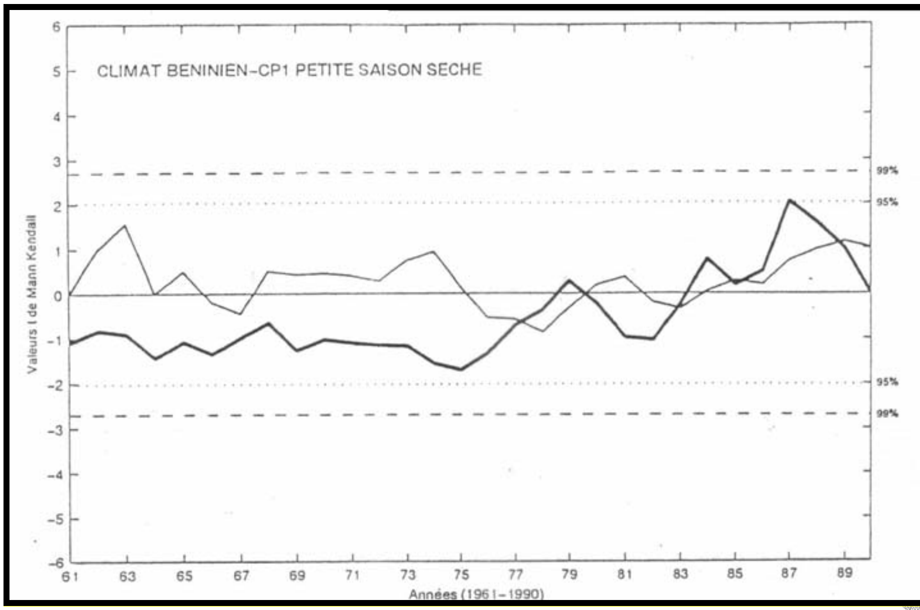
Contrary to the first rainy season in the South of Benin, the small dry season knows an increase pluviometry since 1978 on the inter annual scale (Figure 4.6.5-2). But this rising trend is not significant. The set of period 1961-1990 is however more sprayed than the previous.normal one.

Figure 4.7-2
The Evaluation of the CP1 Tendency on the of the Beninese Small Dry Season in the Environment (1961-1990) By Mann-Kendall Method. (The direct curve is in fined line, the curve degrades is represented in fat, the threshold of 95 % is in dotted lines, the threshold of 99 % is achieved with a point - hyphen.) (Houndénou, on 1999)



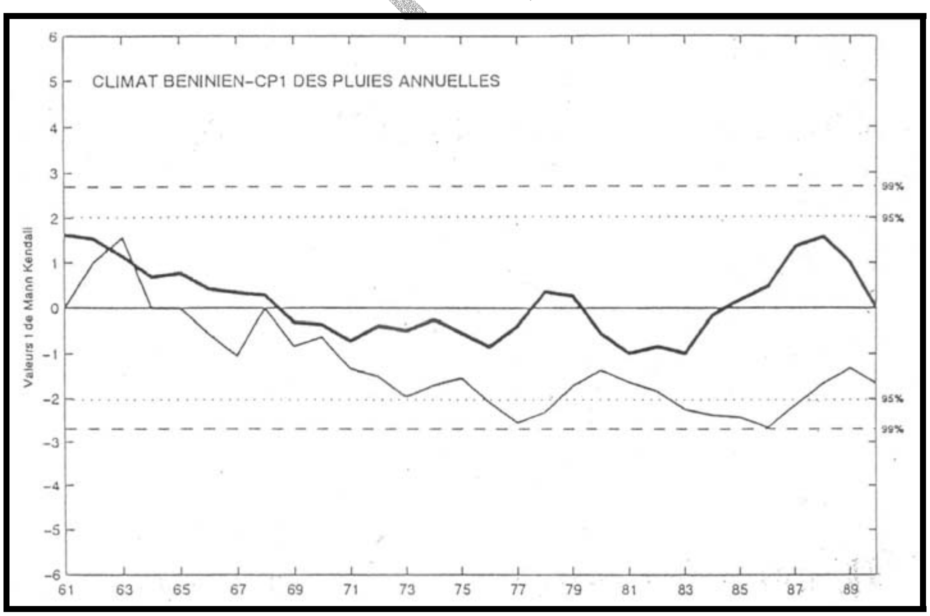
The pluviometry of the second rainy season is marked by a net falling trend, but which, , is not still significant till now (Figure 3).

Figure 4.7-3
Evaluation of the CP1 Tendency on the of the Second Season of Cultivation in the Benenese Environment (1961-1990) by Mann-Kendall Method. (The direct curve is in full line; the curve degrades is represented in fat; the threshold at the beginning of 95% is in dotted lines, the threshold at the beginning of 99% is achieved with a point-hyphen)



At the threshold of annual time, climatic phenomenon is expressed by an almost continuous decrease of the rains which reached the threshold of 99% in 1977, then again in 1983 (Figure 4.6.5-4).

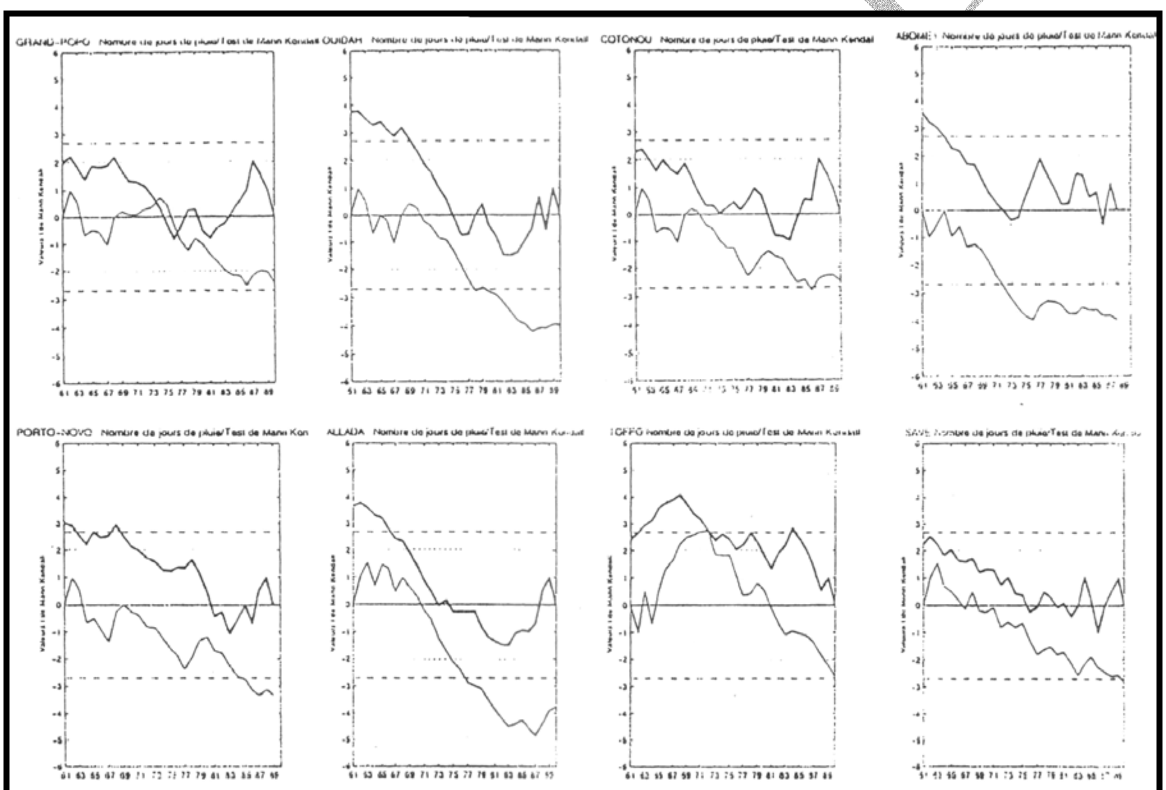
Figure 4.7-4
Full Low Season , Evaluation of the CP1 Tendency at the Threshold of Annual Time in Benin Environment from the Test of Mann-Kendall. (The direct curve is in fined line; the curve degrades is represented in fat; the threshold at the beginning of 95 % is in dotted lines; the threshold at the beginning of 99 % is achieved with a point accompanied with a hyphen)



In the South of Benin, the falling trend of the pluviometry is also shown by a recurrence of aridities as between 1980 and 1985, although on some stations it began since the 70s. The peroration is shown some important scores of negative abnormalities with high distances–types.

This general tendency to the decline of the pluvial seasons resource within 1961-1990 came along with the decrease in the number of the rainy days. On the coast the decrease in the number of the rainy days is significant in the southwest (Grand-Popo). This progressive decrease is punctuated by a break of stationary in 1974 which marks a deficit in the number of the rainy days becomes significant at the beginning of 1% in 1977 and in 1983 from Ouidah to Cotonou, (Porto Novo since 1971), the temporal evolution of the NJP is characterized by a continuous decline and significant from 1977 (Figure 4.7-5).

Figure 4.7-5
Variation in the Number of the Rainy Days in the South of Benin



The climatic peroration over 1961-1990 is shown from 1970's with a significant decrease in the number of the rainy days in pluviometrical series. For the most part of stations, the phenomenon is persevering because the reduction in the number of days remains significant. The situation of aridity of 1977 for some sub-regions of the country and that of the 1983-1984 widened in all the Benin bay, confirms pluviomtrical history of the West Africa. Guinea.

4.7.6 Sunstroke

On the coast, within 1972-1974, the energy balance estimated by the values of the sunstroke was superfluous with positive abnormalities, while from 1980 to 1984, the duration of the sunstroke decreased with regard to significant value. Altogether, the temporal distribution of the duration of sunstroke varies in a very different way from one station to another.

4.7.6.1 The Variation of Temperatures

Minimal Temperatures

The abnormalities of temperature evolve uneven. The years of negative abnormalities are 1975, 1976, and 1977.

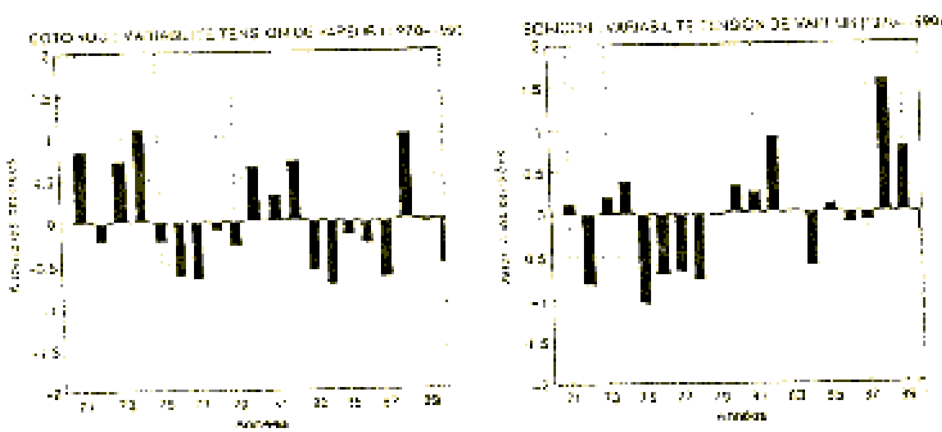
Maximal Temperatures

On the coast, thermic variability is different. Contrary to what happens in the other regions of the country, the beginning of that period is marked by an increase of the temperatures which vary among 0.5°C and 1°C from 1971 to 1974. From 1975 to 1987, the evolution of maximal temperatures was characterized by a succession of negative abnormalities, except in 1978. Since 1988, the increase of maximal temperatures confirms a tendency to the reheating.

4.7.6.2 Vapour Pressure

At the threshold of inter annual, vapour pressure is subjected to a big variability and the temporal configuration differs from one station to another. In the margino-littoral environment in Cotonou coast, vapour pressure was in decline from 1975 to 1979. From 1980 to 1982, it knows an increase (Figure 4.6.6.2-1).

Figure 4.7-6
Variability of the Water Vapour Pressure in Cotonou



The diagnosis of the other constituents of the climate (temperature, sunstroke, vapour pressure) confirms a climatic peroration in the South of Benin. The analysis of temperatures shows a tendency to the reheating on all the stations, whatever is their pluviometrical regime. The evolution of the thermo metrical tendencies shows that decade 1981-1990 is warm, contrary to the fresher decade 1961-1970. The climatic peroration is characterized by a falling trend of the potential pluviometry and an increase of temperatures. This divergent evolution of the constituents of the Benin climate indubitably causes the degradation of ecological and edaphical conditions

4.7.7 Conclusion

This study presents the climatic surface of the Benin margino-coast domain where the western-African main gas will pass. The precipitations constitute the major climatic variability element, which affects the coast.

The Benin pluviometrical diagnosis within 1931-1990, puts in evidence the existence of a climatic peroration started for some decades. The statistical analysis of the climate elements confirms that precipitations remain the best indicator of the climatic fluctuations in Benin.

The climatic variability is shown in the margino-littoral domain by a significant decrease in the number of the rainy days, a reduction of total pluviometry in the majority of stations and an abnormal reheating of temperatures.

4.7.8 Air Quality

With an urban macrocephaly, the coastal plain owes its originality to the economic cotonou pole. This region considered as one of the economic source depends on an essentially fiscal budget the sources of supply which is partially based on the customs taxes perceived on the imported second hand vehicles which manifestly pollute urban environment. So, the coastal plain of Benin remains confronted with severe environmental problems of air quality. This quality negatively modified by the anthropical action has an impact on the littoral communities health, the bio variety, the ecosystem, and consequently on the natural variability of the climate. (Houndénou and al. 1997). This natural variability of the coastal climate seems to be amplified with the gas emissions; with sensitive greenhouse effect to gradually lead towards a climatic peroration and later to the climatic change punctuated by an ecological degradation (Houndénou, on 1999)

4.7.8.1 Causes and Demonstrations of the Air Pollution on the Coastal Plain

The causes are in two ways namely: natural causes and anthropical causes. However the natural causes remain the minor ones with regard to the action of man in the disturbance of the natural order on the coastal plain. We shall not emphasize on this natural causes analysis but rather on anthropical causes.

Natural Factors

The natural factors of the air pollution are dusts provoked by the wind during storms or the disturbances passages, the pollens conveyed by the various movements of the air, the streams of the maritime sea sprays.

Anthropical Factors

The continuous impoverishment led to an almost economic growth, the phenomenon of the motorcycle taxi "Zémidjan or Zem" which increased the park of the rolling stock using oil productions as source of energy, deteriorate among others the degradation of our environment formerly a little bit healthy towards the 60s.

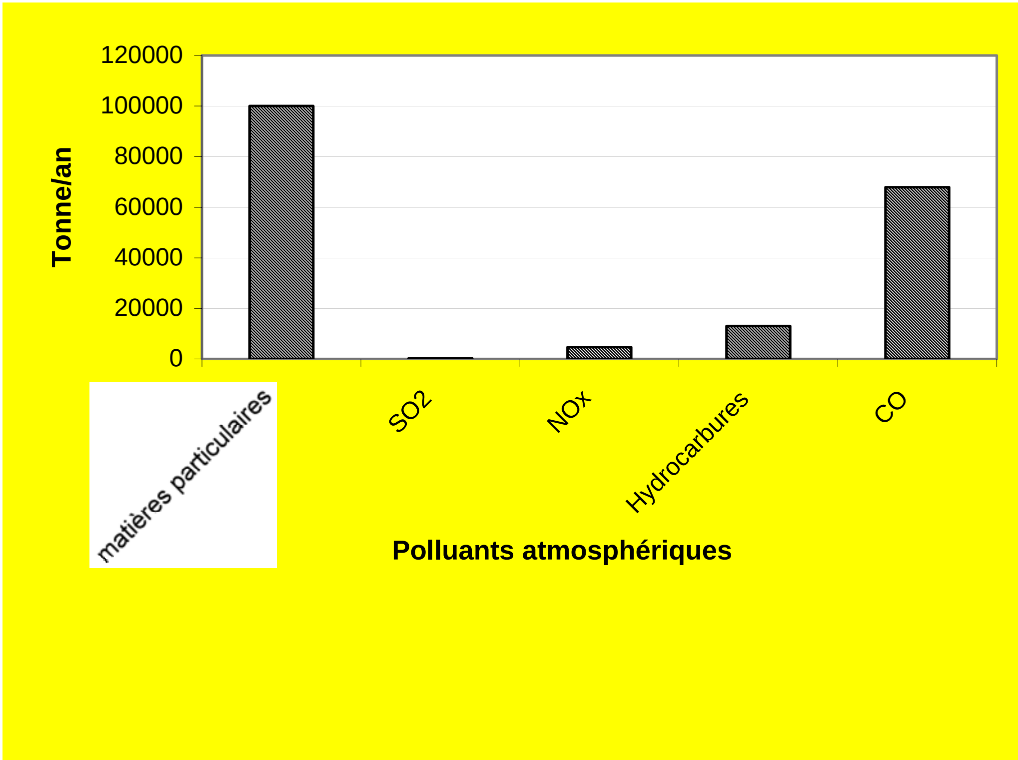
4.7.8.2 Facts and Environmental Indicators of the Air Quality on the Coastal Plain of Benin

At present, the air quality on the coastal plain in the big cities the economic capital, mainly Cotonou is strongly degraded with several loosened pollutants in the domains of the transport, the agriculture, the industry. The obvious dimension of the air pollution in the main urban area of Benin coupled with the climatic peroration identified by recent studies Janicot (1992), Paturel and al. (1995), Houndénou and Hernandez (1996), Houndénou, (1999), Vissin (2000), etc. puts an environmental systematic problem of regional scale and health service on the country scale because the atmosphere has no political border like the administrative limits of State. Only quantification or simulation of the emitted gas pollutants and the main elements analysis of the climate presented under shape of indicators will allow to better follow the state of the environment generally and the air quality in particular.

4.7.8.3 Quantification and Assessment of the Air Pollution

Since the 1990's in favour of the democratic wind in the country, the demographic boom, and the conurbation in the main economic centre (Cotonou) of the country, we witness a continuous degradation of the air quality because of an absence of a national policy in energy, in waste management and organization of the urban transport. The main pollutants are gas tracks, the gas emission of vehicles, the smokes of factory and the bush fires. The first estimations of the GES concentrations rates of the gas tracks from models "Greenhouse Gas Inventory software for workbook" of the GIEC and the version revised of the 1996 IPCC show that the concentration rate of pollutants from any merged in the air quality 17,179 for T/year period 1994-1999. This indicator well informs about the contagion of the air and its degradation (Figure 4.6-7).

Figure 4.7-8
Concentration des divers de polluants dans l'air das la plaine côtièree



This rate of concentration relatively increased on the scale of the country is due to the strong pressure that the population exercise on the environment to adapt themselves to it in the economy area. So, the rate of gas emission by certain inhabitant is about 3.18 .10-9 Gg in 2001 for the CO_2 (Figure 4.7-8), in ,04. 10-9 Gg for the SO_2 in 2001, in 2449,74. 10-9 for the CH_4 (Figure 4.7-9), in 1.67. 10-9 for Pb, in 6.668. 10-9 for the NOX (not shown figures). The temporal evolution of CO_2's emissions shows that the tendency is in decline from 1993 to 2010 because of the data nature (Figure 4.7-9). This evolution is not in touch with the evolution of the population because the size of the population does not only explain the volumes of broadcast emission ; this tendency can be associated to the not industrial character of the economy of the plain except the case of Cotonou.

Figure 4.7-9
Temporal Variation of CO_2 / ht emissions ; from 1993 to 2010 (Source: Houndénou and al.: on 2002)

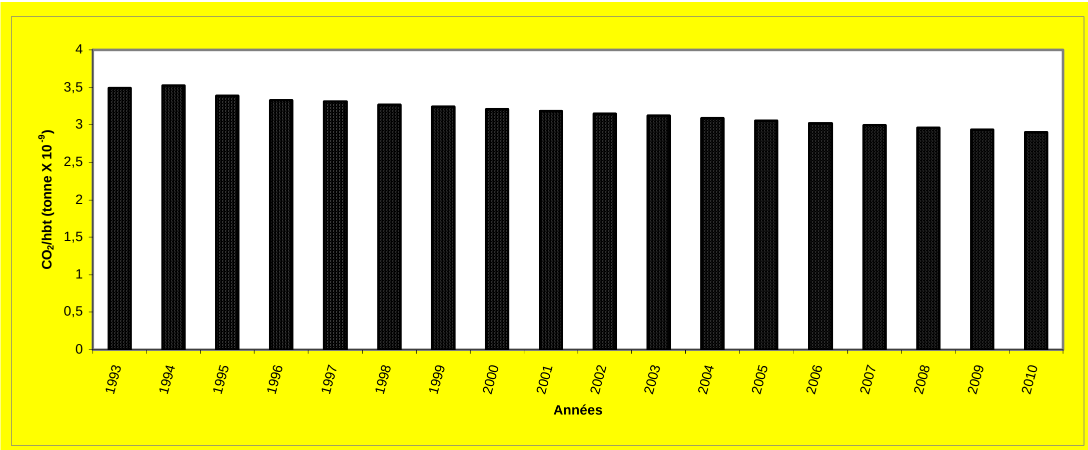
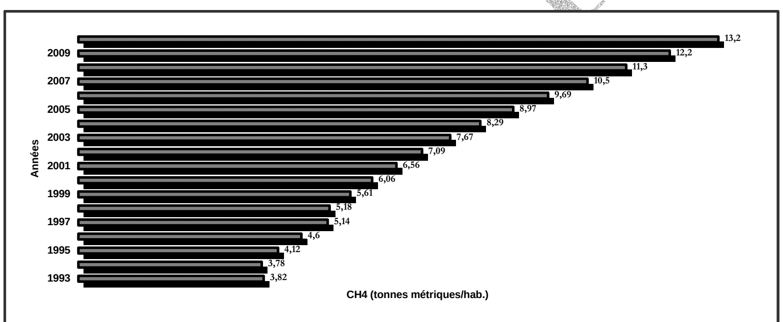


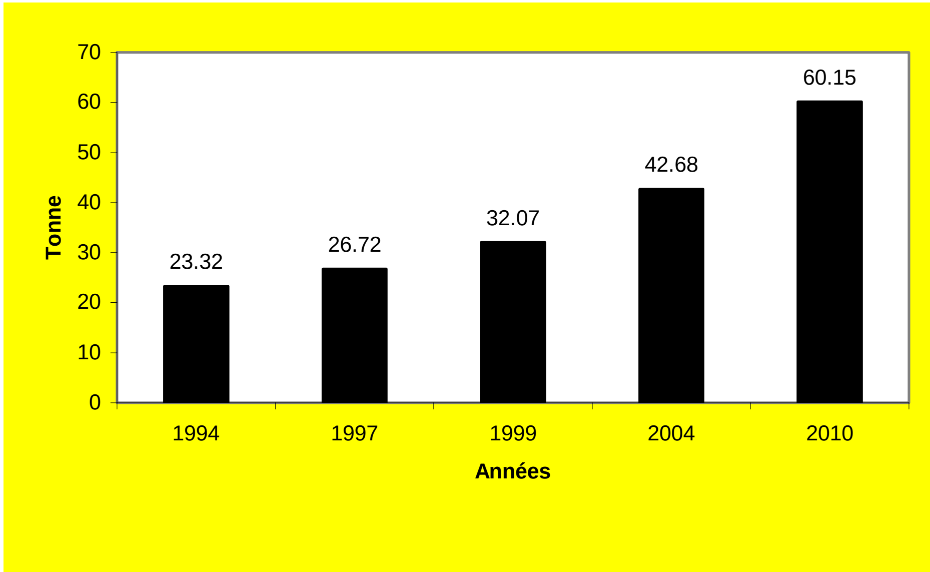
Figure 4.7-10
Temporal Variation of CH_4 / ht emissions; in Benin from 1993 to 2010



Source: Houndénou and al. (2002)

On the scenario basis of no intervention, the tendency of emissions is increasing. Of 1566.7 Gg in 1993, the volume of emitted gas will reach 922x10E9 tons in 2010. According to the scenario, CH_4 missions will pass to 1566.7x10E9 tons in 1993 to 9922x10E9 tons in 2010 and are essentially produced by agriculture. NOX emissions are constantly in progress (Figure 4.7-11).

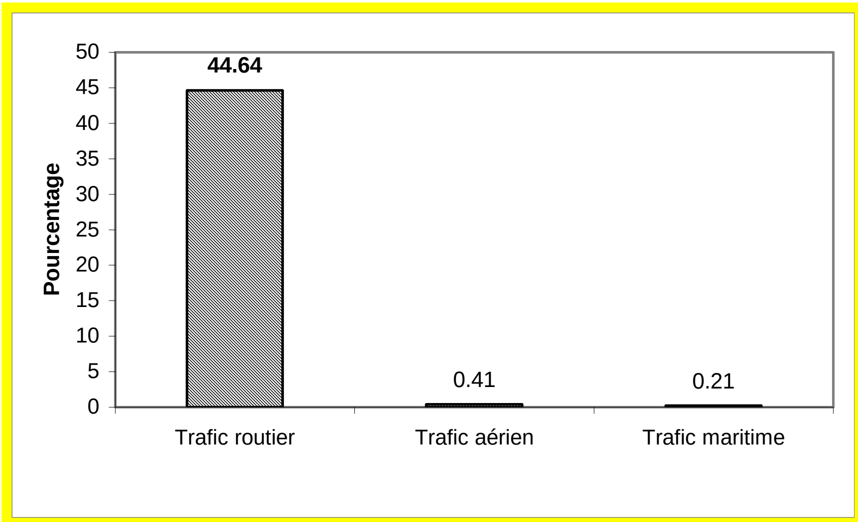
Figure 4.7-11
Evolution des émissions de NOx



Source : Données : Ajavon et Amégankpoé (1998)

The increased number of vehicles on the road is a source that constitutes a large percentage of air pollution, 44.64%.

Figure 4.7-12
Secteurs de transport

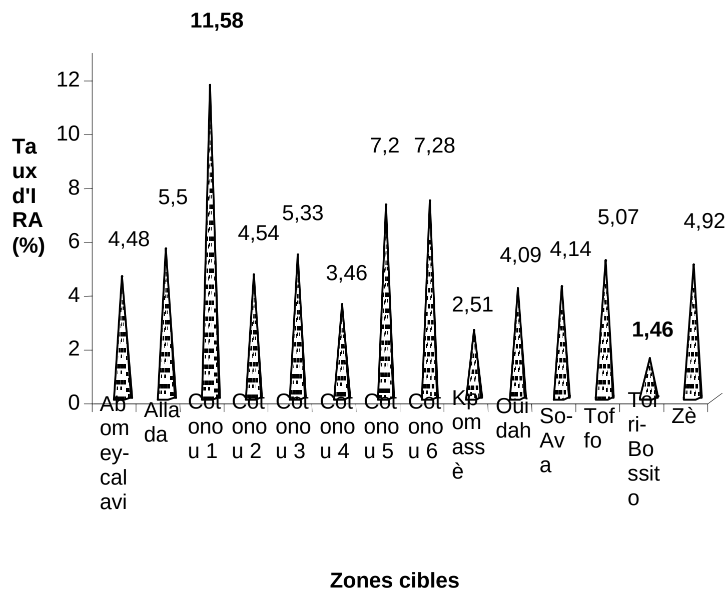


Source: Soclo, (1999)

The vehicles on the road constitutes as the main source of pollutants with 44.64% (Figure 4.7-12). Negligible sources include aircraft and the maritime industry at 0.41% and 0.21% respectively. The numbers of vehicles on the road is continuously increasing, and more specifically in the number of motorcycles and second-hand vehicles, which have increased at a rate of 76% from 1985-1990 and 81% from 1990-1995 respectively. (Plan of Traffic of Cotonou, 1996).

In Cotonou on the coastal plain, the international scientific standards required for a good air quality are high (Initial National Communication of Benin, on 2001) and the city-dwellers are exposed to infections respiratory pointed with a rate of prevalence equal to 5.11% in 1999 (Tractable, on 2000) (Fig 4.7-13).

Figure 4.7-13
taux des infactions respiratoires aigües dues à la dgrdatio de la qualité de l'ir à Cotonou



Source : Tractebel, adapté de Houndénou, (2002)

4.7.8.4 Consequences of the degradation of the air quality and enfeeblement measures

The temporal variability of the indicator is characterized by an increase in the number of cases from 1994 to 1996 with a light decline registered in 1998 (Houndénou, in 2001). On the spatial plan, the evolution of the indicator is characterized by a net disparity. The district of Cotonou 1 remains the place where the rate of prevalence is the highest in 1999.

According to the Population and Economic Plan, the cost of respiratory infections is estimated at 600,000 F cfa (French Cefas) a year. The cost of air pollution along the Cotonou borders is approximately 1.2% of the GDP (2000).

Measures of long-term and short-term enfeeblement and regulation are taken in terms of texts of laws, decrees and orders. Benin signed and ratifies some agreements with the regional policies of Gas enfeeblement with greenhouse gas. Structures of repression like the environmental police which enrolled 9 agents in 2001 for all the country try to inform pollutants on the formula "pollutant-payer" in Benin. The lack of reliable statistics allows transgression in this stage of the air quality area diagnosis on the coastal plain and in Benin. Data used to quantify air pollution arise from simulations made with the IPCC models. Although expensive, it would be desirable that real measures of ground are made for better decisions in the organization policy, enfeeblement and mitigation to surmount vulnerability.

Punctual studies of short duration relative to the air quality and the results of simulations obtained from the IPCC models give an idea of the degradation of the air quality in Cotonou in Benin. However, from the inventories of greenhouse gas Benin, compared with the other countries is a well of energy (Guendéhou, on 2002). The strong concentrations of pollutants in the urban environment associated to the important volumes of solid waste give evidence of the degradation of the air quality. The various indicators of state, pressure, impact and answer show that air pollution in urban environment is a problem of the public health characterized by a rate of prevalence raised by respiratory infections discovered since 1999 which the average city-dweller can not face be cause of the sound weak income, and the urban poverty. In spite of the various introduced and started principles of caution, pollution remains a reality because of heavy traffic road, of the urban network obsolete character , the absence of a real road policy. This air pollution is deteriorated by important climatic abnormalities which are signs of a climatic peroration begun since the 60s and significant from 1970.

CHAPTER 5
CONCLUSION

5.1 VEGETATION

The impact of the gas main on the vegetation and the flora of the concerned zone will certainly concern the destruction of various listed formations and individuals loss of different listed sorts. In view of the quite reduced width of the band, we can deduce that damages will not be enormous. Various listed sorts are found somewhere else and no rare sort was identified.

Apart from this band on which, the plant carpet will inevitably be destroyed, the project should undertake to respect more the plant carpet during accesses to the sites of works.

5.2 SOILS

The granoulometric composition of the study ground brings indications on environmental conditions having presided these soils formation.

5.2.1 On The Coastal Plain

The nature and distribution of the facies of the sandy cords were widely affected by the action of maritime currents (wave, tide and littoral drift) and in a lesser measure by the river influences. These processes contributed to in the sedimentary supply of the littoral cords on which the various types of grounds indicated developed namely: the little evolved developed raw mineral soils on the current cordon or subactual and the mineral hydromorphes soils in gley on sands sailor developed Quaternaries on grey or yellow sands.

Beyond the more or less regular sediments deposits of during Holocène, the discontinuities of the observed facies on surface and which are by intercords depressions are tracks of breaks the observed facies of balance in the conditions of deposits; these breaks of balance interprete indeed fluctuations in the sedimentary and biologic paleoenvironnement which are oscillations of tthebank line , variations at the level of climatic parameters and finally probably appearance of the anthropic influence. It is on these depressions that the organic soils in gley are formed, sometimes salted and floting lagon zones or subfloting.

The pH of these soils is variable, influenced in the maritime zone with basic tendency and the weakly acid lagon environment.. They have a weak capacity of water keeping back and undergo a very fast vertical drainage because of the dominance of the sandy material, where their lack of fertility.

The chemical analyses concerning the soils heavy metals at the gas main passage reveal that the content of soils in metals (Pb, Fe, Cd, Hg, Cu, Zn, …) is weak; there is then no pollution of soils. However these soils are made for big cultivations because they are little evolved, so very less deep.

5.2.2 On The Plateau

We have qualified ferrallitic soils that we disover on the ground plateau of bar summit hillsides leading in depressions. They are soils relatively more evolved, richer in clayed sandy materials and deep even through some unrefined elements can be met here and there. They are acid soils which are not favourable to agriculture.

On the plateau, contents in heavy metals show neither values which could give evidence of a certain pollution of soils.

Globally speaking, the physical characteristics of the initial state of the environment are known.

The hydrodynamic and hydrochemical characteristics of the project zone were well enough Identified. The identified impacts consern two aspects:

- A quantitative aspect: disturbance of the hydrodynamic regime (surface water as well as subterranean waters)

- A qualitative aspect: contagion, so change or degradation of the quality of waters.

These impacts are linked:

- To the construction of the pipeline on terra-firma (heightened or relief grounds) on the wet soils (grounds), in lagoons, through islands barriers, on the beach and alongside the bank line;

- To the preparation and organization of sites;

- To the starting of the equipments;

- To the activities of maintenance;

- And possibly in the displacement of the project;

The enumerated impacts are for the whole momentary, except those linked to the maintenance activities which are permanent even recurring. They are indeed linked to the management of the solid waste and the other waste resulting from the tubes maintenance, to the oil, the chemical products and other liquids or waste resulting from the filters systems, in the streaming rained waters and in the removal of the sewers materials. Also let us indicate the production of waste by possible piggeries and by the transport, the transfer and the stocking of fuels and lubricants.

The risks linked to these impacts are less important at the littoral plain than the plateau (Maria Gleta). Indeed, the zone of the project situated on the plateau constitutes a big sector risk, because of the presence of the harnessings of the SBEE. The very sensitive character of this zone of the plateau, would require a study of a suited impact before any installation, in order to identify correctly the impacts on the field of harnessing of the SBEE and possibly to identify the required measures of mitigation.

5.3 THE ENVIRONMENTAL IMPACT ASSESSMENT

Activities envisaged within the framework of the WAGP (installation and exploitation of gas mains and station R&M) work through the realization of infrastructures which necessary have impacts on the parameters of the physical environment. The sensitive constituents to be reached were reviewed. The study does not show positive impact on the topography, the soil. Sending, distribution and use of the gas should on the other hand allow the populations to reduce the use of other sources of energy like wood, oil, which emit greenhouse gas, compromising the quality of life. Negative impacts on the physical environment are of unimportant importance in moderated.

At the end of this study, we can assert that the WAGP is a project of a high reach for the improvement of the living conditions of the populations and at the same time contributes to the protection of the environment.

Some measures of enfeeblement should be taken into account. It is necessary, notably:

- To mark out the zones of installation and construction in order to manage them well.
- To provide these zones of dustbins and latrines to limit the deposit of organic and faecal materials on the ground and in waters
- To protect the ground and the water plans banks against the erosion by setting up a hidden lawn
- To restore the destroyed mangrove swamp, even to generalize the mangrove plantations on everybody the whole borders of the lagoon, to increase the zones of for fishes growth and consequently the fish breeding productivity on the lagoon
- To proceed to the dredging and to the fish stocking of swamps crossed with pipes to facilitate a better follow-up and the maintenance of installations, and make by this organization the pleasant zone to the eco-tourism
- To interest the local populations in the project by building a health centre one of the villages crossed by the installations. We could then avoid by this best cooperation, pollutions of criminal origin (gas leak, fire etc.).

CHAPTER 6
REFERENCES

AGASSOUNON L. C. (2002). Evolution pédosédimentaire du géosystème margino-littoral de l'Ouémé-Sô au cours de l'holocène (Bénin-Afrique de l'Ouest). Thèse de Doctorat en Sciences de la Terre et de l'Environnement. 425p.

AZONTONDE A. (2000). Dynamique de la matière organique et de l'azote dans le système Mucuna-Maïs sur un sol ferralitique (terre de barre) au Sud-Bénin. Thèse de Doctorat ENSAM-Université de Montpellier, Montpellier, 235p.

BAIZE D. et GIRARD, M.-C. (1995). Référence pédologique. AFES, Paris, 332 p.

DUSSART B. (1966). Limnologie. Etude des eaux continentales. Géologie – Ecologie – Aménagement. Paris, 676 p.

GUILCHER A. (1959). La région côtière du bas-Dahomey occidental. Bull. IFAN, XXI (3/4), pp. 357-424.

LAMOUROUX M. (1953). Etude pédologique de la vallée de l'Ouémé, rive droite de la Sô. Rapport ORSTOM, Paris, 32 P.

LANG J., PARADIS G. et OYEDE L. M. (1988). Le domaine margino-littoral du Bénin (Golfe de Guinée, Afrique de l'Ouest) : Age holocène et mise en place marine des "Sables jaunes". Journal of African Earth Sciences, Vol. 7, N° 5/6, 829-833.

OYEDE L. M. (1983). Un exemple de sédimentation biodétritique quaternaire dans le domaine margino-littoral en climat tropical humide : le « lac » Ahémé (Bénin – Afrique de l'Ouest). Thèse Doctorat 3ème cycle, Université Nationale du Bénin – Université de Bourgogne, Dijon, 171 p.

OYEDE L. M. (1991). – Dynamique sédimentaire actuelle et messages enregistrés dans les séquences quaternaires et néogènes du domaine margino-littoral du Bénin (Afrique de l'Ouest) ; Thèse Univ. de Bourgogne. 302 p.

OYEDE L.M., KAKI C. & YESSOUFOU S. (2001). Reconnaissance géologique d'un site de décharge et de valorisation des véhicules hors d'usage : étude d'impact environnemental sur le milieu physique. DST/UNB, 17 p.

SLANSKY M. (1962). – Contribution à l'étude géologique du bassin sédimentaire côtier du Dahomey et du Togo. Mémoires du BRGM, n° 11, 270 p.

IRB (1987). - Etude de la cartographie géologique et prospection minière de reconnaissance au Sud de 9ème parallèle.

SBEE (1995). - Adduction d'eau des villes de Cotonou et Porto-Novo. Rapport final.

VOLKOFF B. (1976). Carte pédologique de reconnaissance de la République Populaire du Bénin. ORSTOM, Paris, Inédit.

Adjanohoun E. 1968. Le Dahomey. Acta phytogeogr. Suec, 54 : 86-91.

Adjakidjè V. 1984. Contribution à l'étude botanique des savanes guinéennes de la République Populaire du Bénin. Thèse 3ème cycle. Univ. Bordeaux III. 301 p.

Akpagana K., Arnason J.T. & Akoègninou A., 1998. La disparition des espèces végétales en Afrique Tropicale : cas du Togo et du Bénin en Afrique de l'Ouest. Le monde des plantes, N°463. pp. 18-20.

Akoègninou A. 1984. Contribution à l'étude botanique des îlots de forêts denses humides semi-décidues en République Populaire du Bénin. Thèse 3ème cycle. Univ. Bordeaux III. 250p

Essou J-P. 1991. Contribution à l'étude des pâturages et des systèmes agro-pastoraux du sud-Bénin. Thèse de doctorat, Univ. Bordeaux III. 370 p.

Frontier S. & Pichod-Vitale D. 1991. Ecosystème : structure, fonctionnement, évolution. Collection d'écologie 21 : 392 p. Masson, Paris-France.

Guinko S. 1974. Contribution à l'étude des savanes marécageuses du Bas-Dahomey. Thèse 3ème cycle, Fac. Sc. Abidjan, 142 p.

Hutchinson J. & Dalziel J. M. 1954. Flora of West Tropical Africa. Ed.2, Vol.1-3. Millbank

SWI, Crow Agents for Oversea Governments and Administrations, London.

Lebrun J-P. & Stork A. L. 1991-1997. Enumération des plantes à fleurs d'Afrique tropicale.

Vol.I, II, III IV. Conser. et Jard. Bot. Génève, Suisse. 249 p., 257p., 341p., 712p.

Legendre L. & Legendre P. 1984. Ecologie numérique. Tome 2 : La structure des données écologiques. Masson – Collection d'écologie n°13. 335p.

Mondjannagni A. 1969. Contribution à l'étude des paysages végétaux du Bas-Dahomey. Ann.

Univ. Abidjan, sér. G., t.1 fasc. 2, p.191

Paradis G., 1975a. Observations sur les forêts marécageuses du Bas-Dahomey : localisation, principaux types, évolution au cours du Quaternaire récent. Ann. Univ. Abidjan, sér. E, 8 : 281-315.

Paradis G., 1976. Contribution à l'étude de la flore et de la végétation littorale du Dahomey. Bulletin du Muséum National d'Histoire Naturelle. 3ème série, n° 383, 66 p.

Paradis G., 1977. Observations sur l'Holocène récent du Sud-Bénin (ex-Dahomey). Ass. Sénégal. Et. Quatern. Afr., Bull. liaison, Sénégal, 51 : 49-73.

Sokpon, N. 1995. Recherches écologiques sur la forêt dense semi-décidue de Pobè au Sud-Est du Bénin : groupements végétaux, structure, régénération naturelle et chute de litière. Thèse Doct. Univ. Bruxelles (Belgique), 350 p.

Paradis G. et Adjanohoun E., 1974. L'impact de la fabrication du sel sur la végétation de mangrove et la géomorphologie dans le Bas-Dahomey. Ann. Univ. Abidjan. Sér. E, (7), 599-612.

Paradis G., de Souza S. et Hougnon P., 1978. Les stations à *Lophira lanceolata* dans la mosaïque forêt-savane du Sud-Bénin (ex-Dahomey). Bull. Mus. Hist. Nat. (Pariq), sér. 3, 34 : 169-197.

Adokpo S., Fanou T. (1992) : Rapport sur l'inventaire et l'analyse de la législation environnementale au Bénin. MEHU, 1992, Cotonou, 108 pages.

Ajavon A. L (2000) : Stratégie nationale de la lutte contre la pollution atmosphérique en République du Bénin. MEHU, 70 pages.

Ajavon A. L., Amegankpoé A. (1998) : Contribution à l'évaluation de la pollution de l'air à Cotonou.

Association de Climatologie du Québec (1997) : Les défis des changements environnementaux à l'échelle planétaire. Actes du colloque du 63 ème congrès de l'ACFAS, Québec, 212 pages

BOAD (2001) : Etude sur l'impact du transport urbain par les véhicules à deux roues et perspectives de développement dans les pays de l'UEMOA (bénin, Niger, Togo). Rapport de synthèse provisoire.

Direction de l'Environnement/MEHU (2001) : Communication nationale initiale du Bénin , Cotonou, 92 pages +annexes.

Guendéhou S. (2001) : Résultats des inventaires des gaz à effet de serre au Bénin. In actes de l'atelier des journées de restitution de l'atelier régional sur les inventaires des gaz à effet de serre, Accra. 11 pages.

Houndénou C. et ABE (2002) : Tableau de bord du kiosque informations et produits du SISEI-Bénin : indicateurs environnementaux et statistiques (compendia). ABE pour l'environnement, 236 pages.

Houndénou C. (1999) : Variabilité climatique et maïsiculture en milieu tropical humide. Thèse pour le Doctorat d'Université : Option géographie Spécialité : Climatologie. Centre de Recherches de Climatologie. UMR 5080 du CNRS « Climatologie de l'Espace Tropical ». Université de Bourgogne, Dijon, 390 pages, INSAE (2000) : Résultats provisoires du recensement de la population et de l'habitat.

Janicot S. (1990) : Variabilité des précipitations en Afrique de l'ouest et circulations quasi-stationnaires durant une phase de transition climatique. Thèse de Doctorat d'Etat, Paris, 178 pages +annexes

MEHU/GTZ, 2001 : Pollution atmosphérique urbaine au Bénin. 49 pages + annexe.

Tractebel (2000) : Etude sur la qualité de l'air en milieu urbain : cas de Cotonou. MEHU, 137 pages.

ADJAKIDJE ,V. 1984 : Contribution à l'étude botanique des savanes guinéennes en République du Bénin. Thèse de Doctorat de 3è Cycle-*Université de Bordeaux III*

ADJAKPA J. B. 2001.: Etude des potentialités en espèces aviaires des sites constitutifs du réseau de réserves biologiques dans les zones humides du Sud-Bénin *Programme de l'UNESCO, l'Homme et la Biosphère / MAB-UNESCO/CBRST*, 14 p.

ADJANOHOUN, E. ,1965 : Comparaison entre les savanes cotières de Cote d'Ivoire et du Dahomey. *Ann. Université Abidjan Sc*. 1, 1-20

ADJANOHOUN, E. 1968 ; Le Dahomey in «Conservation of vegetation in Africa South of the Sahara » .*Acta Phythogeogr.Suecica* 54 : 86-91

ADJANOHOUN & *al*, 1989 ; Contribution aux études ethnobotaniques et floristique en République Populaire du Bénin : *Collect. Médecine-Traditionnelle et Pharmacopée-ACCT*-Paris 895p. 466 figures.

BURTON,M., WINANDY, A., LAMBIOTTE, A. F. & DERGENT, L. (---)_ Reptiles et Amphibiens. *Collect.* «*Nature et Vie* » ,Comptoire du Livre, 3-5, Rue de Nesle Paris. 128p. 112 photos couleurs.

DEKEYSER, J. P. 1955- Les Mammifères de l'Afrique Noire Française *Bull. IFAN*, Dakar 1955-

DORST, J. & DANDELOT, 1972 : Guide Mammifères de l'Ouest Africain.

Delachaux & Niesthé, Paris

FELIX, J. 1984 : Faune d'Afrique *GRUND* Paris .

HALTENORTH, Th ; DILLER, H. & CUISIN, M. 1985 : Les Mammifères d'Afrique et de M adagascar. *Delachaux & Niestlé E*d .Neuchàtel -Paris

MARCHE-MARCHAD,.J. 1965 : Le monde végétal en Afrique Intertropicale . *Editions de l'Ecole*, Paris- 471p. 571figures.

MARCHE –MARCHAD,.J. 1969 : Le monde animal en Afrique Intertropicale -

Edition de l'Ecole – Paris- 608p-450 illustrations

SERLE, W. & MOREL, G. J. 1993 : Les oiseaux de l'Ouest Africain.

Delachaux & Niestlé, Paris, 331p.

WHITFIELD, Ph. 1984. Le grand livre des animaux. *Edition France Loisir* Paris

APPENDIX A
THE LAGOONS AND MARSHES HABITATS

The lagoon and marshy zones crossed by the pipeline on the Benin territory are represented by the coastal lagonn (at Hio) and a series of marshes of heights more or less important situated between the village of Adjahindji (near the lagoon) and the district Maria-Gléta at Godomey, farther in the North (place of stockage and of gaz supply). They are sensitive zones on the ecological plans as well as socio-economic which is important to know the natural huts and/or species.

A.1 COASTAL LAGOON (TRANSECT B5)

A.1.1 Physico-chemical characteristics of the water

- In dry season (December 2002 to January 2003):
- Temperature: 28.6°C 30.30°C (average: 29.47°C)
- Salinity: 10.2% to 10.70% (average 10.37%)
- Ph: 5.25 to 8.50 (average: 7.49)
- Dissolved oxygen: 3.00mg/l to 7.55 mg/L (average: 4.58mg/L)
- Water's height: 0.45m to 2m (average: 1.31m)
- NO_2: 0.029mg/L to 0.071mg/L (average: 0.049mg/L)
- NO_3: 0.97mg/L to 2.04mg/L (average: 1.67mg/L)
- NO_4: 17.3mg/L to 20.97mg/L (average:18.99mg/L)
- PO_4: 3.75mg/L to 21.25mg/L (average: 11.75mg/L)
- In rainy season (june-july 2003)
- Temperature: 28.2°C to 28.6°C (average: 28.4°C)
- Salinity: 0.3% to 1.7% (average:0.66%)
- Ph: 6.70 to 6.92 (average: 6.82)
- Dissolved oxygen: 1.01mg/L to 2.58mg/L (average: 2.22mg/L)
- Water's height:
- NO_2: 0.78mg/L to 0.163mg/L (average: 0.117mg/L)
- NO_3 : 9.72mg/L to 16.08mg/L (average: 12.50mg/L)

- NO4: 24.58mg/L to 31.08mg/L (average: 27.12mg/L)
- PO4: 0.23mg/L to 2.31mg/L (average: 1.27mg/L)

A.1.2 VEGETATION

The coastal lagoon is occupied by fragment of mangrove and grassland to Paspalum vaginatum. The mangrove is constituted of two parallel units following the topography.

In the lagoon edge where the flood is very prolonged, one note the mono-specific ground to Rhizophora racemosa. This grouping of a 6m high has an average covering of 60%. The temporal flood zone in the background of the above grouping to Avicenia germinans and Acrostichum aureum. It is structured in two stratums: the bushy stratum of 6m high is very opened with 15% covering. The herbaceous stratum, more dense contains a lot of species whose most frequent are: Pasalum vaginatum,Pycreus polystachyos, Eleocharis mutala,Scqaria dular,Pentadon pentadrus and Fuira umbrella.

The grassland of Paspalum vaginatum characterises the places where the mangrove is entirely destroyed. It constitutes a formation the most extended of the lagoon. One notes some isolated feet of Avicennia germinans, Acrostichum aureum and herbaceous companions species such as: Pycreus polystachyos, Fimbristylis ferruginea, Kyllinga erecta, Torenia thouwarsii, S permacoce ocimoides, Fuirena umbrellata, Eleocharis mutata, etc.

A.1.3 THE SOIL

They are hydromorphs organic soils with with gley more or less salty. They are developed on the lagoon materials; they are seasonally salty which which shows the presence of mangrove.

These soils are characterized by a homogeneous clayey texture with in places a texture more heterogeneous with sandy chief characteristic.

The mangrove sediment is characterized by the accumulation within the clay-sandy material more particularly at the level of mangroves' roots, iron pyrites, mainly pyrite. This one comes from the reduction of sea water sulfates in anaerobic environment under the influence of the sulphato-reducing bacteria present in the soil. The dominant factors of the mangrove soils evolution is the sufur and the coumpound sulfred where the term of soils acid sulphated is currently used to distinguish them.

Remark: We must particularly note that the lagoon ecosystem constitute the very rich biotopes on ecological view point as a result of the rotated influence of marine waters and soft waters. However thanks to their stilt roots, mangrove constitute for fish some particularly calm spawns and the predator's shelter. Thenin the coastal lagonn, the fish, crabs and shrimps of commercial importance and frequently encountered belong to the following families and genders:

- Cichlidae: *Sarotherodon, tilapia, hemichromis;*
- Clupeidae: *ethmalosa, pellonula;*

- Mugilidae *: liza, mugil ;*
- Dasyatidae *: dasyatis ;*
- Clarotidae *: chrisichthys ;*
- Carangidae *: caranz ;*
- Portunidae *: callinectes ;*
- Peneidae *: penaeus*

A.2 MARSH OF ADJAHINDJI (TRANSECT B4)

A.2.1 Physic and chemical characteristics of water

In dry season (December 2002 to January 2003)

- Water height:
  - NO^{-}_{2}: 0.39mg/L to 0.48mg/L (average: 0.44mg/L)
  - NO^{-}_{3}: 2.95mg/L to 3.O4mg/L (average: 2.99mg/L)
  - NO^{-}_{4}: 20.98mg/L to 22.06mg/L (average: 21.80mg/L)
  - PO3-$_{4}$: 0.087mg/L to 0.13mg/L (average: 0.103mg/L)
  - Because of the rains (june – july 2003)
- Temperature: 29.6°C to 3.16°C (average: 30.74°C)
- Saltiness: 4.95% to 5.40% (average: 5.30%)
- Ph: 6.27 to 6.37 (average: 6.32)
- Dissolved oxygen: 1.87mg/L to 2.35mg/L (average: 2.10mg/L)
- Water height: 110-120cm
- NO2 : 0.49mg/L to 0.61mg/L (average: 0.54mg/L)
- N03: 17.48mg/L to 21.07mg/L (average: 19.57mg/L)
- NO4: 23.87mg/L to 26.08mg/L (average: 24.79mg/L)
- PO4: 0.97mg/L to 1.56mg/L (average: 1.35mg/L)

A.2.2 Vegetation

The Adjahindji marsh of about 400m wide is covered by some mangrove scraps and a grassland from the mangrove degradation.

The permanent clogging zone is occupied by mangrove and grassland. The monospecific mangrove is constituted of *Rhyzophora racemosa* reaching 8m height. The grassland is greatly dominated by *Cyperus articulatus* associated to some rare yellow feet of *Rhizophora racemosa*. It is 1.5m height and covers the biggest part of the marsh (about 380m wide).

The zone with temporally flood of 10m height contains also two types of plant formation: mangrove of *Avicenia germinans* and grassland of *Paspalum vaginatum*. Mangrove of *Avicenans germunatum* is observed in places less degraded. It is presented in two stratums. The tree planted stratum is very opened and dominated by *Pasplum vaginatum*. The low grassland of *Pasplum* characterises the area where the mangrove is completely destroyed. It constitutes the most spread formation in the zone of temporary flood. We can note there some isolated feet of *Avicenia germinans*, *Acrostichum aureum* and companion herbaceous species such as: *Pycreus polystachyos*, *Fimbristylis ferruginea*, *Kyllinga erecta*, *Toremia thouwarsii*, *Permacoce ocimoides*, *Fuirena umbrella*, *Eleocharis mutala*, etc.

At the level of exonde zones, some small islands of coastal thickets and fallows can be observed. The thickets comprise many species whose most important are: *Dalbergia acastaphyllum*, *Chrisobalanus icaco*, *Zanthoxylum zanthoxyloides*, *Anona senegalensis*, etc...The fallows are largely dominated by *Aristida adscensionis* followed *with Schyzachyrium sanguineum and Spermacoce verticillata.*

However, the Adjahindji marsh possesses a filled up branch called Dagbétomè marsh with about 10 to 12m wide. That branch is occupied by a grassland presenting three floristic composition grouping of *Vetiveria nigritana*; the zone with prolonged flood is covered by the grouping of *Eleocharis complanata* and the grouping of *Eleocharis dulcis.*

A.2.3 The soil

The drilling in the hollows (marsh) during the different works of Oyede (1988,1991) shows that the lowest part is always sandy, surmounted by a hydromorph of gley, of variable depth and so much important that we approach the hollow axis. Some marsh hollows were old channels of abandoned water course. The sediments are clayed.

A.3 THE AKADJAMÈ MARSH (TRANSECT B2)

A.3.1 Physico-chemical charasteristic of water

On account of dry season (December 2002 to January 2003)

- NO_2: 0.37mg/L to 0.41mg/L (average: 0.388mg/L)
- NO_3 : 1.47mg/L to 1.52mg/L (average: 1.50mg/L)
- NH_4: 15.8mg/L to 16.11mg/L (average: 15.92mg/L)
- PO_4: 0.89mg/L to 1.13mg/L (average:0.96mg/L)
- On account of rains (june-july 2003)

- Temperature: 28.4°C to 28.7°C (average:28.57)
- Saltiness: 0%
- Ph: 6.62 to 7.86 (average:7.05)
- Dissolved oxygen: 1.93mg/L to 3.32mg/L (average: 2.31)
- Water height: 30cm to 50cm on the edge; 1.20m centerwarding great water
- NO_2: 0.45mg/L to 0.61mg/L (average: 0.50mg/L)
- NO_3: 15.32mg/L to 21.16mg/L (average: 18.12mg/L)
- NO_4: 18.03mg/L to 23.41mg/L (average: 21.05mg/L)
- PO_3: 0.076mg/L to 0.18mg/L (average:0.12mg/L)

A.3.2 Vegetation

The Akadjamè marsh is covers by a vegetation whose appearance and floristic composition vary in terms of hydromorphy degree. The marsh central zone with a permanent clogging is occupy by small islands of grasslands whose floristic composition and extent are in term of the filling up level. Thus, the low filling up parts are covered with water where we can observe some grouping of *Eleocharis complanata* or of *Cyperus articulatus* of about 1m ray and some floating grassland of *Nymphaea* or of *Utricularia spp*. However, in the most important filling up grasslands we note a grouping of *Typha austalis* and *Scirpus cubensis* strewed of small water puddles spangled with herbaceous like *Nymphara* lotus and *Ipomoea aquatica.*

The marsh floodable edge in time of flood is occupied of grassland and some small islands of degraded marshy forest. The grassland is dominated by *Fuirena umbrellata*. That species is associated with many other less importance taxous like: *Leersia hexandra, Cypirus distans, Toenia thouwarsii, Pycreus polystachyos, Clappertomia ficifolia*, etc. The small island of marshy forest are very reduced about 1m wide. The characteristic species are represented by shrubs and herbaceous whose most important are: *Mussaenda isertiana, Isora brochypoda, Alchornea cordifolia, Vitex grandiflora, Phoenix reclinata, Tetracer alnifolia, Dissotis segregata and Scleria naummanniana*. That floodable zone is used in parts for the production of tomatoes, pepper and corn.

The exonded zone of the marsh is characterised by a fallow mosaic of palm trees and coconut palm. The most frequent species encountered in those formations are: *Vetiveria nigritana, Dolichos argenteus, Hyptis lanceolata, Scoparia dulcis*, etc.

A.4 THE HÊVIÉ MARSH

It is a big marsh spreading over about 5km long and over a modest 500m wide in average.

The first part of that marsh is bordered by the pipeline of the zone from the bridge on Hêvié road and a bit beyond. Then, the pipeline passes through the second part of the marsh (transect B8) before coming out to run along (transect B9) over a great distance and ends at Maria-gléta (gas storage and distribution site).

A.4.1 Physico-chemical characteristic of water

On account of the rains (june – july 2003)

- Temperature: 26.2°C to 29.6°C (average: 27.43°C)
- Saltiness: 0%
- Ph: 4.91 to 5.30 (average: 5.17)
- Dissolved oxygen: 0.14mg/L to 2.15mg/L (average:1.1mg/L)
- Water height: 0.60m to 1.5m
- NO2: 0.63mg/L to 0.98mg/L (average: 0.78mg/L)
- NO3: 44.92mg/L to 63.41mg/L (average: 53.47mg/L)
- NO4: 28.76mg/L to 47.86mg/L (average: 39.93mg/L)
- PO3: 1.69mg/L to 3.11mg/L (average: 2.53mg/L)

A.4.2 Vegetation

The fist part of the bordered marsh by the pipeline presents a hollow constituted of a degraded marshy forest mosaic and of grassland according to the clogging degree and the degradation level. The zone of permanent flood contains the grouping of Raphia hookeri and Cyrtosperma senegalense. It is structured in to two stratums. The shrubby stratum of 6m height and 30% covering comprises only Raphia hookeri. The herbaceous stratum is denser. It is largely dominated by the Cyrtosperma senegalense.

The peripheral grasslands of the mars where the clogging is temporary, are occupied by the grouping of Ficus congensis and Leersia hexandra constitute of two stratums. The shrubby stratum, very opened, contains species such as: Ficus congensis, Psychotria articulata, Alchornea cordifolia, Ixora brachypoda and symphonia globilifera. The low stratum, very dense with 95% covering and 1m height.

The largely dominant species is Leersia hexandra associated with many other species like: Rhynchospora corymbosa, Cyclosorus striatus, Clappertonia ficifolia etc.

The areas completely degraded of the marsh are occupied by a vegetation whose appearance varies in terms of constitutive plant species. Thus, we can observe the grouping of Typha australis and Nymphaea lotus, the grouping of Cyclosorus striatus, the grouping of vossia cuspidate and the grouping of Thalia welwitschii which is a species often grown for its leaves.

The exonded zone of the marsh comprises fallows, other cultures and palm tree plantations and Artocarpus communis.

For the second part of the marsh crossed by the pipeline, the zone with permanent flood contains a homogeneous vegetation. It is a grassland of Typha australis and Cyclosorus striatus (greatly dominant) Cyrtosperma senegalense, Lecrsia hexandra etc... Sme rare plants of shrubs emerge. They are Berlinia grandiflora and Anthocleista vogelii in the marsh depth.

The marsh floodable zone is constituted of inter-seasonal culture and fallows whose common species are: Torenia thouwarsii, Fuirena umbrellata, Lycopodium cernuum, Emilia sonchifolia, Pycreus polystchyos, etc.

The exonded grassland of the marsh are occupied by the fallos and palm-trees plantations and Artocarpus communis. As far as the third part of the marsh bordered by the pipeline is concerned, its zone with permanent clogging contains a degraded marshy forest with a shrubby stratum and a herbaceous stratum. The shrubby stratum, with 1 to 3m height is very opened. It covering is only 30%. It is greatly dominated by *Anthocleista vogelii* followed byLycopodium cernuum, Psychotria articulata and Raphia hookeri. The herbaceous stratum is very closed with 80% covering. The most abundant species are: *Cyclosorus striatus, Thalia* welwitschii, Cyperus distants, Anthocleista vogelii, Lycopodium cernuum.

The marsh floodable edge in time of flood is occupied by a grassland dominated by *Leersia* hexandra. That latter is associated with many other species which are: *Cyclosorus striatus*, *Fuirena umbrellata, Dissotis segregata, Ludwigia stenorraphe, Kyllinga perruviana, Mussaenda isertiana* etc... That floodable zone is used in parts for the cultivation of Thalia *welwitschii.*

The exonded slopes of the marsh contain a mosaic of fallow, market gardening, thicket and palm groves.

APPENDIX B
LISTE DES ESPÈCES RECENSÉES

(A : arbre ; a : arbuste ; h : herbacée ; J : jachère ; FMD : forêt marécageuse dégradée ; P : prairie ; M : mangrove ; CL : cocoteraie littorale ; PL : pelouse littorale ; C : cocoteraie ; CH : champ ; Axe 1 : Axe Océan – Station R & M ; Axe 2 : Axe Station R & M – Mariagléta ; s : présent seulement en saison sèche ; p : présent seulement en saison pluvieuse ; sp : présent à la fois en saison sèche et en saison pluvieuse ; 1 : présent).

			Axe 1						Axe 2				
TB	**Espèces**	**Famille**	**J**	**FM**	**F**	**P**	**M**	**CL**	**C**	**J**	**P**	**CH**	**F**
h	*Abrus praecatorius*	Fabaceae						sp					
A	*Acacia auriculiformis*	Mimosaceae		sp	sp		sp	sp	1	1		1	1
A	*Acrostichum aureum*	Adianthaceae				sp	sp						
h	*Adenia lobata*	Passifloraceae							1				
h	*Aeschynomene afraspera*	Fabaceae		s									
h	*Aeschynomene cristata*	Fabaceae		s									
a	*Agelae obliqua*	Connaraceae			sp								1
A	*Albizia adianthifolia*	Mimosaceae			sp				1				1
A	*Albizia ferruginea*	Mimosaceae			sp					1			
A	*Albizia zygia*	Mimosaceae			p							1	
a	*Alchornea cordifolia*	Euphorbiaceae		sp							1		
a	*Allophylus africanus*	Sapindaceae										1	1
h	*Alysicarpus ovalifolius*	Fabaceae					sp	sp					
h	*Amaranthus hybridus*	Amaranthaceae										1	
h	*Amaranthus spinosus*	Amaranthaceae					p						
h	*Ampelocissus leonensis*	Vitaceae								1			
A	*Anacardium occidentale*	Anacardiaceae							1				
h	*Andropogon gayanus*	Poaceae	p										
a	*Angylocalyx oligophyllus*	Fabaceae										1	1
h	*Anisea marinicensis*	Convolvulaceae		sp							1		
a	*Annona senegalensis*	Annonaceae	sp	p	sp			sp					
A	*Anthocleista djalonensis*	Loganiaceae		p	sp								
A	*Anthocleista vogelii*	Ochnaceae											1
A	*Antiaris toxicarisa*	Moraceae								1		1	
h	*Aristida adscencionis*	Poaceae						sp					
h	*Asparagus warneckei*	Liliaceae											1
h	*Aspilia africana*	Asteraceae											1
h	*Aspilia bussei*	Asteraceae			sp					1		1	1
h	*Aspilia helianthioides*	Asteraceae		s									
h	*Asystasia gangetica*	Acanthaceae	s	s	sp				1	1		1	1
A	*Avicennia germinans*	Avicenniaceae					sp						
h	*Axonopus compressus*	Poaceae		sp						1			
A	*Azadirachta indica*	Meliaceae			sp			sp					
A	*Berlinia grandiflora*	Caesalpiniaceae									1		
h	*Biophytum petersianum*	Oxalidaceae											1
A	*Borassus aethiopum*	Poaceae	p										
h	*Brachiaria distichophylla*	Poaceae	sp					p	1	1		1	
h	*Brachiaria distachyoides*	Poaeceae						p					
a	*Bridelia ferruginea*	Euphorbiaceae	s		sp				1	1		1	1

TB	Espèces	Famille			Axe 1				Axe 2				
			J	FM	F	P	M	CL	C	J	P	CH	F
h	*Bulbostylis barbata*	Cyperaceae	p					p					
h	*Bulbostylis pilosa*	Cyperaceae	sp		sp				1				
a	*Byrsocarpus coccineus*	Connaraceae	sp	sp	sp			p	1	1		1	1
a	*Carissa edulis*	Apocynaceae	sp		sp				1	1			1
a	*Carpolobia lutea*	Polygalaceae			sp				1	1		1	1
h	*Cassia mimosoides*	Caesalpiniaceae	sp		p								
h	*Cassia occidentalis*	Caesalpiniaceae					s						
h	*Cassia rotundifolia*	Caesalpiniaceae	sp	p	sp			sp	1				
A	*Cassia siamea*	Caesalpiniaceae											1
A	*Cassipourea barteri*	Rhizophoraceae					sp	sp					
h	*Cassytha filiformis*	Lauraceae		s	sp	sp		sp		1	1		1
h	*Catharanthus roseus*	Apocynaceae						sp					
a	*Celastraceae*	Celastraceae										1	
h	*Centella asiatica*	Apiaceae		sp		sp							
a	*Chassalia kolly*	Rubiaceae	sp		sp				1	1		1	1
h	*Chromolaena odorata*	Asteraceae			s								
a	*Chrysobalanus icaco*	Chrysobalanaceae			s			sp					
A	*Chrysobalanus icaco subsp ellipticus*	Chrysobalanaceae		p									
h	*Cissus sp.*	Vitaceae							1				
A	*Citrus aurantifolia*	Rutaceae											1
a	*Clappertonia ficifolia*	Tiliaceae		p						1			
a	*Clausena anisata*	Rutaceae								1			
h	*Cleome viscosa*	Capparidaceae						p	1	1			
a	*Clerodendrum capitatum*	Verbenaceae	sp		sp								
a	*Clerodendrum thyrsoideum*	Verbenaceae								1		1	
a	*Cnestis ferruginea*	Connaraceae	p		sp				1	1		1	1
A	*Cocos nucifera*	Arecaceae		sp				sp	1		1		
a	*Combretum mucronatum*	Combretaceae											1
h	*Commelina benghalensis*	Commelinaceae	s					s					
h	*Commelina diffusa*	Commelinaceae		sp	p			p	1	1		1	
h	*Commelina erecta*	Commelinaceae	sp		sp		s		1	1		1	1
h	*Commelina sp.*	Commelinaceae								1		1	1
h	*Commelinaceae*	Commelinaceae	s										
h	*Corchorus aestuans*	Tiliaceae								1			
h	*Crotalaria retusa*	Fabaceae				sp							
h	*Croton lobatus*	Euphorbiaceae			p			sp					
h	*Ctenium newtonii*	Poaceae			s								
h	*Culcasia scandens*	Araceae										1	
h	*Curculigo pilosa*	Hypoxidaceae	p										
h	*Cyanotis lanata*	Commelinaceae			sp								
h	*Cyclosorus striatus*	Thelypteridaceae									1		
h	*Cyperus articulatus*	Cyperaceae				sp					1		
h	*Cyperus distans*	Cyperaceae		sp		sp							
h	*Cyperus margaritaceus*	Cyperaceae	sp										
h	*Cyperus rotundus*	Cyperaceae	p		p								
h	*Cyperus dilatatus*	Cyperaceae	s					p		1			1
h	*Cyrtosperma senegalense*	Araceae									1		
h	*Dactyctemium aegyptium*	Poaceae	sp					s					
a	*Dalbergia afzeliana*	Fabaceae								1		1	1

TB	Espèces	Famille	Axe 1						Axe 2				
			J	FM	F	P	M	CL	C	J	P	CH	F
a	*Dalbergia ecastaphyllum*	Fabaceae				sp	sp						
a	*Dalbergia lactea*	Fabaceae			sp					1		1	
a	*Dalbergia setifera*	Fabaceae	sp		sp								1
a	*Deinbollia pinnata*	Sapindaceae								1		1	
h	*Desmodium adscendens*	Fabaceae		p									
h	*Desmodium gangeticum*	Fabaceae										1	
h	*Desmodium ramosissimum*	Fabaceae		sp	sp				1			1	1
h	*Desmodium velutinum*	Fabaceae			sp					1			
A	*Dialium guineense*	Caesalpiniaceae			sp					1		1	1
a	*Dichapetalum guineense*	Dichapetalaceae											1
a	*Dichrostachys cinerea*	Mimosaceae			sp				1				
h	*Digitaria exilis*	Poaceae	p								1		
h	*Digitaria horizontalis*	Poaceae						p		1		1	1
h	*Digitaria sp*	Poaceae	s					p					
h	*Digitaria argyrotricha*	Poaceae	p										
h	*Digitaria sp*	Poaceae	p										
h	*Diodia scandens*	Rubiaceae		sp			sp	sp					1
a	*Diospyros tricolor*	Ebenaceae		sp	p								
h	*Dissotis rotundifolia*	Melastomataceae		sp									
h	*Dissotis segregata*	Melastomataceae		sp									
h	*Dolichos argenteus*	Fabaceae	sp		sp					1			
a	*Dracaena arborea*	Arecaceae						p					
A	*Elaeis guineensis*	Cyperaceae	sp		sp			s		1		1	1
h	*Eleocharis complanata*	Cyperaceae		sp			p						
h	*Eleocharis mutata*	Cyperaceae					s						
h	*Emilia coccinea*	Asteraceae										1	1
h	*Emilia sonchifolia*	Asteraceae									1		
h	*Eragrositis ciliaris*	Poaceae	s		p								
h	*Eragrostis tremula*	Poaceae	sp										
h	*Eriosema glomerata*	Fabaceae	p						1	1			
A	*Eucalyptus camadulensis*	Myrtaceae							1				
h	*Euphorbia hirta*	Euphorbiaceae			sp							1	
a	*Ficus sur*	Moraceae			sp							1	
h	*Fimbristylis ferruginea*	Cyperaceae				sp	sp						
h	*Fimbristylis hispidula*	Cyperaceae	sp	p	sp				1	1			
h	*Fimbristylis obtusifolia*	Cyperaceae					sp						
h	*Fimbristylis sp*	Cyperaceae	s										
a	*Flacourtia flavescens*	Flacourtiaceae	p		sp			p	1				1
a	*Fluegea virosa*	Euphorbiaceae										1	1
h	*Fuirena umbellata*	Cyperaceae		sp		sp	s				1		
h	*Gloriosa simplex*	Liliaceae								1			1
a	*Grewia carpinifolia*	Tiliaceae						p					1
h	*Hackelochloa granularis*	Poaceae			p							1	1
h	*Heteropogon contortus*	Poaceae	s										
h	*Hibiscus sp*	Malvaceae						p					
h	*Hibiscus surrattensis*	Malvaceae						p					
a	*Hoslundia opposita*	Lamiaceae	p						1	1			
h	*Hybanthus enneaspermus*	Violaceae	sp	p	p			p	1				
h	*Hyptis lanceolata*	Lamiaceae	p										
h	*Hyptis suaveolens*	Lamiaceae		sp				s					

TB	Espèces	Famille	Axe 1						Axe 2				
			J	FM	F	P	M	CL	C	J	P	CH	F
a	*Icacina tricantha*	Icacinaceae											1
h	*Imperata cylindrica*	Poaceae			p				1	1		1	
h	*Indigofera hirsuta*	Fabaceae			s								
h	*Indigofera pulchra*	Fabaceae	sp						1	1			
h	*Ipomoea involucrata*	Convolvulaceae	sp	p	sp				1	1		1	1
h	*Ipomoea mauritiana*	Convolvulaceae											1
h	*Ipomoea stolonifera*	Convolvulaceae						sp					
a	*Ixora brachypoda*	Rubiaceae		sp						1			
a	*Jasminum dichotomum*	Oleaceae	p		sp			p	1				
a	*Jaundea pinnata*	Connaraceae											1
h	*Kyllinga erecta var erecta*	Cyperaceae	p		p			p					
h	*Kyllinga erecta var perruviana*	Cyperaceae	p										
a	*Landolphia owariensis*	Apocynaceae			sp								
h	*Landolphia owariensis*	Apocynaceae								1			1
A	*Lannea acida*	Anacardiaceae								1			1
A	*Lannea barteri*	Anacardiaceae							1				
A	*Lannea nigritana*	Anacardiaceae			sp								1
A	*Lecaniodiscus cupanioides*	Sapindaceae								1		1	1
h	*Leersia hexandra*	Poaceae		sp							1		
a	*Leptoderris brachyptera*	Fabaceae										1	
a	*Lonchocarpus cyanescens*	Fabaceae	sp						1	1			
h	*Ludwigia stenorraphe*	Onagraceae		p							1		
h	*Lygodium microphyllum*	Schizaeaceae									1		
a	*Macrosphyra longistyla*	Rubiaceae							1	1		1	1
a	*Mallotus oppositifolius*	Euphorbiaceae							1	1		1	1
A	*Mangifera indica*	Anacardiaceae			sp								
a	*Manihot esculenta*	Euphorbiaceae											1
a	*Manilkara obovata*	Sapotaceae						p					
a	*Margaritaria discoidea*	Euphorbiaceae										1	
h	*Mariscus cylindristachyus*	Cyepraceae	sp		sp			p	1	1		1	1
h	*Mariscus ligularis*	Cyperaceae				p	sp						
h	*Mariscus soyauxii*	Sterculiaceae			p			p	1	1		1	
a	*Maytenus ovatus*	Celastraceae										1	1
h	*Melanthera scandens*	Asteraceae										1	
h	*Melochia corchoriifolia*	Tiliaceae		sp									
h	*Merremia tridentata*	Convolvulaceae	sp		sp				1	1			
h	*Micrococa merculiaris*	Euphorbiaceae						p				1	
A	*Milicia excelsa*	Moraceae											1
a	*Milletia barteri*	Fabaceae											1
h	*Mitracarpus scaber*	Rubiaceae	p					sp	1				
h	*Momordica charantia*	Cucurbitaceae					s						
A	*Morinda lucida*	Rubiaceae		s						1		1	
a	*Mussaenda isertiana*	Rubiaceae		sp									
a	*Nauclea latifolia*	Rubiaceae		p									1
h	*Nephrolepis bisserata*	Davalliaceae								1			1
A	*Newbouldia laevis*	Bignoniaceae						p					
h	*Nymphaea lotus*	Nymphaeaceae		sp							1		
a	*Ochna membranacea*	Ochnaceae											1
a	*Olax subscorpioidea*	Olacaceae	sp		sp							1	1
h	*Oldenlandia affinis*	Rubiaceae	sp	p	sp			sp		1	1		1

TB	Espèces	Famille			Axe 1							Axe 2	
			J	FM	F	P	M	CL	C	J	P	CH	F
h	*Oldenlandia corymbosa*	Rubiaceae		s	s			sp	1				
a	*Opilia celtidifolia*	Opiliaceae			sp				1				1
a	*Opuntia tuna*	Cactaceae						sp					
h	*Oryza longistaminata*	Poaceae		sp									
a	*Ouratea affinis*	Ochnaceae											1
a	*Oxyanthus racemosus*	Rubiaceae								1			1
h	*Pandiaka involucrata*	Amaranthaceae	sp	sp	sp								
h	*Pandiaka involucrata*	Amaranthaceae							1	1			
h	*Panicum brevifolium*	Poaceae		sp									
h	*Panicum maximum*	Poaceae							1	1			
h	*Panicum parvifolium*	Poaceae			p								1
h	*Panicum repens*	Poaceae		sp									
h	*Parkia biglobosa*	Mimosaceae	p										
h	*Paspalum orbiculare*	Poaceae	p	sp	sp				1	1			1
h	*Paspalum vaginatum*	Poaceae				sp	sp	s					
h	*Passiflora foetida*	Passifloraceae				s	sp	p					
h	*Paullinia pinnata*	Sapindaceae										1	1
h	*Pennisetum polystachyon*	Poaceae			sp					1			
h	*Pentodon pentandrus*	Rubiaceae		sp		sp	sp						
h	*Perotis hildebrandtii*	Poaceae	s										
h	*Perotis indica*	Poaceae	sp	p	sp			s	1				1
A	*Persea americana*	Lauraceae											1
h	*Philoxerus vermicularis*	Amaranthaceae					p						
a	*Phoenix reclinata*	Arecaceae		sp									
h	*Phragmites karka*	Poaceae											1
h	*Phyllanthus amarus*	Euphorbiaceae	p	p	p		s		1	1		1	1
h	*Phyllanthus pentandrus*	Euphorbiaceae	sp					sp	1				
a	*Phyllanthus reticulatus*	Euphorbiaceae		s			sp						
h	*Physalis angulata*	Solanaceae						p				1	
h	*Physalis micrantha*	Solanaceae					p						
h	*Pleioceras barteri*	Apocynaceae								1			1
h	*Polygala arenaria*	Polygalaceae	p	sp	sp	s			1			1	1
a	*Pouteria alnifolia*	Sapotaceae	p									1	
a	*Psidium guajava*	Myrtaceae		p				p					1
a	*Psorospermum glaberrimum*	Clusiaceae	sp						1	1			
a	*Psychotria vogeliana*	Rubiaceae											1
A	*Pterocarpus santalinoides*	Fabaceae					s						
h	*Pycreus polystachyos*	Cyperaceae				sp	sp		1		1		
A	*Raphia soudanica*	Arecaceae									1		
a	*Raphiostylis beninensis*	Icacinaceae			sp				1				1
a	*Rauvolfia vomitoria*	Apocynaceae	sp		s				1	1		1	1
a	*Reissantia indica*	Celastraceae											1
A	*Rhizophora racemosa*	Rhizophoraceae				s	sp						
h	*Rhynchelitrum roseum*	Poaceae			sp								
h	*Rhynchosia corymbosa*	Cyperaceae		sp							1		
h	*Rhynchosia minima*	Fabaceae								1			
a	*Ritcheia capparoides*	Capparidaceae			p								
h	*Rottboellia exaltata*	Poaceae										1	1
a	*Rytigynia umbellulata*	Rubiaceae	sp		s				1				1

TB	Espèces	Famille			Axe 1				Axe 2				
			J	FM	F	P	M	CL	C	J	P	CH	F
h	*Sauvagesia erecta*	Ochnaceae		sp									
h	*Schrankia leptocarpa*	Mimosaceae		s									
h	*Schweinkia americana*	Solanaceae	p		sp			p		1		1	1
h	*Schyzachyrium sanguineum*	Poaceae	sp	sp	s				1				
h	*Scleria achtenii*	Cyperaceae		sp									
h	*Scleria naummaniana*	Cyperaceae									1		
h	*Scoparia dulcis*	Scrophulariaceae		p		sp	sp						
h	*Sebastiana chamelea*	Euphorbiaceae			p				1	1		1	
a	*Secamone afzelii*	Asclepiadaceae	p		p				1				1
h	*Sesbania leptocarpa*	Fabaceae	p										
h	*Setaria barbata*	Poaceae	p						1			1	
h	*Setaria longiseta*	Poaceae								1			
h	*Setaria pumila*	Poaceae	sp						1				
h	*Sida acuta*	Malvaceae										1	1
h	*Sida cordifolia*	Malvaceae						p					
h	*Sida linifolia*	Malvaceae	sp		s				1	1			1
a	*Smilax kraussiana*	Smilacaceae										1	1
h	*Solenostemon monostachyus*	Lamiaceae	p	sp					1				
a	*Sorindeia warneckei*	Anacardiaceae	s		sp				1	1		1	1
h	*Spermacoce ocimoides*	Rubiaceae				sp							
h	*Spermacoce sp*	Rubiaceae	p										
h	*Spermacoce stachydea*	Rubiaceae	p	p	sp			sp	1			1	1
h	*Spermacoce verticillata*	Rubiaceae	p	s		sp							
h	*Spigelia anthelmia*	Loganiaceae			p								1
h	*Sporobolus pyramidalis*	Poaceae	sp		p				1	1			1
h	*Stachyanthus occidentalis*	Icacinaceae								1			
h	*Stachytarfetta indica*	Verbenaceae										1	
h	*Stachytarpheta indica*	Poaceae		p									
A	*Sterculia tragacantha*	Sterculiaceae			sp					1		1	1
h	*Stylosanthes erecta*	Fabaceae		s				sp					
h	*Synedrella nodiflora*	Asteraceae											1
A	*Syzygium guineense* var *littorale*	Myrtaceae		sp	sp		sp						
h	*Tacca leontopetaloides*	Taccaceae	p	p	p				1	1			
h	*Talinum triangulare*	Portulacaceae			sp							1	1
A	*Tectona grandis*	Verbenaceae											1
h	*Tephrosia bracteolata*	Fabaceae											1
h	*Tephrosia linearifolia*	Fabaceae	p					p					
h	*Tephrosia purpurea*	Fabaceae						sp					
h	*Tephrosia villosa*	Fabaceae			sp								
a	*Tetracera alnifolia*	Dilleniaceae		sp	sp		s		1		1		1
h	*Torenia thouwarsii*	Scrophulariaceae		sp		sp					1		
h	*Triclisia subcordata*	Menispermaceae			sp					1			1
a	*Tricoscypha oba*	Anacardiaceae	sp		s								
h	*Tridax procumbens*	Asteraceae			sp								
h	*Tristemma hirtum*	Melastomataceae									1		
h	*Triumfetta rhomboidea*	Tiliaceae	sp	sp	sp		p	sp	1	1			1
h	*Typha australis*	Typhaceae									1		
h	*Uraria picta*	Fabaceae			sp					1			
h	*Urena lobata*	Malvaceae	s										
a	*Usteria guineensis*	Loganiaceae		p	sp							1	1

					Axe 1				Axe 2				
TB	**Espèces**	**Famille**	**J**	**FM**	**F**	**P**	**M**	**CL**	**C**	**J**	**P**	**CH**	**F**
h	*Utricularia reflexa*	Utriculariaceae		sp									
a	*Uvaria chamae*	Annonaceae	sp		sp			sp	1	1		1	1
h	*Vernonia cinerea*	Asteraceae							1	1			1
h	*Vetiveria nigritana*	Poaceae		sp									
h	*Vigna racemosa*	Fabaceae									1		
A	*Vitex doniana*	Verbenaceae	p		sp								1
A	*Vitex grandiflora*	Verbenaceae		p						1			
h	*Walhenbergia perrottiti*	Campanulaceae		sp									
h	*Waltheria indica*	Sterculiaceae	sp	sp	s				1				
a	*Ximenia americana*	Olacaceae											1
A	*Zanthoxylum zanthoxyloides*	Rutaceae	sp	sp	sp		p	sp	1	1		1	1
h	*Zea mays*	Poaceae						p		1		1	
h	*Zehneria cappilacea*	Cucurbitaceae					p						
h	*Zornia glochidiata*	Fabaceae	sp	p	sp			p	1				

APPENDIX C
FORM: BIRDS

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Noms des personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito
Date 12 /07/2003 Heure : 08 h à 16 h 30'
Transect N° : WAGP RB2/02 83

Coordonnées des Points d'observation	
Latitude (DD)	Longitude (DD)
N06°23.574'	E002°15.566'

Description de l'habitat : (Observation générale) : Champs de cultures sur sols peu évolués (Akouèhonou)

Noms scientifiques	Noms français	Nombre	Observations /Notes
Phalacrocorax africanus	Cormoran africain	**2**	**Vol**
Ardeola ibis	Héron garde-bœuf	**2**	**Vol**
Turtur afer	Emerauldine à bec rouge	**6**	**Vol**
Streptopelia vinacea	Tourterelle vineuse	**3**	**Vol**
Streptopelia semitorquata	Tourterelle à collier	**6**	**Vol**
Streptopelia senegalensis	Tourterelle maillée	**10**	**Vol**
Agapornis pullaria	Inséparable à tète rouge	**4**	**Vol**
Chrysococcyx caprius	Coucou didric	**1**	**Cri**
0Centropus senegalensis	Coucal du sénégal	**5**	**Vol**
Alcedo cristata	Martin-chasseur huppé	**1**	**Posé**
Pogoniulus chrysoconus	Petit barbu à front jaune	**2**	**Cri**
Pycnonotus barbatus	Bulbul commun	**20**	**Cri**
Turdus pelios	Grive kurrichane	**1**	**Vol**
Camaroptera brachyura	Camaroptère à dos gris	**3**	**Vol**
Platysteira cyanea	Gobe-mouche caronculé à collier	**1**	**Cri**
Lanius collaris	Pie-grièche fiscale	**5**	**Posé**
Corvinella corniva	Corvinelle	**4**	**Vol**
Tchagra senegala	Téléphone tchagra	**2**	**Cri**
Corvus albus	Corbeau pie	**4**	**Vol**
Passer griseus	Moineau gris	**2**	**Cri**
Ploceus cucullatus	Tisserin gendarme	**14**	**Vol**
Lagonosticta senegala	Amarante commun	**9**	**Vol**
Lonchura cucullata	Spermète nonnette	**16**	**Vol**
Lonchura fringilloides	Spermète pie	**4**	**Posé**

FICHE W (suite) : OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Noms des personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito

Date : 14/072003 Heure : 09 h 30' à 17 h 30'

Transect N° : WAGP RB2 /02 62

Coordonnées du Point d'Observation	
Latitude (DD)	Longitude (DD)
N 06°23.635'	E002°15 .669'

Description de l'habitat (Observation générale) : Champs de cultures et fougère le long du marécage (Akouèhonou - Agbogbo ville – Pont Dodji)

Noms scientifiques	Noms français	Nombre	Observations /Notes
Phalacrocorax africanus	Cormoran africain	**6**	**Vol**
Ardeola ibis	Héron garde-bœuf	**5**	**Vol**
Butorides striatus	Héron à dos vert	**1**	**Vol**
Ardea purpurea	Héron pourpré	**2**	**Vol**
Accipiter badius	Epervier shikra		**Posé**
Elanus caeruleus	Elanion blanc	**1**	**Vol**
Limnocorax flavirostra	Ràle noir	**3**	**Vol**
Actophilornis africana	Jacana	**5**	**Vol**
Turtur afer	Emerauldine à bec rouge	**1**	**Vol**
Streptopelia vinacea	Tourterelle vineuse	**8**	**Vol**
Streptopelia semitorquata	Tourterelle à collier	**8**	**Vol**
Streptopelia senegalensis	Tourterelle maillée	**20**	**Vol**
Noms scientifiques	**Noms français**	**Nombre**	**Observations /Notes**
Agapornis pullaria	Inséparable à tète rouge	**4**	**Vol**
Caprimulgus climacurus	Engoylevent à longue queue	**1**	**Vol**
Centropus senegalensis	Coucal du sénégal	**5**	**Cri**
Centropus sp	Coucal épomidis	**2**	**Posé**
Halcyon senegalensis	Martin-chasseur à tète grise	**3**	**Posé**
Ceryle rudis	Martin-pècheur pie	**1**	**Vol**
Alcedo cristata	Martin-chasseur huppé	**1**	**Posé**
Merops pusillus	Guèpier nain	**8**	**Posé**
Hirundo semirufa	Hirondelle à ventre roux	**10**	**Vol**
Hirundo rustica	Hirondelle de cheminée	**6**	**Vol**
Pycnonotus barbatus	Bulbul commun	**7**	**Posé & cri**
Chlorocichla simplex	Bulbul modeste	**2**	**Posé**
Turdus pelios	Grive kurrichane	**2**	**Vol**
Cisticola galatoctes	Cisticole roussàtre	**1**	**Posé**
Platysteira cyanea	Gobe-mouche caronculé à collier	**4**	**Cri**

Noms scientifiques	**Noms français**	**Nombre**	**Observations /Notes**
Camaroptera brachyura	Camaroptère à dos gris	**1**	**Cri**
Hypergerus atriceps	Timalie àtète noire	**4**	**Cri**
Anthreptes collaris	Soui-manga à poitrine rouge	**1**	**Vol**
Nectarinia verticalis	Soui-mangacarmélite	**1**	**Vol**
Anthreptes gabonicus	Soui-manga olivàtre	**1**	**Posé**
Nectarinia superba	Soui-manga superbe	**2**	**Vol**
Lanius collaris	Pie-grièche fiscale	**2**	**Posé**
Tchagra senegala	Téléphone tchagra	**6**	**Posé**
Laniarius barbarus	Gonolek de barbarie	**2**	**Posé**
Euplectes afer	Vorabé	**2**	**Posé**
Euplectes orix	Ignicolore	**5**	**Posé**
Passer griseus	Moineau gris	**2**	**Cri**
Ploceus cucullatus	Tisserin gendarme	**18**	**Champs**
Lagonosticta senegala	Amarante commun	**4**	**Vol**
Lonchura cucullata	Spermète nonnette	**11**	**Vol & posé**
Lonchura bicolor	Spermète à bec bleu	**3**	**Posé**
Estrilda melpoda	Joues-oranges	**2**	**Posé**
Nigrita canicapilla	Sénégali nègre	**1**	**Cri**
Euplectes macrourus	Veuve à dos d'or	**1**	**Vol**
Vidua macroura	Veuve dominicaine	**1**	**Vol**

FICHE W (suite) : OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Noms personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito
Date : 15 /07/2003 Heure : 06 h 50' à 16 h 56'
Transect N° : WAGP RB2/02 125

Coordonnées du Point d'Observation	
Latitude (DD)	Longitude (DD)
N06°25.335'	E002°18.456'

Description de l'habitat (Observation générale) : Champs de cultures sur sols peu évolués (Zounkètomey- Mariagléta)

Noms scientifiques	Noms français	Nombre	Observations / Notes
Ardeola ibis	Héron garde-bœuf	6	**Posé**
Ardea purpurea	Héron pourpré	1	**Vol**
Falco tinnunculus	Crécerelle	1	**Pose**
Streptopelia semitorquata	Tourterelle à collier	4	**Vol**
Streptopelia senegalensis	Tourterelle maillée	22	**Posé & vol**
Clamator levaillantii	Coucal épomidis	5	**Vol**
Chrysococcyx caprius	Coucou didric	1	**Cri**
Centropus senegalensis	Coucal du sénégal	2	**Cri**
Halcyon senegalensis	Martin-chasseur du Sénégal	1	**Posé**
Alcedo cristata	Martin-chasseur huppé	5	**Vol**
Hirundo rustica	Hirondelle de cheminée	10	**Posé**
Pycnonotus barbatus	Bulbul commun	12	**Vol cri**
Chlorocichla simplex	Bulbul modeste	1	**Posé**
Turdus pelios	Grive kurrichane	2	**Posé**
Camaroptera brachyura	Camaroptère à dos gris	5	**Cri**
Anthreptes collaris	Soui-manga cuivré	1	**Vol**
Nectarinia verticalis	Soui-manga olive à tête bleue	1	**Posé**
Anthreptes gabonicus	Soui-manga éclatant	1	**Cri**
Lanius collaris	Pie-grièche fiscale	5	**Posé**
Tchagra senegala	Téléphone tchagra	5	**Cri**
Laniarius barbarus	Gonolek de barbarie	1	**Voix**
Passer griseus	Moineau gris	7	**Posé**
Ploceus cucullatus	Tisserin gendarme	40	**Vol**
Ploceus nigrerrimus	Tisserin noir de vieillot	4	**Posé**
Lagonosticta senegala	Amarante commun	8	**Posé**
Lonchura cucullata	Spermète nonnette	6	**Posé**
Euplectes orix	Ignicolore	1	**Posé**

FICHE W (suite) : OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Noms des personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito
Date : 22 /07/2003 Heure : 8h 58'à14 h 05'
Transect N° : WAGP RB2/02 111

Coordonnées du Point d'Observation	
Latitude (DD)	Longitude (DD)
N06°25.816'	E002°17.605'

Description de l'habitat (Observation générale) : Champs de cultures (le long du marécage d'Agroland)

Noms français	Nombre	Observation/ notes
Elanion blanc	1	Vol
Epervier shikra	1	Vol
Jacana	3	Marche,vol
Ràle noir	1	Marche
Emérauldine à bec rouge	4	En vol
Coucal à bec jaune	1	Feuillage
Coucal du sénégal	2	Vol
Coucal épomidis	1	Vol
Martinet des palmiers	2	Vol
Petit barbu à front jaune	2	Cri
Petit martin-chasseur huppé	1	Posé
Traquet tarier	1	Posé
Grive kurrichane	3	Vol
Gonoleck de barbarie	1	Cri
Téléphone tchagra	2	Posé, vol
Soui-manga éclatant	1	Cri
Soui-manga brun	1	Posé
Soui-manga à ventre jaune	1	Posé
Vorabé	2	Vol
Ignicolore	1	Vol
Malimbe à queue rouge	1	Posé

FICHE W (suite): OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Noms personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito
Date : 17 /07/2003 Heure : 07 h 20' à 15 h 40'

Transect n° : WAGP RB 2/02 50 Condition météorologique : Saison de pluies

Type de transect : Terre ferme

Coordonnées du Point d'observation	
Latitude (DD)	Longitude (DD)
N 06°22. 933'	E 002°15. 421'

Description de l'habitat (Observation générale) : Champs de cultures et habitations humaines (Bassoukpa)

Noms français	Noms scientifiques	Nombre	Observations /Notes
Héron garde-bœuf	*Ardeola ibis*	3	Vol
Epervier shikra	*Accipiter badius*	1	Posé
Cormoran africain	*Phalacrocorax africanus*	3	Vol
Crecerelle	*Flco tinnunculus*	1	Vol
Francolin commun	*Francolinus bicalcaratus*	1	Cri
Emerauldine à bec rouge	*Turtur afer*	2	Vol
Tourterelle à collier	*Streptopelia semitorquata*	4	Vol
Tourterelle maillée	*Streptopelia senegalensis*	8	Posé ,vol
Inséparable à tête rouge	*Agapornis pullaria*	2	Vol
Touraco gris	*Crinifer piscator*		Posé
Coucou didric	*Chrysococcyx caprius*	2	Posé cri
Coucal du sénégal	*Centropus senegalensis*	2	Vol
Martin-chasseur à tête grise	*Halcyon leucocephala*	1	Posé
Martin-chasseur du Sénégal	*Halcyon senegalensis*	1	Posé
Camaroptère à dos gris	*Camaroptera brachyura*	1	Cri
Pie-grièche fiscale	*Lanius collaris*	1	Posé
Alouette sentinelle	*Macronyx croceus*	2	Vol
Bulbul commun	*Pycnonotus barbatus*	14	Vol , posé
Grive kurrichane	*Turdus pelios*		
Gobemouche caronculé à collier	*Platysteira cyanea*	1	Cri
Timalie à tète noire	*Hypergerus atriceps*	1	Cri
Soui-manga cuivré	*Nectarinia cuprea*	1	Posé

Noms français	Noms scientifiques	Nombre	Observations /Notes
Soui-manga éclatant	*Nectarinia coccinigaster*		
Pie-grièche fiscale	*Lanius collaris*	1	Posé
Corvinelle	*Corvinella corniva*	1	Cri
Téléphone tchagra	*Tchagra senegala*	1	Cri
Gonolek de barbarie	*Laniarius barbarus*	2	Cri
Corbeau pie	*Corvus albus*	1	Vol
Merle métallique à œil blanc	*Lamprotornis splendidus*	2	Posé
Moineau gris	*Passer griseus*	5	Cri , posé
Moineau – tisserin	*Plocepasser superciliosus*		Nids
Tisserin gendarme	*Ploceus cucullatus*	90	Nids
Tisserin noir de vieillot	*Ploceus nigerrimus*	50	Nids
Amarante commun	*Lagonosticta senegala*	4	Vol

FICHE W (suite) : OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques
Noms des personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Josélito
Date : 18/07 /2003 Heure : 07 h 00 à 17 h 18
Transect N° WAGP 2 / 02 36 Condition météorologique Saison pluvieuse
Type de transect : Lagune côtière

Coordonnées du Point d'observation	
Latitude (DD)	Longitude (DD)
N 06°21.419'	E 002°15. 320'

Description de l'habitat (Observation générale) : Prairie inondable (Hio-Houègbo-Adjahèdji - Agbokpanzotomè-Dakpèvitomè)

Noms français	Noms scientifiques	Nombre	Observations /Notes
Cormoran africain	*Phalacrocorax africanus*	11	En vol
Héron crabier	*Ardeola ralloides*	2	Posé , vol
Héron garde-bœuf	*Ardeola ibis*	6	Posé , vol
Héron à dos vert	*Butorides striatus*	7	Posé, vol ,cri
Héron pourpré	*Ardea purpurea*	6	Vol
Héron noir	*Egretta ardesiaca*	13	Vol
Butor blongios	*Ixobrychus minutus*	5	Vol
Aigrette garzette	*Egretta garzetta*	1	Vol
Elanion blanc	*Elanus caeruleus*	1	Vol
Francolin commun	*Francolinus bicalcaratus*	1	Cri
Râle noir	*Limnocorax flavirostra*	2	Marche
Jacana	*Actophilornis africana*	3	Vol
Sarcelle à oreillons	*Nettapus auritus*	4	Vol ,nage
Chevalier guignette	*Actitis hypoleucos*	1	Vol
Emerauldine à bec rouge	*Turtur afer*	2	Vol
Tourterelle maillée	*Streptopelia senegalensis*	10	Posé, vol
Tourterelle à collier	*Stretopelia semitorquata*	6	Vol, posé
Martin-chasseur à tête grise	*Halcyon leucocephala*	2	Posé
Martin-chasseur du Sénégal	*Halcyon senegalensis*	1	Cri
Martin pêcheur pie	*Ceryle rudis*	10	Vol
Petit martin-pêcheur huppé	*Alcedo cristata*	1	Vol
Coucal du sénégal	*Centropus senegalensis*	3	Posé

Noms français	**Noms scientifiques**	**Nombre**	**Observations /Notes**
Timalie à tète noire	*Hypergerus atriceps*	5	Cri
Corvinelle	*Corvinella corniva*	8	Vol
Gonoleck de barbarie	*Laniarus barbarus*	10	Vol, posé
Hirondelleà long brins	*Hirundo smithii*	10	Vol
Pie-grièche cubla de gambie	*Rainoscopus gambensis*	1	Posé
Alouette sentinelle	*Macronyx croceus*	8	Posé, vol
Bulbul commun	*Pycnonotus barbatus*	13	Vol
Cisticole roussâtre	*Cisticola galactotes*	2	Posé
Cisticole des joncs	*Cisticola juncidis*	1	Vol
Camaroptère à dos gris	*Camaroptera brachyura*	4	Cri
Gobemouche caronculé à collier	*Platysteira cyanea*	11	Cri
Petit barbu à front jaune	*Pogoniulus chrysoconus*	3	Cri
Pie-grièche fiscale	*Lanius collaris*	1	Vol
Téléphone tchagra	*Tchagra senegala*	4	Vol, cri
Spermète nonnette	*Lonchura cucullata*	20	Posé
Soui-manga éclatant	*Nectarinia coccinigaster*	2	Cri
Soui-manga carmélite	*Nectarinia fuliginosa*	1	Vol
Vorabé	*Euplectes afer*	2	Vol ,posé
Inséparable à tète rouge	*Agapornis pullaria*	2	Vol
Tisserin noire de vieillot	*Ploceus nigerrimus*	20	Nids
Soui-manga brun	*Anthreptes gabonicus*	2	Posé
Soui-manga olive à tète bleue	*Nectarinia verticalis*	2	Posé
Soui-manga à collier	*Anthreptes collaris*	2	Posé
Soui-manga cuivré	*Nectarinia cuprea*	1	Feuillage

FICHE W (suite) : OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Nom de la personne ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito
Date : 19/07/2003 Heure : 08 h 32' à 16 h 00'

Transect N° : WAGP 2/02 14 Condition météorologique : Saison de pluie

Type de transect : Terre ferme

Coordonnées du Point d'Observation	
Latitude (DD)	Longitude (DD)
N 06° 22.174'	E 002° 15. 312'

Description de l'habitat (Observation générale) : Champs de cultures sur sols sableux peu évolués, jachères et fourré (Vinawa)

Noms français	Noms scientifiques	Nombre	Observations /Notes
Héron garde-bœuf	*Ardeola ibis*	24	Vol
Elanion blanc	*Elanus caeruleus*	1	Vol
Bulbul commun	*Pycnonotus barbatus*	9	Vol posé
Tourterelle maillée	*Streptopelia senegalensis*	15	Vol
Inséparable à tète rouge	*Agapornis pullaria*	2	Vol
Coucal du sénégal	*Centropus senegalensis*	1	Posé
Martin-chasseur à tête grise	*Halcyon leucocephala*	1	Posé
Martin-chasseur du Sénégal	*Halcyon senegalensis*	2	Vol ,cri
Bulbul à bec grèle	*Andropadus gracilirostris*	6	Cri ,vol
Give kurrichane	*Turdus pelios*	1	Vol
Corvinelle	*Corvinella corniva*	2	Posé
Camaroptère à dos gris	*Camaroptera brachyura*	1	Cri
Gonolek de barbarie	*Laniarius barbarus*	2	
Spermète nonnette	*Lonchura cucullata*	5	Vol
Moineau gris	*Passer griseus*	2	
Téléphone tchagra	*Tchagra Senegala*	2	Vol ,posé
Tisserin gendarme	*Ploceus cucullatus*	300	Vol
Tisserin noir de vieillot	*Ploceus nigerrimus*	10	Vol
Travailleur à bec rouge	*Quelea quelea*	2	Posé
Amarante commun	*Lagonosticta senegala*	15	Vol
Joues oranges	*Estrilda melpoda*	5	Posé

FICHE W (suite) : OISEAUX

Nom du chef de l'équipe de terrain : ADJAKPA Boco Jacques

Noms des personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques & TOSSOU Joselito
Date : 21 /07/2003 Heure : 08 h00 à 16 h12'
Transect N° : WAGP 2/02 12 Condition météorologique : Saison de pluie

Type de transect : Zone humide

Coordonnées du Point d'Observation	
Latitude (DD)	Longitude (DD)
N 06° 22.361'	E 002° 15.394'

Description de l'habitat (Observation générale) : Marécage (Akadjamè)

Noms français	**Noms scientifiques**	**Nombre**	**Observations /Notes**
Cormoran africain	*Phalacrocorax africanus*	1	Posé
Héron crabier	*Ardeola ralloides*	1	Posé
Héron garde-bœuf	*Ardeola ibis*	2	Vol
Héron pourpré	*Ardea purpurea*	2	Pose
Sarcelle à oreillons	*Nettapus auritus*	14	Nage
Elanion blanc	*Elanus caeruleus*		Posé
Buse unibande	Kaupifalco mono gra mmicus	1	Vol
Jacana	*Actophilornis africana*	8	Vol, marche
Râle noir	*Limnocorax flavirostra*	3	Marche
Coucou didric	*Chrysococcyx caprius*	1	Cri
Emerauldine à bec rouge	*Turtur afer*	2	Vol
Tourterelle maillée	*Streptopelia senegalensis*	12	Vol, posé
Coucal du sénégal	*Centropus senegalensis*	1	Vol
Martin-chasseur à tête grise	*Halcyon leucocephala*	1	Posé
Martin-chasseur du Sénégal	*Halcyon senegalensis*	1	Posé
Martin pêcheur pie	*Ceryle rudis*	1	Vol
Petit martin-pêcheur huppé	*Alcedo cristata*	2	Posé
Rolle africain	*Eurystomus glaucurus*	2	Vol
Vorabé	*Euplectes afer*	1	Posé
Corvinelle	*Corvinella corniva*	1	Cri
Joues-oranges	*Estrilda melpoda*	2	Posé
Bulbul commun	*Pycnonotus barbatus*	4	Vol
Amarante commun	*Lagonosticta senegala*	4	Posé
Spermète nonnette	*Lonchura cucullata*	10	Posé

FICHE W (suite) : OISEAUX

Nom du chef de l''équipe de terrain : ADJAKPA Boco Jacques

Noms des personnes ayant enregistré l'échantillon : ADJAKPA Boco Jacques et TOSSOU Joselito

Date (MM/DD) : 20/07/2003 Heure (000h000) : 07 h 20 à 17 h 40
'

Transect N° : Plage et cordon littoral Condition météorologique : Saison de pluies

Type de transect : Terre ferme

Coordonnées du Point d'Observation	
Latitude (DD)	Longitude (DD)
N 06°20.815'	E 002° 15.137'

Description de l'habitat (Observation générale) : Cocoteraie et champs de tomate et piment

sur cordon littoral

Nom commun	Nom scientifique	Nombre	Observations /Notes
Héron garde-bœuf	*Ardeola ibis*	7	Posés au sol
Buse unibande	*Kaupifalco monogrammicus*	2	Posé dans un arbre
Emerauldine à bec rouge	*Turtur afer*	2	Vol
Tourterelle vineuse	*Streptopelia vinacea*	15	Posés
Tourterelle maillée	*Streptopelia senegalensis*	25	Recherche de nourriture
Coucal du sénégal	*Centropus senegalensis*	1	Cri
Martin-chasseur à tête grise	*Halcyon leucocephala*	2	Cri
Martin-chasseur du Sénégal	*Halcyon senegalensis*	3	Vol
Pic gris	*Mesopicos goertae*	3	Dans l'arbre
Bulbul à bec grêle	*Andropadus gracilirostris*	4	Vol
Bulbul commun	*Pycnonotus barbatus*	26	Posés
Grive kurrichane	*Turdus pelios*	1	Posé
Camaroptère à dos gris	*Camaroptera brachyura*	2	Vol
Soui-manga à poitrine rouge	*Nectarinia senegalensis*	1	Nourriture
Soui-manga brun	*Anthreptes gabonicus*	1	Vol
Soui-manga à ventre jaune	*Nectarinia venusta*	1	Vol
Soui-manga à ventre olive	*Nectarinia chloropygia*	2	Vol
Soui-manga éclatant	*Nectarinia coccinigaster*	2	Vol

Nom commun	Nom scientifique	Nombre	Observations /Notes
Corvinelle	*Corvinella corniva*	6	Posés
Téléphone tchagra	*Tchagra senegala*	2	Cri et vol
Gonolek de barbarie	*Laniarius barbarus*	4	Chants
Piac – piac	*Ptilostomus afer*	12	Posés
Moineau gris	*Passer griseus*	5	Vol
Tisserin gendarme	*Ploceus cucullatus*	45	Vols incessants

Tableau: Liste des différentes espèces d'oiseaux recensées

Dates : 12, 14, 15, 17, 18, 19, 20, 21 & 22/07/03

Noms scientifiques	Noms français	Saison de pluies
Phalacrocorax africanus	Cormoran africain	X
Ardeola ibis	Héron garde-bœuf	x
Egretta garzetta	Aigrette garzette	X
Egretta intermedia	Aigrette intermédiaire	x
Ixobrychusminutus	Butor blongios	X
Ardea cinerea	Héron céndré	X
Ardea purpurea	Héron pourpré	X
Butorides striatus	Héron à dos vert	X
Egretta ardeiaca	Héron noir	X
Ardeola ralloides	Héron crabier	x
Dendrocygna viduata	Dendrocygne veuf	x
Nettapus auritus	Sarcelle à oreillons	X
Elanus caeruleus	Elanion blanc	X
Kaupifalco monogrammicus	Buse unibande	X
Accipiter badius	Epervier shikra	X
Falco tinnunculus	Crécerelle	X
Francolinus bicalcaratus	Francolin commun	x
Limnocorax flavirostra	Râle noir	X
Porphyrio porphyrio	Poule sultane	x
Porphyrio alleni	Poule d'allen	x
Actophilornis africana	Jacana	X
Himantopus himantopus	Echasse blanche	X
Tringa hypoleucos	Chevalier guignette	X
Tringa glareola	Chevalier sylvain	x
Turtur afer	Emerauldine à bec rouge	X
Streptopelia vinacea	Tourterelle vineuse	X
Streptopelia semitorquata	Tourterelle à collier	X
Streptopelia senegalensis	Tourterelle maillée	X
Agapornis pullaria	Inséparable à tète rouge	X
Chrysococcyx caprius	Coucou didric	X
Centropus senegalensis	Coucal du sénégal	X
Ceuthmochares aereus	Coucal à bec jaune	X

Noms scientifiques	Noms français	Saison de pluies
Centropus sp	Coucal épomidis	X
Caprimulgus climacurus	Engoulevent à longue queue	X
Cypsiurus parvus	Martinet des palmiers	X
Halcyon senegalensis	Martin-chasseur du Sénégal	X
Halcyon senegalensis	Martin chasseur à tète grise	X
Alcedo cristata	Petit martin chasseur huppé	X
Ceryle rudis	Martin pêcheur pie	X
Merops pusillus	Guêpier nain	X
Eurystomus glaucurus	Rolle africain	X
Pogoniulus chrysoconus	Petit barbu à front jaune	X
Lybius vieilloti	Barbu de vieillot	x
Mesopicos goertae	Pic gris	x
Campethera nivosa	Pic à dos vert	x
Dendropicos fuscescens	Pic cardinal	x
Macronyx croceus	Alouette sentinelle	X
Hirundo smithii	Hirondelle à longs brins	X
Hirundo rustica	Hirondelle de cheminée	X
Hirundo semirufa	Hirondelle à ventre roux	X
Pycnonotus barbatus	Bulbul commun	X
Andropadus gracilirostris	Bulbul à bec grèle	X
Chlorocichla simplex	Bulbul modeste	X
Turdus pelios	Grive kurrichane	X
Hypergerus atriceps	Timalie à tète noire	X
Camaroptera brachyura	Camaroptère à dos gris	X
Cisticola galactotes	Cisticole roussàtre	X
Cisticola juncidis	Cisticole des joncs	X
Platysteira cyanea	Gobe-mouche caronculé à collier	X
Anthreptes collaris	Soui-manga à collier	X
Nectarinia verticalis	Soui-manga olive à tête bleue	X
Anthreptes gabonicus	Soui-manga brun	X
Nectarinia olivacea	Soui-manga olivàtre	X
Nectarinia fuliginosa	Soui-manga carmélite	X
Nectarinia coccinigaster	Soui-manga éclatant	X
Nectarinia senegalensis	Soui-manga à poitrine rouge	X
Nectarinia venusta	Soui-manga à ventre jaune	X
Nectarinia cuprea	Soui-manga cuivré	X
Nectarinia superba	Soui-manga superbe	X
Lanius collaris	Pie-grièche fiscale	X
Corvinella corniva	Corvinelle	X
Tchagra senegala	Téléphone tchagra	X
Laniarius barbarus	Gonolek de barbarie	X
Rainoscopus gambensis	Pie-grièche cubla de Gambie	X
Ptilostomus afer	Piac – piac	x
Corvus albus	Corbeau pie	X
Lamprotornis splendidus	Merle métallique à œil blanc	X
Passer griseus	Moineau gris	X
Ploceus cucullatus	Tisserin gendarme	X
Ploceus nigerrimus	Tisserin noir de vieillot	X
Quelea quelea	Travailleur à bec rouge	X

Noms scientifiques	Noms français	Saison de pluies
Euplectes macrourus	Veuve à dos d'or	**X**
Malimbus scutatus	Malimbe à queue rouge	**X**
Euplectes orix	Ignicolore	**X**
Euplectes afer	Vorabé	**X**
Lonchura bicolor	Spermète à bec bleu	**X**
Nigrita canicapilla	Sénégali nègre	**X**
Lagonosticta senegala	Amarante commun	**X**
Lonchura cucullata	Spermète nonnette	**X**
Lonchura fringilloides	Spermète pie	**X**
Estrilda melpoda	Joues-orange	**X**
Vidua macroura	Veuve dominicaine	**X**

FICHE : Mammifères, Reptiles et Batraciens

Nom du chef de l'équipe de terrain : TCHABI Alphonse

Noms des personnes ayant enregistré l'échantillon : TCHABI Alphonse & CHABI Jéremie
Dates : 12, 14, 15, 17, 18, 19, 21 & 22/07/03

Noms vulgaires	Noms scientifiques	Modalité de recensement			Milieux d'observation - Fréquences					
		Observations	Empreintes	Témoignages	Secteur Nord	Secteur Sud	Présence	Fréquence	Savane	Marécages
MAMMIFERES										
Sitatunga	*Tragelaphus spekei*			+		X				
Guib harnaché	*Tragelaphus scriptus*			+		X				
Potamochère"sanglier	*Potamochoerus porcus*			+	XX	XX		+	+	
Aulacode "agouti"	*Tryonomis swinderianus*		+		XXX	XXX	+	+	+	
Rat de Gambie	*Crycetomys gambianus*		+		XXX	XXX		+	+	
Ecureuil fouisseur	*Xerus erythropus*	+			XX	XX	+		+	
Ecureuil arboricole	*Funisciure sp*	+			XX					
Lièvre à oreilles de lapin	*Lepus crawshayi*		+	+	XX				+	
Singe vert	*Cercopithecus aethiops*				XX	X		+	+	
Singe rouge(patas)	*Erythrocebus patas*				XX			+		
Galago du sénégal	*Galago senegalensis*				X			+	+	
Rat Roussard	*Arvicanthis niloticus*				XXX				+	
Rat noir	*Rattus rattus*	+			XXX			+	+	
Herisson à ventre blanc	*Atelerix albiventris*				XX	XX		+	+	
Musaraigne	*Crocidura sp*	+			XXX			+	+	
REPTILES										
Python royal	*Python regius*	+			XXX	XXX	+	+	+	

Noms vulgaires	Noms scientifiques	Modalité de recensement			Milieux d'observation - Fréquences					
		Observations	Empreintes	Témoignages	Secteur Nord	Secteur Sud	Présence	Fréquence	Savane	Marécages
Python de séba	*Python sebae*	+			XX	XX	+	+	+	
Vipère commune	*Causus rhombeatus*			+		X		+	+	
Vipère heurtante	*Bitis arietans*	+			XX	XX		+	+	
Vipère du Gabon	*Bitis gabonica*			+		X		+	+	
Couleuvre	*Chlorophis heterodermus*					XX		+	+	
Couleuvre	*Psammophis sibilans*				XX				+	
Mamba noir	*Dendroaspis polylepis*				XX			+	+	
Mamba vert	*Dendroaspis viridis*				XXX	XX		+	+	
Naja cracheur	*Naja nigricollis*			+		X		+		
Varan d'eau	*Varanus niloticus*	+			XXX	XXX				+
Varan de terre	*Varanus exanthematicus*				XX			+	+	
Margouillat	*Agama agama*	+			XXX	XX	+		+	
Scinque	*Scincus sp*	+			XX	XX	+		+	
Crocodile du Nil	*Crocodilus niloticus*			+		X				+
Crocodile nain	*Osteolaemus tetraspis*				XX	XX				+
Tortue luth	*Dermochelys coriacea*			+		X				
Tortue d'eau douce	*Pelusio subniger*	+			XX	XX				+
Tortue terrestre	*Kinixys belliana*	+			XX				+	
Caméléon	*Chamaeleo senegalensis*				XX		+	+	+	
AMPHIBIENS										
Grenouille	*Rana occipitalis*	+			XXX	XXX				+
Grenouille rousse	*Rana temporaria*	+			X	XX				+
Crapaud	*Bufo regularis*	+			XX	XX	+	+	+	
Rainette	*Hyperiolus sp*	+			XX	XX	+	+		

<u>Table legende :</u> : x Rare ; xx abundant ; xxx very abundant ; + Presence (yes)

Fiche : Identification des composantes environnementales affectées

ACTIVITES	Faune aviaire	Faune non aviaire
PHASE PREPARATOIRE		
Préparation du site	**X**	**X**
Aménagements des voies d'accès (layons)	X	X
Installation des bornes	X	X
PHASE DE LANCEMENT		
Aménagement des conduits du gaz	X	X
Aménagement de la base de l'entrepreneur (installations de chantier)	X	X
Transport et circulation de la machinerie et des équipements	X	X
PHASE DE CONSTRUCTION		
Construction du gazoduc dans les lagunes	**X**	**X**
Construction du gazoduc en zone marécageuse	X	X
Construction du gazoduc en terre ferme	X	X
Tracé des routes d'accès	X	X
Transport et circulation de la machinerie et des équipements	X	X
Décapage et abattage d'arbres et de prairies marécageuses	X	X
Travaux de terrassements (déblais et remblais)	X	X
PHASE DE CONSTRUCTION		
Construction des stations et divers	X	X
Opérations de revêtement en ciment des conduits	X	X
PHASE D'EXPLOITATION ET DE MAINTENANCE		
Stockage	X	X
Dommages potentiels des conduits du Gazoduc	X	X
Entretien et réparation	X	X
PHASE DE DEMENTELLEMENT		
Fuite de gaz	X	X
Dépôt des matériels divers	X	X
Déménagement des matériels	X	X

Résultats des mesures des paramètres physico-chimiques de l'eau en surface et en profondeur dans les marécages et dans la lagune

Transect	N° échantil-lon Eau	Longitude	Latitude	Température (°C)	O2 dissous (mg L^{-1})	O2 dissous (%)	pH	Conductivité (µS cm^{-1})	TDS (mg L^{-1})	Salinité (‰)	DBO5 mg L^{-1}	Turbidité/transparence(m)	Turbidité (D.O. à 860 nm)	TOC mg C.m-3
B2 (marécage d'eau douce)	2B2 ps1	6°22'26.8	2°15'23.6	31.2	6.17	71.8	6.85	126.0	63.0	0.0	192.24	1	0.07	928
	2B2 pf1	6°22'26.8	2°15'23.6	27.3	2.35	28.5	6.02	125.6	63.0	0.0	48.16	1	0.08	348
	2B2 ps2	6°22'26.8	2°15'39.7	31.2	4.73	65.8	6.24	144.2	73.0	0.0	137.14	1.07	0.05	1044
	2B2 pf2	6°22'26.8	2°15'39.7	27.2	1.52	16.0	6.14	155.0	79.0	0.0	26.12	1.07	0.08	464
B4 (marécage d'eau saumâtre)	2B4 ps1	6°21'10.3	2°15'9.6	30.2	3.83	45.3	6.24	5620	2864	3.4	100.00	0.3	0.08	348
	2B4 pf1	6°21'10.3	2°15'9.6	30.0	1.73	22.8	6.20	5650	2879	3.5	16.73	0.3	0.09	116
	2B4 ps2	6°21'9.9	2°14'58.8	29.1	3.41	31.1	6.89	4140	2110	2.4	69.80	0.62	0.08	232
	2B4 pf2	6°21'9.9	2°14'58.8	29.04	3.39	36.7	6.87	5630	2869	3.5	78.78	0.62	0.06	116
B5 (lagune)	2B5 ps1	6°20'52.3	2°15'7.5	28.5	5.74	61.4	7.24	7210	3675	3.7	177.14	0.9	0.02	464
	2B5 pf1	6°20'52.3	2°15'7.5	27.2	3.83	45.3	7.65	7120	3629	3.7	95.10	0.9	0.03	116
	2B5 ps2	6°20'59.8	2°15'8.4	28.4	4.08	49.8	7.85	6010	3063	3.8	114.29	1.7	0.04	406
	2B5 pf2	6°20'59.8	2°15'8.4	27.3	3.77	47.5	7.8	6660	3394	3.8	82.45	1.7	0.05	232
B8 (marécage d'eau douce)	2B8 ps1	6°23'45.2	2°16'26.1	27.2	2.15	23.4	5.30	177.7	96	0.0	75.10	0.6	0.1	928
	2B8 pf1	6°23'45.2	2°16'26.1	26.8	1.98	22.5	5.27	100.3	96	0.0	26.53	0.6	0.06	580
	2B8 ps2	6°23'45.9	2°16'25.4	29.6	1.3	14.90	4.91	194	197	0.0	24.49	0.38	0.07	696
	2B8 pf2	6°23'45.9	2°16'25.4	26.2	0.4	8.0	5.04	143.3	123	0.0	0.82	0.38	0.06	812
B9 (marécage d'eau douce)	2B9 ps1	6°24'22.0	2°16'54.7	27.8	0.63	9.0	5.19	306	313	0.0	9.39	0.25	0.1	464
	2B9 pf1	6°24'22.0	2°16'54.7	27.0	0.14	1.6	5.29	165.1	232	0.0	1.63	0.25	0.09	464

Ps1 : premier point d'échantillonnage de plancton en surface au niveau du transecte. pf1 : premier point d'échantillonnage de plancton en profondeur au niveau du transecte

Table of total organic carbon (TOC) of the waters of swamps and lagoon

Transect	Stations	Longitude	Latitude	DOb	DOa	Chla (µg/l)	TOC mg C.m-3
B2	2B2 ps1	6°22' 26,8	2°15' 23,6	0.15	0.07	23.2	**928**
	2B2 pf1	6°22' 26,8	2°15' 23,6	0.12	0.09	8.7	**348**
	2B2 ps2	6°22' 26,8	2°15' 39,7	0.13	0.04	26.1	**1044**
	2B2 pf2	6°22' 26,8	2°15' 39,7	0.12	0.08	11.6	**464**
B4	2B4 ps1	6°21' 10,3	2°15' 9,6	0.04	0.01	8.7	**348**
	2B4 pf1	6°21' 10,3	2°15' 9,6	0.08	0.07	2.9	**116**
	2B4 ps2	6°21' 9,9	2°14' 58,8	0.14	0.12	5.8	**232**
	2B4 pf2	6°21' 9,9	2°14' 58,8	0.11	0.1	2.9	**116**
B5	2B5 ps1	6°20' 52,3	2°15' 7,5	0.08	0.04	11.6	**464**
	2B5 pf1	6°20' 52,3	2°15' 7,5	0.02	0.01	2.9	**116**
	2B5 ps2	6°20' 59,8	2°15' 7,5	0.06	0.025	10.15	**406**
	2B5 pf2	6°20' 59,8	2°15' 7,5	0.04	0.02	5.8	**232**
B8	2B8 ps1	6°23' 45,2	2°16' 26,1	0.25	0.17	23.2	**928**
	2B8 pf1	6°23' 45,2	2°16' 26,1	0.17	0.12	14.5	**580**
	2B8 ps2	6°23' 45,9	2°16' 25,4	0.16	0.1	17.4	**696**
	2B8 pf2	6°23' 45,9	2°16' 25,4	0.14	0.07	20.3	**812**
B9	SB9 ps1	6°24' 22,0	2°16' 54,7	0.15	0.11	11.6	**464**
	2B9 pf1	6°24' 22,0	2°16' 54,7	0.18	0.14	11.6	**464**

Dob : densité optique après acidification, Doa : densité optique avant acidification

Moyenne par plan d'eau

	Transect B2	Transect B4	Transect B5	Transect B8	Transect B9
TOC surf.	986	290	435	812	464
TOC prof.	406	116	174	696	464

Water Column Profiles

ONSHORE BIOLOGICAL DATA

Sediment Biological Data

Tableau. Diversité et abondance relative des insectes des sols simples et composés des différentes stations

Echantillons	2B1a1	2B1a2	2B1a3	2B1a4	2B1cp1	2B1cp2
Longitude	6°22'56,1"	6°22'56,1"	6°22'56,1"	6°22'56,1"	6°22'56,1''	6°22'56,1"
Latitude	2°15'25,4"	2°15'25,4"	2°15'25,4"	2°15'25,4"	2°15'25,4''	2°15'25,4"
HYMENOPTERES						
Formicidae		2(40)	1(50)			
Myrmicidae	2(16,66)	1(20)	1(50)		3(50)	
Braconidae				1(100)	1(16,66)	
HETEROPTERES						
Aradidae	1(8,33)					
Hydrometidae	2(16,66)					
MYRIAPODES	1(8,33)					
LEPIDOPTERES						
Geometroidea	1(8,33)					
Pieridae	2(16,66)					
ORTHOPTERES						
Acridoidea						
COLEOPTERES						
Meloidae					1(16,66)	
Silphidae	2(16,66)					
Aphodiidae	1(8,33)					
ANNELIDES						
Achètes		2(40)				
ARACHNIDES						
THYSANOURES						
Machilidae					1(16,66)	

STATION 2B2						
Echantillons	**2B2a1**	**2B2a2**	**2B2a3**	**2B2a4**	**2B2cp1**	**2B2cp2**
Longitude	6°22'28,5"	6°22'28,5"	6°22'28,5"	6°22'28,5"	6°22'28,5"	6°22'28,5''
Latitude	2°15'23,8"	2°15'23,8"	2°15'23,8"	2°15'23,8"	2°15'23,8"	2°15'23,8''
MYRIAPODES	1(5,26)					
HYMENOPTERES						
Formicidae						
Myrmicidae	2(10,52)	5(100)				
HETEROPTERES						
Aradidae	1(5,26)					
Hydrometidae	2(10,52)					
LEPIDOPTERES						
Geometroidea	1(5,26)					
Pieridae	2(10,52)					
COLEOPTERES						
Silphidae	2(10,52)					
ANNELIDES						
Lumbricidae						2(100)
Lumbriculidae	8(42,10)				9(100)	

STATION 2B3

Echantillons	**2B3a1**	**2B3a2**	**2B3a3**	**2B3a4**	**2B3cp1**	**2B3cp2**
Longitude	6°22'7,3"	6°22'7,3"	6°22'7,3''	6°22'7,3"	6°22'7,3"	6°22'7,3''
Latitude	2°15'23,9"	2°15'23,9"	2°15'23,9"	2°15'23,9"	2°15'23,9"	2°15'23,9"
HYMENOPTERES						
Formicidae		1(12,5)	1(33,33)	1(20,0)	1(20,0)	
Myrmicidae		7(87,50)	2(66,67)	4(80,0)	4(80,0)	

STATION 2B4

Echantillons	2B4a1	2B4a2	2B4a3	2B4a4	2B4cp1	2B4cp2
Longitude	6°21'9,5"	6°21'9,5"	6°21'9,5"	6°21'9,5"	6°21'9,5"	6°21'9,5"
Latitude	2°15'9,0"	2°15'9,0"	2°15'9,0"	2°15'9,0"	2°15'9,0"	2°15'9,0"
HYMENOPTERES						
Myrmicidae	2(40)					
Formicidae		2(100)				
ORTHOPTERES						
Acridoidea	2(40)					
Opilionide	1(20)					

STATION 2B5

Echantillons	2B5a1	2B5a2	2B5a3	2B5a4	2B5cp1	2B5cp2
Longitude	6°20'59,8"	6°20'59,8"	6°20'59,8"	6°20'59,8"	6°20'59,8"	6°20'59,8"
Latitude	2°15'8,4"	2°15'8,4"	2°15'8,4"	2°15'8,4"	2°15'8,4"	2°15'8,4"
HYMENOPTERES						
Formicidae	1(9,09)	2(2)	1(100)			
Myrmicidae	4(36,36)	8(8)				
HETEROPTERES						
Capsidae	1(9,09)					
Hydrometidae	2(18,18)					
ARTHROPODES						
Acariens	1(9,09)					
Opilionides	2((18,18)					

STATION 2B6

Echantillons	2B6a1	2B6a2	2B6a3	2B6a4	2B6cp1	2B6cp2
Longitude	6°20'46,2"	6°20'46,2"	6°20'46,2"	6°20'46,2"	6°20'46,2"	6°20'46,2"
Latitude	2°15'17,3"	2°15'17,3"	2°15'17,3"	2°15'17,3"	2°15'17,3"	2°15'17,3"
HYMENOPTERES						
Myrmicidae	1(10)					
Perilampidae	1(10)					
Formicidae	3(30)					
ORTHOPTERES						
Acridoidea	2(20)					
Opilionide	1(10)					
LEPIDOPTERES						
Pieridae	1(10)					
Geometrioidea	1(10)					

STATION 2B7

Echantillons	2B7a1	2B7a2	2B7a3	2B7a4	2B7cp1	2B7cp2
Longitude	6°23'37,4"	6°23'37,4"	6°23'37,4"	6°23'37,4"	6°23'37,4"	6°23'37,4"
Latitude	2°15'40,2"	2°15'40,2"	2°15'40,2"	2°15'40,2"	2°15'40,2"	2°15'40,2"
HYMENOPTERES						
Ponéridae	6(16,66)					
Formicidae	10(27,77)	1(50)				
COLEOPTERES						
Chrisomelidae	1(2,77)					
Cleridae	1(2,77)					
TRICHOPTERES						
Hydroptiliae	2(2,55)					
MYRIAPODES	4(11,11)	1(50)			1(33,33)	
ODONATES						
Zygoptères	2(5,55)					
DYCTIOPTERES						
Mantodea	1(2,77)					
OLIGOCHETES						

Echantillons	2B7a1	2B7a2	2B7a3	2B7a4	2B7cp1	2B7cp2
Longitude	6°23'37,4"	6°23'37,4"	6°23'37,4"	6°23'37,4"	6°23'37,4"	6°23'37,4"
Latitude	2°15'40,2"	2°15'40,2"	2°15'40,2"	2°15'40,2"	2°15'40,2"	2°15'40,2"
Tubificidae					1(33,33)	
Naididae					1(33,33)	
COLLEMBOLES						
Arthropleons	1(2,77)					
ARACHNIDES	1(2,77)					
LEPIDOPTERES						
Pyraloidea	2(5,55)					
Lycaeidae	2(5,55)					
ORTHOPTERES						
Acridoidea	2(5,55)					
Gryllidae	1(2,77)					

STATION 2B8

Echantillons	2B8a1	2B8a2	2B8a3	2B8a4	2B8cp1	2B8cp2
Longitude	6°23'45,3"	6°23'45,3"	6°23'45,3"	6°23'45,3"	6°23'45,3"	6°23'45,3"
Latitude	2°16'25,0"	2°16'25,0"	2°16'25,0"	2°16'25,0"	2°16'25,0"	2°16'25,0"
HYMENOPTERES						
Evaniidae	1(6,66)					
Bethylidae	1(6,66)					
Formicidae	1(6,66)					52(98,11)
TRICHOPTERES						
Hydroptilidae	1(6,66)					
MYRIAPODES			1(100)			
ODONATES						
Lestidae	1(6,66)					
OLIGOCHETES						
Tubificidae		2(100)				
ARACHNIDES	2(13,33)					
LEPIDOPTERES						
Ceometroidea	4(26,66)					
Tortricoidea	1(6,66)					
Lycaenidae	1(6,66)					
ORTHOPTERES						
Tetticonioidea	1(6,66)					
PHASMOPTERES	1(6,66)					

Echantillons	2B8a1	2B8a2	2B8a3	2B8a4	2B8cp1	2B8cp2
Longitude	6°23'45,3"	6°23'45,3"	6°23'45,3"	6°23'45,3"	6°23'45,3"	6°23'45,3"
Latitude	2°16'25,0"	2°16'25,0"	2°16'25,0"	2°16'25,0"	2°16'25,0"	2°16'25,0"
COLEOPTERES						
Sitaris muralis						1(1,88)

STATION 2B9

Echantillons	2B9a1	2B9a2	2B9a3	2B9a4	2B9cp1	2B9cp2
Longitude Latitude	6°24'22,3" 2°16'55,4"	6°24'22,3" 2°16'55,4"	6°24'22,3" 2°16'55,4"	6°24'22,3" 2°16'55,4"	6°24'22,3" 2°16'55,4"	6°24'22,3" 2°16'55,4"
HYMENOPTERES						
Myrmicidae	18(100)		4(50)		2(15,38)	
Formicidae			1(12,5)		1(7,69)	
TRICHOPTERES						
Hydroptilidae					1(7,69)	
MYRIAPODES		1(100)	2(25)		3(23,07)	1(50)
OLIGOCHETES						
Tubificidae					1(7,69)	
LEPIDOPTERES						
Ceometroidea					1(7,69)	
HETEROPTERES						
Aradidea					1(7,69)	
DIPLOURES						
Japycidae					3(23,07)	1(50)
ANNELIDES						
Nereidea			1(12,5)			

STATION 2B10

Echantillons	2B10a1	2B10a2	2B10a3	2B10a4	2B10cp1	2B10cp2
Longitude	6°26'3,1"	6°26'3,1"	6°26'3,1"	6°26'3,1"	6°26'3,1"	6°26'3,1"
Latitude	2°17'43,6"	2°17'43,6"	2°17'43,6"	2°17'43,6"	2°17'43,6"	2°17'43,6"
MYRIAPODES		1(14,28)				
HYMENOPTERES					18(90)	
Formicidae	8(88,88)	6(85,71)				4(100)
Myrmicidae					2(10)	
COLEOPTERES						
Melandryidae	1(11,11)					

STATION 2B11

Echantillons	2B11a1	2B11a2	2B11a3	2B11a4	2B11cp1	2B11cp2
Longitude	6°25'24,7"	6°25'24,7"	6°25'24,7"	6°25'24,7"	6°25'24,7"	6°25'24,7"
Latitude	2°18'23,1"	2°18'23,1"	2°18'23,1"	2°18'23,1"	2°18'23,1"	2°18'23,1"
MYRIAPODES					1(25)	
HYMENOPTERES						
Formicidae		2(75)			2(75)	
Poneridae	1(50)					
Arachnides	1(50)					
Oligochètes						
Tubificidae		1(25)				1(100)

Tableau . Diversité spécifique et abondance relative du benthos des différentes stations

(A l'extérieur de la parenthèse, on a le nombre de l'organisme et à l'intérieur, son abondance relative)

STATION 2B2 (Eaux Douces)

Echantillons	**2B2b1**	**2B2b2**	**2B2b3**	**2B2b4**	**2B2b5**
Longitude	6°22'26,8"	6°22'26,8"	6°22'26,8"	6°22'26,8"	6°22'26,8"
Latitude	2°15'23,6"	2°15'23,6"	2°15'23,6"	2°15'23,6"	2°15'23,6"
PLECOPTERES					
Perlodidae		1(20,0)			
Taeniopterygidae					
Taeniopteryx	1(8,33)				
EPHEMEROPTERES					
Baetis sp.	1(8,33)		1(16,66)		9(13)
centroptilum sp.					4(6)
MEGALOPTERES					
Sialis sp.	3(25,0)	1(20,0)			21(30)
HETEROPTERES					
Naucoris					2(3)
ODONATES					
Libellulidae			1(16,66)	1(20,0)	
Platycnemididae			1(16,66)		
DIPTERES					
Ceratopogonidae					1(1)
Culicidae					
Chironomidae	3(25,0)	1(20,0)	2(33,33)	2(40,0)	5(7)
Chaoboridae		1(20,0)			1(1)
OLIGOCHETES					
Naididae					
Stylaria lacustris					21(30)
Lumbriculidae	3(25,0)				
Lumbricidae	1(8,33)				4(6)
Tubificidae		1(20,0)	1(16,66)	1(20,0)	
HYDRACARIENS					1(1)

STATION 2B4 (Eaux saumâtres)

Echantillons	2B4b1	2B4b2	2B4b3	2B4b4	2B4b5
Longitude	6°22'26,8"	6°22'26,8"	6°22'26,8''	6°22'26,8"	6°22'26,8"
Latitude	2°15'23,6"	2°15'23,6"	2°15'23,6''	2°15'23,6"	2°15'23,6"
MOLLUSQUES					
Naticidae					
Natica macrochiensis					1(0,19)
Littorinidae					
Littorina sp.				7(2,05)	
Gasteropodes					
Tellina nymphalis					2(0,38)
Turritella ligar				17(5,0)	
Turritella torulosa	47(83,92)	56(93,33)	17(70,83)	313(92,05)	514(99,03)
Turritella bicingulata					2(0,38)
DIPTERES					
Chironomidae	3(5,35)	2(3,33)	4(16,66)		
OLIGOCHETES					
Lumbriculidae				3(0,88)	
POLYCHETES					
Nereidae			2(8,33)		
CRUSTACES					
Melitidae	1(1,78)				
Phoxocephalidae	5(8,92)	2(3,33)	1(4,16)		

STATION 2B5 (Lagune côtière)

Echantillons	2B5b1	2B5b2	2B5b3	2B5b4	2B5b5
Longitude	6°20'52,3"	6°20'52,3"	6°20'52,3''	6°20'52,3"	6°20'52,3"
Latitude	2°15'7,5"	2°15'7,5"	2°15'7,5"	2°15'7,5"	2°15'7,5"
MOLLUSQUES					
Gasteropodes					
Naticidae					
Natica marochiensis		1(02,22)			
Melaniidae					
Pachymelania aurita					2(00,79)

Echantillons	2B5b1	2B5b2	2B5b3	2B5b4	2B5b5
Longitude	6°20'52,3"	6°20'52,3"	6°20'52,3"	6°20'52,3"	6°20'52,3"
Latitude	2°15'7,5"	2°15'7,5"	2°15'7,5"	2°15'7,5"	2°15'7,5"
Potamididae					
Tympanotonus fuscata					2(00,79)
Vermetidae					
Dendropoma ghanaense	2(02,27)		2(02,60)	3(02,97)	3(01,18)
MOLLUSQUES					
Neritidae					
Neritina cristata				3(02,97)	
Neritina afra sowerby				1(00,99)	
Neritina senegalense				1(00,99)	
Neritina adansoniana				2(01,98)	
Turitella ungulina			2(02,60)	27(26,73)	29(11,42)
Turritella ligar	24(27,27)	6(13,33)	13(16,88)	24(23,76)	33(12,99)
Turritella torulosa	3(03,41)	14(31,11)	12(15,58)		44(17,32)
Vitrinella bushi		1(02,22)			2(00,79)
Mesalia brevialis					11(04,33)
Turritella bicingulata			8(10,39)	1(00,99)	19(07,48)
Naticidae					
Natica marochiensis		1(02,22)			
Melaniidae					
Pachymelania aurita					2(00,79)
Potamididae					
Tympanotonus fuscata					2(00,79)
Vermetidae					
Dendropoma ghanaense	2(02,27)		2(02,60)	3(02,97)	3(01,18)
Bivalve					
Pecten sp.					
Thracia papyracea					11(04,33)
Bittium reticulatum	3(03,41)				
Tellina sp.					
Tellina nymphalis	10(11,36)	5(11,11)	10(12,99)		20(07,87)

Echantillons	2B5b1	2B5b2	2B5b3	2B5b4	2B5b5
Longitude	6°20'52,3"	6°20'52,3"	6°20'52,3"	6°20'52,3"	6°20'52,3"
Latitude	2°15'7,5"	2°15'7,5"	2°15'7,5"	2°15'7,5"	2°15'7,5"
Mytilidae					
Mytilus perna	23(26,14)	1(02,22)	1(01,30)	3(02,97)	39(15,35)
Veneridae					
Pitaria tumens		9(20)	10(12,99)	20(19,80)	7(02,76)
Tivela tripla	3(03,41)	7(15,55)	7(09,09)	8(07,92)	12(04,72)
Ungulinidae					
Diplodonta diaphana			8(10,39)	4(03,96)	10(03,94)
Donacidae					
Donax rugosus	12(13,64)		2(02,60)		3(01,18)
Donax pulchellus	2(02,27)				
CRUSTACES					
Haustoridae				1(00,99)	
ANNELIDES					
Nephtyidae	101,14)				
Nereidae	202,27)				
Capitellidae					
Capitella capitata	1(01,14)				

STATION 2B8 (Eaux Douces) Hêvié

Echantillons	2B8b1	2B8b2	2B8b3	2B8b4	2B8b5
Longitude	6°23'45,2''	6°23'45,9''	6°23'46,3''	6°23'46,6"	6°23'44,5"
Latitude	2°16'26,1''	2°16'25,4''	2°16'25,4''	2°16'25,3"	2°16'25,8"
ODONATES					
Platycnemis sp					1(16,66)
Corduliidae		2(28,57)			
EPHEMEROPTERES					
Ephemerella sp					1(16,66)
Baetidae		1(14,28)			
PLECOPTERES					
Brachyptera sp					1(16,66)
Capniidae				1(20)	
Taeniospteryx sp					1(16,66)
DIPTERES					
Psychodidae					1(16,66)
Chironomidae	2(10,52)				

Echantillons	2B8b1	2B8b2	2B8b3	2B8b4	2B8b5
Longitude	6°23'45,2''	6°23'45,9''	6°23'46,3''	6°23'46,6''	6°23'44,5''
Latitude	2°16'26,1''	2°16'25,4''	2°16'25,4''	2°16'25,3''	2°16'25,8''
Ptychopteridae	1(5,26)				
Ceratopogonidae	13(68,42)	2(28,57)	1(25)		
HETEROPTERES					
Corixidae	1(5,26)				1(16,66)
Plea sp			1(25)		
COLEOPTERES					
Hygrobia sp				1(20)	
OLIGOCHETES					
Tubificidae			2(50)		
Stylaria lacustris	2(10,52)				
Naididae		1(14,28)		3(60)	
MEGALOPTERES					
Sialis sp		1(14,28)			

STATION 2B9 (Eaux Douces)

Echantillons	2B9b1	2B9b2	2B9b3	2B9b4	2B9b5
Longitude	6°24'22,0''	6°24'22,3''	6°24'22,4''	6°24'22,7''	6°24'23,1''
Latitude	2°16'54,7''	2°16'54,9''	2°16'54,8''	2°16'54,9''	2°16'54,3''
Annelides					
Tubificidae	4(30,76)				
Naididae	5(38,46)		1(11,11)	2(40)	
Coléoptères					
Gyrinidae			1(11,11)		
Helodidae			1(11,11)		
Hygrobia sp				3(60)	
Diptères					
Chironomidae	1(7,69)	3(27,27)			
Ceratopogonidae		8(72,72)			
Culicidae	3(23,07)				
Hétéroptères					
Naucoris sp					1(50)
Hyménoptères					
Agriotus sp			1(11,11)		
Mégaloptères					

Echantillons	2B9b1	2B9b2	2B9b3	2B9b4	2B9b5
Longitude	6°24'22,0''	6°24'22,3''	6°24'22,4''	6°24'22,7''	6°24'23,1''
Latitude	2°16'54,7''	2°16'54,9''	2°16'54,8''	2°16'54,9''	2°16'54,3''
Salis sp					1(50)
Odonates					
Corduliidae			4(44,44)		
Caloptéryx sp			1(11,11)		

Tableau. Résultats des analyses microbiologiques de sols (simples et composés), de sédiments et d'eau échantillonnés pendant la saison de pluie.

Echan tillons	Flore aérobie mésophile totale	Coliformes Totaux	Coliformes Fécaux	E. coli Présumés	E. coli	Strepto CoquesD	Clostridium Sulfitoré Ducteurs	Bacillus	Levures et moisissures
					SOLS				
2B1 a1	30400/g	2310/g	1600/g	200/g	16/g		>100sp/g	558/g	2800L/g
2B1 a2	94000/g	abs/g	abs/g	abs/g	abs/g		abs/g	990/g	330L/g
2B1 a3	9000/g	560/g	330/g	abs/g	abs/g		20/g	123/g	2200L/g
2B1 a4	30800/g	410/g	340/g	8/g	8/g		abs/g	25/g	1300M /g
2B1cp1	21000/g	20000/g	12000/g	abs/g	abs/g		abs/g	26/g	2400L/g
2B1cp2	17000/g	1100/g	510/g	abs/g	abs/g		abs/g	960/g	900L/g
2B2 a1	37000/g	abs/g	Abs/g	abs/g	abs/g		5/g	12/g	2900L/g 100M/g
2B2 a2	27000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	256/g	1600L/g 300M/g
2B2 a3	13000/g	abs/g	Abs/g	abs/g	abs/g		20/g	259/g	4100L/g
2B2 a4	44800/g	abs/g	Abs/g	abs/g	abs/g		200sp/g	158/g	2100L/g 200M/g
2B2 cp1	23000/g	abs/g	Abs/g	abs/g	abs/g		20/g	258/g	1100L/g 1700M/g
2B2 cp2	45600/g	abs/g	Abs/g	abs/g	abs/g		abs/g	745/g	400L/g
2B3 a1	57000/g	4600/g	1760/g	abs/g	abs/g		>100sp/g	55/g	1100L/g 400M/g
2B3 a2	23000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	22/g	2300L/g
2B3 a3	16000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	125/g	1500L/g 2400M/g
2B3 a4	11600/g	abs/g	Abs/g	abs/g	abs/g		abs/g	66/g	abs/g
2B3 cp1	27000/g	abs/g	Abs/g	abs/g	abs/g		20/g	218/g	1100L/g 1700M/g
2B3 cp2	60000/g	930/g	Abs/g	abs/g	abs/g		abs/g	659/g	IncL/g 11000M/g
2B4 a1	86000/g	360/g	260/g	100/g	16/g		abs/g	69/g	2000L/g 100M/g
2B4 a2	32410/g	110/g	Abs/g	abs/g	abs/g		200sp/g	556/g	880L/g 2500M/g
2B4 a3	44400/g	abs/g	Abs/g	abs/g	abs/g		200sp/g	469/g	2400L/g
2B4 a4	32800/g	760/g	520/g	200/g	18/g		abs/g	125/g	2300L/g 200M/g
2B4 cp1	22400/g	930/g	580/g	280/g	200/g		abs/g	255/g	1300L/g
2B4 cp2	18000/g	250/g	250/g	abs/g	abs/g		abs/g	189/g	1000L/g

Echan tillons	Flore aérobie mésophile totale	Coliformes Totaux	Coliformes Fécaux	E. coli Présumés	E. coli	Strepto CoquesD	Clostridium Sulfitoré Ducteurs	Bacillus	Levures et moisissures
					SOLS				
2B5 a1	33600/g	1260/g	400/g	250/g	25/g		200sp/g	125/g	1000L/g 2200M/g
2B5 a2	13000/g	480/g	310/g	abs/g	abs/g		>100sp/g	258/g	1700L/g
2B5 a3	6800/g	960/g	Abs/g	abs/g	abs/g		>100sp/g	589/g	300L/g 260M/g
2B5 a4	29000/g	460/g	310/g	abs/g	abs/g		abs/g	580/g	1300L/g
2B5cp1	22000/g	930/g	580/g	280/g	200/g		abs/g	255/g	1300L/g
2B5cp2	18000/g	250/g	250/g	abs/g	abs/g		abs/g	189/g	1000L/g
2B6 a1	22000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	69/g	3300L/g
2B6 a2	13000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	862/g	3800L/g
2B6 a3	10000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	25/g	900L/g
2 B6cp1	9000/g	2160/g	1240/g	abs/g	abs/g		abs/g	15/g	2100L/g 100M/g
2B6 cp2	59600/g	1930/g	Abs/g	abs/g	abs/g		abs/g	456/g	430L/g
2B7 a1	16900/g	360/g	156/g	122/g	122/g		>100sp/g	45/g	1800L/g
2B7 a2	7900/g	210/g	200/g	abs/g	abs/g		abs/g	58/g	1220L/g 400M/g
2B7 a3	18000/g	720/g	600/g	100/g	18/g		>100sp/g	758/g	1600L/g 700M/g
2B7 a4	1700/g	800/g	200/g	188/g	102/g		abs/g	120/g	860L/g
2B7 cp1	37000/g	2560/g	250/g	250/g	200/g		abs/g	500/g	180L/g
2B7 cp2	2700/g	260/g	200/g	160/g	60/g		10sp/g	650/g	760L/g 760M/g
2B8 a1	9200/g	abs/g	Abs/g	abs/g	abs/g		abs/g	690/g	1980L/g 1260M/g
2B8 a2	6700/g	660/g	66/g	66/g	60/g		>100sp/g	250/g	2540L/g 1000M/g
2B8 a3	2800/g	920/g	600/g	205/g	25/g		30sp/g	235/g	1060L/g 900M/g
2 B8 a4	2200/g	abs/g	Abs/g	abs/g	abs/g		abs/g	695/g	1980L/g 1260M/g
2B8 cp1	11000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	123/g	3000L/g 700M/g
2B8 cp2	700/g	120/g	120/g	abs/g	abs/g		>100sp/g	454/g	1200L/g
2B9 a1	7800/g	abs/g	Abs/g	abs/g	abs/g		20sp/g	800/g	1020L/g
2B9 a2	7000/g	abs/g	Abs/g	abs/g	abs/g		20sp/g	800/g	1020L/g
2B9 a3	3800/g	1560/g	1250/g	1025/g	102/g		abs/g	325/g	660L/g
2B9 a4	3700/g	680/g	402/g	400/g	105/g		abs/g	596/g	1300L/g 220M/g
2B9 cp1	8600/g	920/g	800/g	650/g	100/g		10sp/g	431/g	2400L/g 1060M/g
2B9 cp2	4800/g	1360/g	1025/g	656/g	600/g		abs/g	99/g	860L/g
2B10 a1	5200/g	250/g	250/g	200/g	190/g		abs/g	78/g	260L/g
2B10 a2	7700/g	190/g	166/g	160/g	abs/g		abs/g	781/g	360L/g
2B10 a3	9000/g	440/g	222/g	200/g	100/g		abs/g	880/g	840L/g
2B10 a4	2300/g	2040/g	126/g	abs/g	abs/g		10sp/g	565/g	900L/g 640M/g
2B10 cp1	8400/g	400/g	299/g	200/g	178/g		abs/g	560/g	520L/g
2B10 cp2	2100/g	600/g	200/g	180/g	25/g		abs/g	654/g	640L/g
2B11 a1	3100/g	2040/g	180/g	160/g	100/g		abs/g	321/g	2060L/g 600M/g
2B11 a2	3600/g	520/g	402/g	356/g	16/g		abs/g	250/g	3560L/g 1860M/g
2B11 a3	3200/g	abs/g	Abs/g	abs/g	abs/g		60sp/g	45/g	440L/g
2B11 a4	1700/g	400/g	356/g	300/g	108/g		abs/g	456/g	1040L/g 800M/g
2B11 cp1	6100/g	1260/g	556/g	500/g	352/g		abs/g	68/g	13200L/g 1200M/g
2B11 cp2	800/g	abs/g	Abs/g	abs/g	abs/g		abs/g	160/g	2060L/g 1900M/g
					EAUX				
2B2 ps1	1100/ml	2200/100ml	2200/100ml	6/100ml	abs/100ml	1000/50ml	400sp/20ml	1225/ml	
2B2 pf1	57000/ml	4/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	789/ml	

Echan tillons	Flore aérobie mésophile totale	Coliformes Totaux	Coliformes Fécaux	E. coli Présumés	E. coli	Strepto CoquesD	Clostridium Sulfitoré Ducteurs	Bacillus	Levures et moisissures
EAUX									
2B2 ps2	1420/ml	186/100ml	186/100ml	abs/100ml	abs/100ml	10/50ml	abs/20ml	256/ml	
2B2 pf2	56000/ml	3/100ml	3/100ml	abs/100ml	abs/100ml	abs/50ml	>100sp/20ml	585/ml	
2B4 ps1	1340/ml	86/100ml	86/100ml	18/100ml	4/100ml	abs/50ml	abs/20ml	12//ml	
2B4 pf1	960/ml	2200/100ml	2200/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	864/ml	
2B4 ps2	50000/ml	4/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	>100sp/20ml	555/ml	
2B4 pf2	36000/ml	4/100ml	4/100ml	4/100ml	4/100ml	abs/50ml	>100sp/20ml	454/ml	
2B5 ps1	2060/ml	76/100ml	76/100ml	7/100ml	abs/100ml	abs/50ml	abs/20ml	852/ml	
2B5 pf1	37000/ml	7/100ml	7/100ml	abs/100ml,	abs/100ml	abs/50ml	abs/20ml	689/ml	
2B5 ps2	2890/ml	96/100ml	96/100ml	8/100ml	abs/100ml	abs/50ml	abs/20ml	852/ml	
2B5 pf2	65000/ml	9/100ml	4/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	699/ml	
2B8 ps1	300/ml	150/100ml	100/100ml	85/100ml	75/100ml	200/50ml	10sp/20ml	55/ml	
2B8 pf1	1500/ml	7/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	12/ml	
2B8 ps2	2590/ml	18/100ml	5/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	156/ml	
2B8 pf2	3900/ml	186/100ml	80/100ml	80/100ml	8/100ml	2300ml	30sp/20ml	300/ml	
2B9 ps1	2500/ml	0/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	120/ml	
2B9 pf1	1800/ml	46/100ml	25/100ml	25/100ml	8/100ml	2400/50ml	>100sp/20ml	75/ml	
SEDIMENTS									
2B2 s1	30400/g	abs/g	Abs/g	abs/g	abs/g		abs/g	777/g	3800L/g 100M/g
2B2 s2	62000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	789/g	200L/g
2B2 s3	46400/g	270/g	Abs/g	abs/g	abs/g		200sp/g	984/g	1200L/g
2B2 s4	70000/g	1030/g	abs/g	abs/g	abs/g		200sp/g	45/g	1100M/g 200M/g
2B2 s5	26000/g	340/g	130/g	108/g	30/g		abs/g	45/g	6100L/g 200M/g
2B4 s1	40800/g	800/g	640/g	250/g	112/g		abs/g	778/g	2300L/g 100M/g
2B4 s2	50800/g	700/g	590/g	350/g	102/g		abs/g	898/g	2300L/g 100M/g
2B4 s3	19200/g	300/g	70/g	25/g	abs/g		abs/g	431/g	2600L/g
2B4 s4	50400/g	1080/g	abs/g	abs/g	abs/g		abs/g	78/g	2200M/g 100L/g
2B4 s5	78000/g	2200/g	540/g	300/g	28/g		>100sp/g	958/g	2400L/g
2B5 s1	64000/g	abs/g	abs/g	abs/g	abs/g		200sp/g	56/g	800M/g
2B5 s2	15200/g	1200/g	1090/g	900/g	250/g		>100sp/g	284/g	3900L/g 100M/g
2B5 s3	12800/g	410/g	220/g	115/g	112/g		abs/g	698/g	2100L/g 100M/g
2B5 s3	3700/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	636/g	140L/g
2B5 s4	29200/g	abs/g	abs/g	abs/g	abs/g		abs/g	45/g	2000L/g
2B8 s1	3400/g	190/g	98/g	60/g	18/g		20sp/g	458/g	180L/g
2B8 s2	3600/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	510/g	260L/g
2B8 s3	3600/g	50/g	abs/g	abs/g	abs/g		>100sp/g	412/g	460L/g
2B8 s4	7700/g	1960/g	1600/g	560/g	206/g		>100sp/g	156/g	1960L/g 1260M/g
2B8 s5	5400/g	30/g	abs/g	abs/g	abs/g		>100sp/g	75/g	240L/g 300M/g
2B9 s1	940/g	40/g	abs/g	abs/g	abs/g		40sp/g	145/g	600L/g 800M/g
2B9 s2	8600/g	90/g	80/g	75/g	70/g		>100sp/g	458/g	300L/g 140M/g
2B9 s3	9800/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	458/g	1800L/g
2B9 s4	4700/g	320/g	300/g	200/g	65/g		20sp/g	450/g	1740L/g
2B9 s5	5700/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	458/g	720L/g

N.B: selon la nature de l'échantillon, les résultats constituent des Unités formant colonies UFC et sont exprimés en millilitre pour les eaux et en gramme pour les sols. Ps : eau en surface au niveau du transect, pf : eau en profondeur au niveau du transect, a : sol simple, cp : sol composé, s : sédiment

Tableau. Résultats des analyses microbiologiques de sols (simples et composés), de sédiments et d'eau échantillonnés pendant la saison de pluie.

Echan tillons	Flore aérobie mésophile totale	Coliformes Totaux	Coliformes Fécaux	E. coli Présumés	E. coli	Strepto CoquesD	Clostridium Sulfitoré Ducteurs	Bacillus	Levures et moisissures
					SOLS				
2B1 a1	30400/g	2310/g	1600/g	200/g	16/g		>100sp/g	558/g	2800L/g
2B1 a2	94000/g	abs/g	abs/g	abs/g	abs/g		abs/g	990/g	330L/g
2B1 a3	9000/g	560/g	330/g	abs/g	abs/g		20/g	123/g	2200L/g
2B1 a4	30800/g	410/g	340/g	8/g	8/g		abs/g	25/g	1300M /g
2B1cp1	21000/g	20000/g	12000/g	abs/g	abs/g		abs/g	26/g	2400L/g
2B1cp2	17000/g	1100/g	510/g	abs/g	abs/g		abs/g	960/g	900L/g
2B2 a1	37000/g	abs/g	Abs/g	abs/g	abs/g		5/g	12/g	2900L/g 100M/g
2B2 a2	27000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	256/g	1600L/g 300M/g
2B2 a3	13000/g	abs/g	Abs/g	abs/g	abs/g		20/g	259/g	4100L/g
2B2 a4	44800/g	abs/g	Abs/g	abs/g	abs/g		200sp/g	158/g	2100L/g 200M/g
2B2 cp1	23000/g	abs/g	Abs/g	abs/g	abs/g		20/g	258/g	1100L/g 1700M/g
2B2 cp2	45600/g	abs/g	Abs/g	abs/g	abs/g		abs/g	745/g	400L/g
2B3 a1	57000/g	4600/g	1760/g	abs/g	abs/g		>100sp/g	55/g	1100L/g 400M/g
2B3 a2	23000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	22/g	2300L/g
2B3 a3	16000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	125/g	1500L/g 2400M/g
2B3 a4	11600/g	abs/g	Abs/g	abs/g	abs/g		abs/g	66/g	abs/g
2B3 cp1	27000/g	abs/g	Abs/g	abs/g	abs/g		20/g	218/g	1100L/g 1700M/g
2B3 cp2	60000/g	930/g	Abs/g	abs/g	abs/g		abs/g	659/g	IncL/g 11000M/g
2B4 a1	86000/g	360/g	260/g	100/g	16/g		abs/g	69/g	2000L/g 100M/g
2B4 a2	32410/g	110/g	Abs/g	abs/g	abs/g		200sp/g	556/g	880L/g 2500M/g
2B4 a3	44400/g	abs/g	Abs/g	abs/g	abs/g		200sp/g	469/g	2400L/g
2B4 a4	32800/g	760/g	520/g	200/g	18/g		abs/g	125/g	2300L/g 200M/g
2B4 cp1	22400/g	930/g	580/g	280/g	200/g		abs/g	255/g	1300L/g
2B4 cp2	18000/g	250/g	250/g	abs/g	abs/g		abs/g	189/g	1000L/g
2B5 a1	33600/g	1260/g	400/g	250/g	25/g		200sp/g	125/g	1000L/g 2200M/g
2B5 a2	13000/g	480/g	310/g	abs/g	abs/g		>100sp/g	258/g	1700L/g
2B5 a3	6800/g	960/g	Abs/g	abs/g	abs/g		>100sp/g	589/g	300L/g 260M/g
2B5 a4	29000/g	460/g	310/g	abs/g	abs/g		abs/g	580/g	1300L/g
2B5cp1	22000/g	930/g	580/g	280/g	200/g		abs/g	255/g	1300L/g
2B5cp2	18000/g	250/g	250/g	abs/g	abs/g		abs/g	189/g	1000L/g
2B6 a1	22000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	69/g	3300L/g
2B6 a2	13000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	862/g	3800L/g
2B6 a3	10000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	25/g	900L/g
2 B6cp1	9000/g	2160/g	1240/g	abs/g	abs/g		abs/g	15/g	2100L/g 100M/g
2B6 cp2	59600/g	1930/g	Abs/g	abs/g	abs/g		abs/g	456/g	430L/g
2B7 a1	16900/g	360/g	156/g	122/g	122/g		>100sp/g	45/g	1800L/g
2B7 a2	7900/g	210/g	200/g	abs/g	abs/g		abs/g	58/g	1220L/g 400M/g
2B7 a3	18000/g	720/g	600/g	100/g	18/g		>100sp/g	758/g	1600L/g 700M/g

Echan tillons	Flore aérobie mésophile totale	Coliformes Totaux	Coliformes Fécaux	E. coli Présumés	E. coli	Strepto CoquesD	Clostridium Sulfitoré Ducteurs	Bacillus	Levures et moisissures
2B7 a4	1700/g	800/g	200/g	188/g	102/g		abs/g	120/g	860L/g
2B7 cp1	37000/g	2560/g	250/g	250/g	200/g		abs/g	500/g	180L/g
2B7 cp2	2700/g	260/g	200/g	160/g	60/g		10sp/g	650/g	760L/g 760M/g
2B8 a1	9200/g	abs/g	Abs/g	abs/g	abs/g		abs/g	690/g	1980L/g 1260M/g
2B8 a2	6700/g	660/g	66/g	66/g	60/g		>100sp/g	250/g	2540L/g 1000M/g
2B8 a3	2800/g	920/g	600/g	205/g	25/g		30sp/g	235/g	1060L/g 900M/g
2 B8 a4	2200/g	abs/g	Abs/g	abs/g	abs/g		abs/g	695/g	1980L/g 1260M/g
2B8 cp1	11000/g	abs/g	Abs/g	abs/g	abs/g		>100sp/g	123/g	3000L/g 700M/g
2B8 cp2	700/g	120/g	120/g	abs/g	abs/g		>100sp/g	454/g	1200L/g
2B9 a1	7800/g	abs/g	Abs/g	abs/g	abs/g		20sp/g	800/g	1020L/g
2B9 a2	7000/g	abs/g	Abs/g	abs/g	abs/g		20sp/g	800/g	1020L/g
2B9 a3	3800/g	1560/g	1250/g	1025/g	102/g		abs/g	325/g	660L/g
2B9 a4	3700/g	680/g	402/g	400/g	105/g		abs/g	596/g	1300L/g 220M/g
2B9 cp1	8600/g	920/g	800/g	650/g	100/g		10sp/g	431/g	2400L/g 1060M/g
2B9 cp2	4800/g	1360/g	1025/g	656/g	600/g		abs/g	99/g	860L/g
2B10 a1	5200/g	250/g	250/g	200/g	190/g		abs/g	78/g	260L/g
2B10 a2	7700/g	190/g	166/g	160/g	abs/g		abs/g	781/g	360L/g
2B10 a3	9000/g	440/g	222/g	200/g	100/g		abs/g	880/g	840L/g
2B10 a4	2300/g	2040/g	126/g	abs/g	abs/g		10sp/g	565/g	900L/g 640M/g
2B10 cp1	8400/g	400/g	299/g	200/g	178/g		abs/g	560/g	520L/g
2B10 cp2	2100/g	600/g	200/g	180/g	25/g		abs/g	654/g	640L/g
2B11 a1	3100/g	2040/g	180/g	160/g	100/g		abs/g	321/g	2060L/g 600M/g
2B11 a2	3600/g	520/g	402/g	356/g	16/g		abs/g	250/g	3560L/g 1860M/g
2B11 a3	3200/g	abs/g	Abs/g	abs/g	abs/g		60sp/g	45/g	440L/g
2B11 a4	1700/g	400/g	356/g	300/g	108/g		abs/g	456/g	1040L/g 800M/g
2B11 cp1	6100/g	1260/g	556/g	500/g	352/g		abs/g	68/g	13200L/g 1200M/g
2B11 cp2	800/g	abs/g	Abs/g	abs/g	abs/g		abs/g	160/g	2060L/g 1900M/g
					EAUX				
2B2 ps1	1100/ml	2200/100ml	2200/100ml	6/100ml	abs/100ml	1000/50ml	400sp/20ml	1225/ml	
2B2 pf1	57000/ml	4/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	789/ml	
2B2 ps2	1420/ml	186/100ml	186/100ml	abs/100ml	abs/100ml	10/50ml	abs/20ml	256/ml	
2B2 pf2	56000/ml	3/100ml	3/100ml	abs/100ml	abs/100ml	abs/50ml	>100sp/20ml	585/ml	
2B4 ps1	1340/ml	86/100ml	86/100ml	18/100ml	4/100ml	abs/50ml	abs/20ml	12//ml	
2B4 pf1	960/ml	2200/100ml	2200/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	864/ml	
2B4 ps2	50000/ml	4/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	>100sp/20ml	555/ml	
2B4 pf2	36000/ml	4/100ml	4/100ml	4/100ml	4/100ml	abs/50ml	>100sp/20ml	454/ml	
2B5 ps1	2060/ml	76/100ml	76/100ml	7/100ml	abs/100ml	abs/50ml	abs/20ml	852/ml	
2B5 pf1	37000/ml	7/100ml	7/100ml	abs/100ml,	abs/100ml	abs/50ml	abs/20ml	689/ml	
2B5 ps2	2890/ml	96/100ml	96/100ml	8/100ml	abs/100ml	abs/50ml	abs/20ml	852/ml	
2B5 pf2	65000/ml	9/100ml	4/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	699/ml	
2B8 ps1	300/ml	150/100ml	100/100ml	85/100ml	75/100ml	200/50ml	10sp/20ml	55/ml	
2B8 pf1	1500/ml	7/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	12/ml	
2B8 ps2	2590/ml	18/100ml	5/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	156/ml	
2B8 pf2	3900/ml	186/100ml	80/100ml	80/100ml	8/100ml	2300ml	30sp/20ml	300/ml	
2B9 ps1	2500/ml	0/100ml	Abs/100ml	abs/100ml	abs/100ml	abs/50ml	abs/20ml	120/ml	

Echan tillons	Flore aérobie mésophile totale	Coliformes Totaux	Coliformes Fécaux	E. coli Présumés	E. coli	Strepto CoquesD	Clostridium Sulfitoré Ducteurs	Bacillus	Levures et moisissures
2B9 pf1	1800/ml	46/100ml	25/100ml	25/100ml	8/100ml	2400/50ml	>100sp/20ml	75/ml	
SEDIMENTS									
2B2 s1	30400/g	abs/g	Abs/g	abs/g	abs/g		abs/g	777/g	3800L/g 100M/g
2B2 s2	62000/g	abs/g	Abs/g	abs/g	abs/g		abs/g	789/g	200L/g
2B2 s3	46400/g	270/g	Abs/g	abs/g	abs/g		200sp/g	984/g	1200L/g
2B2 s4	70000/g	1030/g	abs/g	abs/g	abs/g		200sp/g	45/g	1100M/g 200M/g
2B2 s5	26000/g	340/g	130/g	108/g	30/g		abs/g	45/g	6100L/g 200M/g
2B4 s1	40800/g	800/g	640/g	250/g	112/g		abs/g	778/g	2300L/g 100M/g
2B4 s2	50800/g	700/g	590/g	350/g	102/g		abs/g	898/g	2300L/g 100M/g
2B4 s3	19200/g	300/g	70/g	25/g	abs/g		abs/g	431/g	2600L/g
2B4 s4	50400/g	1080/g	abs/g	abs/g	abs/g		abs/g	78/g	2200M/g 100L/g
2B4 s5	78000/g	2200/g	540/g	300/g	28/g		>100sp/g	958/g	2400L/g
2B5 s1	64000/g	abs/g	abs/g	abs/g	abs/g		200sp/g	56/g	800M/g
2B5 s2	15200/g	1200/g	1090/g	900/g	250/g		>100sp/g	284/g	3900L/g 100M/g
2B5 s3	12800/g	410/g	220/g	115/g	112/g		abs/g	698/g	2100L/g 100M/g
2B5 s3	3700/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	636/g	140L/g
2B5 s4	29200/g	abs/g	abs/g	abs/g	abs/g		abs/g	45/g	2000L/g
2B8 s1	3400/g	190/g	98/g	60/g	18/g		20sp/g	458/g	180L/g
2B8 s2	3600/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	510/g	260L/g
2B8 s3	3600/g	50/g	abs/g	abs/g	abs/g		>100sp/g	412/g	460L/g
2B8 s4	7700/g	1960/g	1600/g	560/g	206/g		>100sp/g	156/g	1960L/g 1260M/g
2B8 s5	5400/g	30/g	abs/g	abs/g	abs/g		>100sp/g	75/g	240L/g 300M/g
2B9 s1	940/g	40/g	abs/g	abs/g	abs/g		40sp/g	145/g	600L/g 800M/g
2B9 s2	8600/g	90/g	80/g	75/g	70/g		>100sp/g	458/g	300L/g 140M/g
2B9 s3	9800/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	458/g	1800L/g
2B9 s4	4700/g	320/g	300/g	200/g	65/g		20sp/g	450/g	1740L/g
2B9 s5	5700/g	abs/g	abs/g	abs/g	abs/g		>100sp/g	458/g	720L/g

N.B: selon la nature de l'échantillon, les résultats constituent des Unités formant colonies UFC et sont exprimés en millilitre pour les eaux et en gramme pour les sols. Ps : eau en surface au niveau du transect, pf : eau en profondeur au niveau du transect, a : sol simple, cp : sol composé, s : sédiment

Plankton

Tableau Production primaire dans les marécages et dans la lagune

Transect	Stations	Longitude	Latitude	DOb	DOa	Chla (µg/l)	n (mg/m^3)	Biom. algale (mgC/m^3)	Profondeur de secchi	K' (1/m)	Pj (mgO_2 m^2J^{-1})	Pj ($mgC.m^2.J^{-1}$)
B2	2B2 ps1	6°22' 26,8	2°15' 23,6	0.15	0.07	23.2	23.2	928	1	2.00	7830.0	2351.4
	2B2 pf1	6°22' 26,8	2°15' 23,6	0.12	0.09	8.7	8.7	348	1	2.00	2936.3	881.8
	2B2 ps2	6°22' 26,8	2°15' 39,7	0.13	0.04	26.1	26.1	1044	1.07	1.87	9425.4	2830.4
	2B2 pf2	6°22' 26,8	2°15' 39,7	0.12	0.08	11.6	11.6	464	1.07	1.87	4189.1	1258.0
B4	2B4 ps1	6°21' 10,3	2°15' 9,6	0.04	0.01	8.7	8.7	348	0.3	6.67	880.9	264.5
	2B4 pf1	6°21' 10,3	2°15' 9,6	0.08	0.07	2.9	2.9	116	0.3	6.67	293.6	88.2
	2B4 ps2	6°21' 9,9	2°14' 58,8	0.14	0.12	5.8	5.8	232	0.62	3.23	1213.7	364.5
	2B4 pf2	6°21' 9,9	2°14' 58,8	0.11	0.1	2.9	2.9	116	0.62	3.23	606.8	182.2
B5	2B5 ps1	6°20' 52,3	2°15' 7,5	0.08	0.04	11.6	11.6	464	0.9	2.22	3523.5	1058.1
	2B5 pf1	6°20' 52,3	2°15' 7,5	0.02	0.01	2.9	2.9	116	0.9	2.22	880.9	264.5
	2B5 ps2	6°20' 59,8	2°15' 7,5	0.06	0.025	10.15	10.15	406	1.7	1.18	5823.6	1748.8
	2B5 pf2	6°20' 59,8	2°15' 7,5	0.04	0.02	5.8	5.8	232	1.7	1.18	3327.8	999.3
B8	2B8 ps1	6°23' 45,2	2°16' 26,1	0.25	0.17	23.2	23.2	928	0.6	3.33	4698.0	1410.8
	2B8 pf1	6°23' 45,2	2°16' 26,1	0.17	0.12	14.5	14.5	580	0.6	3.33	2936.3	881.8
	2B8 ps2	6°23' 45,9	2°16' 25,4	0.16	0.1	17.4	17.4	696	0.38	5.26	2231.6	670.1
	2B8 pf2	6°23' 45,9	2°16' 25,4	0.14	0.07	20.3	20.3	812	0.38	5.26	2603.5	781.8
B9	SB9 ps1	6°24' 22,0	2°16' 54,7	0.15	0.11	11.6	11.6	464	0.25	8.00	978.8	293.9
	2B9 pf1	6°24' 22,0	2°16' 54,7	0.18	0.14	11.6	11.6	464	0.25	8.00	978.8	293.9
Moyenne par station												
Station	**B2**	**B4**	**B5**	**B8**	**B9**							
Pj surf.	2590.895	314.49324	1403.4628	1040.5	293.92							
Pj prof.	1069.865	135.2027	631.92568	831.79	293.92							

Formule de Talling: **Pj (mgO2/m²/j) = n.Pmax/k * ln (2Io/Ik) * Dt * 0,9**

En milieu tropical, Pmax = 25 mgO2 /mgChla/heure, K= 2/profondeur de Secchi, ln (2Io/Ik) = 2 - 3 ici on prend 2,5, Dt = 12Heures

Dob : densité optique avant acidification, Doa : densité optique après acidification (HCl 0,1N)

Tableau . Diversité spécifique et abondance relative du phytoplancton des marécages et de la lagune

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
Transect B2					
2B2ps1			*Closterium aciculare*	5	1.3
			Closterium lanceolatum	3	0.8
			Coelosphaerium confertum	1	0.3
			Cyclotella sp	340	89.2
	6°22' 26,8	2°15' 23,6	*Navicula cryptocephala*	3	0.8
			Navicula sp	2	0.5
			Nitzschia sp	3	0.8
			Oscillatoria sp	10	2.6
			Stephanodiscus sp	6	1.6
			Synedra ulna	8	2.1
2B2 pf1			*Closterium aciculare*	3	1.1
			Closterium lanceolatum	2	0.8
			Cyclotella sp	212	81.2
			Diatoma sp	1	0.4
			Microcystis sp	10	3.8
	6°22' 26,8	2°15' 23,6	*Navicula pigmaea*	8	3.1
2B2 pf1			*Navicula sp*	11	4.2
			Nitzschia sigma	1	0.4
			Oscillatoria sp	4	1.5
			Stephanodiscus sp	1	0.4
			Synedra ulna	7	2.7
			Tetraedron sp	1	0.4
2B2 ps2			*Calothrix sp*	1	0.4
			Closterium aciculare	1	0.4
			Closterium lanceolatum	2	0.9
			Closterium sp	6	2.7
			Coelastrum microporum	3	1.3
			Cyclotella sp	137	61.4
			Micrasterias radians	1	0.4
			Microcystis sp	21	9.4
	6°22' 26,8	2°15' 39,7	*Mougeotia floridana*	2	0.9
			Navicula sp	6	2.7
			Nitzschia sp	2	0.9
			Oscillatora boryana	7	3.1
			Oscillatoria sp	4	1.8

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
Transect B2					
2B2 ps2			*Pinnularia cardinalis*	3	1.3
			Pleurotaenium trabecula	11	4.9
			Spirogyra gracilis	2	0.9
			Synedra ulna	7	3.1
			Tetraedron gracile	2	0.9
			Ulothrix zonata	3	1.3
			Volvox aureus	2	0.9
2B2 pf2			*Closterium sp*	4	1.4
			Cocconeis sp	6	2.1
			Coelastrum microporum	1	0.3
			Cyclotella sp	223	76.6
			Cymatopleura solea	1	0.3
			Diatoma sp	1	0.3
			Micrasterias tropica	1	0.3
	6°22' 26,8	2°15' 39,7	*Microcystis sp*	20	6.9
			Navicula sp	9	3.1
			Nitzschia sp	5	1.7
			Oscillatoria boryana	6	2.1
			Oscillatoria sp	4	1.4
			Pleurotaenium trabecula	3	1.0
			Sphaerocystis schroeleri	1	0.3
			Surirella capronii	1	0.3
			Synedra ulna	5	1.7
Transect B4					
2B4ps1			*Closterium aciculare*	1	0.3
			Cyclotella sp	234	79.1
			Melosira sp	1	0.3
			Microcystis sp	13	4.4
	6°21' 10,3	2°15' 9,6	*Navicula cryptocephala*	8	2.7
			Navicula sp	3	1.0
			Nitzschia acicularis	8	2.7
			Oscillatoria sp	4	1.4
			Pleurotaenia trabecula	1	0.3
			Stephanodiscus sp	23	7.8
2B4pf1			*Closterium aciculare*	2	0.8
			Cyclotella sp	216	84.7
			Cymatopleura solea	4	1.6

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
			Melosira sp	2	0.8
			Navicula cryptocephala	2	0.8
	6°21' 10,3	2°15' 9,6	*Navicula sp*	1	0.4
			Nitzschia acicularis	13	5.1
			Nostoc entophytum	3	1.2
			Oscillatoria sp	4	1.6
2B4pf1			*Pleurotaenia trabecula*	2	0.8
			Synedra ulna	4	1.6
			Tabellaria sp	2	0.8
2B4ps2			*Amphora ovalis*	13	3.2
			Anabaena flos-aquae	4	1.0
			Botryococcus braunii	3	0.7
			Closterium aciculare	3	0.7
			Closterium navicula	6	1.5
			Cocconeis placentula	17	4.1
			Coelastrum microporum	2	0.5
			Cyclotella sp	95	23.1
			Cymbella sp	8	1.9
			Melosira sp	4	1.0
	6°21' 9,9	2°14' 58,8	*Microcystis sp*	54	13.1
			Navicula cryptocephala	25	6.1
			Navicula sp	12	2.9
			Nitzschia sigma	33	8.0
			Nitzschia sp	46	11.2
			Nostoc entophytum	20	4.9
			Oscillatoria sp	18	4.4
			Spharoeca volvox	1	0.2
			Spirulina sp	1	0.2
			Synechococcus aeruginosus	6	1.5
			Synechocystis aquatilis	8	1.9
			Synedra ulna	27	6.6
			Tabellaria sp	6	1.5
2B4pf2			*Amphora ovalis*	2	0.6
			Cocconeis placentula	10	3.2
			Cyclotella sp	27	8.7
			Cymatopleura solea	3	1.0
			Diatoma sp	15	4.8
			Microcystis delicatissima	57	18.4
			Microcystis sp	82	26.5

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
2B4ps2			*Navicula cryptocephala*	14	4.5
	6°21' 9,9	2°14' 58,8	*Navicula pigmaea*	13	4.2
			Navicula sp	8	2.6
			Nitzschia sigma	16	5.2
			Nitzschia sp	23	7.4
			Oscillatoria sp	5	1.6
			Phacus orbicularis	3	1.0
			Raphidiopsis curvata	7	2.3
			Spirulina sp	3	1.0
			Surirella capronii	1	0.3
			Synechococcus aeruginosus	9	2.9
			Synechocystis aquatilis	12	3.9
Transect B5					
2B5ps1	6°20' 52,3	2°15' '7,5	*Closterium aciculare*	4	1.0
			Coelosphaerium confertum	3	0.8
			Cyclotella sp	269	68.6
			Gomphosphaeria aponina	2	0.5
			Microcystis delicatissima	12	3.1
			Microcystis sp	20	5.1
			Navicula cryptocephala	4	1.0
			Nitzschia sigma	9	2.3
			Oscillatoria boryana	1	0.3
			Oscillatoria sp	6	1.5
			Pleurotaenia trabecula	4	1.0
			Synechocystis aquatilis	58	14.8
2B5pf1	6°20' 52,3	2°15' '7,5	*Cyclotella sp*	30	32.3
			Coelosphaerium confertum	9	9.7
			Diatoma sp	6	6.5
			Microcystis delicatissima	14	15.1
			Microcystis sp	24	25.8
2B5pf1			*Mougeotia floridana*	1	1.1
			Oscillatoria boryana	1	1.1
			Oscillatoria sp	5	5.4
			Stephanodiscus sp	3	3.2

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
2B5ps2	6°20' 59,8	2°15' 8,4	*Cyclotella sp*	79	37.6
			Anabaena sphaerica	7	3.3
			Diatoma sp	3	1.4
			Microcystis delicatissima	9	4.3
			Microcystis sp	18	8.6
			Mougeotia floridana	2	1.0
			Navicula cryptocephala	4	1.9
			Nitzschia sigma	6	2.9
			Oscillatoria boryana	3	1.4
			Oscillatoria sp	77	36.7
			Surirella capronii	2	1.0
2B5pf2	6°20' 59,8	2°15' 8,4	*Cyclotella sp*	69	43.7
			Gomphospherium aponina	6	3.8
			Cymatopleura solea	3	1.9
2B5pf2			*Tetraedron sp*	2	1.3
			Microcystis sp	12	7.6
			Scenedesmus quadricauda	6	3.8
			Oscillatoria sp	39	24.7
			Surirella capronii	1	0.6
			Oscillatoria boryana	2	1.3
			Microcystis delicatissima	17	10.8
			Stephanodiscus sp	1	0.6
Transect B8					
2B8 ps1			*Navicula cuspidata*	30	5.3
			Spirulina sp	396	69.4
			Oscillatoria sp	5	0.9
			Closterium aciculare	11	1.9
			Gonatozygon monotaenium	1	0.2
			Closterium sp	3	0.5
			Navicula sp	7	1.2
			Cyclotella sp	5	0.9
	6°23' 45,2	2°16' 26,1	*Closterium parvulum*	2	0.4
			Pinnularia cardinalis	11	1.9
			Nitzschia sp	5	0.9
			Closterium lanceolatum	1	0.2

Stations	Longitud e	Latitude	Espèces	Nbre/ml	Abondance (%)
			Oscillatoria boryana	49	8.6
			Spirogyra sp (2 à 3plastes)	13	2.3
			Stauroneis phoenicenteron	15	2.6
			Cymatopleura solea	6	1.1
			Microcystis sp	7	1.2
			Pleurotaenia sp	1	0.2
			Coelasterium microporum	2	0.4
2B8 ps1			*Micrasterias truncata*	1	0.2
2B8 pf1			*Oxillatoria sp*	3	2.3
			Closterium aciculare	4	3.0
			Cymatopleura solea	1	0.8
			Oxillatoria boryana	13	9.8
			Spirulina sp	54	40.6
			Navicula sp	3	2.3
	6°23' 45,2	2°16' 26,1	*Pinnularia cardinalis*	10	7.5
			Cyclotella sp	4	3.0
			Navicula cuspidata	16	12.0
			Microcystis sp	3	2.3
			Stauroneis phoenicenteron	6	4.5
			Spirogyra sp (2à3plastes)	2	1.5
			Navicula cryptocephala	14	10.5
2B8 ps2			*Spirogyra sp (2à3plastes)*	213	55.3
			Closterium aciculare	31	8.1
			Oxillatoria sp	4	1.0
			Oxillatoria boryana	3	0.8
			Pinnularia cardinalis	1	0.3
2B8 ps2			*Spirulina sp*	5	1.3
			Closterium lanceolatum	32	8.3
	6°23' 45,9	2°16' 25,4	*Navicula cryptocephala*	3	0.8
			Coelasterium microporum	2	0.5
			Microcystis sp	4	1.0
			Gonatozygon monotaenium	38	9.9

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
			Micrasterias radians	8	2.1
			Microcystis elachista	13	3.4
			Pledorina sphaerica	3	0.8
			Microcystis delicatissima	17	4.4
			Anabaena sp	8	2.1
2B8 pf2			*Closterium aciculare*	18	9.5
			Closterium lanceolatum	57	30.2
			Navicula sp	8	4.2
			Pinnularia cardinalis	5	2.6
	6°23' 45,9	2°16' 25,4	*Microcystis sp*	6	3.2
			Cyclotella sp	5	2.6
			Oxilallatoria boryana	3	1.6
			Spirogyra sp (2à3plastes)	32	16.9
2B8 pf2			*Oxillatoria sp*	45	23.8
			Gonatozygon monotaenium	10	5.3
Transect B9					
2B9 ps1			*Closterium aciculare*	12	16.9
			Oscillatoria boryana	16	22.5
			Gonatozygon monotaenium	5	7.0
			Navicula cryptocephala	7	9.9
	6°24' 22,0	2°16' 54,7	*Pleurotaenium trabecula*	6	8.5
			Oscillatoria sp	13	18.3
			Microcystis sp	4	5.6
			Spirogyra sp (2à3plastes)	1	1.4
			Navicula sp	5	7.0
			Mougeotia floridana	2	2.8
2B9 pf1			*Navicula cryptocephala*	19	13.3
			Closterium aciculare	60	42.0
			Navicula sp	12	8.4
			Oscillatoria boryana	12	8.4
2B9 pf1	6°24' 22,0	2°16' 54,7	*Pinnularia cardinalis*	3	2.1
			Stauroneis phoenicenteron	10	7.0
			Cyclotella sp	3	2.1

Stations	Longitude	Latitude	Espèces	Nbre/ml	Abondance (%)
			Nitzschia sp	6	4.2
			Closterium sp	14	9.8
			Closterium lanceolatum	2	1.4
			Ulothrix zonata	2	1.4

Tableau. Diversité spécifique et abondance relative du zooplancton des marécages et de la lagune

			Rotifères			Cladocères			Copépodes			Ostracodes		
Stations	Longitude	Latitude	Espèces	N/ml	A (%)	Espèces	N/ml	A (%)	Espèces	N/ml	A (%)	Espèces	N/ml	A (%)
2B2 ps1			*Lecane leontina*	2.7	22.2	*Daphnia sp*	2.0	23.1	*Cyclops sp*	2.0	37.5	Ostracodes	15.0	100.0
			Lecane monostyla	2.0	16.7	*Simocephalus sp*	0.3	3.8	Nauplii	3.3	62.5			
			Polyarthra vulgaris	5.0	41.7	*Ceriodaphnia sp*	3.7	42.3						
	6°22' 26,8	2°15' 23,6	*Hexarthra sp*	0.3	2.8	*Macrothrix sp*	2.0	23.1						
			Mytilina sp	0.7	5.6	*Moina brachiata*	0.7	7.7						
			Epiphanes brachionus	0.3	2.8									
			Keratella quadrata	0.7	5.6									
			Anuraepsis fissa	0.3	2.8									
2B2 pf1			*Polyarthra vulgaris*	4.7	35.0	*Diaphanosoma brachyurum*	0.7	100.0	*Cyclops sp*	1.7	27.8	Ostracodes	22.0	100.0
			Lecane monostyla	4.0	30.0				Nauplii	4.3	72.2			
			Trichocera capucina	1.3	10.0									
	6°22' 26,8	2°15' 23,6	*Keratella quadrata*	1.0	7.5									
			Lecane leontina	1.7	12.5									
			Trichocera chattoni	0.3	2.5									
			Chomogaster sp	0.3	2.5									
2B2 ps2			*Mytilina sp*	5.7	15.5	*Bosmina sp*	3.3	25.0	*Cyclops sp*	3.0	18.4	Ostracodes	12.7	100.0
			Lecane leontina	3.0	8.2	*Daphnia sp*	1.7	12.5	Nauplii	13.3	81.6			
			Polyarthra vulgaris	3.3	9.1	*Ceriodaphnia sp*	2.3	17.5						
			Euchlanis sp	0.3	0.9	*Macrothrix sp*	3.7	27.5						
			Brachionus patulus	0.3	0.9	*Moina sp*	0.3	2.5						
	6°22' 26,8	2°15' 39,7	*Keratella quadrata*	0.3	0.9	*Simocephalus sp*	0.3	2.5						
			Dicranophorus prionacis	5.0	13.6	*Moina brachiata*	1.0	7.5						
			Lecane monostyla	17.3	47.3	*Chydorus sp*	0.3	2.5						
			Trichocera capucina	0.3	0.9	*Leptodora kindtii*	0.3	2.5						
			Keratella tropica	0.3	0.9									
			Synchaeta longipes	0.3	0.9									
			Brachionus quadridentatus	0.3	0.9									
2B2 pf2			*Lecane leontina*	2.3	10.8	*Diaphanosoma brachyurum*	1.3	25.0	*Cyclops sp*	3.0	30.0	Ostracodes	17.3	100.0
			Lecane monostyla	5.0	23.1	*Ceriodaphnia sp*	2.0	37.5	Nauplii	7.0	70.0			
			Mytilina sp	2.3	10.8	*Bosmina sp*	1.0	18.8						

			Rotifères			Cladocères			Copépodes			Ostracodes		
Stations	Longitude	Latitude	Espèces	N/ml	A (%)	Espèces	N/ml	A (%)	Espèces	N/ml	A (%)	Espèces	N/ml	A (%)
			Monommata naculata	1.0	4.6	*Moina sp*	0.3	6.3						
			Conochilus sp	0.7	3.1	*Simocephalus sp*	0.3	6.3						
2B2 pf2	6°22' 26,8	2°15' 39,7	*Trichocera capucina*	0.7	3.1	*Latona sp*	0.3	6.3						
			Polyarthra vulgaris	3.0	13.8									
			Dicranophorus prionacis	5.0	23.1									
			Keratella falcatus	0.7	3.1									
			Ascomorpha sp	0.3	1.5									
			Brachionus quadridentatus	0.3	1.5									
			Trichocera pusilla	0.3	1.5									
2B4 ps1			*Keratella quadrata*	0.3	100.0	*Daphnia sp*	3.0	81.8	*Cyclops sp*	0.3	0.6			
	6°21' 10,3	2°15' 9,6				*Bosmina sp*	0.3	9.1	Nauplii	59.0	99.4			
						Chydorus sp	0.3	9.1						
2B4 pf1	6°21' 10,3	2°15' 9,6	*Trichocera capucina*	0.3	100.0	*Daphnia sp*	2.3	70.0	*Cyclops sp*	4.3	20.0			
						Latona sp	1.0	30.0	Nauplii	17.3	80.0			
2B4 ps2			*Monommata sp*	0.3	50.0	*Sida sp*	0.3	100.0	*Cyclops sp*	2.3	5.9			
	6°21' 9,9	2°14' 58,8	*Euchlanis sp*	0.3	50.0				Calanoïde	0.7	1.7			
									Nauplii	36.3	92.4			
2B4 pf2						*Simocephalus sp*	0.3	100.0	*Cyclops sp*	3.3	15.9			
	6°21' 9,9	2°14' 58,8							*Canthocamptus sp*	0.3	1.6			
									Nauplii	17.3	82.5			
2B5 ps1	6°20' 52,3	2°15' 7,5							Nauplii	0.7	100.0			
2B5 pf1	6°20' 52,3	2°15' 7,5							Nauplii	4.0	100.0			
2B5 ps2	6°20' 59,8	2°15' 7,5	*Filina sp*	0.3	100.0				Nauplii	8.3	100.0			
2B5 pf2	6°20' 59,8	2°15' 7,5	*Keratella quadrata*	1.0	25.0	*Latona sp*	0.7	66.7	*Cyclops sp*	0.7	11.1			
			Synchaeta longipes	3.0	75.0	*Sida sp*	0.3	33.3	Nauplii	5.3	88.9			
2B8 ps1			*Brachionus falcatus*	0.3	2.9	*Bosmina sp*	1.3	14.3	*Cyclops sp*	6.3	24.7	Ostracodes	16.0	100.0
			Dicranophorus prionacis	6.0	51.4	*Eurycenus sp*	2.3	25.0	Nauplii	15.0	58.4			
			Platyias sp	0.3	2.9	*Ceriodaphnia*	1.0	10.7	Calanoides	4.3	16.9			
			Ascomorpha sp	0.7	5.7	*Sida sp*	0.3	3.6						
	6°23' 45,2	2°16' 26,1	*Mytilina sp*	0.3	2.9	*Alona costata*	4.3	46.4						
			Lecane monostyla	2.3	20.0									
			lecane leontina	0.7	5.7									
			Brachionus patulus	1.0	8.6									
2B8 pf1			*Dicranophorus prionacis*	3.0	45.0	*Alona costata*	11.0	62.3	*Cyclops sp*	4.7	34.1	Ostracodes	5.7	100.0
			lecane leontina	1.7	25.0	*Ceriodaphnia*	0.7	3.8	Nauplii	7.3	53.7			
	6°23' 45,2	2°16' 26,1	*Lecane monostyla*	2.0	30.0	*Sida sp*	0.3	1.9	Calanoide	1.7	12.2			
						Eurycenus sp	5.3	30.2						
						Bosmina sp	0.3	1.9						
2B8 ps2			*Lecane leontina*	1.7	41.7	*Daphnia sp*	0.3	2.4	*Cyclops sp*	3.0	18.4	Ostracodes	5.0	100.0
			Lecane monostyla	1.7	41.7	*Ceriodaphnia sp*	0.7	4.9	Nauplii	4.3	26.5			

			Rotifères			Cladocères			Copépodes			Ostracodes		
Stations	**Longitude**	**Latitude**	**Espèces**	**N/ml**	**A (%)**	**Espèces**	**N/ml**	**A (%)**	**Espèces**	**N/ml**	**A (%)**	**Espèces**	**N/ml**	**A (%)**
			Brachionus patulus	0.3	8.3	*Sida sp*	0.7	4.9	Calanoide	9.0	55.1			
	6°23' 45,9	2°16' 25,4	*Dicranophorus prionacis*	0.3	8.3	*Bosmina sp*	0.7	4.9						
						Latona setifera	0.3	2.4						
						Alona costata	3.3	24.4						
						Eurycenus sp	7.7	56.1						
2B8 pf2			*Lecane monostyla*	0.7	50.0	*Macrothrix laticornis*	0.3	2.9	*Cyclops sp*	0.3	25.0	Ostracodes	3.7	100.0
			Dicranophorus prionacis	0.7	50.0	*Macrothrix rosea*	0.3	2.9	Nauplii	0.7	50.0			
2B8 pf2	6°23' 45,9	2°16' 25,4				*Eurycenus sp*	5.7	48.6	Calanoide	0.3	25.0			
						Ceriodaphnia	1.0	8.6						
						Alona costata	4.3	37.1						
SB9 ps1			*lecane leontina*	1.7	41.7	*Ceriodaphnia*	19.7	25.7	*Cyclops sp*	3.0	30.0	Ostracodes	14.0	100.0
			Lecane monostyla	2.0	50.0	*Bosmina sp*	8.3	10.9	Nauplii	6.3	63.3			
			Brachionus patulus	0.3	8.3	*Eurycenus sp*	4.7	6.1	Calanoide	0.7	6.7			
						Macrothrix sp	6.0	7.8						
	6°24' 22,0	2°16' 54,7				*Simocephalus sp*	11.3	14.8						
						Daphnia sp	3.3	4.3						
						Chydorus sp	10.3	13.5						
						Sida sp	3.7	4.8						
						Polyphemus sp	4.7	6.1						
						Moina sp	4.7	6.1						
2B9 pf1			*Dicranophorus prionacis*	0.3	16.7	*Ceriodaphnia*	13.0	28.3	Nauplii	1.7	100.0	Ostracodes	11.3	100.0
			Lecane monostyla	0.7	33.3	*Macrothrix sp*	3.3	7.2						
			lecane leontina	1.0	50.0	*Chydorus sp*	7.3	15.9						
	6°24' 22,0	2°16' 54,7				*Bosmina sp*	4.7	10.1						
						Sida sp	2.3	5.1						
						Moina sp	2.7	5.8						
						Polyphemus sp	2.0	4.3						
						Simocephalus sp	10.7	23.2						

Ghana
West African Gas Pipeline
Environmental Baseline Survey
Second Season

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

Prepared by:

Environmental Solutions (ESL), LTD
Accra, Ghana

Authors

Ayaa Kojo Armah (M.Sc)	Offshore Macrobenthic infauna, Offshore Fisheries and Water Quality.
George Asare Darpaah (M.Sc	Onshore Aquatic Productivity and Fisheries
George Wiafe (Ph.D)	Offshore Productivity
James Kojo Adomako (M.Sc)	Onshore/Terrestrial Ecology

Contributors

Joseph Ampofo (Ph.D)	Microbiology
Kwame Abu Koranteng (Ph.D)	Offshore Fisheries
Osmund Ansa-Asare (Ph.D)	Environmental Chemistry
Daniel Korley Attuquayefio (Ph.D)	Wildlife Management
Daniel Kpakpo Allotey (Ph.D)	Soil Physics/Chemistry
Kwaku Amoako Atta de-Graft Johnson (M.Sc)	Limnology
Millicent Asaaba Cobblah (M.Sc)	Soil Ecology
Samuel Addo (M.Sc)	Onshore Fisheries
Selorm Djako Ababio (M.Sc)	Water Chemistry & Ecology
Emmanuel Lamptey (M.Sc)	Benthic Ecology (Offshore)
Eunice Tetteh (BSc)	Environmental Chemistry

Table of Contents

Page

Chapter 1 Introduction and Background **1-1**

1.1 Geological Setting **1-1**

1.2 Meteorology **1-2**

1.3 Physical and Chemical Oceanography **1-3**

1.3.1 Currents and Tidal Patterns 1-3

1.3.2 Marine Traffic Patterns 1-4

1.3.3 Existing Pollution 1-4

1.4 Biological Setting **1-4**

1.4.1 Habitats 1-4

Chapter 2 Onshore Field Methods **2-1**

2.1 Vegetation Sampling **2-1**

2.1.1 Floristic Composition 2-1

2.1.2 Species Abundance and Diversity 2-1

2.2 Soil Sampling **2-1**

2.2.1 Soil Macrofauna and Ecology 2-2

2.3 Surface Water and Sediment Quality and Hydrobiology **2-2**

2.3.1 Zooplankton 2-2

2.3.2 Phytoplankton 2-3

2.3.3 Macroalgae 2-3

2.4 Soil and Groundwater at the Compressor Station (N/A) **2-4**

2.5 In-situ Method **2-4**

2.6 Wildlife and Animal Resources **2-6**

2.6.1 Herpetofaunal Survey 2-6

2.6.2 Sea Turtle Survey 2-7

2.7 Fish and Fisheries Resources **2-7**

2.8 Sample Tracking, Storage, and Shipping **2-7**

Chapter 3 Analytical Methods **3-1**

3.1 Physical Laboratory Methods **3-1**

3.1.1 Grain Size/particle Size Distribution 3-1

3.2 Chemical Laboratory Methods **3-1**

3.2.1 pH 3-1

3.2.2 Alkalinity 3-2

3.2.3 Biochemical Oxygen Demand (BOD_5) 3-2

3.2.4 Electrical Conductivity 3-2

3.2.5 Nitrogen forms (Nitrate, Nitrite, Ammonia Nitrogen, Total Nitrogen) 3-2

3.2.6 Phosphorus forms (phosphate, orthophosphate, reactive phosphorus, total phosphorus) 3-3

3.2.7 Solids (Total Suspended Solids (TSS), Total Dissolved Solids(TDS)) 3-4

Table of Contents

Page

3.2.8 Sulfate 3-4
3.2.9 Total Petroleum Hydrocarbons (TPH)..3-4
3.2.10 Total Organic Carbon (TOC)...3-4
3.2.11 Turbidity 3-4
3.3 Biological Laboratory Methods 3-5
3.3.1 Plankton 3-5
3.3.2 Phytoplankton Productivity 3-5
3.3.3 Quantitative Estimation of Bacterial Flora 3-6
3.3.4 Quantitative Estimation of Fungal Flora..3-7
3.3.5 Macrobenthic infauna 3-7
Chapter 4 Onshore Results..4-1
4.1 Vegetation 4-1
4.1.1 Tema 4-1
4.1.2 Aboadze/Takoradi...4-3
4.2 Soil Characterization...4-4
4.2.1 Physical..4-4
4.2.2 Chemical 4-7
4.2.3 Biological...4-11
4.3 Surface Water and Sediment Characteristics 4-19
4.3.1 Surface Water...4-19
4.3.2 Sediment 4-29
4.4 Wildlife, Animal Resources and Turtle Survey 4-47
4.4.1 Wildlife and Animal Resources (Tema) 4-48
4.4.2 Wildlife and Animal Resources (Aboadze/Takoradi)..........................4-49
4.4.3 Sea Turtle Survey (Tema New Town and Kpone Beaches) 4-51
4.5 Fish and Fisheries Resources 4-55
4.5.1 Tema 4-55
4.5.2 Aboadze/Takoradi..4-57
4.6 Climate and Meteorology 4-61
4.6.1 Tema 4-61
4.6.2 Aboadze/Takoradi..4-61
Chapter 5 References 5-1
Chapter 6 Appendix D...6-1
Chapter 7 Appendix E...7-1

Table of Contents

Page

List of Figures

Figure 1.1-1 Marine Environment of Ghana Showing Configuration of the Coastline and Bathymetry (Source: Armah and Amlalo, 1998) 1-2

Figure 4.1-1 Life form Analysis of the Coastal strand Vegetation at Tema 4-1

Figure 4.1-2 Life form Analysis of the Coastal Scrub and Grassland Vegetation of Tema .. 4-2

Figure 4.1-3 Life form Analysis of the Coastal strand Vegetation at Aboadze/Takoradi 4-3

Figure 4.1-4 Life form Analysis of the Coastal scrub and Grassland Vegetation of Aboadze/Takoradi 4-3

Figure 4.2-1 Soil Temperature at Tema Onshore Location (Transect A and B) 4-5

Figure 4.2-2 Soil Redox Potential at Tema Onshore Location (Transect A and B) 4-6

Figure 4.2-3 Soil Temperature at Aboadze/Takoradi Onshore Location (Transect C and D). 4-6

Figure 4.2-4 Soil Redox Potential at Aboadze/Takoradi Onshore Location (Transect C and D) 4-7

Figure 4.2-5 Soil pH at Tema Onshore Location (Transect A and B) 4-8

Figure 4.2-6 Soil Total Organic Carbon (TOC) Content at Tema Onshore Location (Transect A and B) 4-9

Figure 4.2-7 Soil pH at Aboadze/Takoradi Onshore Location (Transect C and D) 4-10

Figure 4.2-8 Soil Total Organic Carbon (TOC) Content at Aboadze/Takoradi Onshore Location (Transect C and D) 4-10

Figure 4.3-1 Air and Water Temperature, Electrical Conductivity and Turbidity Distribution in Surface Water at Tema 4-19

Figure 4.3-2 Air and Water Temperature, Turbidity and Conductivity Distribution in Surface Water at Aboadze/Takoradi 4-20

Figure 4.3-3 pH, Salinity, DO, TSS and TDS Distribution in Surface Water at Tema 4-22

Figure 4.3-4 Levels of Nutrients in Surface Water at Tema 4-22

Figure 4.3-5 Levels of BOD in Surface Water at Tema 4-23

Table of Contents

Page

Figure 4.3-6 pH, Salinity, DO, TSS and TDS Distribution in Surface Water at Aboadze/Takoradi 4-24

Figure 4.3-7 Levels of Nutrient in Surface Water at Aboadzi/Takoradi 4-25

Figure 4.3-8 Levels of BOD in Surface Water at Aboadze/Takoradi 4-25

Figure 4.3-9 Sediment Grain Size Distribution at Tema 4-30

Figure 4.3-10 Sediment Grain Size Distribution at Aboadze/Takoradi 4-31

Figure 4.3-11 pH and Temperature Distribution in Sediment at Tema 4-31

Figure 4.3-12 Redox Potential Distribution in Sediment at Tema 4-32

Figure 4.3-13 Total Organic Carbon Distribution in Sediment at Tema 4-32

Figure 4.3-14 Total Petroleum Hydrocarbon (TPH) Distribution in Sediment at Tema 4-33

Figure 4.3-15 pH and Temperature Distribution in Sediment at Aboadze/Takoradi 4-34

Figure 4.3-16 Redox Potential of Sediments at Aboadze/Takoradi 4-35

Figure 4.3-17 Total Organic Carbon Distribution in Sediment at Aboadze/Takoradi 4-35

Figure 4.3-18 Total Petroleum Hydrocarbon (TPH) Distribution of Sediment at Aboadze/Takoradi 4-36

Figure 4.3-19 Distribution and Abundance of Major Macrobenthic Fauna at Intertidal zones of Tema 4-38

Figure 4.3-20 Distribution and Abundance of Major Macrobenthic Fauna at Aboadze/ Takoradi Intertidal Zone 4-39

Figure 4.3-21 Macroalgal Distribution in the Tema Intertidal Zone 4-40

Figure 4.3-22 Macroalgal Distribution in the Aboadze/Takoradi Intertidal Zone 4-41

Figure 4.3-23 Species Diversity of Major Phytoplankton Groups in the Gao Lagoon and the Intertidal Zone 4-42

Figure 4.3-24 Species Diversity of Major Phytoplankton Groups in the Aboadze/Takoradi Wetlands and the Intertidal Zone 4-44

Figure 4.3-25 Species Diversity of Major Zooplanktonps in the Aboadze/Takoradi Wetlands and the Intertidal Zone 4-46

Figure 4.3-26 Species Composition of Major Macrofauna associated with the Plankton Community in the Aboadze/Takoradi Wetlands 4-47

Table of Contents

Page

Figure 4.4-1 Perceived Nesting Frequency of Marine Turtles in the Tema/Kpone Area 4-52

Figure 4.4-2 Awareness of Changing Patterns of Turtle Nesting in the Tema/Kpone Area .. 4-53

Figure 4.4-3 Agents of Turtle Eggs Destruction in the Tema/Kpone Area 4-53

Figure 4.4-4 Perceptions on Enforcement Agencies of Marine Turtle Laws 4-54

Figure 4.5-1 Percent Composition of Cast net Catch from Gao Lagoon (June 2003)......... 4-55

Figure 4.5-2 Size Structure of S. *melanopteron* from Cast Net Fishing in the Gao Lagoon4-56

Figure 4.5-3 Length Weight Relationship of S. *melanopteron* from Cast Net Fishing in the Gao Lagoon.. 4-56

Figure 4.5-4 Percent Composition of Cast Net Catch from the Swamp (Aboadze/Takoradi) 4-57

Figure 4.5-5 Percent Composition of Cast Net Catch from the Anankwari Lagoon (Aboadze/Takoradi) 4-58

Figure 4.5-6 Percent Composition of Cast net Catch of Inshore Fisheries.......................... 4-58

Figure 4.5-7 Length - weight Relationship of *Ilisha africana* of the Inshore Fisheries 4-59

Figure 4.5-8 Length – weight Relationship of *Mugil cephalus* from the Anankwari Lagoon. 4-59

Figure 4.5-9 Length – weight Relationship of S. *melanoptera* from the Aboadze Swamp. 4-60

Figure 4.6-1 Mean Monthly Rainfall Distribution at Tema (1999 – 2001) 4-61

Figure 4.6-2 Mean Monthly Rainfall Distribution at Takoradi (1999 – 2001).................... 4-62

List of Tables

Table 2.5-1 Equipment Type used in Onshore In-situ Measurements.................................. 2-5

Table 2.8-1 EBS Sampling Tracking Record 2-8

Table 4.2-1 Levels of isolated Microbes in the Bulk Soil Samples at Tema A and B transects 4-14

Table 4.2-2 The levels of Microbes as Identified in the Soil samples at Aboadze/Takoradi .. 4-18

Table of Contents

Page

Table 4.3-1 Levels of isolated Microbes in the Water samples during Low and High tide 4-27

Table 4.3-2 Values of the various Microbes recorded in Water samples at Aboazde/Takoradi 4-28

Table 4.3-3 Abundance and Distribution of Macrobenthic Fauna in the Gao Lagoon of Tema 4-37

Table 4.3-4 Dissolved Oxygen measurements in Dark and Light Bottles in the Gao Lagoon 4-42

Table 4.3-5 Gross Photosynthesis, Net Photosynthesis, Respiration and Relative Productivity in the Gao Lagoon........ 4-43

Table 4.3-6 Dissolved Oxygen Measurements in the Aboadze/Takoradi Wetlands 4-44

Table 4.3-7 Gross photosynthesis, Net photosynthesis, Respiration and Relative Productivity in the Aboadze / Takoradi Wetlands........ 4-45

Table 4.4-1 Check-list of Species Recorded at Tema........ 4-48

Table 4.4-2 Check-list of Species Recorded at Aboadze/Takoradi 4-50

Table 4.4-3 Summary Results of Questionnaire Administered during Marine Turtle Survey at Tema/Kpone Area........ 4-51

Table D-1 Possible Fauana Associated with the Vegetation to R&M Sites........ 6-1

Table D-2 Species of Fish and Shellfish Expected from Onshore Water Bodies and the Nearshore Fishery 6-8

Table D-3 ESL and ICF WAGP Onshore 2nd Season EBS Fieldwork Plan........ 6-12

Table D-4 Summary of Laboratory Responsibilities........ 6-13

Table D-5a Onshore Scientific Field Team 6-14

Table D-5b Onshore Field Parameter Outline and Activity 6-16

Table D-5c Onhsore Fieldwork Plan and Daily Activities 6-18

Table D-6 Floristic Composition of the Coastal Strand Vegetation of the WAGP Route at Tema 6-21

Table D-7 Floristic Composition of the Coastal Scrub and Grassland Vegetation of the WAGP Route at Tema 6-22

Table D-8 Floristic Composition of the Coastal Strand Vegetation of the WAGP Route at Aboadze/Takoradi........ 6-23

Table of Contents

Page

Table D-9 Floristic Composition of the Coastal Scrub and Grassland Vegetation of the WAGP Route at Aboadze/Takoradi 6-25

Table D-10 Strand and Scrub Vegetation of Aboadze/Takoradi Swamp 6-27

Table D-11 Soil Parameters (Physiacal and Chemical 6-27

Table D-12 List of Butterfly Species Recorded at Tema 6-28

Table D-13 Butterfly Diversity at Aboadze/Takoradi 6-32

Table D-14 Onshore Water Parameters 6-36

Table D-15 Relative Abundance of Common Intertidal Macrobenthic Fauna at Tema 6-38

Table D-16a Macroalgal Species Observed at Tema 6-40

Table D-16b Macroalgal Species at Aboadze/Takoradi 6-41

Table D-17 Phytoplankton Community Structure at Tema 6-43

Table D-17b Zooplankton Community Structure at Tema 6-45

Table D-18 Water Parameters, Physical and Chemical 6-47

Table D-19 Macroalgal Species at Aboadze/Takoradi 6-49

Table D-20a Phytoplankton Community Structure at Aboadze/Takoradi Wetlands and Intertidal Zone 6-50

Table D-20b Zooplankton Community at Aboadze/Takoradi 6-52

Table D-20c Macroinvertebrate (Macrophyte Asscociated) Community Structure at Aboadze/Takoradi 6-53

Table D-21a Relative Abundance of Common Intertidal Macrobenthic Fauna at Aboadze/Takoradi 6-55

Table D-22 Fisheries of the Gao Lagoon 6-57

Table D-23 Fisheries of the Aboadze/Takoradi Swamps 6-57

CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 GEOLOGICAL SETTING

The coastal geological formations of Ghana were likely determined by continental drift during the Cretaceous period (about 135 million years ago), when Africa broke away from South America (Allersma and Tilmans, 1993). The geological composition consists of hard granites, granodiorites, metamorphosed lava, and pyroclastic rock. Some coastal areas are covered by Ordovician, Silurian, and Devonian sand stone and shales (Allersma and Tilmans, 1993).

Seismic studies have indicated that Ghana's seismicity is associated with active faulting, particularly near the intersection of the east-west trending Coastal Boundary Fault and the north-east to south-east Akwapim Fault Zone (Tsidzi *et al*., 1995). It has been reported that the first major seismic activity in Ghana occurred in Elmina (Central Region) in 1615 (Armah and Amlalo, 1998). Thereafter, subsequent events took place in 1636, 1862, 1906, 1939, and 1997. In 1997 alone, three events were recorded in January, February, and March with magnitudes (on the Richter scale) of 3.8, 4.1, and 4.8 respectively.

The continental shelf varies in width from a minimum of about 20km off Cape St. Paul to about 90km at the widest portion between Takoradi and Cape Coast. Submarine canyons exist off the Volta Delta (Edwards *et al*., 1997). The entire shelf is traversed by a belt of dead madreporarian coral beginning at 75m. Beyond this coral belt, the bottom falls sharply marking the transition from the continental shelf to the slope. Soft sediments predominate along the coastline up to the coral belt (Figure 1.1-1).

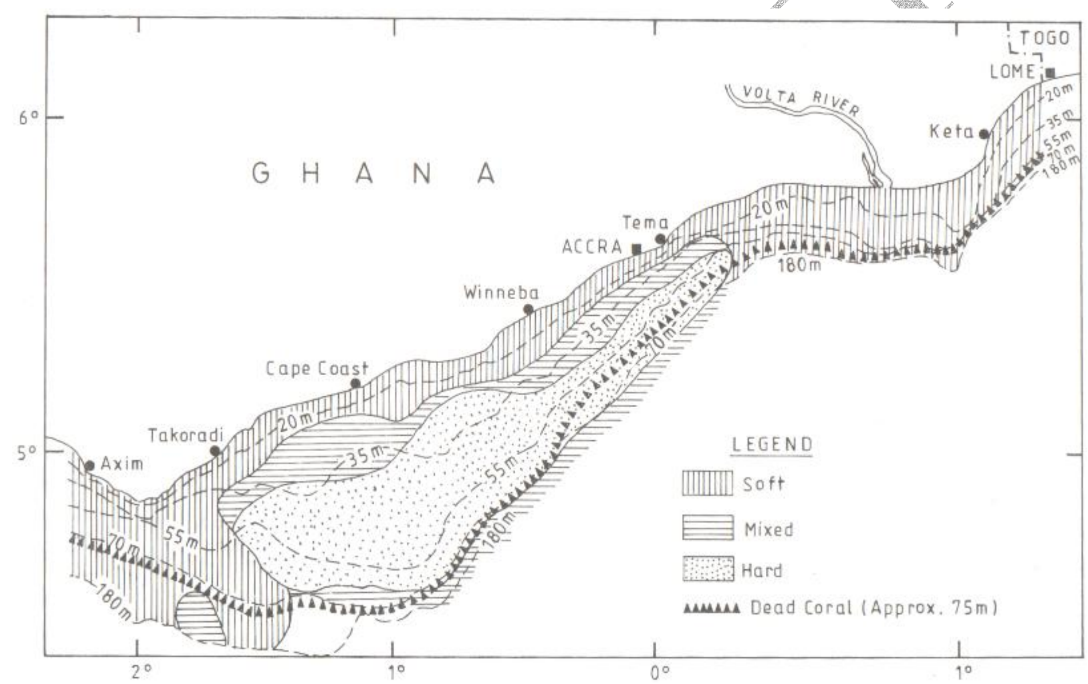
In Ghana, sandy beaches constitute about 70% of the coastline. The sediments along the coastline are redistributed mainly by a primarily eastward longshore current, in the form of littoral drifts and, less importantly, tidal currents. There are several coastal streams and lagoons along the coastline that deposit sediment into the marine environment. The amount of sediment transported is closely related to levels of river discharges into the sea (Mensah, 1991). The latter is a factor of the amount of rainfall, which follows a major (May to July) and a minor (September to November) season in the country. It has been estimated that the two major rivers in the country (Volta and Pra) transport a total of $17.9x10^{6}$ tons of sediment per year into the sea.

The sediment grains range from coarse sand particles in the inner shelf, to fine sand to dark grey mud in the outer shelf. The mean sediment size ranges from 0.29 to 2.00 Phi. The sediment types that dominate the offshore region contain more than 75% terriginous grains lying on most parts of the shelf and upper slope, detrital sands with an admixture of carbonate on most of the outer shelf and upper slope and with glauconite-rich sediment with mixtures of biogenic carbonate in the outer part of the shelf and upper slope. The carbonate-rich sediment found on the outer shelf and upper slope off Cape Three Points is mainly silty mud, composed primarily of molluscan debris.

From the inshore waters (~10m) down to 200m depth of the continental shelf margin, the surface coverage of the ocean bottom is comprised of 75% muddy to sandy mud, 23% hard and sandy, and 2% rocky type (Berncsek, 1986 from Armah & Amlalo, 1998).

Both WAGP locations are characterized by medium to high energy intertidal rocky platforms with extensive algal growth and diverse fauna. At Tema, the nearshore sediment could be described as being sandy and the offshore sandy-mud. At Takoradi, information from local fishermen suggest that the near shore is rocky as well with considerable colonization by barnacles.

Figure 1.1-1
Marine Environment of Ghana Showing Configuration of the Coastline and Bathymetry (Source: Armah and Amlalo, 1998)



1.2 METEOROLOGY

The climate of coastal Ghana is Equatorial with a bimodal rainfall distribution (June/July and September/October) and slight annual temperature variations (Church, 1980).

Tema falls in the coastal savannah zone with a mean annual rainfall of 800mm. The mean monthly temperature is estimated to be 26.7^{o}C; the mean monthly minimum temperature may be as low as 15^{o}C and mean monthly maximum temperature could be as high as 35^{o}C. The relative humidity ranges between 50 to 80 percent. Day length is approximately 12 hours, varying by less than ½ an hour over the year. The winds blow predominantly in a south-westerly direction with an average speed of 3ms^{-1} throughout the year.

Takoradi lies in a region with annual rainfall of between 1250 and 1500mm. The mean daily temperature is between 21^{o}C and 23^{o}C while the mean daily maximum temperature is between 27°C and 31°C. Relative humidity is generally high, ranging between 70% and 100%.

1.3 PHYSICAL AND CHEMICAL OCEANOGRAPHY

1.3.1 Currents and Tidal Patterns

The oceanography of the region is influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral currents (Merle and Arnault, 1985; Fontaine *et al*., 1999). The cold Canary and Benguela Currents are warmed as they flow towards the equator along the coastal margins. These currents then turn westwards near the equator and diverge as the North and South Equatorial Currents (Longhurst, 1962). Between the North and South Equatorial Currents flows the Equatorial Counter Current (ECC). This ECC becomes known as the Guinea Current as it runs from Senegal to Nigeria. The Guinea Current flows the whole length of the coast, as far as the Bight of Biafra, year-round. It maintains its highest velocities during the season of the south-westerly winds from June to October (Longhurst, 1962).

The ECC is driven by westward wind stress. When this subsides during February to April and October to November, it is reversed (Garzoli and Katz, 1983; Richardson, 1984; Merle and Arnault, 1985). A small westward flowing counter current lies beneath the Guinea Current. Below 40m depth it appears that the westward flowing counter current turns to the southwest with velocities ranging between 0.5m/s to 1.0m/s and 0.05m/s to 1.02m/s near the bottom (Akpati, 1975; Binet *et al*., 1991). The cold subsurface water could be a branch of the Benguela Current that penetrates and dominates the ECC.

The coastal waters experience seasonal changes at the surface of the Tropical Surface Water (TSW). There is little change in the subsurface waters. The TSW layer is characterised by warm, well-mixed water that extends from the surface to the depth of the thermocline (about 30m to 40m). Seasonal changes in the hydrographic regime are in the form of minor and major upwelling alternating with periods of stratification. Between January and February, the surface waters tend to be slightly cooler indicating a minor upwelling. By the end of June there is an increase in the easterly wind in the western equatorial Atlantic that brings up cold South Atlantic Central Water (SACW) to replace the TSW (Moore *et al*., 1978). When the thermocline breaks, it signals the onset of the major upwelling. The sea surface temperature can fall from 30 degrees Celsius (°C) in May to 18°C in August.

The subsurface system appears to comprise all the principal water masses of the South Atlantic. In the tropical regions of the Atlantic, a relatively thin superficial stratum of TSW of high temperature and of varying salinity overlies a density discontinuity layer at the thermocline. The horizontal extent of the TSW in the central Atlantic is determined by the position of the Tropical Convergence where south flowing TSW meets north flowing SACW. This convergence generally occurs at about latitude 10 °S in the eastern half of the Atlantic Ocean, but as far as 25°S in the western half, thus reflecting the effect of the gyral current system of the South Atlantic.

The SACW lies below the discontinuity layer and has a characteristic temperature-salinity profile. The salinity is 35% at 6°C, and 36% at 18°C (Longhurst, 1962; Houghton, 1983). There are three other types of water masses below the SACW: the Antarctic Intermediate Water (AIW), North Atlantic Deep Water (NADW), and Antarctic Bottom Water. AIW originates in the Antarctic region as sinking Antarctic Surface Water moves towards the equator. The AIW and NADW are relatively homogenous, but the latter is more saline and denser than all the other water masses.

1.3.2 Marine Traffic Patterns

Ghana has two major marine ports, located at Tema and Takoradi with a total import of 4.29 million tonnes. The Tema port is one of the largest shipyards in Africa. Available data indicate that the commercial vessel call and the volume of imports to the ports are increasing. The turnaround time for the ports, which previously averaged 4.0 days in 1990, had decreased to 1.5 days in 1999.

1.3.3 Existing Pollution

The potential threat of pollution in the marine environment is mainly from industrial, agricultural, and domestic sources. More than 250 industries are located in the coastal zone mainly within the Accra-Tema metropolis and a few in the Sekondi-Takoradi urban area. Most of these industries discharge their waste either untreated or only partially treated into drains which eventually end up in the sea. Available data on heavy metal concentrations in bottom sediments have revealed the presence of zinc, lead, copper, chromium and nickel in varying quantities (Ihenyen, 1998). However, investigations conducted on impacts of these pollutants on water quality and aquatic organisms in the coastal waters suggest that heavy metal levels have not yet reached undesirable toxic levels (Biney, 1986). It must be noted that much of the industrial activity has taken place only within the last decade, and therefore, increasing heavy metal pollution may not show up until a later time.

The work of Joiris *et al*. (1997) indicates increasing effects of DDT, aldrin, and heptachlor in the coastal waters. Other studies by Nyarko and Evans (1997) has also indicated the effects of tributylin, a compound used in the manufacture of antifouling paint used on ship hulls, on marine mollusk populations (*Thais haemostoma* and *T. nodosa*) from Tema.

The present situation, where a quarter of the population live in the coastal zone, has brought about an increase in the amount of domestic waste discharged (untreated) into the marine environment. This has resulted in faecal and nutrient-pollution of the marine environment, especially in high pollution areas such as Tema and Takoradi (Afoakwa *et al*., 1988; Wiafe and Quist, 2002).

1.4 BIOLOGICAL SETTING

1.4.1 Habitats

The identifiable habitats in the area of influence of the project are terrestrial habitats (of fauna and flora) at the Regulating and Metering (R&M) stations, intertidal habitats of rocky and sandy shore organisms, inshore and offshore habitats encompasing planktonic, nektonic and benthic organisms. Other identifiable habitats include a coastal lagoon at Tema (the Gao lagoon) and a wetland at Aboadze.

Aboadze R&M site

The vegetation is coastal strand, characterized by flora of the *Cyperus-Ipomeoa* association dominated by *Cannavalia obtusifolia, Cocos nucifera, Cyperus articulatus, C. maritimus, Imperata cylindrical, Ipomoea pes-caprae, Opuntia vulgaris, Paspalum vaginatum, Phoenix reclinata, Sporobolus virginicus, Thespesia populnea,* and *Triumfetta rhomboidea*. The major soils of the area are forest and coastal savanna ochrosols. Forest ochrosols are developed in forest and savanna environment under rainfall of between 900mm and 1650mm. The organic matter content of such soils is low, with pH generally less than 5.5. Coastal Savanna ochrosols are mainly red and brown, moderately well drained medium to light-texture soils developed over Voltaian sandstone, granite, phyllites and schists. They are also generally low in organic matter due to insufficient accumulation of biomass (less than 2% in the topsoil). Soil reaction ranges from near neutral (pH 6.0-7.0) near the surface, to moderately acidic with depth. The actual habitats surveyed were characterized by wetlands with burnt portions, which were liable to flooding during the rainy season. The area was dominated by coconut trees, grass, and thicket “islands”.

Tema R&M site

The vegetation is coastal scrub and grassland, characterized by coastal grassland/thicket composed of an almost continuous grass layer with small thicket “islands” and numerous termite mounds. Dominant floral species include Abutilon spp., Allophyllus warneckei, Andropogon spp, Cassia mimosoides, Ctenium spp., Grewia carpinifolia, Heteropogon contortus, Securinega virosa, Vetiveria spp. The area is characterized by lateritic sandy soils, which are either sandy or gravely in texture, and generally form the bulk material for the construction and building industries. The habitats surveyed were generally characterized by coastal grassland and neem tree thickets interspersed with food crop farms of cassava, maize, okro and pepper.

A list of possible fauna likely to be associated with the characteristic vegetation described above is presented in Appendix D, Table D-1 for the Aboadze swamps and the Tema strand vegetation.

1.4.1.1 Plankton

The plankton community is comprised of three economically important groups that sustain the aquatic ecosystems. These are the generally microscopic algae or the phytoplankton, the permanently resident zooplankton and the temporary resident meroplankton. In the near shore locations, they play additional role of providing more to the general productivity of the systems due to the maximum penetration of solar irradiance. Furthermore, the adjoining coastal water bodies like the lagoon systems located near the R&M sites, which serve as nursery grounds to the fishery derive maximum production from the plankton community.

The inshore and offshore phytoplankton can be grouped as grouped as diatoms, dinoflagellates, and coccolithophores. They are microscopic and range between 30μm and 60μm in size. Their occurrence is limited to the euphotic zone of the pelagic environment. Species diversity and abundance is linked to seasonal variation of the oceanographic regime; namely, high diversity and low abundance during thermal stratification, and low diversity but high abundance during upwelling periods (Wiafe, 2002).

Diatoms normally dominate the phytoplankton community, especially during the major upwelling season when the water temperature is relatively cold (20°C to 25°C) and conducive for their growth. Dinoflagellates, on the other hand, thrive well when the temperature is above 25°C. The principal species of diatoms recorded in Ghana during the upwelling belong to the genera *Skeletonema, Nitzschia, Chaetoceros, Rhizosolenia*, and *Thalassiosira.*

Dinoflagellates are better adapted to survive under conditions of low nutrient levels (Harris, 1986), and thus abound during periods of thermal stability. For example, *Ceratium* spp. exhibit slow growth rate and have low nutrient requirements.

Other planktonic groups, while normally sparse, can become prolific. For example, chaetognaths can become more abundant in September to November. Very marked proliferation of thaliaceans, mainly *Thalia democratica,* can occur in December and July, while appendicularians can be more abundant in June and October (Thiriot, 1977). The explosive development of these plankton groups in the offshore and inshore locations have a rippling effect on the development of the fishery of the nearshore and adjoining coastal water bodies as much production is made available to the fishery of the nearshore habitats.

1.4.1.2 Benthic Organisms

The benthic macrofauna within inshore habitats have been described by Bassindale, (1961), Buchanan (1957), Edmunds (1978), and Evans *et al*. (1993). The organisms include polychaetes, arthropods, molluscs, bryozoans, and echinoderms. Edmunds (1978) has recorded 68 taxonomic families of molluscs. Some species appear to be declining in abundance (e.g., *Cymbium* spp, a gastropod; and *Panulirus* spp., the spiny lobster), while others have disappeared altogether (e.g., *Astropecten* spp., a star fish (Armah and Amlalo, 1998).

1.4.1.3 Sea turtles

At present, five species of sea turtles have been identified in Ghanaian waters (Armah *et al*., 1997a). These are the leatherback (*Dermochelys coriacea*), the hawksbill (*Erectmochelys imbricata*), green turtle (*Chelonia mydas*), the loggerhead (*Caretta caretta*) and the most abundant of all, the olive ridley (*Lepidochelys olivacea*). The hawksbill is very rare and only seen occasionally. Sea turtles nest on sandy beaches beyond or at the high tide mark, and because they always return to the same area to nest, it is important that such beaches are protected from human activities.

In Ghana, sandy beaches constitute about 70% of the coastline and stretches from the western border with Cote d'Ivoire to Axim, and from the east of Tema to the border with Togo. The prime turtle nesting sites are located within rapidly eroding sites between Tema and the Volta estuary. The nesting period has been reported to begin as early as July to March, with a peak in November (Armah *et al*., 1997b).

1.4.1.4 Soil Organisms & Terrestrial Ecology

Soil invertebrate macrofauna such as earthworms, ants, termites, collembolans and woodlice etc have been recognized as contributing immensely to soil quality; assuming their importance in regulating soil processes which are vital to the continued formation of soil. The insects also play a vital role as bio-indicators. For example, the movements of soil by termites and ants have been observed to have very important implications for soil formation rates and the distribution of soil particles, nutrient and organic matter. They can therefore be used as bio-indicators of ecosystem functioning; principally, their ability to maintain or restore soil quality. The ants especially are able to survive in soils under very severe climatic conditions and other environmental disturbances.

Some of the most important soil organisms found in these areas are the dry wood termite, the black ant, *Camponotus aquapimensis*, the wood louse, *Asellus* spp. and *Crematogaste*r spp.

1.4.1.5 Hydrobiology and Fisheries

The aquatic systems associated with the project areas are the open Gao lagoon and the adjoining sea at the Tema site and the swamp complex, the Anankwari lagoon and the adjoining sea at the Aboadze site.

The near shore fishery forms part of the prolific and dynamic fishery complex that throngs the whole of the Ghanaian coastline. The open lagoon systems of Gao at Tema and Anankwari, near Aboadze facilitate a year round fishing activity, the intensity of which is dictated by the nature and dynamics of the inshore and offshore artisanal fishery. The Aboadze swamps, however, comprise of a dense growth of aquatic and semi- aquatic vegetation as well as the typical swamp forest vegetation. The complex nature of the swamp setting restricts the nature of fishing exploitation to the use of basket traps and occasional use of hook and line. During the flood periods, cast netting as a fishing method may be employed but at limited areas.

The hydrobiological regime of the water bodies are equally complex. While the Gao lagoon maintains twice-daily flushing regime from tidal water, it nonetheless receives a lot of exogenous materials from the catchment area which comprise of domestic waste and industrial effluents of anthropogenic origin. The soft bottom terrigenous ooze is largely derived from a combination of sea waves-deposit sand and accumulation of allochthonous materials, including eroding soils, derived from farming activities within the catchment area. The general vegetation along the banks of the lagoon is largely of the strand type. Although there is luxuriant stands of mangrove swamps along the Eastern banks of the lagoon, its distribution is very patchy and appears to be a direct result of conservation practice put up by the local Kpone community as well as the area being revered as the home of a deity. The distribution of the mangrove swamps becomes more patchy further upstream in the North-eastern and North-western directions of the lagoon. The water quality parameters are expected to follow trends typified by stressed coastal water bodies. The elemental contamination of the terrigenous sediment is expected to follow trends that will reflect the contents of the industrial wastes that are indirectly discharged into the system. The microbial load is also expected to reflect the extent and type of domestic waste discharged into the system.

Although the information on the productivity of the lagoon is scanty, it has been described as being moderately rich in fish and other shellfish species (Adomako and Armah, 1989). Some of the species recorded in the lagoon are *Tilapia* spp. and several juvenile marine fishes that follow the tide to forage in the coastal lagoons and other nearshore water bodies. The narrow strip of mangrove forest that lines the Eastern bank of the lagoon is suggested to be a breeding ground for some marine fishes (Adomako and Armah, 1989).

At Aboadze there is a *Cyperus articulatus* dominated wetland (Oteng-Yeboah, 1994) near the pipeline route and the R&M station. During the wet season, the entire wetland area gets flooded and joins the nearby Anankwari lagoon, located to the South West of the proposed R&M site. This allows for a cross transport of materials of freshwater and sea water origin to and from the sea. The biota has been described as varied and diverse. The wetland harbours fishes and edible crabs. (Adomako and Armah, 1989).

A checklist of expected fish and fisheries resources expected to be associated with the water bodies in Tema and Aboadze is provided in Appendix D, Table D-2.

CHAPTER 2
ONSHORE FIELD METHODS

2.1 VEGETATION SAMPLING

2.1.1 Floristic Composition

Floristic composition was studied by walking through the study areas and listing all the species encountered. The families and life forms (growth forms) of the species were determined to enable the establishment of the dominant families and life forms. The species were classified as Climber, Herb, Shrub, Shrublet or Tree. The nomenclature used is after Hutchinson and Dalziel (1954-1972).

2.1.2 Species Abundance and Diversity

Four 60m transects were placed at random in the study area (two in each habitat type). Along the first transect, three sampling points were located at 20m intervals. The geographic co-ordinates of each transect was determined with a Garmin 12 GPS receiver. At each sampling point, information on plant species abundance and diversity were collected as follows:

- Trees greater than 7.5cm diameter at breast height was sampled in a 10m radius circular quadrat.

- Shrubs and saplings greater than 1m tall were sampled in a 5m radius circular quadrat.

- Herbaceous and woody plants less than 1m tall were sampled in five randomly placed 1x1m quadrats.

The abundance of trees in each habitat was expressed in terms of average stand basal area G, obtained by averaging the basal area across the sampling points. The Basal area for a sampling point was calculated using the formula

$$G = \frac{\Pi}{40000} * \frac{\sum dbh^2}{a} = 0.0000785398 * \frac{\sum dbh^2}{a}$$

2.2 SOIL SAMPLING

Four 60m transects were placed at random in the study areas, Tema and Aboadze (two in each habitat type). Along the first transect, three sampling points were located at 10m intervals. The geographic co-ordinates of each transect was determined with a Garmin 12 GPS receiver. These points corresponded to the point locations for the vegetation sampling. Within each habitat type, soil samples were taken from the depth of 0-15cm (point samples) and 15-50cm at each of the sampling points on the two transects. These were pooled together as composite samples and labeled as bulk samples (15-50cm). Portions of the point samples were also pooled together and labeled as Bulk samples (0-15) for each transect. This was repeated for all the 4 transects in the two proposed R&M sites.

2.2.1 Soil Macrofauna and Ecology

Standard butterfly nets were employed in sampling aerial insects. In addition, other insects were collected opportunistically, using bait consisting of banana and palm wine and sweeping of vegetation.

Butterflies were collected along the transects. All species observed were identified in free flight and recorded. Those that could not be immediately identified were either captured and identified or preserved for later identification in the laboratory.

Ant fauna were used as bio-indicators of soil in this survey. Three complementary sampling methods of ants and other soil macrofauna were used. These were pitfall trapping, mapping of ant nests, collection of litter and soil cores. These give a more accurate representation of the ant fauna especially those species with a more active role in soil function.

Pitfall trapping at the four soil sampling locations along the 60m transect was done. In addition ant nests density were determined in a $1m^2$ quadrat thrown randomly on either side of the seven points along the transects in each sampling site. Invertebrates in the litter and soil core samples collected from the point locations along the transects were extracted with a modified Berlese Funnel in the laboratory.

2.3 SURFACE WATER AND SEDIMENT QUALITY AND HYDROBIOLOGY

Acid-washed 250ml plastic bottles, thoroughly rinsed with de-ionized water, was used to collect water samples from the onshore sampling locations by direct dipping to the required water depth. Another set of samples were collected using thoroughly rinsed 250ml plastic bottles from the required depths and immediately placed on ice for the determination of alkalinity.

2.3.1 Zooplankton

Two groups of the zooplankton community; the holoplankton and meroplankton (larvae of fish and crustaceans of economic importance) were investigated in the Gao lagoon and the Aboadze swamps during this phase of the study. The near-shore plankton community was also investigated at the Tema and Aboadze/Takoradi intertidal zones. Nine sampling stations within the two study areas (4 at Tema and 5 at Aboadze) were sampled. Two replicate samples, one in the Gao lagoon at Tema and the other in the Aboadze swamps were also taken during the sampling period. A total of 15 samples were collected in the study, 8 from Gao Lagoon at two tidal levels which include 2 replicate samples from 3 stations), 1 sample from the nearshore (intertidal) area at Tema, and 5 from the Aboadze swamps (only 1 replicate sample from each station) and 1 from the nearshore (intetidal area at Aboadze/Takoradi). The sampling method employed was the filtration method as water level was not sufficiently high at all times to facilitate the towing of nets. 50L water sample was collected directly from the sampling station and filtered through 250µ net using a 10-L bucket. The sides of the plankton net was thoroughly washed into the collecting bottle attached to the zooplankton net and the entire content of the collecting bottle decanted into a sample tube and fixed in 10% mentholated-formaldehyde solution for further analysis in the laboratory.

In the laboratory, the plankton samples were left to settle for five days. After this s, the mentholated-formalin solution used to fix the samples was drained off to consistent 50ml volumes. 2.5ml each was then taken with a Stempel pipette after thoroughly mixing the sample, onto a sedgwick-Rafter counting chamber. All individuals in each sample were identified to the lowest possible taxon and counted under a dissecting microscope. Species and group abundance from the four replicate counts were averaged for all the 15 samples. Counts were expressed as individuals/10L.

2.3.2 Phytoplankton

Water sample for phytoplankton analysis was collected from 3 sampling sites in the Gao lagoon at two tidal levels (low tide level and high tide level) using a thoroughly rinsed sampling bottle. One sample was also taken at the nearshore (intertidal) area at Tema. At the Aboadze site, 4 sample were taken from the swamp stations and one from the nearshore intertidal station. A total of 12 samples were taken from 9 sampling stations in the two study areas. Water sample for analysis of the phytoplankton diversity and abundance was let into a 250ml acid-cleaned and thoroughly rinsed plastic bottle and preserved in 10% Lugol's solution. All samples were given the same treatment and transported to the laboratory for further analysis.

2.3.2.1 Phytoplankton, Respiration, Photosynthesis, and Productivity

Water samples were taken for an initial dissolved oxygen (DO) value determination at four sampling stations in Tema and four sampling stations in the Aboadze/Takoradi area at 0600 GMT. The light and dark bottles were then put in place at the selected stations between 0600-0630 GMT and retrieved between 1800-1830 GMT (12-hour lapse period). The dissolved oxygen (DO) concentration in the water sample was determined using the Azide modification of the Winkler method.

2.3.3 Macroalgae

The high and low water marks coordinates were determined using a GPS and recorded. The habitat, shore type, biotope and community of macroalgae in the general shore area was described for a 10m-line transect drawn from where macroalgae cover begins and move seawards. One-meter square quadrat was placed at the 1, 5, 7 and 9-meter marks on the line transect drawn (Plate 2.3-1). The algal species within the bare ground and their percentage cover/abundance were estimated by eye. The presence of faunal forms and other characteristic species in the general quadrat area were noted and recorded.

Plate 2.3-1
Sampling of Macroalgae at Aboadze/Takoradi Intertidal with Ghana EPA observers

2.3.3.1 Benthic Infauna

Benthic macrofauna were sampled using an Orange-peel grab of volume $0.002m^3$. The grab was released into the sediment to a depth of about 20cm and the samples emptied into sample trays, washed and screened through a sieve of mesh size 0.5mm. Four replicates were taken at each station. The resulting sample was fixed in 10% buffered formalin and stained with Rose Bengal solution to ease the sorting process.

2.4 SOIL AND GROUNDWATER AT THE COMPRESSOR STATION (N/A)

2.5 IN-SITU METHOD

In-situ measurements were made on onshore surface water and in the sediments. Indirect in-situ measurements were also performed on the soil samples. The sample type and parameters measured in the Tema and Aboadze/Takoradi locations are presented in Table 2.5-1 below.

pH measurement in water samples was done using a pocket-sized microprocessor pH meter (pHep 3, Hanna Instruments) with accuracy of ±0.1pH units. After calibration, the probe was dipped below the water surface at each station and the average reading taken to the nearest 0.1pH unit, for three replicate readings.

For the measurements of pH of sediment and soil, however, a portable pH/ISE meter (sension2 model; HACH Instruments) was employed. The probe of this instrument was dipped to a depth of about 2cm in the sediment/soil after calibration and the reading recorded. The probe was rinsed in de-ionized water after each reading. Three replicate readings were taken at each station and the mean was calculated.

Table 2.5-1
Equipment Type used in Onshore In-situ Measurements

Sample	Parameter	Units	Instrument/Equipment used
Surface Water	Water Temperature	(°C TW)	NIST Traceable Thermometer
	Dissolved Oxygen	ppm (DO)	DO Meter (55/12 FT)
	pH	pH units	pH Meter (pHep 3)
	Salinity	(ppt NaCl)	Salinity Refractometer (S-28E)
	Total Dissolved Solids (TDS)	mg/L	TDS Meter (Corning TDS-60 Sensor)
	Electrical Conductivity	mS/cm	Conductivity Meter (Corning CD-55 Sensor)
Sediment	Redox Potential	mV	Portable pH/ISE Meter (sension2)
	pH	pH Units	Portable pH/ISE Meter (sension2)
	Temperature	°C	NIST Traceable Thermometer
Soil	pH	pH Units	Portable pH/ISE Meter (sension2)
	Temperature	°C	NIST Traceable Thermometer

pH measurement in water samples was done using a pocket-sized microprocessor pH meter (pHep 3, Hanna Instruments) with accuracy of ±0.1pH units. After calibration, the probe was dipped below the water surface at each station and the average reading taken to the nearest 0.1pH unit, for three replicate readings.

For the measurements of pH of sediment and soil, however, a portable pH/ISE meter (sension2 model; HACH Instruments) was employed. The probe of this instrument was dipped to a depth of about 2cm in the sediment/soil after calibration and the reading recorded. The probe was rinsed in de-ionized water after each reading. Three replicate readings were taken at each station and the mean was calculated.

Temperatures of surface water (ambient and water), sediment and soil were measured with a digital long-stem thermometer (NIST Traceable Thermometer, Fisher Scientific Instruments) with a precision of ±0.2^{o}C and a resolution of 0.1^{o}C. The long-stem (Stem Length: 20.3cm) was held in the air for the ambient temperature, dipped below the surface of the water for surface water measurements or stuck directly into the sediment/soil wherever possible, for the reading to be taken. Mean readings were recorded for three replicate readings.

A hand-held salinity refractometer (S-28E, Atago Instruments) with a precision measurement of 1‰ was used to measure the salinity of surface water in the two locations. About 1ml water sample was obtained using a calibrated micro-medicine dropper from the required water depth and dropped onto the instrument's sensitive prism-face. The drop of water on the sensitive prism is held against light and the readings taken in parts per thousand.

Measurements for electrical conductivity were made on water samples using a portable conductivity meter (Corning CD-55 Sensor, Fisher Scientific Instruments). The instrument has a resolution of 1mS/cm and an accuracy of ±3mS/cm. For the estimation of the electrical conductivity, the instrument was dipped below the water surface and the mean value recorded from three replicate readings.

Dissolved oxygen measurement was taken with a digital DO Meter (model 55/12 FT, YSI Incorporated). The probe mounted on a long electrical cable connected to the instrument was lowered to the desired depth and held in place for about 60 seconds to allow for equilibration of the instrument. The altitude and the pressure were set as part of the calibration and the DO level read to the nearest 0.01mg/L.

Total dissolved solids (TDS) in surface water samples were measured using a portable TDS Meter (Corning TDS-60 Sensor; Fisher Scientific Instruments). The instrument has a resolution of 1 ppm and an accuracy of ±3 ppm. TDS measurement is done by dipping the sensor slightly below the water surface and the readings taken. The final reading recorded represents an average of three replicate readings.

Redox potential for sediments was determined at each station with a Portable pH/ISE Meter (sension2 model; HACH Instruments) with a resolution of 0.1mV and an accuracy of ±0.2mV. At each station, measurements of both the sample and the Zobell standard solution were taken. The redox potential of the sample is calculated as follows:

$Eh_{sample} = E_{observed} + Eh_{ZoBell/reference} - Eh_{ZoBell\ observed}$. *Where:*

$E_{observed}$ = sample potential relative to reference electrode.

$Eh_{ZoBell/reference}$ = theoretical Eh of reference electrode and Zobell's solution, relative to the standard hydrogen electrode

$Eh_{ZoBell\ observed}$ = observed potential of Zobell's solution relative to the reference electrode

2.6 WILDLIFE AND ANIMAL RESOURCES

2.6.1 Herpetofaunal Survey

Herpetofauna and birds were recorded using direct opportunistic observation. The former were further surveyed by refuge examinations using reptile hooks to search, since they often conceal themselves under and in fallen logs, rotten tree stumps, under rocks, in leaf litter, rodent burrows, ponds, old termite mounds, etc.). Small mammals were surveyed using

Sherman Collapsible Live-Traps (H.B Sherman Traps Inc., Florida, USA) laid along transects cut at 10-metre intervals in the various habitats. The traps were checked early in the morning and late afternoon for three consecutive nights. Captured animals were euthanized with chloroform, identified on the spot (if possible), sexed, aged, weighed, and examined for reproductive condition. Unidentifiable specimens were later identified using Kingdon (1997). Large mammals were recorded largely through interviews of a section of the local population and the use of spoors.

2.6.2 Sea Turtle Survey

The sea turtle survey involved walking the length of the coastline beginning from Tema Newtown area, across the Gao Lagoon and along the shores of Kpone community up to 2 km away to the shores of the proposed R & M site at Tema.

The walk began at 11:30 pm on each selected day and it involved two teams doing the walk in opposite directions. This was repeated for 5 days over a two week period in August 2003. Observations were made on all features reminiscent of turtle tracts. The methodology followed all the precautionary protocols proposed by Eckert et al (1999).

In addition to this, simple questionnaires were distributed to some local fishermen to ascertain their perception of occurrence of turtle species types (as either hard-shelled or soft shelled) and their relative abundance within the study area.

2.7 FISH AND FISHERIES RESOURCES

The fisheries component of this study combined site examination of fish catches from fishermen and interviews as major tools for determining the structure and form of the fisheries of the Gao Lagoon at Tema and the swamps at Aboadze/Takoradi.Furthermore, information was obtained from the nearby Anankware lagoon off the Project site at Aboadze. Finally, desk- bound literature survey and interviews from some personnel of Marine Research and Utilization branch of the Ministry of Food & Agriculture were used to establish the structure and form of the nearshore and inshore fisheries near the R & M sites. The composition and size structure of some fishes taken from some selected fishing methods were estimated from meristematic measurements. A species list, based on actual observations and interviews is provided for the Gao lagoon and the Aboadze swamps.

2.8 SAMPLE TRACKING, STORAGE, AND SHIPPING

The main activities involved in the data collection, including personnel involved in the data collection, type of field data collected, period of collection and handling of samples in the field are presented in Appendix D, Table D-1. A summary of the tracking record is presented in Table 2.8-1.

Table 2.8-1
EBS Sampling Tracking Record

Sample Type	Storage	Shipping	Destination
Vegetation	-	Vehicular	-
Soil (in-situ)	-	"	ESL
Soil Organics (TOC)	Frozen	"	CSIR
Soil Microbiology	"	"	"
Soil Macrofauna	Formaldehyde	"	ESL
Sediment (in-situ)	-	"	ESL
Sediment Characterization(grain-	-	"	CSIR
size)	Cool 4°C	"	CSIR
Sediment Organics (TOC, TPH)	"	"	ESL
Surface Water (In-situ)	"	"	ESL5, CSIR
Surface Water Quality	"	"	CSIR
Water Microbiology	Formaldehyde	"	ESL4
Intertidal Algae	Formaldehyde	"	ESL4
Macrobenthic fauna	Lugols Iodine	"	ESL3
Phytoplankton	Formaldehyde	"	"
Zooplankton	Formaldehyde	"	"
Fisheries			

Legend ---CSIR Council for Scientific and Industrial Research

ESL (3-5) Environmental Solutions/University of Ghana

CHAPTER 3
Analytical Methods

The descriptions below provide an overview of the methodologies used, references to the methods used, a discussion of comparability of different methods where appropriate, and information about the quality of data the methods are capable of generating.

3.1 PHYSICAL LABORATORY METHODS

3.1.1 Grain Size/particle Size Distribution

Sediment texture or particle size distribution was determined by the hydrometer method (Bouyoucous, 1952). Samples preparation involved air-drying, grinding, sieving (2.0mm mesh-size sieve), the addition of a dispersion agent (calgon) and water. A fixed volume of the sample mixture is agitated in a reciprocal shaker at a determined speed (30rpm).

The distribution of particle sizes smaller than approximately 75µm is determined by a sedimentation process, using a hydrometer. The hydrometer methodology quantitatively determines the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer. The hydrometer method of estimating particle size analysis (sand, silt and clay content) is based on the dispersion of soil aggregates using a sodium hexametaphosphate solution (calgon) and subsequent measurement based on changes in suspension density. The use of the ASTM 152 H-Type hydrometer is based on a standard temperature of 20°C and a particle density of 2.65g/cm^3 and units are expressed as grams of soil per liter. Corrections for temperature and for solution viscosity may be made by taking a hydrometer reading of a blank solution. The method has a detection limit of 1 percent sand, silt and clay (dry soil basis) and is generally reproducible within 8 percent (relative).

3.2 CHEMICAL LABORATORY METHODS

3.2.1 pH

Onshore surface water, soil and sediment samples were analyzed for pH using a pH meter (glass electrode, automatic temperature compensation) method. The pH meter was calibrated with standard pH buffers.

The pH of surface water samples was determined by immersing the pH meter into the water sample. The samples were stirred gently for the meter to equilibrate and the pH reading was taken. For soil and sediment samples, a saturated paste of the sample is made and the pH determined. It is not possible to determine the total acidity or alkalinity of the soil and sediment samples from pH because of the nature of the colloidal system and junction potential. This method does however provide information on the disassociated H^+ ions affecting the sensing electrode. The method is generally reproducible within 0.2 pH units.

3.2.2 Alkalinity

Onshore surface water samples were analyzed for alkalinity. Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity of water is due primarily to the presence of bicarbonate, carbonate, and hydroxide ions. Salts of weak acids, such as borates, silicates, and phosphates, may also contribute. Salts of certain organic acids may contribute to alkalinity in polluted or anaerobic water. Bicarbonate is the major source of alkalinity. Carbonates and hydroxide may be significant when algal activity is high, and in certain industrial water and wastewater, such as boiler water. Alkalinity is expressed as phenolphthalein alkalinity or total alkalinity. Both types can be determined by titration (APHA 2310 STD Method, 19th ed. 1995) with a standard sulfuric acid solution to an end point pH, evidenced by the color change of a standard indicator solution (phenolphthalein, methyl orange).

3.2.3 Biochemical Oxygen Demand (BOD_5)

Onshore surface water samples were analyzed for BOD_5 to determine the organic loading or the oxygen demand within a sample. The method used for the determination of BOD was the APHA 5210 B (STD Method, 19th ed. 1995).

The method consists of filling with sample, to overflowing, an airtight bottle of the specified size, seeding it with appropriate bacterial flora if necessary and incubating it at $25^{o}C$ for five days. The dissolved oxygen content of the water is measured initially and after incubation, and the BOD_5 is computed from the difference between initial and final dissolved oxygen readings. The dissolved oxygen readings were taken with a YSI 55 dissolved oxygen meter.

3.2.4 Electrical Conductivity

Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, on their total concentration, mobility, valence, and on the temperature of the solution. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct current very poorly, if at all. Electrical conductivity was measured *in-situ* in surface water samples using standard conductivity meters.

3.2.5 Nitrogen forms (Nitrate, Nitrite, Ammonia Nitrogen, Total Nitrogen)

The forms of nitrogen measured include nitrate, ammonia-nitrogen and total nitrogen. The analysis of the various forms rely on chemical reaction of the samples with catalyzing agents to ensure or distinguish chemical forms of nitrogen. This is followed by reaction with color forming agents to form specifically colored complexes and/or compounds. Measurements of the concentrations of the nitrogen form are then made spectrophotometrically at specific wavelengths against standard concentration curves.

Total Nitrogen is measured using the persulfate digestion method (APHA 4500-NC, STD Method, 19th ed. 1995). In the method, alkaline oxidation at 100 to $110^{o}C$ converts organic and inorganic nitrogen to nitrate. The total nitrogen is determined by analyzing the nitrate in the digestate.

Nitrate was measured employing Hach Method 8039 (Hach, 2000) using Hach prepackaged reagents (NitraVer 5 Nitrate reagent powder pillow) and Hach DR/2010 Spectrophotometer. In the method, cadmium metals reduce nitrates present in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt, which couples to gentisic acid to form an amber-colored product. This is measured with the spectrophotometer at 400nm.

Nitrogen Ammonia is measured employing Hach Method 8155 (Hach, 2000) and Hach prepackaged powder pillows (Ammonia Salicylate reagent and Ammonia Cyanurate reagent powder pillows) and Hach DR/2010 Spectrophotometer. The method is adapted from Clin. Chim. Acta. 14:403 (1966). In the method, ammonia compounds combine with chlorine to form monochloramine. Monochloramine reacts with salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidized in the presence of a sodium nitroprusside catalyst to form a blue-colored compound. The blue color is masked by the yellow color from the excess reagent present to give a final green colored solution. The final solution is read off the spectrophotometer.

3.2.6 Phosphorus forms (phosphate, orthophosphate, reactive phosphorus, total phosphorus)

Onshore water samples were analyzed for forms of phosphorus. Phosphates are important nutrients at low concentrations and indicators of discharge at higher levels and can lead to eutrophication under certain conditions. Phosphorus analyses APHA 4500-PE (STD Methods 19th ed.) consist of two general procedural steps: (*a*) conversion of the phosphorus form of interest to dissolved orthophosphate, and (*b*) colorimetric/spectrophotometric determination of dissolved orthophosphate. The primary forms determined in this program were reactive phosphorus and total phosphorus.

Phosphates that respond to colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample are termed ‘‘reactive phosphorus.’’ While reactive phosphorus is largely a measure of orthophosphate, a small fraction of any condensed phosphate present usually is hydrolyzed unavoidably in the procedure. Reactive phosphorus occurs in both dissolved and suspended forms. Total phosphorus (orthophosphate, condensed, and organically bound) can be determined by acid oxidation with persulfate, followed by the reactive phosphorus test.

Total Phosphorous is determined by the persulfate acid digestion method (APHA 4500-P A, STD Methods, 19th ed. 1995). Persulfate acid digestion is used to release phosphates from combination with organic matter as orthophosphates. The total phosphorous is determined by analysing the orthophosphate in the digestate.

The method used in determining reactive phosphorus (Orthophosphate) is the Hach Method 8048, using Hach prepackaged reagents (PhosVer 3 powder pillow reagent) and Hach DR/2010 Spectrophotometer. The method is adapted from the Standard Methods for the Examination of Water and Wastwater (Method 4500-P-E) and is equivalent to USEPA method 365. Orthophosphate reacts with molybdate in an acid medium to produce a phosphomolybdate complex. Ascorbic acid then reduces the complex, giving an intense molybdenum blue color which is read with the spectrophotometer at 890nm. The reading is compared with a preprogrammed standard curve. The estimated detection limit for the method is 0.01mg/L.

3.2.7 Solids (Total Suspended Solids (TSS), Total Dissolved Solids(TDS))

Measurements of solid components (TSS and TDS) provides a measure of the total water soluble/insoluble fraction and do not reveal the quantity or type of individual contaminants in the sample. TDS analyses were determined using *in situ* meter determinations calculated at reference conditions from conductance. TSS was determined using gravimetric procedures equivalent to APHA 2540 D (STD Method, 19th ed, 1995).

3.2.8 Sulfate

Determination of sulfate in surface water samples was based on the barium chloride turbidity method equivalent to APHA 4500-Si (STD Method, 19th ed, 1995). Barium chloride is added to the sample and turbidity caused by barium sulfate suspension which is proportional to sulfate concentration is measured spectrophotometrically.

3.2.9 Total Petroleum Hydrocarbons (TPH)

TPH analysis was performed on soil, sediment, and surface water samples. TPH analysis provides a determination of organic petroleum –related compounds. Measurements of TPH involve preparation of the sample to concentrate the compounds of concern, and analysis by gas chromatography typically by flame ionization. Additional extract clean ups may precede analysis where other suspected interfering compounds may be present. Quantitation of the results as TPH provides a relative measure of the petroleum related concentrations.

3.2.10 Total Organic Carbon (TOC)

Determination of total organic carbon in sediment and soil samples was by the Walkley and Black (1934) method modified by Nelson and Somners (1982) using potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement. This method quantifies the amount of oxidizable organic matter (OM) in which OM is oxidized with a known amount of Cr_2O7_2 in the presence of sulfuric acid. The remaining Cr^{3+} chromate is determined spectrophotometrically at 600nm wavelength. The calculation of organic matter is based on organic matter containing 58% carbon. The method has a detection limit of approximately 0.01% and is generally reproducible within 8%.

3.2.11 Turbidity

The method used in determining turbidity was APHA 2130 B (STD Method 19th ed., 1995) (Nephelometric method). Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. Nephelometer measurements are considered fully quantitative.

3.3 BIOLOGICAL LABORATORY METHODS

Biological laboratory methods for assessment of phytoplankton, zooplankton, phytoplankton productivity, microbiology identifications, and macrobenthic identification and diversity were performed to characterize the biological baseline conditions.

3.3.1 Plankton

In the laboratory known values of water samples for phytoplankton analysis were analysed using a Carl Zeiss Inverted microscope with counting chambers at x 10 and x 40 stage magnification. Sedimentation was carried out in counting chambers, cell counts were made in duplicate and average cell counts per ml computed.

Filamentous and colonial forms were counted as individuals and their numbers multiplied by the average numbers of cells for filament or colony (determined for some 20 individuals) as carried out by Lund *et al.* (1958). Identifications were carried out using Manual of Algal Species drawings for the Laboratoire D'Ichthyologie, Meseum National D'Histoire Naturelle, Paris (1988).

3.3.2 Phytoplankton Productivity

The formulas used for estimation of Respiration, Photosynthesis and Relative productivity were as per Wetzel and Likens (1990).

1. Respiratory activity per unit volume
   Per time interval ($mgO_2/L/hr$)
   IB - DB (IB = initial oxygen)
   (DB = 0_2 Dark bottle)

2. Net Photosynthetic activity per unit
   Volume per time interval ($mg0_2/L/hr$)
   LB - IB (IB = initial oxygen)
   (LB = 0_2 light bottle)

3. Gross photosynthetic activity ($mg0_2/L/hr$)

(LB - IB) + (IB - DB) = Net photosynthesis + Respiration

4. Relative Production ($mgC/m^3/hr$)
   [(O_2 LB) - (O_2 DB)] x (1000) (0.375)

(PQ) t

0.375 = ratio of moles of carbon to moles of oxygen (12 mgC/32 $mg0_2$)
t = time of exposure = 12 hrs
PQ = 1.2 = Dimensionless number indicating the relative amount of carbon Involved in the processes of photosynthesis and the constant is given as 1.2
Relative productivity ranges are
1.0$mgC/hr/m^3$/ for sea (Ref. Doty and Oguri, (1957)
11(- 29) ($mgC/hr/m^3$) for Inland water (Ref. Elster, 1965:82,90)

3.3.3 Quantitative Estimation of Bacterial Flora

3.3.3.1 Total Viable Bacterial Density Determination

Viable heterotrophic bacterial populations were determined for all the water and soil samples using the heterotrophic plate count procedure (Standard Methods, 1998) at 22 ± 0.5°C and 37 ± 0.5°C. The low-nutrient medium NWRI agar (HPCA) (Standard Method, 1998) was used. One (1.0) ml of each sample was mixed with liquefied (45°C) NWRI agar, in sterile Petri dishes and the mixture allowed to solidify. One set of Petri dishes was incubated at 22°C and another set at 37°C for 48 hours. Bacterial colonies, which developed, were counted using the Karl Kolb Colony Counter (Model D-6072), and the value obtained was converted to number of Colony Forming Units per millilitre of sample.

3.3.3.2 Total coliform counts

The Membrane Filtration method (Standard Methods, 1995) was used to determine the levels of total coliform bacteria. 50ml of each of the water samples and one (1.0) ml of each soil (solution) were separately filtered using 0.45µm membrane filter (Millipore). Each membrane filter was incubated on M-Endo agar (Oxoid) and incubated at 37±0.5°C for 18 to 24 hours. All colonies that showed metallic sheen were counted as positive total coliform bacteria. Deep red colonies were confirmed as coliforms using MacConkey broths.

3.3.3.3 Faecal coliform counts

The Membrane Filtration Method was used. 20ml of each water sample and one (1.0) ml of each soil (solution) filtered. Each membrane filter was then incubated on MFC agar (Difco) and incubated at 44+0.5°C for 18 to 24 hours. All colonies that showed blue colours were counted as positive faecal coliforms.

3.3.3.4 Sulphate Reducing Bacteria Counts – Desulphovibrio spp.

1ml of each water and soil sample was inoculated into molten beef-peptone agar (with 1% lead acetate) in sterile Petri plates. Inoculated plates were incubated anaerobically at 20-22°C for 6 days. Bacterial colonies, which developed, were counted and the value obtained was converted to number of Colony Forming Units per millilitre of sample.

3.3.3.5 Sulphate Reducing Bacteria Counts – Clostridium spp.

10ml of each of the water and soil samples were separately pasteurized at 80°C for 10 mins. 1ml of each water and soil sample was inoculated into molten Yeast Extract Agar (Oxoid) in sterile Petri plates. Inoculated plates were incubated anaerobically at 37°C for 48 hours. Bacterial colonies, which developed, were counted and the value obtained was converted to number of Colony Forming Units per millilitre of sample.

3.3.3.6 Pseudomonas Counts

50ml of each of the water sample and 1ml of each soil solution was passed through a 0.45µm membrane filter and the filter transferred to Petri dish containing Cetrimide agar (Difco).

Inoculated plates were incubated aerobically at 37°C for 48 hours. Bacterial colonies, which developed, were counted and the value obtained was converted to number of Colony Forming Units per millilitre of sample.

3.3.3.7 Hydrocarbon Degraders – Hydrocarbon decomposers

1ml of each water and soil sample was added to molten medium made up of Distilled water, 1000ml; NH_4NO_3, 1g; K_2HPO_4, 1g; KH_2PO_4, 1g; $MgSO_4.7H_2O$, 0.2g; $CaCl_2.6H_2O$, 0.02g; $FeCl_3.6H_2O$ 2 drops and Agar, 20g. Sterile petroleum was thinly spread on the solidified surface and incubated at 20–22°C for 7 days. Colonies were counted and the value obtained was converted to number of Colony Forming Units per millilitre of sample.

3.3.3.8 Hydrocarbon Degraders – Hydrocarbon oxidizers

1ml of each water and soil sample was added to molten medium containing Tap water 1000ml; KNO_3, 1g; K_2HPO_4, 1g; $MgSO_4.7H_2O$, 0.2g; NaCl, 1g; and Agar, 20g. Sterile petroleum was thinly spread on the solidified surface and incubated at 20–22°C for 7 days. Colonies counted were converted to number of Colony Forming Units per millilitre of sample.

3.3.4 Quantitative Estimation of Fungal Flora

3.3.4.1 Moulds Determination

1ml of each water and soil sample was inoculated separately into Neopeptone-glucose-rose Bengal aureomycin agar (Standard Methods, 1998) in sterile Petri plates. 0.05ml of tetracycline (1g water soluble antibiotic/150ml distilled water) was added to the molten mixture to check the growth of bacteria. Incubation was at 20–22°C and plates were counted after 3, 5 and 7 days. Colonies counted were converted to number of Colony Forming Units per millilitre of sample.

3.3.4.2 Yeasts count

1ml of each water and soil sample was inoculated separately into Yeast extract-malt extract-glucose agar (Standard Methods, 1998). Inoculated plates were incubated at 20–22°C and plates counted after 2 to 3 days. Colonies were counted and the value obtained was converted to number of Colony Forming Units per millilitre of sample.

3.3.5 Macrobenthic infauna

Sediment samples were washed thouroughly in a 200µm mesh-sized sieve to get rid of the fixative. The organisms were then manually sorted into a sample preservation tube and preserved with 70% alcohol solution containing glycerol. In the laboratory, each of the macrobenthic samples was emptied into a Petri-dish and examined using a Leica Zoom 2000 dissecting microscope and a Leica Gallen 2000 compound microscope. The organisms were identified, sorted into groups and counted. Identification was done as much as possible to species level using relevant literature. Where fragmented animals were found, only those with heads were counted.

CHAPTER 4
ONSHORE RESULTS

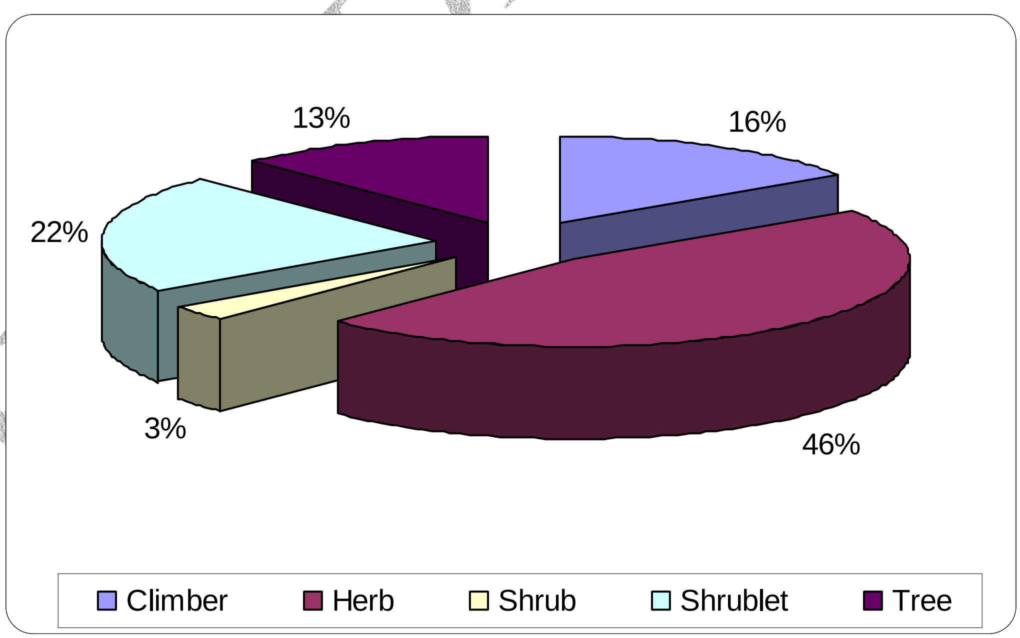
4.1 VEGETATION

4.1.1 Tema

4.1.1.1 The Coastal Strand Vegetation of Tema

The floristic composition of the WAGP route at Tema during the wet season is provided in Appendix D, Table D-6. A total of 32 species were recorded in the sampling area. These belonged to 31 genera in 17 families. The most highly represented families were the Graminae (41%), Papilionaceae (29%) and Euphorbiaceae (24%). The quadrat sampling indicated that *Cenchrus echinatus*, *Heteropogon contortus and Paspalum conjugatum* dominated the area. The life form composition analysis of the vegetation (Figure 4.1-1) indicated a clear dominance of the Herb life form. The low representation of the Tree and Shrub life forms indicates a high level of disturbance. Species diversity for herbs and shrublets was found to be very low (Shannon's Index, H'=1.560). It must be noted that it was not possible to calculate diversity indices for the shrub and tree life forms since these were not encountered along the transect.

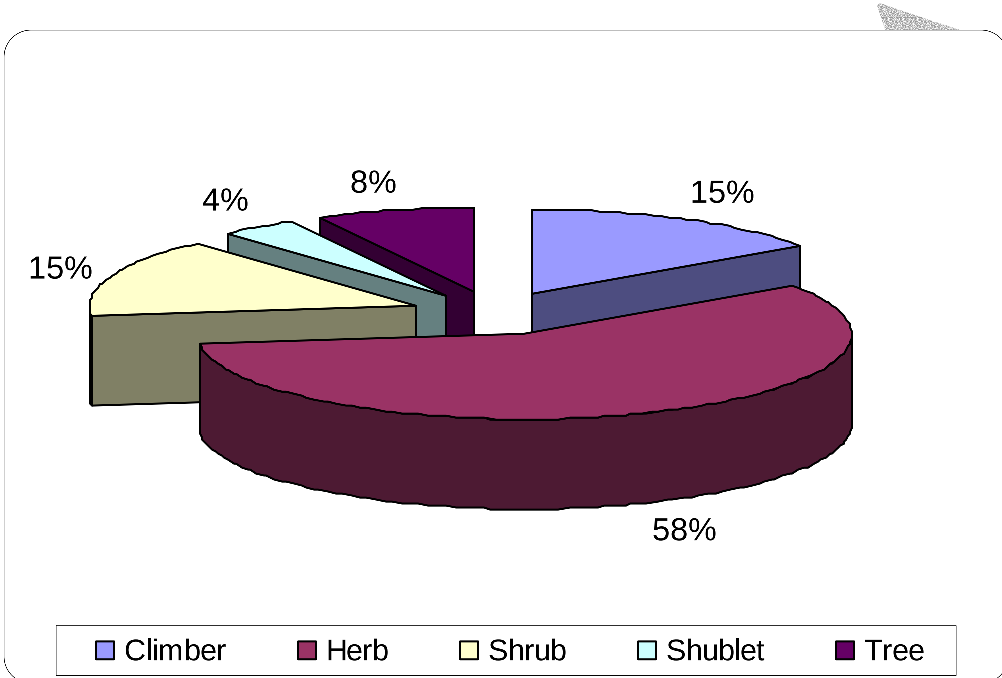
Figure 4.1-1
Life form Analysis of the Coastal strand Vegetation at Tema



4.1.1.2 The Inland Coastal Scrub and Grassland Vegetation of Tema

The floristic composition of the Coastal Scrub vegetation of the WAGP route at Tema is given in Appendix D, Table D-7**.** It shows that 26 species in 26 genera belonging to 19 families were recorded. The dominant families were the Euphorbiaceae (11%), Papilionaceae (16%) and Graminae (21%). *Dactyloctenium aegyptium* (a grass) and *Indigofera hirsuta* (a shrublet) were found to be the dominant species in the area. The life form composition (Figure 4.1-2) shows an abundance of the Herb life form (58%), the other life form categories being poorly represented. Species diversity was very low (Shannon's Index, H'=1.124).

Figure 4.1-2
Life form Analysis of the Coastal Scrub and Grassland Vegetation of Tema



A large portion of the natural scrub vegetation of the WAGP route at Tema has been converted into vegetable and food crop farms. The main crops on the farms are maize, Okra, cowpea and pepper. This accounts for low the species diversity observed.

4.1.1.3 Discussion

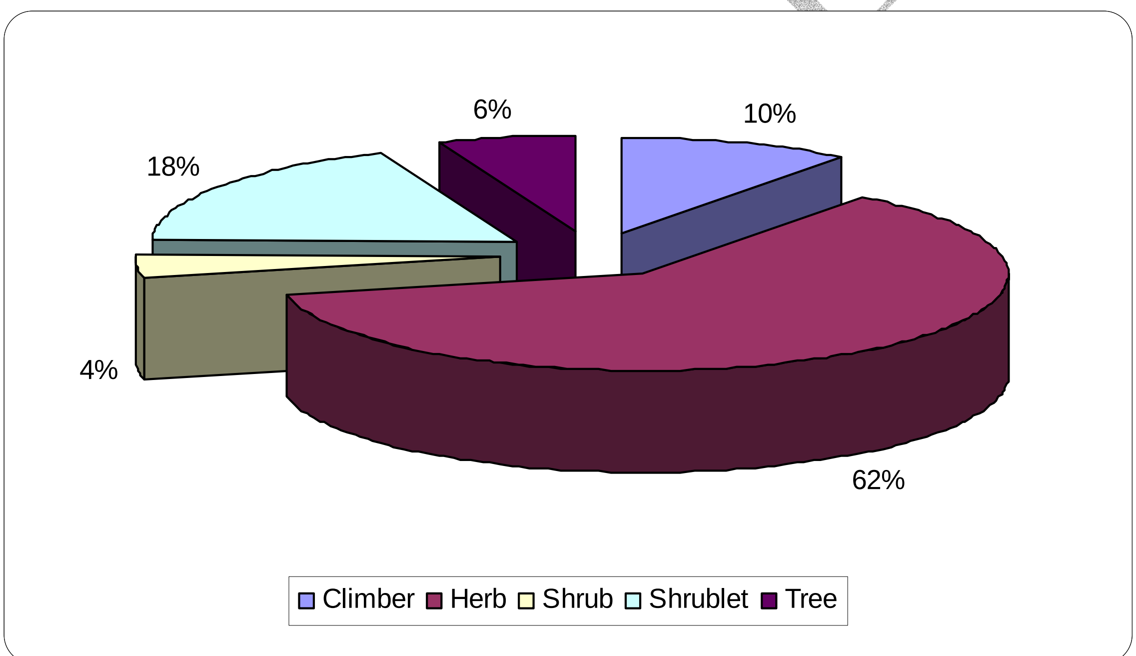
The Wet Season vegetation survey of the Tema route showed that there had been a significant reduction in the species diversity (cf. Dry Season H'=2.105 and Wet Season H'=1.56 for coastal strand; Dry Season H'=2.526 and Wet Season H'=1.124 for Scrub). The luxuriant growth of species such as *Cenchrus echinatus*, *Heteropogon contortus* and *Paspalum conjugatum* that suppresses other species, as well as farming, account for the reduction in the species diversity observed. No new species were recorded during the survey.

4.1.2 Aboadze/Takoradi

4.1.2.1 The Coastal Strand Vegetation of Aboadze/Takoradi

The floristic composition of the coastal strand vegetation at Aboadze/Takoradi is presented in Appendix D, Table D-8. It shows that a total of 49 species were encountered at the site. The species belonged to 41 genera in 23 families. The dominant families were found to be the Papilionaceae (39%), Graminae (35%) and Cyperaceae (22%). *Passiflora foetida, Cyperus maritimus, Asystasia calicina* and *Desmodium scorpiurus* dominated the quadrat samples. The life form composition analysis indicated a dominance of the herb life form (62%) over the other life form categories (Figure 4.1-3). Species diversity was low (Shannon's Index, H'=1.831).

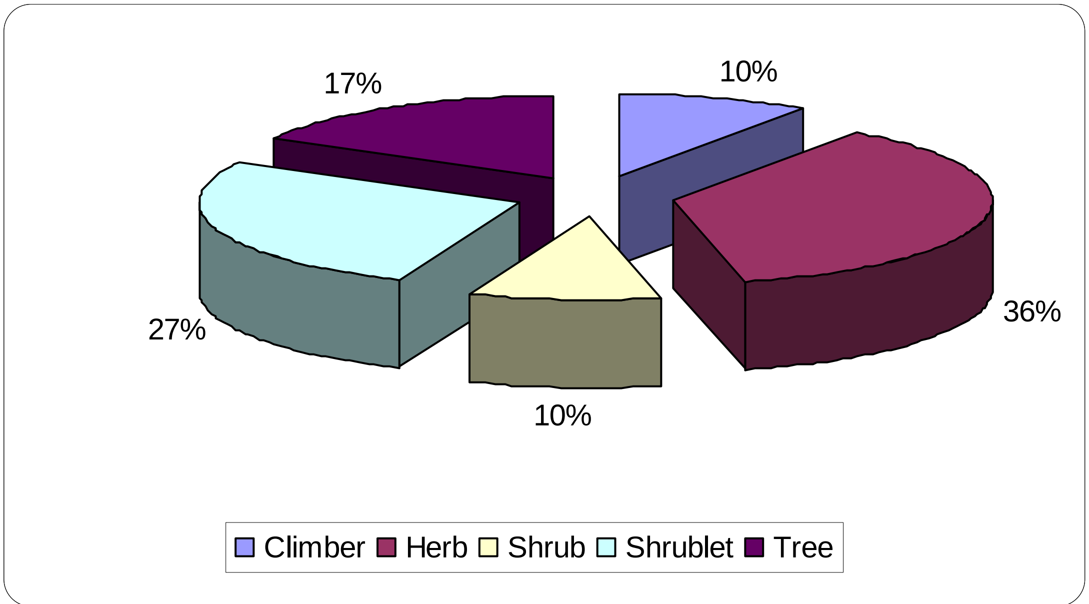
Figure 4.1-3
Life form Analysis of the Coastal strand Vegetation at Aboadze/Takoradi



4.1.2.2 The Coastal Scrub Vegetation of Takoradi/Aboadze

The floristic composition of the coastal scrub and grassland vegetation at Aboadze is presented in Appendix D, Table D-9. A total of 41 species in 37 genera belonging to 19 families were recorded. The Gaminae (42%) and Papilionaceae (32%) were the dominant families while *Paspalum vaginatum, P. conjugatum, Mimosa pudica* and *Chloris pilosa* dominated the quadrat samples. The life form composition analysis (Figure 4.1-4) shows the Herb (37%) and shrublet (27%) life forms to be well represented in the flora. Species diversity was found to be intermediate (Shannon's Index, H'=2.362).

Figure 4.1-4
Life form Analysis of the Coastal scrub and Grassland Vegetation of Aboadze/Takoradi



4.1.2.3 The Freshwater Swamp at Aboadze/Takoradi

The swamp occupies a depression between the strand vegetation and the scrub or thicket vegetation. It is dominated by *Cyperus articulatus*, which covers over 80% of the water surface. The swamp serves as receptacle of effluents from the thermal generating plant. Other species recorded in the swamp are *Cyperus iria*, *Avicennia germinans* (one individual only), *Crinum ornatum* (one individual), *Paspalum vaginatum, Pentodon pentandrus, Imperata cylindrica, Schrankia leptocarpa* (fringe) and isolated individuals of *Phoenix reclinata* (Appendix D, Table D-10).

4.1.2.4 Discussion

The Wet Season vegetation of the WAGP route at Aboadze indicated a slight reduction in species diversity in the coastal strand vegetation compared to that of the Dry Season (cf. H'=1.831 and H'=1.956 for Wet and Dry Season respectively). The Scrub vegetation however, recorded a significant change in species diversity (cf. H'=2.362 and H'=1.664 for Wet and Dry Season respectively). Some new species were recorded in the Strand and Swamp vegetations. Notable among these are *Tacca leontopetaloides* and *Avicennia germinans. T. leontopetaloides* is a rare aroid in the coastal savanna zone while *A. germinans* is a threatened mangrove species.

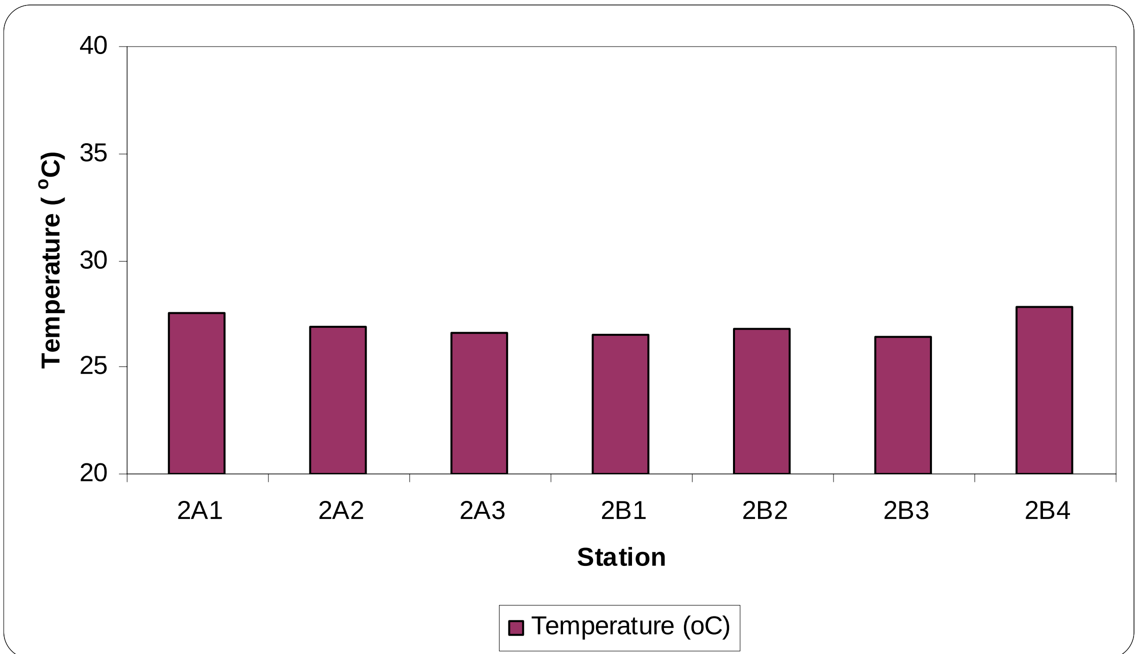
4.2 Soil Characterization

4.2.1 Physical

4.2.1.1 Tema

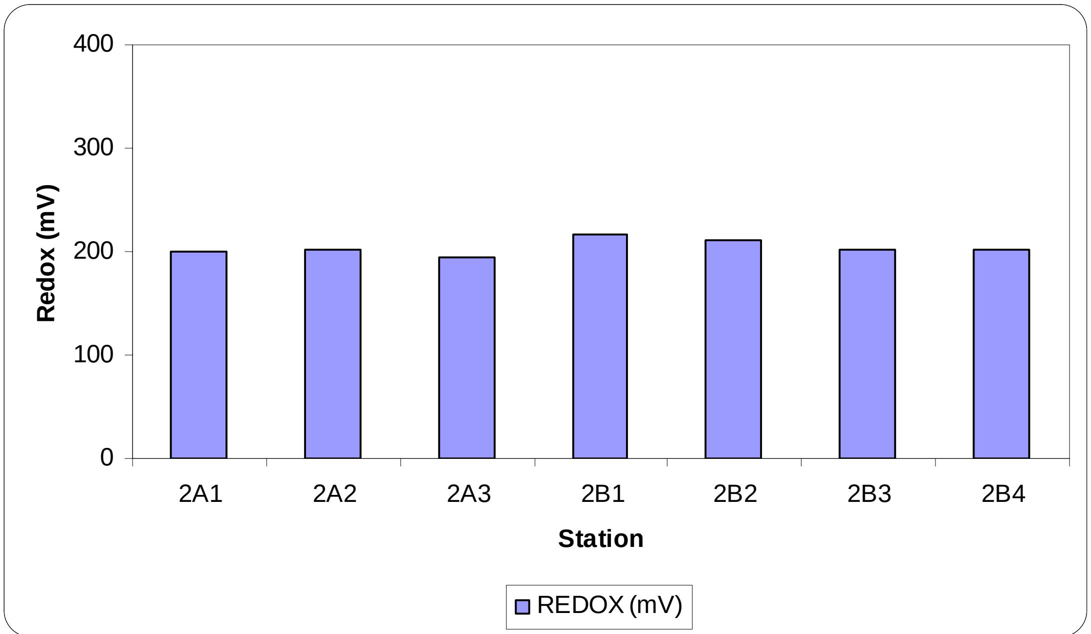
The soil temperature (Figure 4.2-1) was fairly constant for all the stations sampled and fluctuated within very narrow limits. The soil temperature ranged between 26.4^{o}C and 27.8^{o}C. Not much variability was expected in the soil temperature values, since soil temperature, to a large extend is dependent on climatic factors which does not vary much in the tropics.

Figure 4.2-1
Soil Temperature at Tema Onshore Location (Transect A and B)



Soil redox values (Figure 4.2-2) were positive for all the samples along both transect, ranging between 195mV and 216mV. Positive redox values are indicative of an oxidized state, hence the presence of adequate oxygen in the samples. Oxygen is important for soil micro and macro organisms and for processes such as decomposition in the soil. The soil samples along Transect B on the average recorded higher redox potential values than those from Transect A.

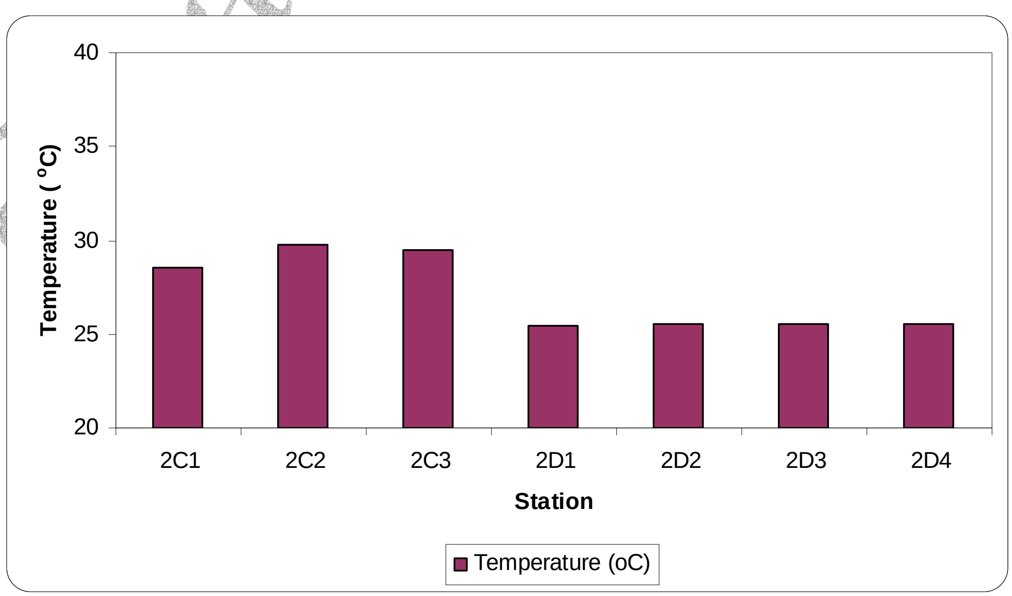
Figure 4.2-2
Soil Redox Potential at Tema Onshore Location (Transect A and B)



4.2.1.2 Aboadze/Takoradi

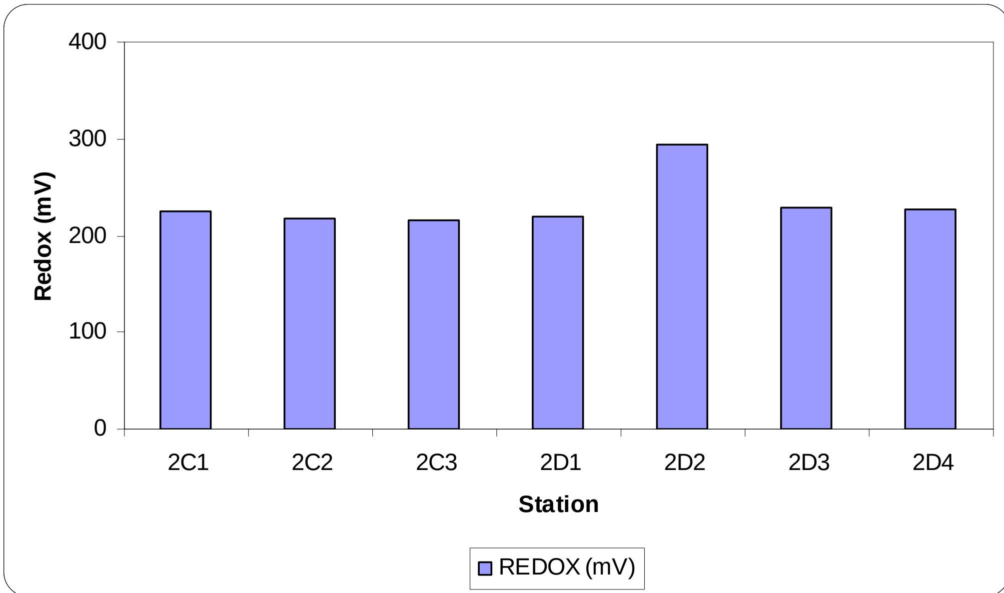
The soil temperature (Figure 4.2-3) fluctuated within very narrow limits, ranging between 25.4°C and 29.8°C. Soil temperature was higher for stations along transect C than for those along transect D.

Figure 4.2-3
Soil Temperature at Aboadze/Takoradi Onshore Location (Transect C and D)



The redox potential determined for the soil samples were all positive (Figure 4.2-4). The values ranged between 215.4mV and 293.6mV. Station D2 along Transect D recorded the highest redox potential value.

Figure 4.2-4
Soil Redox Potential at Aboadze/Takoradi Onshore Location (Transect C and D)

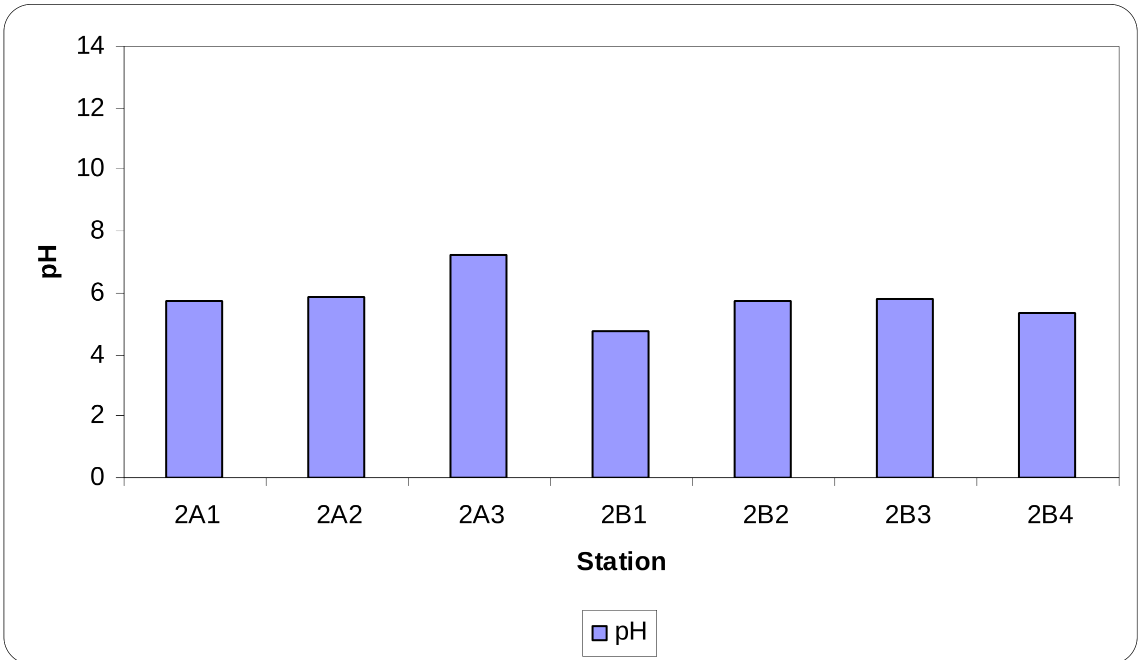


4.2.2 Chemical

4.2.2.1 Tema

The results obtained from the soil pH analysis are presented in Figures 4.2-5. The soil was, on the average, acidic with pH values ranging between 4.73 (Station 2B1) and 7.25 (Sta2A3). Soil samples from Transect A were, on the average slightly less acidic than those from Transect B.

Figure 4.2-5
Soil pH at Tema Onshore Location (Transect A and B)



The total organic carbon (TOC) contents of the soil samples (Figure 4.2-5) were generally low on both transects, ranging from 0.177 % to 0.470%. Station 2A3 on Transect A however had higher soil TOC content than the other stations.

Discussion

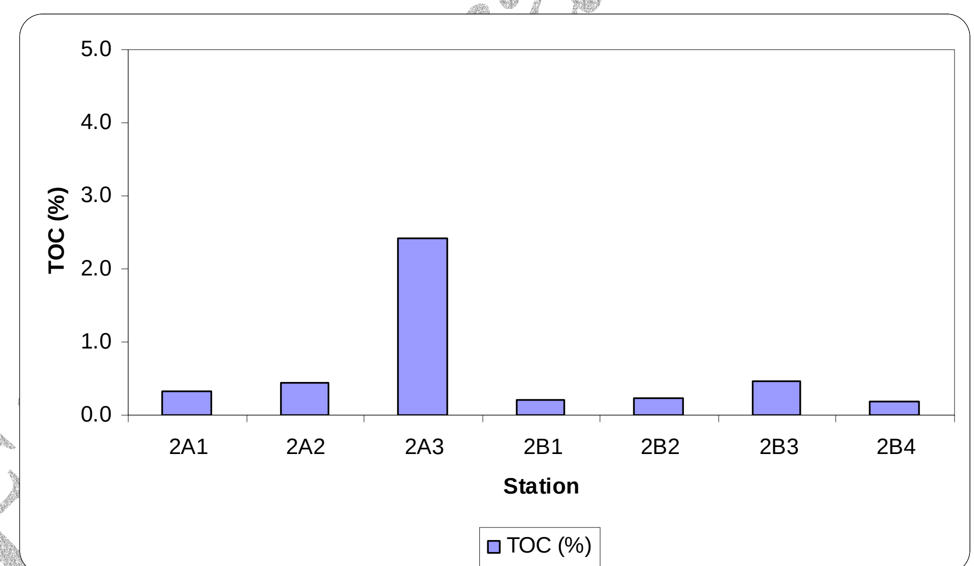
The soil temperature values were more indicative of the climate and were influenced by insolation and air temperature. The absence of seasonal extremes (such as winter) results in a relatively stable climate, influenced mainly by prevailing seasonal pattern. Soil temperature hence was not expected to vary much along transects sampled, as was observed along both transects sampled. Soil temperature is important for soil micro- and macro organisms and for processes in the soil such as decomposition.

The pH of the soil samples from Tema ranged from mildly acidic to mildly alkaline. Soil pH measures the acidity and alkalinity of the soil samples. This is again indicative of the presence of ions in the soil which are capable of accepting or donating electron pairs in solution. The pH of soil is important in facilitation soil reaction, since most chemical reactions occur at specific pH values. Soil pH is also important in creating optimum environments for the survival of soil organisms. The variations in soil pH observed for the samples is more indicative of localized differences among samples than from any significant external cue, except Station 2A3, where the more alkaline pH could be from the presence of materials in the soil.

The redox potential of a material measures the extent of oxidation or reduction of the material. Positive redox values indicate a state of oxidation while negative redox values indicate reduction. Positive soil redox potential hence serves as an index of the presence of oxygen in the soil layer, since anoxic conditions in the soil will create a highly reduced soil layer. The Tema soil samples recorded positive redox values, indicating the presence of oxygen in the soils. Station 2A3 however had a slightly lower redox potential, compared to the other stations. This could be as a result of the presence of organic materials in the soil, using up oxygen in decomposition. A visual examination of the station indicated that it was probably used as a dumping ground of refuse, since it contained traces of domestic garbage. Soil oxygen is important for soil micro- and macro organisms and for other soil processes such as decomposition, which is largely an oxidative process.

Soil TOC content measures the amount of organic carbon in soil samples. Organic carbon content may also be an index of some level of organic pollution in the soil, such as if the site had previously been used as a refuse dumping ground. The soil organic content at Tema (Figure 4.2-6) were low except for Station 2A3 at Tema along Transect A which was much higher. As was previously noted, the redox potential for soil samples from the station were slightly less than for the other stations. This factor, in addition to the higher TOC content serves to back up the observation of the site as a previous dumping ground for garbage.

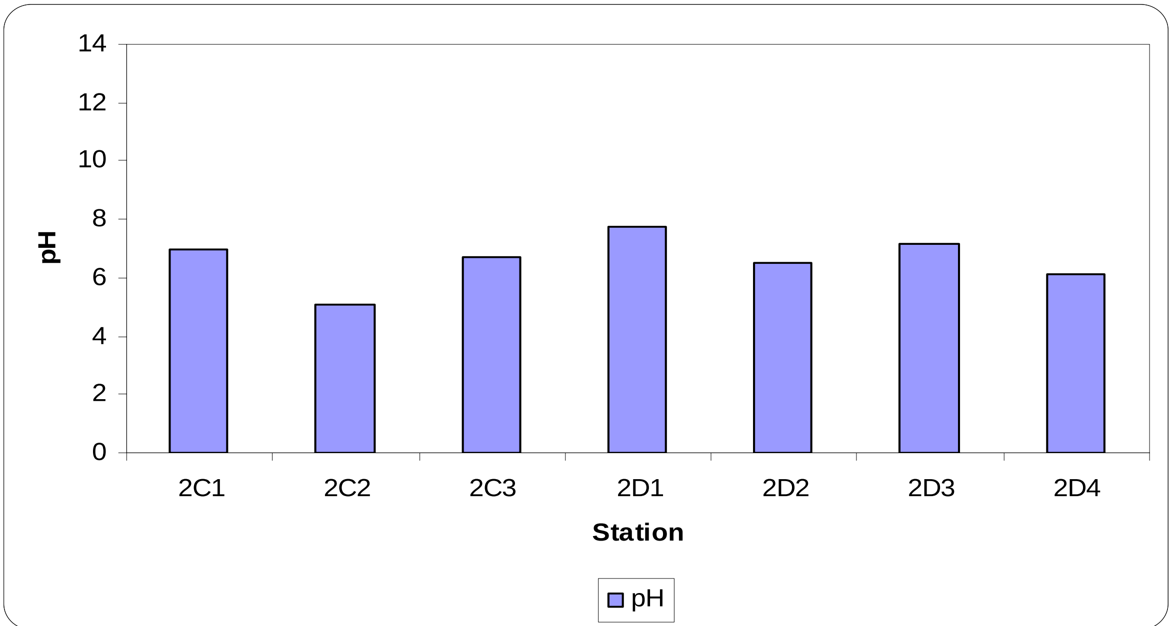
Figure 4.2-6
Soil Total Organic Carbon (TOC) Content at Tema Onshore Location (Transect A and B)



4.2.2.2 Aboadze/Takoradi

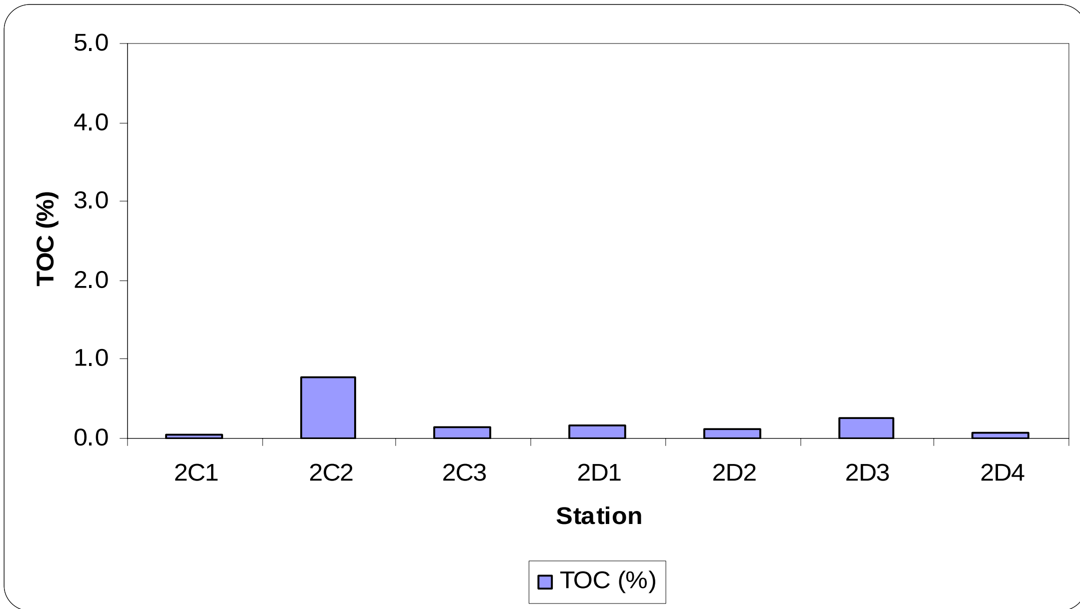
The soil samples along the Aboadze/Takoradi transects (Figure 4.2-7) were, on the average, slightly acidic with their pH ranging between 5.11 and 7.76. The soil pH on Transect C, on the average, was slightly more acidic than that for Transect D. pH was highest for sample 2D1 and lowest for 2C2.

Figure 4.2-7
Soil pH at Aboadze/Takoradi Onshore Location (Transect C and D)



Results of the total organic carbon (TOC) content of the soil samples (Figure 4.2-8) ranged between 0.059% (Station 2D4) and 0.769% (Station 2C2). TOC content was low on both transects. Station C2 on Transect C however recorded a much elevated TOC content than the other stations.

Figure 4.2-8
Soil Total Organic Carbon (TOC) Content at Aboadze/Takoradi Onshore Location (Transect C and D)



Discussion

The soil temperature from the Aboadze/Takoradi sites were similar and fluctuated within very narrow limits. Samples from Transect C had, on the average, a higher soil temperature than those from Transect D. This difference could be more a function of the location of the transects As was discussed previously soil temperature is more a function of prevailing climatic conditions, which are fairly constant in the tropics and do not vary much.

The pH of the soil samples were from mildly acidic to mildly alkaline and did not show much inter-station variability. Station 2D1 though had a more alkaline pH than the other stations while Station 2D4 had a more acidic soil. These differences are seen to be normal fluctuations expected in samples and does not indicate any major difference in the soil pH of the Aboadze/Takoradi ROW.

The redox potential of the sediment at the Aboadze/Takoradi onshore location was positive. The redox potential were similar to each other with the exception of Station 2D2 which was significantly higher. No particular reason is immediately attributable to this observation, though it is possible that the soil sample from the station may contain less organic material, hence is more oxidized.

The soil TOC was generally low. No significant distribution pattern was observed among the samples from both transects sampled. Station 2C2 on the average had slightly more TOC content than the other stations; an indication of a more elevated organic content.

4.2.3 Biological

4.2.3.1 Tema

Soil ecology

Species diversity and abundance at this site was low. Eleven butterfly species belonging to three major families: pipilionidae, nymphalidae and pieridae were identified (Appendix D, Table D-12). The two *Papilio* species, *Nepheronia argia* and *Catopsilia florella* were each spotted once. None of the others were spotted more than fiver times. The diurnal arctid moth *Utetheisa pulchella* which was very common during the dry season survey was rare. In this study 5 individuals were spotted. The satyrids as well as the lycaenids which were strongly associated with the grass and *Tridax procumbens* were also not present. A few acridid grasshoppers were associated with the grasses.

Transect A

Pitfall trapping at Point A yielded one hundred and sixteen (116) individuals. These were identified into 14 species of arthropods belonging to 7 orders. The orders included all the major ones: hymenoptera, Diptera, Coleoptera, Isopoda, Araneae, Heteroptera and Orthoptera.

The most predominant group in terms of abundance at Point A was the insect order hymenoptera followed by the Diptera. The most abundant species was *Pheidole megacephala* forming 50% of the total. The least represented were the Coleoptera, Heteroptera, and Isopoda. Each of these formed between 1-2% of the total. The only diptera observed was the greenbottle fly *Lucilia sericata.*

Analysis of soil core samples taken at the point locations indicated that 14 individuals belonging to six orders were represented. The top soil cores (0-15cm) for all the three point locations along this transect contained one form of invertebrate. Of the typical soil inhabiting (terrestrial) invertebrate species only one earthworm species *Eudrilid* sp. and a single wood louse *Oniscus* sp. were recorded from the top core at point A3. A single individual of *Geophilomorph* species of centipede was recorded from the top soil core at point A 1. Nothing was recorded from the deep soil cores of (15-50cm) at points A1 and A3.

General sampling (meandering) at this location indicated that density of ant nests was about two (2) per square meter. The nests belong to five species: *Camponotus aquapimensis, Camponotus (Myrmopelta) barbarossa, Pheidole megacephala, Pheidole* sp. and *Crematogaster castanea*. Of the sixty (64) ant nests 73% were active, 27% not in use or abandoned. The most common nests belonged to *Pheidole megacephala*. Three small mounds of *Macrotermes natalensis* were noted at this site.

Transect B

Arthropod abundance was higher at transect B than at A. A total of three hundred and ninety one (391) individuals comprising 18 species in 7 orders were recorded from the pitfall trappings. The most common arthropods recorded belong to the Hymenoptera of which the most abundant was the shiny black medium size ant *Camponotus (Myrmopelta) barbarossa*. This species form 51% of the total arthropod fauna recorded followed by *Crematogaster castanea* (13%). The greenbottle fly *Lucilia sericata* formed 3 % of the total. Woodlice which are typical terrestrial invertebrates were poorly represented. Only 4 individuals belonging to two species were trapped.

The soil cores at the points along the transect at this location yielded a rather low invertebrate diversity. Only 2 larvae of a scarabid beetle, 2 individuals of Pheidole megacephala and 3 shells of a small snail (mollusc) were recorded. Points B2 and B4 yielded no invertebrate for both top and deep soil cores. All the three snail shells were observed from point B1.

General sampling (meandering) in quadrats indicated that 4 species of ants nest at this site. These were *Camponotus (Myrmopelta) barbarossa, Camponotus acquapimemsis, Camponotus vestitus* and *Oecophyla* sp. A higher nest density was recorded at this site than at A. A total of 116 nests were recorded indicating a density of about 4 nests per square meter. Most of the nests were in the process of being excavated. About 89% of the nests were active, 11% inactive or abandoned. Nests of *C. barbarosa* and *C. aquapimensis* were the most abundant and were mainly concentrated at point B2. This point and surrounding area had been cleared for farming activities and consisted of dry sandy soil. The former species formed conspicuous crater nests with single or multiple entrances in the loose soil while the former formed simple holes with rounded openings on hard ground.

Several termite mounds were observed in the vicinity. Eleven mounds of *Macrotermes natalensis* were noted within the sampling site and general surroundings. The scattered thickets consisting of neem trees and other plants at the site also contain mounds of termites as well as of ants.

Abundance of macrofauna and species diversity

The analysis of macro fauna abundance shows that transects B has twice the number of species as compared to transect A.

Discussion

Generally diversity and abundance of macro fauna was low at the sites considering the season. However the presence of typical soil macrofauna such as ants, termites, earthworm woodlice and staphylinid beetles indicate that the health status of the soil is quite good. These however, occurred in unexpectedly low numbers. The presence of the greenbottle fly *Lucilia sericata* in the pitfall samples from both transects at Tema, is explained by the dumping of fish waste by some factories at the industrial area.

The almost complete absence of earthworms at the transects A and B may indicate very low levels of humus or organic matter in the soils.

Very few (Isopods) woodlice were present in the samples at the transects. The results also suggest a slightly more calcareous nature of the soil. Woodlice are generally more abundant in calcareous than acidic soils. It also indicates that even though some amount of farming is carried on, transect B insecticides or herbicides are either not used at all or used on a low level. Even though there appears to be a lot of debris, pieces of rocks and other materials thrown about near the site, the area along the transect points did not have these characteristics as a result of which many arthropods foraged but did not nest especially the ants.

Isopods generally respond quickly to environmental contamination and impact with increased mortality, loss of biomass and a decrease in the number of species resulting from heavy levels of pollution. Isopods can accumulate high levels of heavy metals and so can be used as bioaccumulators of these metals to monitor pollution.

In addition they are large, conspicuous and easily collected so are well suited to act as bioindicators of contamination and pollution. It is there suggested that putting in place a monitoring system using woodlice could be useful.

Microbiology

The study involved the isolation and identification of total coliform bacteria, thermotolerant coliform bacteria, *Pseudomonas* spp., *Clostridium* spp., Sulphate-reducing *Desulphovibrio* spp., hydrocarbon oxidizing bacteria, hydrocarbon degrading bacteria, and total heterotrophic bacteria, as well as the moulds and yeasts. The microbes isolated in the transects A and B bulk samples are presented in Table 4.2-1.

The levels of total coliform for the various soil samples were all high ranging from 72 x 10^2 to 23 x 10^4 cfu/100 ml. Levels of faecal coliform obtained were low, an indication of less contamination of the soil with faecal matter. Faecal coliform counts were all less than 1 cfu/100 ml.

Pseudomonas spp., opportunistic pathogens, which are also active in the breakdown of petroleum products were found to be more abundant in the soil samples with values ranging from 3 x 10^2 to 30 x 10^2 cfu/ml.

Hydrocarbon oxidizing bacteria and hydrocarbon degrading bacteria, together with total coliform bacteria, formed the largest group of bacteria present. Values for the hydrocarbon oxidizers ranged from 27 to 110 cfu/g. The values of hydrocarbon decomposers ranged from 2 to 13 cfu/g. The high proportion of hydrocarbon decomposing bacteria in the samples is an indication of the presence of high oil content in these soil samples. The levels of clostridia present in the various soil samples were high. Values ranged from 46 cfu/g to 960 cfu/g. Sulphite-reducing *Desulphovibrio* spp. was not detected in any of the samples analyzed.

Moulds were present in the soil samples and ranged from 18 to 120 cfu/g. Yeasts cells isolated ranged from 15 to 34 cfu/g. Mould and yeasts are important oil decomposers in the environment.

Table 4.2-1
Levels of isolated Microbes in the Bulk Soil Samples at Tema A and B transects

Microbial parameter	**$2A_{0-15}$**	**$2A_{15-50}$**	**$2B_{0-15}$**	**$2B_{15-50}$**
Total coliform (g^{-2})	30800	230000	7200	61600
Faecal coliform (g^{-2})	< 1	< 1	< 1	< 1
Total heterotrophic bacteria (g^{-1})	1340	1530	960	1230

Pseudomonas spp. (g^{-1})	1540	3080	340	1540
Clostridium spp. (g^{-1})	620	960	46	98
Desulphovibrio spp. (g^{-1})	< 1	< 1	< 1	< 1
Hydrocarbon oxidizers (g^{-1})	110	27	61	56
Hydrocarbon degraders (g^{-1})	13	2	16	6
Moulds (g^{-1})	75	18	120	95
Yeasts (g^{-1})	28	20	34	15

4.2.3.2 Aboadze/Takoradi

Soil ecology

Butterfly diversity and abundance were very low at this site. Nine species of butterflies were observed (Appendix D, Table D-13). None of these was spotted more than 4 times. *Papilio demodocus and Leptosia medusa* were each spotted once. A few satyrids and lycaenids were observed on the grasses and *Tridax procumbens.* The Odonata were markedly absent except one or two which occasionally seen. These were identified as *Ceriagrion glabrum* and *Aciagrion gracil* belonging to the family Coenargriidae.

Transect C

Invertebrates as observed from pitfall samples were not abundant at this site. For the entire transect only 48 individuals belonging to five arthropod orders: Hymenoptera, Diptera, Heteroptera, Coleoptera and Araneae were noted in the pitfall traps.

A rather high diversity of species, (nine), *Camponotus aquapimensis, Camponotus sericeus, Crematogaster castanea Palthothyreus* sp. *Pheidole megacephala, a* Scarabid beetle *Craspidophorus* sp. *a Chironomid* sp., *Clavigralla* sp. and a spider, Lycosa sp. were represented.

The hymenoptera constituted the most abundant forming about 90% of the total. *Pheidole megacephala* were the commonest ants in the samples collected. Several ceratopogonidae and a few mosquitoes were observed in the samples.

The soil core analysis indicated very few individuals of the earthworm *Eudrilid* sp. along this transect. Only fourteen (14) individuals restricted to points C 1 and C2 were observed. The deep core (15-50cm) of point C1 contained two and half times (2 1/2) the number of individuals in the upper core (0-15cm). The upper core of Point C2 on the other hand contained 7 individuals (50%) of the total number of earthworms with the deep core bearing none. Nothing was recorded for the point location C3.

General observations (meandering) and quadrat sampling along this transect and its surrounding indicated that 12 species of arthropods belonging to five orders: Coleoptera (beetles), Hymenoptera (ants wasps and bees), Neuroptera (antlions), Lepidoptera (butterflies) and Araneae (spiders) were represented. The Coleoptera were represented by single individuals of the carabid *Tefflus* sp. the cincindelid Catesiopus beauvoisi, the chrysomelid *Mylabris afzelli* and *Mylabris lemoulti*. The capenter bees *Xylocopa* sp. were often observed on tridax procumbens and other flowering plants. The vespid wasp *Synagris cornuta* occasionally flew along.

The quadrat sampling indicated that the density of nests at this site was about 4 per square meter. A total of 133 nests were observed of which 66% were active and 34% inactive or abandoned. The commonest arthropods were the hymenoptera of which nine species were identified in the nest mapping. There were 3 species of *Camponotus aquapimemsis, C. vestitus, C sericeus, Crematogaster castanea, Crematogaster castanea, Crematogaster depressa, Odontomachus* sp., *Pheidole megacephala and Pheidole* sp.

The *Pheidole* species nest near the bases of plants or in open sandy patches surrounded by vegetation. In the latter case they put loose gravel at the nest entrance. These ants may also form small mounds. One nest of a *Myrmeliontid* sp. was noted near the coconut trees.

Transect D

Pitfall trapping at this sample site yielded 119 individuals in 5 orders of arthropods consisting of 10 species of the Hymenoptera, Coleoptera, Orthoptera, Diptera and Araneae. The hymenoptera constituted the most abundant group making 97% of the total. *Palthothyreus* sp formed about 38% of the total followed by the three species of *Camponotus* (30%). Several midges and a few mosquitoes were also trapped.

Analysis of the soil core samples indicated a generally more invertebrates (21) and a higher diversity of species at this site than at C. Six orders of invertebrates were represented. These were the earthworm order Haplotaxida, the insect orders, Diptera, Coleoptera and Heteroptera, the crustacean Isopoda and a piece of cuticle of an arthropod or a crustacea.

Soil core sample analysis indicated a somehow vertical stratification or wide distribution of the earthworm *Eudrilid* sp. at this site. Fifteen individuals were noted with the highest number (50%) of earthworms being recorded from both upper and deep cores at Point D1. The deep cores from points D2 and D4 yielded no earthworms whilst only one was noted from the upper core of the latter point. The upper core of point D3 also had no earthworms.

Ant nests were rare with only four ant species being recorded. These were *Pheidole megacephala, Pheidole* sp, *Camponotus aquapimensis* and *Camponotus sericeus.* Six nests of the *Pheidole* spp were mapped out. The *Camponotus* species do not seem to nest in this area due to the very stony nature of the ground and the vegetation type. The *Pheidole* spp nested in the small cleared patches surrounded by vegetation. The *Camponotus* spp were only observed foraging on the plants.

Abundance of macrofauna and species diversity

The abundance species at transect D was slightly higher than transect C. The trend was similar in terms of species diversity. Transect D has a higher diversity of species due mainly to litter dwellers such as the spiders, staphylinids and bugs.

Discussion

Generally diversity and abundance of macro fauna was low at the sites considering the season. However the presence of typical soil macrofauna such as ants, termites, earthworm woodlice and staphylinid beetles indicate that the health status of the soil is quite good. These however, occurred in unexpectedly low numbers.

On the other hand the presence of many bioindicator ant species especially harvesters such as *Pheidole megacephala* and *Camponotus barbarossa* which prefer open dry sandy soil may also indicate an unhealthy state of the environment.

The representation of earthworms in the macro fauna in the soils at Aboadze (Takoradi) suggests a higher moisture and organic content. Other factors that may impose limitations on the distribution of earthworms are degree of acidity, moisture content, amount of oxygen (a factor in wet soils) and texture of soil.

Very few (Isopods) woodlice were present in the samples at Aboadze/Takoradi area. The results suggest a less calcareous nature of the soil at Aboadze/Takoradi. Woodlice are generally more abundant in calcareous than acidic soils.

Isopods generally respond quickly to environmental contamination and impact with increased mortality, loss of biomass and a decrease in the number of species resulting from heavy levels of pollution. Isopods can accumulate high levels of heavy metals and so can be used as bioaccumulators of these metals to monitor pollution.

In addition they are large, conspicuous and easily collected so are well suited to act as bioindicators of contamination and pollution. It is there suggested that putting in place a monitoring system using woodlice could be useful.

The larvae of the greenbottle fly *Lucilia sericata* feeds on carcasses, purulent wounds or dead tissue associated with septic wounds on vertebrates. This fly including the common housefly *Musca domestica* and many other true fliesare capable of causing Myiasis, a condition in which maggots infest the bodies of vertebrates.

Microbiology

Microbes isolated and identified from the soil samples were total coliform bacteria, thermotolerant coliform bacteria, *Pseudomonas* spp., *Clostridium* spp., Sulphate-reducing *Desulphovibrio* spp., hydrocarbon oxidizing bacteria, hydrocarbon degrading bacteria, and total heterotrophic bacteria, as well as the fungi moulds and yeasts.

The levels of microbes isolated in the soil samples are presented in Table 4.2-2 below. The results showed high counts of total coliform bacteria in the different samples. The soil samples contained higher levels of the coliform bacteria, recording 14 x 10^3 to 15 x 10^5

cfu/100g. Total coliform bacteria are normal flora of soil and their presence may not necessary indicate contamination. Faecal coliform bacteria count, which is an indication of possible contamination of the soil with faecal matter, ranged from < 1 to 110 cfu/100g, with sample $C_{BULK(15-50)}$ recording the highest count.

The total heterotrophic bacteria count was high and ranged from 560 to 800 cfu/100g. These included the various coliform bacteria, the *Clostridia*, the *Pseudomonas*, and the hydrocarbon bacteria. The levels of sulphate-reducing bacteria in the different sampling areas were very low. This is because the activity of sulphate-reducing bacteria is particularly apparent in mud at bottom of ponds and streams and along seashores.

Hydrocarbon oxidizing bacteria and hydrocarbon degrading bacteria, together with the total coliform bacteria, formed the largest group of bacteria present. Values for hydrocarbon oxidizers in the various samples ranged from 18 to 126 cfu/g. The hydrocarbon decomposers isolated ranged from 44 to 110 cfu/g. The presence of hydrocarbon decomposing bacteria in a sample is an indication of presence of high oil content. The levels of hydrocarbon oxidizing bacteria ranged from 18 to 126 cfu/g.

The level of *Clostridium* spp. recorded was very high for the soil samples. The values ranged from 400 to 960 cfu/g. Naturally, soil samples harbour high levels of clostridia.

There were high levels of mould but very low levels of yeasts in the soil samples. Values of mould ranged from 70 to 640 cfu/g. Moulds in soil assist with decomposition of organic compounds with some acting as pathogens.

Table 4.2-2
The levels of Microbes as Identified in the Soil samples at Aboadze/Takoradi

Microbial parameter	**$C_{BULK\ (0-15)}$**	**$C_{BULK\ (15-50)}$**	**$D_{BULK\ (0-15)}$**	**$D_{BULK\ (15-50)}$**
Total coliform (g^{-2})	14620	154000	154000	150000
Faecal coliform (g^{-2})	< 1	110	< 1	< 1
Total heterotrophic bacteria (g^{-1})	680	560	720	800
Pseudomonas spp. (g^{-1})	9	24	18	154
Clostridium spp. (g^{-1})	960	520	800	400
Desulphovibrio spp. (g^{-1})	< 1	< 1	< 1	< 1
Hydrocarbon oxidizers (g^{-1})	126	27	18	115
Hydrocarbon degraders (g^{-1})	80	44	90	110

Moulds (g^{-1})	640	440	480	70
Yeasts (g^{-1})	50	14	8	4

4.3 SURFACE WATER AND SEDIMENT CHARACTERISTICS

4.3.1 Surface Water

4.3.1.1 Physical

Tema

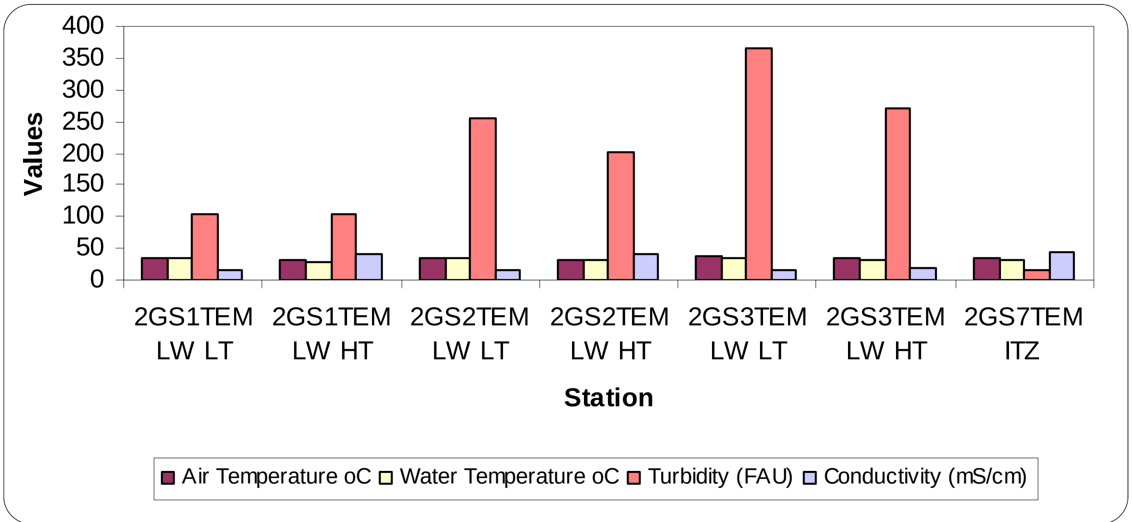
The physical parameters determined for the surface water samples were temperature, electrical conductivity (EC) and turbidity. These are presented graphically in Figure 4.3-1.

Air and water temperature values fluctuated within narrow limits at all the stations sampled, ranging between 30.1^{o}C and 37.2^{o}C (for air temperature) and 30.0^{o}C and 33.6^{o}C (for water temperature). Water temperature values were lower during high tide than during low tide. This pattern was also seen in air temperature values, leading to the inference that air temperature has significant influence on water temperature. Air and water temperature were lowest for the seawater sample.

Turbidity values ranged between 16 FAU and 366 FAU. Turbidity values were generally higher at low tide than at high tide. The values also increased from the mouth of the lagoon inwards into the lagoon. Turbidity values were lowest for the seawater sample.

The electrical conductivity (EC) values for samples from stations located in the lagoon were lower during low tide samples than during high tide. The values were also higher for stations closer to the mouth of the lagoon than for those more upstream. The EC in the lagoon samples ranged between 15.44mS/cm and 41.90mS/cm.

Figure 4.3-1
Air and Water Temperature, Electrical Conductivity and Turbidity Distribution in Surface Water at Tema



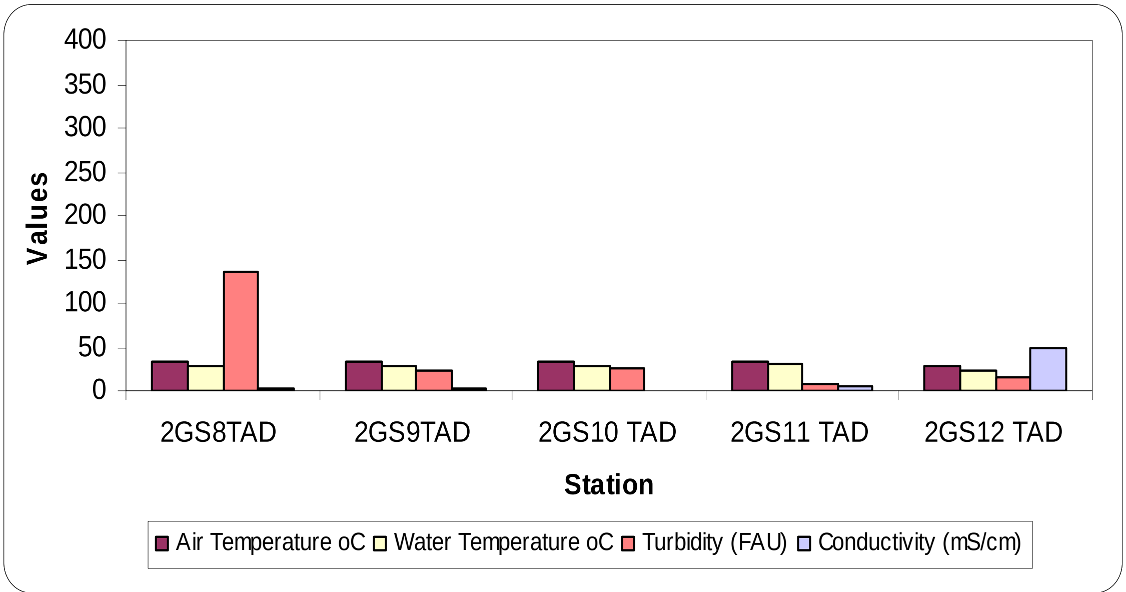
Aboadze/Takoradi

The physical parameters estimated for the surface water and seawater at the Aboadze/Takoradi onshore location are presented graphically in Figure 4.3-2.

Air and water temperature distributions exhibited a similar pattern, with values ranging between 28.7^{o}C and 34.6^{o}C (for air temperature) and 23.3^{o}C and 31.3^{o}C (for water temperature). The lowest temperature values (both air and water) were recorded for the seawater sample.

Turbidity values were highest at Station 8 and lowest at Station 11, ranging between 136 FAU and 7 FAU. The electrical conductivity (EC) of the surface water was low, compared with that for the seawater. The EC values ranged between 0.117mS/cm and 4.67mS/cm while that for TDS was between 55mg/L and 2440mg/L.

Figure 4.3-2
Air and Water Temperature, Turbidity and Conductivity Distribution in Surface Water at Aboadze/Takoradi



4.3.1.2 Chemical

Tema

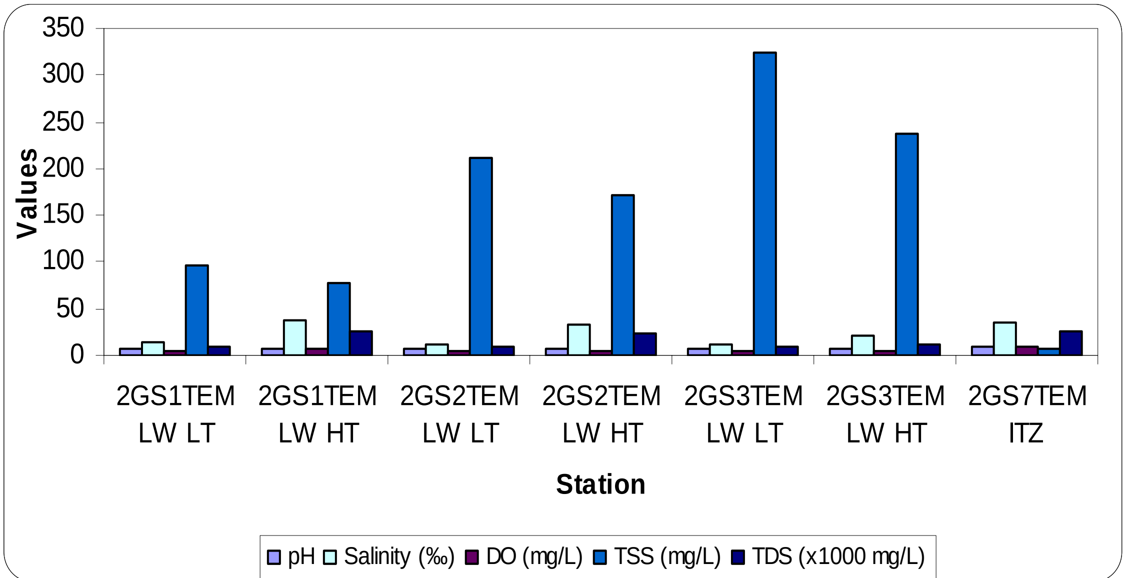
The chemical parameters were pH, dissolved oxygen (DO), total suspended solids (TSS), salinity, total dissolved solids (TDS), nutrients (ammonia-nitrogen (NH_3–N), nitrate nitrogen (NO_3–N), total nitrogen (N), total phosphorus (P), orthophosphate phosphorus (PO_4–P) and sulphate (SO_4)), alkalinity and BOD.

Figure 4.3-3 shows the distributions for pH, DO, TSS, salinity, TDS and conductivity. The water samples were generally alkaline, with the pH of the lagoon samples ranging between 8.13 and 8.22. The seawater sample recorded the highest pH value of 8.69. The dissolved oxygen values were lower for the lagoon samples than the seawater sample. The DO range for the lagoon samples were between 5.13mg/L and 6.46mg/L. No clear pattern was observed in the pH and DO values in relation to tidal effects. The high DO value (9.3mg/L) recorded in the seawater sample is believed to be as a result of wave action churning the water mass on the rocks and photosynthetic activity of the dense algal mat growing on the rocks in the intertidal zone.

The total suspended solids (TSS) distribution closely mimicked the turbidity distribution at all the stations. TSS values ranged between 8mg/L and 323mg/L. TSS values were generally higher at low tide than at high tide. The values also increased from the mouth of the lagoon inwards into the lagoon. TSS values were lowest for the seawater sample.

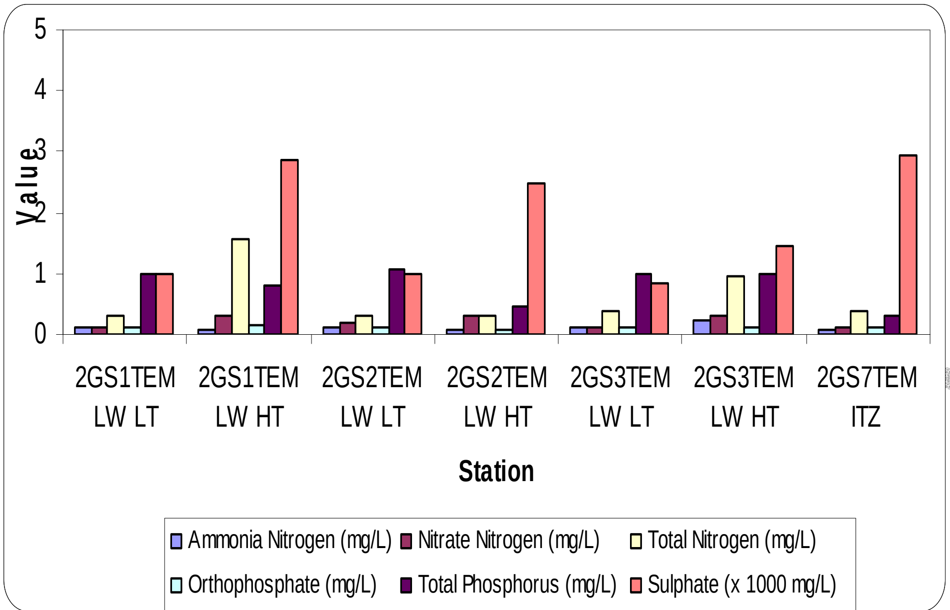
Salinity values at the stations located in the lagoon were lower for low tide samples than for high tide samples. The values were also higher for stations closer to the mouth of the lagoon than for those more upstream. The salinity in the lagoon samples ranged between 11‰ and 37‰. The salinity of the seawater sample was 36‰. The electrical conductivity (EC) and TDS distributions exhibit a pattern closely similar to the salinity distributions in all the stations.

Figure 4.3-3
pH, Salinity, DO, TSS and TDS Distribution in Surface Water at Tema



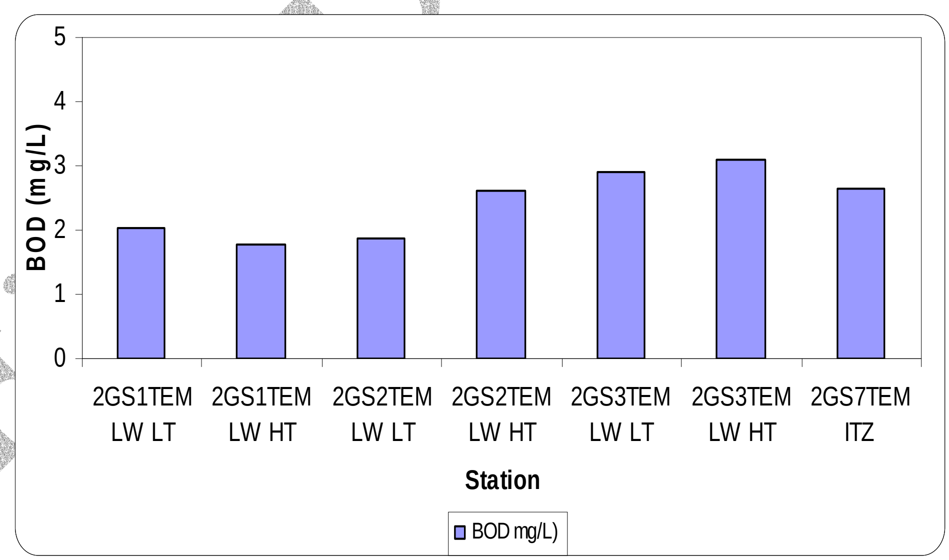
The nutrient distributions in the lagoon water and seawater samples are presented graphically in Figure 4.3-4. Ammonia-nitrogen (NH_3–N) levels generally increased from the intertidal across the mouth of the lagoon inland to the higher reaches. The same trend was evident at both high and low tides. Ammonia levels ranged from 0.09mg/L (intertidal) to 0.23mg/L (lagoon, upstream). The nitrate and total nitrogen values did not show any clear pattern. The nitrate values ranged between 0.1mg/L and 0.3mg/L and the total nitrogen values ranged between 0.3mg/L and 1.58mg/L. Orthophosphate, total phosphorus and sulphate values also did not show any definite trend among the stations. The orthophosphate values ranged between 0.097mg/L and 0.169mg/L, the total phosphorus values ranged between 0.31mg/L and 1.05mg/L and the sulphate values ranged between 850mg/L and 2950mg/L.

Figure 4.3-4
Levels of Nutrients in Surface Water at Tema



The biochemical oxygen demand (BOD) values determined for the lagoon water and seawater samples are presented in Figure 4.3-5. The values ranged from 1.78mg/L to 3.11mg/L. No clear pattern was observed in the distribution among the stations.

Figure 4.3-5
Levels of BOD in Surface Water at Tema



Discussion

Patterns of air and water temperature distributions are reflections of existing climate at the onshore location. Very little variability is seen in ambient temperature distributions in the tropics, since climatic extremes (such as winter) do not occur. Hence, the fairly stable temperature observed between the stations was expected. The difference in the water temperature between high tide and low tide is more likely a function of when the respective tidal maxima and minima occurred.

Turbidity is a measure of the transparency of water and is largely influenced by the quality and quantity of suspended matter in the water column. Water turbidity hence exhibits a direct relationship with total suspended solids (TSS). Sources of suspended matter in the lagoon may be mainly allochthonous, coming from landward sources rather than authochthonous, which could be as a result of the resuspension of sediment in the water column. Hence it is seen that the turbidity, hence TSS distribution of the lagoon water is higher at low tide when the net movement of water is from the upper reaches of the lagoon into the sea. This is also evident in the attenuation of turbidity as the water mass moves towards the sea.

The opposite effect is seen in the salinity, EC and TDS distributions, where the values are higher during high tide than at low tide. The lagoonal water, which is mainly from landward sources has little dissolved solids, compared to the seawater. Hence during low tide when the net movement of the water is towards the sea, the amount of dissolved solids is low. The salinity, EC and TDS values show a similar distribution pattern since they are all influenced by the amount of dissolved solids in solution.

No clear pattern was observed in the nutrients distribution in the lagoon and intertidal zone, with the exception of ammonia. The nutrients in the lagoon were generally low and their values were comparable with the seawater samples. Ammonia however exhibited a pattern with values decreasing towards the mouth of the lagoon. It is inferred that the ammonia in the lagoon water may have originated from landward sources (i.e. such as from domestic sewage) but was adsorbed to and settled with particulate matter in suspension in the water, or was released in the gaseous form, hence the observed attenuation.

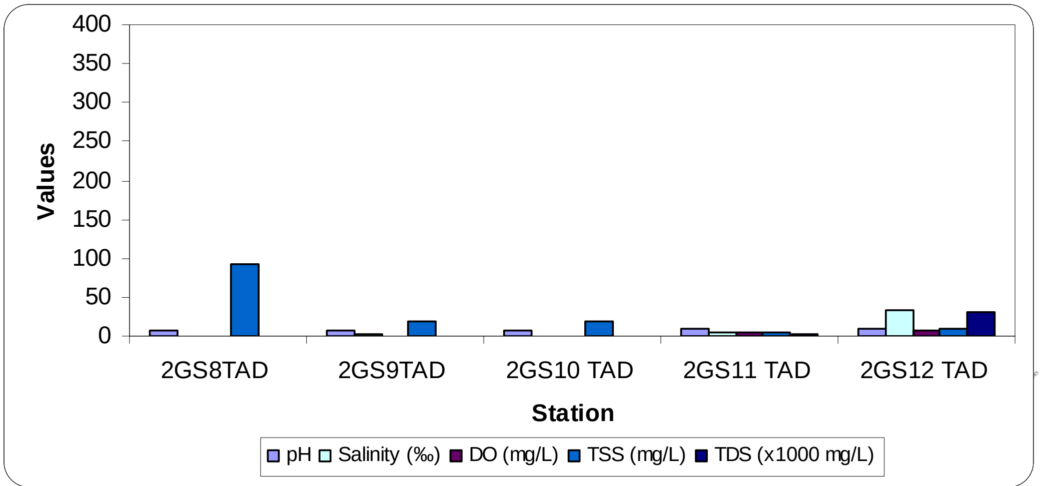
Biochemical oxygen demand (BOD) measures the amount of organic loading in an aquatic system. The BOD values measured in the lagoon indicated some form of elevated organic loading. The values were however comparable with the seawater BOD values.

Aboadze/Takoradi

The chemical parameters determined are presented graphically in Figure 4.3-6. The pH values of the samples from the wetland ranged from alkaline (pH 8.33) to acidic (pH 6.63). The pH of the seawater sample was however alkaline. Dissolved oxygen values were very low for the wetland water samples with the exception of Station 11. The DO at the other stations ranged between 0.67mg/L and 1.05mg/L. The TSS distribution was similar to the turbidity distribution with values ranging from 5mg/L and 93mg/L.

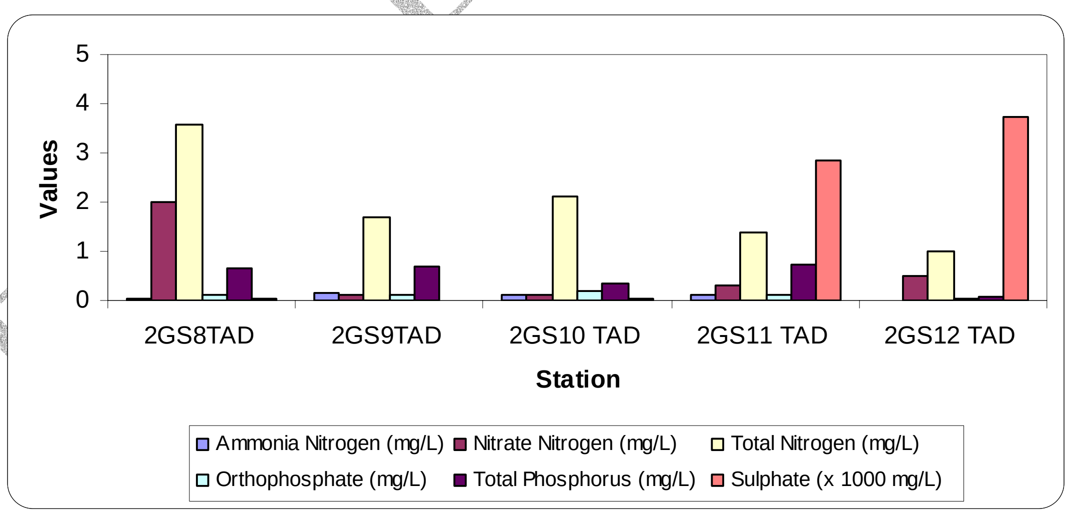
The water samples from the wetland were basically freshwater with salinity values ranging between 0‰ and 4‰. The salinity of the seawater sample was however high and comparable to seawater along the Ghanaian coast. The conductivity and TDS distributions were similar to the salinity distributions at all the stations. TDS values ranged between 55mg/L and 2440mg/L.

Figure 4.3-6
pH, Salinity, DO, TSS and TDS Distribution in Surface Water at Aboadze/Takoradi



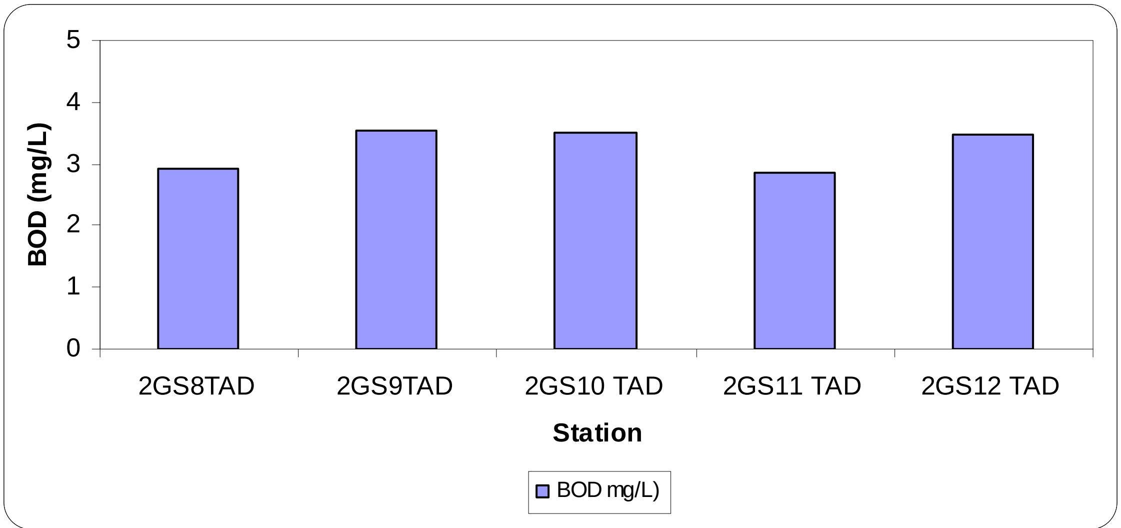
The nutrient values determined for the surface and seawater samples from Aboadze/Takoradi are presented graphically in Figure 4.3-7. Ammonia levels were generally low at all the stations sampled, ranging between 0.01mg/L and 0.16mg/L. Nitrate values were highest at Station 8 and lowest at Station 9 while the total nitrogen values were also highest at Station 8 but lowest at Station 12. The nitrate values ranged between 0.1mg/L and 2.0mg/L and the total nitrogen values ranged between 1.00mg/L and 3.58mg/L. The orthophosphate values ranged between 0.57mg/L and 0.175mg/L, the total phosphorus values ranged between 0.08mg/L and 0.74mg/L and the sulphate values ranged between 13mg/L and 3750mg/L.

Figure 4.3-7
Levels of Nutrient in Surface Water at Aboadzi/Takoradi



The biochemical oxygen demand (BOD) values determined for the wetland surface water and seawater samples are presented in Figure 4.3-8. The values ranged from 2.86mg/L to 3.55mg/L.

Figure 4.3-8
Levels of BOD in Surface Water at Aboadze/Takoradi



Discussion

The air and water temperature values measured were similar to each other and thought to be under the influence of climatic factors. The patterns exhibited could be directly related to diurnal fluctuations observed in temperature. The wetland water is lentic and experiences little mixing, as a result of the presence of weeds and other aquatic vegetation which prevent air from churning the surface of the water. This is probably the reason for the low DO values observed for the water samples from the wetland.

The water is basically fresh, since it has no connection with the adjacent sea, hence the salinity, EC and TDS values were generally low. The nutrient values did not exhibit any clear patterns but were generally low at all the stations sampled. The BOD values were comparable to the seawater samples but exhibited some level of organic loading in the system.

4.3.1.3 Biological

Microbiology

Tema

The study involved the isolation and identification of total coliform bacteria, thermotolerant coliform bacteria, *Pseudomonas* spp., *Clostridium* spp., Sulphate-reducing *Desulphovibrio* spp., hydrocarbon oxidizing bacteria, hydrocarbon degrading bacteria, and total heterotrophic bacteria, as well as moulds and yeasts.

Table 4.3-1 shows the levels of isolated microbes at the various stations during high and low tidal regimes. The levels of total coliform were all high and ranged from 2 $x10^2$ to 10 x 10^3 cfu/100ml. High values of faecal coliform were also obtained, ranging from 2 to 96 cfu/100ml.

Based on recommended and permissible levels of total coliform bacteria in the environment (WHO, 1985) sample 2GS3 (LT) qualifies as primary contact water (i.e. for swimming). Samples 2GS1 (LT), 2GS1 (HT), 2GS2 (LT), 2GS2 (HT), 2GS3 (HT), 2GS4 (LT) and 2GS4 (HT), however, qualify to be used as secondary contact water only (i.e. for boating and fishing).

The levels of *Pseudomonas* species range from 2 to 28 cfu/ml. *Pseudomonas* species are opportunistic pathogens and are also active in breakdown of petroleum products. Moulds and yeast cells were not detected in the samples.

Values for the hydrocarbon oxidizers in the water samples ranged from 36 to 180 cfu/ml and values of hydrocarbon decomposers ranged from 8 to 29 cfu/ml. The high proportion of hydrocarbon decomposing bacteria in the samples is an indication of presence of high oil content. The formation of methane is a process that occurs throughout nature. Methane is liberated in large quantities as a result of decomposition of organic substances present by various bacteria. The methane is further oxidized by hydrocarbon oxidizing bacteria. Because of the activity of methane-oxidizing bacteria, a significant amount of the methane formed in benthic sediments is oxidized and hence does not find its way up into the water mass itself.

Low populations of *Clostridium* spp. were recorded in the water samples with values ranging from 3 cfu/ml to 24 cfu/ml. Sulphite-reducing *Desulphovibrio* spp. was, however, not detected in any of the samples analyzed.

Table 4.3-1
Levels of isolated Microbes in the Water samples during Low and High tide

Microbial parameter	**2GS1 (LT)**	**2GS1 (HT)**	**2GS2 (LT)**	**2GS2 (HT)**	**2GS3 (LT)**	**2GS3 (HT)**	**2GS4 (LT)**	**2GS4 (HT)**
Total coliform (g^{-2})	3080	3850	6930	2310	200	1540	10010	4620
Faecal coliform (g^{-2})	12	2	20	14	6	4	34	96
Total heterotrophic bacteria (g^{-1})	6	11	5	10	19	30	72	68
Pseudomonas spp. (g^{-1})	15	19	6	9	9	2	25	28
Clostridium spp. (g^{-1})	6	8	6	3	5	7	24	9
Desulphovibrio spp. (g^{-1})	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	120	21	250	36	140	127	180	150
Hydrocarbon oxidizers (g^{-1})	25	8	23	14	25	29	14	25
Hydrocarbon degraders	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Microbial parameter	2GS1 (LT)	2GS1 (HT)	2GS2 (LT)	2GS2 (HT)	2GS3 (LT)	2GS3 (HT)	2GS4 (LT)	2GS4 (HT)
(g^{-1}) Moulds (g^{-1}) Yeasts (g^{-1})	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Aboadze/Takoradi

The isolated microbes in the water samples are presented below in Table 4.3-2. The results showed high counts of total coliform bacteria with values ranging from 30 x 10^2 to 77 x 10^2 cfu/100ml. Faecal coliform bacteria ranged from < 1 to 160 cfu/100ml. Based on WHO's recommended and permissible limits acceptable for water quality, all the water samples analyzed qualify to be used as secondary contact waters only, i.e. for boating and fishing.

Table 4.3-2
Values of the various Microbes recorded in Water samples at Aboazde/Takoradi

Microbial parameter	2GS8 TAD	2GS9 TAD	2GS10 TAD	2GS11 TAD	2GS12 TAD
Total coliform (g^{-2})	7700	4620	3080	6160	4500
Faecal coliform (g^{-2})	30	< 1	< 1	160	40
Total heterotrophic bacteria (g^{-1})	550	151	136	222	56
Pseudomonas spp. (g^{-1})	30	19	6	30	1
Clostridium spp. (g^{-1})	17	2	4	2	1
Desulphovibrio spp. (g^{-1})	< 1	< 1	< 1	< 1	< 1
Hydrocarbon oxidizers (g^{-1})	140	22	60	36	24
Hydrocarbon degraders (g^{-1})	18	110	12	13	56
Moulds (g^{-1})	584	26	98	140	5
Yeasts (g^{-1})	2	2	15	12	1

The total heterotrophic bacteria count was high and ranged from 56 to 550 cfu/ml. This consisted of total coliform bacteria, thermotolerant (faecal) coliform bacteria, *Pseudomonas* spp., *Clostridium* spp., Sulphate-reducing *Desulphovibrio* spp., hydrocarbon oxidizing bacteria and hydrocarbon degrading bacteria. The sulphate-reducing bacteria were very low in the entire study area.

Hydrocarbon oxidizing bacteria and hydrocarbon degrading bacteria, together with the total coliform bacteria, form the largest group of bacteria present. Values for hydrocarbon oxidizers ranged from 24 to 140 cfu/ml while the hydrocarbon decomposers ranged form 12 to 110 cfu/ml. The high proportion of hydrocarbon decomposing bacteria in the samples is an indication of presence of high oil content. Hydrocarbon oxidizing bacteria are found to oxidize methane in nature. Because of the activity of methane-oxidizing bacteria, a significant amount of the methane formed in benthic sediments is oxidized at the place of liberation and does not find its way up into the water mass itself.

In contrast to soil, moulds do not appear to be important oil decomposers in the marine environment although they are found in the ocean. Values for the various water samples ranged from 5 to 584 cfu/ml. The values of yeast cells in the water were very low and ranged from 1 to 15 cfu/ml. Level of *Clostridium* spp. recorded was very low. The values ranged from 1 to 17 cfu/ml.

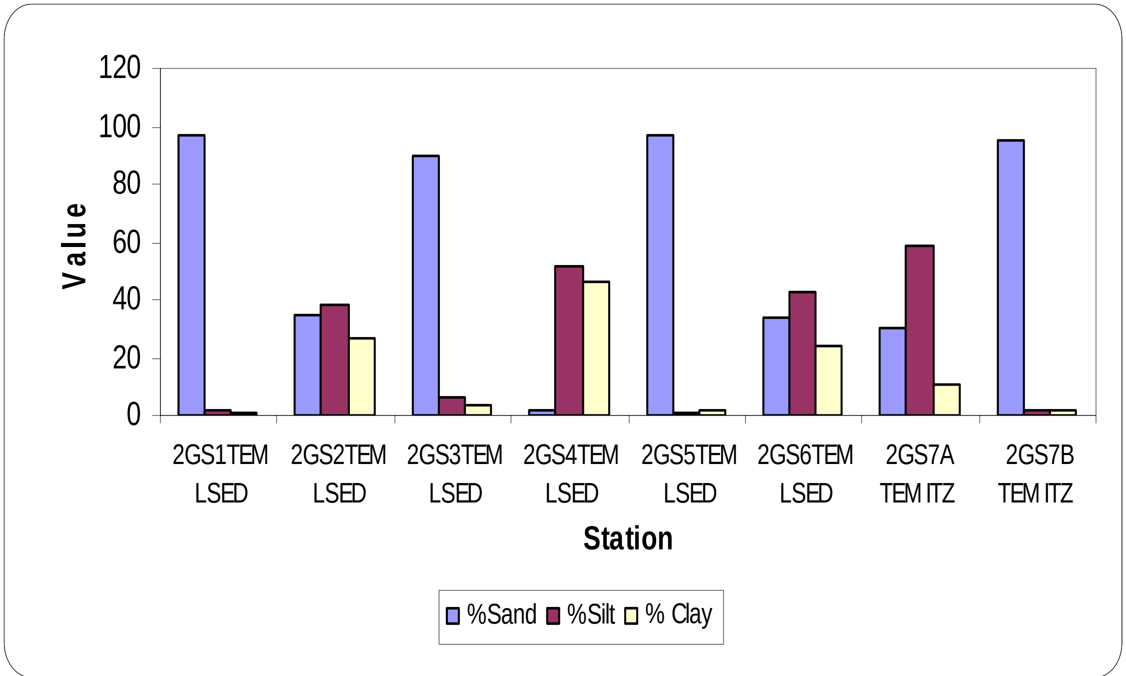
4.3.2 Sediment

4.3.2.1 Physical

Tema

The physical parameter measured was sediment grain size. Sediment grain size analysis (Figure 4.3-9) did not indicate any clear pattern in the grain size distribution. Four of the lagoon stations in addition to the intertidal zone were basically sandy with sand making up over 90% of sediment content. The other stations had appreciable amounts of sand with the exception of Station 4 which predominantly had higher silt and clay components and very little sand component.

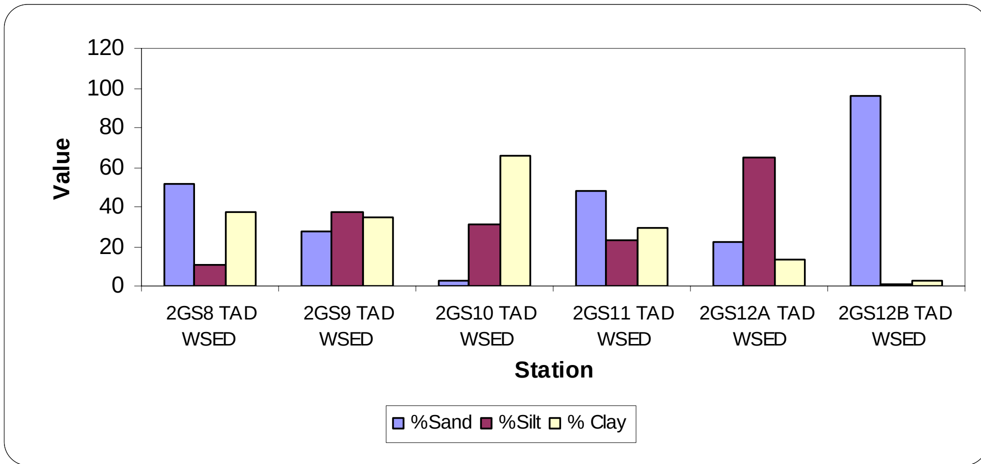
Figure 4.3-9
Sediment Grain Size Distribution at Tema



Aboadze/Takoradi

The sediment grain size distribution is presented graphically in Figure 4.3-10. The lower intertidal sediment sample was mainly sandy with sand making up over 95% of sediment grain size while the upper intertidal was largely silty. The sediment samples from the wetland were of a mixed variety containing varying percentages of sand, silt and clay. Station 10 had the highest clay percentage while Station 8 had the highest sand composition. Silt was present in appreciable quantities at all the stations with the highest silt content recorded at Station 9.

Figure 4.3-10
Sediment Grain Size Distribution at Aboadze/Takoradi



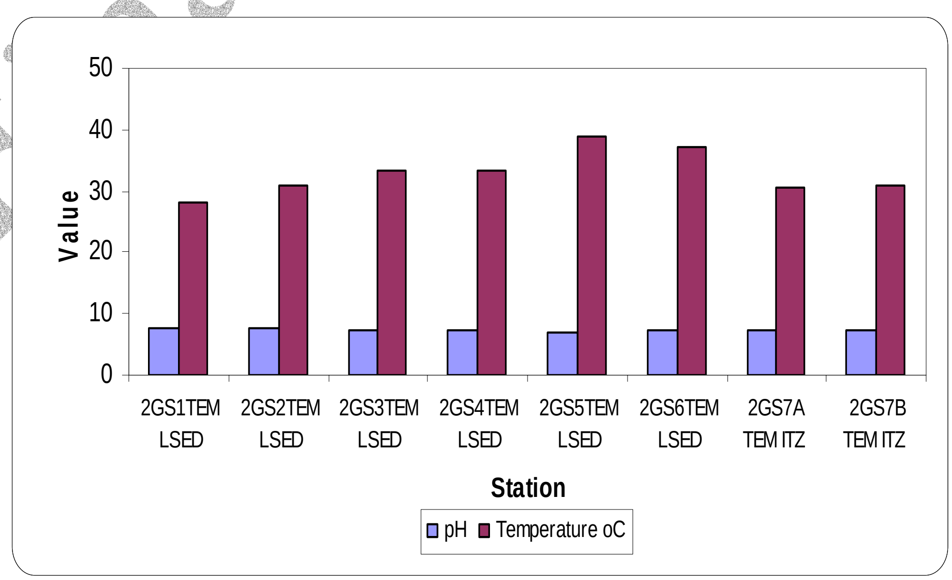
4.3.2.2 Chemical

Tema

The chemical parameters measured were, pH, temperature, redox potential, total organic carbon (TOC) and total petroleum hydrocarbons (TPH).

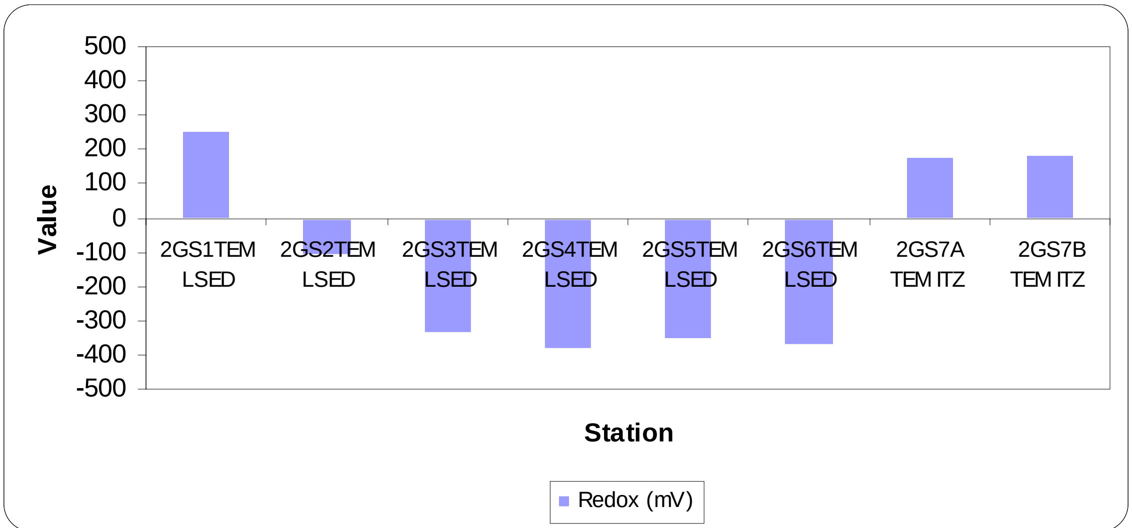
Changes in sediment pH and temperature (Figure 4.3-11) were minimal at all the stations. The variations in temperature reflect diurnal changes in ambient temperature which has a direct relation on sediment temperature. The sediment pH was slightly alkaline and ranged between 7.02 and 7.72.

Figure 4.3-11
pH and Temperature Distribution in Sediment at Tema



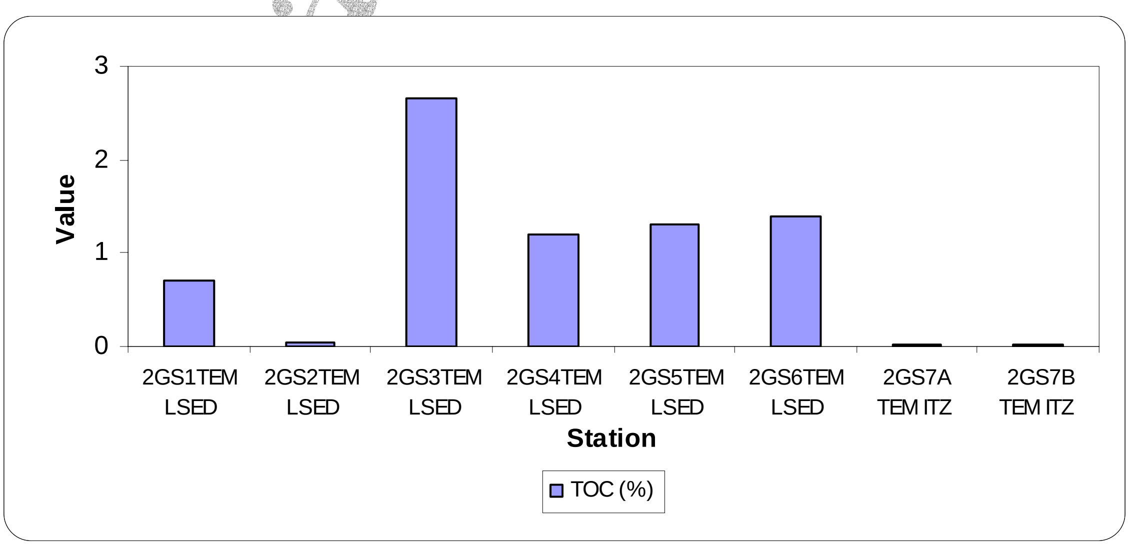
The sediment redox potential (Figure 4.3-12) was negative at most of the stations in the lagoon, indicating a highly reduced, hence anoxic conditions in the lagoon sediment. The sediment sampled at the intertidal zone was however oxidized, as indicated by the positive redox value.

Figure 4.3-12
Redox Potential Distribution in Sediment at Tema



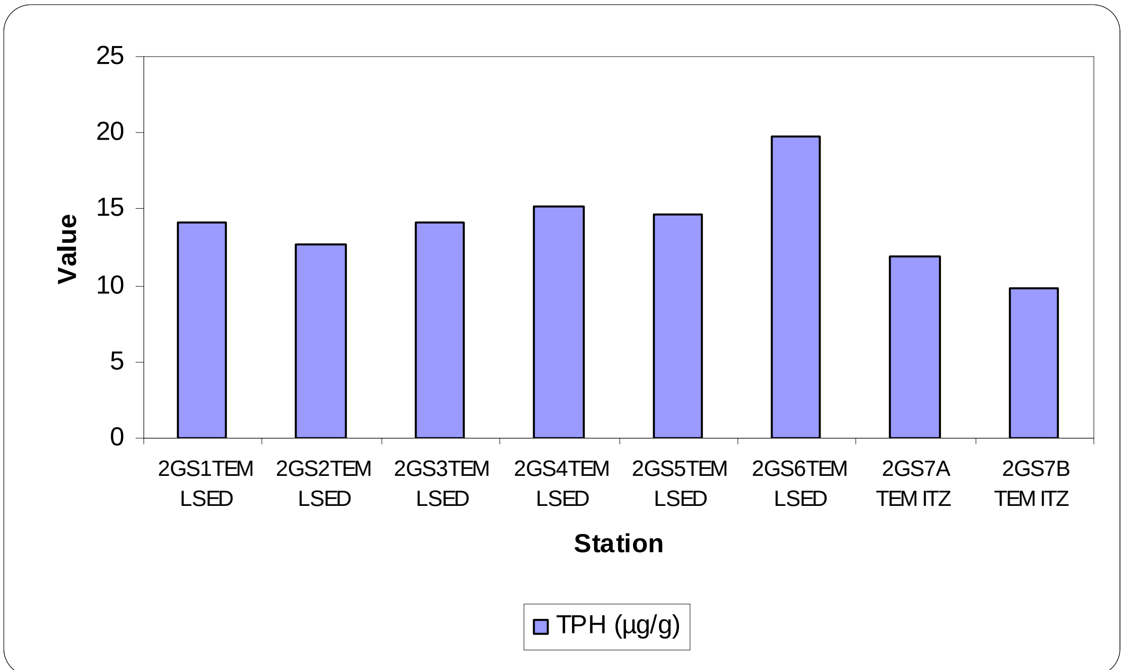
The total organic content (TOC) in the sediment samples (Figure 4.3-13) ranged between 0.02% and 2.66%. No clear pattern was observed in the TOC distribution, apart from the fact that the intertidal sediment sample and the sample from Station 2 had very low TOCs.

Figure 4.3-13
Total Organic Carbon Distribution in Sediment at Tema



The total petroleum hydrocarbon (TPH) content of the sediment samples (Figure 4.3-14) ranged from 9.8µg/g to 19.7µg/g. The highest value was recorded at Station 6 while the intertidal zone sediment recorded the lowest value. The TPH values in the lagoon sediment samples were relatively constant, fluctuating within very narrow limits.

Figure 4.3-14
Total Petroleum Hydrocarbon (TPH) Distribution in Sediment at Tema



Discussion

The negative sediment redox potential recorded for the sediment samples from Tema indicates that the lagoonal sediment is reduced, implying inadequate oxygen (or anoxic conditions) in the sediment. Sediment anoxia can be caused by high levels of organic matter which utilize oxygen during decomposition, hence depriving the sediment of oxygen. Sediment anoxia creates stress for aerobic organism in the sediment and interferes with their respiration. The sediment samples from Station 1 and the intertidal were however oxidised, indicating adequate oxygen content. Station 1, being located at the mouth of the estuary may have had most of the organic content washed out of the sediment by wave activity, hence substantially reducing the organic load there. The sediment TOC levels were lowest for the intertidal sediment samples but high for most of the lagoon samples. Some correlation is seen in the TOC values and redox potential of the sediments.

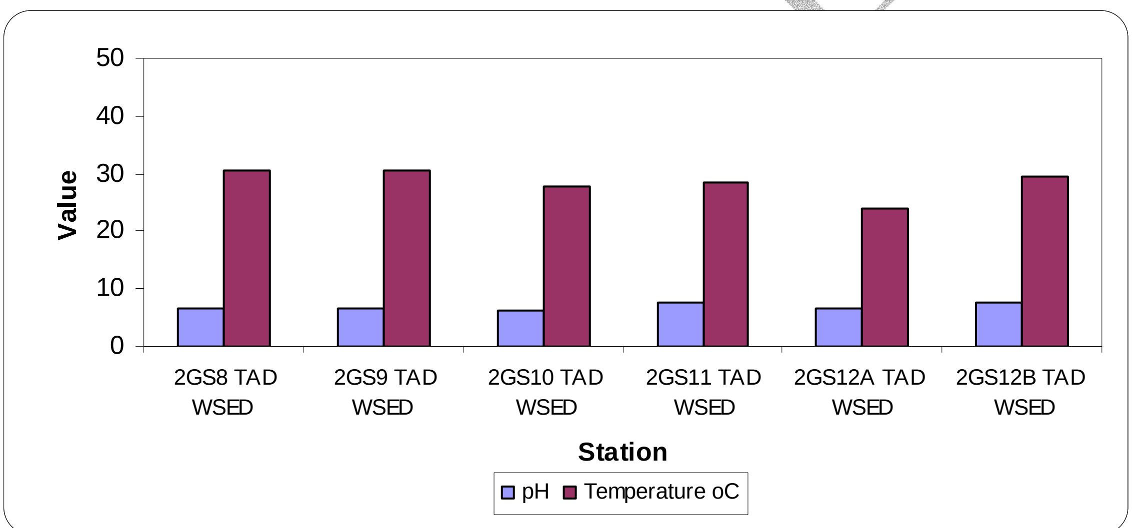
The sediment was mainly sandy or silty at most of the stations sampled. Sand dominated in the intertidal sample and the sample from the mouth of the lagoon. The high energy waves experienced at these stations may have washed out the silt and clay content of the sediment making it predominantly sandy.

The total petroleum hydrocarbon content of the lagoonal sediment samples were slightly higher than that for the intertidal sediment samples. The THC content however did not fluctuate much in the lagoon sediment except at Station 6 further inland where it is higher. Petroleum hydrocarbons may enter the lagoon from landbased sources such as fuel depots and from spillages from motor vehicles.

Aboadze/Takoradi

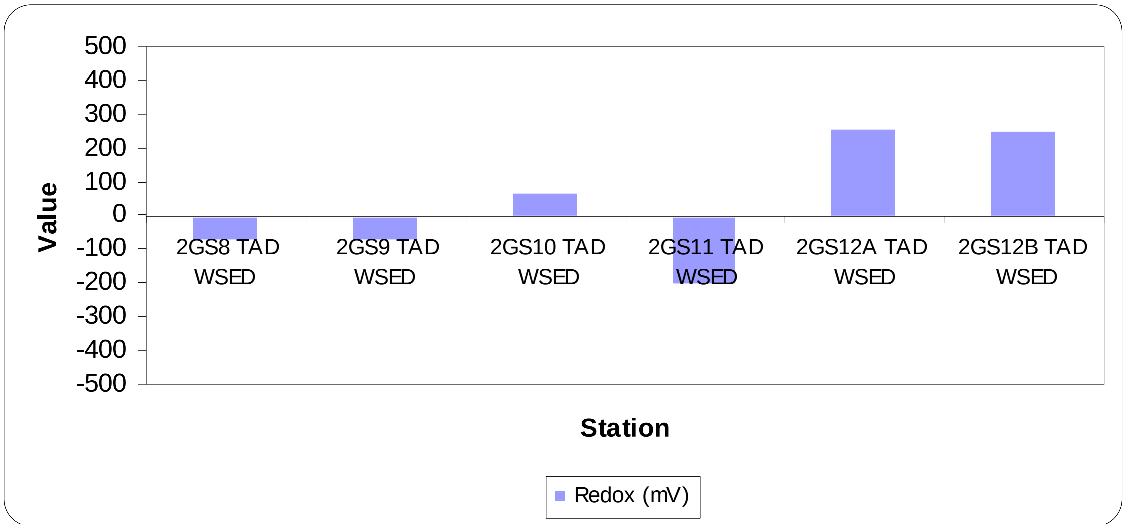
Sediment pH and temperature distributions for the wetland and intertidal zone are presented in Figure 4.3-15. The variations in temperature reflect diurnal changes in ambient temperature which has a direct relation on sediment temperature. The sediment was slightly acidic with pH values ranging between 6.37 and 7.59.

Figure 4.3-15
pH and Temperature Distribution in Sediment at Aboadze/Takoradi



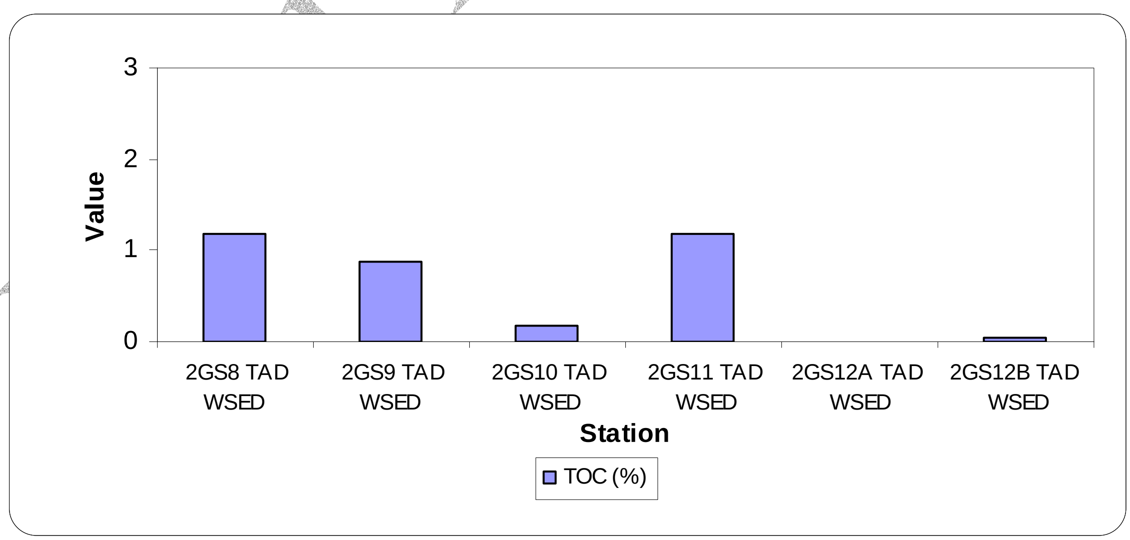
The sediment redox potential (Figure 4.3-16) indicated mainly reduced sediment in the wetland sediment samples and oxidized sediment in the intertidal sediment. This is seen in the negative values recorded at most of the stations. Station 10 however gave positive values, though this was lower in magnitude than the intertidal sediment samples.

Figure 4.3-16
Redox Potential of Sediments at Aboadze/Takoradi



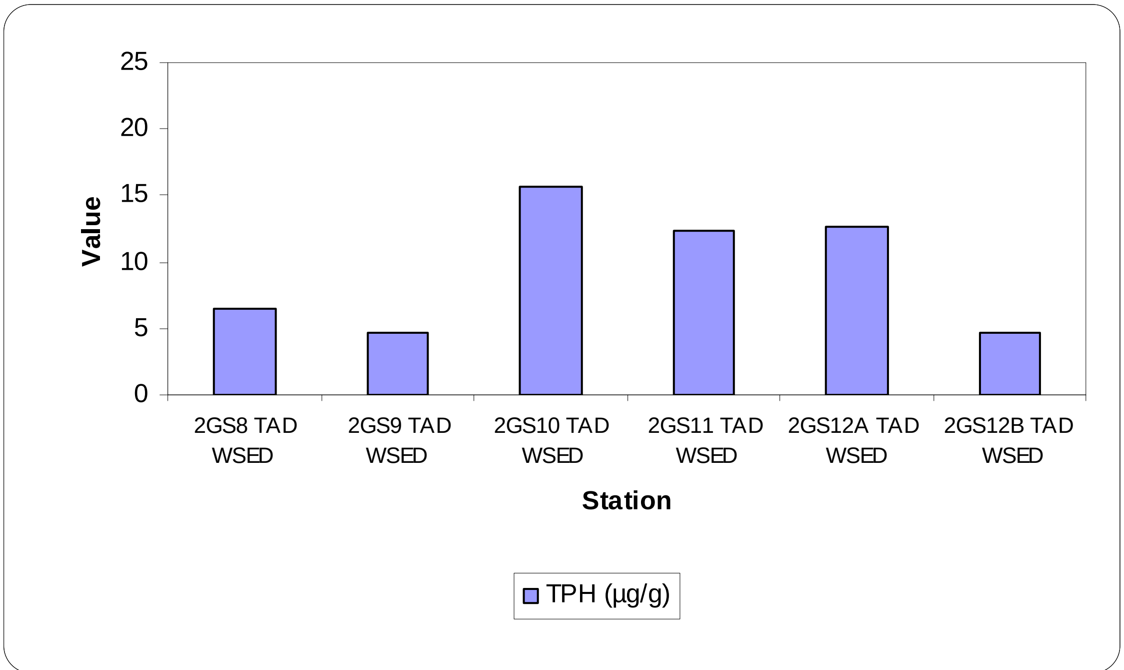
The total organic content (TOC) distribution in the sediment samples is presented in Figure 4.3-17. The sediment samples from the wetland generally had high TOC content, compared to the sediment samples from the intertidal zone. Sediment TOC values for the wetland samples ranged between 0.165% and 1.19% while the intertidal samples were 0.035% and 0.005% for lower intertidal and upper intertidal respectively.

Figure 4.3-17
Total Organic Carbon Distribution in Sediment at Aboadze/Takoradi



The total petroleum hydrocarbon (TPH) content of the sediment samples is presented in Figure 4.3-18. The values ranged from 4.6µg/g to 15.7µg/g. The highest value was recorded at Station 10. There was some variability in the TPH distribution in the wetland sediment samples.

Figure 4.3-18
Total Petroleum Hydrocarbon (TPH) Distribution of Sediment at Aboadze/Takoradi



Discussion

The pH and temperature recorded for the sediment samples from Aboadze/Takoradi did not vary much between stations. Sediment temperature probably reflected diurnal changes in ambient temperature. The sediment samples from the intertidal region were oxidized while those from the wetland were reduced, with the exception of the sample from Station 10. Station 11 which is at the point of discharge of surface water from the thermal facility exhibited the most reduced sediment. This is probably as a result of oil slicks on the water surface preventing the dissolution of oxygen in the water. The TOC content of the sediments from the wetland was also higher than for the intertidal samples. TOC at Station 10 was low, lending credence to the positive redox value obtained at that station.

The TPH content was high at Stations 10, 11 and 12A. These stations are closest to the thermal facility and may have been contaminated with some hydrocarbon substance. Station 11 which is at the point of discharge of gutter draining the surface water from the facility also exhibited a high level of TPH.

The sediment samples from the intertidal were sandy or silty whereas that from the wetland had more clay content. Station 10 had the highest clay content and the lowest sand content.

4.3.2.3 Biological

Benthic Fauna

Macroinfauna

Tema

Gao Lagoon

The number of species recorded at the Gao Lagoon, grouped into the major taxanomic groups are presented in Table 4.3-3. There were 2 species belonging to polychaeta, and one each for crustacea and mollusca. These species occur at different stations in the lagoon.

Table 4.3-3
Abundance and Distribution of Macrobenthic Fauna in the Gao Lagoon of Tema

SPECIES	2GS1 TEM	2GS2 TEM	2GS3 TEM	2GS4 TEM	2GS5 TEM	2GS6 TEM
Polychaeta						
Capitella capitata	0	0	0	1	0	0
Notomastus aberrans	0	1	0	0	0	0
Crustacea						
Hermit crab	1	0	0	0	0	0
Mysid spp.	0	0	0	0	1	0
Mollusca						
Diplodonta diaphana	1	0	0	0	0	0

In the intertidal area of the lagoon, densities of fiddler crab, *Uca tangeri*, estimated were as high as 20 burrows/m^2, along the portions of the shoreline. The gastropods, *Pachymelania* spp. and *Tympanotonus* spp. occur in large numbers with densities as high as 50/m^2 within the mangrove vegetation along the Gao Lagoon.

Discussion

The Gao lagoon at Tema does not appear to support much macrobenthic fauna as very few species were recorded. Species recorded was mainly polychaetes, crustaceans and molluscs. The polychaetes were mainly from the family Capitellidae and included *Capitella capitata* at station 2GS4 TEM and *Notomastus aberrans* at 2GS2 TEM. These species had been known to occur in organically rich environment. A mollusc and crustacean were recorded at station 2GS1 TEM, a station that has a rapid water movement frequently due to the tidal regimes.

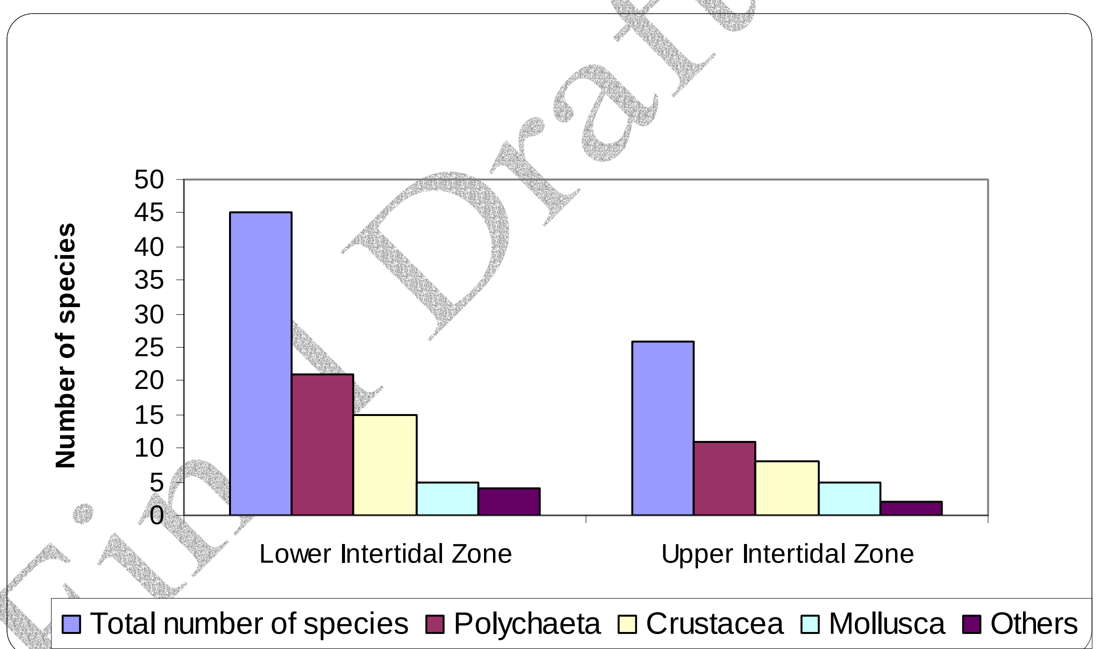
The high numbers of gastropods found in the intertidal area could be attributed to the availability of food and suitable niches and/or environmental conditions.

Intertidal

The relative abundance of common intertidal macrobenthic fauna at the Tema is shown in Appendix D, Table D-15. A total of 57 species, comprising 27 polychaete species, 19 crustacean species, 6 mollusc species and 5 species placed in 'other' category, were found in the intertidal zone of Tema locality. The species placed as 'others' category included mainly echinoderms, anthozoan, zoanthid caelenterates, sipunculids (peanut worms) and echiurana (gutter worms).

Figure 4.3-19 shows the distribution and abundance of macrobenthic fauna groups at Tema intertidal zones. The total number of species included the occurrence of all species from polychaeta, crustacean, mollusca and 'others' category. Polychaetes were the dominant group followed by crustacean, molluscs and 'others' category in that hierarchical order. However, the numbers of these species were much higher in the lower intertidal zone than the upper intertidal zone.

Figure 4.3-19
Distribution and Abundance of Major Macrobenthic Fauna at Intertidal zones of Tema

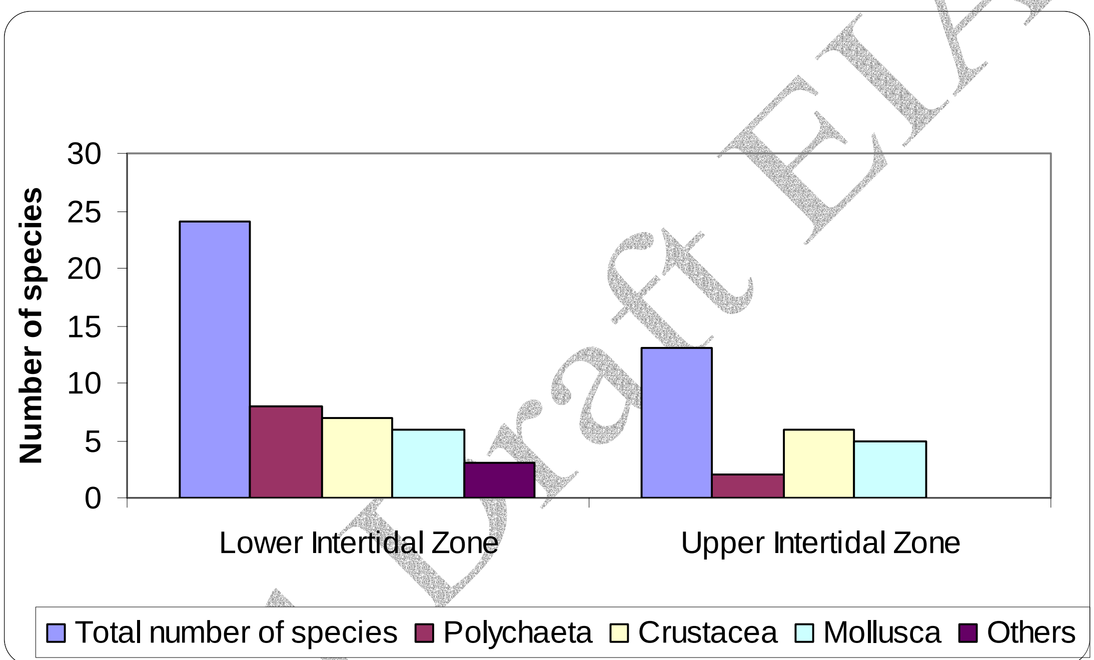


Aboadze/Takoradi (Intertidal Zone)
The species recorded in the Aboadze/Takoradi wetland is show in Appendix D, Table D-22.

No species was virtually found in the sediment analysed from Aboadze/Takoradi wetland except a crustacean species, *Ischyroceros* spp. at station 2GS8 TAD.

A total of 26 taxa comprising 8 polychaete species, 9 crustacean species, 6 mollusc and 3 species placed in the 'others' group were identified (Appendix D, Table D-22). The species placed as 'others' category included mainly echinoderms, anthozoan, zoanthid caelenterates, sipunculids (peanut worms) and echiurans (gut worms). Figure 4.3-20 shows the distribution and abundance of macrobenthic fauna groups at Aboadze/Takoradi intertidal zone. The dominant species encountered were the polychaetes in the lower intertidal zone and crustacean in the upper intertidal zone. Polychaetes ranked very low in the upper intertidal zone than crustacean and mollusc, however, species placed in the 'others' were virtually absent in this zone. The lowest rank group in the lower intertidal was the 'others' category.

Figure 4.3-20
Distribution and Abundance of Major Macrobenthic Fauna at Aboadze/ Takoradi Intertidal Zone



Discussion

The Takoradi intertidal zone, which has extensive mats of different species of algae seem to support higher species of crustaceans and molluscs. The availability of food and suitable niches could account for the abundance of mollusc and crustacean species recorded. This explains why the upper intertidal zone had low numbers of polychaetes than the lower zones, as the upper zones has little niches to explore compared to other groups.

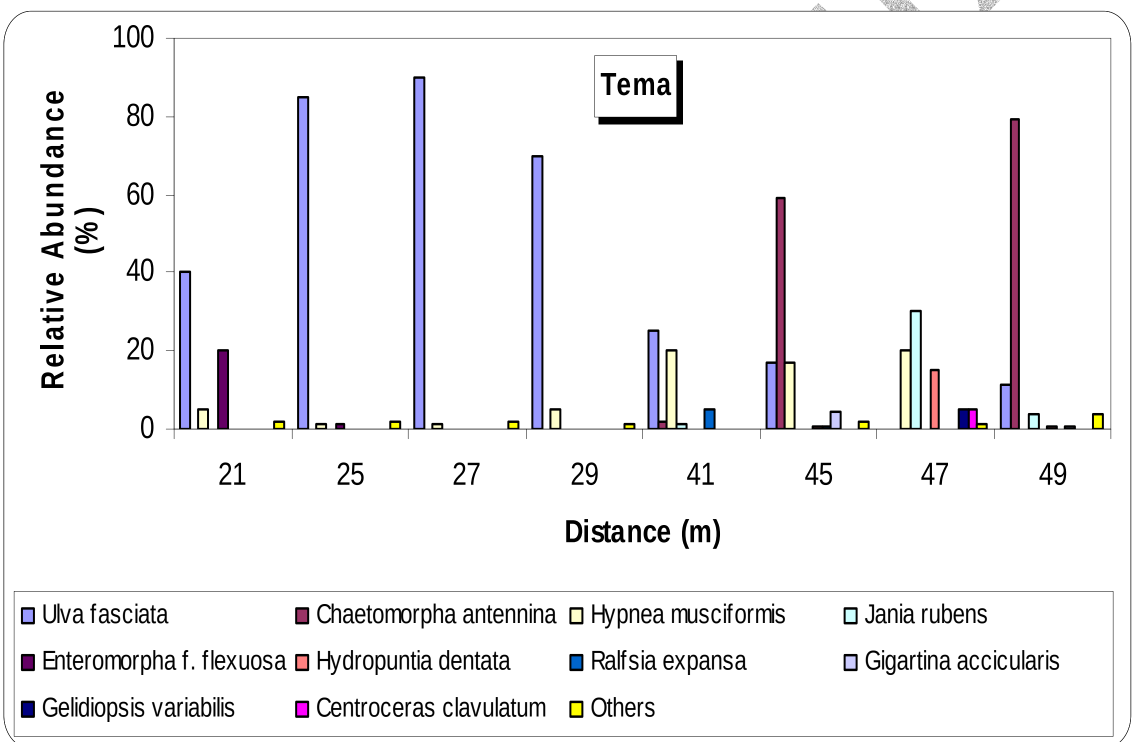
Macroalgae

Tema

The intertidal zone of the Tema site is a mixture of bedrock, boulder, cobble, shingle and shelly silty sand. The Tema seashore is an extensive shallow – sloping platform with boulders, with a high shore backfacing the open sea but close to the embayment and inlet of The Gao Lagoon. It is largely colonized by ephemeral seaweed, possibly sustained by excessive nutrients inputs derived from the catchment area. Eight quadrats were sampled in the Tema intertidal zone. The quadrats were sampled at two-meter intervals between 20m and 30m and between 40m and 50m from the low water mark.

Fourteen species of macroalgae were identified in the Tema intertidal. Figure 4.3-21 shows the abundance of the 10 most dominant species found in the environment. The algal abundance did not exhibit any clear trend along the transect sampled. Algal diversity however increased away from the intertidal. *Ulva facsciata* was most dominant and occurred in seven out of the eight quadrats sampled. The species less represented were *Centroceras clavulatum*, *Cladophora prolifera*, *Bryopsis pennata* and *Gelidium arbuscula*.

Figure 4.3-21
Macroalgal Distribution in the Tema Intertidal Zone

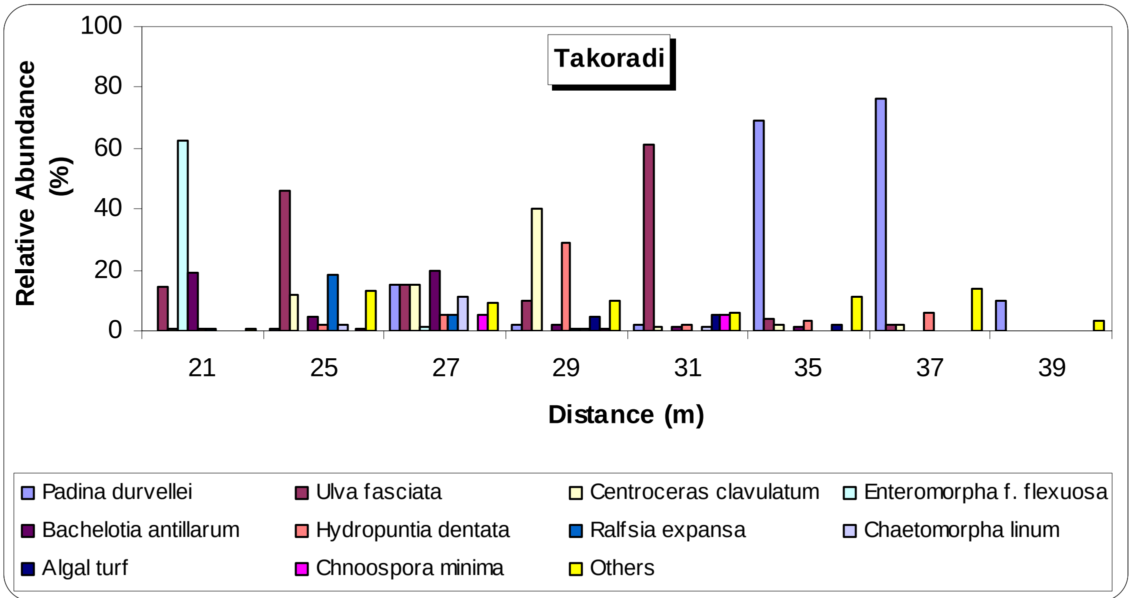


Aboadze/Takoradi

The intertidal zone at Takoradi is predominantly sandy with rocky outcrop in the lower intertidal. The algal flora is mainly located on the rocks.

Thirty species of macroalgae were identified in the Aboadze/Takoradi intertidal. Figure 4.3-22 shows the abundance of the 10 most dominant species found in the environment. *Padina durvellei* and *Ulva fasciata* were the most dominant species and occurred in seven out of the eight quadrats sampled. No clear trend was observed in the abundance of the macroalgae distribution along the transect. Species diversity however decreased along the transect in a landward direction.

Figure 4.3-22
Macroalgal Distribution in the Aboadze/Takoradi Intertidal Zone



Plankton

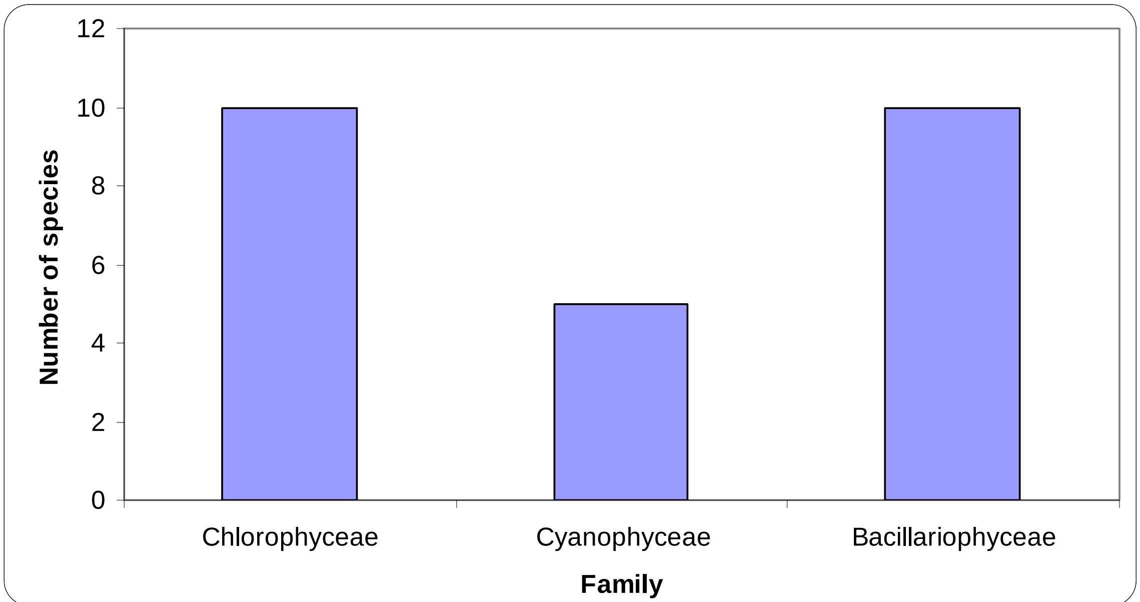
Phytoplankton

Tema (Gao Lagoon)

Results of the phytoplankton community structure in the Gao Lagoon during the wet season survey is presented in Appendix D, Table D-17b. The phytoplankton biomass in the lagoon was fairly represented in all the sampling stations. In sampling station 2GS1, closest to the sea, the blue green algae, represented largely by *Gomphosphaeria* and *Oscillatoria* dominated samples. Halfway along the length of the lagoon, station 2GS3, the dominant species was the green algae *Ankistrodesmus*. The blue green algae were represented in all the stations at relatively high densities.

In terms of species diversity in the major families the dominant group in the lagoon was the chlorophyceae (green algae). This was followed by bacillariophyceae and cyanophyceae in that order (Figure 4.3-23).

Figure 4.3-23
Species Diversity of Major Phytoplankton Groups in the Gao Lagoon and the Intertidal Zone



The largest number of phytoplankton cells was recorded for the bacillariophyceae. This was followed by the cyanophyceae and then chlorophycea in that order.

Phytoplankton Respiration, Photosynthesis and Relative Productivity in the Gao Lagoon

Results of initial dissolved oxygen measurements made in the Gao Lagoon for productivity experiments ranged from 10.8mg/L to 14.0mg/L in all the stations. DO levels in light bottles after 12-hour incubation ranged from 2.65mg/L to 5.20mg/L and the levels in the dark bottles, ranged from 2.01mg/L to 3.20mg/L (Table 4.3-4).

Table 4.3-4
Dissolved Oxygen measurements in Dark and Light Bottles in the Gao Lagoon

Sampling station	Dissolved Oxygen Content (mg /L)		
	Initial Oxygen Level (IB)	Oxygen Level in Light Bottle (LB)	Oxygen Level in Dark Bottle (DB)
2 GS 1 Tem LW	12.9	3.55	3.10
2 GS 3 Tem LW	10.8	2.65	2.01
2 GS 5 Tem LW	14.0	4.10	3.2
2 GS 5 Tem LW (2)	14.0	5.20	2.85

The computed results of gross photosynthesis, net photosynthesis, community respiration and relative productivity is presented in Table 4.3-5.

With the exception of replicated sample from station 2GS5, the level of productivity measurements showed constant decrease in magnitude from the mouth of the Gao lagoon to the upper reaches of the lagoon. Gross photosynthesis measurements were generally low and ranged from 0.42mg O_2 /L/hr to 2.35mg O_2 /L/hr.

Net photosynthesis results were negative in all the 3 stations and ranged from -9.35mg O_2/L/hr to -8.8mg/O_2/L. The community respiration, on the other hand, was high in all the 3 stations and ranged from 8.79mgO_2 /L/hr in station 2GS3 to 11.15mg O_2/L/hr while the relative productivity ranged from 11.72mgC/m^3/hr to 61.19mgC/m^3/hr (Table 4.3-5).

Table 4.3-5
Gross Photosynthesis, Net Photosynthesis, Respiration and Relative Productivity in the Gao Lagoon

Sampling Station	Gross Photosynthesis (mg O_2 / L/ hr)	Net Photosynthesis (mg O_2/ L/hr)	Respiration (mg O_2/L/ hr)	Relative Productivity (mgC/m^3/hr
2 GS 1 TEM LW	0.42	-9.35	9.8	11.72
2 GS 3 TEM LW	0.64	-8.15	8.79	16.67
2 GS 5 TEM LW	0.90	-9.9	10.80	23.44
2GS5TEM LW (2)	2.35	-8.8	11.15	61.19

Discussion

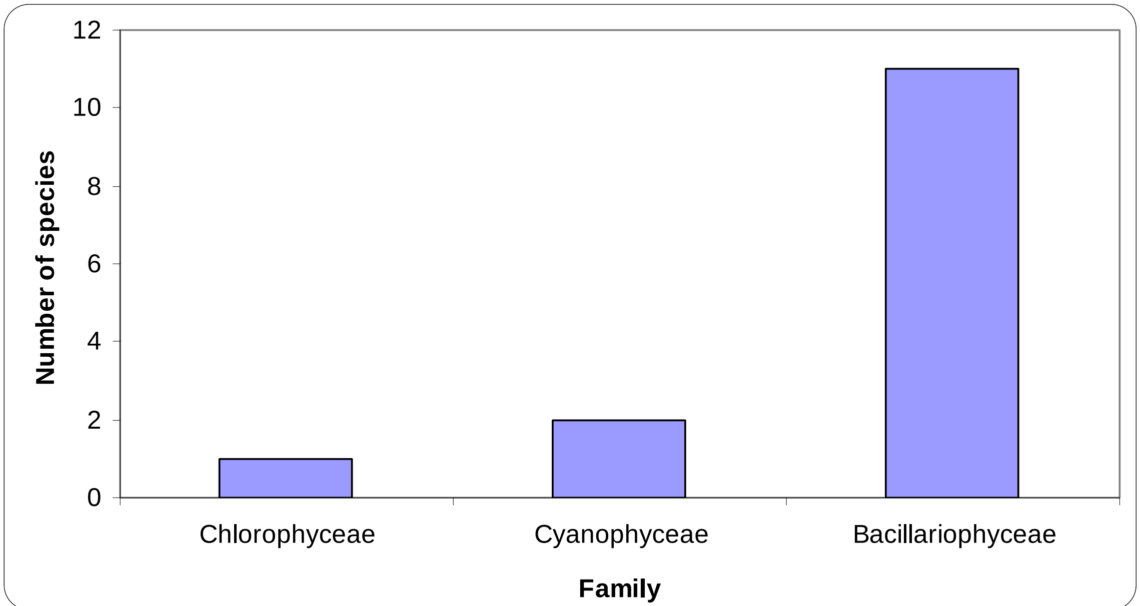
The initial high values of Dissolved Oxygen measurements made in the Gao lagoon as measured in the productivity measurements were as expected given the nature of mixing of seawater in the lagoon. The low levels of DO measurements in the light and dark bottles give an indication that air induced enrichment of the water was more important than algal and photosynthetic enrichment. This is confirmed in the low levels of Gross photosynthetic measurements made in all the three stations and the negative values of net photosynthesis. The latter values might also have been due to excessive respiratory demands by bacteria and other high demand species in the lagoon. Values of the relative productivity ranging from 11.72–61.19mgCm^3/hr however makes the lagoon a moderate primary producing water body.

Aboadze/Takoradi

Phytoplankton population structure in the Aboadze/Takoradi wetlands is presented as Appendix D, Table D-23a. In all the stations sampled in the wetlands, the phytoplankton was dominated by cynophyceae, (blue green algae) and to a larger extent the bacillariophyceae (diatoms). The green algae was very sparsely represented in samples from the wetlands.

In terms of species richness, the diatoms were the dominant forms being represented by as many as 10 species. This was followed by the blue-green algae and the green algae in that order (Figure 4.3-24).

Figure 4.3-24
Species Diversity of Major Phytoplankton Groups in the Aboadze/Takoradi Wetlands and the Intertidal Zone



Dissolved oxygen measurements in the Aboadze/Takoradi swamps indicate that the initial DO levels in the productivity measurements ranged from 5.3mg/l to 7.3mg/l. The range of DO concentration in the light bottles were all lower than the initial DO levels and ranged from 4.92mg/L to 5.20mg/L. In the dark bottles, the range of DO levels after the 12-hour incubation was 2.16mg/L to 3.88mg/L (Table 4.3-6).

Table 4.3-6
Dissolved Oxygen Measurements in the Aboadze/Takoradi Wetlands

Sampling Station	Dissolved Oxygen levels (mg/L)		
	Initial DO level (IB)	DO levels in light bottles (LB)	DO levels in dark bottles (DB)
2GS8	6.5	5.01	3.88
2GS9	6.8	4.68	2.16
2GS10	7.3	5.03	2.73
2GS11	5.3	4.92	3.25

Gross primary production levels ranged from 1.13mgO_2/L/hr to 2.3 mgO_2/L/hr for all the four stations. Net photosynthesis was negative in all the four stations and ranged from -2.27 mgO_2/l/hr to -0.38 mgO_2/L/hr. The community respiration ranged from 2.05 mgO_2/L/hr to 4.64 mgO_2/L/hr. The net relative productivity ranged from 43.49 mgC/m^{-3}/hr to 65.63mgC/m^{-3}/hr for all the four stations (Table 4.3-7).

Table 4.3-7
Gross photosynthesis, Net photosynthesis, Respiration and Relative Productivity in the Aboadze / Takoradi Wetlands

Sample Station	Gross photosynthesis mg O_2/L/hr	Net photosynthesis mg O_2/L/hr	Respiration Mg O_2 /L/hr	Relative Productivity Mg C/m^3 hr
2GS8TAD ww	1.13	-1.49	2.62	29.42
2GS9TAD ww	2.22	-2.12	4.64	65.63
2GS10TADww	2.30	-2.27	2.27	58.89
2GS11TADww	1.67	-0.38	2.05	43.49

Discussion

Low densities of phytoplankton biomass in the swamps are not unexpected in such ecosystem where the vegetation cover limits solar irradiance in water. Secondly wind-induced mixing of water column is also very limited as the vegetation cover obstructs wind getting into contact with the water column.

The relatively low oxygen levels of DO measured in all the sampling stations beside the factors enumerated above, may also be due to excessive microbial load in the swamps, high decomposing rate of the dense vegetation and a generally high biological oxygen demand (BOD) exerted on the system by the biota.

Zooplankton

Tema

Results of the zooplankton community sampled from the Gao Lagoon during the wet season showed six major groups represent during the low tide and high tide levels. The groups were made up of largely crustacean groups and a few other species from the groups diptera and nematoda. The species distribution was generally low at both high tide and low tide levels. Results for the adjoining intertidal zone were very poor, recording only 2 species (Appendix D, Table D-17b).

Discussion

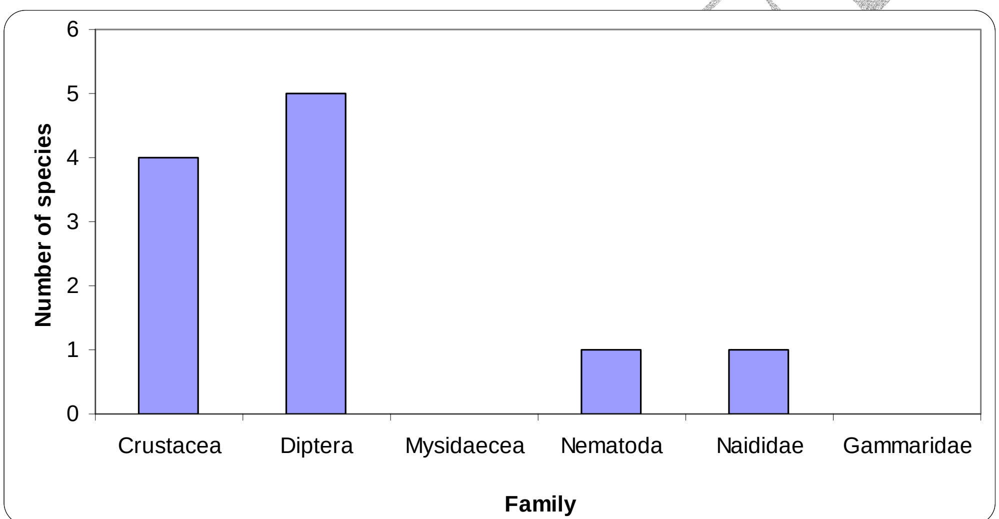
The abundance and diversity of zooplankton communities of such coastal water bodies as the Gao lagoon is determined by an array of environmental parameters including sediment load, dilution and water depth. The wet season sampling of the Gao Lagoon coincided with sediment loading of the lagoon from the construction activities of a nearby sewer line across the lagoon. Freshwater discharges from land drainage might have also contributed to the sediment loading of the system thereby decimation the abundance and diversity of the plankters. The complete absence of the meroplankton (shrimp and fish larvae) during this period of sampling cannot, however be easily explained by the changes in the habitat given the tidal nature of the lagoon.

Aboadze/Takoradi

Results of the zooplankton community survey in the Aboadze/Takoradi wetlands during the wet season is presented in Appendix D, Table D-23b.

The zooplankton samples were dominated by the crustaceans represented largely by the ostracods and the cladocerans. All the other groups were sparsely represented in the four stations. The zooplankton community of the intertidal zone was equally poor and represented only by two species of cladocera and copepoda. The species diversity of the major groups is presented in Figure 4.3-25.

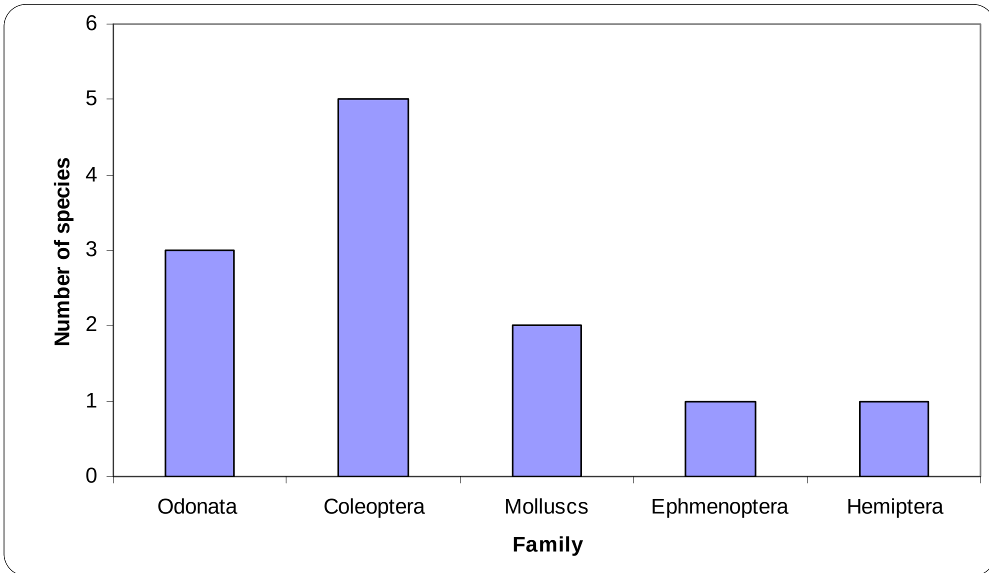
Figure 4.3-25
Species Diversity of Major Zooplanktonps in the Aboadze/Takoradi Wetlands and the Intertidal Zone



A result of the macro invertebrate fauna of the wetlands that were accidentally caught in the plankton net during sampling is presented in Appendix D, Table D-23b.

The species composition of the major groups is presented in Figure 4.3-26 and discussed.

Figure 4.3-26
Species Composition of Major Macrofauna associated with the Plankton Community in the Aboadze/Takoradi Wetlands



4.4 Wildlife, Animal Resources and Turtle Survey

Issues of conservation significance in the onshore and nearshore habitats for Tema and Aboadze/Takoradi are presented below.

Conservation Significance

- Global Criteria

CITES

CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna publishes a list of three Appendices (CITES Appendices, 1975) which limits global trade of certain categories of animal species:

- Appendix I species are threatened species which cannot be traded in
- Appendix II species are species for which levels of trade are limited
- National Criteria (Ghana Wildlife Conservation Regulations)

Ghana's Wildlife Laws (Ghana Wildlife Conservation Regulations, 1971, and Ghana Wildlife Conservation (Amendment) Regulations, 1988; 1995) also categorize animal species into two main Schedules based on the level of protection required for a particular species:

- Schedule I species are completely protected (i.e., their hunting, capture or destruction is prohibited at all times)

- Schedule II species are partially protected (i.e., their hunting capture or destruction is absolutely prohibited between 1st August and 1st December of any season, and the hunting, capture and destruction of any young animal, or adult accompanied by young, is absolutely prohibited at all times)

4.4.1 Wildlife and Animal Resources (Tema)

The actual organisms observed and recorded at Tema are presented in Table 4.4-1.

A total of 15 species were recorded (excluding interviews). This comprised three species of herpetofauna and 12 species of birds. Six of these species, which are all birds, are of conservation significance. Two species (*Milvus migrans* and *Neophron monachus*) are of both international (CITES Appendix II) and national (National Schedule I) conservation concern, while four species (*Ploceus cucullatus, Euplectes orix, Lonchura cucullata, and Turtur afer*) are of national conservation concern (National Schedule II) (Table 4.4-1).

Table 4.4-1
Check-list of Species Recorded at Tema

Species	**Common Name**	**Tema**	**Conservation Significance**	
			CITES	**National**
HERPETOFAUNA				
Reptilia				
Squamata: Lacertilia				
Agama agama	Rainbow Lizard	x		
Mabuya affinis	Skink	x		
M. perroteti	Orange-flanked Skink	x		
Aves (Birds)				
Bubulcus ibis	Cattle Egret	x		
Milvus migrans	Black Kite	x	II	I
Neophron monachus	Hooded Vulture	x	II	I
Turtur afer	Red-billed Wood-dove	x		II
Ceryle rudis	Red/Pied Kingfisher	x		
Halcyon senegalensis	Senegal Kingfisher	x		
Corvus albus	Pied Crow	x		
Euplectes orix	Red Bishop	x		II
Hirundo abyssinica	Lesser-striped Sparrow	x		
Lonchura cucullata	Bronze Mannkin	x		II
Ploceus cucullatus	Village Weaver	x		II
Pycnonotidae				
Pycnonotus barbatus	Common Garden Bulbul	x		

The vegetation around the Tema R&M site is coastal scrub and grassland, characterised by coastal grassland/thicket composed of an almost continuous grass layer with small thicket "islands" and numerous termite mounds. Dominant floral species include *Abutilon* spp., *Allophyllus warneckei, Andropogon* spp, *Cassia mimosoides, Ctenium* spp., *Grewia carpinifolia, Heteropogon contortus, Securinega virosa, Vetiveria* spp. The area is characterized by lateritic sandy soils, which are either sandy or gravely in texture, and generally form the bulk material for the construction and building industries. The habitats surveyed were generally characterized by coastal grassland and neem tree thickets interspersed with abandoned and active food crop farms of cassava, maize, okro and pepper.

Discussion

Since all floral and faunal species play important roles in the ecosystem food web, any activity that is likely to impact negatively on the environment should be undertaken with the welfare of these species and their habitats in mind; being of prime concern. It is also imperative to conduct conservation education and awareness programmes for the local people to sensitize them on the potential negative impacts of the proposed project on human populations in the vicinity.

4.4.2 Wildlife and Animal Resources (Aboadze/Takoradi)

The animals observed and recorded in the study area are presented in Table 4.4-2.

There were 15 species recorded (excluding interviews), comprising seven species each of herpetofauna and birds, and one species of mammal. Five of these species, which are all birds, are of conservation significance. Two species (*Milvus migrans* and *Neophron monachus*) are of both international (CITES Appendix II) and national (National Schedule I) conservation concern, while three species (*Ploceus cucullatus, Lonchura cucullata, and Streptopelia semitorquata*) are of national conservation concern (National Schedule II) (Table 4.4-2).

The vegetation is coastal strand, characterised by flora of the *Cyperus-Ipomeoa* Association dominated by *Cannavalia obtusifolia, Cocos nucifera, Cyperus articulatus, C. maritimus Imperata cylindrical, Ipomoea pes-caprae, Opuntia vulgaris, Paspalum vaginatum, Phoenix reclinata, Sporobolus virginicus, Thespesia populnea,* and *Triumfetta rhomboidea*. The major soils of the area are forest and coastal savanna ochrosols. Forest ochrosols are developed in forest and savanna environment under rainfall of between 900mm and 1650mm. The organic matter content of such soils is low, with pH generally less than 5.5. Coastal Savanna ochrosols are mainly red and brown, moderately well drained medium to light-texture soils developed over Voltaian sandstone, granite, phyllites and schists. They are also generally low in organic matter due to insufficient accumulation of biomass (less than 2% in the topsoil). Soil reaction ranges from near neutral, pH 6.0 - 7.0 near the surface, becoming slightly to moderately acid with depth. The actual habitats surveyed were characterised by wetlands with burnt portions, which were liable to flooding during the rainy season. The area was dominated by coconut trees, grass, and thicket "islands".

Table 4.4-2
Check-list of Species Recorded at Aboadze/Takoradi

Species	Common Name	Aboadze	Conservation Significance	
			CITES	**National**
HERPETOFAUNA				
Amphibia				
Bufo regularis	Common Toad	x		
Hylarana galamensis	Common Frog	x		
Reptilia				
Squamata: Lacertilia				
Agama agama	Rainbow Lizard	x		
Lygodactylus conraui	Gecko	x		
Mabuya affinis	Skink	x		
M. perroteti	Orange-flanked Skink	x		
Squamata: Serpentes				
Psammophis sibilans	Hissing Sand Snake	x		
Aves (Birds)				
Milvus migrans	Black Kite	x	II	I
Neophron monachus	Hooded Vulture	x	II	I
Halcyon senegalensis	Senegal Kingfisher	x		
Corvus albus	Pied Crow	x		
Lonchura cucullata	Bronze Mannkin	x		II
Ploceus cucullatus	Village Weaver	x		II
Mammalia				
Rodentia				
Lemniscomys striatus	Spotted Zebra Mouse	x		

Discussion

Floral and fauna species play important roles in the ecosystem food web. The interdependency of these species emphasizes the need to study them together and not in isolation. The nature of the vegetation in the area determines the abundance and diversity of faunal species. The more coastal areas tend to have lower species diversity and abundance than areas farther inland, where biodiversity may be enhanced by the presence of rare or endemic species which are more vulnerable to environmental change. Habitat disturbance in coastal areas should therefore pose much less danger to biodiversity than disturbance in the more inland areas.

However, any activity that is likely to impact negatively on the environment should be undertaken with the welfare of these species and their habitats as prime concern. It is also essential that conservation education and awareness programmes are organized for the local communities to sensitize them on the potential negative impacts that the proposed project may have on the human populations in the vicinity.

4.4.3 Sea Turtle Survey (Tema New Town and Kpone Beaches)

Beach Survey

Results from the onshore survey conducted during the wet season sampling did not indicate the presence of any sea turtle nesting on the beaches of the Tema New-Town and Kpone.

Results from Questionnaire Administration

Analyzed results of questionnaire on the inventory of the sea turtles along the beaches off Tema New –Town and Kpone are presented in Table 4.4-3.

Table 4.4-3
Summary Results of Questionnaire Administered during Marine Turtle Survey at Tema/Kpone Area

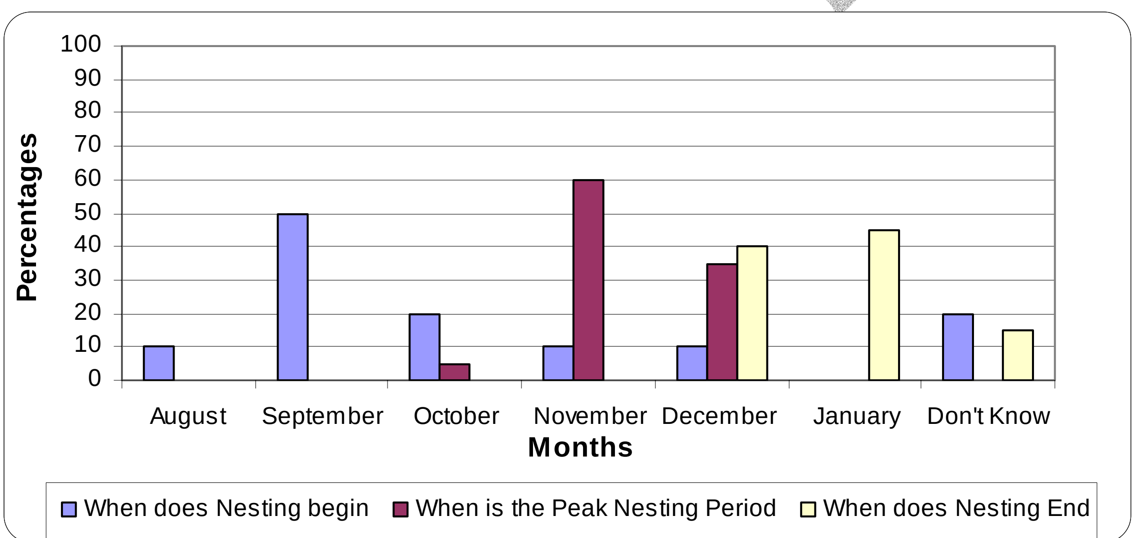
NUMBER OF RESPONDENTS = 20	Percent Response						
	August	**September**	**October**	**November**	**December**	**January**	**Do not Know**
When does Nesting begin	10	50	20	10	10		20
When is the Peak Nesting Period			5	60	35		
When does Nesting End					40	45	15

	Percent Response		
	Yes	**No**	**Do not Know**
Nesting Frequency Increasing	15	65	20
Nesting Frequency Decreasing	65	15	20
Knowledge of How Turtle Eggs are Destroyed	90	10	
Knowledge of Law Banning Turtle Hunt	40	60	
Who Should Enforce Ban on Turtle Hunt	**Local Gov't**	**Chief Fisherman**	**Fishermen**
	10	60	30
Major Agents of Sea Turtle Eggs Destruction	**Man**	**Pigs**	**Dogs**
	10	50	40

The questionnaires administered to the local community showed that they could clearly identify the hawskbill, *Eretmochelys inbricata* while the rest were classified either as hard back (loggerhead, green or olive ridley) or soft back (leatherback). On the possible role of the sea turtles in the marine environment, almost all the respondents were of the view that the turtles are just like any other fish in the sea that did not have any special role to play in the sea.

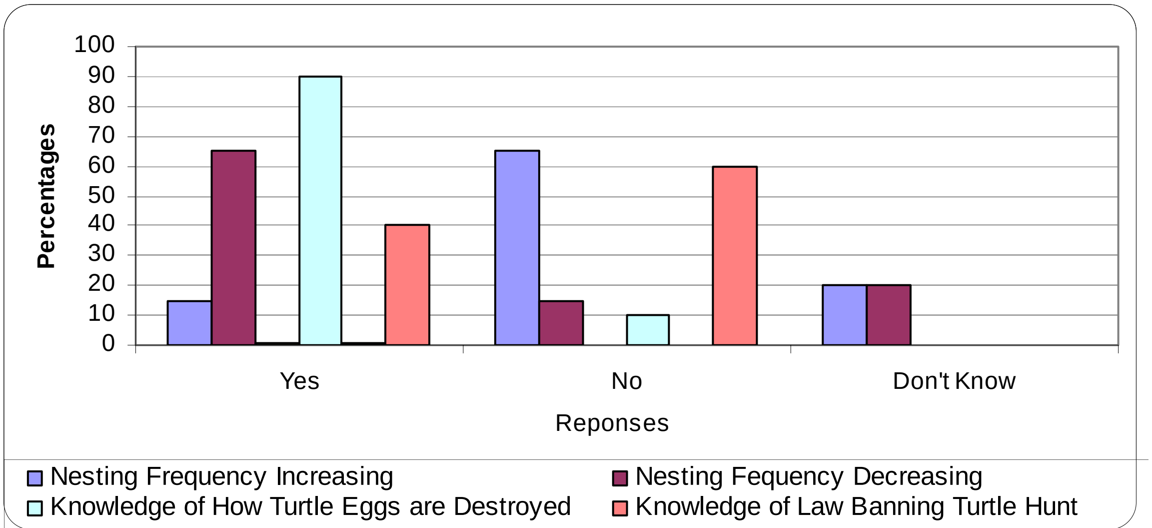
The responses show that turtle nesting along the beaches span the period of August to January with the peak period around November (Figure 4.4-1). About 15% of the respondents indicated that nesting activity has been increasing in the past 5 years. Sixty-five percent of all the respondents were however of the view that the frequency of nesting of turtles has been reducing systematically for the past 5 years. Approximately 20% did not know whether this had been increasing or decreasing.

Figure 4.4-1
Perceived Nesting Frequency of Marine Turtles in the Tema/Kpone Area



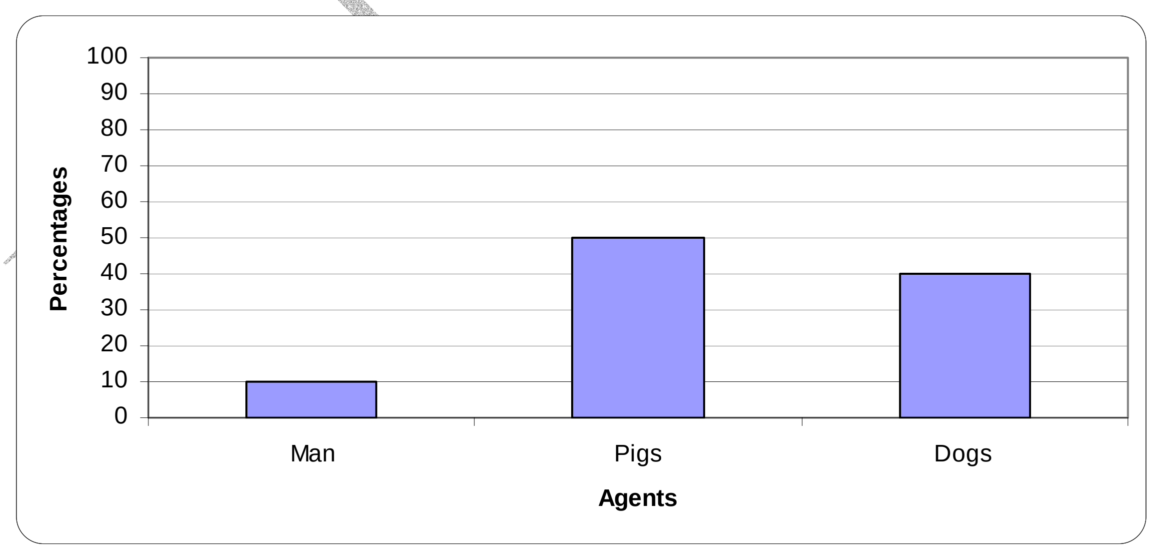
On the knowledge of legislation outlawing the capture or destruction of turtles, 60% of the respondents indicated that they had no knowledge of the existence of any such laws while 40% indicated that they were aware of existence of the legislations (Figure 4.4-2).

Figure 4.4-2
Awareness of Changing Patterns of Turtle Nesting in the Tema/Kpone Area



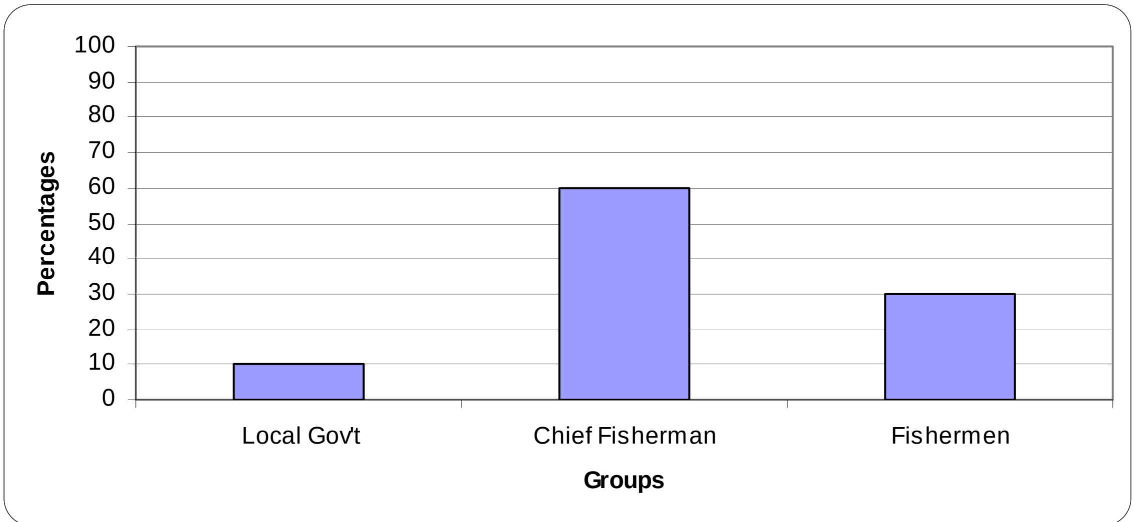
On the vulnerability of turtle eggs, almost all the respondents knew that the sea turtle eggs were under severe potential threat with 10% of them attributing the courses to man, 50% to pigs and 40% to dogs (Figure 4.4-3). It was also established in the course of the study that 60% of the respondents were aware of the existing of laws banning turtle hunt. Thirty percent (30%) of the respondents thought that the fishermen should be made to police themselves since they form the bulk of the people who come into contact with the reptiles.

Figure 4.4-3
Agents of Turtle Eggs Destruction in the Tema/Kpone Area



Sixty percent (60%) of the respondents were however of the view that the chief fishermen should be given the responsibility of enforcing the legislation while the remaining 10% were of the view that any law enforcement should be the responsibility of the Local Government Authorities (Fig. 4.4-4).

Figure 4.4-4
Perceptions on Enforcement Agencies of Marine Turtle Laws



Discussion

Previous works made on the dynamics of the sea turtle on the coastline of Ghana clearly indicate that most of the beaches provide sites suitable for nesting by all the five species of turtle in Ghana. The prime nesting sites have been identified as the coastline from Prampram (about 10-15km East of Tema) to Ada and the areas beyond the Volta estuary to Denu, in the Volta region. It is also evident that moderate nesting occurs from Winneba through Bortianaor and some beaches around Accra such as Gbegbeseh and Sakumono (Amiteye, 2002, Tando 1999). In general, most of the beaches are known to provide nesting sites for the leatherbacks. Although the current survey along the beaches of Tema New Town and Kpone did not yield any positive results, this is not surprising given that the survey was conducted in August which is thought, from the survey results, to be the beginning of the nesting period

Factors that tend to work against the nesting frequency are identified as urbanization and coastline development. The Tema-New town area has high concentration of shanty towns along the beaches besides it being generally rocky. The main factors that are likely to account for the decimation of nesting frequency will be predation as pigs and dogs are largely left un-caged and roam the beaches of these areas. The knowledge of the people on the legislations banning the destruction of sea turtles is commendable and appears to be a result of a previous awareness campaign undertaken by a Non-Governmental Organization called REDO in 1996-1999.

Although the area around the Tema R &M site has been recognized as a potential site for sea turtle nesting, the present survey results does not lend much support to this observation. It is believed therefore that impact emanating from the operations of the WAGP project, if any, would be generally minimal.

4.5 FISH AND FISHERIES RESOURCES

4.5.1 Tema

The artisanal fishery of Ghana comprises of the inshore, nearshore and inland water exploitation of fish (finfish & shellfish) and fisheries resources. These together, contribute substantial proportions of the annual fish landing in the country.

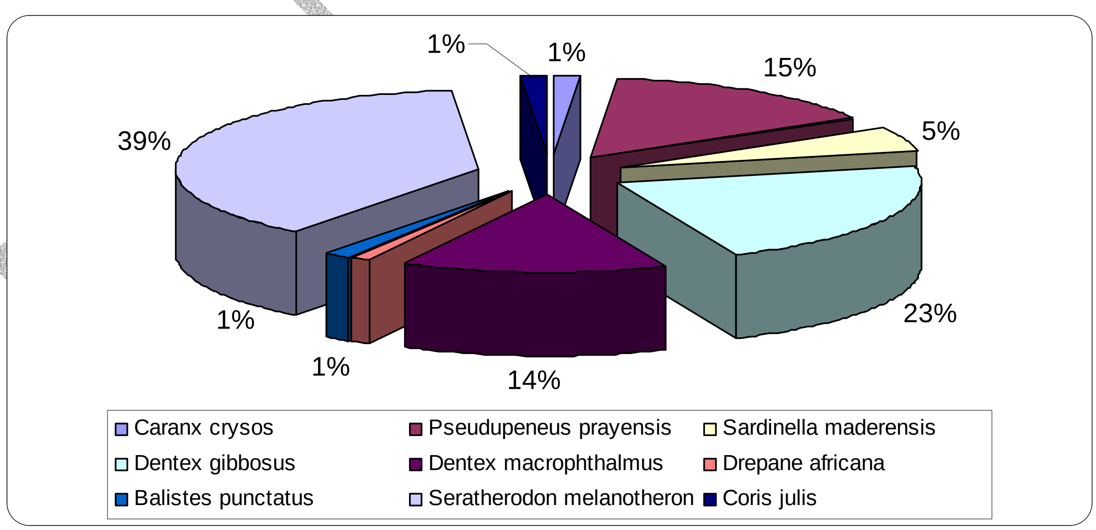
The nearshore fishing, comprising of the beach seine fishing and several other fishing methods are practiced in the estuaries and lagoons along the entire 550km shoreline of Ghana.

Around the Tema R & M site, the major fishing grounds comprise the Sakumono Lagoon, the Gao Lagoon and the adjoining nearshore beaches. Although the output from the fisheries is very small, they nonetheless produce reasonable amount of fish for the domestic market and for subsistence consumption.

Based on direct observation from the 2EBS wet season fish survey of the Gao Lagoon, eight (8) species of fish belonging to seven families were recorded from cast net fishing. A checklist of the species type and community structure in the Gao Lagoon is presented in Appendix D, Table D-22.

The catch was dominated by the typical brackish water cichlid, *Sarotherodon, melanopteron* (the black chin tilapia) that comprises as much as 39% of the total catch. The remaining groups were largely marine and ranged from 1% to 23% (Figure 4.5-1).

Figure 4.5-1
Percent Composition of Cast net Catch from Gao Lagoon (June 2003)



The size structure of *S. melanopteron* collected from the lagoon during this season shows a mixed size distribution with less than 50% falling below 10cm total length. Fishes with total length (Figure 4.5-2) greater than 10cm showed corresponding weights (Figure 4.5-3) in excess of 20g.

Figure 4.5-2
Size Structure of S. *melanopteron* from Cast Net Fishing in the Gao Lagoon

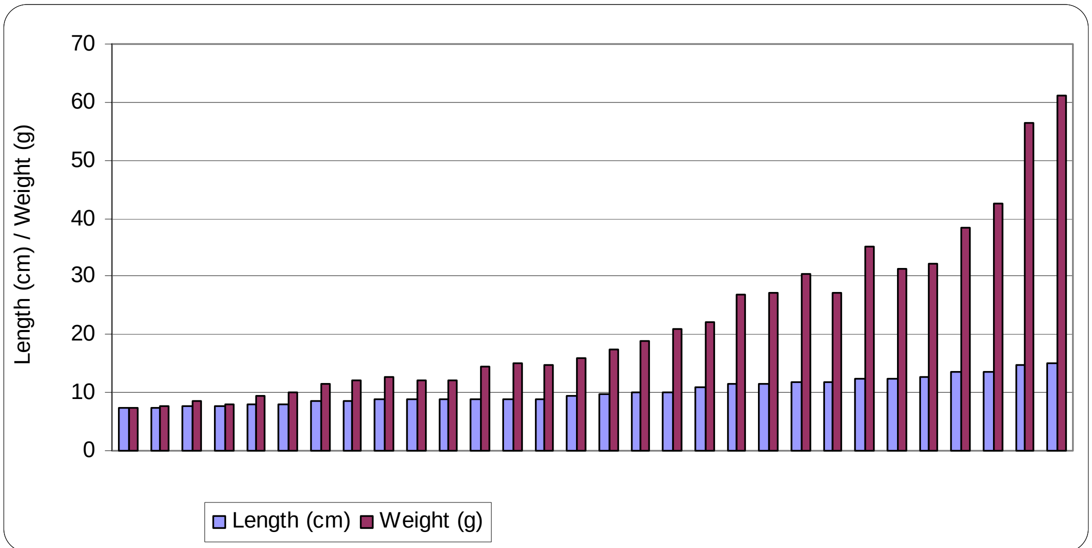
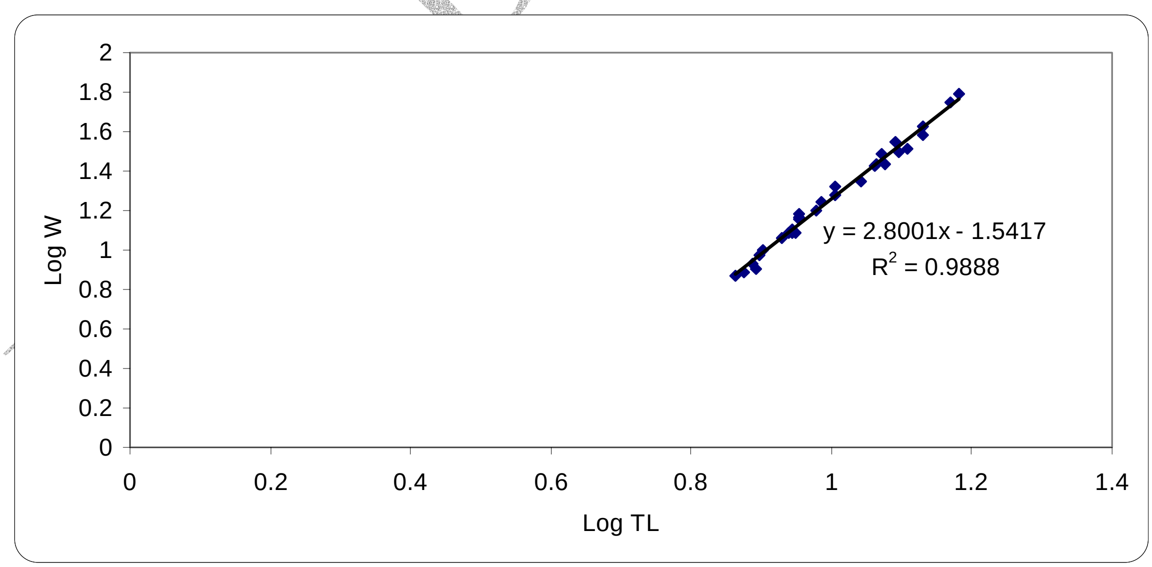


Figure 4.5-3
Length Weight Relationship of S. *melanopteron* from Cast Net Fishing in the Gao Lagoon



Discussion

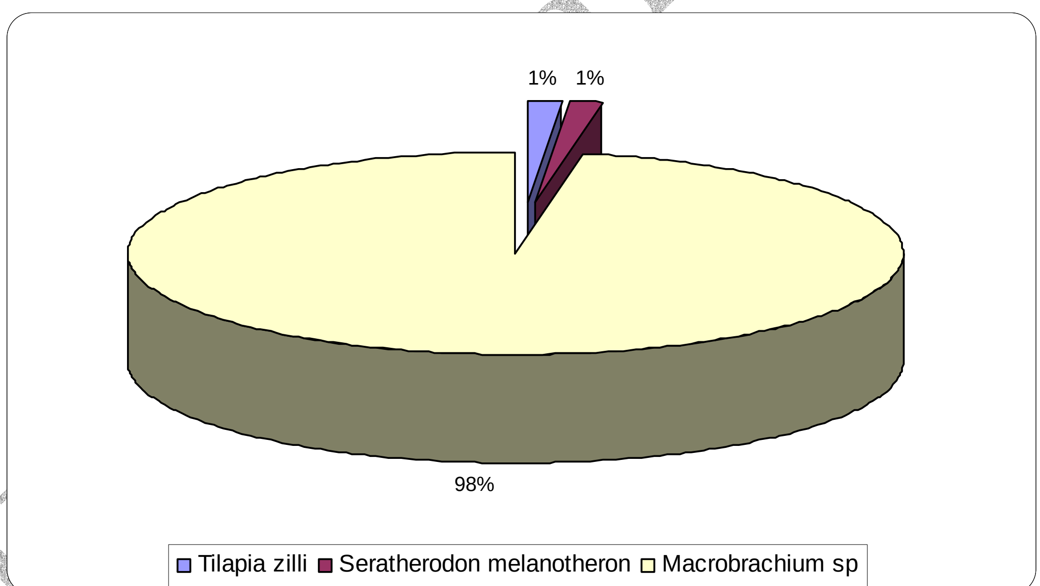
The fishery of the coastal lagoon tends to be defined by the nature of the nearshore fishery as the fishes tend to follow the tide to forage in the generally productive lagoons and the adjoining mangrove swamps. The fish catch and its composition found during the wet season survey typifies this nearshore fishery structure. Besides *S. melanopteron* which is usually resident in such water system, a large number of the other fishes are typical marine species which visit the lagoon to forage and sometimes to spawn valuable fishes to go through the initial valuable juvenile stages away from the larger predators of the inshore and offshore habitats.

4.5.2 Aboadze/Takoradi

The Aboadze/Takoradi location has three major fishery: freshwater wetlands/swamps, the lagoonal system and the inshore fishery of the Aboadze beach landing. The catch composition of the fish resources collected from the different water systems is presented in Appendix D, Table D-23.

Results from the wet season survey of the wetlands sampling shows that 98% of the total catch from a days fishing activity of a local resident fisherman comprised of the black chin tilapia, *Sarotherodon. melanopteron.* The only two other species are the freshwater prawn, *Macrobrachium* spp and the red belly tilapia – *T. zilli* (Figure 4.5-4).

Figure 4.5-4
Percent Composition of Cast Net Catch from the Swamp (Aboadze/Takoradi)



In the nearby Anakwari lagoon, a day's cast net fishing exploitation yielded about 68% the flat head mullet, *Mugil cephalus*. The rest comprised of several typical marine fishes ranging from 1% - 9% of occurrence (Figure 4.5-5).

Figure 4.5-5
Percent Composition of Cast Net Catch from the Anankwari Lagoon (Aboadze/Takoradi)

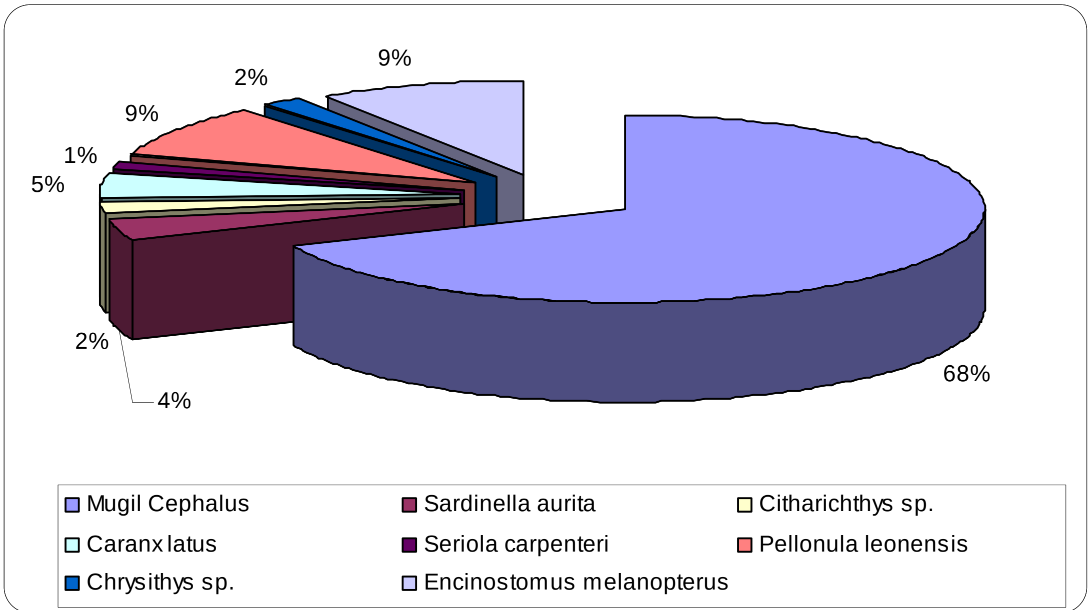
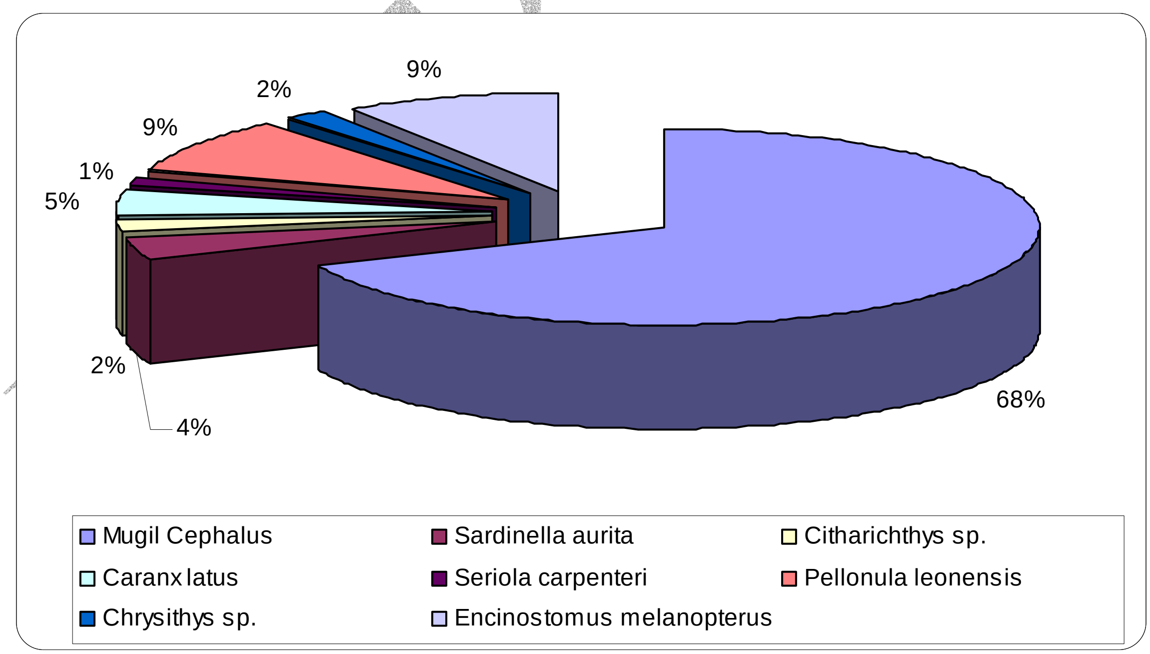


Figure 4.5-6
Percent Composition of Cast net Catch of Inshore Fisheries



A log transformed length-weight relationship of *I. africana* and *B. auritus* from the inshore catch shows the gradient of the regression curve to be 3.29 and 2.65 respectively (Figure 4.5-7 and Figure 4.5-8).

Figure 4.5-7
Length - weight Relationship of *Ilisha africana* of the Inshore Fisheries

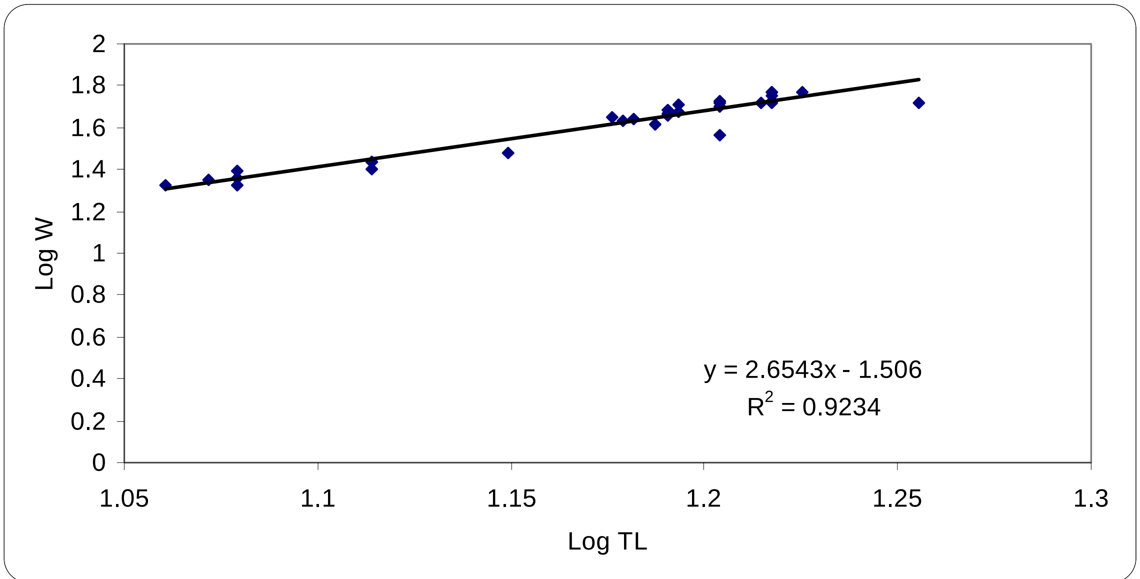


Figure 4.5-8
Length – weight Relationship of *Mugil cephalus* from the Anankwari Lagoon

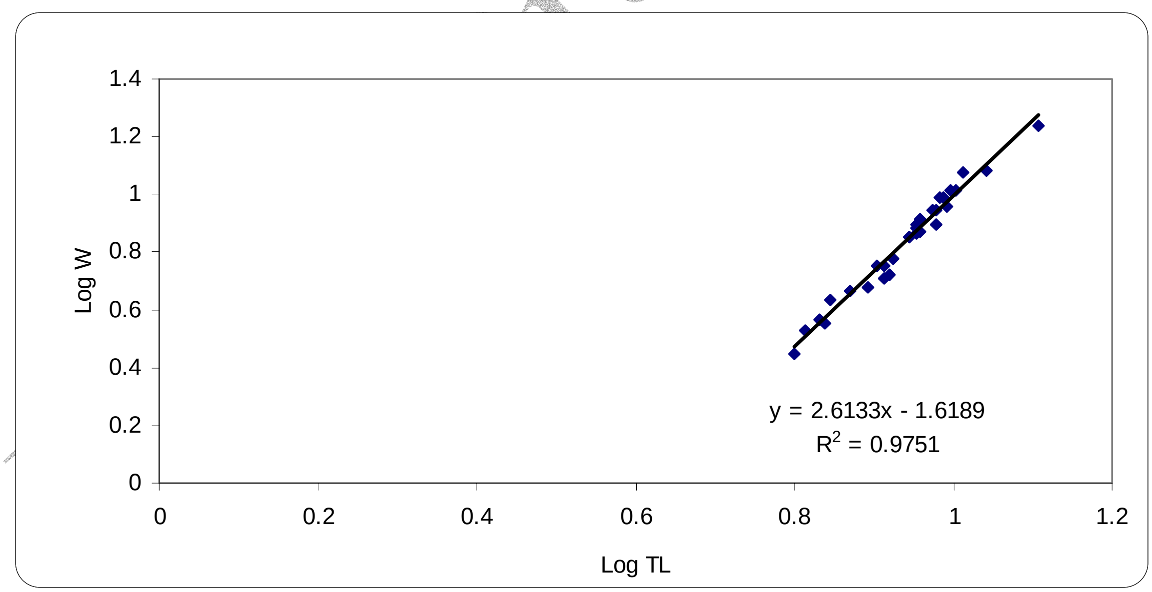
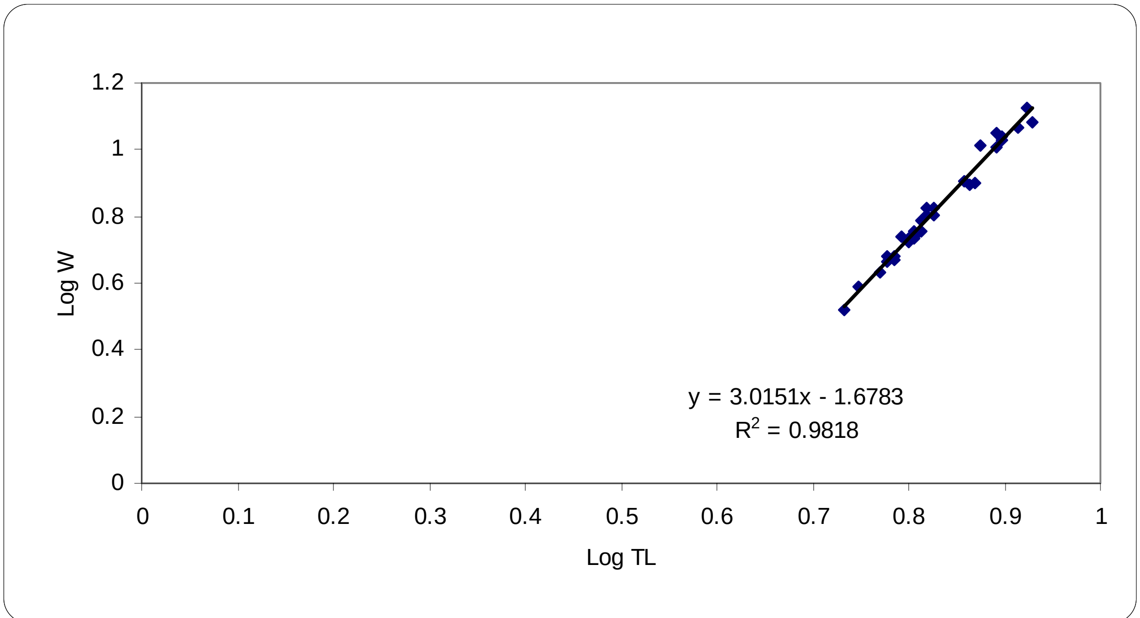


Figure 4.5-9
Length – weight Relationship of S. *melanoptera* from the Aboadze Swamp



Discussion

The fishery of the swamps is very complex following the complexity of that ecological biotope. The nature of the habitat is such only hardy species can survive there. Diversity is thus usually very low. The complex ecological set up also allows for specialization among the fishes especially with respect to tolerance to low oxygen content and acidity. In this respect, the typical cartilaginous fish with accessory respiratory organs e.g. *Clarias* spp, *Heterotis* sp, *Heterobranchus* etc tend to predominate in samples. The fact that these fish species were not encountered during this wet season survey does not suggest that they may not be present but rather emphasizing the complexity of the environment. The predominance of *S. melanopteron* in the swamps is not unexpected. During the wet season the water level rises significantly. There is regular exchanging of saline water from the lagoon with areas of the wetlands bothering that water body. Hardy fishes like *S. melanopteron* can use the wetland as both feeding grounds and hideouts during high water.

Results obtained from the Anakwari lagoon with the mugils dominating catch are expected. Although they are typically marine the juvenile mullets use the estuaries and coastal lagoons as feeding ground. The value of 2.613 as gradient of the regression curve gives an indication of non-isometric but in reality it is because the fishes are only juveniles and still growing.

The scatter of points along a wide range on the *Brachydeuterus auritus* regression line with a gradient of 2.65 indicates that the fish is still in the juvenile stages. *Illisha africana* is seasonal and respond to the inshore productivity of the well-lit inshore waters during the period of upwelling. Most fishes grow rapidly during this period for an important food source of the migrating tunas.

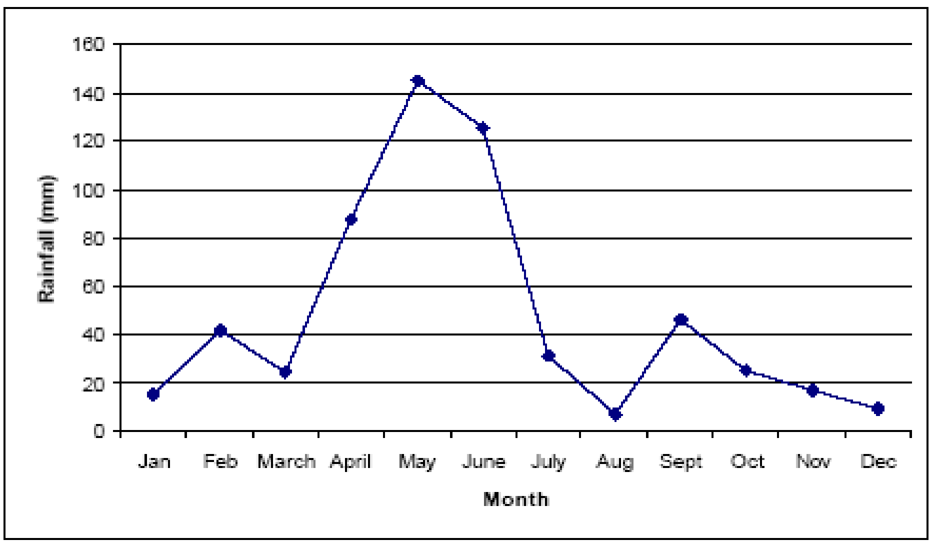
Given the sensitive nature of the nearshore fishery to changes in the environment, any severe environmental perturbations that act to alter the physico-chemical condition of the habitats and the general ecology of the system is likely to impinge negatively on the fish and fisheries of this area.

4.6 CLIMATE AND METEOROLOGY

4.6.1 Tema

The rainfall pattern in Ghana is generally bimodal; i.e. major and minor rainy seasons. In the Tema area, the major rainy season is normally between March and July while the minor season occurs between August and October. The month of June is usually considered the wettest month with mean rainfall of about 370mm (Figure 4.6-1). Tema is considered one of the driest in the country with mean annual rainfall of about 800mm. The average monthly duration of solar radiation ranges between 4.4 and 9.3 hours. Monthly relative humidity for 1999 to 2001 was generally high all year round, ranging between 82 and 96%.

Figure 4.6-1
Mean Monthly Rainfall Distribution at Tema (1999 – 2001)

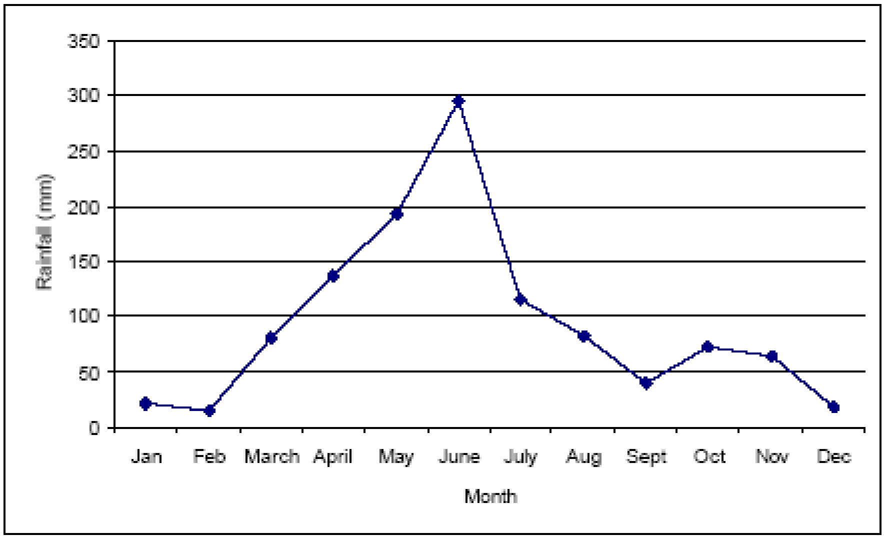


Ambient temperature ranges between 25 to 34°C with very small mean annual variations. The hottest month is normally in April (~34°C), and the coldest month is usually in August (~ 24.7°C). The prevailing wind is south westerly, with a speed ranging between 3.2 and 6.1m/s at Tema but changes direction on certain occasions. For instance, the wind was recorded as being south easterly in December 1999.

4.6.2 Aboadze/Takoradi

Takoradi has a mean annual rainfall of about 1200mm (Figure 4.6-2). The wettest months are May and June, which usually records more than 250mm of rain during this period. There is consistent daily variation in relative humidity with night values (95 to 100%), slightly higher than daytime values (70 to 80%).

Figure 4.6-2
Mean Monthly Rainfall Distribution at Takoradi (1999 – 2001)



There is little temperature variation during the year. Daily ambient temperature normally ranges between 27°C in July to September and 31°C in November to April. Barometric pressure is highest during night time and lowest during the hottest period of daytime. The prevailing SW monsoon wind is relatively light but steady throughout the year with distinct diurnal variation relative to the land/sea breeze effect. Average monthly wind speed rarely exceeds 2.3m/s at Takoradi.

CHAPTER 5
REFERENCES

Adomako, J.K. and Armah A.K. (1998) Gulf of Guinea Large Marine Ecosystem Project – Mangrove Survey of Ghana. Abidjan, GEF-GOG/LME Project.

Afoakwa, S.N., Agbodaze, D. and Abrahams, C.A. (1988) Microbiological quality of the coastal waters of Ghana: a bacteriological appraisal. Accra: GNC/IOC Seminar on the Conservation and Utilisation of Marine Resources.

Akpati, B. N. (1975) Source and dispersal of Holocene sediments on the continental shelf of Ghana, West Africa., pp.44. Accra: Research report of UNESCO. Contract SC/RP600.874.

Allersma, E. and Tilmans, W.M.K. (1993) Coastal conditions in West Africa: a review. Ocean and Coastal Management 19, 199 - 240.

Amiteye, B.T. (2002) Distribution and ecology of nesting sea turtles in Ghana. Unpublished Thesis, University of Ghana.

APHA, AWWA, WEF. (1998) Standards Methods for the Examination of Water and Wastewater. Eds: Clesceri, L. S., Greenberg, A. E., Eaton. A. D. 20th Ed.

Armah, A.K. and Amlalo, D.S. (1998) Coastal zone profile of Ghana. Gulf of Guinea Large Marine Ecosystem Project. Ministry of Environment, Science and Technology, Accra,Ghana. vii + 111pp.

Armah, A.K., Darpaah, G.A., Wiafe, G., Adomako, J.K. and Fiagbedzi, S. (1997) Save sea turtles - a primer on sea turtle conservation for coastal communities in Ghana. Accra: Royal Crown Press Ltd.

Armah, A K., Darpaah, G.A., Wiafe, G., Adomako, J.K., Quartey, S.Q., Abotchie, C., Ansah, F. and Fiagbedzi, S. (1997) Traditional and modern perspectives of marine turtle conservation in Ghana. In Biodiversity Conservation: traditional knowledge and modern concepts. (ed. Amlalo D.S., L.D. Atsiatorme and C. Fiati), pp. 80 - 87: EPA/MAB/UNESCO.

Bassindale, R. (1961) On the marine fauna of Ghana. Proceedings of the Zoological Society of London 137, 481 - 510.

Binet, D., Marchal, E. and Pezennec, O. (1991) Sardinella aurita de Cote d'Ivoire et du Ghana: fluctuations halientiques et changements climatiques. In Pecheries Ouest Africaines: varibilite, instabilite et changement. (ed. P. Cury and C. Roy): ORSTOM.

Biney, C.A. (1986) The state of pollution of the west and central African marine environment: aspects of the Ghanaian situation., pp. 24. Accra: Institute of Aquatic Biology.

Bouyoucous, G.J. (1936) Directions for making Mechanical Analysis by Hydrometer Method. Soil Sci. 42: 255-258.

Buchanan, J.B. (1957) Benthic fauna of the continental edge off Accra, Ghana. Nature 179, 634 - 635.

Doty, M.S., and Oguri, M. (1957) Evidence for a photosynthetic daily periodicity. Limnol. Oceanogr. 2, 37-40

Eckert, K.L., Bjoundal, F. Alberto Abreu-Grobois, F. and Donnelly, M (Editors) (1999) Research and management techniques for the conservation of sea turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4

Edmunds, J. (1978) Sea shells and other molluscs found on West African coast and estuaries, pp. 146. Accra: Ghana Universities Press.

Edwards, R.A., Whitmarsh, R.B. and Scrutton, R.A. (1997) Synthesis of the crustal structure of the transform continental margin off Ghana, northern Gulf of Guinea. Geophysical Marine Letters 17, 12 - 20.

Elser, J.J. and Goldman, C.R. (1991) Zooplankton effects on phytoplankton in lakes of contrasting trophic status. Limnology and Oceanography, 36, 64-90

Evans, S.M., Gill, M.E., Hardy, F.G. and Seku, F.O.K. (1993) Evidence of change in some rocky shore communities on the coast of Ghana. Journal of Experimental Marine Biology and Ecology 172, 129 - 141.

Fontaine, B., Janicot, S. and Roucou, P. (1999) Coupled ocean-atmosphere surface variability and its climate in the tropical Atlantic region. Climate Dynamics 15, 451 - 473.

Garzoli, S.L. and Katz, E.J. (1983) The forced annual reversal of the Atlantic North Equatorial Counter Current. Journal of Physical Oceanography 13, 2082.

Harris, G.P. (1986) Phytoplankton ecology: structure, function, and fluctuation, pp. ix, 384. New York: Chapman and Hall.

Church, R.J. (1980) West Africa. London, Longman.

Houghton, R.W. (1983) Seasonal variations of the subsurface thermal structure in the Gulf of Guinea. Journal of Physical Oceanography 13, 2070 - 2081.

Hutchison, J. and Dalziel, L.M. (1954-1972) Flora of West Tropical Africa. 2bd ed., Revised by Keay and Hepper, 3 vol.

Ihenyen, A.E. (1998) Appraisal of heavy metal concentrations in bottom sediments of the Gulf of Guinea. In Nearshore dynamics and sedimentology of the Gulf of Guinea (ed. A. C. Ibe, L. F. Awosika and A. Aka), pp. 93 - 98. Cotonou: IOC-UNESCO/UNIDO.

Joiris, C.R., Otchere, F.A., Azokwu, M.I. and Ali, I.B. (1997) Total and organic mercury, and organochlorides in a bivalve from Ghana and Nigeria. In The coastal zone of West Africa: problems and management (ed. S. M. Evans, C. J. Vanderpuye and A. K. Armah), pp. 89 - 92. London: Penshaw Press.

Longhurst, A.R. (1962) A review of the oceanography of the Gulf of Guinea. Bulletin d'Institute franc Africain noire 24, 633 - 663.

Lund, J.W.G., Kipling, C. and Le Cren, E.D. (1958) The inverted microscopoe method of estimating algal numbers and the statistical basis of estimates by counting. Hydrobiologia, 11, 143-170

Mensah, M.A. (1991) The influence of climatic changes on the coastal oceanography of Ghana. In Pecheries ouest Africaines: variabilite, instabilite et changement (ed. C. Phillipe and C. Roy), pp. 67- 79. Abidjan: ORSTOM.

Merle, J. and Arnault, S. (1985) Seasonal variability of the surface dynamic topography in the Tropical Atlantic Ocean. Journal of Marine Research 43, 267 - 288.

Moore, D.W., Hisard, P., McCreary, J.P., Merle, J., O'Brien, J.J., Picaut, J., Verstraete, J.M. and Wunsch, C. (1978) Equatorial adjustment in the eastern Atlantic ocean. Geophysical Research Letters 5, 637 - 640.

Nyarko, E. and Evans, S.M. (1997) Impacts of tributyltin pollution and human food gathering on populations of gastropods Thais haemastoma and Thais nodosa along the Ghana coast. In The coastal zone of West Africa: problems and management (ed. S.M. Evans, C. J. Vanderpuye and A. K. Armah), pp. 93 - 101. London: Penshaw Press.

Oteng-Yeboah, A.A. (1994) Takoradi Thermal Plant: Terrestrial Ecological Survey Report, Volta River Authority.

Reardon, J., Foreman, J. A. and Searcy, R. L. (1966) New reactants for the colorimetric Determination of Ammonia. Clinica Chimica Acta, 14(3): 403-405

Richardson, P.L. (1984) Moored current meter measurements in the Atlantic North Equatorial Counter Current during 1983. Geophysical Research Letters 11, 749 - 752.

Tandoh, D.M. (199) Nesting of sea turtles along the Shiabu-Grefe sandy beaches, Wets Africa, Unpublished Thesis, University of Ghana.

Thiriot, A. (1977) Zooplankton in the upwelling zones of the African Atlantic littoral. Document Scientifique Centre Recherche Oceanographique (ORSTOM) 8, 1 - 72.

Tsidzi, K.E.N., Akoto, M.A. and Iddrisu, Y. (1995). Geological hazards mitigation in Ghana: the state of the art. Ghana Mining Journal Vol. 1. Nos. 1&2

Wiafe, G. (2002) Spatial and temporal dynamics of plankton communities in the Gulf of Guinea ecosystem. Ph.D. Thesis submitted to the Department of Oceanography and Fisheries, University of Ghana, Legon., pp. 188. Legon: University of Ghana.

Wiafe, G and Quist, M (2002) Nutrient pollution in Ghana, p31 Accra:UNIDO Thematic Area Paper for Stocktaking Meeting (PDF – B)

Wetzel, R.G. (1983) Limnology, W.B. Saunders Co., Philadelphia

Wetzel, R.G. and Likens, G.E. (1990) Limnological Analysis. W.B. Saunders Co., Philadelphia. 237pp

CHAPTER 6
APPENDIX D

Table D-1 Possible Fauana Associated with the Vegetation to R&M Sites

Species		**Likely-occurring Species**	
Herpatofauna	**Common Name**	**Aboadze**	**Tema**
Amphibia			
Bufo regularis	Common Toad	**X**	**x**
B. superciliaris	Giant Toad	**X**	
Dicroglossus occipitalis	Common Frog	**X**	**x**
Hylarana galamensis	Common Frog	**X**	**x**
H. viridiflavus	“	**X**	
Phrynobatrachus accraensis	Sharp-nosed Frog		**x**
Reptilia			
Chelonia (Tortoises/Terrapins)			
Kinixys homeana	Hinged Tortoise	**X**	
Pelomedusa subrufa	Marsh Terrapin	**X**	**x**
Squamata: Lacertilia			
Agama agama	Rainbow Lizard	**X**	**x**
Chamaeleo gracilis	Chameleon	**X**	**x**
Hemidactylus brookii	House (Wall) Gecko	**X**	
Lygodactylus conraui	Gecko	**X**	
Mabuya affinis	Skink	**X**	**X**
M. perroteti	Orange-flanked Skink	**x**	**X**
Panaspis togoensis	Skink		**X**

Varanus exanthematicus	Savanna Monitor	**x**	**X**
V. niloticus	Nile Monitor	**x**	**X**
Squamata: Serpentes			
Bitis arietans	Puff Adder		**X**
Causus maculates	Night Adder		**X**
Dasypeltis scabra	Egg-eating Snake	**x**	**X**
Dendroaspis viridis	Green Mamba		**X**
Lamprophis fuliginosus	House Snake		**X**
Naja melanoleuca	Black Cobra	**x**	
N. nigricollis	Spitting Cobra		**X**
Philothamnus semivariegatus	Green Tree Snake		**X**
Psammophis sibilans	Hissing Sand Snake		**X**
Python regius	Royal Python	**x**	**X**
P. sebae	African Python	**x**	**X**
Rhamphiophis oxyrhynchus	Beaked Snake		**X**
Thelothornis kirtlandii	Twig Snake	**x**	**X**
Aves (Birds)			
Ardeidae			
Ardea cinerea	Grey Heron	**x**	
Bubulcus ibis	Cattle Egret	**x**	**X**
Egretta garzetta	Little Egret	**x**	
Nycticorax nycticorax	Night Heron	**x**	
Accipitricidae			
Buteo augularis	Red-tailed Buzzard	**x**	**x**
Milvus migrans	Black Kite	**x**	**x**

Neophron monachus	Hooded Vulture	**x**	**x**
Falconidae			
Falco naumanni	Lesser Kestrel		**x**
Phasianidae			
Francolinus ahantensis	Ahanta Francolin	**x**	
Ptilopachus petrosus	Stone Partridge		**x**
Charadriidae			
Charadrius hiaticula	Ringed Plover		**x**
Haematopus ostralegus	Eurasian Oystercatcher		**x**
Himantopus himantopus	Black-winged stilt		**x**
Jacanidae			
Actophilornis africana	African Jacana		**x**
Burhinidae			
Burhinus senegalensis	Senegal Thick-knee		**x**
Columbidae			
Columba livia	Pigeon		**x**
Streptopelia semitorquata	Red-eyed Dove	**x**	**x**
S. senegalensis	Laughing Dove	**x**	**x**
Turtur afer	Red-billed Wood-dove	**x**	**x**
Psittacidae			
Agapornis pullaria	Red-headed Lovebird	**x**	
Musophagidae			
Crinifer piscator	Grey Plantain-eater	**x**	**x**
Tauraco persa	Green-crested Touraco		**x**
Cuculidae			
Centropus senegalensis	Senegal Coucal	**X**	**x**

Ceuthmocares aereus	Yellow-bill		
Chrysococcyx klaas	Klaas Cuckoo	**X**	**x**
Apodidae			
Apus affinis	Little Swift	**X**	**x**
Cypsilurus parvus	Palm Swift	**X**	**x**
Alcedinidae			
Ceryle rudis	Red/Pied Kingfisher	**X**	**x**
Halcyon malimbicus	Blue-breasted Kingfisher	**X**	
H. senegalensis	Senegal Kingfisher	**X**	
Bucerotidae			
Tockus fasciatus	Allied Hornbill	**X**	
T. nasutus	Grey Hornbill	**X**	**x**
Capitonidae			
Lybius vieilloti	Vieillot's Barbet		**x**
Pogoniulus subsulphureus	Yellow-fronted Tinkerbird		**x**
Corvidae			
Corvus albus	Pied Crow	**X**	**x**
Estrildidae			
Estrilda melpoda	Orange-cheeked Waxbill	**x**	
L. cucullata	Bronze Mannikin	**x**	**x**
N. canicapilla	Grey-crowned Negro-finch	**x**	
Hirundinidae			
Hirundo rustica	European Swallow		**x**
Laniidae			
Laniarius barbarus	Barbary Shrike		**x**
Lanius collaris	Fiscal Shrike	**x**	

Muscicapidae			
Cossypha niveicapilla	Snowy-crowned Robin-chat		**x**
Platysteira cyanea	Scarlet-spectacled Wattle-eye	**x**	**x**
Terpsiphone rufiventer	Red-bellied Paradise Flycatcher	**x**	
Trochocercus nitens	Blue-headed Crested Flycatcher	**x**	
Nectariniidae			
Nectarinia chloropygia	Olive-bellied Sunbird	**x**	
N. coccinigaster	Splendid Sunbird		**x**
N. cuprea	Copper Sunbird	**x**	
N. fuliginea	Carmelite Sunbird	**x**	
N. olivacea	Olive Sunbird	**x**	
N. oritis	Blue-headed Sunbird	**x**	
Ploceidae			
Euplectes orix	Red Bishop	**x**	**x**
Hirundo abyssinica	Lesser-striped Sparrow	**x**	
Lonchura cucullata	Bronze Mannkin	**x**	**x**
Malimbus scutatus	Red-vented Malimbe	**x**	
Passer griseus	Grey-headed Sparrow	**x**	
Ploceus cucullatus	Village Weaver	**x**	**x**
P. nigricollis	Spectacled Weaver	**x**	**x**
Tchagra senegala	Black-crowned Tchagra	**x**	**x**
Pycnonotidae			
Andropadus curvirostris	Cameroon Sombre Greenbul	**x**	
A. virens	Little Grrenbul	**x**	
Chlorocichla simplex	Simple Leaf-love	**x**	**x**
Nicator chloris	West African Nicator	**x**	

Pycnonotus barbatus	Common Garden Bulbul	**x**	**x**
Sturnidae			
Lamprotornis purpureus	Purple Glossy Starling		**x**
Sylviidae			
Camaroptera brachyura	Grey-backed Camaroptera		**X**
Cisticola natalensis	Striped Cisticola		**X**
Hylia prasina	Green Hylia	**x**	
Prinia subflava	West African Prinia	**x**	**X**
Timaliidae			
Turdioides plebejus	Brown Babbler		**X**
T. reinwardii	White-capped Babbler		**X**
Turdidae			
Luscinia megarhynchos	Nightingale		**X**
Turdus pelios	West African Thrush	**x**	**X**
Mammalia			
Insectivora			
Crocidura oliveri	White-toothed Shrew	**x**	
Erinaceus albiventris	White-bellied Hedgehog		
Chiroptera			
Eidolon helvum	Straw-coloured Fruit Bat		**X**
Primates			
Cercopithecus aethiops	Green Monkey/Guenon		**X**
C. mona	Mona Monkey	**x**	
Galago senegalensis	Senagal Galago	**x**	
Galagoides demidoff	Demidoff's Galago		**x**
Perodicticus potto	Bosman's Potto	**x**	

Rodentia			
Arvicanthis niloticus	Rufous Nile rat		**x**
Atherurus africanus	Brush-Tailed Porcupine	**x**	
Cricetomys gambianus	Gambian Giant Pouched Rat	**x**	**x**
Dasynys incomtus	Shaggy Swamp Rat	**x**	
Euxerus erythropus	Unstriped Ground Squirel		**x**
Hystrix cristata	Crested Porcupine	**x**	
Lemniscomys striatus	Spotted Zebra Mouse	**x**	
Lophuromys flavipunctatus	Brush-furred Mouse	**x**	
Mastomys erythroleucus	Multimammate Mouse	**x**	**x**
Praomys tullbergi	Soft-furred Rat		**x**
Rattus rattus	Common Rat		**x**
Thryonomys swinderianus	Grasscutter	**x**	**x**
Lagomorpha			
Lepus zechi	Togo Hare		**x**
Pholidota			
Phataginus tricuspis	Tree Pangolin	**X**	
Uromanis tetradactyla	Long-tailed Pangolin	**X**	
Carnivora			
Civettictis civetta	African Civet	**X**	
Mungos gambianus	Gambian Mongoose	**X**	**x**
Hyracoidea			
Dendrohyrax dorsalis	Tree Hyrax	**X**	
Procavia ruiceps	Rock Hyrax		**x**
Artiodactyla			

Cephalophus maxwelli	**Maxwell's Duiker**	**X**	**x**
Neotragus pygmaeus	**Royal Antelope**	**X**	**x**
Potamochoerus porcus	**Red River Hog**	**X**	
Tragelaphus scriptus	**Bushbuck**	**X**	**x**

Table D-2 Species of Fish and Shellfish Expected from Onshore Water Bodies and the Nearshore Fishery

Species of fish and shellfish expected from onshore water bodies and the near shore fishery				
Fish Species	**Sakumono near shore fishery**	**Gao Lagoon**	**Anankwari Lagoon**	**Aboadze Swamps**
Alectis alexandrinus	*x*	*x*	*x*	
Balistapus aculeatus	*x*			
Balistes punctatus	*x*			
Balistes capriscus	*x*			
Bothus podas africanus	*x*	*x*	*x*	
Brachydeuterus auritus	*x*	*x*	*x*	
Caranx crysos	*x*	*x*		
Caranx hippos	*x*	*x*		
Caranx senegallus	*x*			
Chloroscombrus chrysurus	*x*	*x*	*x*	
Cynoglossus monodi	*x*	*x*	*x*	
Cynoglossus senegalensis	x			
Daysatis margarita	x			
Decapterus punctatus	x	x	x	

Decapterus rhonchus	x				
Drepane africana	x				
Echeneis naucrates	x				
Elops lacerta	x	x	x		
Engraulis encrasicolus	x				
Ephippion guttifer	*x*				
Epinephelus aeneus	*x*	*x*	*x*		
Ethmalosa fimbriata	*x*		*x*		
Eucinostomus melanopterus	*x*				
Fodiator acutus	*x*				
Galeiodes decadactylus	*x*	*x*	*x*		
Gerres nigri	*x*	*x*	*x*		
Hemiramphus brasiliensis	*x*				
Hemicaranx bicolor		*x*	*x*		
Ilisha africana	*x*	*x*	*x*		
Lagocephalus laevigatus	*x*	*x*			
Lagocephalus lagocephalus	*x*				
Lethrinus atlanticus	*x*				
Lichia amia	*x*				
Liza falcipinnis	*x*	*x*	*x*		
Monacanthus setifer	*x*				
Melicthys niger	*x*				
Pellonula leonensis	*x*	*x*	*x*		

Pentanemus quinquarius	x	x	x	
Plectoryhncus macrolepis	x			
Pomadasys rogerii	x	x	x	
Polydactylus quadrifilis	x	x	x	
Priacanthus arenatus				
Pseudotholithus brachygnathus	x			
Pseudotholithus elongatus	x	x	x	
Pseudotholithus senegalensis	x			
Pseudotholithus typus	x			
Rhinobatus cemicullus	x			
Sarda sarda	x			
Sardinella aurita	x	x	x	
Sardinella maderensis	x	x	x	
Sarotherodon melanotheron	x	x	x	
Selene dorsalis	x	x	x	
Sphyraena sphyraena	x	x	x	
Stromateus fiatola	x			
Torpedo nobliana	x			
Trachinotus glaucus	x			
Trachinotus goreensis	x	x	x	
Trachinotus ovatus	x			
Trichiurus lepturus				

Tylosorus crocodilus crocodiles	x			
Umbrina canariensis	x			
Umbrina steindachneri	x			
Clarias sp				x
Hemichromis bimaculatus				x
Hemichromis fasciatus				x
Heterobranchus sp				x
Heterotis niloticus				x
Parophiochalus obscurus				x
Polypterus sp				x
Tilapia zilli				x
Crustaceans				
Callinectes marginatus	x	x	x	
Callinectes pallidus	x	x	x	
Gymnura sp.	x			
Exhippolysmata hastatoides	x			
Nematopalaemon hastatus	x			
Panulirus regius	x			
Paramola cuvieri	x			
Parapeneopsis atlantica	x	x	x	
Parapenaeus longirostris	x	x	x	
Penaeus notialis	x	x	x	
Penaeus kerathurus	X	x	x	

Plesiopenaeus edwardsianus	*x*			
Isopod	*x*			
Amphipoda	*x*	*x*	*x*	
Mollusca				
Ostrea sp		*x*	*x*	

Table D-3 ESL and ICF WAGP Onshore 2nd Season EBS Fieldwork Plan

DATE	LOCATION	MAJOR AREAS	MAJOR ACTIVITIES
10/6/2003	ACCRA	COMMUNICATION (ESL CORE TEAM)	BRIEFING ON SAFETY MEASURES FOR ONSHORE/OFFSHORE EBS FIELD WORK AND DISCUSSING SAMPLING PLAN FOR 2ND SEASON EBS SURVEY
13-14/06/03	TEMA	FIELD WORK	INTERTIDAL ROCKY HABITATS FOR ALGAE AND BENTHIC INFAUNA
			IDENTIFYING AND FIXING POSSIBLE SAMPLING LOCATIONS FOR THE VEGETATION,
20-22/06/03	TEMA	FIELD WORK	SOILS AND SEDIMENT SAMPLING, WILD LIFE, FISHERIES AND WATER CHEMISTRY
		VEGETATION	SAMPLE COLLECTION
		BIOLOGY	SAMPLE COLLECTION
		BENTHIC FAUNA	SAMPLE COLLECTION
		SURFACE WATER CHEM	SAMPLE COLLECTION
		MICROBIOLOGY	SAMPLE COLLECTION
		FISHERIES	SAMPLE COLLECTION
25/06/03	ESL ONSHORE SCIENTIFIC	EBS TEAM TRAVEL TO TAKORADI	

25-28/06/03	TAKORADI	VEGETATION	SAMPLE COLLECTION
		BIOLOGY	SAMPLE COLLECTION
		WILDLIFE	SAMPLE COLLECTION
		SOIL ECOL	SAMPLE COLLECTION
		BENTHIC FAUNA	SAMPLE COLLECTION
		SURFACE WATER CHEM	SAMPLE COLLECTION
		MICROBIOLOGY	SAMPLE COLLECTION
		FISHERIES	SAMPLE COLLECTION
30/06 -01/07/03	TAKORADI	FIELD WORK	INTERTIDAL ROCKY HABITATS FOR ALGAE AND BENTHIC INFAUNA
07-18/07/2003		**MOP-UP FIELD SAMPLING AT TEMA AND TAKORADI**	
	TEMA	FIELD WORK	
7/7/2003		SURFACE WATER BIOLOGY	SAMPLE COLLECTION
		SOIL ECOLOGY	
16 -18/07/03	TAKORADI	WILDLIFE AND MICROBIOLOGY	SAMPLE COLLECTION

Table D-4 Summary of Laboratory Responsibilities

ESL	**Offshore**		**Onshore**		
Parameters	Water	Sediment	Water	Sediment	Soil
In-situ Measurements			X	X	X
Nutrients	X		X		
Organics					
Productivity					

Phytoplankton	X				
Zoopolankton	X		X		
Fisheries	X		X		
Microbiology					
Benthos		X		X	
Grain Size					
Soil Ecology and Wildlife					X
CSIR	Offshore			Onshore	
Parameters	Water	Sediment	Water	Sediment	Soil
In-situ Measurements					
Nutrients	X		X		
Organics				X	X
Productivity			X		
Phytoplankton			X		
Zoopolankton					
Fisheries					
Microbiology			X		X
Benthos					
Grain Size				X	
Soil Ecology and Wildlife					

Table D-5a Onshore Scientific Field Team

MAJOR AREAS	ESL FIELD TEAM/CONSULTANT IN CHARGE

MAJOR AREAS	ESL FIELD TEAM/CONSULTANT IN CHARGE
INTERTIDAL ROCKY HABITATS FOR ALGAE AND BENTHIC INFAUNA	A. K ARMAH
	F. SEKU
	E. LAMPTEY
VEGETATION	J ADOMAKO
SOILS CHEMISTRY/PHYSICS	D. K. Allotey
ONSHORE MACROBENTHIC FAUNA	AK ARMAH
	E. LAMPTEY
	H. D. Darkinson
SURFACE WATER CHEMISTRY	S. D. Ababio
	E. Armah
	G. A. Darpaah
ONSHORE FISHERIES	S. ADDO
	S. O. Ababio
BIOLOGY/ PRODUCTIVITY	A. A de-Graft Johnson
	S. Addo
	G. Darpaah
SOIL ECOLOGY	M. A. Cobblah
WILDLIFE	D. K. ATTUQUAYEFIO
TURTLE SURVEY	A. K. Armah
	G. A. Darpaah
	E. Lamptey
	S. ADDO
MICROBIOLOGY	S. Addo
	S. O. Ababio

MAJOR AREAS	ESL FIELD TEAM/CONSULTANT IN CHARGE
FIELD TRACKING	G. Darpaah
	S. Addo
	E. LAMPTEY
ONSHORE FIELD CO-ORDINATION	G. Darpaah

Table D-5b Onshore Field Parameter Outline and Activity

DATE	LOCATION	MAJOR AREAS	MAJOR ACTIVITIES
6/10/2003	ACCRA	*COMMUNICATION*	
		(ESL CORE TEAM)	BRIEFING ON SAFETY MEASURES FOR ONSHORE/OFFSHORE EBS FIELD WORK
			AND DISCUSSING SAMPLING PLAN FOR 2ND SEASON EBS SURVEY
13-14/06/03	TEMA	*FIELD WORK*	INTERTIDAL ROCKY HABITATS FOR ALGAE AND BENTHIC INFAUNA
			IDENTIFYING AND FIXING POSSIBLE SAMPLING LOCATIONS FOR THE VEGETATION,
20-22/06/03	TEMA	*FIELD WORK*	SOILS AND SEDIMENT SAMPLING, WILD LIFE, FISHERIES AND WATER CHEMISTRY
		VEGETATION	SAMPLE COLLECTION
		BIOLOGY	SAMPLE COLLECTION
		WILDLIFE	SAMPLE COLLECTION
		BENTHIC FAUNA	SAMPLE COLLECTION
		SURFACE CHEM	SAMPLE COLLECTION
		FISHERIES	SAMPLE COLLECTION
25/06/03	ESL ONSHORE SCIENTIFIC	EBS ONSHORE TEAM TRAVEL TO TAKORADI.	

DATE	LOCATION	MAJOR AREAS	MAJOR ACTIVITIES
25-28/06/03	TAKORADI	VEGETATION	SAMPLE COLLECTION
		BIOLOGY	SAMPLE COLLECTION
		SOIL ECOL	SAMPLE COLLECTION
		BENTHIC FAUNA	SAMPLE COLLECTION
		SURFACE WATER CHEM	SAMPLE COLLECTION
		FISHERIES	SAMPLE COLLECTION
30/06 - 01/07/03	TAKORADI	MACRO ALGAE & BENTHOS TEAMS	INTERTIDAL ROCKY HABITATS SAMPLING FOR ALGAE AND BENTHIC INFAUNA
07-18/07/2003	TEMA	***MOP-UP FIELD SAMPLING AT TEMA AND TAKORADI***	
		FIELD WORK	
7/7/2003		SURFACE WATER BIOLOGY	SAMPLE COLLECTION
		SOIL ECOLOGY	
16 -18/07/03	TAKORADI	WILDLIFE AND MICROBIOLOGY	SAMPLE COLLECTION

Table D-5c Onhsore Fieldwork Plan and Daily Activities

DATE	**ACTIVITY**	**FIELD LOCATION**	**FIELD TEAMS**	**TRANSPORT TYPE**				**TRAVEL TYPE**		**HOTEL RESER-VATION**	**ESTIMATED # DAYS IN FIELD**
				4X RUNNER GR 418E	**TOYOTA DYNA GR 4638P**	**NISSAN PICK-UP GR 7755C**	**Land Rover GR 4558A**	**OVER NIGHT**	**RETURN**		
13-14/06/2003	RECONNAISSANCE VISIT TO FIELD SITE AND SETTING UP; INTERTIDAL ALGAE SAMPLING	TEMA	VEGETATION	X			X		X		1
	OF SAMPLING STATIONS		WATER	X					X		
20-22/06/2003	RECONNAISANCE & SAMPLE COLLECTION	TEMA	ALL TEAMS	X	X	X	X		X		1
	SAMPLE COLLECTION	TEMA	ALL TEAMS	X	X	X	X		X		1
	SAMPLE COLLECTION	TEMA	ALL TEAMS	X	X	X	X		X		1
	SAMPLE COLLECTION (MOP-UP)	TEMA	ALL TEAMS								1

25-Jun	EBS ONSHORE FIELD TEAM TRAVEL TO TAKORADI	TAKORADI	ONSHORE EBS TEAM	X	X	X	X	X		X	4
25-28/06/2003	RECONNAISSANCE VISIT TO SITE BY EBS ONSHORE TEAM										
	AND SELECTION OF SAMPLING SITES	TAKORADI	ONSHORE EBS TEAM	X	X	X	X				
	EBS ONSHORE SAMPLING	TAKORADI	ALL TEAMS	X	X	X	X				1
	EBS ONSHORE SAMPLING	TAKORADI	ALL TEAMS	X	X	X	X				1
	EBS ONSHORE SAMPLING	TAKORADI	ALL TEAMS	X	X	X	X				1
6/28/2003	EBS TEAMS DATA COLLECTION AND DEPARTURE TO ACCRA										
30/06-01/07/2003		TAKORADI	ONSHORE EBS TEAM	X	X	X	X		X		1
07-	MOP-UP FIELD SAMPLING AT TEMA AND										

18/07/2003	TAKORADI										
7/7/2003	TEMA										
	FIELD WORK										
	SURFACE WATER BIOLOGY	TEMA			X	X			X		
	SOIL ECOLOGY	TEMA			X				X		
16 -18/07/03	TAKORADI										
	WILDLIFE AND MICROBIOLOGY	TAKORADI		X				X		X	2

Table D-6 Floristic Composition of the Coastal Strand Vegetation of the WAGP Route at Tema

Floristic Composition of the Coastal Strand Vegetation of the WAGP Route at Tema		
Species	**Life Form**	**Family**
Abutilon mauritianum	Shrublet	Malvaceae
Alternanthera pungens	Herb	Amaranthaceae
Azadirachta indica	Tree	Meliaceae
Boerhavia diffusa	Herb	Nyctaginaceae
Cenchrus echinatus	Herb	Graminae
Centrosema pubescens	Climber	Papilionaceae
Chloris pilosa	Herb	Graminae
Cissus aralioides	Climber	Vitaceae
Cleome viscosa	Herb	Cleomaceae
Clerodendrum sp	Climber	Verbenaceae
Crotalaria retusa	Shrublet	Papilionaceae
Croton lobatus	Shrublet	Euphorbiaceae
Cyperus rotundus	Herb	Cyperaceae
Eleusine indica	Herb	Graminae
Euphorbia hirta	Herb	Euphorbiaceae
Grewia carpinifolia	Climber	Tiliaceae
Heteropogon contortus	Herb	Graminae
Indigofera hirsuta	Shrublet	Papilionaceae
Lantana camara	Shrublet	Verbenaceae
Millettia thonningii	Tree	Papilionaceae
Millettia zechiana	Tree	Papilionaceae
Mimosa pudica	Shrublet	Mimosaceae

Panicum laxum	Herb	Graminae
Paspalum conjugatum	Herb	Graminae
Passiflora foetida	Climber	Passifloraceae
Phyllanthus niruroides	Herb	Euphorbiaceae
Physalis angulata	Herb	Solanaceae
Schrankia leptocarpa	Shrublet	Mimosaceae
Securinega virosa	Shrub	Euphorbiaceae
Setaria pallide-fusca	Herb	Graminae
Spigelia anthelmia	Herb	Loganiaceae
Zanthoxylum xanthoxyloides	Tree	Rutaceae

Table D-7 Floristic Composition of the Coastal Scrub and Grassland Vegetation of the WAGP Route at Tema

Floristic Composition of the Coastal Scrub and Grassland Vegetation of the WAGP Route at Tema		
Species	**Life Form**	**Family**
Cyathula prostrtata	Herb	Amaranthaceae
Calotropis procera	Tree	Asclepiadaceae
Cleome viscosa	Herb	Cleomaceae
Commelina erecta	Herb	Commelinaceae
Blumea aurita	Herb	Compositae
Tridax procumbens	Herb	Compositae
Ipomoea eriopcarpa	Climber	Convolvulaceae
Cyperus rotundus	Herb	Cyperaceae
Euphorbia heterophylla	Herb	Euphorbiaceae
Securinega virosa	Shrub	Euphorbiaceae
Dactyloctenium aegyptium	Herb	Graminae

Panicum maximum	Herb	Graminae
Paspalum conjugatum	Herb	Graminae
Sporobolus pyramidalis	Herb	Graminae
Gloriosa superba	Climber	Liliaceae
Spigelia anthelmia	Herb	Loganiaceae
Abutilon mauritianum	Shrub	Malvaceae
Azadirachta indica	Tree	Meliaceae
Dichrostachys cinerea	Shrub	Mimosaceae
Centrosema pubescens	Climber	Papilionaceae
Desmodium triflorum	Herb	Papilionaceae
Indigofera spicata	Shrublet	Papilionaceae
Passiflora foetida	Climber	Passifloraceae
Spermacoe verticillata	Herb	Rubiaceae
Waltheria indica	Shrub	Sterculiaceae
Corchorus tridens	Herb	Tiliaceae

Table D-8 Floristic Composition of the Coastal Strand Vegetation of the WAGP Route at Aboadze/Takoradi

Floristic Composition of the Coastal Strand Vegetation of the WAGP Route at Aboadze/Takoradi		
Species	Life Form	Family
Abutilon mauritianum	Shrublet	Malvaceae
Agave sisalana	Herb	Agavaceae
Asystasia calycina	Herb	Acanthaceae
Baphia nitida	Tree	Papilionaceae
Canavalia rosea	Herb	Papilionaceae
Cassytha filiformis	Climber	Lauraceae

Centella asiatica	Herb	Araliaceae
Centrosema plumieri	Climber	Papilionaceae
Chloris pilosa	Herb	Graminae
Commelina erectus	Herb	Commelinaceae
Crotalaria retusa	Shrublet	Papilionaceae
Cyperus articulatus	Herb	Cyperaceae
Cyperus maritimus	Herb	Cyperaceae
Cyperus rotundus	Herb	Cyperaceae
Dactyloctenium aegyptium	Herb	Graminae
Desmodium scorpiurus	Shrublet	Papilionaceae
Desmodium triflorum	Herb	Papilionaceae
Eclipta prostrata	Herb	Compositae
Elaeis guineensis	Tree	Palmae
Eleusine indica	Herb	Graminae
Erigeron floribundus	Herb	Compositae
Fuirena umbellata	Herb	Cyperaceae
Imperata cylindrica	Herb	Graminae
Indigofera spicata	Shrublet	Papilionaceae
Ipomoea cairica	Climber	Convolvulaceae
Ipomoea involucrata	Climber	Convolvulaceae
Ipomoea pes-caprae	Herb	Convolvulaceae
Leonotis nepetifolia	Herb	Lamiaceae
Malacantha scandens	Shrub	Compositae
Mimosa pudica	Shrublet	Mimosaceae
Paspalum cojugatum	Herb	Graminae
Paspalum vaginatum	Herb	Graminae

Passiflora foetida	Climber	Passifloraceae
Phaseolus sp	Shrublet	Papilionaceae
Phoenix reclinata	Tree	Palmae
Phyllanthus amarus	Herb	Euphorbiaceae
Remirea maritima	Herb	Cyperaceae
Schranckia leptocarpa	Shrublet	Mimosaceae
Sesuvium portulacastrum	Herb	Ficoidaceae
Spermacoe verticillata	Herb	Rubiaceae
Spigelia anthelmia	Herb	Loganiaceae
Sporobolus pyramidalis	Herb	Graminae
Sporobolus virginicus	Herb	Graminae
Stachytarpheta indica	Shrublet	Verbenaceae
Tacca leontopetaloides	Herb	Taccaceae
Tribulus terrestris	Herb	Zygophyllaceae
Uraria picta	Herb	Papilionaceae
Vernonia cinerea	Shrublet	Compositae
Waltheria indica	Shrub	Sterculiaceae

Table D-9 Floristic Composition of the Coastal Scrub and Grassland Vegetation of the WAGP Route at Aboadze/Takoradi

Floristic Composition of the Coastal Scrub and Grassland Vegetation of the WAGP route at Aboadze/Takoradi		
Species	**Life Form**	**Family**
Abutilon mauritianum	Shrublet	Malvaceae
Baphia pubescens	Tree	Papilionaceae
Cassytha filiformis	Climber	Lauraceae
Ceiba pentandra	Tree	Bombacaceae

Chloris pilosa	Herb	Graminae
Chromolaena odorata	Shrub	Compositae
Crotalaria retusa	Shrublet	Papilionaceae
Dactyloctenium aegyptium	Herb	Graminae
Desmodium scorpiurus	Shrublet	Papilionaceae
Elaeis guineensis	Tree	Palmae
Fuirena umbellata	Herb	Cyperaceae
Funtumia elastica	Tree	Apocynaceae
Griffonia simplicifolia	Climber	Caesalpiniaceae
Indigofera spicata	Shrublet	Papilionaceae
Ipomoea aquatica	Herb	Convolvulaceae
Ipomoea cairica	Climber	Convolvulaceae
Lantana camara	Shrublet	Verbenaceae
Leucaena leucocephala	Shrub	Mimosaceae
Millettia zechiana	Shrub	Papilionaceae
Mimosa pudica	Shrublet	Mimosaceae
Panicum maximum	Herb	Graminae
Paspalum conjugatum	Herb	Graminae
Paspalum vaginatum	Herb	Graminae
Passiflora foetida	Climber	Passifloraceae
Pennisetum pedicellatum	Herb	Graminae
Pennisetum purpureum	Herb	Graminae
Phoenix reclinata	Tree	Palmae
Schrankia leptocarpa	Shrublet	Mimosaceae
Sida linifolia	Herb	Malvaceae
Spathodea campanulata	Tree	Bignoniaceae

Spigelia anthelmia	Herb	Loganiaceae
Sporobolus pyramidalis	Herb	Graminae
Stachytarpheta indica	Herb	Verbenaceae
Trema orientalis	Tree	Ulmaceae
Tridax procumbens	Herb	Compositae
Triumfetta cordifolia	Shrublet	Tiliaceae
Triumpheta rhomboidea	Shrublet	Tiliaceae
Uraria picta	Herb	Papilionaceae
Urena lobata	Shrublet	Malvaceae
Vernonia cinerea	Shrublet	Compositae
Waltheria indica	Shrub	Sterculiaceae

Table D-10 Strand and Scrub Vegetation of Aboadze/Takoradi Swamp

Strand and scrub vegetation of Aboadze/Takoradi swamp	
Species	**Family**
Imperata cylindrica	Graminae
Crinum ornatum	Amaryllidaceae
Pentodon pentandrus	Rubiaceae
Schrankia leptocarpa	Mimosaceae
Paspalum vaginatum	Graminae
Cyperus articulatus	Cyperaceae
Cyperus iria	Cyperaceae
Avicennia germinans	Avicenniaceae

Table D-11 Soil Parameters (Physiacal and Chemical

Soil Parameters (Physical and Chemical)				
STATIONS	**REDOX mV**	**pH**	**Temp oC**	**TOC %**
Tema				
2A1	200.6	5.7	27.5	0.324
2A2	202.2	5.85	26.9	0.451
2A3	195.1	7.25	26.6	2.42
2B1	216.6	4.73	26.5	0.22
2B2	210.3	5.71	26.8	0.231
2B3	201	5.81	26.4	0.47
2B4	201	5.34	27.8	0.177
Aboadze/Takoradi				
2C1	224.4	6.94	28.5	0.043
2C2	218.5	5.11	29.8	0.769
2C3	215.4	6.7	29.5	0.135
2D1	219.5	7.76	25.4	0.174
2D2	293.6	6.54	25.5	0.11
2D3	228.7	7.19	25.5	0.267
2D4	227.1	6.11	25.5	0.059

Table D-12 List of Butterfly Species Recorded at Tema

List of butterfly species recorded at Tema			
Family	**Species**		
Papilionidae	Papilio demodocus		

	Papilio nereus		
Nymphalidae	Junonia orithya		
	Junonia oenone		
	Acraea eponina		
	Acraea natalica		
	Danaus chryssippus		
Pieridae	Eurema hecabe		
	Colotis evippe		
	Catopsilia		
	Nepheronia argia		
Pitfall trapping at transect A			
Class/Order	**Species**	**Abundance**	
Insecta			
Hymenoptera	*Pheidole megacephala*	55	
	Camponotus barbarosa	10	
	Camponotus aquapimensis	12	
	Crematogaster castanea	3	
Diptera	*Lucilia sericata*	15	
Coleoptera	*Mylabris afzelli*	1	
	Carabid sp	1	
	Staphylinid sp	3	
Orthoptera	*Metioche sp*	5	
Heteroptera	*Clavigralla shadabi*	1	
Arachnida			
Araneae	*Lycosa sp*	3	

	Ctenid sp *Gnaphosid sp*	1 2	
Crustacea Isopoda	*Porcellio muscorum*	4	
TOTAL		**116**	
Analysis of soil core samples at transect A and B at Tema			
Depth **0-15cm**	**Abundance of species**	**Depth** **15-50cm**	**Abundance of species**
A1 *Geophilomorph* sp (Centipede) *Staphylinind* sp(Beetle) Carabid larva (Beetle) **A2** *Pheidole megacephala* (ant) Carabid larva (Beetle) **A3** *Eudrilid* sp (Earthworm) *Oniscus sp* (Woodlice) *Lycosa* sp1	1 2 1 1 3 1 1 3	*Crematogaster castanea*(Ant)	1
TOTAL	**13**		**1**
B1 Shell (Mollusc) *Pheidole megacephala* (ant)	2 2	Shell (Mollusc)	1

B2	0	Scarabaed larva	2
B3	0		
B4	0		
TOTAL	**4**		**3**

Pitfall trapping at transect B			
Class/Order	**Species**	**Abundance**	
Insecta			
Hymenoptera	*Pheidole megacephala*	4	
	Camponotus barbarosa	236	
	Camponotus aquapimensis	4	
	Crematogaster castanea	50	
Diptera	*Lucilia sericata*	12	
Coleoptera	*Carabid larva*	1	
	Carabid sp	5	
	Staphylinid sp	1	
Orthoptera	*Acheta sp*	2	
Heteroptera	*Reduvid sp*	5	
	Clavigralla shadabi	1	
Arachnida			
Araneae	*Lycosa sp 1*	1	
	Lycosa sp 2	1	
	Lycosa sp 3	1	
	Ctenid sp	1	
	Gnaphosid sp	1	
Isoptera	*Macrotermes natalensis*	60	

Crustacea			
Isopoda	*Philoscia sp*	3	
	Oniscus sp	1	
TOTAL		**390**	

Table D-13 Butterfly Diversity at Aboadze/Takoradi

Butterfly diversity at Aboadze/Takoradi			
Family	**Species**		
Papilionidae	*Papilio demodocus*		
Nymphalidae	*Junonia orithya*		
	Junonia oenone		
	Acraea eponina		
	Danaus chryssippus		
Pieridae	*Eurema hecabe*		
	Colotis evippe		
	Catopsilia		
	Nepheronia argia		
Pitfall trapping at transect C			
Class/Order	**Species**	**Abundance**	
Insecta			
Hymenoptera	*Pheidole megacephala*	20	
	Palthothyreus sp	4	
	Camponotus sericeus	6	
	Oecophyla sp	1	
	Camponotus aquapimensis	7	

	Crematogaster castanea	5	
Diptera	*Chironomid* sp	1	
Coleoptera			
Scarabaedae	*Craspidophorus* sp	1	
Heteroptera	*Pentatomid* sp	1	
TOTAL		**46**	
Analysis of macrofauna in soil core samples at transect C and D at Aboadze/Takoradi			
Depth 0-15cm	**Abundance of species**	**Depth 15-50cm**	**Abundance of species**
C1			
Eudrilid sp (Earthworm)	2	*Eudrilid* sp (Earthworm)	5
C2			
Eudrilid sp (Earthworm)	7		
C3			
TOTAL	**9**		**5**
D1			
Eudrilid sp (Earthworm)	4	*Eudrilid* sp (Earthworm)	3
Staphylinid larvae (Beetle)	1	.*Chironomid* sp (Midge)	1
D2	0		
Eudrilid sp (Earthworm)	5		
D3	0	*Eudrilid* sp (Earthworm)	2

Staphylinid larvae (Beetle)	1	*Onicid sp* (Woodlice)	1
Lycosa sp (Spider)	1		
Pentatomid sp (Bug)	1		
D4			
Eudrilid sp (Earthworm)	1		
TOTAL	**14**		**7**
Pitfall trapping at transect D			
Class/Order	**Species**	**Abundance**	
Insecta			
Hymenoptera	*Pheidole megacephala*	20	
	Pheidole sp	9	
	Palthothyreus sp	48	
	Camponotus sericeus	9	
	Camponotus vestitus	2	
	Camponotus aquapimensis	7	
	Camponotus macultus	20	
Coleoptera	*Staphylinid* sp	1	
Orthoptera	*Acridid* sp	1	
Arachnida			
Araneae	sp 1	2	
TOTAL		**119**	
Summry of abundance of macro fauna in core samples at Tema and Aboadze/Takoradi			

Transect	Depth		Total no.
	(0-15)cm	(15-50) cm	
A	13	1	14
B	4	3	7
C	9	7	16
D	14	7	21
Summary of species diversity in pitfall and total soil core samples			
Transect	**Pitfall Trapping**	**Soil core**	
A	14	9	
B	18	3	
C	9	1	
D	10	7	

Table D-14 Onshore Water Parameters

STATIONS	pH	DO (mg/l)	Turbidity (FAU)	TDS (mg/l)	Conductivity (ms/cm)	Sulphate (mg/l)	BOD (mg/l)	Ammonia Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)	Total Nitrogen (mg/l)	Ortho-Phosphorus (mg/l)	Total Phosphorus (mg/l)
Water Parameters (Chemical and Physical)												
TEMA												
2GS1TEM LW LT	8.17	5.19	103	9530	16.73	1000	2.02	0.1	0.3	0.096	1	0.097
2GS1TEM LW HT	8.17	6.46	103	25800	41.9	2850	1.78	0.07	0.3	1.58	0.82	0.169
2GS2TEM LW LT	8.15	5.13	256	8600	15.44	1000	1.86	0.1	0.3	0.185	1.05	0.101
2GS2TEM LW HT	8.22	5.63	201	22400	39.7	2500	2.61	0.08	0.3	0.335	0.46	0.062
2GS3TEM LW LT	8.19	5.4	366	8440	14.95	850	2.89	0.13	0.4	0.034	1.01	0.129
2GS3TEM LW HT	8.13	5.63	110	11700	20.4	1450	3.11	0.23	0.3	0.971	1.01	0.099
2GS7TEM ITZ	8.69	9.3	16	26000	44.8	2950	2.66	0.09	0.4	0.034	0.31	0.101

Sediment Parameters (Chemical and Physical)

STATIONS	TEMP oC	pH	Redox mV	TPH ug/g	TOC (%)	GRAIN SIZE %Sand	%Silt	% Clay	Texture

		Units								
TEMA										
2GS1TEM LSED	28.1	7.72	254.6	14.2	0.707	97	2	1	Sand	
2GS2TEM LSED	31	7.62	-106.3	12.7	0.037	35	38	27	Clay Loam	
2GS3TEM LSED	33.2	7.45	-338.7	14.1	2.66	90	**6**	**4**	Sand	
2GS4TEM LSED	33.2	7.37	-385.4	15.2	1.19	2	52	46	Silty Clay	
2GS5TEM LSED	38.9	7.02	-353.6	14.6	1.31	97	1	2	Sand	
2GS6TEM LSED	37.3	7.4	-371.3	19.7	1.39	34	43	24	Loam	
2GS7A TEM ITZ	30.5	7.22	180.7	11.9	0.019	30	59	11	Silt Loam	
2GS7B TEM ITZ	31	7.3	185.3	9.8	0.02	95	2	2	Sand	

Table D-15 Relative Abundance of Common Intertidal Macrobenthic Fauna at Tema

Relative Abundance of Common Intertidal Macrobenthic Fauna at Tema		
SPECIES	Tema	
	Lower Intertidal Zone	Upper Intertidal Zone
Polychaeta		
Arenicola sp.	1-5	0
Capitella capitata	21+	0
Caulleriella capensis	1-5	0
Cirriformia afer	1-5	0
Cirriformia capensis	21+	1-5
Cirriformia dentata	21+	0
Cirriformia saxatilis	21+	1-5
Cirriformia tentaculata	6-10	1-5
Diopatra monroi	21+	0
Diopatra neapolitana	21+	0
Epidiopatra hupferiana monroi	1-5	0
Eunice vitata	0	1-5
Eurythoe sp	6-10	0
Lysidice ninetta	1-5	0
Lysidice collaris	0	1-5
Lysidice ninetta	0	1-5
Marphysa mossambica	0	1-5
Marphysa sanguinea	0	1-5
Marphysa sp.	0	1-5
Nereis sp.	21+	1-5
Nematonereis unicornis	1-5	0

Nereis falsa	21+	6-10
Nereis succinea	21+	0
Notomastus sp.	1-5	0
Polydora antennata	1-5	0
Spirorbis patagonicus	1-5	0
Syllis gracilis	11-15	0
Crustacea		
Alpheus sp.	1-5	0
Anthura sp.	1-5	0
Aorid sp.	21+	1-5
Apseudes latreille	0	1-5
Chthamalus spp.	21+	6-10
Cirolana spp	0	0
Exocirolana sp.	1-5	6-10
Gammarus sp.	21+	0
Hyale sp.	1-5	0
Mysid sp.	6-10	0
Phoxocephalid sp.	6-10	0
Ocypoda cursor	0	1-5
Decapod Crustaceans		
Carpilius sp.	6-10	0
Etisus sp.	1-5	0
Grapsid sp. I	0	11-15
Grapsid sp. II	1-5	1-5
Scylla sp. I	0	1-5
Scylla sp. II	1-5	0

Sersarma sp.	1-5	0
Xanthid sp.	1-5	0
Mollusca		
Littorina punctata	11-15	6-10
Nerita sp.	0	1-5
Patella safiana	6-10	1-5
Perna sp.	1-5	0
Siphonaria pectinana	6-10	16-20
Otrea tulipa	6-10	1-5
OTHERS		
Echinometra lucunter	1-5	0
Sipunculid sp.	1-5	1-5
Thalassema sp.	0	1-5
Zoanthus spp	1-5	0
Palythoa spp	1-5	0

Abundance range:

- = 0, + = 1 – 5, ++ = 6 – 10, +++ = 11 – 15, ++++ = 16 – 20, +++++ = 21+

Table D-16a Macroalgal Species Observed at Tema

Macroagal species at Tema								
Quadrat #	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Distance	**21**	**25**	**27**	**29**	**41**	**45**	**47**	**49**
Ulva fasciata	40	85	90	70	25	20	-	12
Chaetomorpha antennina	-	-	-	-	2	70	-	85
Hypnea musciformis	5	1	1	5	20	20	20	-

Jania rubens	-	-	-	-	1		30	4
Caulerpa taxifolia	-	-	-	-	-	-	28	-
Enteromorpha f. flexuosa	20	1	-	-	-	-	-	-
Hydropuntia dentata	-	-	-	-	-	1	15	1
Ralfsia expansa	-	-	-	-	5	1		-
Gigartina accicularis	-	-	-	-	-	5		1
Gelidiopsis variabilis	-	-	-	-	-	-	5	-
Centroceras clavulatum	2	1	-	-	-	-	-	2
Cladophora prolifera		1	2	1	-	-	-	-
Bryopsis pennata	-	-	-	-	-	2		2
Gelidium arbuscula	-	-	-	-	-	-	1	-
Bare patch	33	11	7	24	47	0	1	0
TOTAL	**100**	**100**	**100**	**100**	**100**	**119**	**100**	**107**

Table D-16b Macroalgal Species at Aboadze/Takoradi

Macroagal species at Aboadze/Takoradi								
Quadrat #	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Distance	**21**	**25**	**27**	**29**	**31**	**35**	**37**	**39**
Padina durvellei	-	1	5	1	1	4	2	10
Ulva fasciata	10	5	5	5	1	2	1	-
Centroceras clavulatum	1	3	10	40	1	1	2	-
Enteromorpha f. flexuosa	5	-	0	-	-	-	-	-
Bachelotia antillarum	10	5	0	2	-	-	-	-
Hydropuntia dentata	1	2	5	-	2	2	5	-

Ralfsia expansa	1	-	-	-	-	-	-	-
Chaetomorpha linum	-	1	1	1	-	-	-	-
Algal turf	-	-	-	-	-	-	-	-
Chnoospora minima	-	-	-	-	-	-	-	-
Cyanophyta (Blue-greens)	-	-	-	-	-	-	-	-
Sargassum vulgare	-	-	-	-	1		7	-
Hypnea musciformis	-	2	-	1		1		-
Bryopsis pennata	-	-	-	-	-	-	-	-
Padina tetratrosmatica	-	-	1	-	-	2	1	-
Jania rubens	-	-	2	-	-	1	1	1
Cladophora vagabunda	-	-		-	-	-	-	-
Dictyota ciliolata	-	-	1	-	-	-	-	-
Laurencia intermedia	-	1	-	-	2	-	-	-
Asparagopsis taxiformis	-	-	1	-	-	-	1	-
Giffordia mitchelliae	-	-	-	-	-	-	3	-
Chaetomorpha antennina	-	-	-	-	-	-	-	-
Gelidium arbuscula	1	1	-	-	-	-	-	-
Dictyopteris delicatula	-	-	-	-	-	-	-	1
Gelidiopsis variabilis	-	-	-	-	-	-	-	1
Bryocladia thyrsigera	-	-	1	-	-	-	-	-
Colpomenia sinuosa	-	-	-	-	-	-	-	-
Gymnogongrus tenuis	-	-	-	-	-	-	-	-
Hypnea cervicornis	-	-	-	-	-	-	-	-
Struvea anastomosans	-	-	-	1	-	-	-	-

Bare patch	-	-	-	-	-	-	-	-
TOTAL	**29**	**21**	**32**	**51**	**8**	**13**	**23**	**13**

Table D-17 Phytoplankton Community Structure at Tema

Genera/Phyla	2 GS1 TEM LW LT	2 GS1 TEM LW HT	2 GS3 TEM LW LT	2 GS3 TEM LW HT	2 GS5 TEM LW LT	2 GS5 TEM LW LT	2GS7C TEM LIZ LT
Chlorophyceae (Green algae)							
Ankistrodesmus	2	205	6900	-	-	-	-
Centritractus	-	-	-	7	-	-	-
Chlorella	-	-	-	-	-	-	-
Closterium	32	-	-	-	8	2	1
Coelastrum	-	-	-	-	-	-	-
Euglena	-	-	-	10	1	-	-
Palmella	-	-	-	-	-	-	-
Pediastrum	-	-	-	4	-	-	-
Scenedesmus	4	-	-	-	-	-	-
Staurastrum	-	-	-	-	2	-	-
Stigeoclonium	-	-	-	5	-	-	-
Ulothrix	-	-	-	-	90	-	-
Volvox	-	-	-	-	2	-	-
Sub total	**38**	**205**	**6900**	**26**	**103**	**2**	**1**
Cyanophyceae (Blue-green algae)							
Anabaena	-	-	-	48	40	21	-

Gomphosphaeria	500	26	107	-	-	-	-
Merismopedia	64	-	-	-	15	26	-
Microcystis	35	-	-	-	-	6	-
Oscillatoria	2840	200	380	1100	190	4288	200
Spirulina	-	-	-	-	-	-	-
Sub total	**3439**	**226**	**487**	**1148**	**245**	**4335**	**200**
Bacillariophyceae							
(Diatoms)							
Asterionella	4	4	-	1	-	-	-
Cocconeis	-	-	-	-	-	-	-
Cyclotella	-	-	-	-	-	-	-
Cymbella	2	-	-	-	-	-	-
Diatoma	-	-	-	5	-	-	-
Gyrosigma	3	15	13	37	12	4	-
Melosira	65	-	-	100	148	44	-
Navicula	42	25	31	18	23	34	3
Nistzchia	-	-	-	-	2	-	-
Pinnularia	-	-	-	250	3	-	-
Surinella	-	-	-	-	-	-	-
Synedra	33	10	2	145	32	-	-
Tabellaria	46	-	-	-	-	-	-
Sub Total	**195**	**54**	**46**	**556**	**220**	**82**	**3**
Total	**3672**	**485**	**7433**	**1720**	**568**	**4419**	**204**

LEGEND

*2GS1TEM LW LT	GHANA STATION 1 TEMA LAGOON WATER (LOW TIDE)
2GS1TEM LW HT	GHANA STATION 1 TEMA LAGOON WATER (HIGH TIDE)

2GS3 TEM LW LT	GHANA STATION 3 TEMA LAGOON WATER (LOW TIDE)
2GS3 TEM LW HT	GHANA STATION 3 TEMA LAGOON WATER (HIGH TIDE)
2GS5 TEM LW LT	GHANA STATION 5 TEMA LAGOON WATER (LOW TIDE)
2GS5 TEM LW HT	GHANA STATION 5 TEMA LAGOON WATER (HIGH TIDE)
2GS7C TEM LIZ LT	GHANA STATION 7 C TEMA LOW INTERTIDAL ZONE (LOW TIDE)

* 2 = second season

Table D-17b Zooplankton Community Structure at Tema

Zooplankton community structure at Tema							
Genera/Phyla	2 GS1 TEM LW LT	2 GS1 TEM LW HT	2 GS3 TEM LW LT	2 GS3 TEM LW HT	2 GS5 TEM LW LT	2 GS5 TEM LW HT	2GS7C TEM LIZ LT
CRUSTACEA	-	-	-	-	-	-	-
Ostracoda	-	-	-	-	-	-	-
Spp. I	4	-	-	-	-	-	-
Spp. II	-	-	-	-	-	-	-
Cladocera	-	-	-	-	-	-	-
Polyphenus spp.	-	-	-	-	1	-	-
Copepoda	-	-	-	-	-	-	-
Cyclops spp.	4	4	10	-	2	-	-
Canthocamptus spp.	-	3	1	2	-	-	-
Limnocalanus spp.	-	1	-	-	-	-	-
Diaptomus spp.	-	-	-	11	-	-	-
DIPTERA	-	-	-	-	-	-	-
Chironomidae	-	-	-	-	-	-	-
Clinotanypus spp.	1	-	-	-	-	-	-
Stictochironomus spp.	-	-	-	-	-	-	-

Polypedilum spp.	-	-	-	-	-	-	-
Chaoboridae	-	-	-	-	-	-	-
Chaoborus spp.	-	-	-	-	-	-	-
Culicinae	-	-	-	-	-	-	-
Culex spp.	-	-	-	-	-	-	-
MYSIDACEA	-	-	-	-	-	-	-
Mysis spp.	-	2	2	-	1	1	-
NEMATODA	-	-	-	3	-	-	1
NAIDIDAE	-	-	-	-	-	-	-
Nais spp.	-	1	-	-	-	-	-
GAMMARIDAE	-	-	-	-	-	-	-
Gammarus spp.	-	-	-	-	-	-	1
TOTAL	**9**	**11**	**13**	**16**	**4**	**1**	**2**

LEGEND

*2GS1 TEM LW LT	GHANA STATION 1 TEMA LAGOON WATER (LOW TIDE)
2GS1 TEM LW HT	GHANA STATION 1 TEMA LAGOON WATER (HIGH TIDE)
2GS3 TEM LW LT	GHANA STATION 3 TEMA LAGOON WATER (LOW TIDE)
2GS3 TEM LW HT	GHANA STATION 3 TEMA LAGOON WATER (HIGH TIDE)
2GS5 TEM LW LT	GHANA STATION 5 TEMA LAGOON WATER (LOW TIDE)
2GS5 TEM LW HT	GHANA STATION 5 TEMA LAGOON WATER (HIGH TIDE)
2GS7C TEM LIZ LT	GHANA STATION 7 C TEMA LOW INTERTIDAL ZONE (LOW TIDE)

* 2 = second season

Table D-18 Water Parameters, Physical and Chemical

Water Parameters(Physical and Chemical)												
STATIONS	pH	DO (mg/l)	Turbidity (FAU)	TDS (mg/l)	Conductivity (ms/cm)	Sulphate (mg/l)	BOD (mg/l)	Ammonia Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)	Total Nitrogen (mg/l)	Ortho-Phosphorus (mg/l)	Total Phosphorus (mg/l)
TAKORADI												
2GS8TAD	6.75	0.67	136	867	1390	23	2.93	0.04	2	3.58	0.67	0.097
2GS9TAD	6.93	0.83	24	902	1838	13	3.55	0.16	1.7	0.061	0.71	0.122
2GS10 TAD	6.63	1.05	25	55	117.3	20	3.52	0.13	2.1	0.075	0.34	0.175
2GS11 TAD	8.33	5.36	7	2440	467	2850	2.86	0.1	1.4	0.289	0.74	0.107
2GS12 TAD	8.36	6.97	15	29800	50	3750	3.48	0.01	1	0.529	0.08	0.057

Sediment Parameters(Physical and Chemical)									
STATIONS	TEMP	pH	Redox	TPH	TOC	GRAIN SIZE			
	oC	pH Units	mV	ug/g	(%)	%Sand	%Silt	% Clay	Texture
TAKORADI									
2GS8 TAD WSED	30.5	6.46	-71.4	6.5	1.19	52	11	37	Sandy Clay Loam
2GS9 TAD WSED	30.5	6.46	-74.4	4.6	0.871	28	37	35	Clay

									Loam	
2GS10 TAD WSED	27.8	6.37	68.8	15.7	0.165	3	31	66	Clay	
2GS11 TAD WSED	28.3	7.59	-204.3	12.3	1.19	48	23	29	Sandy Clay Loam	
2GS12A TAD WSED	23.8	6.56	256	12.7	0.005	22	65	13	Silt Loam	
2GS12B TAD WSED	29.4	7.48	250.7	4.7	0.035	96	1	3	Sand	

Table D-19 Macroalgal Species at Aboadze/Takoradi

Quadrat #	2	3	4	5	6	7	8	9
Distance	**21**	**25**	**27**	**29**	**31**	**35**	**37**	**39**
Padina durvellei	-	1	5	1	1	4	2	10
Ulva fasciata	10	5	5	5	1	2	1	-
Centroceras clavulatum	1	3	10	40	1	1	2	-
Enteromorpha f. flexuosa	5	-	0	-	-	-	-	-
Bachelotia antillarum	10	5	0	2	-	-	-	-
Hydropuntia dentata	1	2	5	-	2	2	5	-
Ralfsia expansa	1	-	-	-	-	-	-	-
Chaetomorpha linum	-	1	1	1	-	-	-	-
Algal turf	-	-	-	-	-	-	-	-
Chnoospora minima	-	-	-	-	-	-	-	-
Cyanophyta (Blue-greens)	-	-	-	-	-	-	-	-
Sargassum vulgare	-	-	-	-	1		7	-
Hypnea musciformis	-	2	-	1		1		-
Bryopsis pennata	-	-	-	-	-	-	-	-
Padina tetratrosmatica	-	-	1	-	-	2	1	-
Jania rubens	-	-	2	-	-	1	1	1
Cladophora vagabunda	-	-		-	-	-	-	-
Dictyota ciliolata	-	-	1	-	-	-	-	-
Laurencia intermedia	-	1	-	-	2	-	-	-
Asparagopsis taxiformis	-	-	1	-	-	-	1	-
Giffordia mitchelliae	-	-	-	-	-	-	3	-

Chaetomorpha antennina	-	-	-	-	-	-	-	-
Gelidium arbuscula	1	1	-	-	-	-	-	-
Dictyopteris delicatula	-	-	-	-	-	-	-	1
Gelidiopsis variabilis	-	-	-	-	-	-	-	1
Bryocladia thyrsigera	-	-	1	-	-	-	-	-
Colpomenia sinuosa	-	-	-	-	-	-	-	-
Gymnogongrus tenuis	-	-	-	-	-	-	-	-
Hypnea cervicornis	-	-	-	-	-	-	-	-
Struvea anastomosans	-	-	-	1	-	-	-	-
Bare patch	-	-	-	-	-	-	-	-
TOTAL	**29**	**21**	**32**	**51**	**8**	**13**	**23**	**13**

Table D-20a Phytoplankton Community Structure at Aboadze/Takoradi Wetlands and Intertidal Zone

Genera/Phyla	2GS 8 TAD WW	2 GS 9 TAD WW	2 GS 10 TAD WW	2 GS 11 TAD WW	2 GS 12 C TAD WIZ
Chlorophyceae					
(Green algae)					
Ankistrodesmus	-	-	-	-	-
Centritractus	-	-	-	-	-
Chlorella	-	-	-	-	-
Closterium	-	7	-	-	13
Coelastrum	-	-	-	-	-
Euglena	-	-	-	-	-
Palmella	-	-	-	-	-
Pediastrum	-	-	-	-	-

Scenedesmus	-	-	-	-	-
Staurastrum	-	-	-	-	-
Stigeoclonium	-	-	-	-	-
Ulothrix	-	-	-	-	-
Volvox	-	-	-	-	-
Sub total	**0**	**7**	**0**	**0**	**13**
Cyanophyceae					
(Blue-green algae)					
Anabaena	3	58	34	-	-
Gomphosphaeria	-	-	-	-	-
Merismopedia	-	-	-	-	-
Microcystis	-	-	-	-	-
Oscillatoria	90	1850	310	350	1050
Spirulina	-	-	-	-	-
Sub total	**93**	**1908**	**344**	**350**	**1050**
Bacillariophyceae					
(Diatoms)					
Asterionella	-	-	-	-	5
Cocconeis	-	-	-	-	-
Cyclotella	-	-	1	-	-
Cymbella	1	-	4	-	-
Diatoma	-	-	12	-	-
Gyrosigma	2	-	-	3	1
Melosira	1	-	-	-	-
Navicula	1	14	40	3	7
Nistzchia	-	-	33	-	-
Pinnularia	-	-	30	-	-
Surinella	-	2	-	-	-
Synedra	-	7	30	4	22

Tabellaria	-	-	-	-	-
Sub Total	**5**	**23**	**150**	**10**	**35**
Total	**98**	**1938**	**494**	**360**	**1098**

LEGEND

*2GS8 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS9 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS10 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS11 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS12C TAD WIZ	GHANA STATION 12C TAKORADI (WATER) INTERTIDAL

*2- Second Season

Table D-20b Zooplankton Community at Aboadze/Takoradi

Genera/Phyla	2GS 8 TAD WW	2 GS 9 TAD WW	2 GS 10 TAD WW	2 GS 11 TAD WW	2 GS 12 C TAD WIZ
CRUSTACEA	-	-	-	-	-
Ostracoda	-	-	-	-	-
Spp. I	13	-	25	-	-
Spp. II	3		-	-	-
Cladocera	-		-	-	-
Polyphenus spp.	5	16	30	-	6
Copepoda	-	-	-	-	-
Cyclops spp.	4	7	-	-	4
Canthocamptus spp.	-	-	-	-	-
Limnocalanus spp.	-	-	-	-	-
Diaptomus spp.	-	-	-	-	-
DIPTERA	-	-	-	-	-
Chironomidae	-	-	-	-	-

Clinotanypus spp.	-	-	-	1	-
Stictochironomus spp.	3	-	-	-	-
Polypedilum spp.	-	9	-	-	-
Chaoboridae	-	-	-	-	-
Chaoborus spp.	1	-	-	-	-
Culicinae	-	-	-	-	-
Culex spp.	-	-	1	-	-
MYSIDACEA	-	-	-	-	-
Mysis spp.	-	-	-	-	-
NEMATODA	3	-	3	-	-
NAIDIDAE	-	-	-	-	-
Nais spp.	1	-	-	-	-
GAMMARIDAE	-	-	-	-	-
Gammarus spp.	-	-	-	-	-
TOTAL	**33**	**32**	**59**	**1**	**10**

LEGEND

*2GS8TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS9 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS10 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS11 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS12C TAD WIZ	GHANA STATION 12C TAKORADI (WATER) INTERTIDAL ZONE

* 2 = second season

Table D-20c Macroinvertebrate (Macrophyte Asscociated) Community Structure at Aboadze/Takoradi

Genera/Phyla	2GS 8 TAD WW	2 GS 9 TAD WW	2 GS 10 TAD WW	2 GS 11 TAD WW	2 GS 12 C TAD WIZ

Genera/Phyla	2GS 8 TAD WW	2 GS 9 TAD WW	2 GS 10 TAD WW	2 GS 11 TAD WW	2 GS 12 C TAD WIZ
ODONATA					
Calopterygidae	-	-	-	-	-
Phaon iridipennis	-	-	-	-	1
Libellulidae	-	1	-	-	-
Zygonyx spp.	1	-	-	-	-
COLEOPTERA					
Notonectidae	-	-	-	-	-
Anisops spp.	1	-	-	-	-
Hydroptilidae	-	-	-	-	-
Berosus spp.	1	-	-	-	-
Pleidae	-	-	-	-	-
Plea spp.	1	-	-	-	-
Dytiscidae	-	-	-	-	-
Laccophilus spp.	2	-	1	-	-
Elmidae	-	-	1	-	-
MOLLUSC					
Gastropoda	-	-	-	-	-
Gyraulus spp.	3	-	-	-	1
Physidae	-	-	-	-	-
Physa spp.	1	-	-	-	-
EHPEMEROPTERA					
Baetidae	-	-	-	-	-
Centroptilum spp.	-	4	-	-	-
HEMIPTERA					

Genera/Phyla	2GS 8 TAD WW	2 GS 9 TAD WW	2 GS 10 TAD WW	2 GS 11 TAD WW	2 GS 12 C TAD WIZ
Nepidae	-	-	-	-	-
Laccotrephes spp.	1	-	-	-	-
TOTAL	**11**	**5**	**2**	**0**	**2**

LEGEND

*2GS8 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS9 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS10 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS11 TADWW	GHANA STATION 8 TAKORADI WETLAND WATER
2GS12C TAD WIZ	GHANA STATION 12C TAKORADI (WATER) INTERTIDAL ZONE

* 2 = second season

Table D-21a Relative Abundance of Common Intertidal Macrobenthic Fauna at Aboadze/Takoradi

SPECIES	Takoradi Lower Intertidal Zone	 Upper Intertidal Zone
Polychaeta		
Cirriformia afer	1-5	0
Diopatra monroi	6-10	0
Eunice vitata	1-5	0
Eurythoe sp	6-10	1-5
Marphysa sanguinea	1-5	0
Nereis sp.	11-15	0
Polydora antennata	1-5	0
Syllis gracilis	6-10	1-5
Crustacea		

SPECIES	Takoradi Lower Intertidal Zone	Takoradi Upper Intertidal Zone
Aorid sp.	6-10	1-5
Apseudes latreille	0	0
Chthamalus spp.	16-20	11-15
Cirolana spp	1-5	0
Exocirolana sp.	0	6-10
Mysid sp.	6-10	0
Phoxocephalid sp.	1-5	0
Ocypoda cursor	0	1-5
Decapod Crustaceans		
Sersarma sp.	1-5	1-5
Xanthid sp.	6-10	1-5
Mollusca		
Littorina punctata	11-15	6-10
Nerita sp.	11-15	6-10
Patella safiana	6-10	1-5
Perna sp.	16-20	6-10
Siphonaria pectinana	6-10	16-20
Otrea tulipa	1-5	0
OTHERS		
Echinometra lucunter	6-10	0
Zoanthus spp	1-5	0
Palythoa spp	1-5	0

Abundance range:

SPECIES	Takoradi Lower Intertidal Zone	Upper Intertidal Zone
- = 0, + = 1 – 5, ++ = 6 – 10, +++ = 11 – 15, ++++ = 16 – 20, +++++ = 21+		

Table D-21b Abundance and Distribution of the Crustacea *Ischyroceros* sp. of Aboadzi/Takoradi Wetland

Crutacea	*Ischyroceros* spp.
2GS8 TAD	1
2GS9 TAD	0
2GS10 TAD	0
2GS11 TAD	0

Table D-22 Fisheries of the Gao Lagoon

No.	Family	Species	Common name	No. of individuals	Percent occurrence
1	Carrangidae	*Caranx crysos*	Blue runner	1	1.3
2	Mullidae	*Pseudupeneus prayensis*	West African goatfish	12	15.4
3	Clupeidae	*Sardinella maderensis*	Madeiran sardinella	4	5.1
4	Sparidae	*Dentex gibbosus*	Pink dentex	17	21.8
5	Sparidae	*Dentex macrophthalmus*	Large eye dentex	11	14.1
6	Drepanidae	*Drepane africana*	African sicklefish	1	1.3
7	Balistidae	*Balistes punctatus*	Bluespotted triggerfish	1	1.3
8	Cichlidae	*Seratherodon melanotheron*	Black chin tilapia	30	38.5
9	Labridae	*Coris julis*	Rainbow wrasse	1	1.3
Sample from cast net fishing (One man day catch)					

Table D-23 Fisheries of the Aboadze/Takoradi Swamps

Catch from Castnet Fishing (One Man-day Catch)					
No.	**Family**	**Species**	**Common name**	**No. of individuals**	**Percent occurrence**
1	Cichlidae	*Tilapia zilli*		1	1.4
2	"	*Seratherodon melanotheron*	Black chin tilapia	1	1.4
3	Paleamonidae	Macrobrachium sp	River prawn	67	97.1
Fisheries of the Anakwari Lagoon					
(Catch from Castnet Fishing (One Man-day Catch)					
No.	**Family**	**Species**	**Common name**	**No. of individuals**	**Percent occurrence**
1	Mugilidae	*Mugil Cephalus*	Flathead grey mullet	74	66.1
2	Gerreidae	*Sardinella aurita*	Deepwater rose shrimp	4	3.6
3	Bothidae	*Citharichthys sp.*	Smooth flounder	2	1.8
4	Carrangidae	*Caranx latus*	Horse-eye jack	5	4.5
5	"	*Seriola carpenteri*	Guinea amberjack	1	0.9
6	Clupeidae	*Pellonula leonensis*	Guinea sprat	10	8.9
7	"	*Chrysithys sp.*	Catfish	2	1.8
8	Batridae	*Encinostomus melanopterus*	Flagfin mojarra	10	8.9
9	Penaeidae	*Parapenaeus longirostris*	Round sardinella	4	3.6
Inshore Fisheries of Aboadze/Takoradi Landing Beach					
(Random sample from inshore fishery catch)					
No.	**Family**	**Species**	**Common name**	**No. of individuals**	**Percent occurrence**

1	Clupeidae	*Sardinella maderensis*	Madeiran sardinella	4	3.9
2	Chlorophthamidae	*Ilisha africana*	West African ilisha	23	22.3
3	Shyraenidae	*Sphyraena sphyraena*	European barrcuda	2	1.9
4	Haemulidae	*Bachydeuterus auritus*	Bigeye grunt	64	62.1
5	Polynemidae	*Galeoides decadactylus*	Lesser African threadfin	6	5.8
6	Trichiruridae	*Trichiurus lepturus*	Largehead hairtail	1	1.0
7	Carrangidae	*Chloroscombrus chrysurus*	Atlantic bumper	1	1.0
8	"	*Selene dorsalis*	African moonfish	1	1.0
9	Batrachoididae	*Batrachoides liberiensis*	Hairy toadfish	1	1.0

CHAPTER 7 APPENDIX E

SEA TURTLE NESTING

SURVEY QUESTIONAIRE

1. ***Name of area……………………………………………………………………***

2. ***What is the commonest turtle species seen on your beach laying eggs***:

   i. a. Soft Back b. Hard Back c. Hawksbill.

3. ***When does nesting begin in your area?***

January	February	March	April
May	June	July	August
September	October	November	December

4. ***When does the nesting season end***?

January	February	March	April
May	June	July	August
September	October	November	December

5. ***When is the peak season for turtle nesting in your area?***

January	February	March	April
May	June	July	August
September	October	November	December

6. ***Is the turtle nesting frequency increasing or decreasing in the past 5years***?

   i. Increasing ii. Decreasing

7. ***Do you know that the turtles play vital role in the sea?***

   i. Yes ii. No

8. ***Do you know how turtle eggs are destroyed?***

   i. Yes ii. No

9. ***What should be done to the destroyers of the eggs***………………………………………………………………………………

10. Do you know any law on prohibition of turtle hunting?

i. Yes ii. No

ESL Interviewer ……………………………………….. Date: ………………………..

Nigeria
West African Gas Pipeline
Environmental Baseline Survey Report
Second Season

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

Environmental Resources Managers Limited, ERML
Lagos, Nigeria

Table of Contents

Page

Chapter 1 INTRODUCTION AND BACKGROUND **1-1**

1.1 Introduction **1-1**

1.2 Environmental Baseline Survey (EBS) Program Objectives **1-1**

1.3 Report Organization **1-3**

Chapter 2 ONSHORE FIELD METHODS **2-1**

2.1 Vegetation Sampling **2-1**

2.2 Soil Sampling **2-1**

2.2.1 Study Approach 2-1

2.2.2 Soil Investigation and Sampling 2-1

2.3 Surface Water and Sediment Quality and Hydrobiology **2-2**

2.4 Soil and Groundwater at the Compressor Station **2-3**

2.4.1 Groundwater Analysis 2-3

2.4.2 Soil Collection and Analysis 2-4

2.5 In Situ Methods **2-4**

2.5.1 Water Samples 2-4

2.5.2 Air Quality Studies at the Proposed Compressor Site 2-4

2.6 Wildlife, Animal Resources and Marine Turtles **2-5**

2.6.1 Wildlife and animal Resources 2-5

2.6.2 Marine Turtles 2-6

2.7 Fish and Fisheries Resources **2-6**

2.8 Sample Tracking, Storage and Shipping **2-6**

2.8.1 Quality Assurance Programme 2-6

2.8.2 Sample Preservation and Shipping 2-7

2.8.3 Analytical Quality Control (AQC) 2-7

2.8.4 Control of Data Storage and Treatment 2-7

Chapter 3 ANALYTICAL METHODS **3-1**

3.1 Physical Laboratory Methods **3-1**

3.1.1 Soil 3-1

3.1.2 Water and Sediment Quality and Hydrobiology 3-1

3.2 Chemical Laboratory Methods **3-1**

3.2.1 Soil 3-1

3.2.1.1 pH 3-1

3.2.2 Water and Sediment Quality and Hydrobiology 3-2

3.3 Biological Methods **3-3**

3.3.1 Soil 3-3

3.3.1.1 Surface Fauna 3-3

3.3.1.2 Microbial Analysis 3-4

Table of Contents

Page

3.3.2 Water and Sediment Quality and Hydrobiology 3-4

Chapter 4 ENVIRONMENTAL CHARACTERISTICS OF THE AREA 4-1

4.1 Vegetation 4-1

4.1.1 Coastal Vegetation 4-1

4.1.1.1 Strandline Vegetation 4-1

4.1.1.2 Barrier Island Dominated By Coconut 4-1

4.1.1.3 Bare Ground/Farms/Grassland Mosaic 4-2

4.1.1.4 Marsh Area on the Barrier Island 4-3

4.1.2 Inland Locations 4-4

4.1.2.1 Raphia Dominated Riparian Forest 4-4

4.1.2.2 Coastal Savanna 4-5

4.1.2.3 Marshland/Grassland 4-6

4.2 Soil 4-7

4.2.1 Soil Physico-chemistry 4-7

4.2.1.1 The Coastal Area (Nearshore) 4-7

4.2.1.2 The Inland Area 4-8

4.2.1.3 The Lagoon Area (Nearshore) 4-9

4.2.2 Soil Ecology 4-9

4.2.3 Microbiology 4-11

4.3 Water and Sediment Quality 4-13

4.3.1 Water and Sediment Physico-chemistry 4-13

4.3.1.1 Water Physico-chemistry 4-13

4.3.1.2 Sediment Physico-Chemical Characteristics 4-1

4.3.2 Biological Characteristics 4-3

4.3.2.1 Benthic Infauna 4-3

4.3.2.2 Sediment Microbiology 4-6

4.4 Shallow Groundwater Resources 4-7

4.4.1 Introduction 4-7

4.4.2 River Flow 4-8

4.4.3 Groundwater Flow and Aquifer Hydraulics 4-8

4.4.4 Water Level Changes and Water Level Predictions 4-10

4.4.4.1 Seasonal Variations 4-11

4.4.4.2 Biological components 4-11

4.5 Wildlife, Animal Resources and Marine Turtles 4-13

4.5.1 Wildlife 4-13

Table of Contents

Page

4.5.1.1 Mammals....4-13

4.5.1.2 Birds....4-13

4.5.1.3 Reptiles....4-13

4.5.1.4 Amphibians....4-14

4.5.1.5 Economic and Cultural Significance of Wildlife....4-14

4.5.1.6 Species of Conservation Concern....4-14

4.5.2 Marine Turtles....4-14

4.5.2.1 Pacific Riddley turtle (*Lepidochelys olivacea*)....4-15

4.5.2.2 Atlantic Loggerhead turtle (*Carreta carretta carretta*)....4-15

4.5.2.3 Atlantic Hawksbill turtle (*Eretmochelys imbricata*)....4-15

4.5.2.4 Leatherback (*Dermochelys coriacea coriacea*)....4-16

4.6 Fish and Fishery Resources....4-16

4.6.1 The Status of Fish Exploitation and Methods Used....4-16

4.6.2 Fish Faunal Composition....4-17

4.6.3 Economic Importance of Fisheries Resources....4-22

4.6.3.1 Fish Preservation and Processing Methods....25

4.7 Meteorology and Air Quality....26

List of Appendices

List of Tables

Table 2.5-1 Parameters and Equipment used for Air Quality Studies....2-4

Table 3.2-1 Analytical Methods of Chemical Determination of Water Sample....3-2

Table 4.1-1 Plant Species Composition within the Strandline Zone....4-1

Table 4.1-2 Plant Species Composition and Habit in the Grassland/Farm/Bare Land Mosaic4-2

Table 4.1-3 Plant Species Composition within the Marsh Habitat....4-3

Table 4.1-4 Plant Species Composition in the Riparian Forest....4-4

Table 4.1-5 Plant Species Composition in the Coastal Savanna Habitat....4-5

Table 4-1-6 Population Density of the Major Economic Plants in the Study Area....4-6

Table 4.2-1 The Average Chemical Characteristics of Soils in the Different Habitats within the Barrier Island (Coastal Area)....4-8

Table of Contents

Page

Table 4.2-2 The Average Chemical Characteristics of Soils in the Different Habitats within the Inland Area 4-9

Table 4.2-3 The Average Chemical Characteristics of Soil in the Habitat within the Lagoon Area 4-9

Table 4.2-4 Mean Numbers of Soil Microarthropods Extracted from the Soil in Different Habitat Types. (Mean Based On Four Sampling Units) 4-10

Table 4.2-5 Average Microbial Densities of Soil Samples from WAGP Project Area 4-12

Table 4.3-1 Mean Daily Temperature of Major Waterbodies in the WAGP Project Area . 4-13

Table 4.3-2 Diurnal Variation in Ambient Air And Water Temperature At Badagry Creek .. 4-14

Table 4.3-3 Colour Characteristics of Waterbodies in the WAGP Project Area 4-14

Table 4.3-4 The Chemical Composition of Waterbodies in WAGP Project Area (Rainy Season) 4-1

Table 4.3-5 The Mean Values of Conductivity and Major Ions of Major Waterbodies in the WAGP Project Area (Rainy Season) 4-1

Table 4.3-7 Particle Size Distribution of Sediments from WAGP Project Area (Rainy Season) 4-2

Table 4.3-8 Sediment Characteristics of Major Waterbodies in the WAGP Project Area 4-2

Table 4.3-9 Variation In Sediment Chemical Characteristics With Textural Composition .. 4-3

Table 4.3-11 Summary of Benthic Organisms Encountered in the Study Area 4-5

Table 4.3-12 Summary of Major Groups Benthic Organisms Encountered in the Study Area 4-6

Table 4.3-13 Average Microbial Densities Of Sediment Samples From WAGP EIA Project (Dry Season) 4-7

Table 4.4-1 Average Monthly Flow Values of Some Rivers in the Area 4-8

Table 4.4-2 Water Levels Measured in Dug Wells 4-9

Table 4.4-3 Water Levels Encountered in Auger Drill Holes 4-9

Table 4.4-4 Aquifer Hydraulic Features in the Coastal Plain Sands Formation around Lagos 4-10

Table of Contents

Page

Table 4.6-1 Faunal Composition and Occurrence record of finfish in the WAGP Project Area (2002/2003) 4-19

Table 4.6-2 Size Composition of Some Recorded Finfish in WAGP Project Area 4-23

Table A-1: The Mammals of Alagbado/Badagry Area 2

Table A-2: Birds seen or heard along the WAGP ROW 5

Table A-3: Reptiles found in the Alagbado/Badagry Area 14

Table A-4: Amphibians recorded in the vicinity of the proposed pipeline ROW 16

Table A-5: Species Composition, Distribution and Relative Abundance of Macrobenthic Fauna attached to floating macrophytes at the Study Area 17

Table A-6: Species Composition, Distribution and Relative Abundance of Macrobenthic Fauna in the Sediment at the Study Area 22

Table A-7: Meteorological Parameters at the Compressor Station At Badagry (day 1) 24

Table A-8: Meteorological Parameters at the Compressor Station At Badagry (day 2) 26

Table A-9: Meteorological Parameters at the Compressor Station At Badagry (day 3) 28

Table A-10: Meteorological Parameters at the Compressor Station At Badagry (day 4) 30

Table A-11: Meteorological Parameters at the Compressor Station At Badagry (day 5) 32

Table A-12: Ambient Air Quality Compressor Station At Badagry (day 1) 34

Table A-13: Ambient Air Quality Compressor Station At Badagry (day 2) 36

Table A-14: Ambient Air Quality Compressor Station At Badagry (day 3) 38

Table A-15: Ambient Air Quality Compressor Station At Badagry (day 4) 40

Table A-16: Ambient Air Quality Compressor Station At Badagry (day 5) 42

Table of Contents

Page

List of Figures

Figure 4.1-1 Profile Diagram of a Typical Coconut Palm Grove along the Barrier Coast c= Coconut 4-2

Figure 4.1-2 Profile Diagram of the Vegetation Structure in the Middle Part of the Barrier Island C= Coconut 4-3

Figure 4.1-3 Profile Diagram of the Marsh Area Dominated by *Cyperus articulatus* 4-4

Figure 4.1-4 Profile Diagram of Raphia Palm Dominated Swamp R=*Raphia hookeri;* A=*Alstonia boonei;H=Hallea* ciliata........ 4-5

Figure 4.1-5 Profile Diagram of the Vegetation of the Coastal Savanna E=Elaeis guineensis; v=Vitex doniana........ 4-6

CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

ERML is part of a consortium, coordinated by ICF that has been retained to carry out the environmental impact assessment (EIA) of the proposed West African Gas Pipeline (WAGP) Project. The purpose of the WAGP EIA is to determine if WAGP construction activities and/or post-construction operations, including emergency situations, may have persistent, non-localized adverse impacts to the environment. As part of the EIA process, comprehensive environmental baseline surveys (EBS) were conducted for the purpose of elucidating the environmental characteristics of the project area. This is a necessary activity to facilitate the process of impact identification and quantification. This report relates to the second season EBS, which was conducted between July 15 and 30, 2003.

1.2 ENVIRONMENTAL BASELINE SURVEY (EBS) PROGRAM OBJECTIVES

The purpose of the EBS is to provide an analytical basis for the WAGP EIA. The scope of the EBS activities aims at addressing any data gaps that exist, focusing particularly on biological parameters likely to be affected by the proposed project, and augmenting the sampling scope where necessary due to project routing or design changes. The EBS activity was augmented with a thorough review of the relevant literature.

EBS sampling emphasized environmental parameters that are of particular significance to the proposed project. The sampling covered physical, chemical and biological characteristics of the water column, aquatic and terrestrial vegetation, soil, groundwater, and surface water/sediment environments.

The EBS aims at addressing the following:

a. What is the diversity of terrestrial and aquatic habitats?

b. What are the presence, abundance and species diversity of terrestrial trees, shrubs, understory plants, wildlife, and intertidal zone aquatic macrophytes?

c. What are the presence and abundance of riverine (and adjacent water body) plankton, macrophytes, and macrobenthic infauna?

d. What is the character of the riverine fisheries resources?

e. Are threatened and/or endangered species, sensitive habitats, or commercially significant species/fishing zones present?

f. What is the character of the soil and is there existing soil impairment with respect to or as indicated by:

    i. pH, redox potential TOC, grain size

ii. Microbiology
iii. Macrobiology and soil ecology

g. What is the character of the groundwater and soil borings and is there impairment at the proposed compressor station location with respect to or as indicated by:

i. TPH
ii. Trace metals
iii. pH

h. What is the character of the riverine (and adjacent water bodies) surface water and is there surface water-quality impairment with respect to or as indicated by:

i. Salinity
ii. Conductivity
iii. Turbidity
iv. DO
v. TDS/TSS
vi. Temperature
vii. Oil and grease
viii. BOD5
ix. Total Alkalinity
x. Nutrients and anions (ammonia N, nitrate N, total N, orthophosphate P, total P, sulfate)
xi. Plankton productivity and biomass

i. What is the character of the riverine (and adjacent water body) sediments and is there sediment-quality impairment with respect to or as indicated by:

i. TOC
ii. pH, grain size, redox potential, and temperature
iii. Macrobenthic infauna

j. Are there important sources of air emissions, and what are the associated pollutant concentrations as indicated by:

i. PM
ii. VOCs
iii. Nox
iv. Sox

k. For all of the above is there significant seasonal variation that the EIA needs to consider?

l. Would meteorological patterns likely exacerbate persistent, non-localized impacts?

The EBS methodology and laboratory procedures were consistent with relevant established standard operating procedures (SOPs) and the guidelines of the Federal Ministry of Environment (FMEnv and the Department of Petroleum Resources (DPR) in Nigeria.

1.3 REPORT ORGANIZATION

This second season EBS report is organized as follows:

Chapter One	Introduction and Background
Section Two	Onshore Field Methods
Section Three	Analytical Methods
Section Four	Environmental Characteristics of the Area

CHAPTER 2
ONSHORE FIELD METHODS

2.1 VEGETATION SAMPLING

In order to acquire baseline information on the vegetation, study sites were established within homogenous habitats that were identified in the study area. Information on tree species composition and structure were obtained using 100m^2 quadrats established within relatively homogenous habitat. Within each plot, all plants were identified to species level, and their heights measured with a Haga altimeter where necessary. The timed meander search method was used within each habitat type. The search time was 30 minutes. The number of strata in the vegetation was noted and the dominant species recorded. Where counting of individuals are not possible as in situations where there are creeping plants, cover was measured using the Braun-Blanquet scale (Sutherland, 1997). The population density of the trees was determined using 100m^2 quadrats placed along the transect. The structure of the vegetation was determined using data colleted along the transects. Cover of the herbaceous layer was estimated within five 1m x 1m quadrats. Unique, exotic and endangered species were listed. Samples of plants not identified on the field were collected and carried to the herbarium for correct identification. The biomass of the herbaceous vegetation was determined by collecting the above ground plant parts within an area of 1m^2. The sub-samples were taken to the laboratory for further processing. The health status of the vegetation was visually determined. Where a disease symptom was noticed, samples of the plant organ(s) were taken to the laboratory for correct identification of causative organism(s). An inventory and population density of economic plants within the study area was undertaken.

2.2 SOIL SAMPLING

2.2.1 Study Approach

The field investigations to identify, map and characterize the soil type along the proposed right of way (ROW) of the pipeline were carried out using the habitat type approach. This approach was considered time saving, more economic, reliable and scientifically sound since it had been established that a strong relationship exists between vegetation type (i.e. plant community) and soils, and that changes in vegetation pattern are often indicative of changes in soil distribution. Therefore, prior to the field survey, the vegetation pattern and/or habitat type in the study area was clearly established through careful interpretation of a number of multispectral imageries covering the area. On the basis of the number of habitats identified on the imagery maps, proposed soil investigation points were marked out and their coordinates specified. On the field, concerted efforts were made to ensure that the specified coordinates were obtained before embarking on soil description, characterization and sampling.

2.2.2 Soil Investigation and Sampling

One transect, about 500m long was established in the coastal part of the ROW, which extended from the shoreline to the southern bank of Badagry Creek, within the barrier Island complex. One sampling point each was located along this transect in each new habitat type encountered. In all therefore, there were a total of four sampling points along the coastal transect.

In the hinterland, 5 soil investigation transects were established, based on habitat type. Within each habitat, a transect of at least 100m length was established. Soils were described, mapped and sampled at four locations along each transect. Thus soil observation and sampling points along a 100m long transect were 0m, 25m, 50m and 100m points. Again, 5 to 10 core soil samples were taken at every sampling point to ensure the collection of a truly representative soil samples and guide against micro-habitat variations. The core soil samples were bulked and thoroughly homogenized before sub-sampling for laboratory analysis. Soil samples meant for polyaromatic hydrocarbon (PAH) determinations were obtained by sub-sampling all the samples taken along a ransect and bulking same to give a ‘composite’ soil sample. Soil sampling depths were 0-15cm and 15-50cm at every sampling point, to represent surface and sub-surface soil conditions respectively.

2.3 SURFACE WATER AND SEDIMENT QUALITY AND HYDROBIOLOGY

Samples for water and sediment quality and hydrobiology studies were collected from representatives of the different available waterbodies in the study area. These include the nearby Atlantic Ocean at Jegeme, its associated tidal waterbodies (Badagry Creek, Ologe Lagoon and Yewa River), non-tidal rivers (River Owo and its tributaries), rainwater, and hand-dug wells.

Most of the selected sampling stations are located close to the pipeline right-of-way (ROW) as much as possible. Most of the others occur within the buffer zone of the ROW but within the drainage basin of the study area. The tributaries of Owo River thus covered were R. Iju, R. Ore, R. Imede, and R. Ijako.

Because the investigated waterbodies were generally shallow (less 5m) and apparently well mixed, only one water sample was collected per sampling station, and this was from just below (ca. 5cm) the surface level. For the tidal waterbodies, samples were collected both at high tide and low tide regime (the two tide regime were separated by about 6 hour interval). Water samples were collected from each station by dipping directly a 2-litre polyvinylchloride (PVC) plastic bottle into the water from the boat (in case of the large waterbodies) or by wading into the waterbody (in case of streams). Samples were drawn from the hand-dug wells using the draw-containers used by the well owners (which were either an improvised rubber container or a small plastic bucket).

Separate water samples were collected for the following determinations: dissolved oxygen, BOD_5, oil and grease/total petroleum hydrocarbon, microbiology, heavy metals, and the other physico-chemical analyses, all using the bottle containers recommended by APHA (1995), FEPA (1991) and DPR (2002) as applicable. Samples for dissolved oxygen and BOD_5 were collected in 250ml glass reagent bottles (commonly referred to as “oxygen bottles”). The dissolved oxygen samples were fixed immediately with Winkler’s reagents while the BOD_5 samples were wrapped with aluminum foil and incubated in the dark at room temperature (27 ± 2^oC) for five days before being fixed with Winkler’s reagents. Samples for heavy metals as well as oil and grease/TPH were collected in a 500ml glass bottles and acidified to pH 2 with concentrated nitric acid and sulphuric acid respectively.

Samples for plankton analyses were collected from the sample site as for water quality analyses but only from surface waterbodies (i.e. excluding the hand-dug wells). Six (6) litres of water sample was collected from each station and strained through a phytoplankton net (fine-meshed of about 0.45 micron size) and reduced to a concentrate volume of about 50ml. The concentrate plankton samples were then fixed in 5% formalin solution (by the addition of suitable amount of formaldehyde). Water microbiology samples were collected directly into a pre-sterilized McCartney bottles.

Sediment samples from the relatively deep water bodies, viz Yewa Creek, Badagry Creek, Ologe lagoon and the lower reach of Owo River were collected at the selected sampling stations with the aid of Van Veen grab sampler with an internal surface area of $0.1m^2$. The grab was attached to a thick nylon line by which was deployed into and out of water from an engine-powered boat for sample collection. Every grab sample was inspected after retrieval (from the waterbody) for disturbance such as washout. The sample was discarded if significant disturbance was observed. For acceptable samples, the entire grab sediment was poured out onto a sieve (1mm), spread out carefully and washed clean leaving the organisms, if any, exposed for collection. Organisms found were carefully picked out using a came-hair brush or a pair of forceps (as applicable) into a sampling bottle and preserved in 10% buffered formalin solution. At the shallow sampling stations, mostly on Iju River and Ore River, sediment samples were collected using a scoop net. The sediment was scooped into a bucket from where it was carefully spread and sieved through a 1mm mesh size sieve. The organisms, if any, were washed free of debris and sediments, picked out carefully into a bottle and preserved in 10% buffered formalin solution. Roots of macrophytes, namely water hyacinth (*Eichornia crassipes*), water lily (*Nymphaea lotus*), water lettuse (*Pista lotus*) and *Ceratophylum demersum* were also collected at all the sampling stations, vigorously shaken in a bucket and the content filtered through the same 1mm mesh sieve for macro-invertebrate animals.

A second undisturbed grab sample was collected for sediment physico-chemical analysis. Sub-samples of the sediment were collected in aluminum foil for microbiology and TPH analysis, and the rest into a plastic bag for general physico-chemical analyses.

All the samples collected were properly and adequately labelled on the field, providing information on sampling site, date, time, preservative, collector, etc. They were packed in such a way as to avoid contamination and exposure to direct sunlight. Microbiology samples were transported in a cooler with ice blocks to the laboratory base where they were immediately transferred into refrigerator prior to the commencement of bioassay.

2.4 SOIL AND GROUNDWATER AT THE COMPRESSOR STATION

2.4.1 Groundwater Analysis

Water samples were collected from the monitoring boreholes drilled at the compressor station. Sampling involved the flushing of the boreholes by continuous pumping for 30-

minutes each, before collecting samples for analyses. Methods for the analysis of groundwater samples are contained in Section 3.3.2.

2.4.2 Soil Collection and Analysis

Handheld Rotary drilling rig was used to drill and collect soil samples at the compressor station, up to a maximum of 10m depth during the first season EBS. This activity was not repeated for the second season EBS.

For groundwater, the wells drilled in the first season were flushed for a period of 30min each, using a 1HP pumping machine, after which water samples were collected from the wells. The water samples were pre-treated as described for surface water in an earlier section, and subjected to the same analyses as for surface waters.

2.5 IN SITU METHODS

2.5.1 Water Samples

As required in the field data for the studies, adequate information was obtained on each sampling station and the prevailing weather condition during sampling. The relevant site location data, including grid coordinates (latitude and longitude) and altitude, were recorded using a portable GPS hand set (Garmin 12xL model). The GPS gave readings directly in degrees and minutes (for longitude and latitude) and feet above the mean sea level (for altitude). Water depth at the sampling site was estimated using a graduated plumb-line while water transparency was measured using a graduated Secchi disc. Ambient air and water temperature values were measured in situ using a mercury in glass-bulb thermometer. The thermometer was left in the medium until a stable reading was obtained. In situ measurements of water salinity, total dissolved solids (TDS) and electrical conductivity (EC) of samples were obtained using a combined Temp-Conductivity-TDS-Salinity Hach meter. Sample pH was also measured in situ using a pH meter.

2.5.2 Air Quality Studies at the Proposed Compressor Site

Ambient meteorology and Air quality investigations were carried out in situ at the proposed compressor site from 20th to 30th July, 2003. Three sampling locations were determined and geo-referenced using a Garmin GPS III plus. The sampling stations were determined to align as much as possible with the predominant winds in the area.

Details of the investigated parameters and equipment used are presented in Table 2.5-1.

Table 2.5-1
Parameters and Equipment used for Air Quality Studies

	Parameters (units)	***Equipment***
Air Quality Studies	*Total hydrocarbons (THC) (ppm)*	*ELE PID Volatile Organic Compounds (VOC) Meter*
	Methane (ppm)	*Lamotte ® Model BD Air Sampling Pump*
	Carbon monoxide (CO) (ppm)	

	Parameters (units)	***Equipment***
	Nitrogen oxide (NO_2) (ppm)	*in combination with Lamotte Air Pollution Test Equipment*
	Total Suspended Particulate (TSP) (mg/m^3)	Haz-Dust^{TM} Environmental Particulate Monitor (Model EPAM-5000)
	Particulate Matter less than 10 micron (PM_{10}) (mg/m^3)	
	Noise (dB)	Extech® noise meter
Ambient Meteorology	Temperature (°C)	Kestrel Mobile meteorological Station
	Humidity (%)	
	Heat Index (°C)	
	Wind Chill (°C)	
	Dew Point (°C)	
	Average Wind Speed (m/s)	

Samples were collected over a five-day period from three sampling stations, namely AQS1 (06° 24’ 58”N, 002° 59’ 26”E), AQS2 (06° 25’ 00”N, 002° 59’ 17”E) and AQS3 (06° 25’ 02”N, 002° 59’ 15”E). Each day, samples were collected for five minutes every hour for the next consecutive eight hours. Eight-hour averaging interval was adopted in consonance with the Nigerian ambient air quality regulations.

2.6 WILDLIFE, ANIMAL RESOURCES AND MARINE TURTLES

2.6.1 Wildlife and animal Resources

The wildlife resources associated with these habitats are generally mobile and therefore difficult to assess accurately the fieldwork. Consequently, we relied mainly on interviews with farmers and hunters who were most likely to be familiar with the wildlife of the area through daily interaction. Interviews were conducted in Ilogbo, Ajido, Ilado, Ago-Imowo, Imeke and Akarakumo. These scattered settlements, which lie on the pipeline route from the Agbara-Seme highway to the coast, were within two kilometers of the ROW. The information obtained from these interviews was supplemented with direct observations whenever possible.

The aim of the interviews was to obtain information on which species still occurred in the area, which species had become scarce in recent years, and which had disappeared or declined in numbers during the respondent’s lifetime. Questions asked also included whether animals were hunted for commercial purposes or for the pot, and whether any species were regarded as taboos or objects of veneration. Interviews usually ended with the respondent being asked to identify from Alden, et al. (1995), Dorst & Dandelot (1972) or slides and photographs, the animal he had just described. His ability to do so accurately was taken as a measure of the reliability of the information he had given. Because of the short time available for the study no attempt was made to estimate population sizes of species.

Hunters and farmers were interviewed either singly or in groups while observations were made during morning and/or afternoon stroll, usually along the roads leading to the settlements visited.

2.6.2 Marine Turtles

Daily and overnight surveillance was conducted on the site and covered a beach stretch of about 500m on either side of the ROW. This was done to search for signs or tracts left behind on the beach sands by adult turtles coming to lay eggs and/or the hatchlings going out to the sea. Oral interview of the inhabitants was also conducted as to the occurrence of turtles in the area. Pictures of the various turtle species where shown to the fishermen to help in the identification of turtles species that occur in the area.

2.7 FISH AND FISHERIES RESOURCES

Information on fish and fisheries resources of the study area was based mainly on a combination of catch inspection and actual fishing activities conducted by hiring artisanal fishermen for this purpose. The major waterbodies; Badagry Creek, Yewa river and Ologe Lagoon were investigated in this regard. Fisherfolks encountered during sampling were interviewed and their catch examined for fauna composition, relative abundance, condition factor and size measurements. Photographs of samples were taken in case it could not be immediately identified and where the fisherfolk was agreeable, fish specimens were purchased for further analyses later. Such samples were preserved in 10% formalin solution.

Fishing camps were also visited to examine available resources especially gear being used and also to interview the fisher folks. On interview, information was obtained on the seasonal occurrence and abundance of enumerated fish types.

2.8 SAMPLE TRACKING, STORAGE AND SHIPPING

2.8.1 Quality Assurance Programme

This involved all aspects of the study beginning from representative sample collection to handling, laboratory analysis, data coding, manipulation, statistical analysis, presentation and communication of results.

Sample collection and handling were carried out in accordance with DPR (2002) Guidelines and Standards (Part VIII D). The methods of analyses used were those specified in DPR guidelines and standards and other international analytical standards such as in Standard Methods for Water and Wastewater Analysis (APHA, 1995), *Methods of Soil Analysis* (Page, *et al*. 1987), U.S. Agronomy No 9: *Soil Survey Analytical Continuum* (USDA/SSIR No 42 Version 3.0 of 1996) and Methods of *Soils and Plant Tissue Analysis* (International Institute for Tropical Agriculture (IITA), Ibadan, 1979).

With proper sustained calibration of the instruments and the use of standardized observational procedures, equipment errors were brought to acceptable minimum. The range, true mean and the estimated variance and the number of samples taken were determined so as to establish a reasonable level of confidence in the results obtained.

2.8.2 Sample Preservation and Shipping

Samples meant for total hydrocarbon (THC), Polyaromatic hydrocarbon (PAH), and microbiological analysis determinations were kept on ice - chips immediately after collection. Under cold conditions the samples were shipped to the laboratory for further storage and analysis. In the laboratory, the samples were kept in the refrigerator while laboratory analyses were on. Water samples with short or no holding time were analyzed in-situ as described in sub-section 2.2.5.

2.8.3 Analytical Quality Control (AQC)

During laboratory analyses, likely sources of errors were: contamination from reagents/materials; lack of sensitivity by the instruments; lack of proper calibration-human error, and errors in data reporting. Efforts were made to minimize these probable sources errors.

2.8.4 Control of Data Storage and Treatment

ERML recognizes the fact that every stage of data handling increases the risk of introduced errors. To reduce such errors, direct electronic recording and data transfer processes were used. In cases where data were manually transcribed, they were normally checked against the original for errors.

Another common problem is loss of data due to accidental erasure of computer files. To guard against this, raw, unprocessed data were kept on a master file, controlled by the use of a password system. Generally, back-up files were created for every study and were regularly updated only by authorized personnel.

CHAPTER 3
ANALYTICAL METHODS

3.1 PHYSICAL LABORATORY METHODS

3.1.1 Soil

Soil samples were air-dried at room temperature and the dried samples were gently crushed with a ceramic mortar and pestle after which they were sieved through 2mm mesh sieves. The less than 2mm size fraction was stored and sub-sampled for the following determinations.

3.1.2 Water and Sediment Quality and Hydrobiology

The physical analyses carried out on water samples in the laboratory were Total Suspended Solids (TSS), Turbidity and Colour. TSS was determined gravimetrically on the filtered samples dried at 105 ± 2^{o}C to constant weight. Apparent turbidity was determined on unfiltered samples colorimetrically against nephelometric turbidity standard (NTU). Apparent colour was also determined colorimetrically on unfiltered samples against Platinum-Cobalt (Pt-Co) standards and expressed in Pt-Co units.

The physical laboratory analysis carried out on sediment samples was particle size distribution to determine the textural composition of the sediments. Like soil samples, this and other analyses for sediments were based on air-dried samples. Air-drying of sediment samples was carried out at room temperature (27 ± 2^{o}C) and in a spacious area of the laboratory. The dried samples were gently crushed with ceramic mortal and pestle after which they were sieved through 2mm mesh sieves. Particle size analyses was based on the sieved samples using the hydrometer method. Based on the estimated percentage contribution of the three major sediment particles (% sand, % silt, and % clay) the textural class of the investigated sediments was determined.

Sediment pH was determined on both aqueous sediment suspensions (H_2O 1:2) as well as in suspension of a neutral salt (KCl 1:2).

3.2 CHEMICAL LABORATORY METHODS

3.2.1 Soil

3.2.1.1 pH

This was determined in 1:1 soil-to-water suspension with a glass electrode pH meter. For soil samples high in organic matter, a soil-water ratio of 1:5 was used (Page *et al.*, 1987).

Organic carbon

This was determined by the loss on ignition method (Page *et al.*, 1987).

3.2.2 Water and Sediment Quality and Hydrobiology

The chemical determinations carried out on water samples collected are grouped with outline of the analytical methods employed given in Table 3.2-1. The methods can be grouped broadly into two categories viz: instrumental methods and non-instrumental methods. The instrumental methods include the use of colorimeters, Atomic Absorption spectrometry, Gas Chromatographic and flame analysers. The non-instrumental methods were mainly titrimetric (or volumetric). The respective equipment were handled only by competent analysts following strictly manufacturers guidelines. Chemical determinations were carried out on samples within the holding time of each determination. Samples were adequately preserved prior to chemical determinations.

The same chemical analytical methods of determinations were used for soil and sediments. For some parameters, COD and TOC the same methods were employed for water, soil, and sediments with very little or no modification. Highlights of these methods are given in Table 3.2-1.

Table 3.2-1
Analytical Methods of Chemical Determination of Water Sample

Parameters	**Methods**	**Reference**
Major Anions		
Total Alkalinity	Titrimetric (Acid-base Method)	APHA 2310 (STD Method, 19th ed. 1995)
Sulphate	Turbidimetric (Barium Chloride)	APHA 4500-Si (STD Method, 19th ed, 1995)
Chloride	Titrimetric (Molar titration)	
Major Cations		
Calcium	Complexiometric	
Magnesium	Complexiometric	
Sodium	Flame Analyser	Jones (1988)
Phosphorus	Flame Analyser	Jones (1988)
Organic &Oxygen parameter		
Dissolved oxygen	Titrimetric Method	APHA 422 (STD Method 19th ed., 1995)
BOD_5	Titrimetric Method	APHA 422 (STD Method 19th ed., 1995)
COD	Titrimetric Method	APHA 5220C (STD Method 19th ed., 1995)
TOC	Dichromate wet oxidation	APHA 422 (STD Method 19th ed., 1995)
TPH	Gas Chromatography	ASTM 422 (STD Method 19th ed., 1995)
THC	Gas Chromatography	
PAH	Gas Chromatography	
Heavy Metals	Atomic Absorption Spectrophotometer (AAS)	
Nutrient Compounds		

Parameters	Methods	Reference
Silica	Molybdo-Silicate Method	APHA 4500-Si D(STD Methods 19th ed)
PO_4^-P (Available)	Ascorbic Acid Method	APHA 4500-PE (STD Methods 19th ed)
PO_4^-P (Total	Persulphate digestion/Ascorbic acid	APHA 4500-P B5/4500-PE (STD Methods 19th ed 1995)
NO_2^-N	Cadmium reduction Method	APHA 4500-NO_3 E (STD Methods 19th ed)
NO_3–N	Colorimetric Method	APHA 4500-NO_2 B (STD Methods 19th ed)
NH_3–N	Nesslerization	APHA 4500 – NH_3 (STD Methods 19th ed)

3.3 BIOLOGICAL METHODS

3.3.1 Soil

3.3.1.1 Surface Fauna

In the laboratory, the soil samples were processed for microarthropod extraction in the modified Berlese – Tullgren extractor where a metal cylinder is used to concentrate heat and light from a 40-Watt bulb onto the soil core in a sample container whose base is a 2mm wire mesh. The sample container rests on a steep sided funnel whose angle of inclination to the horizontal is about 60°. This ensures unhindered journey of the arthropods through the funnel into the collecting tube below.

The collecting tube contained 70% ethanol, which preserves the specimens for a fairly long period without altering the taxonomic features of the specimen. A few drops of Lactic acid were added to the ethanol in other to prevent the growth of fungi.

The extraction lasted for seven days after which the specimens were removed. When the extraction was on, care was taken not to disturb the extractor so as to avoid contamination of the content of specimen bottles with soil particles and debris. Nocturnal insects were prevented from contaminating the content of collecting tubes by making the extractor airtight. Illustrations and detailed descriptions of this extractor can be found in Badejo (1982).

After extraction, the contents of the collecting tubes were emptied into a petri dish under the dissecting microscope for sorting and identification. Identified specimens were picked with the aid of a camel hairbrush into a labelled tube containing 70% ethanol. Each taxonomic group was put in a different tube and counted simultaneously.

The brush was always examined in the field of view under the dissecting microscope to ensure that specimens dropped into the tubes as well as other already in the tubes were not returned into the sorting dish.

The extracted microarthropods were carefully sorted, counted and identified to generic level where possible, using keys and illustrations provided in Balogh and Balogh (1992) and was confirmed in the laboratory using the reference of Tian and Badejo (1999).

3.3.1.2 Microbial Analysis

The following microbial analyses were carried out for the water, soil and sediment samples:

- Total heterotrophic bacterial count
- Total heterotrophic fungal count
- Hydrocarbon degrading bacterial and fungal counts
- Total coliform count
- Sulphate reducing bacterial count
- Identifiaction of the microbial isolates

For the microbial counts, serial dilution of the water, soil and sediments samples were carried out in sterile normal saline and 1 ml of the of the appropriate dilutions were plated using the standard pour plate techniques as described by Seeley and Vandenmerk (1981). Nutrient agar (Oxoid) and Plate count agar (LabM) were used for the bacterial count, while potato dextrose agar containing 0.05% chloramphenicol was used for the fungal assay. The heterotrophic bacterial plates were incubated aerobically at 28°C for 48 hours, while the fungal plates were incubated at 28°C for 7 days. At the end of the incubation period, plates containing between 30 and 300 colonies were selected for estimation.

Total coliform was determined using the Most Probable Number (MPN) technique and eosin methylene blue agar (EMB) for the confirmation of the presence of *E. coli*. Hydrocarbon degrading bacteria and fungi counts were determined as described by Mills et al (1978) and Mulkins and Stewart (1974). Crude oil was used as the test hydrocarbon. Bacterial identification was done as described by Bergey's (1977), and Cowan and Steel (1974), while fungal identification was done as described by Talbot (1978).

3.3.2 Water and Sediment Quality and Hydrobiology

The composition and cell count biomass of plankton flora (phytoplankton) and fauna (zooplankton) were based on microscopic analysis of the concentrate plankton samples collected. The concentrate samples were examined under various magnifications of the compound light microscope. The recorded plankters were measured and drawn to scale and identified using available taxonomic keys including APHA (1995). Phytoplankton biomass was based on cell counts (expressed by unit volume of the original water sample).

The biomass of phytoplankton was also determined based on the concentration of photosynthetic pigments, notably chlorophylls, and phaeophytin. These pigments were extracted in 90% acetone and measured spectrophotometrically for chlorophyll a, b, c, and phaeophytin according to APHA (1995).

In the laboratory, each of the macrobenthic samples was emptied into a petri-dish and examined under the dissecting microscope. The recorded organisms were sorted out, identified and counted. Identification was done as much as possible to species level using relevant literature. Where fragmented animals were found, only those with heads were counted. The determination of diversity (species richness and diversity indices) of the original macrobenthic communities were based on the measurements made. Taxa richness was computed using Margalef's index (D) expressed as

$$D = \frac{S-1}{InN}$$

where S = number of taxa
N = total number of all individuals
In = natural logarithm

General species diversity using Shannon Wiener (H) index was computed as

$$H' = \frac{NlogN - \sum_{i=1}^{k} nilogni}{N}$$

where: n = total number of individuals
ni = number of individuals in species
k = total number of species

Evenness index (E) which expresses the degree of uniformity in the distribution of individuals among the taxa in the collection was also calculated as follows:

$$E = \frac{H'}{H_{max}}$$

where: H' = Shannon-Wiener index
H_{max} = maximum expected diversity expressed as logs
S = number of taxa

Besides the application of the diversity indices, interstation comparisons were carried out to test for significant differences in the faunal abundance using one-way analysis of variance (ANOVA) according to Zar (1984).

CHAPTER 4
ENVIRONMENTAL CHARACTERISTICS OF THE AREA

4.1 VEGETATION

The vegetation in the study area is of two categories, inland and coastal/nearshore. In the coastal area, the habitat types encountered include Strandline, coconut-dominated Barrier Island, bare ground/farms/grassland mosaic, and Cyperus dominated marsh. The inland habitats include:

4.1.1 Coastal Vegetation

4.1.1.1 Strandline Vegetation

This habitat is located between the extreme high water mark and the coconut groves. It is characterized by creepers. They have rhizomes or stolons for vegetative propagation. These plants form a more or less continuous mat above the shoreline. (Figure 4.1-1 and Table 4.1-1). The commonest species include *Canavalia maritima, Ipomoea pes caprae and Chrysobalanus icaco* (Table 4.1-1).

The strandline plants are exposed to full sunlight. They have scattered distribution because of trampling by humans. The biomass of the strandline plants is 60±15g/m^2

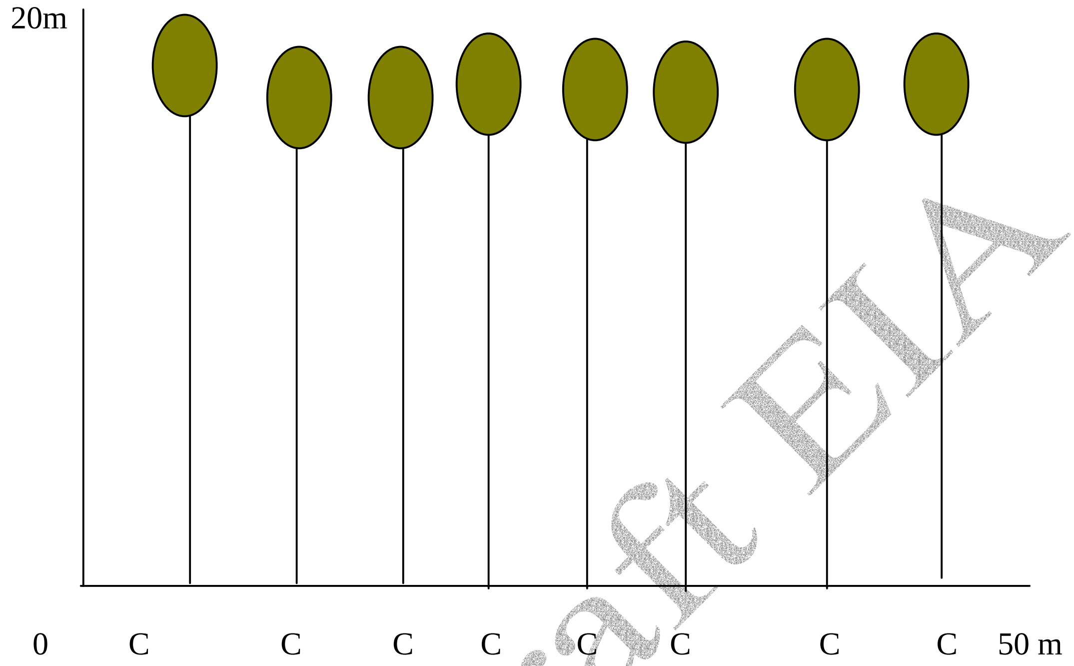
Table 4.1-1
Plant Species Composition within the Strandline Zone

S/No	Scientific Name	Common name	Habit
1	*Brachlaria sp.*		Creeper
2	*Cassytha filiformis*		Twinner
3	*Kylingia peruviana*		Herb
4	*Chrysobalanus icaco*		Shrub
5	*Crotalaria sp.*		herb
6	*Commelina erecta var. maritime*	Wandering Jews	Creeper
7	*Ipomoea pes caprae*	Seaside goat foot	Stoloniferous creeper

4.1.1.2 Barrier Island Dominated By Coconut

The second site is dominated by groves of coconut trees (Appendix Plate A-1). Young coconuts were observed in the gaps within the more or less closed canopy. A few weeds (including *Chrysobalanus icaco* and *Commelina erecta*) occur under the canopy of the coconut trees. The coconut trees have an average canopy height of about 17 meters. The vertical and spatial structure of the coconut belt is shown in Figure 4.1-1. The population density of the coconut trees is 400 plants per hectare. Most of the coconuts were yellowish and few fruits were on the trees. The biomass value for the herb layer is 46±6 g/m^2.

Figure 4.1-1
Profile Diagram of a Typical Coconut Palm Grove along the Barrier Coast
c= Coconut



4.1.1.3 Bare Ground/Farms/Grassland Mosaic

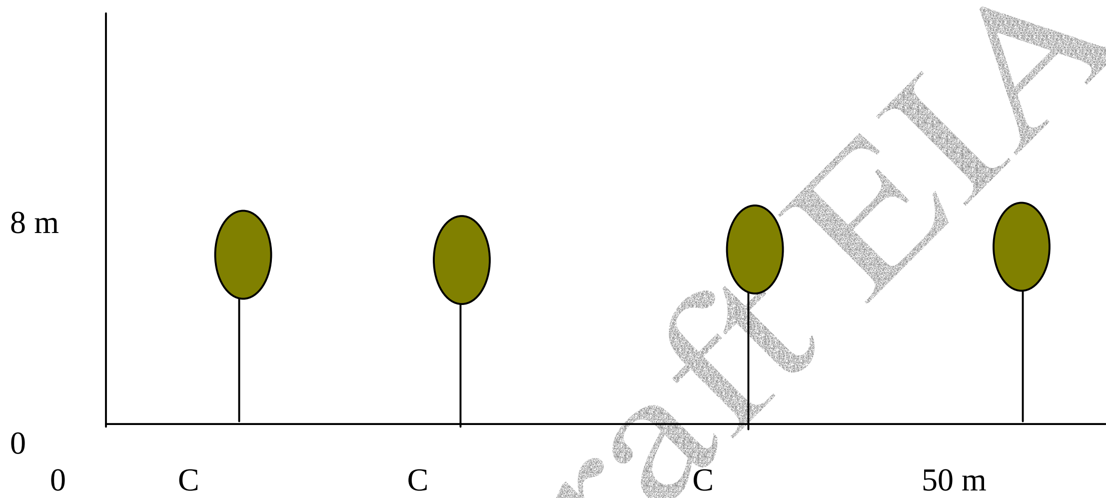
The third site is within the barrier island and consists of a mosaic of bare ground, cassava farms and grassland. Populations of young coconut palms also occur here (Plates A-2 and A-3). The grasses include *Imperata* cylindrica (spear grass), *Cynodon dactylon* and *Andropogon gayanus.* There are also scattered population of *Vitex doniana* (black plum). The mosaic of bare ground, cassava farms and grassland which occupy the middle part of the barrier island is physiognomically dominated by young coconut palms (Appendix Plate A-2 & A-3). The canopy height is about 8 meters. The species composition is shown in Table 4.1-2 with the profile diagram shown in Figure 4.1-2.

Table 4.1-2
Plant Species Composition and Habit in the Grassland/Farm/Bare Land Mosaic

S/No	Scientific name	Common name	Habit
1	Annona senegalensis		Shrub
2	Bridela sp		tree
3	Cassytha filiformis		Twinner
4	Chrysobalanus icaco	plum	Shrub
5	Cocos nucifera	coconut	Tree
6	Dialium guineense		Tree
7	Imperata cylindrica	Spear grass	Herb
8	Panicum maximum	Guinea grass	Herb
9	Pennisetum purpureum	Elephant grass	Herb

S/No	Scientific name	Common name	Habit
10	Vitex doniana	Black plum	Tree
11	Panicum maximum	Guinea grass	herb

Figure 4.1-2
Profile Diagram of the Vegetation Structure in the Middle Part of the Barrier Island
C= Coconut



4.1.1.4 Marsh Area on the Barrier Island

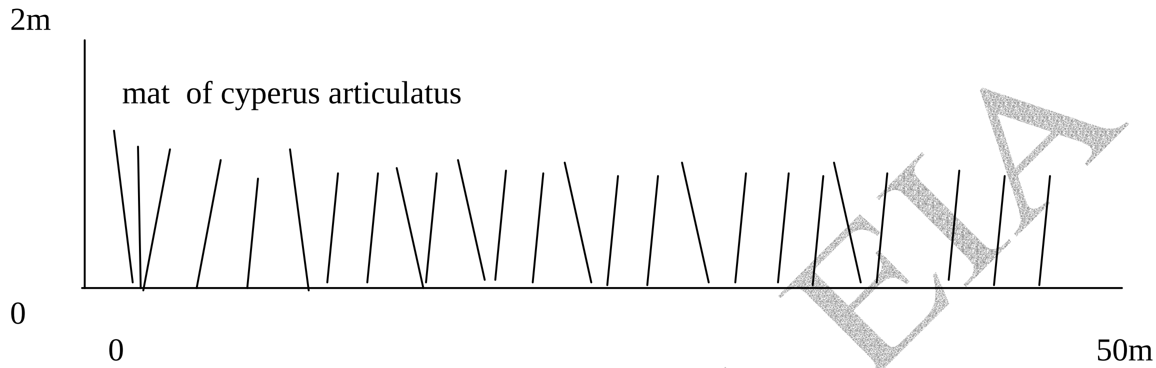
The 4th coastal site consists of a narrow belt of marshy area at the fringe of Badagry Creek. This is dominated by extensive mats of *Cyperus articulatus* (Figure 4.1-3). Scattered stands of coconut trees as well as flood tolerant trees such as *Phoenix reclinata* and the shrub *Machaerium lunatus* exist under *the* canopy (Appendix Plate A-4). This site is fringed by aquatic macrophytes such as water hyacinth, *Polygonium africanum* and *Pistia stratiotes*. A consolidated list of the plants is presented in Table 4.1-3. The canopy of the vegetation is open (Figure 4.1-2). The biomass for the herb layer is 220±22g/m^2.

Table 4.1-3
Plant Species Composition within the Marsh Habitat

S/No	Scientific name	Common name	Habit
1	*Cyperus articulatus*	Bizzy-bizzy	Rhizomatous sedge
2	*Eichhornea crassipes*	Water hycainth	Free floating
3	*Ludwigia repens*		Erect herb
4	*Machaerium lunatus*		Shrub
5	*Paspalum sp.*		herb
6	*Pistia stratiotes*	Water lettuce	Free floating
7	*Polygonium africana*	Smart weed	Emergent
8	*Saccharium officinarium*	Sugarcane	Erect grass

S/No	Scientific name	Common name	Habit
9	*Typha domingensis*	Reed	Emergent macrophyte

Figure 4.1-3
Profile Diagram of the Marsh Area Dominated by *Cyperus articulatus*



4.1.2 Inland Locations

4.1.2.1 Raphia Dominated Riparian Forest

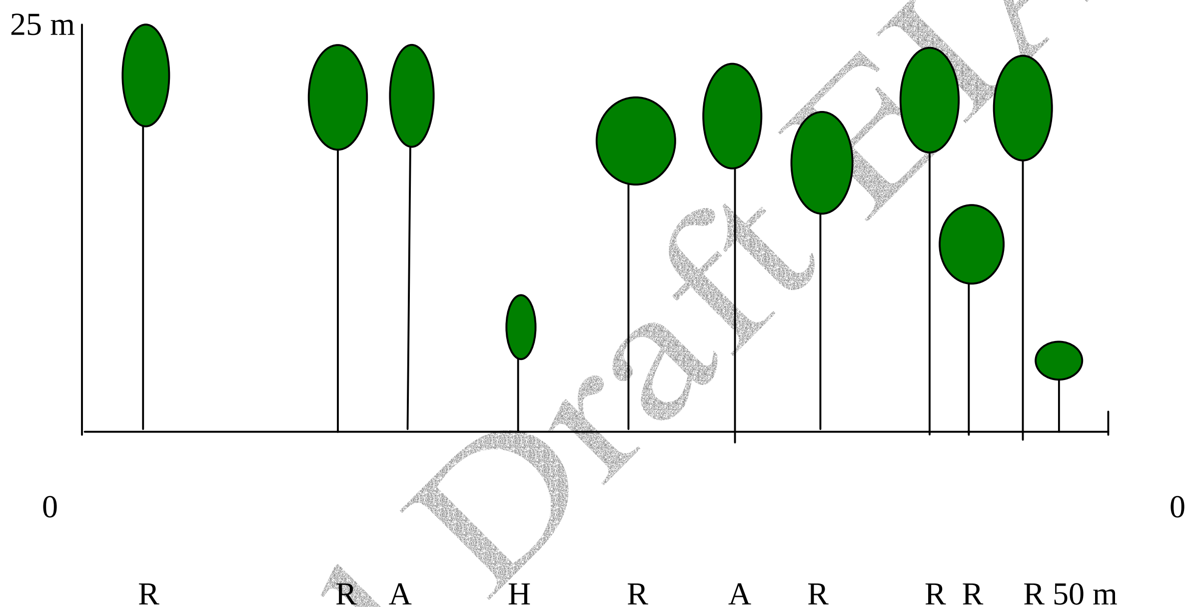
The riparian forest is dominated by raphia palm. It is close to coconut groves. Flood tolerant plants such as *Hallea ciliata* and *Alstonia boonei* are associated with raphia palm (Table 4.1-4). The swamp vegetation has a canopy height of about 20 meters. The canopy is relatively open and it is covered by climbing plants such as *Sellaginella* sp., shrubs (e.g. *Mussaeda alba* and *Alchornea cordifolia)*. Herbaceous species (e.g. *Acroceras sizanioides* and *Slceria verrucosa*), macrophytes such as *Cyrtosperma senegalense,w*ater lily and *Salvinia nymphellula*, as well as saplings and seedlings of Raphia palm dominated the understorey (Figure 4.1-4). Raphia palm (*Raphia hookeri*) has a mean population density of 300 plants per hectare. The biomass value for the herb layer is 350±12g/m^2.

Table 4.1-4
Plant Species Composition in the Riparian Forest

S/No.	Scientific name	Common name	Habit
1	*Alstonia boonei*	Stool wood	Tree
2	*Anchomanes difformis*		Erect herb
3	*Anthostema aubryanum*		Tree
4	*Cyrtosperma senegalense*		Emergent macrophyte
5	*Ficus* sp.	Fig tree	Tree
6	*Hallea ciliata*	Abura	Tree
7	*Nephrolepis biserrata*		Epiphytic fern
8	*Nymphaea lotus*	Water lily	Floating –leaved
9	*Scleria pterota*	Razor grass	Erect grass
10	*Salvinia nymphellula*		Fern
11	*Clappertonia ficifolia*		Shrub

S/No.	Scientific name	Common name	Habit
12	*Mussaeda alba*		Shrub
13	*Alchornea cordifolia*	Christmas tree	Shrub
14	*Clestopholis patens*		Tree
15	*Ficus leprieuri*	Fig	Tree
16	*Bombax buonoposenze*	Silk tree	Tree

Figure 4.1-4
Profile Diagram of Raphia Palm Dominated Swamp
R=*Raphia hookeri;* A=*Alstonia boonei;H=Hallea* ciliata



4.1.2.2 Coastal Savanna

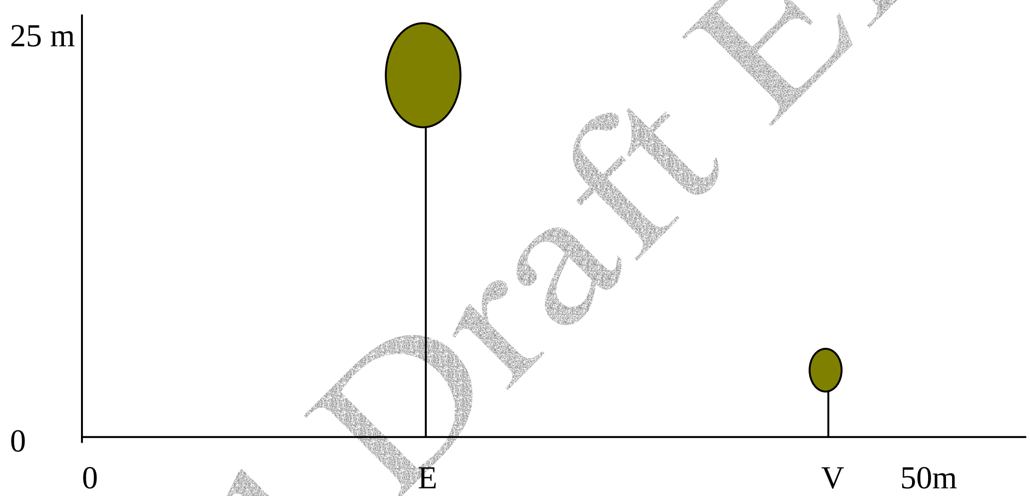
The coastal savanna occurs in parallel belts. They are grazed by cattle and subjected to burning annually. There are scattered shrubs and trees within the large expanse of grasses. The vegetation canopy is open and characterized by isolated emergent trees between extensive grassland (Figure 4.1-5). The coastal savanna give indications of just recovering from bush burning in the immediate past dry season. Herds of cattle were observed grazing within the area. Table 4.1-5 shows the species composition in the coastal savanna.

Table 4.1-5
Plant Species Composition in the Coastal Savanna Habitat

S/No	Scientific name	Common name	Habit
1	*Elaeis guineensis*	Oil palm	Tree
2	*Imperata cylindrica*	Spear grasss	Rhizomatous grass
3	*Panicum maximum*	Guinea grass	Erect grass
4	*Pennisetum purpureum*	Elephant grass	Erect grass
5	*Vitex doniana*	Black plum	Tree

S/No	Scientific name	Common name	Habit
6	*Zanthozyllum sp.*		Tree
7	*Cassia mimosoides*		Herb
8	*Abuliton sp.*		Herb
9	*Cassytha filiformis*		Creeper
10	*Cnestis ferruginea*		Shrub
11	*Andropogon sp.*		Herb
12	*Psidium guajava*	Guava	Tree

Figure 4.1-5
Profile Diagram of the Vegetation of the Coastal Savanna
E=Elaeis guineensis; v=Vitex doniana



4.1.2.3 Marshland/Grassland

The extensive mat of marsh vegetation is dominated by *Marantochloa leucantha* and *Megaphrynium macrostachyum*. There are scattered populations of Raphia palms within the marsh. The habitat is inhabited by many aquatic macrophytes. Examples include *Cyrtosperma senegalense*, *Polygonium africanum Acroceras zizanioides and Crinum jagus.* The canopy of the vegetation is open and the cover of the herb layer is about 95%. The habitat is flooded during the wet season sampling.

Table 4-1-6
Population Density of the Major Economic Plants in the Study Area

S/No	Scientific name	Common name	Density (No/ha)
1	*Saccharum officinarum*	Sugar cane	700±50
2	*Cocos nucifera*	Coconut	400±25
3	*Elaeis guineensis*	Oil palm	17±5
4	*Hallea ciliata*	Abura	9±4

S/No	Scientific name	Common name	Density (No/ha)
5	*Artocarpus communis*	Bread fruit	10±3
6	*Piptadeniatrum africanum*		5±2
7	*Manihot esculentum*	Cassava	1350±120
8	*Cola nitida*	cola nut	70±12
9	*Raphia hookeri*	wine palm	600±50
11	*Cyperus articulatus*		27±16

4.2 SOIL

4.2.1 Soil Physico-chemistry

The properties of soils in the area are discussed based on the habitat types encountered. Two major habitat groups are present in the study area: The coastal area; the inland area and the lagoon area.

4.2.1.1 The Coastal Area (Nearshore)

The selected properties of representative soils characterized within the different habitats mapped in the nearshore (coastal area) are indicated in Table 4.2-1. The various habitat types and the chemical properties of the associated soils are as follows:

The Bare Beach Sand

The mean pH value of representative samples of the beach sand is 6.43, which is indicative of a slightly acidic soil. Total organic matter (TOC) content is low, averaging 0.29%, and this accounts in part, for the low cohesiveness of the soils. Visual observations indicate predominantly sandy beach soils that are not bound together and cannot form hard lumps when moistened. The pH value recorded indicates that the soils are not likely to be chemically aggressive to buried metals.

Coconut Dominated Barrier Island

The soils are slightly acidic with average pH of 6.34. At this pH, mobilization (i.e. solubilization) of heavy metals in soil solution is not envisaged more so that the soils are well drained (due to sandy texture). The mean TOC is 0.62% and is considered to be very low, thus indicating that soil aggressivity will be minimal.

Bare Land/Cleared Area/Grassy

The pH of soils in this habitat is slightly acidic with a mean value of 6.60 while the mean TOC value of 0.54% is considered too low to enhance soil aggressivity. The soils are loose, well drained with low moisture holding capacity.

The Bush Fallow

The soils here are clayey, and acidic with an average pH of 5.58. The TOC content of the soils has average value of 29.4%. The soils are muddy, massive in structure and dark gray to black in the surface. They are poorly drained, poorly aerated and have properties indicating that the soil can be chemically aggressive to buried metals.

Table 4.2-1
The Average Chemical Characteristics of Soils in the Different Habitats within the Barrier Island (Coastal Area)

Sampling coordinates		Habitat Type	pH	TOC (%)
Latitude (^{o}N)	Longitude (^{o}E)			
06^o 23’ 50”	002^o 59’ 19”	Bare Beach Sand	6.43	0.29
06^o 23’ 57”	002^o 59’ 19	Coconut Dominated Barrier	6.34	0.62
06^o 24’ 04”	002^o 59’ 19”	Bare land/Cleared Area/Grassland	6.60	0.54
06^o 24’ 09”	002^o 59’ 19”	Cyperus dominated marsh	5.58	29.4

4.2.1.2 The Inland Area

Four main habitat types are encountered in this part of the project area. The chemical properties of representative soil samples collected from these habitats are given in Table 4.2-2 below.

Marshland/Bush Fallow

The pH is acidic with a mean value of 5.41 and low TOC of 0.29% (Table 4.2-2). The observed properties of the soils suggest that they cannot be chemically aggressive to metals that may be buried in the soils.

Bare Land/Cleared Area/Grass Land

The soils in this habitat are near neutral with an average pH of 6.70 and generally contain low TOC, about 1.45% (Table 4.2-2). At pH of 6.0 and above, mobilization of heavy metals into soil solutions from soil solids is not expected (Amusan and Ashaye, 1989; Ashaye, 1967). The low TOC content together with the texture of the soils (silty loam) are not expected to be physically and chemically aggressive to metals that may be buried in them.

Raphia Palm Dominated Freshwater Swamp Forest

The pH of soils in this habitat is about 5.03 (strongly acidic) with TOC content of about 1.77% (Table 4.2-2). Low pH, poor aeration and TOC in soils combine to impart on such soils a tendency to be chemically aggressive to buried metals. Therefore, metals to be buried in soils within this habitat should be properly treated against external corrosion.

Table 4.2-2
The Average Chemical Characteristics of Soils in the Different Habitats within the Inland Area

Sampling Coordinates		Habitat Type	PH	TOC (%)
Latitude (^oN)	Longitude (^oE)			
06^o 25' 02"	002^o 59' 19"	Marshland/Bush Fallow	5.41	0.29
06^o 25' 14"	003^o 00' 27"	Raphia palm dominated freshwater swamp forest	5.03	1.77
06^o 25' 58"	002^o 59' 48"	Bare land/Cleared Area/Grassland	6.70	1.45

4.2.1.3 The Lagoon Area (Nearshore)

The only habitat type encountered is the secondary forest. The chemical properties of representative soil sample collected from this habitat are given in Table 4.2-3 below.

Secondary Forest

The soils in this habitat are acidic with an average pH of 5.97 and generally contain low TOC, about 0.51% (Table 4.2-3). At this pH, solubilization of heavy metals in the soil is likely to occur however, the TOC content is considered low and therefore not enough to enhance soil aggressivity to buried metals.

Table 4.2-3
The Average Chemical Characteristics of Soil in the Habitat within the Lagoon Area

Sampling Coordinates		Habitat Type	pH	TOC (%)
Latitude (^oN)	Longitude (^oE)			
06^o 24' 54"	002^o 59' 09"	Secondary forest	5.97	0.51

4.2.2 Soil Ecology

Results of soil arthropod survey in the area are depicted in Table 4.2-4. The most abundant taxonomic group of soil microarthropods in the study area is Acarina. In all, 21 groups of arthropods were recorded over the sampling zone (described in an earlier section). Apart from Acarina, the other arthropods groups, which were recorded in the area include: Araneida, Schizopeltida, Isopoda, Diplura, Psocoptera, Hemiptera and Coleptera larva. All of these groups were recorded from the *Rhapia* dominated site. In general however, the freshwater swamp habitat supported the highest microarthropod populations while the sandy beach supported the least population. Using the microarthopod population densities recorded in the area (2,833–4,000 per m^2) as an index, it could be inferred that the soils in the area may not be agriculturally viable. In productive soils of the western region of Nigeria, densities of soil mites (Acarina) alone reach a peak of about 80,000 per m^2 in the wet season (Badejo and Lasebikan, 1988; Badejo, 1990, Badejo, 1999).

Table 4.2-4
Mean Numbers of Soil Microarthropods Extracted from the Soil in Different Habitat Types. (Mean Based On Four Sampling Units)

Microarthropod Group	Grass near beach	Coconut + grass/bushy undergrowth near beach	Coconut near swampy area	*Rhapia* with scattered trees and shrubs	Grassland with few shrubs	Freshwater swamp dominated by *Rhappia*
ACARINA						
Oribatida						
Indotritia sp.	0	0	0	0	0	1
Annectacarus sp.	0	2	0	2	0	3
Mixacarus sp.	0	0	0	0	0	1
Bicyrthermannia nigeriana	0	0	0	1	0	6
Epilohmania sp.	0	0	0	0	0	6
Carabodes sp.	1	0	0	0	0	0
Aokiella sp.	0	0	0	0	0	1
Dolicheremeus sp.	0	0	0	0	2	0
Tectocepheus sp.	0	1	0	0	0	0
Scheloribates m'similaris	1	0	1	0	1	9
Peloribates nigeriensis	0	0	0	0	1	2
Teleiolides sp.	0	0	1	1	2	1
Eremulus sp.	0	0	0	0	1	0
Oppia sp.	0	0	1	1	0	1
Galumnidae	0	0	1	2	1	19
Cepheidae	0	0	0	0	0	2
Belbidae	0	2	1	0	0	0
Gamasida						
Polyaspidae	0	1	1	1	1	1
Parasitidae	0	0	1	1	0	2
Uropodidae	0	0	0	0	0	2
Trachyuropodiade	0	1	1	0	0	1
Actinedida	0	3	0	1	0	0
Araneida (Spider)	0	0	0	0	0	1
Symphylla	0	1	0	1	1	1
Pseudoscorpionida	0	0	0	1	0	1
Schizopeltida	0	0	0	0	1	2
Isopoda	0	0	0	1	1	2
Chilopoda (Centipedes)	0	0	1	1	0	1
Diplura (*Japyx*)	0	1	1	1	0	1
Collembola (Springtails)	0	1	0	1	1	1
Psocoptera	0	1	5	3	2	2
Hemiptera (Bugs)	0	1	0	0	0	0
Coleoptera (Beetles)	0	1	1	1	1	6
Coleoptera larva	0	0	1	0	2	2
Formicoidea (Ants)	0	8	1	1	0	14
Total	2	24	18	21	17	92
Density (No. per m^2)	333	4,000	3,000	3,500	2,833	15,333

The most abundant acarine group in Freshwater swamp is the Galumnidae. In a dry season study of the area, they acarine groups were barely present. This suggests that seasonality of soil microarthropods, which have been recorded in similar sites all over the world (Belfield, 1956 and Butcher et al., 1971) also occurs around this area. The extremely low density of microarthropods in the sandy beach habitat is a further confirmation of the previous observation that sparse vegetation is not conducive to the growth of soil dwelling arthropod populations.

4.2.3 Microbiology

The results of microbial analyses for soil samples are shown in Table 4.2-5. Total heterotrophic bacterial count ranged in the order of 10^7 to 10^8 cfu/g. Fungal densities were lower, in the range of 10^5 cfu/g. Hydrocarbon degrading bacterial count of the soils varied in the order of 10^4 to 10^6 cfu/g, while their fungal counterpart were observed to vary between 0 and 6.5×10^5 cfu/g. The sulphate reducing bacterial populations were generally low and ranged between 0 and 10^3 cells/g.

The microbial species isolated from the soil samples includes such bacteria species as *Bacillus subtilis, Bacillus polymyxa, Streptomyces spp., Aeromonas spp., Arthrobacter spp., Sarcinia spp., Proteus mirabilis, Corynebacterium spp., Pseudomonas aeruginosa, Klebsiella pneumoniae, Micrococcus luteum, Desulfotomaculum spp., Bacillus cereus, Pseudomonas fluorescence* and *Flavobacterium spp*; as well as fungal isolates such as *Microsporium audovinii, Microsporium gypseum, Aspergillus flavus, Aspergillus niger, Cladosporium spp., Trichoderma spp., Daldenia spp., Scopulariopsis brevicaulis, Penicillium notatum, Rhodotorula spp.,* and *Rhodotorula spp.*

The observed bacterial and fungal densities and diversities in the area fall within the range reported for some undisturbed tropical soils (Okoh et al., 2000). Also, the hydrocarbon degraders population of the soil and sediments is a good indication of the potential of the area for intrinsic bioremediation. Most of the isolates identified in this study, especially those belonging to the genus *Pseudomonas* are renowned for their versatility (Golovleva et al., 1992), and their roles in the bioremediation of hydrocarbon-polluted systems have been extensively documented. These microorganisms are often the primary mediators of hydrocarbon degradation and removal in soils. Their presence in sufficient numbers therefore, serves as a good indicator of biodegradation potential of a soil (Bossert and Compeau, 1995).

Table 4.2-5
Average Microbial Densities of Soil Samples from WAGP Project Area

S/N	Sample code	THB (cfu/g)	HDB (cfu/g)	SRB (cells/g)	THF (cfu/g)	HDF (cfu/g)
1	T1S1	2.8×10^6	4.5×10^2	Nil	1.5×10^3	25
2	T1S2	1.6×10^6	3.2×10^2	Nil	3.4×10^3	20
3	T1S3	2.8×10^6	4.4×10^4	10^1	3.0×10^2	Nil
4	Plot ID3 0 - 15	3.3×10^7	4.2×10^5	10^3	1.2×10^5	2.3×10^2
5	Plot ID3 15 - 50	2.1×10^8	5.5×10^6	10^2	2.4×10^5	5.1×10^3
6	Plot ID4 0 - 15	5.0×10^7	1.1×10^6	10^2	1.5×10^5	3.4×10^3
7	Plot ID4 15 - 50	2.3×10^7	5.3×10^4	Nil	2.2×10^5	9.1×10^2
8	Plot ID5 0 - 15	2.3×10^7	4.4×10^6	Nil	3.2×10^5	4.3×10^2
9	Plot ID5 15 - 50	4.6×10^7	4.2×10^5	10^1	5.0×10^5	86
10	N2ITD 0 -15	6.5×10^7	8.9×10^4	10^1	1.8×10^5	1.7×10^2
11	N2ITD 15 - 50	2.2×10^7	5.8×10^4	Nil	2.6×10^5	1.2×10^3
12	N2ITE 0 -15	4.4×10^7	3.8×10^5	Nil	2.6×10^5	65
13	N2ITE 15 - 50	1.1×10^7	5.4×10^5	Nil	1.8×10^5	92
14	N2IDTC 0 - 15	5.3×10^7	3.2×10^6	10^2	4.5×10^5	1.0×10^2
15	N2IDTC 15 - 50	5.0×10^7	2.1×10^6	10^3	4.1×10^5	2.1×10^2
16	N2CT 0 -15	5.7×10^7	2.2×10^5	Nil	2.7×10^5	1.9×10^3
17	N2CT 15-50	5.6×10^7	3.0×10^4	10^3	6.4×10^5	3.2×10^2
18	N2LT 0 -15	2.0×10^7	2.0×10^6	10^3	3.3×10^5	88
19	N2LT 15 - 50	9.5×10^7	1.5×10^6	Nil	2.3×10^5	8.2×10^2
20	N2ITA 0 -15	4.3×10^7	3.3×10^5	Nil	4.3×10^5	1.6×10^2
21	N2ITA 15-50	3.6×10^7	6.6×10^5	10^2	2.1×10^5	90

Keys:
THB - Total heterotrophic bacteria; **HDB** - Hydrocarbon degrading bacteria; **SRB** – Sulphate reducing bacteria; **THF** – Total heterotrophic fungi; **HDF** – Hydrocarbon degrading fungi

4.3 WATER AND SEDIMENT QUALITY

4.3.1 Water and Sediment Physico-chemistry

4.3.1.1 Water Physico-chemistry

Physical Characteristics

In Table 4.3-1 the mean water temperature values of the major water bodies in the project area over the two seasons of the annual cycle are compared. Most probably due to the generally cloudy weather during the rainy season, mean temperatures were generally lower then (i.e. rainy season) than in the dry season. On the average, the rainy season values were about 1-9% (Mean=5%) lower than that of the dry season for the different water habitats. For the two seasons, the lowest water temperature values in the area were recorded for the non-tidal water bodies (rivers and streams) most probably because their courses were heavily covered by the forest vegetation, thus reducing insolation to the minimum. On the other hand, the hand-dug wells were characterized by the highest temperature values during the rainy season (among the inland waters).

The hand-dug well and the coastal near offshore sea were characterized with the lowest seasonal difference in mean temperature. The season differences were ≤1^{o}C.

Information on diurnal variation in ambient air and water temperature in the open water bodies (Badagry Creek) is provided in Table 4.3-2. During the typical cloudy days water temperature was usually slightly higher than the ambient air temperature. In general, temperature rises gradually from the morning to a peak in the afternoon (about 14.00 and 15.00 hours) and fall thereafter. Temperature generally occurred within the range of 25–29^{o}C between mid-morning and late afternoon suggesting that diurnal variation is slightly higher than seasonal variation even in cloudy weather condition.

Table 4.3-1
Mean Daily Temperature of Major Waterbodies in the WAGP Project Area

Waterboby	Dry Season (^{o}C)	Rainy Season (^{o}C)
Rivers and Streams	27.2 ± 1.6	25.9 ± 0.7
Hand-dug well	28.9 ± 0.8	28.6 ± 0.3
Ologe Lagoon	30.3 ± 1.2	27.7 ± 0.9
Badagry Creek	30.2 ±1 1.1	27.9 ± 1.0
Sea	30	29.0

Table 4.3-2
Diurnal Variation in Ambient Air And Water Temperature At Badagry Creek

Temp (^OC)	Time of day (Hr)							
	10.00am	**11.00m**	**12.00noon**	**13.00pm**	**14.00pm**	**15.00pm**	**16.00pm**	**17.00pm**
Air temp (AT)	25.60	25.80	27.10	27.90	28.00	27.80	26.60	26.30
Water temp (WT)	26.00	26.20	27.40	28.10	28.30	28.50	28.40	28.10
AT/WT	0.980	0.98	0.99	0.99	0.99	0.98	0.94	0.94

Information on apparent watercolour and other optical properties of water bodies during the two seasons of the annual cycle is provided in Table 4.3-3. As expected, water depth and channel width increased during the rainy season than the dry season due to runoff inflow. There was little or no change in water colouration as the waters still remained generally brownish in colour during the rainy season. However, Secchi disc transparency and the depth of euphotic zone (i.e. depth of 1% incident light) became lower during the rainy season than in the dry season. However for streams and river ≤1m depth, Secchi disc transparency extended through to river bed. On the whole, the relationship between the depth of euphotic zone (Zeu) and total water depth (Zm) for the two seasons was as follows:

Water depth (m)	Zeu/Zm (%)
< 1	100±3
1-2	89±8
2-3	83±7
3-4	65±7
4-5	52±11
5-6	25±11

Table 4.3-3
Colour Characteristics of Waterbodies in the WAGP Project Area

Waterbody	**Dry Season (DS)**					**Rainy Season (RS)**				
	Colour	**Depth (m)**	**Transp (m)**	**Zeu (m)**	**%**	**Colour**	**Depth (m)**	**Transp (m)**	**Zeu (m)**	**%**
R. Owo at Agbara	Brown	4.0	0.9	2.7	68	Dark brown	4.6	0.53	1.6	35
R. Ore at Agbara Ota	Brownish green	0.4	TB	0.4	100	Brwon	1.0	TB	1.0	100
R. Yewa at Ibaye	Dark brown	4..0	0.85	2.6	65	Greenish brown	4.5	0.76	2.3	51
Ologe lagoon UR	Dark brown	2.4	0.79	2.4	100	Dark brown	2.3	0.71	2.1	91
Ologe lagoon LR	Dark brown	2.8	0.69	2.1	75	Greenish	3.3	0.63	1.9	58

Waterbody	Dry Season (DS)					Rainy Season (RS)				
	Colour	Depth (m)	Transp (m)	Zeu (m)	%	Colour	Depth (m)	Transp (m)	Zeu (m)	%
						brown				
Badagry Ck at Topo	Brownish	5.3	0.54	1.6	30	Greyish brown	5.9	0.30	0.9	15
Badagry Ck at ROW	Brownish	4.4	0.44	1.3	30	Greenish brown	4.8	0.40	1.2	25
Badagry Ck at Tafi	Greenish brown	5.8	0.81	2.4	41	Greenish brown	6.1	0.28	0.8	13
Badagry Ck at orufo	Greenish brown	4.0	0.82	2.5	63	Dark brown	6.4	0.31	0.9	20

Along Badagry Creek, euphotic zone as a proportion of total depth tended to increase from west to East i.e. from Topo through ROW to Tafi and Orufo.

Water Salinity and Major ions

Tables 4.3-4 through 4.3-6 provide some information on the chemical composition of water bodies in the project for the rainy season period. With regard to salinity parameters (conductivity and TDS) all the non-tidal water bodies could be classified as fresh while all the tidal water bodies (Badagry Creek, Yewa River lower reach, and Ologe Lagoon) could all be classified as tidal–fresh. The tidal fresh water bodies were much more diluted during the rainy season than the dry season indicating the strong influence of freshwater discharge on the water quality during the rainy season. On the average, the hand-dug well waters were slightly more saline than Badagry creek water even at high tide of the Creek. Like the nearby seawater, the water bodies (including rain water) all belong to the chlorided series. Whereas the order of anionic dominance in the seas was Cl>S04>Hco$_3$ in the other surface water bodies the order was Cl> HCO3>SO4 while in the Hand-dug wells it was HCO3>Cl>SO4 i.e. typical of the standard freshwater.

Oxygen Parameters and Nutrient Compound

In general, the water bodies were characterized by low dissolved oxygen contents and level of saturation. Dissolved oxygen contents were generally below 5mg while the degree of saturation was less 60%. The levels of BOD$_5$ were generally below $3mg^{t-1}$ suggesting low biological oxygen demand. Chemical Oxygen Demand (COD) was comparatively high and seem to be directly related to salinity. The concentration of oil and grease were generally below $6mg^{t-1}$ (range=0.1–$5.6mg^{t-1}$). On the average, values were slightly higher on the Creek than the other water bodies most probably because of heavier boat transportation of the creeks.

Ammonia nitrogen (NH3-N) occurred in the range of 0.03–1.70 with mean values being higher in the tidal water bodies than in the non-tidal water bodies (Table 4.3-6). Similarly both total phosphate (PO4) and available P were also higher in Badagry Creek than the non-tidal water bodies (rivers, streams, and hand-dug wells).

Table 4.3-4
The Chemical Composition of Waterbodies in WAGP Project Area (Rainy Season)

Waterbody	Conductivity (µScm^{-1})	Total Alkalinity (mgCaCO$_3$)	TDS (mgl^{-1})	HCO_3 (mgl^{-1})	Cl (mgl^{-1})	SO_4^{2-} (mgl^{-1})	DO (mgl^{-1})	DO (%sat)	BOD (mgl^{-1})	COD (mgl^{-1})	NH_3–^{N}N (mgl^{-1})	Total PO_4 (mgl^{-1})	Avail PO_4 (mgl^{-1})	O&G (mgl^{-1})
R. Yewa (HT)	140	26.9	70.4.0	32.5	23.4	12.1	2.0	2.6	0.4	30.7	1.02	0.14	0.07	1.5
Badagry Ck at Badagry (HT)	ND	30.8	ND	37.5	50.5	20.4	3.5	4.5	1.1	15.4	1.64	0.23	0.17	3.1
Badagr Ck at Topo (LT)	274	31.8	137.0	38.8	60.0	25.5	2.0	26.0	0.7	15.4	1.64	0.23	0.17	0.1
Badagry Ck at Topo (HT)	274	31.8	135.0	38.8	58.2	23.7	3.0	39.0	0.2	46.1	1.56	0.22	0.17	3.6
Badagry Ck at ROW	280	39.4	141.0	39.4	60.0	22.1	2.5	32.0	1.9	46.1	1.51	0.22	0.15	3.6
Badagry Ck at ROW (HT)	271	39.8	135.0	36.8	63.7	21.2	4.5	56.0	2.3	30.7	1.52	0.30	0.15	2.5
Badagry Ck at Tafi (LT)	300	31.3	152.0	38.1	67.1	19.0	3.0	30.0	0.2	42.3	1.45	0.22	0.16	4.1
Badagry Ck at Tafi (HT)	310	32.3	156.0	39.4	75.0	18.8	2.7	35.0	0.7	45.4	1.52	0.20	0.16	3.5
Badagry Ck at Orufo (HT)	348	31.8	174.0	38.8	76.0	20.0	2.6	34.0	0.8	15.0	1.48	0.20	0.15	5.6
Ologe lagoon (HT)	103	14.9	51.0	18.1	17.4	10.9	1.8	38.0	ND	46.1	1.47	0.08	0.05	2.5
Ologe Ck (HT)	176	15.9	88.0	19.4	41.3	12.5	1.4	18.0	ND	76.8	1.44	0.09	0.04	4.1
R. Owo at Agbara	72	13.3	36.0	16.3	10.0	10.0	0.5	6.0	0.1	30.7	1.22	0.06	0.04	0.1
R.Imede at Oke-Ijan	45	3.8	22.0	3.1	7.3	15.1	1.6	19.0	0.9	15.4	1.70	0.11	0.09	1.5
R. Iju at Oko-Omi	ND	10.3	ND	12.1	7.9	3.3	0.2	3.0	ND	76.8	0.55	0.12	0.11	3.1
R. ore at Onigbogbo	89	9.2	45.0	11.3	71.1	10.4	ND	ND	ND	30.7	0.74	0.07	0.05	0.1
R. Iju at Ijako	ND	15.4	ND	18.8	15.5	4.7	0.4	5.0	2.1	15.6	0.67	0.04	0.04	2.0
R. Ijako at Ijako	100	20.5	50.0	25.0	9.7	4.0	1.5	19.0	ND	30.7	0.25	0.04	0.04	2.0
HDW at Ilogbo	597	3.6	290.0	4.4	54.0	10.7	1.7	22.0	0.9	46.1	0.06	0.09	0.08	4.6
HDW at Onigbogbo	57	114.8	28.0	122.5	10.2	2.2	1.1	14.0	0.1	15.4	0.06	0.04	0.04	3.6
HDW at Osuke	ND	14.4	ND	17.5	17.2	5.0	2.1	27.0	ND	30.7	0.03	0.04	0.04	2.0

HDW = Hand-dug well ND = No data HT = High Tide LT = Low tide Sat = Saturation

Table 4.3-5
The Mean Values of Conductivity and Major Ions of Major Waterbodies in the WAGP Project Area (Rainy Season)

Waterbody	Conductivity (μScm^{-1})	Total Alkalinity ($mgCaCO_3$)	TDS (mgl^{-1})	HCO_3 (mgl^{-1})	Cl (mgl^{-1})	SO_4^{2-} (mgl^{-1})
Rain	14.0	2.1	8.5	2.5	3.9	1.1
Non-tidal Rivers	76.5±20.7	11.9±5.5	38.3±10.6	14.5±6.80	20.3±22.9	7.9±4.3
Hand-dug well	327.0±270.0	59.5±48.7	159.0±131.0	69.0±56.0	38.6±33.2	6.6±3.2
Tidal Rivers/Creeks						
Low Tide (LT)	204.9±109.6	26.9±6.9	96.7±55.4	32.9±8.4	50.7±20.6	19.5±4.6
High Tide (HT)	277.4±38.1	31.8±5.4	139.0±20.1	38.8±6.5	62.4±43.3	22.2±3.7
Coastal marine	50,500.0	140.7	30,800.0	140.7	20,326.0	285.2

Table 4.3-6
The Mean Values of Oxygen Parameters and Nutrient Compounds in Major Waterbodies in the WAGP Project Area (Rainy Season)

Waterbody	DO (mgl^{-1})	DO (% Sat)	BOD_5 (mgl^{-1})	COD (mgl^{-1})	NH_3-N (mgl^{-1})	Total PO_4 (mgl^{-1})	Available PO_4 (mgl^{-1})	Oil & grease (mgl^{-1})
Rain	ND	ND	ND	16.1	0.48	0.10	0.04	1.5
Non-tidal Rivers	0.8±0.6	10.4±7.1	0.1±2.0	33.3±20.6	0.86±0.48	0.07±0.03	0.06±0.03	1.82±1.5
Hand-dug well	2.0±0.5	21.0±5.0	0.5±0.4	110.0±171.0	0.38±0.54	0.07±0.01	0.05±0.02	2.6±1.5
Tidal Rivers/Creeks								
Low Tide (LT)	2.7±0.9	34.5±11.6	0.09±0.7	35.0±20.0	1.51±5.5	0.22±0.00	0.16±0.51	2.6±1.8
High Tide (HT)	2.5±0.4	29.0±13.0	1.0±0.6	62.0±45.0	1.46±0.18	0.18±0.07	0.12±0.05	3.3±1.2
Coastal marine	1.0	13.0	ND	492.0	1.58	0.10	0.10	3.1

4.3.1.2 Sediment Physico-Chemical Characteristics

Information on sediment physico-chemical characteristics is highlighted in Table 4.3-7 through 4.3-10. The sediments were essentially sandy in textural composition (Table 4.3-7). They fall into three textural classes: sand, Clayey sand and Clay mud. For Badagry Creek the total sand fraction was generally above 80% (range=84.2–91.7%) comprising mainly of fine sand (FS) and medium sand (MS) fraction while coarse fine (CS) and very fine sand (VFS) fractions were relatively low. Ologe Lagoon was characterized by relatively low sand fraction compared to Badagry Creek while the non-tidal rivers were mostly clayey sand.

Sediment pH was quite variable ranging from acidic to moderately alkaline over a range of 3.89–8.24. In general, Ologe Lagoon and the non-tidal rivers were comparatively more acidic than the tidal Badagry Creek. The concentrations of both TOC and THC were also quite variable in the sediments. The level of TOC was highest within the main body of Ologe Lagoon (10.14%); this is most probably due to the heavy vegetal cover now decomposing to enrich the sediment work organic material. The level of TOC was moderately high in Badagry creek except at Badagry Bridge area, which has been dredged.

In general, pH, TOC and THC seemed to showed some definite relationship with sediment type (Table 4-18). For instance, mean TOC content was lowerst in sandy sediment and highest in clayey mud sediment. On the other hand, pH was highest in sandy soil and lowest (most acidic) in clayey sand sediment. Table 4.3-10 provides data on the sediment characteristics of Badagry creek, which is essential sandy in texture.

Table 4.3-7
Particle Size Distribution of Sediments from WAGP Project Area (Rainy Season)

Waterbody	CS	MS	FS	VFS	% T. Sand	% Silt	% Clay	Texture
R. Yewa	1.79	3.63	22.39	17.73	46.57	8.91	44.52	Clayey sand
Badagry Ck at Topo	5.18	27.90	41.46	9.13	84.20	6.36	9.44	Sand
Badagry Ck at ROW	8.71	38.11	38.58	2.79	89.01	2.18	8.81	Sand
Badagry Ck at Tafi	25.11	35.28	20.72	0.37	88.88	2.39	8.73	Sand
Badagry Ck at Orufo	14.10	47.31	24.36	1.45	88.15	2.41	9.44	Sand
Ologe lagoon upper reach	5.94	5.37	8.07	10.23	32.95	29.08	37.97	Clay mud
Ologe lagoon extension	7.12	20.32	27.58	1.12	60.39	17.82	21.79	Clayey sand
R. Iju at Oko-Omi	13.68	25.88	20.94	5.85	74.86	2.53	22.58	Clayey sand
R. Iju at Osuke	13.26	25.97	7.53	32.75	82.47	5.90	11.63	Sand
Ijako Stream at Ijako	18.42	14.98	10.18	3.23	59.86	10.97	29.17	Clayey sand
Badagry Ck at Badagry	4.91	37.49	47.93	0.72	91.70	3.34	4.96	Sand

Table 4.3-8
Sediment Characteristics of Major Waterbodies in the WAGP Project Area

Waterbody	Sampling Coordinates		pH	TOC (%)	THC (ppm)
R. Yewa at Ibaye Village	06^{o} 28.155’ N	002^{o} 52.091’E	5.76	1.56	24.58
Badagry Ck at Badagry	06^{o} 25.162’ N	002^{o} 11.892’E	7.68	0.18	28.70
Badagr Ck at Topo	06^{o} 24.464’ N	002^{o} 55.863’E	7.27	1.96	2.64
Badagry Ck at ROW	06^{o} 24.326’ N	002^{o} 59.266’E	6.77	1.56	20.50
Badagry Ck near Tafi	06^{o} 24.546’ N	003^{o} 04.326’E	7.73	0.29	39.91
Badagry Ck at Ibodi/Orufo	06^{o} 24.690’ N	003^{o} 07.693’E	8.24	0.43	37.71
Ologe lagoon upper reach	06^{o} 29.283’ N	003^{o} 05.996’E	3.89	10.14	21.95
Ologe lagoon extension	06^{o} 26.897’ N	003^{o} 08.542’E	4.17	0.23	23.56
R. Iju at Oko-Omi	06^{o} 37.543’ N	003^{o} 08.678’E	5.84	0.62	ND
R. Iju at Osuke	06^{o} 36.083’ N	003^{o} 09.501’E	5.94	0.23	36.84
Ijako Stream at Ijako	06^{o} 42.655’ N	003^{o} 18.160’E	7.44	1.07	21.22

Table 4.3-9
Variation In Sediment Chemical Characteristics With Textural Composition

Sediment type	pH			TOC (%)			THC (ppm)		
	Range	**Mean**	**s.d**	**Range**	**Mean**	**s.d**	**Range**	**Mean**	**s.d**
Sand	5.94-8.24	7.27	0.75	0.18-1.96	0.78	0.71	2.62-39.91	27.7	13.0
Clayey sand	4.17-5.84	5.26	0.76	0.23-1.58	0.80	0.56	23.56-24.58	24.07	0.5
Clay mud	-	3.81	-	-	10.14	-	-	21.95	-

Table 4.3-10
Sediment Characteristics of Badagry Creek

Statistics	pH	TOC (%)	THC (ppm)	Sand (%)	Silt (%)	Clay (%)
Min	6.77	0.18	2.62	84.20	2.18	4.96
Max	8.24	1.96	39.91	91.70	6.36	9.44
Mean	7.54	0.88	25.88	88.40	3.34	8.28
s.d	0.49	0.73	13.52	2.40	1.56	1.68
%CV	6.5	82.7	52.20	2.70	46.9	20.36

4.3.2 Biological Characteristics

4.3.2.1 Benthic Infauna

A total of **428** individuals in 15 species were encountered from the fifteen (15) sediment samples analyzed. A summary of the data is shown in Table 4.3-11 to 4.3-12, while the original data is presented in appendix. Three groups of organisms namely, molluscs, dipteran larvae and oligochaete worms forms the bulk of the fauna community representing 67.76%, 16.82% and 14.49% respectively. The remaining 0.93% is represented by the polychaetes, decapod, and Neuroptera put together. The molluscs particularly, *Egeria paradoxa* (bivalve) and *Pachymelania aurita* (Gastropoda) occur in significantly large numbers in the stations located along Badagry creek (S2, S3, S4, S5 and S39) and Yewa River (S1) respectively, while the dipteran larvae and oligochaete worms are more in the slow running forest streams in the study area. The chironomids are particularly more abundant at stations S12, S21, S29 and S37, while *Tubifex tubifex* an oligochaete worm is in large number also at S37. Beside this *Tubifex tubifex*, another oligochaete that is in fairly large number is *Nais communis*. Sampling stations S1, S2, S3, S4, S5, S12, S29, S37, and S37 thus have the highest number of macrobenthic fauna in the area. The oligochaetes and chironomidae which are amongst the well known macrobenthic fauna that have great tolerance of organic pollution thus forms the bulk of the macrobenthic fauna in the slow running forest streams in the study area.

The range of species number is 2 to 7. Diversity is generally low, while Margalef's index of species richness (D) ranged between 0.253-2.012, Shannon-Weiner index of general diversity ranged between 0.163 and 1.633. Evenness index also ranged between 0.224 and 1.00. Station S4 generally has the lowest diversity while the station with the highest diversity is

S21. Analysis of variance (ANOVA) revealed that Stations S1, S2, S3, S4, S5, S37, and S39 has significantly ($p<0.05$) higher population than other stations.

Roots of floating weeds collected from ten (10) of the sampling stations recorded the highest number of species (46 species) and average population of 477 individuals. The class Insecta with thirty (30) species, constituted 58.07% of the entire population of the macrobenthic fauna to form the bulk of the fauna community attached to the roots of the floating weeds. The Insect recorded belongs to the Orders Diptera (35.85%), Coleoptera (12.16%), Anisoptera (6.29%), Ephemeroptera (9.22%), Hemiptera (0.84%), Zygoptera (2.94%), Plecoptera (0.63%), and Tricoptera (0.63%). Other components of the fauna community are crustaceans made up of Decapoda (3.35%), Amphipoda (7.34%) and Isopoda (0.84%). Amphibian tadpoles (7.97%), Oligochaetes worms (6.5%), Hirudinea (2.1%), gastropod molluscs (1.1%) and bivalve molluscs (0.5%) are also part of the benthic fauna. Amphipoda and Decapoda which are relatively clean water inhabitants were restricted in distribution to the large water bodies of Badagry creek (S4 and S39) and Ologe Lagoon (S8), while others particularly Insects in the Orders Anisoptera, Coleoptera and Diptera, Oligochaete worms and amphibian tadpoles occurred across the various sampling stations. Sampling stations S26, S29 and S31 have relatively higher population of fauna because of either the sole dominance of Insects in the Orders Anisoptera, Coleoptera and Diptera, Oligochaetes worms and amphibian tadpoles or a combination of two or more of these groups. The range of species number is 13 (in stations S11) to 23 (in station S31), diversity is generally high, while Margalef's index of species richness (D) ranged between 3.299–5.214, Shannon-Weiner index of general diversity ranged between 2.171and 2.771. Evenness index ranged between 0.779and 0.950. Station S26 and S31 generally had the highest diversity while the station with the lowest diversity are S11 and S37. Analysis of variance (ANOVA) revealed that stations S26, S29, and S31 are significantly ($p<0.05$) more diverse than the other station.

Table 4.3-11
Summary of Benthic Organisms Encountered in the Study Area

MAJOR GROUPS		WAGP EIA ONSHORE SAMPLING STATIONS														TOTAL	%
	S	S1	S2	S3	S4	S5	S8	S9	S11	S12	S21	S26	S29	S31	S37			
ANNELIDA																		14.72
OLIGOCHAETA	3	1					1	2	1	3	3			1	50		62	14.49
POLYCHAETA	1	1															1	
DECAPODA	1										1		2				3	0.70
DIPTERA	5									17	8	4	19	4	20		72	16.82
MOLLUSCA																		67.76
BIVALVIA	4	7	43	45	52	55			1							32	235	
GASTROPODA	1	31	5	2			1	1								15	55	
Abundance(N)		40	48	47	52	55	2	3	2	20	12	4	21	5	70	47	428	
Diversity																		
I. Taxa number(S)	15	5	3	2	2	3	2	3	2	4	6	2	4	4	7	4		
II. Species Richness(D)		1.084	0.517	0.260	0.253	0.499	1.443	1.821	1.443	1.001	2.012	0.721	0.985	1.864	1.412	0.779		
III. Shannon-Weiner index (H,)		0.759	0.433	0.176	0.163	0.246	0.693	1.099	0.693	1.238	1.633	0.562	0.996	1.332	1.256	0.815		
IV. Evenness index (E)		0.471	0.394	0.254	0.235	0.224	1.000	1.000	1.000	0.893	0.911	0.811	0.719	0.961	0.645	0.588		

Table 4.3-12
Summary of Major Groups Benthic Organisms Encountered in the Study Area

MAJOR GROUPS	S	WAGP EIA ONSHORE SAMPLING STATIONS										TOTAL	%	% total
		S4	S8	S11	S12	S21	S26	S29	S31	S37	S39			
Amphibia	1				3	1	6		25	3		38	7.97	7.97
Annelida														8.6
Oligochaeta	4			2	1	1	14	7	4	2		31	6.5	
Hirudinea	3	2		3	3				2			10	2.1	
Crustacea														11.53
Amphipoda	1	12	14								9	35	7.3	
Decapoda	1	8	6								2	16	3.4	
Isopoda	1	1	2								1	4	0.8	
Insecta														58.07
Coleoptera	5			7	9	3	5	3	9	22		58	12.2	
Diptera	10	9	4	8	11	6	46	67	5	7	8	171	35.9	
Ephemeroptera	5	8	9	1	5		2	2	7	3	7	44	9.2	
Hemiptera	1				1	2			1			4	0.8	
Odonata														10.48
Anisoptera	5	3	1	2	5	1	1	1	10	1	5	30	6.3	
Zygoptera	2	6	2	1					1		4	14	2.9	
Plecoptera	1					2			1			3	0.6	
Tricoptera	1				1		2					3	0.6	
Mollusca														3.35
Bivalvia	1		1			1			2			4	0.8	
Gastropoda	4		1	2	2	2		2	1		2	12	2.5	
Abundance(N)		49	40	26	41	19	76	82	68	38	38	477		
Diversity														
I. Taxa number(S)	46	15	14	13	17	12	21	17	23	13	15			
II. Species Richness(D)		3.597	3.524	3.683	4.309	3.736	4.618	3.631	5.214	3.299	3.849			
III. Shannon-Weiner index (H,)		2.368	2.171	2.378	2.585	2.361	2.771	2.415	2.441	2.264	2.463			
IV. Evenness index (E)		0.874	0.823	0.927	0.913	0.950	0.910	0.852	0.779	0.883	0.909			

4.3.2.2 Sediment Microbiology

Sediment samples from this location were observed to be rich in different microbial communities as shown in Table 4.3-13. An overview of the microbial densities of the sediment samples indicate that average total heterotrophic bacterial count ranged between 2.7

$\times 10^5$ and 2.8×10^6 cfu/g. Average total fungal densities varied from 3.0×10^2 to 3.6×10^3 cfu/g. Hydrocarbon degrading bacterial population ranged between 1.1×10^4 and 1.2×10^6 cfu/g, while their fungal counterpart range from 0 to 3.1×10^3 cfu/g. Sulphate reducing bacteria population varied between 0 and 10^3 cfu/g. The bacteria species isolated from the sediment include *Proteus vulgaris, Desulfuvibrio spp., Pseudomonas pseudomallei, Sarcinia spp., Corynebacterium spp., Pseudomonas aeruginosa, Arthrobacter spp., Klebsiella pneumoniae, Micrococcus luteum, Streptomyces spp., Staphylococcus aureus, Aeromonas spp., Bacillus cereus, Bacillus subtilis, Pseudomonas fluorescence, Proteus mirabilis, Bacillus polymyxa* and *Flavobacterium spp*. The isolated fungal species include *Daldenia spp., Aspergillus niger, Cladosporium spp., Trichoderma spp., Rhodotorula spp., Aspergillus flavus, Botrytis spp., Scopulariospsis brevicaulis, Pullularia spp, Microsporium gypseum, Cunninghamella spp., Penicillium notatum, Rhodotorula spp., Neurospora spp.,* and *Microsporium audovinii.*

Table 4.3-13
Average Microbial Densities Of Sediment Samples From WAGP EIA Project (Dry Season)

S/N	Sample code	THB (cfu/g)	HDB (cfu/g)	SRB (cells/g)	THF (cfu/g)	HDF (cfu/g)
1	SE1	1.8×10^6	1.5×10^5	10^3	2.0×10^3	1.2×10^2
2	SE2-TO	1.1×10^6	1.1×10^4	10^3	1.7×10^3	41
3	SE3-ROW	2.1×10^6	1.2×10^6	10^1	8.0×10^2	32
4	SE4	8.8×10^5	6.5×10^5	Nil	1.1×10^3	1.4×10^2
5	SE5	1.1×10^6	6.3×10^4	Nil	1.3×10^3	50
6	SE6	2.8×10^6	4.4×10^4	Nil	1.4×10^3	33
7	SE8	1.1×10^6	5.3×10^5	10^3	3.0×10^2	12
8	SE9	1.5×10^6	7.9×10^3	10^2	6.0×10^2	35
9	SE10	6.9×10^5	1.5×10^5	10^1	3.0×10^2	21
10	SE11	1.3×10^6	7.7×10^3	10^3	1.9×10^3	2.1×10^2
11	SE16	1.2×10^6	2.3×10^4	10^2	9.0×10^2	52
12	SE21	4.9×10^5	1.1×10^5	10^2	1.8×10^2	23
13	SE23	1.6×10^6	4.8×10^4	Nil	5.0×10^2	15
14	SE24	3.5×10^5	3.5×10^4	Nil	3.6×10^3	3.1×10^2
15	SE31	2.8×10^5	7.9×10^3	Nil	1.0×10^3	47
16	SE33	6.5×10^5	1.3×10^5	10^2	4.0×10^2	24
17	SE34	5.3×10^5	4.7×10^4	10^2	4.0×10^2	Nil
18	SE36	2.7×10^5	6.5×10^4	10^3	6.0×10^2	15
19	SE37	6.2×10^5	3.6×10^4	Nil	1.1×10^3	1.7×10^2

Keys:
THB - Total heterotrophic bacteria; HDB - Hydrocarbon degrading bacteria; SRB – Sulphate reducing bacteria; THF – Total heterotrophic fungi; HDF – Hydrocarbon degrading fungi

4.4 SHALLOW GROUNDWATER RESOURCES

4.4.1 Introduction

The proposed West African Gas Pipeline Project traverses along a northeast-southwest direction from Alagbado in Ogun State to Ajido in Lagos State. The terrain drops from a high elevation of about 79m above sea level in the northern extremity around Alagbado to low-lying topography, just about 20m above sea level, where it is prone to periodic flooding during the rainy season that is characterised by a bimodal trend. There is a marked dry season from about November to end of March, during which less than 10% of the average annual precipitation of about 1800mm occurs. The Ota and Agbara Industrial Complex is a major user of water in this area.

Major hydrological features include the R. Owo, R. Abesan, R. Illo, the Ologe Lagoon and the network of creeks, all of which empty into the Atlantic ocean. Freshwater swamps are found at the margins of the lagoons and along the valleys of the influent rivers. Mangroves and brackish water vegetation found along these waterways play a significant role in the migration of pollutants from the hinterland to the sea.

4.4.2 River Flow

In Table 4.4-1 below are the average monthly values of river flow in m^3/s in the area.

Table 4.4-1
Average Monthly Flow Values of Some Rivers in the Area

Station	Depth (m)	J	F	M	A	M	J	J	A	S	O	N	D
R. Owo at Agbara	1-7	4.9	3.7	5.0	6.1	12.3	17.8	2.3	16.2	20.0	19.4	18.4	6.1
R. Owo at Isasi	2-5	3.1	2.3	3.3	3.8	7.7	11.2	12.8	10.2	12.6	12.2	11.6	3.8
R. Owo at Camp Davies	2-4	2.4	1.8	2.6	3.0	6.0	8.7	9.9	7.9	9.8	9.5	9.0	3.0
R. Illo at Ayobo	1-3	0.9	0.7	1.1	1.1	2.3	3.2	3.7	29	3.6	3.5	3.3	1.1
R. Abesan	0.2 – 2	0.5	0.4	0.6	0.8	1.2	1.8	2.0	1.6	2.0	1.9	1.8	0.6

(modified after T&T Associates, 1992)

There is a general strong correlation between river flow and rainfall pattern over the area. It is important to note that the depth variation of the various streams is indicative of the fact also that these streams are in hydraulic contact with shallow groundwater of the Coastal Plain Sands Formation through which the streams traverse, and depending on seasonal water fluctuations, may either receive flow from groundwater or contribute to groundwater flow.

4.4.3 Groundwater Flow and Aquifer Hydraulics

In order to have an understanding of the groundwater flow situation in the area, water levels in dug wells found in the area were measured and also depth to water in auger drill holes were taken. The values obtained are presented in Tables 4.4-2 and 4.4-3. Soil samples taken from auger holes were also examined for soil mechanical properties such as: moisture content, grain size distribution, consistency limits and specific gravity.

Table 4.4-2
Water Levels Measured in Dug Wells

Location	Well No.	GPS Position		Top of well (m)	Depth to water (m)	Surface Elevation	Remarks
		Northing	Easting	Above ground	From top of well	(m asl)	
Ajido	1	06º 24.908'	002º 59.808'	1.05	4.15	22.55	Pa Olatunji Center
Ajido	2	06º 24.894'	003º 00.180'	0.86	3.56	22.55	Opp. PDP Center
Ajido	3	06º 24.915'	003º 00.349'	0.95	3.60	21.94	Zangbeto Shrine
Ajido	4	06º 24.915'	003º 00.349'	0.50	3.20	21.94	-ditto- Hand pump
Ajido	5	06º 24.924'	003º 00.484'	0.75	3.40	22.25	NEPA TRAFO
Imeko	6	06º 26.155'	002º 59.551'	0.07	3.62	24.69	Opp. Anglican ch.
Imeko	7	06º 26.132'	002º 59.574'	0.65	3.85	24.38	Opp. Well 6
Imeko	8	06º 26.135'	002º 59.534'	0.79	3.89	24.38	DFRRI Well 2
Imeko	9	06º 26.187'	002º 58.846'	1.10	3.38	21.33	Ascension College
Imeko	10	06º 26.220'	002º 58.631'	0.40	3.45	21.94	DFFRI Well Magbon
Araromi	11	06º 28.236'	003º 00.311'	0.85	3.35	21.94	Cele Church KM42 Badagry Exp

Table 4.4-3
Water Levels Encountered in Auger Drill Holes

Drill hole Location	Code	Depth drilled (m)	Depth to water (m)	Remarks
Itoki Gas Station	AH1	2	Not met	Inorganic clays
Abudu	AH2	1.8	0.3	Organic, silty sands
Igboloye	AH3	2	Not met	Organic silty sands
Ikomi	AH4	1.4	Not met	Inorganic clays
River Ore	AH5	2	1.3	Organic silty sands
R. Ogbe	AH6	1.8	0.6	Organic silty sands
Ilogbo	AH7	1.6	0.6	Organic silty sands
Asepe Mushin	AH8	1.7	0.8	Organic silty sands
Ajudo	AH9	1.9	0.7	Organic silty sands
Ajudo	AH10	1.8	0.8	Organic silty sands

Though aquifers are known to exist in all the sedimentary formations represented in the area (Jones & Hockey, 1964)(Table 4.4-4), this study is concerned with the aquifers in the Coastal Plain Sands Formation of Late Tertiary. The coastal Plain Sands Fm is made up of loose red earth overlying unconsolidated, very poorly sorted clayey sands, gravelly sands and sandy clays that are intercalated with grey clays and peat. The sands are generally friable, but become increasingly compacted with depth.

Evidence from borehole lithologic logs shows the presence of a multi-layer aquifer system which may be simplified into 3 major aquiferous zones, separated by thick layers of clay aquiclude.

- A shallow water table aquifer that is mostly tapped for domestic supplies via dug wells or boreholes. The water table varies seasonally.
- A middle aquiferous zone consisting of two water-bearing horizons separated by a layer of clay.
- A lower aquiferous zone with many water-bearing levels.

Table 4.4-4
Aquifer Hydraulic Features in the Coastal Plain Sands Formation around Lagos

Investigator	Location	Effective grain size (d_{10}) (mm)	Aquifer Thickness (m)	K_{Hazen} (m/s) $=0.0116(d_{10})^2$	T_{Hazen}(m^2/s) = Kb	T_{Jacob}(m^2/s)
Longe et. al.(1987)	Middle Aquifer					3.53×10^{-3}
	Lower Aquifer					17.4×10^{-3}
Vaughan (1998)	Bh 2	0.32	30	1.2×10^{-3}	3.6×10^{-2}	2.1×10^{-3}
	Bh 3	0.26	30	2.4×10^{-4}	2.8×10^{-2}	1.2×10^{-3}
	Bh 4	0.26	45	8.0×10^{-4}	3.6×10^{-2}	1.7×10^{-3}
	Bh 6	0.22	36	5.6×10^{-4}	2.0×10^{-2}	1.7×10^{-3}
	Bh 9	0.28	42	9.0×10^{-4}	3.8×10^{-2}	1.4×10^{-3}
Present Study	AH10	0.15	2	2.61×10^{-4}	5.22×10^{-4}	
	AH9	0.10	2	1.16×10^{-4}	2.32×10^{-4}	
	AH8	0.18	2	3.76×10^{-4}	7.52×10^{-4}	
	AH7	0.08	2	7.42×10^{-4}	1.48×10^{-4}	

The generally lower transmissivity values obtained from the pumping test reflect the irregular facies distribution within the aquifer system. However it is obvious that the values are very similar to those obtained from the empirical calculations. From the above it is evident that the aquifers are of good permeability and transmissivity.

4.4.4 Water Level Changes and Water Level Predictions

In the project area water level changes are primarily due to seasonal fluctuations of the shallow water table aquifer. There are no great abstractions from this shallow aquifer, which is mainly tapped by dug wells serving domestic uses in small villages and towns located in the area. Such seasonal fluctuations are however usually less than 1m, depending on the amount of rainfall in any particularly season.

Coode Blizzard (1997) carried out a steady state simulation of the Lower coastal Plain Sands and the result is reproduced and presented in Fig.4. Based on this model it is observed that groundwater will flow from the northern extremity around Ota towards the coast. Although the model was handicapped by lack of sufficient input data, the result may be accepted as field checks confirm these water levels to an appreciable degree.

Similarly transient state simulations were run for the same aquifer to predict future water levels in the aquifer. It may be observed from the figures that the project area is not likely to experience any great drawdown given the present conditions of abstraction in the area. The emerging cone of depression to the north represents the Ota industrial complex, while the well-developed cone of depression to the southeast is the major abstraction zone in central Lagos.

Except at Alagbado and Ikomi, soils found in these areas are basically non-plastic and they have moisture content varying from about 7% to about 35%. The laying of pipeline may lead to an increase in moisture content and may also cause a rise in ground water level on either side of the pipeline, as this constitutes a barrier to flow. The extent of such impact however must be investigated using appropriate models.

4.4.4.1 Seasonal Variations

Seasonal variations were recorded in some of the environmental indicators measured in the study area. For ease of comprehension, these issues are discussed under two broad headers:

a. Variations in biological components of the environment;
b. Variations in physico-chemical indicators of the environment

4.4.4.2 Biological components

Wildlife and Endangered Species

A total of 53 species belonging to 31 families were seen or heard in the study area. Twenty-eight of these species (52.8%) were recorded in both seasons, which indicate that they are resident.

Eight species (the Shikra, Black Kite, Lizard Buzzard, Water Thick-knee, African Green Pigeon, Grey-headed Kingfisher, White-throated Bee-eater and the Little Bee-eater), which had been seen during the dry season, were not recorded during the second visit; while twenty-five new species were added to the list. This may either indicate local seasonal movement as in the case of the Black Kite, Grey-headed Kingfisher and the White-throated Bee-eater (Elgood, et al., 1994), or perhaps a reflection of the patchy occurrence of the species.

Fisheries

No notable variations occurred in the fishery species composition and/or abundance. However, fishing activities appear to be more pronounced in the dry season, in the seas and major rivers, probably because they are less turbulent and therefore more receptive to fishing activities than in the rainy season. For this reason, there may be a drop in catch quantities and/or frequencies, but certainly no observable changes in fish species composition.

Benthic Fauna

In the rainy season study, 15 species of macrobenthic fauna are encountered in the sediment as against the 20 species encountered during the dry season, while 46 species species of macrobenthic invertebrates were collected from the roots of the aquatic macrophytes particularly, water hyacinth (Eichhornia crassipes), as against the 49 species collected earlier in the dry season. In both instances the numbers are high and confirms previous work in similar habitat (Egborge, (1988). The benthic communities in the sediment and those associated with the waterweeds in the aquatic system in the study area are admixtures of fresh and brackish water species.

In the sediment, fauna was on the average low in abundance, however, in the roots of aquatic weeds there is a large variety and abundance of different stages of insects, leeches and other invertebrates, thus providing a very conducive habitat for detritophagous and omnivorous fish to strive if other environmental conditions are right. The whole array of common and rare benthic fauna on the roots of the aquatic weeds and the sediment therefore provides an economic and practical utility in fish culture practices.

Finally, it is obvious that a natural variation in faunal composition and diversity occurs within the sediment, a situation that can be explained by the differences in the sediment texture, for according to Daan *et al* (1996) in a natural situation, a shift in sediment composition will involve a differentiation in habitats and therefore a shift in species composition.

Comparatively, the dry and rainy season samples do not show much variation in both species composition and abundance. There was however, a slight reduction in the species number and population during the rainy season.

Soil Fauna

Unlike in the dry season when 15 taxonomic groups of Acarina were identified, 21 groups were recorded in the wet season. The new groups, which were recorded only in the wet season, are: Araneida, Schizopeltida, Isopoda, Diplura, Psocoptera, Hemiptera and Coleoptera larva.

Vegetation

No significant change was observed in the vegetation pattern of the area, except perhaps that vegetation appeared to be thriving better in the rainy season, probably due to improved edaphic conditions. For instance, sites, which had been burnt out in the dry season, had sprouted and so biomass productivity of the herbaceous layers was higher. Similarly, plants, which had dried up in the dry season, were quite luxuriant in the rainy season.

Air Quality

TSP was the main air quality parameter that indicated major seasonal response. It was much lower in the rainy season than in the dry and this is hardly unexpected given that rainfall has some "scavenging" effects. Typically, the air is scrubbed by rainfall thereby giving low TSP concentrations. All other parameters are fairly even across the season.

4.5 WILDLIFE, ANIMAL RESOURCES AND MARINE TURTLES

4.5.1 Wildlife

Four major groups of wildlife species occur in the project area. These are mammals, birds, reptiles and amphibians.

4.5.1.1 Mammals

The mammals, which occur in the vicinity of the pipeline ROW, based on information obtained from respondents are shown in Appendix Table A-1. As expected, the fauna included forest and savanna species and consisted largely of small game.

There were very few experienced hunters in the locality and hunting was mainly for the pot, which would suggest that hunting pressure is relatively low, especially as the inhabitants depended mainly on fishing for their livelihood. Nevertheless, it is believed that species like the Sitatunga (*Tragelaphus spekei*), Maxwell's Duiker (*Cephalophus maxwelli*), Red-flanked Duiker (*Cephalophus rufilatus*), the Grasscutter (*Thryonomys swinderianus*) and the Brush-tailed Porcupine (*Atherurus africanus*), which are much sought after as bushmeat, are under intense hunting pressure. They may have continued to thrive only because of their resilience and secretive habits, as well as relatively high fecundity. It is also suspected that as a result of hunting pressure and habitat destruction, certain large mammals (e.g. elephants, White-collared Mangabey, chimpanzees and the Bushpig) have become extinct in this area. Thus hunters confirmed that the Bushpig (*Potamochoerus porcus*) had not been seen in the area for a long time. On the other hand, the Manatee (*Trichechus senegalensis*) has been sighted frequently in the Badagry Creek and its tributaries.

4.5.1.2 Birds

A total of 53 species belonging to 31 families were seen or heard in the study area (Appendix Table A-2). Twenty-eight of these species (52.8%) were recorded in both seasons, which indicates that they are resident.

The list, it must be pointed out, is not exhaustive, because some birds that are notoriously difficult to identify in the field without mist-netting may have been overlooked, especially the small-sized species that forage in thick foliage or tree canopy.

4.5.1.3 Reptiles

Based on reports by the indigenes, the reptilian fauna of the area consists of crocodiles, turtles, land tortoises, snakes and lizards (Appendix Table A-3). Several species of snakes were reported in the area. These include the Black Cobra (*Naja melaneuca*), Spitting Cobra (*Naja nigricollis*), Night Adder (*Causus maculatus*), Gabon Viper (*Bitis gabonica*) and the African Python (*Python sebae*). The Monitor Lizard (*Varanus niloticus*), the Nile Crocodile (*Crocodylus niloticus*) and the Dwarf (or Short-snouted) Crocodile (*Osteolaemus tetraspis*) are hunted for meat (it was noted however that some people consider the Monitor Lizard a taboo). Marine turtles are well known to the populace, who admitted hunting them for food and collecting their eggs when they come ashore to breed between August and December.

4.5.1.4 Amphibians

Amphibians found in the area include the African Clawed Toad (*Xenopus tropicalis*), Common Toad (*Bufo regularis*), Bush Toad (*Bufo maculatus*), Bullfrog (*Dicroglossus occipitalis*), a few species of treefrogs and ranid frogs (Appendix Table A-4).

4.5.1.5 Economic and Cultural Significance of Wildlife

Apart from consumption as food, parts of wild animals are also used in folk medicine (e.g. the head of the Monitor Lizard, Spitting Cobra and Egyptian Mongoose). The skins of large reptiles, e.g. snakes, crocodiles and monitor lizards, are reportedly sold to itinerant traders. Thus the local populace do not only supplement their protein intake from these animals but also their meagre income from other sources. Unfortunately, although these animals represent a vital resource in the local economy, exploitation is neither regulated nor indeed was there any awareness that both Federal and international laws protect some of these animals.

Thus the survival of these animals is threatened not only by hunting but also land clearance for farming, road construction and expansion of human settlements.

4.5.1.6 Species of Conservation Concern

Several species considered to be sensitive either because they face threat of imminent extinction or are vulnerable (i.e. could become endangered in the near future if nothing was done to remove the threat) according to the IUCN Red List (1994, 2002) and the Federal Government's Endangered Species Act (1985), are found in the area. These include Bosman's Potto, Demidov's Galago, Western Black-and-White Colobus, Mona Monkey, Brush-tailed Porcupine, Tree Pangolin, Cape Clawless Otter, the Serval, Manatee, Sitatunga, Buffon's Kob, genets, mongooses, all herons, egrets, pelicans, hawks, eagles, falcons, all three species of crocodile, all marine turtles and the African Python.

4.5.2 Marine Turtles

The gravid female turtles lay their eggs in burrow-nests along the sandy beaches during a particular period of the year, usually from the month of August. The search on the Ajido beach, around the WAGP ROW confirmed the fact that turtles actually do visit the Ajido beach and nest there. Two empty shells of the Pacific Riddley – *Lepidochelys olivacea* were seen. Oral interviews conducted indicated that four to five species of sea turtles nest at the beach at different times of the year. The species were identified by pictures shown to the villagers. The species are; *Lepidochelys olivacea* (Pacific riddley turtle) *Dermochelys* *coriacea* (Leatherback), *Carreta carretta carretta* (Loggerhead) and *Eretmochelys imbricata* (Hawksbill). The first two species are very common during their season. The occurrence of a fifth species, *Chelonia mydas,* at the beach is doubtful.

Brief information on the biology of each of the four species is presented below.

4.5.2.1 Pacific Riddley turtle (*Lepidochelys olivacea*)

They are found in shallow coastal waters and the open sea forming "flotillas". The most important nesting areas are in West Africa. The adult female starts nesting between August and December and incubation period is between 45 and 65 days. Their carapace is semicircular in outline, depressed, small head with two pairs of prefrontal scutes and horny beak, which may be finely serrated. There are usually more than five pairs of lateral scutes on the carapace, the anterior pair touching the pre-central scutes. There are four pairs of infra-marginal scutes, each perforated by a pore towards its hind margin. They adults have only one claw on each flipper. The colour is olive brown on the upper side and yellowish white on the under side.

They are found in shallow coastal waters and the open sea forming "flotillas". The most important nesting areas are in West Africa. The adult female starts nesting between August and December and incubation period is between 45 and 65 days. Their carapace is semicircular in outline, depressed, small head with two pairs of prefrontal scutes and horny beak, which may be finely serrated. There are usually more than five pairs of lateral scutes on the carapace, the anterior pair touching the pre-central scutes. There are four pairs of infra-marginal scutes, each perforated by a pore towards its hind margin. They adults have only one claw on each flipper. The colour is olive brown on the upper side and yellowish white on the under side.

4.5.2.2 Atlantic Loggerhead turtle (*Carreta carretta carretta*)

They are found entering streams and brackish water but are also encountered in open seas and around islands. They are known to be highly migratory and nesting sites are found along many West African countries, including Nigeria. They occur in West African coast between July to December and their incubation period is between 45 to 65 days.

The carapace is heart-shaped, depressed and is very broad, with two pairs of prefrontal scutes and strong horny beak. They possess five pairs of lateral scutes, the anterior pair touching the pre-central scutes; there are three pairs of enlarged infra-marginal scutes on plastron. There are two claws on each flipper. The colour of the loggerhead is usually brownish red with light spots on the upper side and pale yellow with diffuse orange spots on the underside. Their eggs are white and spherical.

4.5.2.3 Atlantic Hawksbill turtle (*Eretmochelys imbricata*)

They inhabit coastal waters including shallow vegetated bottoms, bays and lagoons with muddy and coralline bottoms lacking extensive bed of sub-marine vegetation. Nesting period in west Africa is between September and February and the incubation period between 45 to 60 days. The carapace is oval in shape and depressed. There are two pairs of prefrontal scutes and a strong horny beak. Scutes on the shells are imbricated (overlapping) or juxtaposed. Four pairs of lateral scutes are present on the carapace and the anterior pair not touching the pre-central scutes. There are four pairs of infra-marginal scutes on plastron. There are two claws on each flipper. The colour is dark brown with yellow and reddish streaks on the scutes and pale yellow on the underside.

4.5.2.4 Leatherback (*Dermochelys coriacea coriacea*)

They have horny skin, smooth and scuteless. The carapace is black with seven narrow longitudinal ridges, the plastron with five longitudinal ridges also. The upper jaw of the leatherback has well-defined cusp on each side, giving the horny beak a V-shaped appearance. The flippers are without claws, the anterior pair are much larger and the posterior broadly connected with the tail by a web in adults.

The fecundity of turtles varies from species to species, but they are reputed to lay between 40 and 500 eggs. *Dermochelys coriacea* (Leatherbacks) lay about 400 to 500 eggs.

The nesting period is determined by season, rather than time, current and moon phase. Some sea turtles come in to lay their eggs during the low tides while others do not follow the tides to come to the beach and depart at low tide. Sea turtles come out at all times of the day to nest in less habited areas of the beach.

The catch rate is very high at Ajido and an individual fisherman can catch between 5 to 10 sea turtles per night while the least number is between 1 to 2 turtles per night. Often times the turtles are followed to their nesting sites and after laying the eggs, they are caught and the eggs also exhumed and either sold or consumed.

The young hatchlings are usually seen emerging from nests in various locations along the beach on their way to the sea. Many a times, nests are located within the compound of fishermen. The fishermen usually assist the young ones back to sea.

In view of the facts given above, it can be said that this survey is inconclusive and has only been able to establish that turtles nest in the WAGP ROW area and that they are heavily predated upon by locals. In order to be able to establish the species that nest here, their nesting periods and hatching periods, their relative abundance and other pertinent issues, it will be necessary to conduct a longer survey, spanning at least 6months, during which nesting and hatching can be effectively monitored.

4.6 FISH AND FISHERY RESOURCES

4.6.1 The Status of Fish Exploitation and Methods Used

On the whole, fishing is a major occupation of the local people in the project area. It is also an attraction for a number of non-indigenes that have migrated to the area both from within and outside Nigeria. There is evidence that some of the existing communities in the area originally started off as fishing settlements later attracting migrants from near and far. Most of the fishing settlements by the sea e.g Jegeme near Ijede (06^{o}23.31N, 003^{o} 00.1^{1}E). comprise of fisherfolks from Ghana, Benin Republic and parts of Nigeria. This pattern of mixed ethnicity and nationality is essentially the same for all the fishing settlements directly along the seacoast in the area. In these communities, fishing is the sole or principal occupation of the settlers. In most cases, the fisherfolks (especially the non-Nigerians) have organized themselves into fishing co-operative groups and fish exploitation is at the artisanal level. The craft used here are commonly motorized planked wooden canoes or half dugout wooden canoes completely with plank (usually in the range of 10-16m total length). The latter is used mainly by the Ghanaian co-operative fisherfolks. Their main gear include gillnets and purse seine nets of various types.

Along the Badagry Creek and associated network of inland waterbodies, fish exploitation is mostly at subsistence level. The most common craft are half dug-out and dug-out wooden canoes. Only a small proportion of the fisherfolks uses planked wooden canoes with motorized engines. A wide variety of gear are used but gill-netting is by far the most common method of fishing (Appendix Plate A-5). Others are cast-netting (Appendix Plate A-6) and beach seining with and without bags (Appendix Plate A-7). A wide variety of traps, including fence traps, pot traps and basket traps which are the commonest are also used. Pole and line is commonly used along the River Owo and its tributaries while hooks and line is a common pastime among young fisherfolks. Aquaculture practice is limited. An example of this is the Pilot Community Fish Pond Programme at Dale near Topo ($06^{0}24.4^{1}$ N, 002^{0} 55.6^{1}E) established February 2001. At the upper reach of the project area drained by River Owo and its tributaries only a small proportion of the population take to fishing. It is a secondary occupation for the few people involved.

4.6.2 Fish Faunal Composition

Although finfish is the main target of exploitation in the study area, a wide range of fish resources abound. They include a wide range of shellfishes (Molluscs, crustaceans, turtles etc) and miscellaneous invertebrate and vertebrate animals.

Table 4.6-1 is an inventory of the finfish reported and/or actually observed during the dry and rainy seasons. On the whole, the fauna comprise over 50 species belonging to over 40 genera in about 30 families. This record is higher than what is known for any single habitat previously covered in the entire coastal area. For instance, Ikusemiju (1981) recorded a total of 28 species belonging to 15 families at Lekki Lagoon while Arawomo (1995) recorded a total of 18 species belonging to 12 families in the Abesan/Illoh rivers system. With the exception of a few species, most of the species recorded at Lekki Lagoon and Abesan/Illoh area were also reported for the present work. There is evidence that the fauna is qualitatively rich and this is most probably due to the wide variety of habitats involved (coastal marine, brackish, tidal fresh and freshwater bodies).

About 17 genera were recorded for the coastal marine while 40 were recorded for the brackish water and 15 genera for the freshwater bodies (Table 4.6-1). The most widely occurring genera were *Chrysichthys* and *Tilapia*. A number of taxa appear to be restricted to the coastal marine environment of the sea. They include *Albula* sp, *Scyris* sp, *Trachinotugoreensis, Cynoponticus, Raja* and *Trichuru*s species. On the other hand, members of the following genera *Ctenopoma, Paraauchinoglan*is *Hemichromis, Barbus, Epiplatys, Melapterus, Chana, Calamichthys* and *Polypterus* seem to be restricted to the freshwater bodies. The number of t*axa* recorded to be present per site ranged from 3 to 18 genera. Qualitatively the most important groups were the bagrid catfish, the cichlids and the clupeids. This is probably due to the ability of their members to adapt to the different available habitats. Whereas some species were common throughout the year, some others showed seasonal occurrence.

Table 4.6-1
Faunal Composition and Occurrence record of finfish in the WAGP Project Area (2002/2003)

Scientific Name	Common Name	Yoruba Name	Family	Fishing Settlements * 1	2	3	4	5	6	7	8	9	10	11	12
Albula sp	Ladyfish	Okadokun	Albulidae	x											
Ctenopoma sp	Climbing perch	Anabantidae				x			x	x					
Chrysichthys spp	Catfish	Obokun	Bagridae		x	x		x			x				
Paraauchenoglanis sp	Catfish	Obokun	Bagridae												x
Scyris sp	Pompano	Akaraba	Carangidae	x											
Trachinotus goreensis	Pompano	Owere	Carangidae	x											
Hemichromis spp	Jewel/fish	Epiya	Cichlidae										x	x	x
Oreochromis niloticus	Bream	Epiya	Cichlidae							x		x	x		x
Tilapia spp	Bream	Epiya	Cichlidae		x	x	x	x		x		x		x	x
Claria garipenus	Mudfish	Aro/Aso	Claridae						x			x	x	x	x
Clarias lazera	Mudfish	Aro/Aso	Claridae												
Ethmalosa fimbriata	Bonga	Agbodo	Clupeidae	x	x	x		x							

Ilisha africana	Ilisha	Opalamu	Clupeidae	x	x		x						
Pellonula vorax	Clupeid	Salope	Clupeidae				x	x					
Sardinella sp	Sardine	Sawa	Clupeidae	x	x			x					
Sterrathrisa leonensis	Clupeid	Sawa	Clupeidae					x	x				
Barbus spp	Barbels		Cyprinidae									x	x
Epiplatys spp	Panchax		Cyprinidae							x	x		x
Cynoglossus niloticus	Tongue fish	Abo/Oteke	Cynoglossidae	x	x		x		x				
Chaetodipterus goreensis	Spadefish	Akaraba	Ephippidae	x		x	x						
Drepam africana	Spadefish	Akaraba	Epippidae	x		x							
Gobioides africanus	Gobies		Gobiidae	x	x								
Hepsetus odoe	Pike	Okodo	Hepsetidae										
Lutjanus goreensis	Snapper	Igbakere/koro	Lutjanidae	x	x	x	x						
Malapterurus electricus	Electric/fish	Ojiji	Malapteriidae								x	x	x
Synodontis spp	catfish	Akokonibo	Mochochidae										
Mugil sp	Mullet	Atoko	Mugilidae			x	x	x	x				
Cynoponticus sp	Snake/head		Muraenesocidae	x									

Polycentropsis sp			Nandidae						x	x	x
Chana obscura	Snake/head	Agbetoro	Ophiocephalidae						x	x	x
Heterotis niloticus	Bonytongue	Ofo(Aika)	Osteoglossidae				x	x			x
Periophthalmus papilio	Mudskipper		Periophthalmidae		x	x					
Polynemus quadrifiles	Threadfin		Polynemidae	x	x	x					
Calamichthys sp	Sailfin		Polypteridae								x
*Polypterus senegalensis*s	ailfin		Polypteridae								x
Brachydeuterus auritus	Bigeye/grunt	Ikekere	Pomadasyidae	x	x	x					
Pseudotoliltus spp	Croaker	Apo	Sciaenidae	x	x						
Sphyraena spp	Barracuda	Kuta	Sphyraenidae	x	x						
Raja miraletus	Ray		Rajida	x							
Trichiurus lepturus	Silverfish	Oje	Trichiuridae	x							

In general, the numerically important species occurred mostly in the rainy season. Ikusemiju (1981), made a similar observation for fishes of Lekki Lagoon.

The shellfish resources include shrimps, crabs, lobsters, and molluscs (*gastrops, bivalves*, and *cephalopods*). The most common shrimps were the *Panaeid shrimp*, *Parapenaeus longirostris*, *Nematopalaemon hastatus* and *Penaeus notialis*. The most important crab being the bigfisted swimcrab C*allinetes palliolus (Portunidae).*

As indicated in Table 4.6-1, the local fisherfolks has a sound system of folk taxonomy for the fish fauna. Virtually all the recorded species have corresponding local names of specific status especially in Yoruba.

4.6.3 Economic Importance of Fisheries Resources

Table 4.6-2 provides information on the size composition of some of the recorded finfish specimens during the fieldwork. This information reveals that a number of fish species in the area grow to commercial sizes. The economic fish species in terms of size include members of the *bagridae*, catfishes, snappers, croakers, mudfish, Barracuda and Pike. The clupeids *(Clupeids, Ilisha*, *Sardine*, and *Bonga*), and mullets are also important commercially inspite of their small sizes. Apart from fishes, which can grow to commercial sizes, there are others, which are good specimens for aquaria. Such possible aquarium species include *Polycentropsis, Abbreviate, Barbus ablabes, Barbus callipterus, Malapterurus electricus, Epiplatys* spp, *Hemichromis, Drepam* and *Ctenopoma* species. Some other specimens are used as baits in hooks and line fishing.

Table 4.6-2
Size Composition of Some Recorded Finfish in WAGP Project Area

Family	Scientific Name	n	Total length (cm)	Std. Length(cm)	Weight
Anabantidae	*Ctenopoma kingslayea*	1	6.5	5.2	6.0
Bagridae	*Chrysichchys nigrodigitatus*	9	16.0-29.0	11.8-21.5	4.0-190.0
	Chrysichchys furcatus	5	22.0-32.0	15.5-27.0	120.-260.
	Parauchinoglanis sp	4	2.8-5.3	2.1-5.0	0.5-26.0
Carangidae	*Trachinotus goreensis*	1	10.0	7.8	20.0
Cichlidae	*Hemichromis bimaculatus*	12	9.3-12.8	7.0-9.6	40.6-41.5
	Hemichromis fasciatus	1	11.4	9.3	25.5
	Tilapia guiniensis	1	12.5	9.0	27.5
	Tilapia mariae	6	10.2-10.6	7.8-12.6	25.1-120.2
	Tilapia zilli	4	17.2-19.2	13.0-14.9	107.-138
Claridae	*Clarias gariepinus*	28	4.0-26.1	3.8-22.1	1.5-140.2
Clupeidae	*Pellonula vorax*	7	5.5-15.0	4.5-12.5	4.9-25.0
	Sierrathrissa leonensis	2	20.0-23.0	16.0-18.0	60.0-75.0

Cyprinodontidae	*Epiplatys bifasciatus*	1	10.8	8.6	10.0
	Barbus ablabes	10	2.2-6.8	1.6-6.4	0.1-5.6
	Barbus callipterus	6	3.2-6.7	2.7-6.1	0.6-6.4
Dencitipidae	*Denticeps clupeoides*	9	11.2-14.2	9.0-11.3	28.0-40.0
Gobiidae	*Gobioides africanus*	1	45.8	37.5	215.0
Haemulidae	*Pristipoma jubeleni*	1	10.5	9.5	25.0
Hepsetidae	*Hepsetus odoe*	1	38.6	32.1	750.0
Mugilidae	*Mugil cephalus*	13	13.0-19.5	10.2-16.0	25.0-70.5
Polynemidae	*Polynemus quadrofilis*	1	19.0	14.5	50.0
Polypteridae	*Calamichthys calabricus*	1	28.5	27.2	25.5

From visual observations as well as information obtained from the fisherfolks, fish in the area are generally of good condition. For species for which adequate specimens were available, their calculated condition factors (a relationship between body weight to body length of fish) were generally above 1.0. The range of values obtained for most of the species is indicative of good conditions of wellbeing. Investigation on the incidence of parasitic infection of some pond raised fish species from Badagry Creek also showed generally low levels of infection (Awa et al.,1988). None of 60 specimens of *Sarotherodon galilaeus* examined (TL=10.3–16.4cm) had any parasitic or fungal infection. However, low intensities of parasitic infection were recorded from the alimentary tracts of *Tilapia guineensis* (with *trematode* infection), *Chrysichthys nigrodigitatus* (*nematodes* and *cestodes*) and *Clarias gariepinus* (Nematodes and *cestodes* attack). Parasitic infection was observed to be high at the beginning of October reaching a peak in January (i.e. during the dry season) and declined from March till August i.e during the rainy season (Awa op. cit.).

As a major occupation of the coastal people in the study area, fishing is a major source of revenue generation. It provides labour and the required animal protein supplement from the easily available fresh and cured fish supply in the area. Catch per unit effort and accruing revenues to fisherfolks are quite variable from the subsistence to artisanal fisheries. For instance, the average catch per capita of the typical subsistence fisherfolk is less than 5kg (Appendix Plate A-8) while that of the typical artisanal fishermen can be about 25kg (Appendix Plate A-9). The artisanal fisherfolks are well sustained in the business, they are able to change their gear and crafts when due and realize some net gains, over all other operational expenses.

A lot of economic gains can also be realized from the great aquacultural potentials in the area. Many fish species already identified to have good to very good potentials for aquaculture which are also popular (well acceptable) to people occur commonly in the area. They include the *bagrid* catfish C*hrysichtys nigrodigitatus*, the mullets (*Liza* and *Mugil* spp), the mud catfish *Clarias lazera*, and the snapper *Lutjanus* species. Others are the pink shrimp *Penaeus* and the oysters *Crassostris gazar*.

4.6.3.1 Fish Preservation and Processing Methods

Various methods of fish preservation are practiced in the study area. In most cases, catch do not require any preservation by the fisherfolks as the life/fresh dead fishes are procured by vendors immediately on landing or even while on water. A number of the fresh species can stay alive for a couple of hours after catch. These are mainly the species with breathing organs that confer on the fishes the ability to withstand low oxygen tension. They include C*larias lazera, Protopterus senegalus, Ophiocephalus obscurus,* and *Chyrischthys* species. These fishes can be kept in containers, usually basket cages (Appendix Plate A-10) where they can remain alive for many days. The position of the cage is usually marked with a float. Crab and mollusc-fishes are also kept in this way.

Sundrying is commonly applied to small fish species and shrimps. Usually the fishes are descaled, cut into pieces (if necessary) and gutted. Drying may last for days. By far, the commonest method of fish preservation in the area is by smoke-drying. Usually, the fish is descaled, deguted, cut into pieces (if necessary) and allowed to dry before putting on a flat platform over the local kiln. Small fish are usually smoked whole. The smoking kilns are simple and rather crude in appearance. They are made of various methods (mud, clayey bricks) and designed into various shapes. The women fisherfolks are usually in charge of smoking and usually it is the fish that are not sold fresh that are smoked. Freezing and cold storage practices are not commonly practiced because of lack of electrification in most of the fishing communities.

4.7 METEOROLOGY AND AIR QUALITY

Mean diurnal ambient temperature is 27°C, with maximum and minimum values at 32°C and 24°C respectively. Usually, maximum temperatures occur in the late afternoons.

The diurnal average humidity in the area is 77.15%, ranging from 70.6 to over 80%. Higher values typically occur in the mornings and late evenings. The average wind speed measured was 2.3m/sec. A high percentage of the wind (48%) was North and Northeasterly, and this corresponds to the rain-bearing northeasterlies, which typically predominate in the rainy season.

The total volume and speed of wind for a given location is important to air pollution studies. The introduction of greater volume of wind at the point of emission conversely dilutes the plume to ambient concentration because of the greater volume of air per unit intervals. The implications are that wind speed determines the concentration of air emissions at specific distances down wind while the directions determines the cardinal points of reception.

The total volume and speed of wind for a given location is important to air pollution studies. The introduction of greater volume of wind at the point of emission conversely dilutes the plume to ambient concentration because of the greater volume of air per unit intervals. The implications are that wind speed determines the concentration of air emissions at specific distances down wind while the directions determines the cardinal points of reception.

Non-methane hydrocarbons were recorded at the various locations within the compressor stations range from 0.001 ppm–0.004 ppm. Methane was recorded in virtually all stations but at a very low concentration of about 0.001 ppm mean value. The presence of methane in the atmosphere could be indicative of emission from decaying vegetation in nearby swamps and wetlands.

Carbon monoxide (CO) ranged between 0.014 ppm and 0.29 ppm. These values are much lower than regulatory limits. Nitrogen dioxide (NO_2) values were low and ranged between 0.001 ppm and 0.002 ppm. There are natural and man-made sources of $N0_2$. The former sources include releases from lightning, forest fires and soil microbial processes, while the later sources are mainly combustion of fossil fuels (power stations and vehicles). The levels of $N0_2$ obtained in this study are low enough to be regarded as background, resulting from natural sources.

The concentrations of TSP varied between 0.22 mg/m^3 and 29.8 mg/m^3 with station mean values of 10.57 mg/m^3. The low concentrations recorded were indicative of the season. Rains are strong atmospheric cleansers and scrub the air of suspended particulates. This is best seen in Appendix Tables A-7 and A-16, where measurements taken immediately after rainfall were less than 0.5mg/m^3. The Maximum TSP data (29.8mg/m^3) was recorded at station 3 and can be attributed to fugitive contributions from vehicular movements around this point, which is very close (<30m) to the main road leading from the village to Badagry.

The main sources of noise in the area are sea waves breaking on the shore and vehicular movement. Noise level ranged between 25dB and 31.25dB, with mean value at 28.25dB. These recorded values are way below regulatory limits for 8-hr exposure period.

APPENDIX A

Table A-1: The Mammals of Alagbado/Badagry Area

(Based mainly on hunters' & traders reports)

Common Name	Biological Name	Numerical Status (guesstimate)	IUCN Category (Red List)	Federal Protection Status (Decree No. 11 of 1985)
Primates				
Bosman's Potto	*Perodicticus potto*	Uncommon	NT	VU †
Demidov's Galago	*Galago demidovii*	Common	"	"
Mona Monkey	*Cercopithecus mona*	Common	Uncertain	"
Vervet (or Tantalus) Monkey	*Cercopithecus aethiops*	Common	"	"
Western Black-and-White Colobus	*Colobus vellerosus*	Uncommon	VU	EN
Pholidota				
Tree Pangolin	*Manis tricuspis*	Uncommon	Uncertain	Not Protected
Lagamorpha				
Crawshay's Hare	*Lepus crawshayi*	Uncommon	"	"
Rodentia				
Giant Forest Squirrel	*Protoxerus stangeri*	Rare	"	"
Red-legged Sun-Squirrel	*Heliosciurus rufobrachium*	Uncommon	"	"
Gambian Sun Squirrel	*Heliosciurus gambianus*	Common	NT	"
Orange-headed Squirrel	*Funisciurus leucogenys*	Common	"	"
Redless Tree Squirrel	*Funisciurus anerythrus*	Common	"	"
Fire-footed Squirrel	*Funisciurus pyrrhopus*	Uncommon	"	"

† VU = Vulnerable; EN = Endangered; NT = Not Threatened

Common Name	Biological Name	Numerical Status (guesstimate)	IUCN Category (Red List)	Federal Protection Status (Decree No. 11 of 1985)
Pel's Flying Squirrel	*Anomalurus peli*	Uncommon	"	"
Derby's Flying Squirrel	*Anomalurus derbianus*	Uncommon	"	"
Giant Rat	*Cricetomys gambianus*	Common	"	"
Grasscutter	*Thryonomys swinderianus*	Common	"	"
Crested Porcupine	*Hystrix cristata*	Common	"	
Brush-tailed Porcupine	*Atherurus africanus*	Uncommon	"	EN
Carnivora				
Cape Clawless Otter	*Aonyx capensis*	Uncommon	"	EN
African Civet	*Viverra civetta*	Common	"	VU
Large-spotted Genet	*Genetta poensis (G. tigrina)*	Uncommon	"	VU
Gambian Mongoose	*Mungos gambianus*	Common	NT	VU
Cusimanse Mongoose	*Crossarchus obscurus*	Uncommon	"	VU
Marsh Mongoose	*Atilax paludinosus*	Rare	Uncertain	VU
Egyptian Mongoose	*Herpestes ichneumon*	Common	"	VU
Serval	*Felis serval*	Uncommon	Uncertain	EN
Sirenia				
West African Manatee	*Trichechus senegalensis*	Rare	VU	EN
Hyracoidea				
Western Tree Hyrax ("Bush dog")	*Dendrohyrax dorsalis*	Uncommon	NT	Not Protected
Artiodactyla				

Common Name	Biological Name	Numerical Status (guesstimate)	IUCN Category (Red List)	Federal Protection Status (Decree No. 11 of 1985)
Sitatunga	*Tragelaphus spekei*	Uncommon	“	EN
Bushbuck	*Tragelaphus scriptus*	Common	“	Not Protected
Maxwell’s Duiker (“Antelope”)	*Cephalophus maxwelli*	Common	“	“
Red-flanked Duiker	*Cephalophus rufilatus*	Common	“	“
Buffon’s Kob	*Kobus kob*	Uncommon	“	VU

Table A-2: Birds seen or heard along the WAGP ROW

(Nomenclature follows Elgood, et al., 1994)

Common Name	Biological Name	Numerical Status	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)	Nesting	Laying	Hatching	Fledging
NON-PASSERINES								
Phalacrocoracidae								
Long-tailed Cormorant	*Phalacrocorax africanus*	Common	NT	Not Protected	Sep-Feb	-	-	-
Pelecanidae								
Pink-backed Pelican [1]	*Pelecanus rufescens*	Uncommon	“	VU	Sep-Mar	Oct?	-	-
Ardeidae								
Little Egret	*Egretta garzetta*	Uncommon	“	VU	Feb	-	-	-
Cattle Egret	*Bubulcus ibis*	Common	“	VU	Afm[2]	-	-	-

[1] Hunters’ report

[2] Moves seasonally to northern Nigeria to breed

Common Name	Biological Name	Numerical Status	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)	Nesting	Laying	Hatching	Fledging
Purple Heron	*Ardea purpurea*	Common	"	VU	PM[3]	-	-	-
Goliath Heron [b]	*Ardea goliath*	Uncommon	"	VU	-	-	-	-
Grey Heron	*Ardea cinerea*	Uncommon	"	VU	May-Jun	-	-	-
Green-backed Heron	*Butorides striatus*	Uncommon	"	VU	May-Nov	-	-	Nov
Phoenicopteridae								
Lesser Flamingo [b]	*Phoenicopterus minor*	Uncommon	"	Not Protected	-	-	-	-
Accipitridae								
African Harrier Hawk[b]	*Polyboroides typus*	Uncommon	"	EN	Nov-Jul	-	-	-
Falconidae								
Common Kestrel	*Falco tinnunculus*	Common	"	EN	Mar-Jul	-	-	Jul

[3] PM =Palaearctic Migrant

Common Name	**Biological Name**	**Numerical Status**	**IUCN Category**	**Federal Protection Status (Decree No. 11 of 1985)**	**Nesting**	**Laying**	**Hatching**	**Fledging**
Grey Kestrel	*Falco ardosiaceus*	Common	"	EN	Dec-May	Apr	-	-
Phasianidae								
Helmeted Guineafowl[b]	*Numida meleagris*	Common	"	Not Protected	-	Jul-Aug	-	Sep-Oct?
Double-spurred Francolin (Bushfowl)	*Francolinus bicalcaratus*	Common	"	"	Sep-Mar	-	-	-
Jacanidae								
African Lily Trotter	*Actophilornis africana*	Uncommon	"	"	All months	Apr-Jan	-	Apr-Jan
Columbidae								
Red-eyed Dove	*Streptopelia semitorquata*	Common	NT	Not Protected	All months	All months	All months	All months
Laughing Dove	*Streptopelia senegalensis*	Common	"	"	All months	All months	All months	All months
Vinaceous Dove	*Streptopelia vinacea*	Common	"	"	All months	All months	All months	All months
Red-billed Wood Dove	*Turtur afer*	Common	"	"	Oct-Mar	-	-	-

Common Name	Biological Name	Numerical Status	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)	Nesting	Laying	Hatching	Fledging
Musophagidae								
Western Grey Plantain-eater	*Crinifer piscator*	Common	"	"	Year round	All months	All months	All months
Cuculidae								
Senegal Coucal	*Centropus senegalensis*	Common	"	"	Mar-Aug	-	-	-
Apodidae								
Palm Swift	*Cypsiurus parvus*	Abundant	"	"	Mar-Aug	-	-	-
Little Swift	*Apus affinis*	Abundant	"	"	All months	All months	All months	All months
Alcedinidae								
Woodland Kingfisher	*Halcyon senegalensis*	Common	"	"	Apr-Aug	-	-	-
Grey-headed Kingfisher	*Halcyon leucocephala*	Uncommon	"	"	Afm	-	-	-
Pied Kingfisher	*Ceryle rudis*	Uncommon	"	"	Nov-Mar	-	-	-

Common Name	Biological Name	Numerical Status	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)	Nesting	Laying	Hatching	Fledging
Shining-blue Kingfisher	*Alcedo quadribrachys*	"	"	"	-	-	-	-
Meropidae								
White-throated Bee-eater	*Merops albicollis*	Uncommon	"	"	Afm	-	-	-
Little Bee-eater	*Merops pusillus*	Uncommon	"	"	Feb-Jul	-	-	-
Bucerotidae								
African Pied Hornbill	*Tockus fasciatus*	Uncommon	"	"	Jan-May	-	-	-
Capitonidae								
Speckled Tinkerbird	*Pogoniulus scolopaceus*	Common	"	"	All months	Jan-Nov	-	Feb-Nov
Yellow-rumped Barbet	*Pogoniulus bilineatus*	Common	"	"	Mar-Apr	-	Mar?	-
PASSERINES								
Alaudidae								

Common Name	**Biological Name**	**Numerical Status**	**IUCN Category**	**Federal Protection Status (Decree No. 11 of 1985)**	**Nesting**	**Laying**	**Hatching**	**Fledging**
Flappet Lark	*Mirafra rufocinnamomea*	Uncommon	"	"	-	-	-	-
Hirundinidae								
Ethiopian Swallow	*Hirundo aethiopica*	Common	"	"	Mar-Aug	-	-	-
Mosque Swallow	*Hirundo senegalensis*	Rare	"	"	May-Aug	-	-	-
Motacillidae								
Pied Wagtail	*Motacillla aguimp*	Uncommon	"	"	Oct-Apr	-	-	-
Pycnonotidae								
Common Bulbul	*Pycnonotus barbetus*	Common	NT	Not Protected	All months	All months	All months	All months

Common Name	**Biological Name**	**Numerical Status**	**IUCN Category**	**Federal Protection Status (Decree No. 11 of 1985)**	**Nesting**	**Laying**	**Hatching**	**Fledging**
Turdidae								
African Thrush	*Turdus pelios*	Common	"	"	Apr-Sep	-	-	-
Sylviidae								
Grey-backed Camaroptera	*Camaroptera brevicauda*	Abundant	"	"	Apr-Sep Nov-Jan	-	-	-
Muscicapidae								
Pale Flycatcher	*Melaeornis (Empidornis) pallidus*	Uncommon	"	"	Feb-Sep	-	-	-
Nectariniidae								
Carmelite Sunbird	*Nectarinia fuliginosa*	Uncommon	"	"	Mar-Nov?	-	-	Oct-Nov
Olive-bellied Sunbird	*Nectarinia chloropygia*	Common	"	"	All months	-	-	-
Collared Sunbird	*Anthreptes collaris*	Common	"	"	All months	All months	All months	All months
Brown Sunbird	*Anthreptes gabonicus*	Common	"	"	Dec-Mar?	-	-	-

Common Name	Biological Name	Numerical Status	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)	Nesting	Laying	Hatching	Fledging
Malaconotidae								
Brown-headed Bush-Shrike	*Tchagra australis*	Uncommon	“	“	-	-	-	-
Grey-headed Bush-Shrike	*Telophorus (Malaconotus) blanchoti*	Uncommon	“	“	Afm	-	-	-
Corvidae								
Pied Crow	*Corvus alba*	Common	“	“	Mar-Jul	-	-	-
Black Magpie	*Philostomus afer*	Common	“	“	Apr-Jun	-	-	Jan-Oct?
Oriolidae								
Black-winged Oriole	*Oriolus nigripennis*	Uncommon	“	“	Mar-Jun	Mar-Jun	Mar-Jun	Mar-Jun
Sturnidae								
Chestnut-winged Starling	*Onychognathus fulgidus*	Uncommon	“	“	Feb-May?	-	-	-

Common Name	Biological Name	Numerical Status	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)	Nesting	Laying	Hatching	Fledging
Passeridae								
Grey-headed Sparrow	*Passer griseus*	Abundant	"	"	All months	All months	All months	All months
Ploceidae								
Village Weaver	*Ploceus cucculatus*	Abundant	"	"	All months	Mainly Jun-Aug	All months	All months
Estrildidae								
Bronze Mannikin	*Lonchura cucullata*	Abundant	"	"	Apr-Dec	-	-	-

NB: Information on breeding in birds is taken from Elgood *et al***.** (1994).

Similar data for mammals, amphibians and reptiles are hard to come by.

Table A-3: Reptiles found in the Alagbado/Badagry Area

(Based on hunters' and traders report)

Common Name	Biological Name	Numerical Status (guesstimate)	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)
Cheloniidae				
Hawksbill Turtle	*Erethmochelys imbricata*	Uncommon	EN	Not Protected
Olive Ridley Turtle	*Lepidochelys olivacea*	Uncommon	EN	"
Green Turtle	*Chelonia mydas*	Uncommon	EN	"
Loggerhead Turtle	*Caretta caretta*	Uncommon	VU	"
Dermochelyidae				
Leathery Turtle	*Dermochelys coriacea*	Rare	EN	"
Crocodylidae				
Nile Crocodile	*Crocodylus niloticus*	Common	NT	EN
Short-snouted Crocodile ("Alligator")	*Osteolaemus tetraspis*	Common	NT	EN
Long-snouted Crocodile	*Crocodylus cataphractus*	Uncommon	EN	Not protected
Chameleonidae				
Hallowell's Chameleon	*Chameleo gracilis*	Common	NT	"
Scincidae				
Five-lined Skink	*Mabuya quinquetaeniata*	Uncommon	"	"
Varanidae				
Nile Monitor Lizard	*Varanus niloticus*	Common	"	EN

Common Name	Biological Name	Numerical Status (guesstimate)	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)
Boidae				
African Python	*Python sebae*	Uncommon	“	EN
Elapidae				
Spitting Cobra	*Naja nigricollis*	Common	“	Not protected
Black Cobra	*Naja melanoleuca*	Common	“	“
Viperidae				
Gabon Viper	*Bitis gabonica*	Uncommon	NT	Not Protected
Night Adder	*Causus maculatus*	Common	NT	Not Protected

Table A-4: Amphibians recorded in the vicinity of the proposed pipeline ROW

Common Name	Biological Name	Numerical Status (guesstimate)	IUCN Category	Federal Protection Status (Decree No. 11 of 1985)
Hyperolidae (Treefrogs)				
	Afrixalus dorsalis	Common		Not Protected
	Hyperolius fusciventris	"		"
	Hyperolius guttulatus	"		"
	Hyperolius concolor	"		"
Ranidae				
	Ptychadena taenioscelis	"		"
	Ptychadena oxyrhinchus	"		"
	Ptychadena aequiplicata	"		"
	Aubria subsigilata	"		"
	Phrynobactrachus albolabris	"		"
Bullfrog	*Dicroglossus occipitalis*	"		"
Bufonidae				
Common Toad	*Bufo regularis*	"		"
Forest Toad	*Bufo maculatus*	"		"
Pipidae				"
West African Clawed Toad	*Xenopus tropicalis*	"		"

Table A-5: Species Composition, Distribution and Relative Abundance of Macrobenthic Fauna attached to floating macrophytes at the Study Area.

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS									
	S4	S8	S11	S12	S21	S26	S29	S31	S37	S39	TOTAL
AMPHIBIA											
Tadpoles				**3**	**1**	**6**		**25**	**3**		**38**
ANNELIDA											
OLIGOCHAETA											
Branchiodrilus sp					1	1			2		**4**
Chaetogaster diastrophus						2	1				**3**
Nais communis			2	1		5	1	3			**12**
Tubifex tubifex						6	5	1			**12**
HIRUDINEA											
Glossiphonia sp	2							2			**4**
Helobdella punotata lineata			2	1							**3**
Haemopsis marmorata			1	2							**3**
CRUSTACEA											

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS										
	S4	**S8**	**S11**	**S12**	**S21**	**S26**	**S29**	**S31**	**S37**	**S39**	**TOTAL**
AMPHIPODA											
Gammarus fasciatus	12	14								9	**35**
DECAPODA											
Potamalpheops monodi	8	6								2	**16**
Isopoda											
Ligia gracilipes	1	2								1	**4**
INSECTA											
COLEOPTERA											
Copelatus sp			6	8	2	1	3		9		**29**
Hydrocanthus sp						2		5	8		**15**
Hydrophilus sp								2	4		**6**
Hydroporus sp			1	1				2			**4**
Philhydrus sp					1	2			1		**4**
DIPTERA											
Chaoborus sp			1	2			1				**4**

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS										
	S4	S8	S11	S12	S21	S26	S29	S31	S37	S39	TOTAL
Chironomus fractilobus					2	5	9	1			**17**
Chironomus transvaalensis						2	4	1	2		**9**
Clinotanypus maculatus	2	1	3	5		12	15	1		3	**42**
Corynoneura sp		1	3	1		2	6				**13**
Cricotopus sp		2	1			5	8				**16**
Pentaneura sp						5	8	1			**14**
Polypedilum sp	5			1		4			2	2	**14**
Stictochironomus sp	1				4	9	15	1	2	1	**33**
Tanytarsus sp	1			2		2	1		1	2	**9**
EPHEMEROPTERA											
Adenophlebiodes sp	2	1		2				1		1	**7**
Baetis sp	1		1	3		1		4	1	1	**12**
Caenis moesta		1				1	2		2		**6**
Cloeon cylindroculum	2	3						2			**7**
Pseudocloeon sp	3	4								5	**12**

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS										
	S4	S8	S11	S12	S21	S26	S29	S31	S37	S39	TOTAL
HEMIPTERA											
Pelocoris femoratus				1	2			1			**4**
ODONATA											
ANISOPTERA											
Cordulid sp	3							1		3	**7**
Erythemis sp					1			8	1		**10**
Ophiogomphus sp		1					1				**2**
Oxygaster curtisii			2			1		1			**4**
Plathemis sp				5						2	**7**
ZYGOPTERA											
Coenagrion scitulum	5	2								3	**10**
Lestes dryas	1		1					1		1	**4**
PLECOPTERA											
Neoperla sp					2			1			**3**
TRICOPTERA											

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS										
	S4	S8	S11	S12	S21	S26	S29	S31	S37	S39	TOTAL
Plectrocnemia sp				1		2					**3**
MOLLUSCA											
BIVALVIA											
Pisidum pirothi		1			1			2			**4**
GASTROPODA											
Hdrobia sp			2				1				**3**
Lanistes libycus				2				1			**3**
Limnaea auricularia					1		1				**2**
Potamopygus ciliatus		1			1					2	**4**
ABUNDANCE(N)	**49**	**40**	**26**	**41**	**19**	**76**	**82**	**68**	**38**	**38**	**477**
Taxa number(S)	**15**	**14**	**13**	**17**	**12**	**21**	**17**	**23**	**13**	**15**	

Table A-6: Species Composition, Distribution and Relative Abundance of Macrobenthic Fauna in the Sediment at the Study Area.

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS														
	S1	S2	S3	S4	S5	S8	S9	S11	S12	S21	S26	S29	S31	S37	S39	TOTAL
ANNELIDA																
OLIGOCHAETA																
Eiseniella tetrahedra								1								**1**
Nais communis	1					1	1			3			1	5		**12**
Tubifex tubifex							1		3					45		**49**
POLYCHAETA																
Neanthes limnicola	1															**1**
DECAPODA																
Potamalpheops monodi										1		2				**3**
DIPTERA																
Chironomus transvaalensis									10	4		14	1	5		**34**
Clinotanypus maculatus									4	1	3		2	3		**13**
Cricotopus sp										1		3		6		**10**
Pentaneura sp									3	2	1		1	5		**12**

TAXONOMIC LIST	WAGP EIA ONSHORE SAMPLING STATIONS															
	S1	**S2**	**S3**	**S4**	**S5**	**S8**	**S9**	**S11**	**S12**	**S21**	**S26**	**S29**	**S31**	**S37**	**S39**	**TOTAL**
Polypedilum sp												2		1		**3**
MOLLUSCA																
BIVALVIA																
Egeria paradoxa		42	45	50	52			1							30	**220**
Iphigenia rostrata	1	1			2										1	**5**
Mytillus perna	6			2												**8**
Tellina senegambiensis					1										1	**2**
GASTROPODA																
Pachymelania aurita	31	5	2			1	1								15	**55**
ABUNDANCE(N)	**40**	**48**	**47**	**52**	**55**	**2**	**3**	**2**	**20**	**12**	**4**	**21**	**5**	**70**	**47**	**428**

Table A-7: Meteorological Parameters at the Compressor Station At Badagry (day 1)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
	WS (m/s)	2.2	2.5	1.9	2.4	2.1	2.3	2.4	2.0	2.23
	MAX (m/s)	2.3	2.6	2.0	2.5	2.2	2.4	2.5	2.1	2.33
AQS 1	AWS (m/s)	2.0	2.3	1.9	2.2	2.0	2.1	2.2	1.9	2.08
	TEMP. (^{0}C)	30.0	31.1	32.2	30.4	30.0	31.2	30.2	30.3	30.68
	WC (^{0}C)	29.5	30.2	31.3	29.3	29.0	30.1	29.1	29.2	29.71
	HUMIDITY (%)	71	69	74	70	69	71	73	70	70.88
	HEATING	35.1	34.3	34.5	33.2	34.5	35.6	36.4	35.1	34.84
	DP (^{0}c)	27.3	26.1	26.3	24.5	25.3	24.8	26.3	27.4	26
	WS (m/s)	2.3	2.0	2.3	2.2	2.3	2.0	2.3	2.2	2.2
	MAX (m/s)	2.4	2.1	2.4	2.3	2.4	2.1	2.4	2.3	2.3
AQS 2	AWS (m/s)	2.1	1.9	2.1	2.0	2.1	1.9	2.1	2.0	2.03
	TEMP. (^{0}C)	30.3	30.2	30.3	30.5	31.0	30.2	31.0	30.1	30.45
	WC (^{0}C)	28.5	29.5	28.8	29.4	30.1	29.4	29.3	29.3	29.29

	HUMIDITY (%)	74	83	80	79	83	76	74	73	77.75
	HEATING	33.2	33.1	35.2	32.2	33.3	34.7	35.8	34.8	34.04
	DP (^{0}c)	28.5	25.1	27.1	26.3	24.3	25.6	25.1	26.2	26.03
AQS 3	WS (m/s)	2.5	2.4	2.0	2.2	2.3	2.1	2.3	2.2	2.25
	MAX (m/s)	2.6	2.5	2.1	2.3	2.4	2.2	2.4	2.3	2.35
	AWS (m/s)	2.3	2.2	1.9	2.0	2.1	1.9	2.2	1.9	2.06
	TEMP. (^{0}C)	29.5	30.3	29.8	30.5	30.2	29.4	30.3	30.3	30.04
	WC (^{0}C)	28.1	29.2	27.3	26.8	25.7	24.5	28.1	26.3	27
	HUMIDITY (%)	80	77	76	73	81	82	83	81	79.13
	HEATING	32.1	31.3	34.1	34.7	35.1	33.6	32.5	35.2	33.58
	DP (^{0}c)	26.4	24.8	26.1	25.3	25.0	24.5	24.3	24.3	25.09

Table A-8: Meteorological Parameters at the Compressor Station At Badagry (day 2)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	WS (m/s)	1.6	1.4	1.6	1.4	1.9	2.0	2.1	2.1	1.76
	MAX (m/s)	1.7	1.5	1.7	1.5	2.0	2.1	2.2	2.2	1.86
	AWS (m/s)	1.6	1.4	1.5	1.4	1.8	1.9	2.0	2.0	1.7
	TEMP. (^{0}C)	29.1	29.3	30.0	30.3	30.2	30.5	31.2	31.0	30.18
	WC (^{0}C)	27.4	26.5	29.2	29.1	29.3	29.3	30.0	30.0	28.75
	HUMIDITY (%)	67	70	73	79	69	69	72	73	72.88
	HEATING	33.0	32.1	31.2	31.4	32.3	32.3	31.1	31.3	31.84
	DP (^{0}c)	29.1	28.5	28.3	30.0	29.3	29.3	28.4	28.2	28.95
AQS 2	WS (m/s)	1.5	1.3	1.4	1.6	1.7	1.8	1.7	1.9	1. 61
	MAX (m/s)	1.6	1.4	1.5	1.7	1.8	1.9	1.8	2.0	1.71
	AWS (m/s)	1.4	1.2	1.3	1.4	1.5	1.6	1.5	1.8	1.46
	TEMP. (^{0}C)	29.3	30.1	30.0	30.1	31.0	30.2	30.3	30.5	30.18

	PARAMETER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Values (8 – HR Mean)**
	WC (^{0}C)	26.5	25.8	27.0	27.7	28.1	29.0	29.3	28.8	27.78
	HUMIDITY (%)	80	78	76	79	81	71	73	75	76.63
	HEATING	32.5	33.1	32.5	33.0	34.0	32.9	32.9	31.6	32.7
	DP (^{0}c)	29.6	30.1	28.6	28.7	29.5	29.7	29.7	30.0	29.33
AQS 3	WS (m/s)	1.7	1.6	1.8	1.6	1.7	1.8	1.6	1.7	1. 69
	MAX (m/s)	1.8	1.7	1.9	1.7	1.8	1.9	1.7	1.8	1.79
	AWS (m/s)	1.5	1.4	1.6	1.4	1.5	1.6	1.4	1.5	1.49
	TEMP. (^{0}C)	30.0	29.1	29.5	30.1	30.2	30.5	29.5	29.8	29.84
	WC (^{0}C)	27.0	28.5	26.8	28.3	27.5	28.1	26.6	27.7	27.56
	HUMIDITY (%)	68	71	69	74	73	78	79	72	73
	HEATING	33.0	32.3	33.2	34.5	33.8	32.9	33.4	33.3	33.3
	DP (^{0}c)	29.0	29.5	30.1	30.0	29.2\	29.3	30.0	30.3	29.68

Table A-9: Meteorological Parameters at the Compressor Station At Badagry (day 3)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	WS (m/s)	0.8	0.9	0.6	0.6	0.8	0.7	1.0	1.1	0.81
	MAX (m/s)	0.9	1.0	0.7	0.7	0.9	0.8	1.1	1.2	0.91
	AWS (m/s)	0.8	0.9	0.6	0.6	0.7	0.6	1.0	1.0	0.77
	TEMP. (^{0}C)	28.1	28.5	29.0	28.5	29.1	30.1	30.0	29.8	29.14
	WC (^{0}C)	25.1	24.7	26.7	26.8	29.0	28.5	28.2	27.5	27.08
	HUMIDITY (%)	86	83	86	83	79	80	81	79	82.13
	HEAT INDEX	29.5	30.1	30.3	29.9	30.5	30.1	31.0	31.1	30.31
	DP (^{0}c)	28.0	27.3	27.5	28.1	29.0	28.3	29.3	29.3	28.06
AQS 2	WS (m/s)	0.6	0.8	0.7	0.9	0.7	0.6	0.9	0.8	0.75
	MAX (m/s)	0.7	0.9	0.8	1.0	0.8	0.7	1.0	0.9	0.85
	AWS (m/s)	0.5	0.6	0.6	0.7	0.5	0.4	0.7	0.6	0.58
	TEMP. (^{0}C)	28.5	29.3	28.8	29.3	30.0	30.1	30.0	30.0	29.5
	WC (^{0}C)	26.1	27.5	27.0	26.3	28.0	28.5	29.0	28.5	27.61

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
	HUMIDITY (%)	81	83	86	83	82	83	79	77	81.75
	HEAT INDEX	30.0	30.1	29.8	30.5	30.5	30.2	30.3	31.2	30.33
	DP (^{0}c)	29.3	29.3	28.3	29.5	28.5	29.0	28.5	28.4	28.89
AQS 3	WS (m/s)	0.9	0.8	0.7	0.6	0.7	0.8	0.9	0.9	0.79
	MAX (m/s)	1.0	0.9	0.8	0.7	0.8	0.9	1.0	1.0	0.89
	AWS (m/s)	0.8	0.7	0.5	0.4	0.5	0.6	0.7	0.7	0.61
	TEMP. (^{0}C)	28.3	29.3	29.5	29.8	30.1	30.2	30.0	30.3	29.69
	WC (^{0}C)	27.3	28.1	26.4	27.5	28.0	28.4	28.6	29.0	27.91
	HUMIDITY (%)	81	83	83	86	85	84	79	79	82.5
	HEAT INDEX	30.5	30.2	30.3	30.5	31.0	31.2	30.5	31.0	30.65
	DP (^{0}c)	29.0	28.8	29.0	29.4	27.0	27.0	27.3	28.0	28.44

Table A-10: Meteorological Parameters at the Compressor Station At Badagry (day 4)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	WS (m/s)	2.3	2.4	2.0	2.4	2.2	2.2	2.0	2.1	2.2
	MAX (m/s)	2.4	2.5	2.1	2.5	2.3	2.3	2.1	2.2	2.3
	AWS (m/s)	2.1	2.2	1.9	2.2	2.0	2.0	1.9	1.8	2.01
	TEMP. (^{0}C)	31.2	30.3	30.3	30.2	30.0	31.2	30.2	30.1	30.44
	WC (^{0}C)	30.0	29.2	29.1	29.0	29.0	29.4	28.8	29.0	29.19
	HUMIDITY (%)	71	70	70	71	70	71	69	69	70.13
	HEAT INDEX	33.6	34.1	32.1	31.8	31.8	33.2	34.5	33.0	33.13
	DP (^{0}c)	25.6	25.3	27.6	26.4	26.4	24.3	28.1	26.3	26.46
AQS 2	WS (m/s)	2.0	2.1	2.3	2.5	2.4	2.3	2.5	2.3	2.26
	MAX (m/s)	2.1	2.2	2.4	2.6	2.5	2.4	2.6	2.4	2.4
	AWS (m/s)	1.9	2.0	2.1	2.3	2.2	2.1	2.3	2.1	2.13
	TEMP. (^{0}C)	31.0	30.6	31.6	30.4	31.0	30.2	31.0	32.6	31.05

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
	WC (^{0}C)	29.3	28.7	27.6	28.3	29.3	27.4	28.0	29.3	28.48
	HUMIDITY (%)	81	76	74	73	69	83	80	79	76.87
	HEAT INDEX	32.0	31.8	33.6	34.1	33.6	32.8	34.0	34.1	33.25
	DP (^{0}c)	26.1	25.4	27.2	28.3	27.1	26.0	28.4	25.3	26.72
AQS 3	WS (m/s)	2.3	2.4	2.1	2.3	2.4	2.0	2.3	2.0	2.23
	MAX (m/s)	2.4	2.5	2.2	2.4	2.5	2.1	2.4	2.1	2.33
	AWS (m/s)	2.1	2.2	1.9	2.1	2.2	1.8	2.1	1.8	2.02
	TEMP. (^{0}C)	30.0	29.3	30.3	29.6	30.6	30.4	30.2	30.1	30.06
	WC (^{0}C)	29.0	27.1	28.2	26.3	28.3	27.4	28.1	27.3	27.71
	HUMIDITY (%)	84	79	83	76	84	82	78	80	80.75
	HEAT INDEX	33.1	32.6	31.3	34.3	32.4	33.0	32.3	34.0	32.87
	DP (^{0}c)	27.1	26.8	28.3	27.3	27.3	26.7	27.5	26.1	27.13

Table A-11: Meteorological Parameters at the Compressor Station At Badagry (day 5)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	WS (m/s)	0.9	1.1	1.3	1.3	1.0	1.2	1.3	1.2	1.16
	MAX (m/s)	1.0	1.2	1.4	1.4	1.1	1.3	1.4	1.3	1.26
	AWS (m/s)	0.7	1.9	1.2	1.2	0.8	1.9	1.2	1.9	1.35
	TEMP. (^{0}C)	30.1	31.0	30.2	29.8	30.5	31.0	30.1	30.2	30.36
	WC (^{0}C)	29.0	29.5	28.3	27.3	28.3	29.0	27.3	28.0	28.33
	HUMIDITY (%)	76	78	80	83	83	74	71	74	77. 37
	HEAT INDEX	32.3	33.2	32.5	34.5	33.0	32.6	32.3	33.4	32.97
	DP (^{0}c)	28.1	29.3	27.5	26.4	27.0	29.3	28.3	28.1	28.0
AQS 2	WS (m/s)	1.3	1.2	1.0	0.9	0.8	1.0	1.0	1.3	1.06
	MAX (m/s)	1.4	1.3	1.1	1.0	0.9	1.1	1.1	1.4	1.16
	AWS (m/s)	1.1	1.0	1.8	0.7	0.6	0.9	0.9	1.1	1.01
	TEMP. (^{0}C)	31.0	30.0	30.2	30.3	30.6	30.4	31.2	31.0	30.58
	WC (^{0}C)	28.3	27.0	26.9	27.3	26.3	27.0	27.6	28.3	27.33

	PARAMETER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Values (8 – HR Mean)**
	HUMIDITY (%)	83	80	79	74	76	78	81	79	78.75
	HEAT INDEX	32.0	33.1	34.0	33.1	32.5	31.6	32.0	32.1	32.55
	DP (^{0}c)	29.0	28.3	27.1	26.5	27.6	27.5	26.4	27.0	27.42
	WS (m/s)	0.9	0.8	0.9	1.2	1.3	1.2	1.4	1.3	1.12
	MAX (m/s)	1.0	0.9	1.0	1.3	1.4	1.3	1.5	1.4	1.23
AQS 3	AWS (m/s)	0.9	0.6	0.7	1.0	1.1	1.0	1.2	1.1	0.95
	TEMP. (^{0}C)	30.1	31.6	30.2	30.5	29.8	30.0	30.3	30.4	30.36
	WC (^{0}C)	28.3	29.3	28.4	27.3	28.1	26.5	27.3	28.1	27.91
	HUMIDITY (%)	74	78	80	79	81	74	73	75	76.75
	HEAT INDEX	33.1	32.5	33.0	32.1	33.6	34.1	33.0	33.5	33.11
	DP (^{0}c)	28.1	26.3	25.9	27.0	27.3	26.8	27.3	28.0	27.08

Table A-12: Ambient Air Quality Compressor Station At Badagry (day 1)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	THC (ppm)	0.007	0.005	0.006	0.003	0.002	0.009	0.003	0.002	0.004
	Methane (ppm)	0.001	0.001	ND	0.002	0.001	ND	0.002	0.001	0.001
	CO (ppm)	0.23	0.19	0.16	0.36	0.21	0.32	0.33	0.30	0.210
	NO_2 (ppm)	ND	ND	0.004	0.002	ND	0.006	0.004	0.002	0.002
	Noise (dB)	31	28	25	30	28	31	25	28	28.25
	TSP (mg/m^3)	13	19	23	21	12	17	19	21	18.12
AQS 2	THC (ppm)	0.003	0.004	0.001	0.002	ND	0.004	0.002	0.003	0.002
	Methane (ppm)	ND	0.001	0.001	ND	ND	0.002	0.002	0.001	0.001
	CO (ppm)	0.43	0.36	0.17	0.19	0.37	0.28	0.21	0.33	0.29
	NO_2 (ppm)	0.005	ND	0.003	0.003	ND	0.005	0.004	0.002	0.002
	Noise (dB)	36	32	29	30	33	29	25	30	30.5
	TSP (mg/m^3)	18	20	14	15	24	18	17	18	18.0

	PARAMETER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Values (8 – HR Mean)**
AQS 3	THC (ppm)	0.008	0.006	0.004	0.005	0.003	0.004	0.003	0.006	0.004
	Methane (ppm)	ND	ND	0.001	0.001	ND	0.002	ND	ND	0.001
	CO (ppm)	0.39	0.41	0.35	0.31	0.29	0.36	0.37	0.34	0.35
	NO_2 (ppm)	0.003	0.001	0.002	0.004	0.001	ND	0.004	0.002	0.002
	Noise (dB)	36	28	29	25	30	31	27	31	29.8
	TSP (mg/m^3)	21	28	19	20	18	27	30	26	23.62

Table A-13: Ambient Air Quality Compressor Station At Badagry (day 2)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	THC (ppm)	0.001	0.003	0.001	ND	0.004	0.002	0.001	0.003	0.001
	Methane (ppm)	ND	ND	0.001	0.001	ND	0.001	0.002	0.001	0.001
	CO (ppm)	0.012	0.031	0.018	0.043	0.036	0.021	0.031	0.023	0.026
	NO_2 (ppm)	0.003	0.002	0.001	0.003	ND	ND	0.002	0.001	0.001
	Noise (dB)	24	26	27	25	24	27	26	21	25.0
	TSP (mg/m^3)	9	10	12	13	10	9	8	11	8.9
AQS 2	THC (ppm)	0.002	ND	0.004	0.002	0.003	0.001	0.003	ND	0.001
	Methane (ppm)	ND	ND	ND	0.001	ND	0.002	0.001	ND	0.001
	CO (ppm)	0.021	0.023	0.017	0.019	0.021	0.026	0.019	0.018	0.020
	NO_2 (ppm)	ND	ND	ND	0.002	0.003	0.001	ND	0.003	0.001
	Noise (dB)	28	26	30	25	25	27	28	27	27
	TSP (mg/m^3)	11	13	10	9	15	13	12	10	11.62

	PARAMETER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean Values (8 – HR Mean)**
AQS 3	THC (ppm)	ND	0.003	0.001	0.004	ND	0.002	0.003	ND	0.001
	Methane (ppm)	0.001	ND	ND	0.001	0.002	0.003	ND	0.001	0.001
	CO (ppm)	0.010	0.018	0.014	0.021	0.031	0.028	0.030	0.033	0.023
	NO_2 (ppm)	ND	ND	0.003	0.002	ND	0.005	0.002	0.001	0.001
	Noise (dB)	29	30	24	25	26	29	30	28	27.62
	TSP (mg/m^3)	8	7	14	16	13	19	21	20	14.75

Table A-14: Ambient Air Quality Compressor Station At Badagry (day 3)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	THC (ppm)	ND	0.002	0.002	0.004	0.002	0.003	ND	0.001	0.001
	Methane (ppm)	ND	ND	ND	ND	0.001	0.004	0.002	0.003	0.001
	CO (ppm)	0.011	0.013	0.021	0.014	0.017	0.011	0.013	0.015	0.014
	NO_2 (ppm)	ND	ND	ND	ND	0.003	0.003	0.002	ND	0.001
	Noise (dB)	28	31	25	30	28	28	30	31	28.9
	TSP (mg/m^3)	0.36	0.64	0.51	0.89	0.54	0.73	0.78	0.64	0.63
AQS 2	THC (ppm)	0.005	0.003	ND	0.001	ND	ND	0.003	ND	0.001
	Methane (ppm)	0.001	ND	ND	0.001	ND	ND	ND	ND	0.001
	CO (ppm)	0.026	0.031	0.017	0.018	0.011	0.036	0.018	0.023	0.022
	NO_2 (ppm)	ND	ND	ND	ND	ND	ND	0.003	0.005	0.001
	Noise (dB)	28	25	28	29	25	26	28	26	26.9
	TSP (mg/m^3)	0.18	0.20	0.31	0.17	0.26	0.28	0.16	0.21	0.22

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 3	THC (ppm)	0.004	0.001	0.003	0.001	0.002	ND	ND	0.003	0.001
	Methane (ppm)	0.001	0.002	0.001	0.001	ND	0.001	0.001	0.001	0.001
	CO (ppm)	0.017	0.036	0.030	0.030	0.028	0.021	0.031	0.025	0.037
	NO_2 (ppm)	ND	ND	ND	ND	ND	ND	0.002	0.001	0.001
	Noise (dB)	25	30	32	35	29	34	30	29	30.5
	TSP (mg/m^3)	0.18	0.21	0.36	0.31	0.28	0.32	0.33	0.22	0.027

Table A-15: Ambient Air Quality Compressor Station At Badagry (day 4)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	THC (ppm)	0.003	0.004	0.002	0.001	0.001	ND	ND	ND	0.001
	Methane (ppm)	0.001	0.001	0.001	ND	0.001	ND	ND	0.001	0.001
	CO (ppm)	0.024	0.018	0.016	0.024	0.022	0.021	0.017	0.019	0.020
	NO_2 (ppm)	0.001	0.001	0.002	0.003	0.002	ND	0.003	0.001	0.001
	Noise (dB)	24	25	28	26	28	25	25	26	25.9
	TSP (mg/m^3)	11	13	16	9	10	13	12	15	12.37
AQS 2	THC (ppm)	0.003	0.001	0.001	0.002	0.003	0.001	ND	ND	0.001
	Methane (ppm)	ND	0.001	0.001	0.001	ND	ND	ND	ND	0.001
	CO (ppm)	0.011	0.013	0.020	0.031	0.011	0.021	0.017	0.017	0.017
	NO_2 (ppm)	0.003	ND	0.002	ND	ND	ND	ND	ND	0.001
	Noise (dB)	28	27	26	27	30	30	26	25	27.37
	TSP (mg/m^3)	19	21	16	17	23	20	18	16	18.75

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 3	THC (ppm)	0.004	0.005	0.003	0.001	0.002	0.001	0.003	0.002	0.002
	Methane (ppm)	0.001	0.002	0.001	ND	ND	ND	ND	ND	0.001
	CO (ppm)	0.021	0.036	0.028	0.036	0.017	0.021	0.021	0.031	0.026
	NO_2 (ppm)	ND	ND	ND	0.003	0.002	0.001	0.003	0.001	0.001
	Noise (dB)	29	34	35	30	31	32	30	29	31.25
	TSP (mg/m^3)	27	22	19	21	26	28	20	23	23.25

Table A-16: Ambient Air Quality Compressor Station At Badagry (day 5)

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 1	THC (ppm)	0.001	0.002	0.001	ND	0.002	ND	0.004	0.001	0.001
	Methane (ppm)	ND	ND	ND	0.001	0.001	0.001	0.001	ND	0.001
	CO (ppm)	0.016	0.010	0.011	0.017	0.015	0.010	0.012	0.013	0.013
	NO_2 (ppm)	ND	ND	0.002	0.002	0.001	0.002	0.001	0.002	0.001
	Noise (dB)	25	26	30	27	25	26	25	25	26.13
	TSP (mg/m^3)	0.43	0.54	0.73	0.81	0.83	0.66	0.76	0.58	0.66
AQS 2	THC (ppm)	0.003	0.001	0.001	0.001	ND	ND	ND	ND	0.001
	Methane (ppm)	0.001	0.001	ND	ND	ND	ND	0.001	0.001	0.001
	CO (ppm)	0.013	0.021	0.018	0.020	0.031	0.023	0.024	0.015	0.020
	NO_2 (ppm)	ND	ND	ND	0.002	0.001	0.001	ND	ND	0.001
	Noise (dB)	25	27	28	26	30	31	26	28	27.63
	TSP (mg/m^3)	0.36	0.46	0.54	0.60	0.71	0.53	0.53	0.51	0.53

	PARAMETER	1	2	3	4	5	6	7	8	Mean Values (8 – HR Mean)
AQS 3	THC (ppm)	ND	ND	0.003	0.004	ND	0.005	0.004	0.003	0.002
	Methane (ppm)	ND	ND	ND	0.002	0.001	0.003	0.002	ND	0.001
	CO (ppm)	0.076	0.064	0.081	0.093	0.069	0.052	0.061	0.073	0.071
	NO_2 (ppm)	ND	0.002	0.002	ND	ND	0.003	0.001	0.001	0.001
	Noise (dB)	30	32	36	31	28	29	30	32	31
	TSP (mg/m^3)	0.76	0.81	0.66	0.57	0.94	0.68	0.69	0.76	0.77

Plate A-1 Coconut dominated Barrier Island

Plate A-2 Cassava plots within the bare ground/cleared ground mosaic

Plate A-3 Young Coconut Palm/cassava mosaic in the area

Plate A-4 Cyperus-dominated Marsh within the barrier island

Plate A-5 Gill nets typically used for fishing in the area

Plate A-6 Cast netting in the study area

Plate A-7 Beach seining in the area

Plate A-8 Subsistence catch per capita in the area

Plate A-9 Typical per capita catch of artesian fishermen in the area

Plate A-10 Fish preservation in the area using baskets

Nigeria
West African Gas Pipeline
Environmental Baseline Survey Report
Second Season

Supplemental Survey

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

Environmental Resources Managers Limited, ERML
Lagos, Nigeria

1.0 Introduction

This report pertains to the environmental baseline survey (EBS) of portions of the proposed West African Gas Pipeline (WAGP) project. The portions covered in this report, referred to as the “non-greenfield areas” extend from the point where the proposed pipeline ties in to the Escravos-Lagos Pipeline (ELP) system at Alagbado, Ogun State, and extends up till an existing metering station at Agbara, also in Ogun State. This coverage area is referred to as “non-greenfield area” because a pipeline right of way (ROW) is already in existence there. This ROW belongs to the Shell Nigeria Gas Company and is currently supplying natural gas to various consumers within the Agbara industrial estate complex. Prior to the commencement of the pipeline project, an EIA had already been conducted by Shell Gas.

This study was therefore conceived to update the already existing data collected by the Shell EIA and also to bridge data gaps that have been identified in reviewing the Shell EIA report.

Having carefully evaluated existing data, it was concluded that data gaps existed in specific areas and a field team was thus composed and mobilized for the purpose of collecting data that would help to bridge the gaps. The areas covered by the field team are:

i. Soil (physico-chemistry and biology)
ii. Water (Physico-chemistry and biology)

The team mobilized on Thursday October 30, 2003 and was on the field until Tuesday November 4, 2003, when they demobilized. Samples were collected on various environmental components. The results of these efforts are presented in this report.

2.0 Sampling Methodology

Based on previous reconnaissance and walkthrough of the designated area, four (4) distinct habitat types were identified in the project area. Samples were therefore collected from these four habitats. The protocol followed is described below:

2.1 Soil Sampling

Within each habitat, a transect of at least 100m length was established. Soils were described, mapped and sampled at four locations along each transect. Thus soil observation and sampling points along a 100m long transect were 0m, 25m, 50m and 100m points. Again, 5 to 10 core soil samples were taken at every sampling point to ensure the collection of a truly representative soil samples and guide against microhabitat variations. The core soil samples were bulked and thoroughly homogenized before sub-sampling for laboratory analysis. Soil samples meant for polyaromatic hydrocarbon (PAH) determinations were obtained by sub-sampling all the samples taken along a transect and bulking same to give a 'composite' soil sample. Soil sampling depths were 0-15cm and 15-50cm at every sampling point, to represent surface and sub-surface soil conditions respectively.

2.2 Water and Bottom Sediment

Samples for water and sediment quality and hydrobiology studies were collected from representatives of the different available waterbodies in the study area. These include various surface waters encountered in the area, and hand-dug wells.

Most of the selected sampling stations are located close to the pipeline right-of-way (ROW) as much as possible. Most of the others occur within the buffer zone of the ROW but within the drainage basin of the study area.

Because the investigated waterbodies were generally shallow (less 5m) and apparently well mixed, only one water sample was collected per sampling station, and this was from just below (ca. 5cm) the surface level. Samples were drawn from the hand-dug wells using the draw-containers used by the well owners (which were either an improvised rubber container or a small plastic bucket).

Separate water samples were collected for the following determinations: dissolved oxygen, BOD_5, oil and grease/total petroleum hydrocarbon, microbiology, heavy metals, and the other physico-chemical analyses, all using the bottle containers recommended by APHA (1995), FEPA (1991) and DPR (2002) as applicable. Samples for dissolved oxygen and BOD_5 were collected in 250ml glass reagent bottles (commonly referred to as "oxygen bottles"). The dissolved oxygen samples were fixed immediately with Winkler's reagents while the BOD_5 samples were wrapped with aluminum foil and incubated in the dark at room temperature (27 ± 2^oC) for five days before being fixed with Winkler's reagents. Samples for heavy metals as well as oil and grease/TPH were collected in a 500ml glass bottles and acidified to pH 2 with concentrated nitric acid and sulphuric acid respectively.

Samples for plankton analyses were collected from the sample site as for water quality analyses but only from surface waterbodies (i.e. excluding the hand-dug wells). Six (6) litres of water sample was collected from each station and strained through a phytoplankton net (fine-meshed of about 0.45 micron size) and reduced to a concentrate volume of about 50ml. The concentrate plankton samples were then fixed in 5% formalin solution (by the addition of suitable amount of formaldehyde). Water microbiology samples were collected directly into a pre-sterilized McCartney bottles.

Sediment samples from Iju River and Ore River were collected using a scoop net. The sediment was scooped into a bucket from where it was carefully spread and sieved through a 1mm mesh size sieve. The organisms, if any, were washed free of debris and sediments, picked out carefully into a bottle and preserved in 10% buffered formalin solution. Roots of macrophytes, namely water hyacinth (*Eichornia crassipes*), water lily (*Nymphaea lotus*), water lettuse (*Pista lotus*) and *Ceratophylum demersum* were also collected at all the sampling stations, vigorously shaken in a bucket and the content filtered through the same 1mm mesh sieve for macro-invertebrate animals.

A second undisturbed grab sample was collected for sediment physico-chemical analysis. Sub-samples of the sediment were collected in aluminum foil for microbiology and TPH analysis, and the rest into a plastic bag for general physico-chemical analyses.

All the samples collected were properly and adequately labelled on the field, providing information on sampling site, date, time, preservative, collector, etc. They were packed in such a way as to avoid contamination and exposure to direct sunlight. Microbiology samples were transported in a cooler with ice blocks to the laboratory base where they were immediately transferred into refrigerator prior to the commencement of bioassay.

2.3 Wildlife and Endangered Species

The wildlife resources associated with these habitats are generally mobile and therefore difficult to assess accurately the fieldwork. Consequently, we relied mainly on interviews with farmers and hunters who were most likely to be familiar with the wildlife of the area through daily interaction. The information obtained from these interviews was supplemented with direct observations whenever possible.

The aim of the interviews was to obtain information on which species still occurred in the area, which species had become scarce in recent years, and which had disappeared or declined in numbers during the respondent's lifetime. Questions asked also included whether animals were hunted for commercial purposes or for the pot, and whether any species were regarded as taboos or objects of veneration. Interviews usually ended with the respondent being asked to identify from Alden, et al. (1995), Dorst & Dandelot (1972) or slides and photographs, the animal he had just described. His ability to do so accurately was taken as a measure of the reliability of the information he had given. Because of the short time available for the study no attempt was made to estimate population sizes of species.

Hunters and farmers were interviewed either singly or in groups while observations were made during morning and/or afternoon stroll, usually along the roads leading to the settlements visited.

2.4 Sample Tracking, Storage and Shipping

2.4.1Quality Assurance Programme

This involved all aspects of the study beginning from representative sample collection to handling, laboratory analysis, data coding, manipulation, statistical analysis, presentation and communication of results.

Sample collection and handling were carried out in accordance with DPR (2002) Guidelines and Standards (Part VIII D). The methods of analyses used were those specified in DPR guidelines and standards and other international analytical standards such as in Standard Methods for Water and Wastewater Analysis (APHA, 1995), *Methods of Soil Analysis* (Page, *et al.* 1987), U.S. Agronomy No 9: *Soil Survey Analytical Continuum* (USDA/SSIR No 42 Version 3.0 of 1996) and Methods of *Soils and Plant Tissue Analysis* (International Institute for Tropical Agriculture (IITA), Ibadan, 1979).

With proper sustained calibration of the instruments and the use of standardized observational procedures, equipment errors were brought to acceptable minimum. The range, true mean and the estimated variance and the number of samples taken were determined so as to establish a reasonable level of confidence in the results obtained.

2.4.2 Sample Preservation and Shipping

Samples meant for total hydrocarbon (THC), Polyaromatic hydrocarbon (PAH), and microbiological analysis determinations were kept on ice - chips immediately after collection. Under cold conditions the samples were shipped to the laboratory for further storage and analysis. In the laboratory, the samples were kept in the refrigerator while laboratory analyses were on. Water samples with short or no holding time were analyzed in-situ as described in sub-section 2.2.5.

2.4.3 Analytical Quality Control (AQC)

During laboratory analyses, likely sources of errors were: contamination from reagents/materials; lack of sensitivity by the instruments; lack of proper calibration-human error, and errors in data reporting. Efforts were made to minimize these probable sources errors.

2.4.4 Control of Data Storage and Treatment

ERML recognizes the fact that every stage of data handling increases the risk of introduced errors. To reduce such errors, direct electronic recording and data transfer processes were used. In cases where data were manually transcribed, they were normally checked against the original for errors.

Another common problem is loss of data due to accidental erasure of computer files. To guard against this, raw, unprocessed data were kept on a master file, controlled by the use of a password system. Generally, back-up files were created for every study and were regularly updated only by authorized personnel.

3.0 ANALYTICAL METHODS

3.3.1 Soil Analysis

3.3.1.1 Physical Laboratory Methods

Soil samples were air-dried at room temperature and the dried samples were gently crushed with a ceramic mortar and pestle after which they were sieved through 2mm mesh sieves. The less than 2mm size fraction was stored and sub-sampled for the following determinations.

3.3.1.2 Chemical Laboratory Methods

3.3.1.2.1Soil pH

This was determined in 1:1 soil-to-water suspension with a glass electrode pH meter. For soil samples high in organic matter, a soil-water ratio of 1:5 was used (Page *et al.*, 1987).

3.3.1.2.2 Organic carbon

This was determined by the loss on ignition method (Page *et al.*, 1987)

3.3.1.2.3 Biological Methods

3.3.1.2.3.1 Surface Fauna

In the laboratory, the soil samples were processed for microarthropod extraction in the modified Berlese – Tullgren extractor where a metal cylinder is used to concentrate heat and light from a 40-Watt bulb onto the soil core in a sample container whose base is a 2mm wire mesh. The sample container rests on a steep sided funnel whose angle of inclination to the horizontal is about 60^0. This ensures unhindered journey of the arthropods through the funnel into the collecting tube below.

The collecting tube contained 70% ethanol, which preserves the specimens for a fairly long period without altering the taxonomic features of the specimen. A few drops of Lactic acid were added to the ethanol in other to prevent the growth of fungi.

The extraction lasted for seven days after which the specimens were removed. When the extraction was on, care was taken not to disturb the extractor so as to avoid contamination of the content of specimen bottles with soil particles and debris. Nocturnal insects were prevented from contaminating the content of collecting tubes by making the extractor airtight. Illustrations and detailed descriptions of this extractor can be found in Badejo (1982).

After extraction, the contents of the collecting tubes were emptied into a petri dish under the dissecting microscope for sorting and identification. Identified specimens were picked with the aid of a camel hairbrush into a labelled tube containing 70% ethanol. Each taxonomic group was put in a different tube and counted simultaneously.

The brush was always examined in the field of view under the dissecting microscope to ensure that specimens dropped into the tubes as well as other already in the tubes were not returned into the sorting dish.

The extracted microarthropods were carefully sorted, counted and identified to generic level where possible, using keys and illustrations provided in Balogh and Balogh (1992) and was confirmed in the laboratory using the reference of Tian and Badejo (1999).

3.3.1.2.3.2 Microbial analysis

The following microbial analyses were carried out for the water, soil and sediment samples;

- Total heterotrophic bacterial count
- Total heterotrophic fungal count
- Hydrocarbon degrading bacterial and fungal counts
- Total coliform count
- Sulphate reducing bacterial count
- Identifiaction of the microbial isolates.

For the microbial counts, serial dilution of the water, soil and sediments samples were carried out in sterile normal saline and 1 ml of the of the appropriate dilutions were plated using the standard pour plate techniques as described by Seeley and Vandenmerk (1981). Nutrient agar (Oxoid) and Plate count agar (LabM) were used for the bacterial count, while potato dextrose agar containing 0.05% chloramphenicol was used for the fungal assay. The heterotrophic bacterial plates were incubated aerobically at 28 ^{o}C for 48 hours, while the fungal plates were incubated at 28 ^{o}C for 7 days. At the end of the incubation period, plates containing between 30 and 300 colonies were selected for estimation.

Total coliform was determined using the Most Probable Number (MPN) technique and eosin methylene blue agar (EMB) for the confirmation of the presence of *E. coli*. Hydrocarbon degrading bacteria and fungi counts were determined as described by Mills et al (1978) and Mulkins and Stewart (1974). Crude oil was used as the test hydrocarbon. Bacterial identification was done as described by Bergey's (1977), and Cowan and Steel (1974), while fungal identification was done as described by Talbot (1978).

3.3.2 Water and Sediment Quality and Hydrobiology

3.3.2.1 Physical Laboratory Methods

The physical analyses carried out on water samples in the laboratory were Total Suspended Solids (TSS), Turbidity and Colour. TSS was determined gravimetrically on the filtered samples dried at 105 ± 2^{o}C to constant weight. Apparent Turbidity was determined on unfiltered samples colorimetrically against nephelometric turbidity standard (NTU). Apparent colour was also determined colorimetrically on unfiltered samples against Platinum-Cobalt (Pt-Co) standards and expressed in Pt-Co units.

The physical laboratory analysis carried out on sediment samples was particle size distribution to determine the textural composition of the sediments. Like soil samples, this and other analyses for sediments were based on air-dried samples. Air-drying of sediment samples was carried out at room temperature (27 ± 2^{o}C) and in a spacious area of the laboratory. The dried samples were gently crushed with ceramic mortal and pestle after which they were sieved through 2mm mesh sieves. Particle size analyses was based on the sieved samples using the hydrometer method. Based on the estimated percentage contribution of the three major sediment particles (% sand, % silt, and % clay) the textural class of the investigated sediments was determined.

Sediment pH was determined on both aqueous sediment suspensions (H_2O 1:2) as well as in suspension of a neutral salt (KCl 1:2).

3.3.2.2 Chemical Methods

The chemical determinations carried out on water samples collected are grouped with outline of the analytical methods employed given in Table 3-1. The methods can be grouped broadly into two categories viz: instrumental methods and non-instrumental methods. The instrumental methods include the use of colorimeters, Atomic Absorption spectrometry, Gas Chromatographic and flame analysers. The non-instrumental methods were mainly titrimetric (or volumetric). The respective equipment were handled only by competent analysts following strictly manufacturers guidelines. Chemical determinations were carried out on samples within the holding time of each determination. Samples were adequately preserved prior to chemical determinations.

The same chemical analytical methods of determinations were used for soil and sediments. For some parameters, COD and TOC the same methods were employed for water, soil, and sediments with very little or no modification. Highlights of these methods are given in Table 3-1.

Table 3-1:

Analytical methods of chemical determination of water sample

Parameters	**Methods**	**Reference**
Major Anions		
Total Alkalinity	Titrimetric (Acid-base Method)	APHA 2310 (STD Method, 19th ed. 1995)
Sulphate	Turbidimetric (Barium Chloride)	APHA 4500-Si (STD Method, 19th ed, 1995)
Chloride	Titrimetric (Molar titration)	
Major Cations		
Calcium	Complexiometric	
Magnesium	Complexiometric	
Sodium	Flame Analyser	Jones (1988)
Phosphorus	Flame Analyser	Jones (1988)
Organic &Oxygen parameter		
Dissolved oxygen	Titrimetric Method	APHA 422 (STD Method 19th ed., 1995)
BOD_5	Titrimetric Method	APHA 422 (STD Method 19th ed., 1995)
COD	Titrimetric Method	APHA 5220C (STD Method 19th ed., 1995)
TOC	Dichromate wet oxidation	APHA 422 (STD Method 19th ed., 1995)
TPH	Gas Chromatography	ASTM 422 (STD Method 19th ed., 1995)
THC	Gas Chromatography	
PAH	Gas Chromatography	
Heavy Metals	Atomic Absorption Spectrophotometer (AAS)	
Nutrient Compounds		
Silica	Molybdo-Silicate Method	APHA 4500-Si D(STD Methods 19th ed)
PO_4^-P (Available)	Ascorbic Acid Method	APHA 4500-PE (STD Methods 19th ed)
PO_4^-P (Total	Persulphate digestion/Ascorbic acid	APHA 4500-P B5/4500-PE (STD Methods 19th ed 1995)
NO_2^-N	Cadmium reduction Method	APHA 4500-NO_3 E (STD Methods 19th ed)
NO_3–N	Colorimetric Method	APHA 4500-NO_2 B (STD Methods 19th ed)
NH_3–N	Nesslerization	APHA 4500 – NH_3 (STD Methods 19th ed)

3.3.2.3 Biological Methods

The composition and cell count biomass of plankton flora (phytoplankton) and fauna (zooplankton) were based on microscopic analysis of the concentrate plankton samples collected. The concentrate samples were examined under various magnifications of the compound light microscope. The recorded plankters were measured and drawn to scale and identified using available taxonomic keys including APHA (1995). Phytoplankton biomass was based on cell counts (expressed by unit volume of the original water sample).

The biomass of phytoplankton was also determined based on the concentration of photosynthetic pigments, notably chlorophylls, and phaeophytin. These pigments were extracted in 90% acetone and measured spectrophotometrically for chlorophyll a, b, c, and phaeophytin according to APHA (1995).

In the laboratory, each of the macrobenthic samples was emptied into a petri-dish and examined under the dissecting microscope. The recorded organisms were sorted out, identified and counted. Identification was done as much as possible to species level using relevant literature. Where fragmented animals were found, only those with heads were counted. The determination of diversity (species richness and diversity indices) of the original macrobenthic communities were based on the measurements made. Taxa richness was computed using Margalef's index (D) expressed as

$$D = \frac{S-1}{\text{In}N}$$

where S = number of taxa

N = total number of all individuals

In = natural logarithm

General species diversity using Shannon Wiener (H) index was computed as

$$H' = \frac{N\log N - \sum_{i=1}^{k} ni\log ni}{N}$$

where: n = total number of individuals

ni = number of individuals in species

k = total number of species

Evenness index (E) which expresses the degree of uniformity in the distribution of individuals among the taxa in the collection was also calculated as follows::

$$E = \frac{H'}{H_{max}}$$

where: H' = Shannon-Wiener index

H_{max} = maximum expected diversity expressed as logs

S = number of taxa

Besides the application of the diversity indices, interstation comparisons were carried out to test for significant differences in the faunal abundance using one-way analysis of variance (ANOVA) according to Zar (1984).

4.0 Results

4.1 Soil

The coordinates of the various soil sampling points and brief descriptions of the habitat types are presented in Table 4.1

Table 4.1
Soil Sampling Points, their coordinates and brief descriptions of the habitat types

Soil Investigation Points	**Coordinates of the Soil investigation Points**		**Habitat Type**	**Brief Description of the Associated Soils.**
	Latitudes (N)	Longitudes (E)		
PT 1 A B C D	06° 42' 54" 06° 42' 55" 06° 42' 53" 06° 42' 55"	003° 12' 08" 003° 12' 08" 003° 12' 08" 003° 12' 09	Mosaic farmland mixed with forest and fallowland inside cassava (farmland). Secondary forest inside cassava (farmland) Fallowland (possibly 1½ - 2yrs). (Eronpe in Ota) Class 7 Habitat	The soils are brownish to yellowish, well drained, with crumb surface soil structure, generally firm, sandy clay loam. This habitat is a mosaic of secondary forest, with fallow and farmland. A building was sited near the vegetation point and a rural road passes through.
PT 2 A B C D	06º 40' 50" 06º 40' 50" 06º 40' 51" 06º 40' 51"	003º 12' 06" 003º 12' 07" 003º 12' 06" 003º 12' 06"	Onipanu Mosaic of farmland/Fallow/Built up area Fallow Farmland Farmland Fallow	Deep well drained sand clay loam soils found within predominantly built-up area.
PT 3 A B C D	06º 37' 25" 06º 37' 27" 06º 37' 25" 06º 37' 25"	003º 08' 40" 003º 08' 38" 003º 08' 39" 003º 08' 39"	Oko-Omi Area Forest (secondary forest) Forest Forest Forest	Deep well drained, brownish to reddish sandy clay loan soil under secondary forest.
PT 4 A B C D	06º 32' 33" 06º 32' 34" Close 06º 32' 34"	003º 08' 17" 003º 08' 16" Canopy 003º 08' 17"	Degraded Raffia swamp Igbesa Area Degraded Raffia swamp Degraded Raffia swamp Degraded Raffia swamp	Swamp soil carrying highly degraded raffia palms. The undergrowth are thick comprising of timbers and shrub species.

4.1.1 Physico-chemistry

Degraded Raphia Swamp Around Igbessa (Transect PT 4): The soils in this swampy habitat are generally poorly drained, very poorly aerated (due to water-logging), massive in structure, contain high content of partly decomposed to almost un-decomposed organic materials and were flooded. Table 4.2 shows the particle size distributions and texture of representative soils from the habitat. The soils are sandy loam in texture with high total %sand, ranging from 60.5% to 78.2%. The high clay content predisposes the soils to be aggressive to buried metals.

Table 4.2

Physical Characteristics of Soil Samples from Degraded Raphia Swamp

		% Sand Fraction(mm)							
Field Code	VCS	CS	MS	FS	VFS	%T. Sand	%Silt	% Clay	Texture
	1mm	0.5mm	0.25mm	0.106mm	<0.106mm				
PT4/A/0-15	1.47	12.07	26.61	24.86	4.65	69.7	3.2	27.1	Sandy clay loam
PT4/A/15-50	1.49	10.80	22.20	21.79	4.24	60.5	4.8	34.7	Sandy clay loam
PT4/B/0-15	0.89	9.15	26.31	23.26	5.75	65.4	9.2	25.4	Sandy clay loam
PT4/B/15-50	1.57	11.19	22.52	22.05	6.56	63.9	0.2	35.9	Sandy clay
PT4/C/0-15	1.20	10.52	27.63	27.65	6.48	73.5	1.2	25.3	Sandy clay loam
PT4/C/15-50	1.76	10.00	19.69	20.11	5.20	56.7	3.7	39.6	Sandy clay
PT4/D/0-15	1.23	10.76	27.30	26.68	5.94	71.9	2.0	26.1	Sandy clay loam
PT4/D/15-50	1.06	10.51	23.91	21.74	5.34	62.6	1.1	36.3	Sandy clay
PT4/Comp/0-15	4.26	18.23	29.94	21.23	4.51	78.2	0.6	21.2	Sandy clay loam

There is sufficient vegetation cover and the relief is generally low. Erosion susceptibility of the swampy soils is therefore low but the soils can easily be compacted, puddled and degraded if worked when wet.

The pH of soils is strongly acidic, ranging from 4.3 to 5.68. TOC is low to medium, ranging from 1.26 to 8.95% (Table 4.3). Oil and grease levels were moderately high, ranging from 2.84 to 17.22ppm, but much lower than the DPR threshold. Vvvery high levels of Fe were recorded, while Ni, Zn and Mn are medium; the other heavy metals analyzed occur in traces.

Table 4.3

Chemical Characteristics of Soil Samples from Degraded Raphia Swamp Habitat

			O&G	Na	K	Cu	Pb	Cr	Cd	Ni	Zn	Fe	Mn	Mg	Ca
Field Code	pH	TOC (%)	(ppm)	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PT4/P1/15-50	4.30	3.23	3.68	209.15	130.67	4.03	19.10	5.24	<0.02	33.99	16.03	15574	126.81	106.56	2.40
PT4/P2/0-15	4.88	5.74	5.37	230.39	150.75	7.31	19.10	5.24	<0.02	35.98	19.78	22882	118.19	110.84	<0.02
PT4/P2/15-50	4.85	3.59	3.81	166.68	136.81	5.12	19.10	5.24	<0.02	31.99	17.45	18749	114.04	134.43	<0.02
PT4/P3/0-15	5.68	5.02	7.91	209.15	133.12	7.86	19.10	7.49	<0.02	35.98	21.20	21505	95.21	125.14	<0.02
PT4/P3/15-50	5.16	8.07	7.07	272.86	124.52	4.03	14.66	3.00	<0.02	31.99	16.16	14961	92.65	153.02	3.23
PT4/P4/0-15	5.16	3.95	17.22	272.86	183.13	5.67	27.98	5.24	<0.02	41.98	17.71	20816	67.43	118.71	<0.02
PT4/P4/15-50	4.72	5.74	3.99	124.21	90.91	1.29	10.22	<0.02	<0.02	26.00	12.16	10828	72.54	123.47	<0.02
PT4/C/15-50	4.73	1.26	2.84	251.62	122.47	4.03	19.10	5.24	<0.02	35.98	16.42	19094	57.22	110.13	<0.02

<u>Secondary Forest Around Oko-Omi (PT3)</u>: Vegetation in this area consists of secondary regrowth species of freshwater forest trees. While some of the forests are still very thick, with closed or almost closed canopies, there is abundant evidence of their having been altered by anthropogenic activities.

Soils in this habitat are deep, well drained, brownish to reddish sandy clay loam. Table 4.4 shows the particle size distribution of soil samples from within the habitat. The soils have between 71 and 78% sand, dominated by medium (27.25-33.05%) and fine (19.72 to 23.01%) sand fractions. Since the soils are predominantly fine to medium sand in texture and the sand fraction is dominated by quartz coupled with good internal drainage, good aeration regime and low moisture holding ability, they are not expected to be aggressive in reaction to buried metals.

Table 4.4

Physical Characteristics of Soil Samples from Secondary Forest

		% Sand Fraction(mm)							
Field Code	**VCS**	**CS**	**MS**	**FS**	**VFS**	**%T. Sand**	**%Silt**	**% Clay**	**Texture**
	1mm	**0.5mm**	**0.25mm**	**0.106mm**	**<0.106mm**				
PT3/P1/0-15	2.63	14.37	27.25	22.40	4.35	71.0	4.1	24.9	Sandy clay loam
PT3/P2/0-15	3.43	21.49	28.89	20.10	4.01	77.9	1.2	20.9	Sandy clay loam
PT3/P3/0-15	1.87	15.30	30.28	19.72	4.26	71.4	8.6	20.0	Sandy clay loam
PT3/P4/0-15	1.83	16.40	33.05	23.01	3.67	78.0	5.8	16.2	Sandy loam

Soils here are distinctly acidic with pH between 4.64 and 5.65 and generally contain low TOC, ranging between 4.49 and 5.56% (Table 4.5). Since the soils are sandy in texture, well drained, highly porous, with low capacity to retain moisture, together with the very low content of TOC, they are not expected to be physically and chemically aggressive to metals that may be buried in them. The level of oil and grease in the soils is low (4.12 to 6.22ppm) and is way below the DPR limit of 50µg/g. Heavy metal analysis reveals that iron is high, manganese, magnesium and sodium medium, while lead and zinc are relatively low, the other metals occur in traces (see Table 4.5).

Table 4.5

Chemical Characteristics of Soil Samples from Secondary Forest

			O&G	Na	K	Cu	Pb	Cr	Cd	Ni	Zn	Fe	Mn	Mg	Ca
Field Code	pH	TOC (%)	(ppm)	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PT3/P1/0-15	4.68	5.56	4.41	102.97	113.86	2.93	10.22	3.00	<0.02	26.00	12.54	12646	117.23	118.23	2.40
PT3/P2/0-15	4.64	4.49	6.22	145.44	117.96	1.29	10.22	5.24	<0.02	22.00	11.64	11613	87.86	107.03	<0.02
PT3/P3/0-15	5.24	5.38	4.12	102.97	172.06	2.38	14.66	0.76	<0.02	35.98	13.06	11268	90.74	118.95	2.40
PT3/P4/0-15	5.65	5.02	6.22	81.74	129.44	0.74	14.66	<0.02	<0.02	26.00	11.12	9202	99.67	124.43	2.40

<u>Mosaic of Bush Fallow/Farmland/Built-up Area (PT2 and PT1)</u>: This habitat type is generally wide-spread in the inland area, especially close to big towns along the proposed pipeline ROW. In this habitat, the proposed pipeline route passes, sometimes, very close to settlements, across tarred and earth roads, farmlands and fallow plots.

Soils in this habitat are typical of upland, well drained, humic brownish to yellowish red, granular to crumb, slightly sticky, plastic wet, firm moist, sandy loam surface soils, with distinctly brownish red, sub-angular blocky, mottled – free, friable moist sub-soils. The absence of mottles and uniform subsoil colour up to 100cm soil depth indicate that groundwater table is definitely beyond this depth of investigation. It can therefore be inferred that buried metals within 100-cm soil depth may not experience annual fluctuation in the groundwater table. This implies that metals buried within this soil depth (0-100cm) may not experience annual submergence in groundwater. It further indicates that within this depth of the soils, gaseous exchange between the soils and the atmosphere will not be adversely affected by seasonal changes throughout the year. Table 4.6 gives the particle size distribution of representative soil samples taken from the habitat.

Table 4.6
Physical Characteristics of Soils from PT 1 and PT 2

		% Sand Fraction(mm)							
Field Code	VCS	CS	MS	FS	VFS	%T. Sand	%Silt	% Clay	Texture
	1mm	0.5mm	0.25mm	0.106mm	<0.106mm				
PT2/P1/0-15	1.78	10.58	22.19	18.83	3.83	57.2	11.4	31.4	Sandy clay loam
PT2/P2/0-15	0.94	9.49	23.51	22.52	9.39	65.9	9.7	24.4	Sandy clay loam
PT2/P3/0-15	2.90	17.25	34.18	21.32	2.85	78.5	3.3	18.2	Sandy loam
PT2/P4/0-15	2.40	12.13	21.74	17.31	3.87	57.5	6.1	36.4	Sandy clay
PT1/P1/0-15	2.05	16.37	24.97	23.40	5.07	71.9	2.6	25.5	Sandy clay loam
PT1/P2/0-15	4.37	18.37	29.59	21.59	3.74	77.7	6.2	16.2	Sandy loam
PT1/P3/0-15	2.47	14.64	29.66	26.31	5.23	78.3	3.7	18.0	Sandy loam
PT1/P4/0-15	3.08	19.35	30.83	20.09	3.66	77.0	8.2	14.7	Sandy loam

Although the sand content accounts for between 57 and 78% of the total soil separates, nevertheless, the sand is mainly medium (21.74 to 34.18%) and fine (17.31 to 26.31%) sand fractions.

The soils were classified as ultisols (Amusan and Ashaye, 1989) meaning low base-status forest soils. The relief is generally undulating and this can predispose the soils to water erosion, unless adequate measures are put in place.

Morphologically, soils here are highly ferruginized with pH between 5.06 and 6.85 and low TOC of between 4.49 and 5.20% (Table 4.7). The accumulation of iron (in Fe^{3+} form) in the soils is an evidence of good internal drainage and aeration. The chemical properties of the soils suggest that they cannot be chemically aggressive to metals that may be buried in the soils. The oil and grease content of the soils is between 3.3 and 10.45ppm.

Table 4.7
Chemical Characteristics of Soils from PT 1 and PT 2

				Na	K	Cu	Pb	Cr	Cd	Ni	Zn	Fe	Mn	Mg	Ca
Field Code	pH	TOC (%)	O&G(ppm)	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PT2/P1/0-15	5.06	5.20	6.41	177.30	247.06	11.69	23.54	5.24	<0.02	41.98	21.20	12646	125.85	133.72	2.40
PT2/P2/0-15	5.84	4.84	10.45	124.21	164.27	7.31	14.66	5.24	<0.02	27.99	14.61	10235	167.03	134.19	4.90
PT2/P3/0-15	5.87	4.49	10.45	124.21	86.40	4.57	10.22	5.24	<0.02	26.00	15.26	9030	171.18	115.61	2.40
PT2/P4/0-15	5.54	4.84	3.30	81.74	200.34	7.86	14.66	5.24	<0.02	29.99	21.71	11096	96.48	113.70	2.40
PT1/P1/0-15	6.85	6.28	4.53	262.24	152.47	2.93	14.66	3.00	<0.02	24.00	13.19	10752	174.70	176.84	16.59
PT1/P2/0-15	6.48	4.66	5.15	156.06	106.77	1.83	10.22	0.76	<0.02	22.00	11.38	8341	149.48	144.44	9.08
PT1/P3/0-15	6.54	4.84	4.52	166.68	176.57	1.29	14.66	3.00	<0.02	24.00	10.61	9202	149.80	140.87	5.74
PT1/P4/0-15	6.45	4.49	3.57	71.12	54.85	3.48	10.22	7.49	<0.02	24.00	12.29	8857	156.50	122.76	4.07

4.1.2 Biology

4.1.2.1 Microarthropods

Results of soil arthropod survey in the area are depicted in Table 4-.8 The most abundant taxonomic group of soil microarthropods in the study area is Acarina. In all, 12 groups of arthropods were recorded over the sampling zone. Apart from Acarina, the other arthropods groups, which were recorded in the area include: Araneida, Schizopeltida, Isopoda, Diplura, Psocoptera, Hemiptera and Coleptera larva. In general however, the freshwater swamp habitat supported the highest microarthropod populations while the sandy beach supported the least population. Using the microarthopod population densities recorded in the area (2,833 – 4,000 per m^2) as an index, it could be inferred that the soils in the area may not be agriculturally viable. In productive soils of the western region of Nigeria, densities of soil mites (Acarina) alone reach a peak of about 80,000 per m^2 in the wet season (Badejo and Lasebikan, 1988; Badejo, 1990, Badejo, 1999).

The most abundant acarine group in terms of species diversity were the acarina. However, in terms of population, the formicidae (ants) were most populous, recording populations of 11,850individuals per square meter of soil in the grassland (PT1). The general outlook of the results confirm the fact that farmlands and forested areas generally have higher populations of soil arthropods, compared with the swampy terrains, where waterlogging and absence of oxygen contrive to make the edaphic environment unattractive for arthropods.

Table 4-8

Mean numbers of soil microarthropods extracted from the soil in different habitat types. (Mean based on four sampling units).

Microarthropod Group	Coconut near swampy area	*Rhapia* with scattered trees and shrubs	Grassland with few shrubs	Freshwater swamp dominated by *Rhappia*
ACARINA				
Oribatida				
Indotritia sp.	0	0	0	1
Annectacarus sp.	0	2	0	3
Mixacarus sp.	0	0	0	1
Bicyrthermannia nigeriana	0	1	0	6
Epilohmania sp.	0	0	0	6
Carabodes sp.	0	0	0	0
Aokiella sp.	0	0	0	1
Dolicheremeus sp.	0	0	2	0
Tectocepheus sp.	1	0	0	0
Galumnidae	0	1	1	1
Cepheidae	1	2	0	19
Belbidae	0	0	0	2
Gamasida	1	0	1	0
Polyaspidae	1	1	0	1
Parasitidae	1	1	0	2
Uropodidae	0	0	0	2
Trachyuropodiade	1	0	0	1
Actinedida	0	1	0	0
Symphylla	0	1	1	1
Pseudoscorpionida	0	1	0	1
Schizopeltida	0	0	1	2
Isopoda	0	1	1	2
Chilopoda (Centipedes)	1	1	0	1
Diplura (*Japyx*)	1	1	0	1
Collembola (Springtails)	0	1	1	1
Psocoptera	5	3	2	2
Coleoptera (Beetles)	1	1	1	6

Coleoptera larva	1	0	2	2
Formicoidea (Ants)	1	1	0	14
Total	**16**	**20**	**13**	**79**
Density (No. per m^2)	**2,560**	**3,000**	**2,833**	**11,850**

4.2.3 Microbiology

The results of microbial analyses for soil samples are shown in Table 4-9. Total heterotrophic bacterial count ranged in the order of 1.1 x 10^7 to 6.5 x 10^7 cfu/g. Fungal densities were lower, in the range of 10^5 cfu/g. Hydrocarbon degrading bacterial count of the soils varied in the order of 10^4 to 10^6 cfu/g, while their fungal counterpart were observed to vary between 65 and 1.9 × 10^3 cfu/g. The sulphate reducing bacterial populations were generally low and ranged between 0 and 10^3 cells/g.

Table 4-9.
Average microbial densities of soil samples from WAGP project area

S/N	Sample code	THB (cfu/g)	HDB (cfu/g)	SRB (cells/g)	THF (cfu/g)	HDF (cfu/g)
1	PT1 0 -15	6.5 × 10^7	8.9 × 10^4	10^1	1.8 × 10^5	1.7 × 10^2
2	PT1 15 - 50	2.2 × 10^7	5.8 × 10^4	Nil	2.6 × 10^5	1.2 × 10^3
3	PT2 0 -15	4.4 × 10^7	3.8 × 10^5	Nil	2.6 × 10^5	65
4	PT2 15 - 50	1.1 × 10^7	5.4 × 10^5	Nil	1.8 × 10^5	92
5	PT3 0 - 15	5.3 × 10^7	3.2 × 10^6	10^2	4.5 × 10^5	1.0 × 10^2
6	PT3 15 - 50	5.0 × 10^7	2.1 × 10^6	10^3	4.1 × 10^5	2.1 × 10^2
7	PT4 0 -15	5.7 × 10^7	2.2 × 10^5	Nil	2.7 × 10^5	1.9 × 10^3
8	PT4 15-50	5.6 × 10^7	3.0 × 10^4	10^3	6.4 × 10^5	3.2 × 10^2

Keys:

THB - Total heterotrophic bacteria; **HDB** - Hydrocarbon degrading bacteria; **SRB** – Sulphate reducing bacteria; **THF** – Total heterotrophic fungi; **HDF** – Hydrocarbon degrading fungi.

The microbial species isolated from the soil samples includes such bacteria species as *Corynebacterium spp., Pseudomonas aeruginosa, Klebsiella pneumoniae, Micrococcus luteum, Desulfotomaculum spp., Bacillus subtilis, Bacillus polymyxa, Streptomyces spp.,* *Aeromonas spp., Arthrobacter spp., Sarcinia spp., Proteus mirabilis, Pseudomonas fluorescence* and *Flavobacterium spp*. Fungal isolates included species such as *Microsporium audovinii, Microsporium gypseum, Aspergillus flavus, Aspergillus niger, Cladosporium spp., Scopulariopsis brevicaulis, Penicillium notatum, Rhodotorula spp.,* and *Rhodotorula spp.*

The presence of hydrocarbon degrader populations in the soils indicate that the general area has the potential to intrinsically bioremediate, in the event of an oil spill. Most of the isolates identified in this study, especially those belonging to the genus *Pseudomonas* are renowned for their versatility (Golovleva et al., 1992), and their roles in the bioremediation of hydrocarbon-polluted systems have been extensively documented.

4.3 Water and Sediment Quality

The stations where water samples were collected and their corresponding coordinates are shown in Table 4.10

Table 4.10
Water Sampling stations and their co-ordinates

S/N	STATION ID	WATER BODIES	LONGITUDE	LATITUDE
1	S1	IJU RIVER	003^{0} 08.879'E	06^{0} 40.968'N
2	S2	ORE RIVER	003^{0} 07.506'E	06^{0} 36.035'N
3	S3	ORE RIVER	003^{0} 09.805'E	06^{0} 35.558'N
4	S4	ORUKU RIVER	003^{0} 11.499'E	06^{0} 37.291'N
5	S5	OLUWO RIVER	003^{0} 18.160'E	06^{0} 42.655'N

4.3.1 Water and Sediment Physico-chemistry

4.3.1.1 Water Physico-chemistry

The results of water samples analyses are shown in the Table 4.11

Table 4.11
Results of Water Analyses

SAMPLE ID	pH	DO mg/l	Na mg/L	K mg/L	Cu mg/kg	Pb mg/kg	Cr mg/kg	Cd mg/kg	Ni mg/kg	Zn mg/kg	Fe mg/kg	Mn mg/kg	Mg mg/kg	Ca mg/kg
S1	6.5	4.5	7.97	3.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	2.19	0.55	1.18	1.58
S2	6.8	5.2	6.81	2.48	<0.02	<0.02	<0.02	<0.02	<0.02	0.044	1.07	0.40	0.55	0.45
S 3	7.2	4.8	7.13	2.17	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.64	<0.02	1.02	1.16
S4	6.9	4.9	6.81	2.32	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	1.33	0.13	0.45	0.50
S5	6.8	5.1	4.25	0.26	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.75	0.55	0.46	0.66

The waterbodies were generally fresh, with pH values ranging from slightly acidic to neutral. Dissolved oxygen values ranged between 4.5mg/l and 5.3mg/l. These values, though lower than what would normally obtain in larger surface waters, is above the threshold of 4mg/l required to sustain aquatic life.

Salinity indicator cations such as Na, K, Ca and Mg were present at levels expected for freshwaters. Of the heavy metals, only iron (Fe) was present at a value above 1mg/l, ranging between 0.64 and 2.19mg/l. All others were just barely detectable.

In general, the values obtained for monitored parameters are all indicative of unpolluted waterbodies.

4.3.1.2 Sediment Physico-chemistry

The physical characteristics of sediment samples from the waterbodies are presented in Table 4.12

Table 4.12

Physical Characteristics of Sediment samples from the Project Area

Field Code	VCS 1mm	CS 0.5mm	MS 0.25mm	FS 0.106mm	VFS <0.106mm	%T. Sand	%Silt	% Clay	Texture
S1	4.34	11.06	19.83	44.39	7.20	86.8	1.8	11.4	Clayey sand
S2	2.24	9.10	20.91	33.53	16.51	82.3	0.3	17.4	Clayey sand
S3	2.95	11.72	22.27	33.68	15.94	86.5	0.7	12.8	Clayey sand
S4	4.07	17.91	37.12	26.72	4.09	89.9	0.8	9.3	Sand
S5	5.39	25.45	36.58	14.27	2.71	84.4	1.4	14.2	Clayey sand

The sediments were predominantly sandy, having more than 80% total sand fraction in all cases, but composed of mostly fine, medium and coarse sand fractions. Textural classification of the sediment samples was therefore clayey sand to sand.

The chemical characteristics of sediment samples are shown in Table 4.13. the sediment were all distinctly acidic, ranging in pH from 5.13 to 5.89. TOC was low in all samples, ranging from 0.11 to 2.33%. This is hardly unexpected given the predominantly sandy nature of the sediments. Oil and grease values were moderately high ranging from 5.12 to 8.15ppm.

Cations (Na, Ca, K, Mg) were moderately present at levels that indicate that no anthropogenic pollution has occurred. Iron (Fe) was detected in substantial quantities, while Pb, Mn, Zn and Ni were moderately present. All other metals were detected in trace quantities.

Table 4.13

Chemical Characteristics of sediment from the project area

Field Code	pH	TOC (%)	O&G (ppm)	Na mg/kg	K mg/kg	Cu mg/kg	Pb mg/kg	Cr mg/kg	Cd mg/kg	Ni mg/kg	Zn mg/kg	Fe mg/kg	Mn mg/kg	Mg mg/kg	Ca mg/kg
S1	5.13	0.11	8.15	42.48	34.44	<0.02	5.79	<0.02	<0.02	16.01	4.28	1587	27.53	34.04	<0.02
S2	5.23	2.33	7.99	83.89	55.34	<0.02	10.22	0.76	<0.02	20.00	9.19	6753	28.80	34.94	<0.02
S3	5.78	0.90	5.95	90.26	59.03	0.19	10.22	0.76	<0.02	22.00	27.01	5547	31.04	37.13	3.99
S4	5.89	0.18	5.12	35.05	20.70	<0.02	10.22	<0.02	<0.02	20.00	12.29	2534	16.03	23.41	<0.02
S5	5.16	0.36	5.57	82.83	55.13	0.19	10.22	<0.02	<0.02	22.00	9.96	8131	24.33	32.18	<0.02

4.3.3 Biolology

4.3.2.1 Macrobenthos

These are organisms larger than 1.0mm in size that live either wholly, partly on or attached to the sediment. They include a diverse assemblage of plants and animals whose distribution is dependent upon many environmental variables. i.e. physical, chemical and biological factors.

Results of macrobenthic fauna from the study area is listed in Table 4.14. A total of 45 individuals in 17 recognizable species were identified. These are in the major groups; Oligochaeta (3 species) and Insecta, which consisted of the order Diptera (7 species), Coleoptera (3 species), Anisoptera (2 species), Hemiptera (1 species) and Neuroptera (1 species). The order Diptera accounted for 53.3% of the total population. The abundance at the various stations ranged from 1 (at S36) to 16 (at S27) and 17 (at S34) individuals per station. Application of ANOVA shows that S27 and S34 had a significantly higher population ($P < 0.05$) than other stations. Species richness varied between 1 and 9 per station, while diversity was low at S36, S33 and S24 in view of the few number of species and individuals encountered, there was however fairly even distribution of the population of the individuals at the various stations except at S36, as reflected in the high evenness values (0.91 – 0.97).

The presence of a large number of chironomid larvae (53.3%), organisms which are known to be particularly tolerant to organic pollution is an indication that the slow running forest streams in the study area has a high level of organic enrichment.

Table 4.14

Species Composition, Diversity, Distribution and Relative Abundance

TAXONOMIC LIST		SAMPLING STATIONS						
	S	**S24**	**S27**	**S33**	**S34**	**S36**	**TOTAL**	**%**
ANNELIDA								
OLIGOCHAETA	**3**							**8.9**
Eiseniella tetrahedral		1		1			**2**	
Nais communis				1			**1**	
Stylaria fossularis		1					**1**	
INSECTA								
ANISOPTERA	**2**							**8.9**
Cordulid sp					1		**1**	
Erythemis sp			2		1		**3**	
COLEOPTERA	**3**							**24**
Copelatus sp			1		5		**6**	
Hydrocanthus sp					3		**3**	
Hydrophilus sp					2		**2**	
DIPTERA	**7**							**53**

Chironomus fractilobus			1	2	3		**6**	
Chironomus transvaalensis			2	1			**3**	
Clinotanypus maculates		1	5		1		**7**	
Corynoneura sp		2			1		**3**	
Cricotopus sp			1				**1**	
Pentaneura sp		1	2				**3**	
Stictochironomus sp			1				**1**	
HEMIPTERA	**1**							**2.2**
Lethocerus sp			1				**1**	
NEUROPTERA	**1**							**2.2**
Sialis sp						1	**1**	
ABUNDANCE(N / 0.1m^2)		**6**	**16**	**5**	**17**	**1**	**45**	
Diversity								
I. Taxa number(S)	**17**	**5**	**9**	**4**	**8**	**1**		
II. Species Richness(D)		**2.23**	**2.89**	**1.86**	**2.47**	**0.00**		
III. Shannon-Weiner index (H)		**1.56**	**2.01**	**1.33**	**1.89**	**0.00**		
IV. Evenness index (E)		**0.97**	**0.91**	**0.96**	**0.91**	**0.00**		

4.3.2.2 Plankton

These are plants and animals, which by definition are not capable of making their way against the current, but rather drift about at the mercy of current and wind. The plant components are known as Phytoplankton while the animals are Zooplankton. The great majority of the plants in water are various types of these planktonic unicellular algae, which occur throughout the euphotic regions of the water body. Because they are the dominant plants in the water body, their role in the food chain is of paramount importance. The animals making up the zooplankton are taxonomically and structurally diverse. Unlike plants, which carry out autotrophic production by utilizing solar energy to reduce carbon-dioxide, animals obtain carbon and other essentials chemicals by ingesting organic materials.

Three divisions of phytoplankton were encountered; these are Chlorophyta (green algae), Bacillariophyta (diatoms) and Cyanophyta (blue green algae), which were respectively represented by 11, 2 and 1 species. A summary of the diversity, relative abundance and spatial distribution of the flora is shown in Table 4.15. The bulk of the plankton population (49.5%) comprised the green algae particularly the filamentous algae Spirogyra sp and Eudorina sp.

Table 4.15

Summary of Species Richness, Abundance, Diversity and Distribution of the Major groups of plankton at the study area

MAJOR GROUPS	S	Sampling stations						
		S24	**S27**	**S33**	**S34**	**S36**	**TOTAL**	**%**
Phytoplankton								
Bacillariophyta	**2**	3	0	3	2	1	9	**4.9**
Chlorophyta	**11**	17	27	18	12	17	91	**49**
Cyanophyta	**1**	5	2	5	1	2	15	**8.2**
Zooplankton								
Copepoda	**5**	15	11	3	7	5	41	**22**
Cladocera	**6**	3	4	3	8	8	26	**14**
Ciliates	**1**	1	1				2	**1.1**
Abundance(N)		**44**	**45**	**32**	**30**	**33**	**184**	
Population density(N x 10^3 / m^3)		**1.47**	**1.5**	**1.07**	**1**	**1.1**		
Diversity								
I. Taxa number(S)	**26**	**17**	**16**	**15**	**17**	**18**		
II. Species Richness(D)		**4.228**	**3.940**	**4.040**	**4.704**	**4.862**		
III. Shannon-Weiner index (H,)		**2.603**	**2.344**	**2.513**	**2.719**	**2.749**		
IV. Evenness index (E)		**0.919**	**0.845**	**0.928**	**0.960**	**0.951**		

Twelve recognizable animals were found in the plankton. These consist of copepods, cladocerans and ciliates. The dominant and most frequently encountered were the copepods and cladocerans, which represented 22.3% and 14.1% respectively of the plankton population. The range of plankton population within the sampling stations was 1.0 x 103 / m3 to 1.5 x 103 / m3, Species richness varied between 15 and 18 per station. Diversity (H1) ranged between 2.3 and 2.7, while evenness was generally high ranging between 0.85 and 0.96.

The plankton community is typically a freshwater assemblage consisting mainly of green algae, copepods and cladocerans. The phytoplankton is dominated by the filamentous green algae, which points to the fact that the water has high organic enrichment.

4.4 Wildlife and Endangered Species

Four major groups of wildlife species occur in the project area. These are mammals, birds, reptiles and amphibians.

4.4.1 Mammals

The mammals, which occur in the vicinity of the pipeline ROW, based on information obtained from respondents are shown in Table 4-16. As expected, the fauna included forest and savanna species and consisted largely of small game.

There were very few experienced hunters in the locality and hunting was mainly for the pot, which would suggest that hunting pressure is relatively low, especially as the inhabitants depended mainly on farming and fishing for their livelihood. Nevertheless, it is believed that species like the Sitatunga (*Tragelaphus spekei*), Maxwell's Duiker (*Cephalophus maxwelli*), Red-flanked Duiker (*Cephalophus rufilatus*), the Grasscutter (*Thryonomys swinderianus*) and the Brush-tailed Porcupine (*Atherurus africanus*), which are much sought after as bushmeat, are under intense hunting pressure. They may have continued to thrive only because of their resilience and secretive habits, as well as relatively high fecundity. It is also suspected that as a result of hunting pressure and habitat destruction, certain large mammals (e.g. elephants, White-collared Mangabey, chimpanzees and the Bushpig) have become extinct in this area. Thus hunters confirmed that the Bushpig (*Potamochoerus porcus*) had not been seen in the area for a long time. On the other hand, the Manatee (*Trichechus senegalensis*) has been sighted frequently in the Badagry Creek and its tributaries.

4.4.1.2 Birds

A total of 53 species belonging to 31 families were seen or heard in the study area (Table 4-17). Twenty-eight of these species (52.8 %) were recorded in both seasons, which indicates that they are resident.

The list, it must be pointed out, is not exhaustive, because some birds that are notoriously difficult to identify in the field without mist-netting may have been overlooked, especially the small-sized species that forage in thick foliage or tree canopy.

4.4.1.3 Reptiles

Based on reports by the indigenes, the reptilian fauna of the area consists of crocodiles, turtles, land tortoises, snakes and lizards (Table 4.18). Several species of snakes were reported in the area. These include the Black Cobra (*Naja melaneuca*), Spitting Cobra (*Naja nigricollis*), Night Adder (*Causus maculatus*), Gabon Viper (*Bitis gabonica*) and the African Python (*Python sebae*). The Monitor Lizard (*Varanus niloticus*), the Nile Crocodile (*Crocodylus niloticus*) and the Dwarf (or Short-snouted) Crocodile (*Osteolaemus tetraspis*) are hunted for meat (it was noted however that some people consider the Monitor Lizard a taboo). Marine turtles are well known to the populace, who admitted hunting them for food and collecting their eggs when they come ashore to breed between August and December.

4.4.1.4 Amphibians

Amphibians found in the area include the African Clawed Toad (*Xenopus tropicalis*), Common Toad (*Bufo regularis*), Bush Toad (*Bufo maculatus*), Bullfrog (*Dicroglossus occipitalis*), a few species of treefrogs and ranid frogs (Table 4.19).

Table 4.16.
The Mammals in the vicinity of the proposed pipeline ROW

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Primates				
Bosman's Potto	*Perodicticus potto*	1	2	Endangered
Demidov's Galago	*Galago demidovii*	1	2	Common
Mona Monkey	*Cercopethicus mona*	2	2	Vulnerable
Pholidota (Pangolins)				
Tree Pangolin	*Manis tricuspis*		1	Vulnerable
Long-tailed Pangolin	*Manis tetradactyla*		1	Vulnerable
Lagomorpha (Hares and Rabbits)				
Crawshay's Hare	*Lepus crawshayi*			Common
Rodentia (Rodents)				
Giant Forest Squirrel	*Protoxerus stangeri*			Vulnerable
Red-legged Sun-squirrel	*Heliosciurus rufobrachium*			Common
Fraser's Flying Squirrel	*Anomalurus derbianus*			Endangered
Giant Rat ("Rabbit")	*Cricetomys gambianus*			Common
Cane Rat or Grasscutter	*Thryonomys swinderianus*			Common
Brush-tailed Porcupine	*Atherurus africanus*		1	Common
Carnivora (Carnivores)				
Cape Clawless Otter	*Aonyx capensis*		1	Vulnerable
African Civet	*Viverra civetta*		2	Vulnerable
Two-spotted Palm Civet	*Nandinia binotata*		2	Uncommon
Large-spotted Forest Genet	*Genetta poensis*		2	Vulnerable
Cusimanse Mongoose	*Crossarchus obscurus*		2	Common
Gambian Mongoose	*Mungos gambianus*		2	Vulnerable
Marsh Mongoose ('Fox')	*Atilax paludinosus*		2	Endangered
Hyracoidea (Hyraxes)				
Tree Hyrax ("Bush dog")	*Dendrohyrax dorsalis*		2	Common
Artiodactyla				
Bushpig	*Potamochoerus porcus*			Very rare
Maxwell's Duiker	*Cephalophus maxwelli*		2	Common
Bushbuck	*Tragelaphus scriptus*		2	Uncommon
Sitatunga ("Water Deer")	*Tragelaphus spekei*	1	1	Endangered

Table 4.17
Birds seen or heard in the vicinity of the proposed pipeline ROW.

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Ardeidae (Herons and Egrets)				
Cattle Egret	*Bubulcus ibis*		2	Uncommon
Grey Heron	*Ardea cinerea*		2	Common
Accipitridae (Vultures, Hawks, Kites, Eagles, etc.)				
Black-shouldered Kite	*Elanus caeruleus*		1	Common

Shikra	*Accipiter badius*		1	Common
Lizard Buzzard	*Kaupifalco monogrammicus*		1	Common
Black Kite	*Milvus migrans*		1	Abundant
Falconidae (Kestrels, falcons)				
Common Kestrel	*Falco tinnunculus*		1	Common
Grey Kestrel	*Falco ardosiaceus*		1	Common
Phasianidae (Francolins & Guinea Fowls**)**				
Double-spurred Francolin	*Francolinus bicalcaratus*		2	Common
Burhinidae (Thick-knees or Stone Curlews)				
Senegal Thick-knee	*Burhinus senegalensis*			Uncommon
Columbidae (Pigeons and Doves)				
Red-eyed Dove	*Streptopelia semitorquata*			Common
Laughing Dove	*Streptopelia senegalensis*			Common
Vinaceous Dove	*Streptopelia vinacea*			Uncommon
Red-billed Wood Dove	*Turtur afer*			Common
Tambourine Dove	*Turtur tympanistria*			Common
African Green Pigeon	*Treron calva*			Uncommon
Cuculidae (Cuckoos and Coucals)				
Senegal Coucal	*Centropus senegalensis*			Common
Alcedinidae (Kingfishers)				
Woodland Kingfisher	*Halcyon senegalensis*			Common
Grey-headed Kingfisher	*Halcyon leucocephala*			Uncommon
Shining-blue Kingfisher	*Alcedo quadribrachys*			Uncommon
Malachite Kingfisher	*Corythornis cristata*			Common
Pied Kingfisher	*Ceryl rudis*			Unommon
Meropidae (Bee-eaters)				
White-throated Bee-eater	*Merops albicollis*			Uncommon
Little Bee-eater	*Merops pusillus*			Rare
Bucerotidae (Hornbills)				
African Pied Hornbill	*Tockus fasciatus*			Common
Capitonidae (Barbets)				
Speckled Tinkerbird	*Pogoniulus scolopaceus*			Common
Hirundinidae (Swallows)				
Ethiopian Swallow	*Hirundo aethiopicus*			Common
Motacillidae (Wagtails, Pipits, Longclaws)				
African Pied Wagtail	*Motacilla aguimp*			Rare
Pycnonotidae (Bulbuls)				
Common Garden Bulbul	*Pycnonotus barbetus*			Common
Sylviidae (Warblers)				
Grey-backed Camaroptera	*Camaroptera brevicaudata*			Common
Nectariniidae (Sunbirds)				
Olive-bellied Sunbird	*Nectarinia chloropygia*			Common
Collared Sunbird	*Anthreptis collaris*			Common
Corvidae (Crows, Magpies, etc)				
Pied Crow	*Corvus alba*			Common
Passeridae (Sparrows)				
Grey-headed Sparrow	*Passer griseus*			Common
Ploceidae (Weavers)				
Village Weaver	*Ploceus cucullatus*			Common
Estrildidae (Finches, Waxbills, Mannikins)				
Bronze Mannikin	*Lonchura cucullata*			Abundant
Red-billed Fire-Finch	*Lagonosticta senegala*			Uncommon
Viduidae (Whydahs, Indigo Birds)				
Pin-tailed Whydah	*Vidua macroura*			Uncommon

Table 4.18
Reptiles reported to occur in the vicinity of the proposed pipeline ROW

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Crocodylidae (Crocodiles)				
Nile Crocodile	*Crocodylus niloticus*		1	Common
Short-snouted Crocodile ("Alligator")	*Osteolaemus tetraspis*	Endangered	1	Common
Pelomedusidae (Swamp terrapins)				
West African Mud Turtle	*Pelusios castaneus*			Uncommon
Testudinidae (Tortoises)				
Serrate Hinge-backed Tortoise	*Kininxys erosa*			Common
Home's Hinge-backed Tortoise	*Kinixys homeana*			Uncommon
Bell's Hinged Tortoise	*Kinixys belliana*			Common
Varanidae (Monitor Lizards)				
Nile Monitor Lizard	*Varanus niloticus*		1	Common
Boidae (Pythons)				
Royal Python	*Python regius*		1	Uncommon
African Python	*Python sebae*		1	Uncommon
Elapidae (Cobras and Mambas)				
Spitting Cobra	*Naja nigricollis*			Common
Black Cobra	*Naja melanoleuca*			Common
Viperidae (Vipers)				
Night Adder	*Causus maculates*			Common

Table 4.19
Amphibians recorded in the vicinity of the proposed pipeline ROW

COMMON NAME	SPECIES	CONSERVATION STATUS		
		IUCN	DECREE NO. 11	PIPELINE ROW & ENVIRONS
Hyperolidae (Treefrogs)				
	Afrixalus dorsalis			Common
	Hyperolius fusciventris			Common
	Hyperolius guttulatus			Common
	Hyperolius concolor			Common
Ranidae (Frogs)				
	Ptychadena taenioscelis			Common
	Ptychadena oxyrhinchus			Common
	Ptychadena aequiplicata			Common
	Aubria subsigilata			Common
	Phrynobactrachus albolabris			Common
Bullfrog	*Dicroglossus occipitalis*			Common
Bufonidae (Toads)				
Common Toad	*Bufo regularis*			Common
Forest Toad	*Bufo maculates*			Common
Pipidae (Clawed Toads)				
	Xenopus tropicalis			Common
NB. Decree No. 11 refers to the Endangered Species (Control of International Trade and Traffic) Decree of 1985. By virtue of this decree, the hunting, capture of, or international trade in animals listed in Schedule 1 is absolutely forbidden, while trade in animals listed in Schedule 2 may only be conducted under licence from the Federal Ministry of Agriculture and Natural Resources.				

Economic and Cultural Significance of Wildlife

Apart from consumption as food, parts of wild animals are also used in folk medicine (e.g. the head of the Monitor Lizard, Spitting Cobra and Egyptian Mongoose). The skins of large reptiles, e.g. snakes, crocodiles and monitor lizards, are reportedly sold to itinerant traders. Thus the local populace do not only supplement their protein intake from these animals but also their meagre income from other sources. Unfortunately, although these animals represent a vital resource in the local economy, exploitation is neither regulated nor indeed was there any awareness that both Federal and international laws protect some of these animals.

Thus the survival of these animals is threatened not only by hunting but also land clearance for farming, road construction and expansion of human settlements.

Several species considered to be sensitive either because they face threat of imminent extinction or are vulnerable (i.e. could become endangered in the near future if nothing was done to remove the threat) according to the IUCN Red List (1994, 2002) and the Federal Government's Endangered Species Act (1985), are found in the area. These include Bosman's Potto, Demidov's Galago, Western Black-and-White Colobus, Mona Monkey, Brush-tailed Porcupine, Tree Pangolin, Cape Clawless Otter, the Serval, Manatee, Sitatunga, Buffon's Kob, genets, mongooses, all herons, egrets, pelicans, hawks, eagles, falcons, all three species of crocodile, and the African Python.

Wetland Delineation Report for Onshore Nigeria

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

Prepared by:

ICF Consulting Services, LLC
33 Hayden Avenue
Lexington, MA 02421 USA
(781) 676-4000

Environmental Resources Managers Limited, ERML
Lagos, Nigeria

Table of Contents

Page

Chapter 1 INTRODUCTION 1-1

1.1 Background 1-1

1.2 Indicators and Criteria for Wetland Delineation 1-2

1.2.1 Indicator for Wetlands Delineation 1-2

1.2.2 Criteria for Wetlands Delineation 1-2

1.3 Wetland identification 1-6

1.4 Aims and objectives 1-8

1.5 Site Description 1-8

1.6 Technical guidelines for wetland delineation 1-10

Chapter 2 WETLANDS BOUNDARY DELINEATION METHODS USED FOR WAGP 2-1

2.1 Reconnaissance Field Visit 2-1

2.2 Development of base map for ground thruth 2-1

2.3 Field Data Collection/Ground Truth 2-2

2.4 Wetland Inventory 2-4

2.5 QA/QC 2-4

Chapter 3 RESULTS AND DISCUSSIONS 3-1

3.1 Coastal Area 3-1

3.1.1 Vegetation Studies 3-1

3.1.2 Hydrology 3-6

3.1.3 Soil 3-9

3.1.4 Geomorphology 3-11

3.1.5 Redox Measurement and Anaerobic Bacteria 3-13

3.1.6 Wetlands Size and boundary 3-13

3.1.7 Concluding Statement 3-13

3.2 Inland Areas 3-14

3.2.1 Vegetation Studies 3-16

3.2.2 Hydrology 3-20

3.2.3 Soil Studies 3-22

3.2.4 Geomorphology 3-22

3.2.5 Redox Measurement and Anaerobic Bacteria 3-23

3.2.6 Wetlands Size and Boundary 3-23

3.2.7 Concluding Statement 3-23

Chapter 4 ENVIRONMENTAL IMPACTS OF PIPELINE CONSTRUCTION ON WETLANDS AND MITIGATION MEASURES 4-1

4.1 Impacts of Pipeline Laying On Wetlands 4-1

4.1.1 Vegetation Impacts 4-1

4.1.2 Hydrology Impacts 4-1

Table of Contents

Page

4.1.3 Water Quality Impacts 4-2
4.1.4 Wildlife Impacts 4-2
4.2 Measures to Minimize Impacts of Pipeline Construction 4-3
4.2.1 Vegetation 4-3
4.2.2 Hydrology 4-3
4.2.3 Water Quality 4-4
4.3 Best Management Practices for Wetlands Crossing 4-4
Chapter 5 CONCLUSION AND RECOMMENDATIONS 5-1
5.1 Conclusion 5-1
5.2 Recommendations 5-2
Chapter 6 REFERENCES 6-1

List of Appendices

APPENDIX 1: DATA FORM 1 ROUTINE WETLAND DETERMINATION A-1

Appendix 2A Checklist of Vegetation Found in the Coastal Wetland Areas B-1

Appendix 2B A Checklist of the Vegetation Found in the Coastal Upland Areas B-4

Appendix: 3A Checklist of the Vegetation Found In The Inland Wetland Areas C-1

Appendix 3B A Checklist of the Vegetation Found in the Inland Upland Areas C-4

Appendix 3C A Checklist of the Coastal Savannah Vegetation in the Inland Areas C-10

Appendix 3D A Checklist of Derived Savannah Vegetation in the Inland Area C-11

List of Tables

Table 1.2-1 Commonly Used Indicators for Wetlands Delineation 1-3

Table 1.2-2 Plant Indicator Status Categories 1-4

Table 1.2-3 Morphological, Physiological, and Reproductive Adaptations of Plant Species for Occurrence in Areas Having Anaerobic Soil Conditions 1-5

Table 1.2-4 Hydrologic Zones Nontidal Areas 1-6

Table 1.3-1 List Of Primary Indicators for Wetlands Delineation 1-7

Table 1.6-1 Wetland Delineation Manuals/Protocols 1-10

Table 2.3-1 EPA Simple Method for Delineating Wetlands 2-2

Table of Contents

Page

Table 2.3-2 Frequency, Permanence and Duration of Inundation Classes 2-3

Table 3.1-1 A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Groundcover) 3-2

Table 3.1-2 A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Subcanopy) 3-4

Table 3.1-3 A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Vine) 3-4

Table 3.1-4 A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Overstorey) 3-5

Table 3.1-5 A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Aquatic Macrophytes and Epiphytes)... 3-5

Table 3.1-6 Physical and Microbiological Properties of Soils from the Study Area........... 3-11

Table 3.2-1 A Checklist of the Vegetation found in the Inland Wetland Areas (Groundcover) 3-16

Table 3.2-2 A Checklist of the Vegetation found in the Inland Wetland Areas (Subcanopy and Understorey).. 3-18

Table 3.2-3 A Checklist of the Vegetation found in the Inland Wetland Areas (Overstorey) 3-18

Table 3.2-4 A Checklist of the Vegetation found in the Inland Wetland Areas (Vine) 3-19

Table 3.2-5 A Checklist of the Vegetation found in the Inland Wetland Areas (Aquatic Macrophyte, Epiphyte and Liana)... 3-20

List of Figures

Figure 1.5-1 Map of the Onshore Area Showing the Proposed Pipeline ROW 1-8

Figure 3.2 Wetlands delineation map showing the West African Gas Pipeline ROW........ 3-15

List of P-1lates

Plate 1 Vegetation with near surface roots 3-7

Plate 2 *Cyperus* sp. with *Nymphaea lotus* at the Nackground 3-7

Plate 3 Showing water hyacinth and *Cyperus* sp. with coconut at the background............... 3-8

Table of Contents

Page

Plate 4 Watermarks on trees, an indicator of wetland hydrology 3-8

Plate 5 Showing near Surface Groundwater 3-9

Plate 6 Redoximorphic Features, an Indicator of Hydric Soils 3-10

Plate 7 Redoximorphic Features, an Indicator of Hydric Soils 3-10

Plate 8 Water Hyacinth and Red Mangrove (close to the pipeline crossing) 3-12

Plate 9 Showing Shorebird (which is now being considered as wetland indicator) 3-13

Plate 10 Inland Wetlands Dominated by Obligate Hydrophytes 3-21

Plate 11 Inland Wetlands Dominated by Obligate Hydrophytes 3-21

Plate 12 Degraded Raffia, an evidence of Anthropogenic Impacts 3-22

EXECUTIVE SUMMARY

The West African Gas Pipeline Company, WAGPCo wishes to construct and operate a 690.5 km long gas pipeline from Nigeria through to other West African countries including Republic of Benin, Togo and Ghana. The pipeline is planned to link the existing Escravos-Lagos Gas Pipeline (ELP) at Alagbado Tee and head in a southwest direction to Badagary Beach, from where it will pass through the Atlantic Ocean to the other countries.

Out of the total length, about 56.0 km will pass through a number of relatively wet areas/habitats onshore Nigeria. Some of these habitats are suspected to be wetlands. But the extent and boundaries of these wetlands along the proposed pipeline ROW is unknown, which is the basis for the present study.

In recognition of the ecological and socio-economic roles of wetlands, ICF on behalf of WAGPCo/CNL commissioned Environmental Resources Managers Ltd (ERML) to undertake the delineation of wetlands within 1.0 km buffer along the proposed pipeline ROW. Wetlands along the pipeline corridors were identified by analyzing satellite imageries, conducting field surveys and laboratory analysis.

Results of the field study carried out from the 15-25th of July 2003 shows that two types of wetlands (inland and coastal) were recognized according to their vegetation, soil, hydrology and geomorphology/ topography/landscape position.

The coastal wetlands occur at the latter segment of the pipelines, starting from the northern fringes of the Badagry Creek (near the compressor station) and terminating across the Badagry Creek just before the beach. Hydromorphologically, the coastal wetlands are channels with a distinct flow pattern, which is towards the south into the Atlantic Ocean. The hydrology of the area is characterised by tidal influence and is of the semi-diurnal type. The area is permanently flooded, both seasonally and tidally. The duration of flooding is long and occurs very frequently. The soil is very poorly drained. The habitat is surrounded by obligate hydrophytes, which have reproductive, physiological and morphological adaptations for wetland conditions, including prop roots (*Rhizophora* sp), adventitious roots (*Acrostichum aureum*, *Cyperus* sp), near surface roots (*Cocos nucifera*), floating leaves (*Nymphaea lotus*), inflated body parts (aerenchyma) such as stems and leaves (*Hydrolea palustris, Ludwigia sp*), polymorphic leaves (*Lygodium microphyllum*), buttress/knee roots (*Hallea ciliata*) and multi-trunk/stooling (*Machaerium lunatus*). The vegetation prevalence index is 2.08, which is less than 3 and therefore confirms that the area is indeed a wetland.

On the other hand, the inland wetlands occur mostly in depression areas along the pipeline ROW from Alagbado Tee to the compressor station site. These are basin type of wetlands, dominated mostly by obligate hydrophytes including *Raphia hookeri, Cyrtosporma senegalense and Nymphaea lotus*, which occupied the overstorey, subcanopy/ground level and mesophytic strata respectively. These plants with percentage frequency of occurrence above 60%, also exhibits adaptations (morphological, reproductive and physiological) for wetland hydrology. The hydrology of the area is characterised by permanent flooding of long duration, which occurs very frequently. The soils are hydric soils on account of the very poor drainage, aquic soil moisture regimes and being histosols. These properties confirm that the areas are wetlands. Evidence from redox measurements, anaerobic microbiology and topography further confirm the wetland condition/status of the area. The sizes of wetland within 1 km buffer on either side of the pipeline ROW were computed to be 1.73 and 31.46 sq km for coastal and inland wetlands respectively.

The report, which also contained technical guidance for wetland delineation and concludes by recommending ‘open cut dry crossing’ and horizontal directional drilling techniques for laying the pipeline across wetlands and river crossings to minimize environmental impacts.

SYNOMYMS AND ACRONYMS

CBD	Convention for Biological Diversity
CNL	Chevron Nigeria Ltd
ELP	Escravos-Lagos Pipeline
Env. Lab	Environmental Laboratory
ERA	Environmental Rights Action
ERML	Environmental Resources Managers Ltd
FAC	Facultative plant
FACU	Facultative upland plant
FACW	Facultative wetland plant
FICWD	Federal Interagency Committee for Wetland Delineation
FOEN	Friends of the Earth, Nigeria
GIS	Geographic Information Systems
GPS	Global Positioning System
HDD	Horizontal Directional Drilling
ICF	ICF Consulting
IPIECA	International Petroleum Industry Environmental Conservation Association
IUCN	World Conservation Union
NRC	National Research Council
USDA-NRCS	United States Department of Agriculture -Natural Resources Conservation Service
OBL	Obligate wetland plant
PRIMET	Primary Indicator Method
ROW	Right of Way
UPL	Upland plant

US EPA	United States Environmental Projection Agency
US FWS	United States Fish and Wildlife Service
USACE	United States Army Corps of Engineers
USDA-SCS	United States Department of Agriculture -Soil Conservation Service
WAGP	West African Gas Pipeline
WAGPCo	West African Gas Pipeline Company
WWF	Worldwide Fund for Nature

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The West African Gas Pipeline Company, WAGPCo wishes to construct a pipeline from Nigeria through to other West African countries including Republic of Benin, Togo and Ghana. The pipeline is planned to link the existing Escravos- Lagos gas pipeline (ELP) at Alagbado Tee and head in a southwest direction to Badagary beach, from where it will pass through the Atlantic Ocean to the other countries. Pipeline laterals will link the various countries to the main trunkline/ pipeline.

The entire length of the pipeline from Alagbado Tee, Nigeria to Takoradi, Ghana is 690.5 km, out of which about 56.0 km will pass through onshore Nigeria i.e. from Alagbado Tee to Badagry Beach. Although the project is an environmental friendly one, as it support gas flare reduction in Nigeria, provide employment opportunities and source of foreign exchange, but there are environmental concerns from host communities, NGOs and other stakeholders (ERA/FOEN/ Oil Watch Africa, 2000). Also, there are indications that Nigeria's wetlands are shrinking due to anthropogenic influences (Storks, 2002). The EIA, among other issues is expected to address such environmental concerns. Addressing concerns relating to the modification of wetland area is complex and therefore requires special attention, which informed the present study.

The pipeline ROW have been surveyed and pipe route selection options considered. Not withstanding, the approved pipeline ROW passes through a number of relatively wet areas/habitats. Some of these habitats are suspected to be wetlands as revealed through the supervised vegetation classification carried out by Environmental Resources Managers Ltd on a section of the ROW (ERML, 2003a). But the extent and boundaries of these wetlands along the proposed pipeline ROW is unknown. This we intend to find out by carrying out a delineation study. Such studies would naturally form the basis for a comprehensive wetland inventory.

Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors including human interference/disturbance. These among other factors are used to delineate wetlands.

Wetlands are important both regionally and globally especially because of their economic and ecologic roles. For instance wetlands provide valued functions such water filtration, flood storage, erosion control, and shoreline stabilization (IUCN, 1993; IPIECA, 1993, 2000; Tiner, 1999; Kathiresan and Bingham, 2001, Mitsch and Gosselink, 2001; Hoff, 2002). Wetlands also provides habitats for fishes, wildlife and are also sources of important timber, medicinal plants etc. According to Tiner (1999), wetlands are among the most diverse and productive ecosystems, thereby serving as important sites for the conservation of biodiversity. This among others is the reason why the convention on biological diversity in collaboration with the Ramsar Convention are interested in the preservation of wetland biodiversity (WWF/CBD, 1996). Wetlands have been reported to be highly sensitive as well

(Kathiresan and Bingham, 2001, Hoff, 2002), hence delineating their spatial boundaries is expected to guide construction activities to minimize/avoid disturbance of such sites.

In recognition of the ecological and socio-economic roles of wetlands, ICF on behalf of WAGPCo/CNL commissioned Environmental Resources Managers Ltd (ERML) to undertake the delineation of wetlands within 1.0 km buffer along the proposed WAGP ROW. The findings of the field data collection (15-25 July 2003), literature review and digital mapping for the WAGP pipeline ROW is presented in this report. The report also contains technical guidance for wetland delineation.

1.2 INDICATORS AND CRITERIA FOR WETLAND DELINEATION

In this section of the report we present indicators and criteria that are commonly used to establish the presence (or otherwise) of wetland in an area.

1.2.1 Indicator for Wetlands Delineation

Indicators that suggest the presence of hydrophytic vegetation, hydric soils and wetlands hydrology are commonly used for wetlands delineations; details of which are shown in Table 1.2-1. The presence of these indicators confirms that an area is wetland.

1.2.2 Criteria for Wetlands Delineation

Having established the presence of wetlands indicators, there exist criteria for determining the strength and relevance of the various indicators in order to make a wetland determination. Wetlands delineation criteria for hydrophytic vegetation, hydric soil and wetlands hydrology abound in literature (Env. lab 1987, Tiner 1991, 1988, 1991a, b, 1996; FICWD, 1989).

Several indicators may be used to determine whether hydrophytic vegetation is present on a site. However, the presence of a single individual of a hydrophytic species does not mean that hydrophytic vegetation is present. The strongest case for the presence of hydrophytic vegetation can be made when several indicators, such as those listed in Table 1.2-1 are present. With respect to hydrophytic vegetation, the most important criteria for delineation is the presence of greater than 50% of the vegetation being classified as OBL, FACW or FAC (See Table 1.2-1). Also, see Table 1.2-2 for plant species wetland indicator status and ecological index values. This single criterion can be used to establish the presence of wetlands even without carrying out hydric soil and wetland hydrology determinations (Sipple, 1988, FICWD, 1989). However, when other indicators are used to establish the presence of hydrophytic vegetation, hydric soil and wetlands hydrology needs to be considered as well.

Table 1.2-1
Commonly Used Indicators for Wetlands Delineation

Wetlands Indicators	Env. Lab 1987	Sipple, 1988	FICWD, 1989
Hydrophytic Vegetation Indicators			
>50% of dominants are OBL, FACW, or FAC (excluding FAC-)[1]	X		
>50%\of dominants are OBL, FACW, or FAC			X
Presence of dominant OBL species		X	
Visual observations of plants growing in areas of prolonged inundation and/or soil saturation (>10% of the growing season)	X		
Plants with certain morphological adaptations (see Table 1.2-3)	X	X	X
Plants with known physiological or reproductive adaptations to prolonged inundation/saturation (see Table 1.2-3)	X	X	X
Facultative species (FACW, FAC, and FACU) when on undrained hydric soils		X	X
Plant community with a prevalence index of < 3.0			X
Plant community with more coverage by OBL and FACW species than by FACU and UPL species			X
Professional judgment supported by technical literature	X		
Hydric Soils Indicators[2]			
Organic soils (Histosols, except Folists)	X	X	X
Histic epipedons	X	X	X
Sulfidic material	X	X	X
Reducing soil conditions (observed)	X	X	X
Gleyed soils	X	X	X
Mottled soils with low chroma matrix	X	X	X
Soils with aquic or peraquic moisture regimes	X	X	X
Soil on hydric soils list	X	X	X
Iron and manganese concretions	X	X	X
Oxidized root-rhizome channels along living roots	X		
High organic content in surface horizon of sandy soils	X	X	X
Organic streaking in subsurface horizons	X	X	X
Organic pans (wet Spodosols)	X	X	X
Wetland Hydrology Indicators			
Recorded data	X	X	X

[1] See Table 1.2-2 for plant indicator status categories

[2] Indicators are listed in order of decreasing reliability. Although all are valid indicators, some are stronger indicators than others. When a decision is based on an indicator appearing in the lower portion of the list, re-evaluate the parameter to ensure that the proper decision was reached.

Wetlands Indicators	Env. Lab 1987	Sipple, 1988	FICWD, 1989
Visual observations of inundation	X	X	X
Visual observations of saturation (within upper root zone-12 in.)	X	X	X
Watermarks	X	X	X
Oxidized rhizospheres along living roots/rhizomes	X		X
Drift lines	X	X	X
Water-borne sediment deposits	X	X	X
Surface scouring		X	X
Drainage patterns within wetlands	X	X	X
Water-stained leaves	X	X	X
Bare areas (extended flooding)		X	X
Moss lines		X	
Plants with certain morphological adaptations (see Table 1.2-3)		X	X
Hydric soils characteristics (undrained sites)			X
Local soil survey data	X	X	
FAC Neutral Test	X		

Source: modified from Tiner, 1999

Table 1.2-2
Plant Indicator Status Categories[3]

Indicator Category	Indicator Symbol	Ecological Index Value[4]	Definition
OBLIGATE WETLAND PLANTS	OBL	1	Plants that almost always occur (estimated probability >99%) in wetlands under natural conditions, but which may also occur rarely (estimated probability <1%) in non-wetlands. Examples: *Rhizophora mangle*, *Cyperus sp*, *Raphia hookeri*, *Nymphaea lotus*
FACULTATIVE WETLAND PLANTS	FACW	2	Plants that usually occur (estimated probability 67% to 99%) in wetlands, but also occur (estimated probability 1% to 33% in nonwetlands). Example: *Anthocleista vogelii.*
FACULTATIVE PLANTS	FAC[5]	3	Plants with a similar likelihood (estimated probability 34% to 66%) of occurring in both wetlands and non-wetlands. Examples: *Elaeis guineensis*, *Alchornea cordifolia*

[3] Categories were originally developed and defined by the USFWS National Wetlands Inventory and subsequently modified by the National Plant List Panel. The three facultative categories are subdivided by (+) and (-) modifiers (see Reed 1988 and 1993).

[4] Sources: FICWD (1989) and Tiner (1991, 1999)

Indicator Category	Indicator Symbol	Ecological Index Value[4]	Definition
FACULTATIVE UPLAND PLANTS	FACU	4	Plants that sometimes occur (estimated probability 1% to <33%) in wetlands but occur more often (estimated probability 67% to 99%) in non-wetlands. Examples: *Aframomum melegueta, Manihot sp*
OBLIGATE UPLAND PLANTS	UPL	5	Plants that rarely occur (estimated probability <1%) in wetlands but occur almost always (estimated probability >99%) in non-wetlands under natural conditions. Examples: *Chromolaena odorata, Borassus aethiopum*

Source Env. Lab, 1988

Table 1.2-3
Morphological, Physiological, and Reproductive Adaptations of Plant Species for Occurrence in Areas Having Anaerobic Soil Conditions

Morphological adaptations Buttressed tree trunks. Pneumatophores. Adventitious roots. Shallow root systems. Inflated leaves, stems, or roots. Polymorphic leaves. Floating leaves. Floating stems. Hypertrophied lenticels ***Morphological adaptations*** Multitrunks or stooling. Oxygen pathway to roots.	***Physiological adaptations*** Accumulation of malate. Increased levels of nitrate reductase. Slight increases in metabolic rates. Rhizosphere oxidation. Ability for root growth in low oxygen tensions. Absence of alcohol dehydrogenase (ADH) activity. ***Reproductive adaptations*** Prolonged seed viability. Seed germination under low oxygen concentrations. Flood-tolerant seedlings. Viviparity

[5] FAC+ species are considered to have a somewhat greater estimated probability of occurring in wetlands than FAC species, while FAC- species are considered to have a somewhat lesser estimated probability of occurring in wetlands than FAC species.

The presence of partly decomposed organic soil (histosols) or soil with aquic sub-orders (soil with various level of saturation/ inundation) are considered as hydric soil. The presence of other hydric soil indicators listed in Table 1.2-1 is also used as criteria for hydric soils.

Areas that are inundated and/or saturated to the surface for a consecutive number of days for more than 12.5 percent of the growing season have wetlands hydrology and are therefore wetlands, provided the soil and vegetation criteria are met. See Table 1.2-4 for the classification of hydrologic zones. Areas within hydrological zones II – IV are considered wetlands (Env. Lab, 1987). Other indicators of wetland hydrology are shown in Table 1.2-1. Any of these indicators may be evidence of wetland hydrologic characteristics. Plants having morphological, reproductive and physiological adaptation to wetlands also indicate that the area has wetlands hydrology.

Table 1.2-4
Hydrologic Zones Nontidal Areas

Zone[6]	Name	Duration[7]	Comments
I	Permanently inundated	100%	Inundation >6.6 ft mean water depth
II	Semi-permanently to nearly permanently inundated or saturated	>75 % - <100%	Inundation defined as <6.6 ft mean water depth
III	Regularly inundated or saturated	>25% - 75%	
IV	Seasonally inundated or saturated	>12.5% - 25%	
V	Irregularly inundated or saturated	^{3}5% - 12.5%	Many areas having these hydrologic characteristics are not wetlands
VI	Intermittently or never inundated or saturated	<5%	Areas with these hydrologic characteristics are not wetlands

Source: Env. Lab, 1987

1.3 WETLAND IDENTIFICATION

Some protocols such as the USACE suggest that evidence of at least one positive wetland indicator from each parameter (hydrology, soil, and vegetation) must be found in order to make a positive wetland determination. Whereas others, suggests the use of a primary indicator method (PRIMET) as a rapid assessment method in areas with intact hydrology (Tiner, 1991a, b, 1993a, b, 1999, 2000; Jackson, 1995). The National Research Council (NRC, 1995) and the US EPA (Sipple, 1988) also adapted this method. A condensed list of primary indicators for wetlands determination can be found in Table 1.3-1. Also, GIS tools are now increasingly being

[6] Zone I defines an aquatic habitat zone, zones II-IV have wetland hydrology whereas zone VI are non-wetlands.

[7] Refers to duration of inundation and/or soil saturation during the growing season.

used to identify wetlands (Binkley, 1997; Tiner, 1999; Lyon and McCarthy, 1995; Begg and Lowry, 2002; Wetlands Inventory Consortium, 2002). Some of these tools were applied during the delineation of the pipeline ROW (See Chapter Two for details).

Table 1.3-1
List Of Primary Indicators for Wetlands Delineation

Vegetation Indicators of Wetland	
V1	OBL species comprise more than 50% of the abundant species of the plant community. (An abundant species is a plant species with 20% or more areal cover in plant community.)
V2	OBL and FACW species comprise more than 50% of the abundant species of plant in that community.
V3	OBL perennial species collectively represent at least 10% areal cover in plant community and are evenly distributed throughout the community and not restricted to depressional microsites.
V4	One abundant plant species in the community has one or more of the following morphological adaptations: pneumatophores (knees), prop roots, hypertrophied lenticels, buttressed stems trunks, and floating leaves.
V5	Surface encrustations of algae, usually blue-green algae, are materially present.
Soil Indicators of Wetlands	
S1	Organic soils (except Folists) present.
S2	Histic epipedon present
S3	Sulfidic material (hydrogen sulfide, odor of “rotten eggs”) present within 12 inches of the soil surface.
S4	Gleyed (low chroma) horizon or dominant ped faces (chroma 2 or less with mottles or chroma 1 or less with or without mottles) present immediately below the surface layer (A-or E-horizons) and within 18 in. of the soil surface.
S5	Nonsandy soils with a low chroma matrix (chroma of 2or less) within 18 in. of the soil surface and one of the following present within12 in. of the surface: Iron and manganese concretions or nodules Distinct or prominent oxidized rhizospheres along several living roots Low chroma mottles
S6	Sandy soils with one of the following present: Thin surface layer (1 in. or greater) of peat or muck where leaf litter surface mat is present Surface layer of peat or muck any thickness where a leaf litter surface mat is present A surface layer (A-horizon) having a low chroma matrix (chroma 1 or less and value of 3 or less) greater than 4 in. thick Vertical organic streaking or blotchiness within 12 in. of the surface Easily recognized (distinct or prominent) high chroma mottles occupy at least 2% of the low chroma subsoil matrix within 12 in. of the surface Organic concretions within 12 in. of the surface Easily recognized (distinct or prominent) oxidized rhizospheres along living roots

	within 12 in. of the surface A cemented layer (orstein) within 12 in. of the soil surface
S8	Remains of aquatic invertebrates present within 12 in. of the soil surface in nontidal pothole-like depressions.

1.4 AIMS AND OBJECTIVES

The principal aim of the study is to delineate the boundaries and extent of wetlands along the pipeline ROW. By so doing, we intend to:

- Provide data on the floristic composition (list of species diversity)
- Determine the indicator (wetland) status of the encountered species.
- Provide information about the habit, strata and species adaptation(s) (if any)
- Determine whether hydrophytic vegetation are present in the studied sites
- Calculate the prevalence index of species encountered
- Determine whether wetland hydrology is the predominant factor influencing soil formation and vegetation characteristics
- Determine the presence of hydric soils
- Delineate the wetland - nonwetland (upland) boundary
- Determine the extent and quantify the sizes of wetlands within 1000 m buffers along the pipeline ROW, and
- Modify/adapt internationally approved wetland delineation protocols for local use.

1.5 SITE DESCRIPTION

The proposed pipeline ROW passes in a southwest direction from Alagbado Tee towards Badagary beach from where it enters the Atlantic Ocean (see figure 1). The 56.0 km long pipeline passes through a number of habitats both uplands and suspected wetlands. The upland areas are basically either farmland or rainforest. The beach ridge area is also considered upland. The suspected wetland areas occur in slopes and depressions in the inland areas, whereas in the coastal areas, they are either open water bodies or swamplands. The inland wetlands are mostly dominated by *Raphia* palm, while the coastal areas are dominated by grass marsh and to a lesser extent by mangrove.

A detailed description of the various habitats/environments along the pipeline ROW are contained in the Dry Season WAGP Baseline Report (ERML/ICF, 2002) and will not be reproduced here. In this effort, emphasis is laid on the wetland areas only.

Figure 1.5-1
Map of the Onshore Area Showing the Proposed Pipeline ROW

A number of definitions of wetlands abound in literatures; the most commonly used one is that of the US Army Corps of Engineers in collaboration with the US EPA, which states that wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (Environmental Laboratory, 1987). Whereas, the Ramsar Information Bureau (1998) defined wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed 6 m. The United States Fish and Wildlife Service (US FWS) defined wetlands as lands where the saturation with water is the dominant factor determining the nature of soil development and types of animals and plant communities living in the soil and on its surface (Cowardin et al, 1979).

The Department of Water Affairs and Forestry, South Africa defined wetlands as a land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which under normal circumstances supports or would support vegetation typically adapted to life in saturated soil (see Marnewecke and Kotze, 1999). Other literature, which contained excellent review of wetlands definitions are Tiner (1995, 1996, 1999).

The interaction of hydrology, vegetation and soil results in the development of characteristics unique to wetlands. Therefore delineation is carried out to determine the presence of these indicators, which are frequently referred to as wetlands hydrology, hydrophytic vegetation and hydric soil respectively.

The term "wetland hydrology" encompasses all hydrologic characteristics of areas that are periodically inundated or have soils saturated to the surface at some time during the growing season[8]. Areas with evident characteristics of wetland hydrology are those where the presence of water has an overriding influence on characteristics of vegetation and soils due to anaerobic and reducing conditions, respectively. Such characteristics are usually present in areas that are inundated or have soils that are saturated to the surface for sufficient duration to develop hydric soils and support vegetation typically adapted for life in periodically anaerobic soil conditions.

Hydrophytic vegetation is defined as the sum total of plant life that occurs in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species

8 Growing season refers to the period from March to September (see crop calendar of Nigeria, http://fas.usda.gov/pecad/pecad.html)

present. Whereas hydric soils is defined as a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.

Routinely, wetlands delineation is carried out to seek for indicators, which suggest the presence of wetland hydrology, hydrophytic vegetation and hydric soils; these are discussed in details in sections 1.5 and 1.6.

1.6 TECHNICAL GUIDELINES FOR WETLAND DELINEATION

In Nigeria, there are no approved guidelines/protocols for carrying out wetland delineation, and neither is there any national list of wetlands plants and hydric soils as documented in other countries like the U.S (Reed, 1988; USDA-SCS, 1987). In order to overcome these constraints a number of wetland delineation guides were reviewed (see Table 1.6-1). Majority of these guides were tailored along the corps Engineers Wetlands Manuals with minor differences. This section and the next therefore contain the technical basis and criteria for wetlands delineation.

Table 1.6-1
Wetland Delineation Manuals/Protocols

Cowardin et al. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. fish and wildlife service, Washington.
The Florida Department of Environmental Protection et al. 1995. The Florida wetlands delineation manual. Florida Department of Environmental Protection, Wetlands Evaluation and Delineation Section Tallahassee.
Environmental Laboratory 1987. Corps of Engineers Wetlands Delineation manual, Technical Report 7-87-1 U.S Army Corps of Engineers, WES Vicksburg
Federal Interagency Committee for Wetland Delineating. 1989. Federal manual for identifying and delineating jurisdictional wetlands. USACE/USEPA/USFWS/USDC-SCS, Washington DC.
Jackson, S 1995. Delineating bordering vegetated wetlands under the Massachusetts wetlands Protection Act. Massachusetts Department of Environmental Protection Division of Wetlands and Waterways, Boston
Washington State Department of Environmental protection wetlands delineating manual.
Sipple, W.S 1988. Wetlands identification and delineation manual. Volumes I & II. USEPA, office Wetlands Protection, Washington DC
Tiner, R.W. 1993. The primary indicator method - a practical approach to wetlands recognitions and delineation in the United States. Wetlands 13, 50-64
USDA-SCS 1985. National food security manual. USDA, Washington DC

Reed, P.B. 1988. National list of plants that occur in wetlands. Report 88. USFWS, Washington DC
USDA-SCS 1987. Hydric soils of the United States. USDA, Washington DC
Browne et al. 1996. Freshwater wetlands delineation manual. New York State Department of Environmental Conservation, Albany.
NRC. 1995. Wetlands characteristics and boundaries. National Academy Press, Washington DC
Tiner, R.W. Wetlands Indicators: A guide to wetland identification, delineation, classification and mapping. Lewis Publishers, Boca Raton
Wetlands Inventory Consortium. 2002. A methodology proposed for a South African National Wetlands Conservation Orogramme. Department of Environmental Affairs and Tourism, Pretoria, Republic of South Africa.
Vander Walt. 1999. South African National Wetlands Classification Systems definitions and criteria. South African Wetland Conservation Programme, Department of Environmental Affairs and Tourism, Pretoria, South Africa.
Tiner, R.W. 1991. The concept of a hydrophyte for wetlands identification. Bioscience. 41: 236-247
Washington State Department of Ecology 1997.Washington State Wetlands Identification and Delineation Manual
Garnewecke, G and Kotze, D. 1999. Guidelines for delineation of wetland boundary and wetland zones. Department of Water Affairs and Forestry, South Africa
Tiner, R. W. 1991. Technical issues regarding wetlands delineation
Tiner, R. W. 1991. Wetlands delineation
Tiner, R. W. 2000. An overview of wetland identification and delineation techniques, with recommendation for improvement

CHAPTER 2
WETLANDS BOUNDARY DELINEATION METHODS USED FOR WAGP

Notwithstanding the methods described in Chapter one for wetlands delineation, this section presents the methods that were applied specifically for the delineation of wetlands along the WAGP ROW. Methods for vegetation, soil and water sampling are contained in the Dry Season WAGP Baseline Report (see ERML/ICF, 2002) and are therefore not reproduced here.

2.1 RECONNAISSANCE FIELD VISIT

Prior to the fieldwork, several visits were made to the pipeline ROW. This was to appreciate the general location, site topography/geomorphology/landscape position and to look for potential accesses.

2.2 DEVELOPMENT OF BASE MAP FOR GROUND THRUTH

Because of the advantages mentioned in Tiner (1996), remote-sensing methods were used for the delineation study. One of the most critical issues in wetland delineation using satellite remote sensing and geographic information systems is the selection of appropriate imagery. The satellite imagery selected for the purpose of wetland mapping along the WAGP right of way is a Landsat TM satellite Imagery acquired in February 2002. Band 4, 5, and 7 were combined to produce a composite false colour image. The image was chosen because, February coincides with the peak of dry season in the western part of the country and any area that is wet in February is likely to be wetland. In order to enhance the wetlands boundary within the area of study, various image enhancement methods were applied. In addition, *Tassel Cap Transformation* algorithm was run on the imagery. The three Tasseled Cap formulas used in this study were designed to transform the original Landsat TM data into three separate images representing the scene brightness, vegetation greenness, and surface moisture (wetness). The Tasseled Cap (TC) transformation provides excellent information for agricultural applications because it allows the separation of barren (bright) soils from vegetated and wet soils. The algorithm helps to identify area of wetness on the imagery. The combination of *Level Slice* enhancement methods together with the *Tassel cap Transformation* algorithm resulted in an image that shows the pattern of wetland on the satellite imagery.

The pipeline covering the area of study was buffered at a distance of 1km. The buffer was then overlaid on the processed satellite imagery of the area of study. In order to separate only the buffer area from the entire imagery, the buffered polygon resulting from the buffering of the pipeline was used to Clip the Imagery. Furthermore, the drainage network of the area was also digitized and added to the map layer. This process was also undertaken for communities found within the Clip region of the satellite imagery. Once all the map themes were combined, the boundaries of the wetland were produced using 'Heads up digitizing approach'. The output represents the preliminary wetland delineation/base map for the field ground truth exercise.

2.3 FIELD DATA COLLECTION/GROUND TRUTH

The field crew traversed the entire pipeline ROW from Alagbado Tee to Badagary beach making use of a combination of roads, footpaths, waterways, pipeline ROW etc. In most cases, it was observed that the transition between wetland and upland vegetation species was abrupt and distinct, and in line with the topographic/physiographic position, hence a single parameter indicator (i.e vegetation) was used for the delineation (Sipple 1988, Tiner, 1993) see Table 2.3-1 for details. All the wetland found were identified and mapped. Their characteristics, vegetation and water status were also recorded in the field template form. At the wetland boundary, the vegetation was studied in detail; visual observations were made on the soil and hydrology, while the topographic position/land form was observed. In few cases, samples were collected, but the flooded nature of the areas made profile digging impossible. However, a few profiles were dug in some of the relatively less wet areas.

The soil inundation was studied according to the scheme presented in Table 2.3-2. Data were collected using the USACE (1987) Routine Wetlands Delineations Templates (see Appendix1). The landscape position, landform and associated waterbody was described according to the keys provided in Tiner (2000).

Redox potential was measured at the soil-water interface and few samples collected for the analysis of anaerobic bacteria and organic carbon/matter.

Table 2.3-1
EPA Simple Method for Delineating Wetlands

Step 1	The sites were inspected and categorized into vegetation units according to habitat types.
Step 2	In each unit, species list was developed by stratum (ground cover, sub canopy/under storey, vines, over storey and free floating). The percentage occurrence of identified species was estimated. Hereafter, subsequent studies were focused only on the wetland areas (i.e. those having top-ranked species cumulatively representing >50% of the stratum).
Step 3	The habitats were checked if they have been hydrologically modified. If not, one or more OBL species are dominant, the unit is wetland. If not hydrologically altered and one or more UPL species are dominant, the unit is non-wetland. When FACW, FAC, and/or FACU species are the only dominants, then the following step were considered. (Note: This approach recognizes the significance of OBL species for identifying wetlands.)
Step 4	The soils and hydrology were examined to determine the presence or otherwise of hydric soil and wetlands hydrology indicators as listed in Table 1.2-1
Step 5	Wetlands determination was made for all the habitats along the entire pipeline ROW.

Step 6	The wetland-upland boundary was delineated. The approach suggests identifying simple boundaries based on vegetation (i.e., presence of OBL dominants) if possible, but recommends examination of soils where FACW, FAC, and/or FACU species predominate and where the boundary is gradual. In the latter case, a combination of soil properties, hydrology indicators, and vegetation are used to establish the boundary.
Step 7	GPS readings were taken at the identified boundaries and used to develop a map showing the wetlands boundaries along the pipeline ROW.

(Source: Modified from Sipple, 1988 and Tiner, 1999)

Table 2.3-2
Frequency, Permanence and Duration of Inundation Classes

(a) Frequency

None	No reasonable possibility
Very rare	≥ I time in 500 years, but <1 time in 100 years
Rare	1-5 Times in 100 years
Occasional	5-50 Times in 150 years
Frequent	≥ 50 Times in 150years
Very frequent	> 50% of all months in a year

(b) Duration

Extremely brief	≤ 4 hours (flooding only)
Very brief	4 - 48 hours
Brief	2 -7 days
Long	7 days - 1 month
Very long	≥ 1 month

(c) Permanence

Temporary	Inundated occasionally
Seasonal	Inundated only during the raining season
Permanent/semi permanent	Inundated all year round

(d) Soil Drainage Class

Drainage Class	Description
Very poorly drained	Water is at or near the soil surface during the growing season
Poorly drained	The soil is wet at shallow depths periodically during the growing season
Somewhat poorly drained	The soil is wet at shallow depths for significant periods during the growing season
Moderately well drained	Water is removed from the soil somewhat slowly during some period of the growing season
Well drained	Water is removed from the soil readily, but not rapidly
Somewhat excessively drained	Water is removed from the soil rapidly
Excessively drained	Water is removed from the soil very rapidly

Source: Soil Survey Staff, 1993; USDA-NRCS, 2002

2.4 WETLAND INVENTORY

Surface co-ordinates were collected using Garmin GPS at the wetland-upland boundary, i.e the areas where wetland vegetation abruptly changes to upland or vice versa. The landscape position/configuration also aided in recognizing the boundaries in addition to the convectional hydrophytic vegetation, hydric soil and wetlands hydrology. These GPS values were later used to refine the potential wetlands boundaries in the base map. The editing took the form of wetlands boundary adjustment using the various editing tools contained within ArcView GIS software. Furthermore, attribute information about the wetland polygons was also added to the wetland attribute table. With the wetlands boundaries established, the size (area) of wetlands to be crossed by the pipeline within the 1 km buffer was computed from a GIS environment as a ratio of the total land area contained within the buffer area.

2.5 QA/QC

So far, wetland delineation has not been carried out in Nigeria, however, the Niger Delta is a known wetland area. The authors' experience/professional judgement became useful. The vegetation found in the wetland areas of the pipeline ROW compared favorably with some of those found in the Niger Delta.

CHAPTER 3
RESULTS AND DISCUSSIONS

This section contains the results of the field sampling, laboratory analysis, data analysis, and GIS studies. In addition, some data from the dry season baseline studies were used to assess the hydrology and soil properties of the area during the dry months. The results revealed that two types of wetlands occur in the area, coastal and inland, which is co-incidentally in line with the baseline data gathering efforts. The coastal wetlands experience tidal effects, while the inland wetlands are essentially freshwater. Evidence from vegetation, soil, hydrology and geomorphology/physiographic/topographic position also supported this pattern. Scientific evidence that informed our judgment is presented in the following sections.

3.1 COASTAL AREA

These are areas covering from Badagry beach, moving landward/northward across the Badagry Creek and terminated at about 50m just before the proposed compressor site. Vegetation studies were carried out in the entire area to distinguish between upland and wetland areas, thereafter, more emphasis were laid on the wetland areas/

The plants were classified with respect to their wetlands tolerance using literature and author's experience in other wetland areas. It should be noted that the field trip was done at the first peak of the rainy season (July 2003); hence most of the sites were flooded, which made digging of observation pits impossible. Though, few were dug, soil data generated during the dry season sampling (January 2003) was used to overcome this constraint.

3.1.1 Vegetation Studies

The vegetation around the coastal areas is primarily of two types, namely those found along the beach, which is dominated by coconut (*Cocus nuncifera*) and those associated with tidal marsh dominated by *Cyperus.* The former are uplands while the latter are wetland. Details of the floristic diversity of the area can be found in Appendix 2, while
Tables 3.1-1 through 3.1-5 contain the details of plant species encountered in the wetlands areas including their wetland status, habit, strata, percentage occurrence frequency and adaptations to wetland conditions.

The ground cover is dominated by grasses/sedges mostly *Cyperus* sp followed by *Mariscus* sp, *Hydrolea palustris, Typha domingensis*, in that order of dominance. Over 90% of the species were either obligate or facultative wetland plants. The sub canopy is dominated by shrubs and herbs such as *Clappertonia ficifolia, Alchornia cordifolia* and *Musa* sp. The upper story is dominated by trees including *Anthocleista vogelii, Elaeis guineensis* etc. Mangrove comprising of *Rhizophora* sp, *Acrostichum aureum and Machaerium lunatus* fringes the Badagry Creek in combination with *Cyperus* and *Typh*a. Monospecific stands of *Cyperus articulatus* were also encountered in some areas. A number of aquatic macrophytes and epiphytes were found in the coastal area; *Nymphaea sp* were the most common followed by ferns including *Dryopteris filix-mas* and *Nephrolepsis bisserrata.*

Obligate hydrophytes dominated the *Cyperus* swamp, hence the habitat is a wetland according to EPA (Sipple, 1988; see Table 2.3-1 also), NRC (1995), Tiner (1999). A number of the vegetation found here had morphological adaptation for wetlands including prop roots (*Rhizophora* sp), adventitious roots (*Acrostichum aureum*, *Cyperus* sp), near surface roots (*Cocos nucifera*), floating leaves (*Nymphaea lotus*), inflated body parts (aerenchyma) such as stems and leaves (*Hydrolea palustris*, *Ludwigia sp*), polymorphic leaves (*Lygodium microphyllum*), buttress/knee roots (*Hallea ciliata*) and multi-trunk/stooling (*Machaerium lunatus*).

Table 3.1-1
A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Groundcover)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Acroceras amplectens*	-	OBL	Herb	Adventitious Roots	8
2	*Acroceras zizanoides*	-	OBL	Herb	Adventitious Roots	25
3	*Acrostichum aeureum*	Leather fern	OBL	Herb	Adventitious Roots	33
4	*Aframomum melegueta*	Alligator pepper	FACU	Herb	-	8
5	*Aspilia africana*	Haemorrhage plant	UPL	Herb	-	8
6	*Commelina erecta*	Dayflower	FAC	Herb	Adventitious Roots	8
7	*Crinum giganteum*	Poison bulb	FACW	Herb	Adventitious Roots	25
8	*Cyperus articulatus*	Bizzy lizzy	OBL	Herb	Adventitious Roots	90
9	*Cyperus iria*	-	FACW	Herb	Adventitious Roots	42
10	*Desmodium triflorum*	-	UPL	Herb	-	8
11	*Emilia coccinea*	Yellow tassleflower	UPL	Herb	-	25
12	*Fimbristylis littoralis*	-	OBL	Herb	Adventitious Roots	8
13	*Fuirena umbellata*	-	OBL	Herb	Adventitious Roots	8
14	*Heterotis rotundifolia*	-	FACW	Herb	-	33
15	*Hydrolea palustris*	-	OBL	Herb	Inflated stem, Adventitious roots	16
16	*Hyptis lanceolata*	-	FACW	Herb	-	25

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
17	*Kyllinga bulbosa*	-	FACW	Herb	Adventitious Roots	8
18	*Kyllinga erecta*	-	FACW	Herb	Adventitious Roots	8
19	*Ludwigia decurrens*	Water primerose	OBL	Herb	Inflated stem, Adventitious/Balloon roots	8
20	*Ludwigia hyssopifolia*	Water primerose	OBL	Herb	Inflated stem, Adventitious/Balloon roots	8
21	*Ludwigia octovalvis*	Primerose – willow	OBL	Herb	Inflated stem, Adventitious/Balloon roots	16
22	*Mariscus alternifolius*	-	FACU	Herb	Adventitious Roots	25
23	*Mariscus ligularis*	-	OBL	Herb	Adventitious Roots	33
24	*Melastomastrum capitatum*	-	FACW	Shrub	-	33
25	*Paspalum scrobiculatum*	Ditch Millet	FACU	Herb	Adventitious Roots	25
26	*Paspalum vaginatum*	-	OBL	Herb	Adventitious Roots	25
27	*Pennisetum purpereum*	Elephant grass	FACW	Herb	Adventitious Roots	33
28	*Phymatodes scolopendria*	Fern	FACW	Herb	-	8
29	*Saccharum officinarum*	Sugarcane	OBL	Shrub	Adventitious Roots	8
30	*Scleria naumanniana*	-	OBL	Herb	Adventitious Roots	25
31	*Scleria verrucosa*	-	OBL	Herb	Adventitious Roots	25
32	*Scoparia dulcis*	Sweet Broomweed	FAC	shrubby herb	-	33
33	*Spigelia anthelmia*	Worm Bush, Pinkweed	UPL	Herb	-	16
34	*Triumfetta rhomboidea*	Chinese bur	FAC	Shrub	-	8
35	*Typha domingensis*	Cattail	OBL	Herb	Root growth in low oxygen tension	33
36	*Vernonia cinerea*	Little ironweed	UPL	Herb	-	8
37	*Zornia latifolia*	-	UPL	Herb	-	8

Table 3.1-2
A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Subcanopy)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Alchornea cordifolia*	Christmas bush	FAC	Shrub	Multi-trunk, Stooling	25
2	*Andropogon gayanus*	Ganba grass	UPL	Herb	Adventitious Roots	8
3	*Andropogon tectorum*	Giant bluestem	UPL	Herb	Adventitious Roots	16
4	*Clappertonia ficifolia*	-	OBL	Shrub	-	16
5	*Machaerium lunatus*	-	OBL	Shrub	Multi-trunk, Stooling	42
6	*Musa paradisiaca*	Plantain	FACW	Pseudo-tree	Adventitious Roots	16
7	*Musa sapientum*	Banana	FACW	Pseudo-tree	Adventitious Roots	16
8	*Mussaenda spp.*	-	FACU	Shrub	-	8
9	*Nauclea pobeguinii*	-	OBL	Tree	-	16
10	*Phoenix reclinata*	Date palm	OBL	Tree	Adventitious Roots	16
11	*Triumfetta cordifolia*	-	FACW	Shrub	-	8
12	*Urena lobata*	Hibiscus bur, Cadillo	UPL	Shrub	-	8

Table 3.1-3
A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Vine)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Centrosema pubescens*	-	UPL	Twinner	-	8
2	*Ipomoea involucrata*	Morning glory weed	FACU	Twinner	-	8
3	*Ipomoea mauritiana*	-	FAC	Twinner	-	42
4	*Lygodium microphyllum*	-	FACW	Twinner	Polymorphic leaves	16

Table 3.1-4
A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Overstorey)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Anthocleista djalonesis*	Cabbage tree	FAC	Tree	-	25
2	*Anthocleista vogelii*	Cabbage tree	FACW	Tree	Stilt roots (Occasionally)	50
3	*Cocos nucifera*	Coconut	FAC	Tree	Adventitious Roots	58
4	*Elaeis guineensis*	Oil palm	FAC	Tree	Adventitious Roots	33
5	*Hallea ciliata*	Abura	OBL	Tree	Buttress/Knee Roots	8
6	*Raphia hookeri*	Wine palm	OBL	Tree	Pneumatophores, Peg/ Adventitious Roots	20
7	*Rauvolfia vomitoria*	Serpent wood	UPL	Tree	-	8
8	*Rhizophora racemosa*	Red mangrove	OBL	Tree	vivipary, prop roots	25
9	*Vitex doniana*	Black plum	UPL	Tree	-	8

Table 3.1-5
A Checklist of Vegetation found in the Wetlands of the Coastal Areas (Aquatic Macrophytes and Epiphytes)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Azolla pinnata* var. *africana*	Water velvet	OBL	Floating-leaved	Floating leaves	10
2	*Dryopteris filix-mas*	Fern	OBL	Herb	-	16
3	*Eichhornia crassipes*	Water hyacinth	OBL	Floating-leaved	Inflated Leaves, Adventitious roots	40
4	*Nephrolepis biserrata*	Sword Fern	FAC	Herb	Adventitious Roots	16
5	*Nymphaea lotus*	Water Lily	OBL	Floating-leaved	Floating leaves	40
6	*Nymphaea maculata*	Water Lily	OBL	Floating-leaved	Floating leaves	16
7	*Pistia stratiotes*	Water Lettuce	OBL	Free floating	Floating leaves	16
8	*Salvinia*	Salvinia	OBL	Floating-	Floating leaves	8

	nymphellula			leaved		

Furthermore, the prevalent vegetation index was calculated using the weighted average of the percentage occurrence of each species and was found to be 2.08, which is less than 3 and therefore confirm that the area is indeed a wetland according to Tiner (1991, 1999), FICWD, 1989.

3.1.2 Hydrology

The area being close to the sea experiences tides, and therefore exhibits alternating tidal regime, which is of the semi-diurnal type.

During the field study, the area was flooded. The extent of flooding varies both seasonally and tidally. Generally, they shrink during the dry season and expand in the rainy season. Using the scheme shown in Table2.3-2 (Soil Survey Staff, 1993; USDA-NRCS, 2002), the area can be said to experience inundation very frequently and the duration is very long. The swamp could be said to experience permanent/ semi-permanent flooding hydrological regime. The soils are equally very poorly drained.

Many of the indicators of wetlands hydrology were encountered in this habitat including the presence of plants adapted to wetlands hydrology (Plates 1 - 3), water stained leaves, water marks on tree stem (Plate 4) and hydric soils. Therefore, in accordance with the criteria for wetland hydrology, the habitat can be said to experience wetlands hydrology (Env Lab, 1987).

Furthermore, aquatic macrophytes were identified in many of the water boodies draining the study area including Rivers (Yewa, Iju, Owo and Imede), Badagry Creek and Ologe Lagoon. The presence of aquatic macrophytes primarily indicates the presence of wetlands hydrological regime (Sipple, 1988; Tiner, 1991,1993, 1999). Beyond these, aquatic fauna such as waterfowl and shore birds were frequently encountered in the coastal areas. These organisms are now being considered as possible indicators of wetlands (Tiner, 1999).

Plate 1
Vegetation with near surface roots

Plate 2
***Cyperus* sp. with *Nymphaea lotus* in the Background**

Plate 3
Showing water hyacinth and *Cyperus* sp. with coconut at the background

Plate 4
Watermarks on trees, an indicator of wetland hydrology

Plate 5
Showing near Surface Groundwater

3.1.3 Soil

The physical and microbiological properties of soils within the habitat are shown in Table 3.1-6. From the table, it is observed that soils in this habitat have almost equal amount of sand (30%) and silt (28%) and about 42% clay. Texturally, the soils are clayey loam, very poorly drained, poorly aerated and generally contain partly decomposed and un-decomposed organic materials, possibly occasioned by low rate of decomposition due to high moisture and poor aeration regime. Furthermore, the TOC content of the soils is high, with an average of 37.05%. The soils are therefore classified as histosols (Env. Lab 1988; Soil Survey Staff, 1993; USDA, 1998, 1999, 2002). Even during the dry season sampling (January 2003), the soils were still waterlogged/swampy. On account of the presence of a clayey surface horizon with high organic matter (TOC) under aquic soil moisture conditions confirms the presence of histic epipedon (Soil Survey Staff, 1998), which is a key diagnostic feature of hydric soils (Env. Lab, 1987).

Plate 6
Redoximorphic Features, an Indicator of Hydric Soils

Plate 7
Redoximorphic Features, an Indicator of Hydric Soils

Table 3.1-6
Physical and Microbiological Properties of Soils from the Study Area

Wetland Type	**Sand Fraction**					**Soil Separate**			**Texture**	**TOC**	**Redox Potential**		**SRB**
	VCS	**CS**	**MS**	**FS**	**VFS**	**TS**	**Silt**	**Clay**		**(%)**	**(mV)**		**(Cells/g)**
	(%)										**Mean**	**Range**	
Coastal wetland	1	5	11	11	2	30	28	42	Clay loam	37.05	35.78	-49 to 119.9	10
Inland wetland	0	2	4	1	0	7	22	71	Clay	18.38	41.61	-185 to 171.1	1000

VCS = Very coarse sand; CS = coarse sand; MS = medium sand; FS = fine sand; VFS = very fine sand; TS = total sand
SRB = sulphate reducing bacteria
TOC = Total Organic Carbon

The soils are muddy, massive in structure and dark gray to black in the surface. The soils are characterized with aquic soil moisture regime (i.e. a reducing regime) and are virtually free of dissolved oxygen in the water that saturates it in all the horizons. The texture is clay, and the soils are slightly sticky, plastic wet and firm moist. They have Hue of 2.5Y or yellower, chroma of 3 or less and distinct redox colorations. These characteristics will group the soils as Aquents i.e. recently formed poorly drained soils.

In the relatively less wet areas, there exists the presence of near surface groundwater as pit dug (Plate 5) were rapidly occupied by water in less than 3 minutes, and is accompanied by sulfidic odour. On exposure, the soils rapidly oxidizes, forming yellow/reddish mottles (Plates 6 and 7) similar to those encountered by Ohimain (2001) while working on dredged spoils in the Niger Delta.

The Cyperus dominated coastal swamp could be regarded as having hydric soil on account of the high organic content i.e. histosols (37%) relative to adjacent upland areas such as the beach ridge and grassy /cleared areas with TOC values of 0.47% and 0.98% respectively. The presence of histosols is considered conclusive to establish the occurrence of hydric soils. Furthermore, the soils have an aquic moisture regime, low Redox potential, emission of sulfidic gas and the presence of sulphate reducing bacteria unequivocally establish the soil as hydric soil.

3.1.4 Geomorphology

The area slopes gently downwards from Badagry beach towards the Badagry Creek and increased slightly across the River northwards. The area is generally flat and experiences riverine/estuarine processes. Hydrogeomorphically, this is a channel type of wetland. The waterbodies draining the area generally flow in a north-south direction and it is perennial. Because it is tidal, it experiences bidirectional flow. The river channels are distinct and are more or less shallow. Permanently inundated channels of varying sizes and shapes characterizes the rivers. In contrast, the creeks (or feeder streams) are seasonally inundated and are characterized by smaller channels. Lagoons are also present in the area. Near the pipeline crossing at Badagry Creek, mangrove vegetation and/or Cyperus fringes the waterfront (Plate 8), while Cyperus either alone or in combination with other plants such as *Typha* sp occupies a slightly higher topographic positions that are basically swamps. The water bodies within these slightly elevated areas are more or less stagnant and are occupied by mostly aquatic macrophytes such as water lilies (*Nymphaea lotus*) and water hyacinth (*Eichhornia crassipies*). Shore birds, which are now increasingly being used as wetland indicators were also encountered in the area (Plates 8 and 9).

Because it occurs along a shoreline the landform associated with this wetland is regarded as fringe wetland. And because it is situated behind a barrier island another modifier is added, hence it is called barrier island fringe wetland according to the classification keys of Tiner (2000).

Plate 8
Water Hyacinth and Red Mangrove
(close to the pipeline crossing)

Plate 9
Showing Shorebird
(which is now being considered as wetland indicator)

3.1.5 Redox Measurement and Anaerobic Bacteria

The values of the Redox measurements collected at the water/soil interface ranged from – 49.7 to 119.9 mV, which indicated that the area is relatively anaerobic. The presence of anaerobic bacteria (though scanty) especially sulphate reducing species (*Desulfovibrio desulfuricans*) confirmed that the soil is anaerobic.

3.1.6 Wetlands Size and boundary

The boundaries of the wetlands along the pipeline ROW is shown in Figure 3.2-1. The coastal wetland fringes the Badagry Creek and is located south of the proposed compressor station site, which is at the last segment of the ROW just before the beach ridge. The size of the wetland within 1 km buffer on either side of the ROW is about 1.73 sq km.

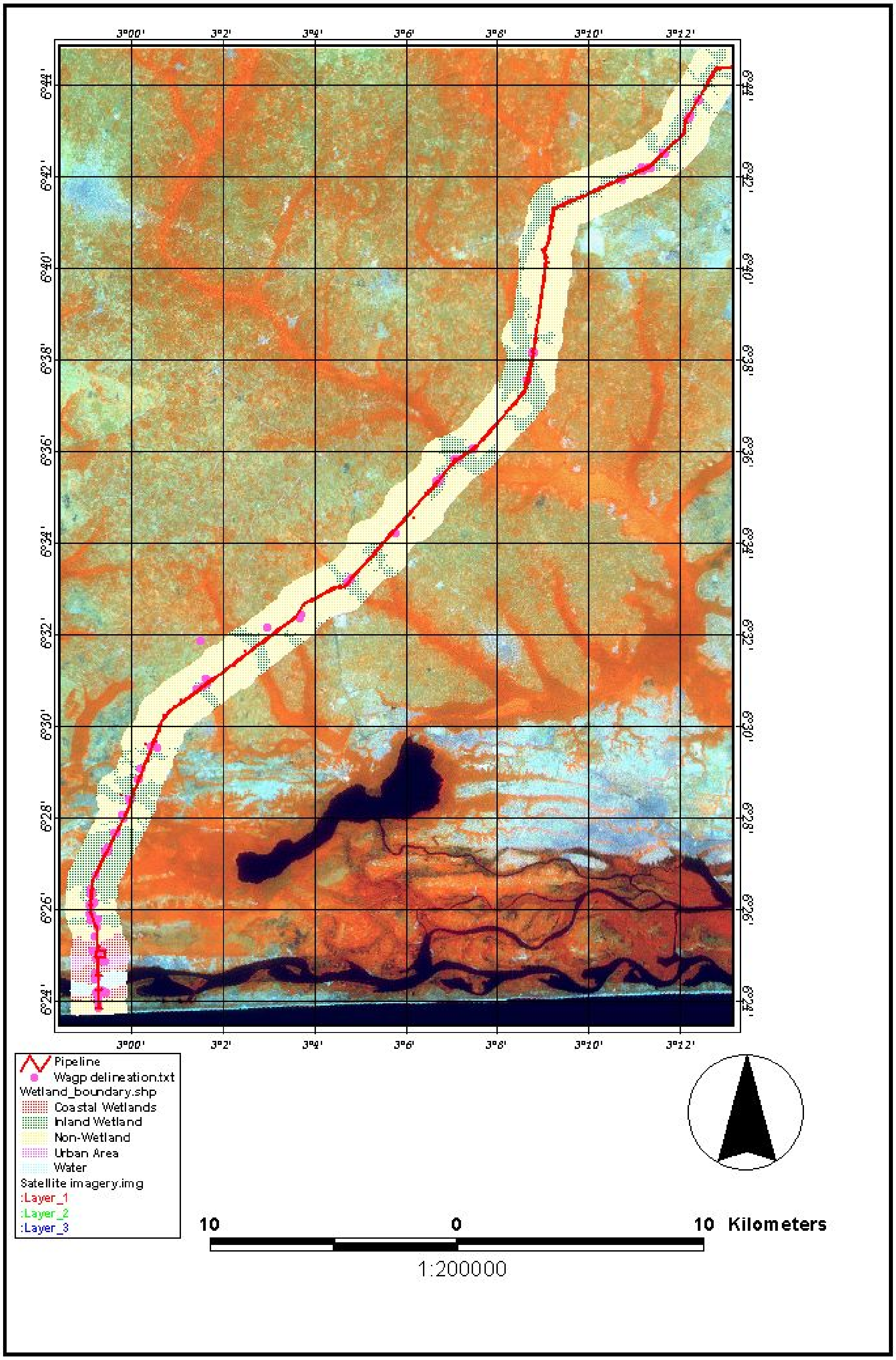
3.1.7 Concluding Statement

On account of the presence of hydrophytic vegetation dominated by obligate species, and the presence of hydric soil driver by wetland hydrology confirms that the area is a wetland. Evidence from coastal geomorphology, Redox measurements and anaerobic microbiology studies further confirm unequivocally that the area is indeed a wetland.

3.2 INLAND AREAS

This comprise of the area starting from the coastal boundary near the proposed compressor station site to the beginning of the pipeline ROW at Alagbado Tee (Northern edge).

Figure 3.2-1
Wetlands delineation map showing the West African Gas Pipeline ROW



3.2.1 Vegetation Studies

The entire area is dominated by alternating sequence of wetlands and upland plants, which coincided with topographic positions. Appendix 3 contains a comprehensive list of plant species in the wetlands and upland areas, while Tables 3.2-1 through 3.2-5 show the list of wetlands plants presented according to vegetation strata. Other information presented included the wetland classification status, plant habit and wetlands adaptation and percentage occurrence.

Table 3.2-1
A Checklist of the Vegetation found in the Inland Wetland Areas (Groundcover)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Achyranthes aspera*	Devil's horsewhip	UPL	Herb	-	7
2	*Acroceras zizanoides*	-	OBL	Herb	Adventitious roots	29
3	*Acrostichum aureum*	Leather Fern	OBL	Herb	Adventitious roots	14
4	*Aframomum melegueta*	Alligator Pepper	FACU	Herb	-	7
5	*Aframomum sceptrum*	Grains of Paradise	FACU	Herb	-	7
6	*Aneilema beniniense*	-	FACU	Herb	-	14
7	*Aspilia africana*	Haemorrhage plant	UPL	Herb	-	7
8	*Cercestris afzelii*	-	FACW	Herb	-	7
9	*Costus afer*	Bush cane	FACW	Herb	-	7
10	*Crinum giganteum*	Poison bulb	FACW	Herb	Adventitious roots	7
11	*Cyperus haspan*	Flat sedge	OBL	Herb	Adventitious roots	7
12	*Cyperus iria*	-	FACW	Herb	Adventitious roots	21
13	*Cyrtosperna senegalense*	Arum	OBL	Herb	Aerenchymatous petiole	71
14	*Desmodium triflorum*	-	UPL	Herb	-	7
15	*Emilia coccinea*	Yellow tasselflower	UPL	Herb	-	7
16	*Fuirena umbellata*	-	OBL	Herb	Adventitious roots	50

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
17	*Heterotis rotundifolia*	-	FACW	Herb	-	21
18	*Kyllinga bulbosa*	-	FACW	Herb	Adventitious roots	7
19	*Leersia hexandra*	Razor grass	OBL	Herb	Adventitous roots	14
20	*Ludwigia decurrens*	Water primerose	OBL	Herb	Inflated/balloon roots	14
21	*Lycopodium cernuum*	-	FACW	Herb	Inflated/balloon roots	7
22	*Mariscus alternifolius*	-	FACU	Herb	Adventitious roots	7
23	*Mariscus flabelliformis*	-	UPL	Herb	Adventitious roots	21
24	*Melastomastrum capitatum*	-	FACW	Shrub	Adventitious roots	14
25	*Nephrolepis biserrata*	Sword fern	FAC	Herb	Adventitious roots	57
26	*Palisota hirsuta*	-	UPL	Herb	-	14
27	*Panicum laxum*	-	FACW	Herb	Adventitious roots	14
28	*Paspalum scrobiculatum*	Ditch millet	FACU	Herb	Adventitious roots	14
29	*Pentodon pentandrus*	-	OBL	Herb	-	7
30	*Rhyncospora corymbosa*	-	OBL	Herb	Adventitious roots	36
31	*Sacciolepis africana*	-	OBL	Herb	Adventitious roots	14
32	*Scleria verrucosa*	-	OBL	Herb	Adventitious roots	21
33	*Scleria naumanniana*	Razor sedge	OBL	Herb	Adventitious roots	36
34	*Thalia geniculata*	-	FAC	Shrub	-	7
35	*Thaumatococcus danielii*	Katemfe	FACU	Herb	-	14
36	*Zornia latifolia*	-	UPL	Herb	-	7

Table 3.2-2
A Checklist of the Vegetation found in the Inland Wetland Areas (Subcanopy and Understorey)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Alchornea cordifolia*	Christmas bush	FAC	Shrub	Multitrunk, Stooling	64
2	*Andropogon gayanus*	Ganba grass	UPL	Herb	Adventitious roots	7
3	*Andropogon tectorum*	Giant bluestem	UPL	Herb	Adventitious roots	7
4	*Chromolaena odorata*	Siam weed	UPL	Shrub	-	7
5	*Clappertonia ficifolia*	-	OBL	Shrub	-	21
6	*Eriosema psoraleoides*	-	UPL	Shrub	-	7
7	*Harungana madagascarienisis*	-	UPL	Shrub	-	21
8	*Musa paradisiaca*	Plantain	FACW	Pseudo-tree	Adventitious roots	7
9	*Musa sapientum*	Banana	FACW	Pseudo-tree	Adventitious roots	7
10	*Mussaenda spp.*	-	FACU	Shrub	-	14
11	*Solanun torvum*	Turkey berry	UPL	Shrub	-	7
12	*Trema orientalis*	Trema	FAC	Tree	-	21
13	*Ficus spp.*	-	FAC	Tree	-	7
14	*Musanga cecropiodes*	Umbrella tree	FAC	Tree	Stilt roots	14

Table 3.2-3
A Checklist of the Vegetation found in the Inland Wetland Areas (Overstorey)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Alstonia boonei*	Stool wood	FAC	Tree	Buttresses (Slight)	43
2	*Anthocleista djalonesis*	Cabbage tree	FAC	Tree	-	50
3	*Anthocleista vogelii*	Cabbage tree	FACW	Tree	Stilt roots (occassionaly)	64
4	*Anthostema*	-	OBL	Tree	-	7

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
	aubryanum					
5	*Artocarpus communis*	Jack fruit	UPL	Tree	-	21
6	*Bambusa bambusa*	Bamboo	FACW	Shrubby tree	Adventitious roots	14
7	*Bombax buonopozense*	Red flowered silk-cotton tree	UPL	Tree	Buttresses	7
8	*Ceiba pentandra*	Kapok, Silk-cotton tree	UPL	Tree	Buttresses	7
9	*Cocos nucifera*	Coconut	FAC	Tree	Adventitious roots	14
10	*Elaeis guineensis*	Oil palm	FAC	Tree	Adventitious roots	21
11	*Hallea ciliata*	Abura	OBL	Tree	Buttresses/Knee roots	71
12	*Lophira alata*	Ironwood	UPL	Tree	-	21
13	*Pentaclethra marcrophylla*	Oil bean tree	UPL	Tree	-	14
14	*Raphia hookeri*	Wine palm	OBL	Tree	Adventitious/peg roots	93
15	*Treculia africana*	African breadfruit	UPL	Tree	Adventitious roots	14
16	*Vitex doniana*	Balck plum	UPL	Tree	-	7

Table 3.2-4
A Checklist of the Vegetation found in the Inland Wetland Areas (Vine)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Cassytha filiformis*	-	UPL	Twinner	Haustoria	7
2	*Ipomoea mauritiana*	-	FAC	Twinner	-	14
3	*Ipomoea aquatica*	Water spinach	OBL	Creeper	Floating stem and leaves	7
4	*Lygodium microphyllum*	-	FACW	Twinner	Polymorphic leaves	36
5	*Smilax anceps*	West African sarsaparilla	UPL	Twinner	Adventitious roots	14

Table 3.2-5
A Checklist of the Vegetation found in the Inland Wetland Areas (Aquatic Macrophyte, Epiphyte and Liana)

S/N	Botanical Name	Common Name	Wetland Status	Habit	Adaptation	% Occurrence Frequency
1	*Azolla pinnata Var. africana*	Water velvet	OBL	Herb	Adventitious roots, Floating leaves	36
2	*Calamus decratus*	Rattam palm, Cane	FACW	Climber	-	7
3	*Cassytha filiformis*	-	UPL	Twinner	Haustoria	7
4	*Dryopteris filix-mas*	Fern	OBL	Herb	Adventitious roots	57
5	*Hydrolea palustris*	False-fiddle	OBL	Herb	Inflated stem, Adventitious roots	7
6	*Lemna paucicostata*	Duckweed	OBL	Herb	Floating leaves	7
7	*Nymphaea lotus*	Water lily	OBL	Herb	Floating leaves	70
8	*Pistia stratiotes*	Water lettuce	OBL	Herb	Floating leaves, adventitious roots	21
9	*Salvinia nymphellula*	Salvinia	OBL	Herb	Floating leaves	14

The ground cover strata are dominated by obligate hydrophytes such as *Cyrtosperma senegalense*, *Nephrolepsis biserrata*, *Fuirena umbrellata*, *Sclera* sp in decreasing order of dominance. The sub canopy is dominated by *Alchornia cordifolia*, while the vines are dominated by *Lygodium microphyllum*, an obligate hydrophyte. The macrophytic/epiphytic/liana zone is mostly occupied by free floating species such as *Nymphaea lotus* and *Azolla pinnata*. The dominant tree in the over storey is the raffia palm, *Raphia hookeri* followed by *Hallia ciliata, Anthocleista vogelii, Anthocleista djalonesis* and *Astonia boonei* in decreasing order of dominance.

The mere fact that obligate hydrophytes dominated the habitat, suggests that it is a wetland. A prevalence index of 2.25 was computed for the habitat, which further confirms that hydrophytic vegetation is predominating (Tiner, 1991).

3.2.2 Hydrology

The areas inland wetlands, which are dominated by obligate hydrophytes also experience wetland hydrology, which could be classified as permanent, since it experiences ponding during both wet and dry seasons. This visual evidence of site inundation met the criteria to classify it as having wetland hydrology. Beyond this, there were other signs/indicators including the dominance of the area by vegetation typically adapted for wetland areas (Plates 10 and 11) such as *Azolla* sp (free floating), *Raphia hookeri* (adventitious roots), *Hallea* *ciliata* (buttress/knee roots) etc. Some degraded *Raphia hookeri*, which are evidences of disturbed wetland were also encountered (Plate 12).

The area is drained by non-tidal freshwater. Apart from being permanent, the duration of ponding could be classified as very long and occurs very frequently according to the classification of Soil Survey Staff (1993) and USDA (2002).

Plate 10
Inland Wetlands Dominated by Obligate Hydrophytes

Plate 11
Inland Wetlands Dominated by Obligate Hydrophytes

Plate 12
Degraded Raffia, an evidence of Anthropogenic Impacts

3.2.3 Soil Studies

The soils are very poorly aerated (due to water-logging), massive in structure, contain high content of partly decomposed to almost un-decomposed organic materials and were all deeply ponded even during the dry months. Tables 3.1-1 through 3.1-5 shows the particle size distributions and texture and other physical properties of representative soils from the habitat. The soils are clayey in texture with very high content of clay – about 71%, and 22% silt. The high clay content due to their relatively small pore spaces may have contributed substantially to the anaerobic nature of the soil (USDA-NRCS, 2002). TOC was in the order of 18%, which indicated that the soils are histosols. The TOC is considered as high in comparison to that of adjacent upland habitats including bushfallows/farmlands (2.96%) and grassy/cleared areas (0.7%). On account of the presence of a clayey surface horizon with high organic matter (TOC) under aquic soil moisture conditions confirms the presence of histic epipedon (Soil Survey Staff, 1998), which is a key diagnostic feature of hydric soils (Env. Lab, 1987).

3.2.4 Geomorphology

In the inland areas, there seems to be an alternating physiographic sequence of wetlands and uplands, with the hillcrest (summit) and valleys (toeslope) being occupied by upland and wetland species respectively. The wetland area (valleys) is drained by surface run offs, near surface groundwater and flood from nearby rivers. The backslope is very steep. The wetland-upland boundary, which occurs on the footslope are distinct and along with the vegetation type clearly followed landscape positions.

Hydrogeomorphically, this type of wetland is associated with depressions or basins, hence the landform is regarded as basin wetland (Tiner, 1989). They have convex bottoms, and with clearly define margins. According to the keys in Tiner (2000), this type of wetland could be classified as lotic during the rainy season because they are associated with flowing stream, but in the dry season, they are relatively stagnant and could be classified as lentic. The associated waterbody is non-tidal. Other modifiers are also used to describe the wetland. For instance, because the surface water inflow is from higher elevation and pass through the wetlands to other wetlands downstream at lower elevation, they are regarded as lentic basin wetlands, and because water flow through them, they are also referred to as throughflow basin wetland.

3.2.5 Redox Measurement and Anaerobic Bacteria

The values of the Redox measurement collected at the water/soil interface ranged from –185 to 117.3 mV, with a mean of 41.61 mV, which clearly indicated that the area is relatively anaerobic. The population of SRB was in the order 10^3 cells/g. The presence of anaerobic bacteria especially sulphate reducing species (*Desulfovibrio desulfuricans*) confirmed that the soil is anaerobic.

3.2.6 Wetlands Size and Boundary

The boundaries of the wetlands along the pipeline ROW as shown in Figure 2 clearly shows that inland wetlands are predominating with an area of 31.46 sq km within 1 km buffer on either side of the ROW. Apart from the narrow strip of coastal wetland that fringes the Badagry Creek, the others are inland wetlands alternating with upland areas in a wavelike fashion. The inland wetland extends from the start of the ROW and terminated at the northern boundary of the proposed compressor station.

3.2.7 Concluding Statement

On account of the presence of hydrophytic vegetation dominated by obligate species, and the presence of hydric soil driven by wetland hydrology confirms that the area is a wetland. Evidence from geomorphology, Redox measurements and anaerobic microbiology studies further confirm unequivocally that the area is indeed a wetland.

CHAPTER 4
ENVIRONMENTAL IMPACTS OF PIPELINE CONSTRUCTION ON WETLANDS AND MITIGATION MEASURES

In this section of the report, environmental impacts arising from pipeline construction in wetlands is succinctly presented. This is followed by measures to minimize such impacts and concludes by recommending best management practices for wetland crossing.

4.1 IMPACTS OF PIPELINE LAYING ON WETLANDS

The construction of pipelines across wetlands has the potential to create serious environmental damage. It can cause impacts on the physical, biological and chemical components of the wetlands (Zwirn, 2002). The activities involved in pipeline construction include ROW surveying, trenching, pipe laying and backfilling. Each of these activities may have negative impacts on wetlands such as vegetation damage, alteration in topography and hydrology and water quality, etc. The impacts and ameliorative measures that need to be put in place are briefly discussed below.

4.1.1 Vegetation Impacts

Impacts on vegetation would be mainly from construction work. This will involve clearing of trees, scrubs and herbaceous vegetation from the wetlands. While vegetation within the construction corridor would be cut and removed leaving root intact where possible, vegetation around the open trench will not only be cleared but its stumps and roots will also be uprooted. Other likely impacts on vegetation will be change in species dominance and the introduction of exotic and invasive species. These new species may out-compete the indigenous species if care is not taken.

4.1.2 Hydrology Impacts

There is the risk of creating a hydraulic change by trenching through the wetlands. Digging trench through wetlands may alter the wetland hydrology in many ways thereby preventing the normal flow of water in the area (Mitsch and Gooselink, 2001). Digging the trench through a wetland could result in three types of risks that could alter hydrology:

- Draining a wetland by allowing water to flow out of the wetland along the pipeline trench, because the replaced material in the trench would have greater hydraulic conductivity than the surrounding undisturbed soils;

- Draining wetland through the subsoil puncturing the impermeable layer with the trench; and

- Altering the sub-basin that drains to a particular wetland by diverting subsurface flows through the trench and away from the wetland.

This has serious implications for water retention in the wetlands and will affect both the soil and vegetation on the long run. Factors that will be used to determine the risk of altering wetland hydrology are the source of the water to the wetland (e.g. groundwater, surface runoff, or streamflow), landscape position, size, surficial geology, and soils (Zwirn, 2002). Wetlands located in a topographic depression or river valley would not be drained through the trench because the trench in the wetland is at the lowest point in the surrounding landscape. Hence these potential risks may only be valid to a lesser extent for the coastal wetlands and pose no threat in the inland wetlands. But the consequence of altered hydrology can be overwhelming, it has be reported to cause large-scale vegetation damage, which could result in a shift in habitat type (Fagbemi et al., 1988; Ohimain, 2003a). Beyond this, pipeline construction in wetland areas have been shown to cause alteration in wetland morphology (Zwirn, 2002). Such habitat modification has also been reported to be the major cause of the observed erosion, flooding and subsidence in the Niger Delta (Ebisemiju, 1985; Eedy *et al*., 1994; World Bank, 1995, Ebisemiju *et al*., 1988).

4.1.3 Water Quality Impacts

Pipeline construction could introduce sediment into wetland thereby degrading the water quality through increase in turbidity, suspended solids and organic matter. It may affect fauna especially fish through impairment of vision, clogging of gills and smothering of their eggs. It may also result in decreased primary production because of reduced euphotic zone. This impact may be temporary in the coastal wetland (perhaps non-existent, since horizontal directional drilling (HDD) is used for the coastal wetland crossing), but it could be major and long term in some of the inland areas that are stagnant. Other potential impacts that may arise from the re-suspension of sediments includes heavy metal pollution, decreased oxygen tension and a corresponding increase in BOD and COD. Other impacts on water quality are chemical and toxic substances releases from construction equipment especially during drilling for wetland crossing.

If the hydrology of the wetlands is altered, it could result in salt-water intrusion from the Atlantic Ocean, which could be devastating to both coastal and inland wetlands alike. The risk is however greater in the coastal wetland because of its proximity to the ocean. The inland wetlands because of their topographic/landscape position, it is quite unlikely for seawater to get there. Furthermore, there is the risk of soil acidification as a result of exposure and oxidation of pyritic soils/sediments (Edwards *et al*., 1998; Ohimain *et al*., 2003). Exposed soils and sediments from the coastal wetlands exhibited redoximorphic features and are highly mottled (see Plates 6 and 7), which suggest acidification. From the dry season study, acidic pH of 4.9 and 5.0 were recorded for the coastal and inland wetlands respectively (ERML, 2003b). Acidification in these low energy wetlands can lead to vegetation damage, heavy metal contamination and general habitat degradation (Ohimain, 2003b).

4.1.4 Wildlife Impacts

Some areas in the wetland, which serve as habitat and also nestling ground for some very important fauna might be impacted during pipeline construction. Being linear, pipelines

ROW can lead to habitat fragmentation and create accesses into these areas, which might encourage poaching and logging (Moffat and Linden, 1995; World Bank, 1995).

4.2 MEASURES TO MINIMIZE IMPACTS OF PIPELINE CONSTRUCTION

During the project conceptualisation, plans were made to minimize wetlands impacts. Selection criteria to identify the proposed route included utilization of existing roads, trails, and transmission line corridors to avoid wetland impacts. A large part of the pipeline ROW passed through the existing Shell Nigeria Gas/ Nigerian Gas Company pipeline ROW. Following field studies, additional wetland impacts were avoided by realignment of the route where feasible. Feasibility includes consideration of land ownership and acquisition of easements, construction costs, reducing sharp angles and bends in the pipeline corridor, and access. Despite these precautions, the impacts discussed above are valid and measures to minimize them are discussed below.

4.2.1 Vegetation

Narrowing the corridors (i.e. limiting the cleared area to as minimum as practicable) within the wetlands areas could minimize vegetation impacts arising from pipeline construction. Wetland impacts are further avoided by placing staging areas for construction and pipe fitting in adjacent upland areas, and crossing the narrowest portion of the wetlands where feasible. Pipeline ROW restoration can also be embarked upon. Replanting of native wetland species after construction, screening of plant species before planting and implementation of about five years monitoring programme as part of the mitigation measures. It should also be noted that forested wetland are difficult to compensate for either through restoration or creation and therefore should be avoided as much as possible.

4.2.2 Hydrology

There is the possibility of altering upslope and down slope hydrologic flow patterns. In the inland areas, the pipeline corridor cuts through the wetlands and adjacent uplands on the slope. These are areas where surface runoffs and shallow subsurface flow drains down slope to the wetland. To prevent potential hydrologic impacts on these wetlands, trench plugs should be installed within the pipeline trench to prevent shallow subsurface water from diverting along the trench and away from the wetland. These plugs would also prevent the lowering of the groundwater by subsurface flows following the trench. Indirect impacts on wetlands located outside of the construction corridor would be avoided by using the same methods to plug the trench line. Appropriate placement of trench plugs could be used to prevent subsurface flows from being rerouted away from wetlands down slope of the trench.

The trench plugs should be impervious materials e.g. concrete, compacted clay, etc. This impervious layer should extend beyond the depth of the pipeline trench. This impervious trench should be connected with or overlaid on existing layers to make a continuous seal. Hydrogeologist, soil and wetlands scientist should identify the sites where impervious layer would be installed in the trench before backfilling. Restoration of the pre-construction topography should be embarked upon to preserve the hydrology of the area.

4.2.3 Water Quality

Most of the impacts on water quality can be controlled by the application of methods that would minimize sediment re-suspension. This can be done by the application of best practices as discussed in section 4.3. However, while working in wet sections of trenches or directional drilling pits, the trenches or pits should be de-watered to maintain safe working conditions. Water removed from the trench should not be discharged into streams or wetlands without first controlling the sediments with temporary sediment basins and filter fences. Sediments/soils arising from the trenching should be selectively handled to prevent acidication. Spoil handling techniques includes placement below the water table, capping with impervious materials, alkaline treatment etc (Ohimain, 2002, 2003a, 2003b). Other potential impacts such as vehicle fuelling, and maintenance should be carried out in adjacent upland areas.

4.3 BEST MANAGEMENT PRACTICES FOR WETLANDS CROSSING

Best management practices in pipeline wetland crossings are designed to minimize and avoid frequently occurring problems, including increased sedimentation and turbidity, changes in stream morphology, altered chemical composition, and the resulting increased mortality and reduced productivity in invertebrates, plant life, and fisheries.

There are three belowground (subterranean) methods and one aerial methods used most frequently in wetland crossings, ranked in order of preference (Zwirn, 2002), as follows:

a) Open Cut Dry ("Isolated") Crossing

b) Horizontal Directional ("Trenchless") Drilling (HDD)

c) Open Cut Wet ("In-Stream") Crossing

d) Aerial crossing

Environmental agencies often prefer the use of particular techniques in cases where either habitat or particular species are vulnerable or endangered. Balancing the need to protect ecological resources, and the need to complete pipeline projects quickly and cost-effectively, results in an imperative to compromise between competing methods. Usually, the trenchless methods (HDD) are preferred in wetland areas where habitat or species are particularly vulnerable or endangered. But open cut dry crossings are allowed in some sensitive regions if conducted with the specifications and recommendations of a qualified specialist. Generally, open cut dry ("isolated") crossing techniques are preferable to open cut wet ("in-stream") crossings in every circumstance, although in-stream crossings are permitted in less vulnerable ecosystems (Zwirn, 2002). The above-mentioned wetlands crossing techniques are briefly discussed below:

a) Open Cut Dry ("Isolated") Crossing. This method is best suited for wetlands with river flows lower than $4m^3s^{-1}$. Under this method, the watercourse is isolated and then diverted around the pipeline crossing while a trench is excavated and the pipe installed, and then the stream is stabilized and allowed to return to its bed. This method is best is applied during dry season in order to allow the use of heavy equipment. This method may be appropriate for crossing the inland wetlands.

There are three methods of diverting stream flow in an open-cut dry crossing:

- Dam the stream and convey the water across the site by pumping
- Dam the stream and install a culvert (flume)
- Dam the stream and install a " superflume" for high-flow watercourses (Zwirn, 2002)

b) Horizontal Directional Drilling (HDD). This process is expensive and time-consuming, and represents the best choice only in riverine wetlands with large water body crossings, or in areas with exceptionally vulnerable species or ecosystems such as the coastal wetland. In HDD, a small diameter tunnel is drilled under the water body, and then enlarged. The pre-assembled gas pipeline is then pulled through the tunnel. No trench is used, and the watercourse in not diverted. HDD can also be used in the inland areas because of the exceptionally steep approach slopes within adjacent upland area and the wetland at the valley toe. Such abrupt topographic difference at the wetland boundary makes it imperative to apply HDD for crossing.

c) Open Cut Wet Crossing. Under this method, the stream is not diverted during construction. The pipe is installed and backfilled while the stream continues flowing through the site. Sediment and pollutant run-off can be very severe. This is an extremely damaging method of construction that can only be mitigated by rapid completion of the pipeline crossing. Particularly damaging elements of an open cut pipeline construction are:

- Trench excavation and backfilling,
- Disposal of fill material near watercourses,
- Run-off from upland worksites, and
- Discharge from pipe testing or trench dewatering

Pipeline developers prefer open cut wet crossings, because of their lower costs and quick completion time (Zwirn, 2002). While this technique has the greatest potential for environmental damage, it is often the method of choice, when regulatory or logistical impediments do not require other techniques.

d) Aerial River Crossing Construction Methods. This differs significantly from subterranean methods. In an aerial crossing, the pipeline extends over the river and is supported by a bridge structure. Because of the abrupt topographic difference at most of the inland wetland boundary, this method can be applied. But there are safety concerns that have to be addressed prior to its application.

Finally, environmental management at pipeline wetland crossings requires assessing and balancing various criteria: cost, scheduling, engineering, and ecological value of habitats and species. For protecting biota and the integrity of the wetland, pipeline construction across wetlands should be done at less vulnerable locations, preferably during the dry season and at periods when fish life cycles are more tolerant of disturbances.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Results of the field study carried out from the 15-25th of July 2003 along the WAGP pipeline ROW in order to delineate the wetland areas are summarised in this section. Highlights of our findings including the methods used are presented below.

A landsat imagery of area was acquired along with themes representing the pipeline ROW, roads and settlements. The imagery was processed using standard methods (Tiner, 1999; Lyon and McCarthy, 1995), which contrasted the "spectra signatures" of the habitat. Manipulation in GIS environment using various tools for infra red colour, true colour and false colour yielded various shades of colours and textural patterns, which was used to locate site environmental features including vegetation, beaches, water bodies/wet spots depressions. A buffer of about 1 km was established along the onshore parts of the ROW. The probable position of wetlands as revealed by the landscape position and water flow pattern in the processed image was delineated. The output represents the preliminary wetland delineation/base map for the field ground truth exercise. Standard methods as described in Chapter Two was used for data collection.

Evidence from soil, vegetation, hydrology, geomorphology/topography, Redox potential and aerobic microbial studies show that the pipeline ROW passes through a number of habitats; both upland and wetland areas. The two types of wetlands (inland and coastal) were recognized according to their vegetation, soil, hydrology and geomorphology/landscape position.

The coastal wetlands occur at the latter segment of the pipelines, starting from the northern fringes of the Badagry Creek (near the compressor station) and terminating across the Badagry Creek just before the beach. Hydromorphologically, the coastal wetlands are channels with a distinct flow pattern, which is towards the south into the Atlantic Ocean. The hydrology of the area is characterised by tidal influence and is of the semi-diurnal type. The area is permanently flooded, both seasonally and tidally. The duration flooding is long and occurs very frequently. The soil is very poorly drained. The habitat is surrounded by obligate hydrophytes, which have reproductive, physiological and morphological adaptations for wetland conditions including prop roots (*Rhizophora* sp), adventitious roots (*Acrostichum aureum*, *Cyperus* sp), near surface roots (*Cocos nucifera*), floating leaves (*Nymphaea lotus*), inflated body parts (aerenchyma) such as stems and leaves (*Hydrolea palustris, Ludwigia sp*), polymorphic leaves (*Lygodium microphyllum*), buttress/knee roots (*Hallea ciliata*) and multi-trunk/stooling (*Machaerium lunatus*).

The vegetation prevalence index is 2.08, which is less than 3 and therefore confirm that the area is indeed a wetland. Other indicators of wetland shown in Table 2 were also encountered. This clearly confirms that area is indeed a wetland. Evidence from Redox, topographic and microbiological studies further confirm the wetland status of the area.

On the other hand, the inland wetlands occur mostly in depression areas along the pipeline ROW from Alagbado Tee to the compressor station site. These are basin type of wetlands, dominated mostly by obligate hydrophytes including *Raphia hookeri*, *Cyrtosporma senegalense and Nymphaea lotus*, which occupied the overstory, subcanopy/ground level and mesophytic strata respectively. These plants with percentage frequency of occurrence above 60%, also exhibits adaptations (morphological, reproductive and physiological) for wetland hydrology.

The hydrology of the area is characterised by permanent flooding of long duration, which occurs very frequently. The soils are hydric soils on account of the very poor drainage, aquic soil moisture regimes and being histosols. These properties confirm that the areas are wetlands. Evidence from redox measurements, anaerobic microbiology and topography further confirm the wetland condition/status of the area.

5.2 RECOMMENDATIONS

The spatial boundaries of the wetlands along the proposed WAGP pipeline ROW as shown in Figure 2. The sizes of wetland within 1 km buffer on either side of the pipeline ROW are 1.73 and 31.46 sq km for coastal and inland wetlands respectively. This has implications for pipeline laying operations. There exist the potential risk of altering the hydrology of the area, as the trenching will be made across shoreline and inland wetlands of different topographic relief. While the former can lead to alteration of the salinity regimes, which may cause large vegetation damage, the latter can cause rapid draining/dewatering of the wetlands, which may also lead to vegetation impacts.

Considering the nearness to the Atlantic Ocean, the coastal zone is at risk of hypersalinization. On the other hand, because of the pronounced topographical differences between the wetlands and adjacent upland areas, the inland wetlands might experience severe drainage/ dewatering, which may impact vegetation and other biota.

We therefore conclude by recommending that best management practices be applied for wetland crossing such as open cut dry crossing and horizontal directional drilling. This should however be weighed against the overall cost of the project, time constraints and the expected environmental benefits.

CHAPTER 6
REFERENCES

Begg, G. and Lowry, J. 2002. Land capability and topographic data as s surrogate for the mapping and classification of wetlands: a case example from the Daly Basin, Northern Territory, Australia.

Binkley, M. 1997. Delineation and Preservation of Wetlands with GIS and Remote Sensing. 1997 ESRI User Conference.

Browne, S et al. 1996. Freshwater wetlands delineation manual. New York State Department of Environmental Conservation, Albany.

Cowardin, L. M., Carter, V., Golet, F. C., and LaRoe, E. T. 1979. "Classification of Wetlands and Deepwater Habitats of the United States," FWS/OBS79/31, US Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Dini, J. 2002. South Africa: Ukhahlamba Drakensberg Park and Nationa Wetlands Inventory. Department of Environmental Affairs and Tourism, Pretoria, Republic of South Africa.

Ebisemiju F. S. 1988. Human impacts on marine processes in the western Niger Delta. In: Sada PO, Odemerho FO: Environmental Isues and Management in Nigerian Development. Woye and Sons Press Ltd., Ilorin, Nigeria 239-251

Ebisemiju, F.S. 1985. Some observations on coastal processes and shoreline retreat in the Western Niger Delta, Nigeria. Malaysian Journal of Tropical Geography. 12: 20-30.

Edwards K. J. Schrenk, M. O., Hamers, R. J. and Banfield, J. F. 1998. Microbial oxidation of Pyrites: Experiments using microorganisms from an extreme environment. *Am. Mineralogist*. 83: 1444-1453.

Eedy, W. Rodgers, B., Saunders, K. E. and Akindunni, F. 1994. Applications of satellite remote sensing to coastal recession analysis in Nigeria. A paper presented at the Coastal Zone Management '94 Conference, Halifax, Canada

Environmental Laboratory 1987. Corps of Engineers Wetlands Delineation manual, Technical Report 7-87-1 U.S Army Corps of Engineers, WES Vicksburg

ERA/FOEN and Oilwatch Africa 2000. Pipe Dream. The West African Gas Pipeline Project and the Environment. Environmental Rights Actions/Friends of the Earth, Nigeria and Oilwatch Africa.

ERML. 2003a. Landuse and land cover map for the West African Gas Pipeline Project Area. A report submitted to ICF by Environmental Resources Managers Ltd, Lagos

ERML. 2003b. Environmetal Baseline Studies for WAGP. Dry season report submitted to ICF by Environmental Resources Managers Ltd, Lagos

Fagbami, A. A., Udo, E. J. and Odu, C.T. I. 1988. Vegetation damage in an oilfield in the Niger Delta of Nigeria. Journal of Tropical Ecology. 4: 61 – 75

FICWD (Federal Interagency Committee for Wetland Delineation). 1989. Federal manual for identifying and delineating jurisdictional wetlands. USACE/ USEPA/ USFWS/ USDA-SCS, Washington DC.

Garnewecke, G and Kotze, D. 1999. Guidelines for delineation of wetland boundary and wetland zones. Department of Water Affairs and Forestry, South Africa

Hoff, R et al. 2002. Oil spills in mangroves planning and response consideratin. NOAA Louisiana.

IPIECA 1993. *Biological Impacts of Oil Pollution.* Volume 4: Mangroves. International Petroleum Industry Environmental Conservation Association, London.

IPIECA 2000. *Guidelines on Biological Impacts of Oil Pollution*. International Petroleum Industry Environmental Conservation Association, London.

Jackson, S 1995. Delineating bordering vegetated wetlands under the Massachusetts wetlands Protection Act. Massachusetts Department of Environmental Protection Division of Wetlands and Waterways, Boston

Kathiresan K, Bingham B L 2001. Biology of mangrove ecosystems. Advances in Marine Biology 40: 81-251.

Lyon, J. G. and McCarthy, J. 1995. Wetland and Environmental Applications of GIS. Lewis Publishers. Boca Ratois.

Mitsch, W. J. and Gosselink, J. G. 2001. Wetlands, Van Nostrand Reinhold, New York, NY.

Moffat D and Linden O 1995. Perception and Reality: Assessing Sustainable Development in the Niger River Delta. Ambio 24: 527 – 538

NRC. 1995. Wetlands characteristics and boundaries. National Academy Press, Washington DC

Ohimain E. I. 2001. Bioremediation of heavy metal contaminated dredged spoil from a mangrove ecosystem in the Niger Delta. PhD thesis, University of Benin, Benin-City

Ohimain, E. 2002. Sustaining Stakeholders' Values through Proper Handling and Restoration of Abandoned Waste Dredge Spoils in the Niger Delta. A paper was presented at the DPR International Conference on Health, Safety & Environment in Oil and Gas Exploration and Production held in Abuja Nigeria, December 2002

Ohimain, E. 2003a. Preservation of Niger Delta Wetland Resources Through Proper Handling and Rehabilitation of Abandoned Waste Sulfidic Dredge Spoils (http://www.battelle.org/bclscrpt/Bookstore/booktemplate.cfm?ISBN=1-57477-138-8).

Ohimain, E. 2003b. Available Options for the Bioremedation and Restoration of Abandoned Pyritic Dredge Spoils Causing the Death of Fringing Mangroves in the Niger Delta (http://www.nereusgroup.gr/congress/ibs2003/html/program.html).

Ohimain, E. 2003c. Environmental Impacts of oil Mining Activities in the Niger Delta Mangrove Ecosystem. Proceedings of the International Mine Water Association (IMWA) 2003 Congress, Johannesborg, South Africa

Ohimain, E., Andriesse, W and van Mensvoort, M.E.F. 2003. Environmental Impacts of Abandoned Dredged Soils and Sediments: Available Options for their Handling, Restoration and Rehabilitation. A paper accepted for publication in Journal of Soils and Sediments, Germany

Ramsar Convention and Convention on Biological Diversity 1996. Wetlands and biological Diversity. Ramsar Convection Bureau/ WWF. Gland, Switzerland

Ramsar Information Bureau. 1998. What are wetlands? Ramsar Information Paper No 1 Gland Switzerland.

Reed, P.B. 1988. National list of plants that occur in wetlands. Report 88. USFWS, Washington DC

Reed, P.B., Jr. 1993. "1993 Supplement to list of plant species that occur in wetlands: Northwest (Region 9)". U.S. Fish and Wildlife Service, Supplement to Biological Report 88(26.9).

Sipple, W.S 1988. Wetlands identification and delineation manual. Volumes I & II. USEPA, office Wetlands Protection, Washington DC

Soil Survey Staff 1999. Soil Taxonomy: A basic system of soil classifications for making and interpreting soil surveys. USDA.

Soil Survey Staff. 1993. Soil Survey Manual. USDA Handbook No. 18. USDA, Washington DC

Storks, S. 2002. Nigeria's shrinking Wetland. Environment Digest. March 21, 2002 Edition.

The Florida Department of Environmental Protection et al. 1995. The Florida wetlands delineation manual. Florida Department of Environmental Protection, Wetlands Evaluation and Delineation Section Tallahassee.

Tiner R.W.1991.Wetlands delineation. In proceedings of the 1991 Storm Water Management /Wetlands/Floodplain Symposium. September 23-24 1991.pp1-23

Tiner, R W. 1996. Practical consideration for wetland identification and boundary delineation. In wetland Environmental Gradients, boundaries and buffers CRC press Baca ration.

Tiner, R. W. 1999. Wetland Indicators: A Guide to Wetland Identifications, Delineations, Classification and Mapping. Lewis Publishers. Boca Raton.

Tiner, R.W. 1991. The concept of a hydrophyte for wetlands identification. Bioscience. 41: 236-247

Tiner, R.W. 1991.Technical issues regarding wetland delineation. Presented at national symposium on sustainable use and wetland protection, Artificial managed wetlands with special Emphasis on Agricultural wetlands (September 10-20 1991 Chicago) Association of state wetland Managers.

Tiner, R.W. 1993. The primary indicator method - a practical approach to wetlands recognitions and delineation in the United States. Wetlands 13, 50-64

Tiner, R.W. 2000. An overview of wetland identification and delineation techniques, with recommendation for improvement. Wetland Journal 12: 15-22.

Tiner, R.W.1989 Classifications of wetland ecosystem. In wetlands Ecology and conservation: Emphasis in Pennsylvania S.K.Majumdar, R.P Brooks, J.F Brennor, and R.W. Tiner [eds]. The Pennsylvania Academy of science.pp 1-10.

Tiner, R.W.1993 Using plants as indicators of wetlands. In proceeding of the Academy of Natural science of Philadelphia 144.240-253.

Tiner, RW 2000. Key of water body type and hyhrogeomorphic type wetlands descriptors for US water and wetlands .US. Fish and wildlife service, National wetlands inventory project, Hadley.

Tiner, RW.1995 Wetland definition and classification in the United state .US. Geological survey water supply paper 2425.

USDA 1983. “List of Soils with Actual or High Potential for Hydric Conditions,” National Bulletin No. 430-3-10, US Department of Agriculture, Washington, D.C.

USDA-NRCS 2002. A field book for describing and sampling soils. US Department of Agriculture, Natural Resources Conservation Service Washington, D.C.

USDA-NRCS. 1998. Keys to Soil Taxonomy, Eighth Edition, US Department of Agriculture, Natural Resources Conservation Service Washington, D.C.

USDA-SCS 1985. National food security manual. USDA, Washington DC

USDA-SCS 1987. Hydric soils of the United States. USDA, Washington DC

Vander Walt. 1999. South African National Wetlands Classification Systems definitions and criteria. South African Wetland Conservation Programme, Department of Environmental Affairs and Tourism, Pretoria, South Africa.

Washington State Department of Environmental Protection. 1997. Wetlands delineating manual. Washington State Department of Environmental Protection.

Wetlands Inventory Consortium. 2002. A methodology proposed for a South African National Wetlands Conservation Programme. Department of Environmental Affairs and Tourism, Pretoria, Republic of South Africa.

World Bank. 1995. Defining an Environmental Development strategy for the Niger Delta. Volume 1. West Central Africa Department, Washington DC.

World Conservation Union. IUCN. 1993. *Oil and gas Exploration and Production in Mangrove Areas*. IUCN, Gland, Switzerland.

Zwirn, M. 2002. Pipeline-stream crossing installations: best management practices. The Wild Salmon Centre, Portland

APPENDIX 1: DATA FORM 1
ROUTINE WETLAND DETERMINATION

Project/Site: **WAGP PIPELINE RIGHT OF WAY** Investigator: Dr Elijah Ohimain & others	Date: ………………. Nearest Community……
Do normal circumstances exist on the site? Yes No Is the site significantly disturbed (A typical situation) Yes No Is the area a potential problem area? Yes No (If needed, explain on reverse)	Habitat ID: ……. Transect ID: ……….. Pipeline segment………. Plot ID: …………….

GENERAL DESCRIPTION OF THE ENVIRONMENT

VEGETATION

Dominant Plant Species

S/N	Scientific Name	Common Name	Stratum	Indicator status	Morphological Adaptation
Percent Dominant Species that are OBL, FACW or FAC (excluding FAC_) Remarks:					

HYDROLOGY

………Recorded Data (Describe in Remarks): ………Stream, Lake, or Tide Gauge ……...Aerial Photographs ……...Other ………No Recorded Data Available	Wetland Hydrology Indicators: Primary Indicators: ……... Inundate ………Saturated in Upper 12 Inches (30.48 cm) ………Water Marks ………Drift Lines ………Sediment Deposits ………Drainage Pattern in Wetlands
Field Observations: Depth of Surface Water:……(cm.) Depth to Free Water in Pit:….(cm.) Depth to Saturated Soil: …….(cm.)	Secondary Indicators (2 or more required): ………Oxidized Root Channels In Upper 12 inches (30.48 cm) ………Water Stained Leaves ………Local Soil Survey Data ………FAC-Neutral Test ………Other (Explain in Remarks)
Remarks:	

SOILS

Map Unit Name (Series and Phase): ……………………………………………………………….. Drainage Class: ……………………..   Field Observations Taxonomy (Subgroup): ………………………………………………………….. Confirm Mapped Type? Yes No
<u>Profile Description:</u> **Depth Horizon Matrix Colour Mottle Colours Mottle Texture , Concrections,** **(cm) (Munsell Moist) (Munsell Moist) Abundance/Contrast Structure, etc.** ………. ………... ……………… ……………… ……………………. ……………………. ………. ………... ……………… ……………… ……………………. ……………………. ………. ………... ……………… ……………… ……………………. …………………….

……….	………...	………………	………………
…………………….	…………………….		
……….	………...	………………	………………
…………………….	…………………….		
……….	………...	………………	………………
…………………….	…………………….		
……….	………...	………………	………………
…………………….	…………………….		

Hydric Soil Indicators:

……..Histosoil	…………. Gleyed or Low-Chroma Colours
……..Histic Epipedon	…………. Concretions
……..Sulfidic Odour	…………. High Organic Content in Surface Layer Sandy Soils
……..Aquic Moisture Regime	…………. Organic Streaking in Sandy Soils
……..Reducing Conditions	…………. Redox potential

Remarks:

WETLAND DETERMINATION

Hydrophytic vegetation present	Yes	No	Is this sampling within a wetland? Yes No
Wetland Hydrology Present	Yes	No	
Hydric Soils present	Yes	No	
Remarks			

WETLAND BOUNDARY GPS READINGS

Boundary	Approx. Distance, m	Northings	Eastings

Appendix 2A
Checklist of Vegetation Found in the Coastal Wetland Areas

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
1	*Acroceras amplectens*	-	OBL	Herb	Groundcover	Adventitious Roots
2	Acroceras zizanoides	-	OBL	Herb	Groundcover	Adventitious Roots
3	*Acrostichum aeureum*	Leather fern	OBL	Herb	Groundcover	Adventitious Roots
4	*Aframomum melegueta*	Alligator pepper	FACU	Herb	Groundcover	-
5	*Alchornea cordifolia*	Christmas bush	FAC	Shrub	Subcanopy	Multi-trunk, Stooling
6	*Andropogon gayanus*	Ganba grass	UPL	Herb	Subcanopy	Adventitious Roots
7	*Andropogon tectorum*	Giant bluestem	UPL	Herb	Subcanopy	Adventitious Roots
8	*Anthocleista djalonesis*	Cabbage tree	FAC	Tree	Overstorey	-
9	*Anthocleista vogelii*	Cabbage tree	FACW	Tree	Overstorey	Stilt roots (Occasionally)
10	*Aspilia africana*	Haemorrhage plant	UPL	Herb	Groundcover	-
11	*Azolla pinnata* var. *africana*	Water velvet	OBL	Floating-leaved	Aquatic macrophyte	Floating leaves
12	*Centrosema pubescens*	-	UPL	Twinner	Vine	-
13	*Clappertonia ficifolia*	-	OBL	Shrub	Subcanopy	-
14	*Cocos nucifera*	Coconut	FAC	Tree	Overstorey	Adventitious Roots
15	*Commelina erecta*	Dayflower	FAC	Herb	Groundcover	Adventitious Roots
16	*Crinum giganteum*	Poison bulb	FACW	Herb	Groundcover	Adventitious Roots
17	*Cyperus articulatus*	Bizzy lizzy	OBL	Herb	Groundcover	Adventitious Roots
18	*Cyperus iria*	-	FACW	Herb	Groundcover	Adventitious Roots
19	*Desmodium triflorum*	-	UPL	Herb	Groundcover	-
20	*Dryopteris filix-mas*	Fern	OBL	Herb	Epiphyte	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
21	*Eichhornia crassipes*	Water hyacinth	OBL	Floating-leaved	Aquatic macrophyte	Inflated Leaves, Adventitious roots
22	*Elaeis guineensis*	Oil palm	FAC	Tree	Overstorey	Adventitious Roots
23	*Emilia coccinea*	Yellow tassleflower	UPL	Herb	Groundcover	-
24	*Fimbristylis littoralis*	-	OBL	Herb	Groundcover	Adventitious Roots
25	*Fuirena umbellata*	-	OBL	Herb	Groundcover	Adventitious Roots
26	*Hallea ciliata*	Abura	OBL	Tree	Overstorey	Buttress/Knee Roots
27	*Heterotis rotundifolia*	-	FACW	Herb	Groundcover	-
28	*Hydrolea palustris*	-	OBL	Herb	Groundcover	Inflated stem, Adventitious roots
29	*Hyptis lanceolata*	-	FACW	Herb	Groundcover	-
30	*Ipomoea involucrata*	Morning glory weed	FACU	Twinner	Vine	-
31	*Ipomoea mauritiana*	-	FAC	Twinner	Vine	-
32	*Kyllinga bulbosa*	-	FACW	Herb	Groundcover	Adventitious Roots
33	*Kyllinga erecta*	-	FACW	Herb	Groundcover	Adventitious Roots
34	*Ludwigia decurrens*	Water primerose	OBL	Herb	Groundcover	Inflated stem, Adventitious/Balloon roots
35	*Ludwigia hyssopifolia*	Water primerose	OBL	Herb	Groundcover	Inflated stem, Adventitious/Balloon roots
36	*Ludwigia octovalvis*	Primerose - willow	OBL	Herb	Groundcover	Inflated stem, Adventitious/Balloon roots
37	*Lygodium microphyllum*	-	FACW	Twinner	Vine	Polymorphic leaves
38	*Machaerium lunatus*	-	OBL	Shrub	Subcanopy	Multi-trunk, Stooling
39	*Mariscus alternifolius*	-	FACU	Herb	Groundcover	Adventitious Roots
40	*Mariscus ligularis*	-	OBL	Herb	Groundcover	Adventitious Roots

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
41	*Melastomastrum capitatum*	-	FACW	Shrub	Groundcover	-
42	*Musa paradisiaca*	Plantain	FACW	Pseudo-tree	Subcanopy	Adventitious Roots
43	*Musa sapientum*	Banana	FACW	Pseudo-tree	Subcanopy	Adventitious Roots
44	*Mussaenda spp.*	-	FACU	Shrub	Subcanopy	-
45	*Nauclea pobeguinii*	-	OBL	Tree	Subcanopy	-
46	*Nephrolepis biserrata*	Sword Fern	FAC	Herb	Groundcover/ epiphyte	Adventitious Roots
47	*Nymphaea lotus*	Water Lily	OBL	Floating-leaved	Aquatic macrophyte	Floating leaves
48	*Nymphaea maculata*	Water Lily	OBL	Floating-leaved	Aquatic macrophyte	Floating leaves
49	*Paspalum scrobiculatum*	Ditch Millet	FACU	Herb	Groundcover	Adventitious Roots
50	*Paspalum vaginatum*	-	OBL	Herb	Groundcover	Adventitious Roots
51	*Pennisetum purpereum*	Elephant grass	FACW	Herb	Groundcover	Adventitious Roots
52	*Phoenix reclinata*	Date palm	OBL	Tree	Subcanopy	Adventitious Roots
53	*Phymatodes scolopendria*	Fern	FACW	Herb	Groundcover	-
54	*Pistia stratiotes*	Water Lettuce	OBL	Free floating	Aquatic macrophyte	Floating leaves
55	*Raphia hookeri*	Wine palm	OBL	Tree	Overstorey	Pneumatophores, Peg/Adventitious Roots
56	*Rauvolfia vomitoria*	Serpent wood	UPL	Tree	Overstorey	-
57	*Rhizophora racemosa*	Red mangrove	OBL	Tree	Overstorey	Pneumatophores, vivipary, prop roots
58	*Saccharum officinarum*	Sugarcane	OBL	Shrub	Groundcover	Adventitious Roots
59	*Salvinia nymphellula*	Salvinia	OBL	Floating-leaved	Aquatic macrophyte	Floating leaves
60	*Scleria naumanniana*	-	OBL	Herb	Groundcover	Adventitious Roots
61	*Scleria*	-	OBL	Herb	Groundcover	Adventitious Roots

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
	verrucosa					
62	*Scoparia dulcis*	Sweet Broomweed	FAC	shrubby herb	Groundcover	-
63	*Spigelia anthelmia*	Worm Bush, Pinkweed	UPL	Herb	Groundcover	-
64	*Triumfetta cordifolia*	-	FACW	Shrub	Subcanopy	-
65	*Triumfetta rhomboidea*	Chinese bur	FAC	Shrub	Groundcover	-
66	*Typha domingensis*	Cattail	OBL	Herb	Groundcover	Root growth in low oxygen tension
67	*Urena lobata*	Hibiscus bur, Cadillo	UPL	Shrub	Subcanopy	-
68	*Vernonia cinerea*	Little ironweed	UPL	Herb	Groundcover	-
69	*Vitex doniana*	Black plum	UPL	Tree	Overstorey	-
70	*Zornia latifolia*	-	UPL	Herb	Groundcover	-

Appendix 2B
A Checklist of the Vegetation Found in the Coastal Upland Areas

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
1	*Achyranthes aspera*	Devil's horsewhip	UPL	Herb	Groundcover	-
2	*Anacardium occidentale*	Cashew	UPL	Tree	Overstorey	-
3	*Ananas comosus*	Pineapple	UPL	Herb	Groundcover	-
4	*Andropogon tectorum*	Giant bluestem	UPL	Herb	Groundcover	Adventitious Roots
5	*Anthocliesta djalonesis*	Cabbage tree	FAC	Tree	Overstorey	-
6	*Anthocleista vogelii*	Cabbage tree	FACW	Tree	Overstorey	Stilt roots (occasionally)
7	*Aspilia bussei*	White-flowered Haemorrhage palnt	UPL	Herb	Groundcover	-
8	*Asystasia gangetica*	-	UPL	Herb	Groundcover	-
9	*Borassus aethiopum*	Borassus palm	FACU	Tree	Overstorey	Adventitious Roots
10	*Brachiaria deflexa*	-	UPL	Herb	Groundcover	Adventitious

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
						Roots
11	*Brachilaria spp.*	-	UPL	Creeper	Groundcover	-
12	*Cassytha filiformis*	-	UPL	Twinner	Vine	Haustoria
13	*Centrosema pubescens*	-	UPL	Twinner	Vine	-
14	*Chromolaena odorata*	Siam weed	UPL	Shrub	Subcanopy	-
15	*Cnestis ferruginea*	-	UPL	Shrub	Subcanopy	-
16	*Cocos nucifera*	Coconut	FAC	Tree	Coverstorey	Adventitious Roots
17	*Commelina beghalensis*	Wandering Jew, tropical spiderwort	UPL	Herb	Groundcover	Adventitious Roots
18	*Commelina erecta* var. *maritima*	Wandering Jew	FACU	Herb	Groundcover	Adventitious Roots
19	*Cynodon dactylon*	Bahama/Bemuda grass	UPL	Herb	Groundcover	Adventitious Roots
20	*Cyperus iria*	-	FACW	Herb	Groundcover	Adventitious Roots
21	*Cyperus maritimus*	-	FAC	Herb	Groundcover	Adventitious Roots
22	*Desmodium ramossissimum*	-	UPL	Herb	Groundcover	-
23	*Elaeis guineensis*	Oil palm	FAC	Tree	Overstorey	Adventitious Roots
24	*Fimbristylis ferruginea*	-	FACW	Herb	Groundcover	Adventitious Roots
25	*Gmelina arborea*	Gmelina	UPL	Tree	Overstorey	-
26	*Heterotis rotundifolia*	-	FACW	Herb	Groundcover	-
27	*Hyperthalia dissoluta*	-	UPL	Herb	Groundcover	Adventitious Roots
28	*Imperata cylindrica*	Spear grass	UPL	Herb	Groundcover	Adventitious Roots
29	*Indigofera hirsuta*	Hairy indigo	UPL	Shrub	Groundcover	-
30	*Ipomoea involucrata*	Morning glory weed	FACU	Twinner	Vine	-
31	*Ipomoea mauritiana*	-	FAC	Twinner	Vine	-
32	*Ipomoea pes-caprae*	Seaside goat foot	FACW	Creeper	Groundcover	Xeromorphic leaves
33	*Kyllinga erecta*	-	FACW	Herb	Groundcover	Adventitious Roots
34	*Kyllinga*	-	UPL	Herb	Groundcover	Adventitious

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
	peruviana					Roots
35	*Mangifera indica*	Mango	UPL	Tree	Overstorey	-
36	*Manihot esculenta*	Cassava	UPL	Shrub	Subcanopy	-
37	*Mariscus alternifolius*	-	FACU	Herb	Groundcover	Adventitious Roots
38	*Melanthera scandens*	-	UPL	Herb	Groundcover	-
39	*Mitracarpus villosus*	-	UPL	Herb	Groundcover	-
40	*Nauclea pobeguinii*	-	OBL	Tree	Subcanopy	-
41	*Panicum laxum*	-	FACW	Herb	Groundcover	Adventitious Roots
42	*Paspalum scrobiculatum*	Ditch millet	FACU	Herb	Groundcover	Adventitious Roots
43	*Pennisetum pedicellatum*	-	UPL	Herb	Groundcover	Adventitious Roots
44	*Pennisetum purpureum*	Elephant grass	FACW	Herb	Groundcover	Adventitious Roots
45	*Perotis indica*	-	UPL	Herb	Groundcover	Adventitious Roots
46	*Philoxerus vermicularis*	-	FACW	Creeper	Groundcover	-
47	*Phyllanthus amarus*	-	UPL	Herb	Groundcover	-
48	*Rauvolfia vomitoria*	Serpent wood	UPL	Tree	Overstorey	-
49	*Rhynchelytrum repens*	Blanket/Natal grass	UPL	Herb	Groundcover	Adventitious Roots
50	*Schizachyrium exile*	-	UPL	Shrub	Groundcover	Adventitious Roots
51	*Schrankia leptocarpa*	-	UPL	Herb	Groundcover	-
52	*Scleria naumanniana*	-	OBL	Herb	Groundcover	Adventitious Roots
53	*Scoparia dulcis*	Sweet broomweed	FAC	Shrubby herb	Groundcover	-
54	*Setaria megaphylla*	-	FACU	Herb	Groundcover	Adventitious roots
55	*Solenostemon monostachyus*	-	FACU	Herb	Groundcover	-
56	*Spermacoce verticillata*	-	UPL	Herb	Groundcover	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
57	*Spigelia anthelmia*	Worm bush, pinkweed	UPL	Herb	Groundcover	-
58	*Tectona grandis*	Teak	UPL	Tree	Overstorey	-
59	*Tephrosia bracteolata*	-	UPL	Shrub	Groundcover	-
60	*Tephrosia linearis*	-	UPL	Herb	Groundcover	-
61	*Tephrosia pedicellata*	-	UPL	Herb	Groundcover	-
62	*Tridax procumbens*	Coat buttons, Tridax	UPL	Herb	Groundcover	-
63	*Triumfetta rhomboidea*	Chinese bur	FAC	Herb	Groundcover	-
64	*Vitex doniana*	Black plum	UPL	Tree	Overstorey	-
65	*Waltheria indica*	-	UPL	Shrub	Groundcover	-

Appendix: 3A
Checklist of the Vegetation Found In The Inland Wetland Areas

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
1	*Achyranthes aspera*	Devil's horsewhip	UPL	Herb	Groundcover	-
2	*Acroceras zizanoides*	-	OBL	Herb	Groundcover	Adventitious roots
3	*Acrostichum aureum*	Leather Fern	OBL	Herb	Groundcover	Adventitious roots
4	*Aframomum melegueta*	Alligator Pepper	FACU	Herb	Groundcover	-
5	*Aframomum sceptrum*	Grains of Paradise	FACU	Herb	Groundcover	-
6	*Alchornea cordifolia*	Christmas bush	FAC	Shrub	Subcanopy	Multitrunk, Stooling
7	*Alstonia boonei*	Stool wood	FAC	Tree	Overstorey	Buttresses (Slight)
8	*Andropogon gayanus*	Ganba grass	UPL	Herb	Subcanopy	Adventitious roots
9	*Andropogon tectorum*	Giant bluestem	UPL	Herb	Subcanopy	Adventitious roots
10	*Aneilema beniniense*	-	FACU	Herb	Groundcover	-
11	*Anthocleista djalonesis*	Cabbage tree	FAC	Tree	Overstorey	-
12	*Anthocleista vogelii*	Cabbage tree	FACW	Tree	Overstorey	Stilt roots (occassionaly)
13	*Anthostema aubryanum*	-	OBL	Tree	Overstorey	-
14	*Artocarpus communis*	Jack fruit	UPL	Tree	Overstorey	-
15	*Aspilia africana*	Haemorrhage plant	UPL	Herb	Groundcover	-
16	*Azolla pinnata Var. africana*	Water velvet	OBL	Herb	Aquatic macrophyte	Adventitious roots, Floating leaves
17	*Bambusa bambusa*	Bamboo	FACW	Shrubby tree	Overstorey	Adventitious roots
18	*Bombax buonopozense*	Red flowered silk-cotton tree	UPL	Tree	Overstorey	Buttresses
19	*Calamus decratus*	Rattam palm, Cane	FACW	Climber	Liana	-
20	*Cassytha filiformis*	-	UPL	Twinner	Vine	Haustoria
21	*Ceiba pentandra*	Kapok, Silk-	UPL	Tree	Overstorey	Buttresses

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
		cotton tree				
22	*Cercestris afzelii*	-	FACW	Herb	Groundcover/ Epiphyte	-
23	*Chromolaena odorata*	Siam weed	UPL	Shrub	Subcanopy	-
24	*Clappertonia ficifolia*	-	OBL	Shrub	Subcanopy	-
25	*Cocos nucifera*	Coconut	FAC	Tree	Overstorey	Adventitious roots
26	*Costus afer*	Bush cane	FACW	Herb	Groundcover	-
27	*Crinum giganteum*	Poison bulb	FACW	Herb	Groundcover	Adventitious roots
28	*Cyperus haspan*	Flat sedge	OBL	Herb	Groundcover	Adventitious roots
29	*Cyperus iria*	-	FACW	Herb	Groundcover	Adventitious roots
30	*Cyrtosperna senegalense*	Arum	OBL	Herb	Groundcover	Aerenchymatous petiole
31	*Desmodium triflorum*	-	UPL	Herb	Groundcover	-
32	*Dryopteris filix-mas*	Fern	OBL	Herb	Epiphyte	Adventitious roots
33	*Elaeis guineensis*	Oil palm	FAC	Tree	Overstorey	Adventitious roots
34	*Emilia coccinea*	Yellow tasselflower	UPL	Herb	Groundcover	-
35	*Eriosema psoraleoides*	-	UPL	Shrub	Subcanopy	-
36	*Ficus spp.*	-	FAC	Tree	Understorey	-
37	*Fuirena umbellata*	-	OBL	Herb	Groundcover	Adventitious roots
38	*Hallea ciliata*	Abura	OBL	Tree	Overstorey	Buttresses/Knee roots
39	*Harungana madagascarienisis*	-	UPL	Shrub	Subcanopy	-
40	*Heterotis rotundifolia*	-	FACW	Herb	Groundcover	-
41	*Hydrolea palustris*	False-fiddle	OBL	Herb	Aquatic macrophyte	Inflated stem, Adventitous roots
42	*Ipomoea mauritiana*	-	FAC	Twinner	Vine	-
43	*Ipomoea aquatica*	Water spinach	OBL	Creeper	Vine	Floating stem and leaves
44	*Kyllinga bulbosa*	-	FACW	Herb	Groundcover	Adventitious roots
45	*Leersia hexandra*	Razor grass	OBL	Herb	Groundcover	Adventitous roots
46	*Lemna paucicostata*	Duckweed	OBL	Herb	Aquatic macrophyte	Floating leaves
47	*Lophira alata*	Ironwood	UPL	Tree	Overstorey	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
48	*Ludwigia decurrens*	Water primerose	OBL	Herb	Groundcover	Inflated/balloon roots
49	*Lycopodium cernuum*	-	FACW	Herb	Groundcover	-
50	*Lygodium microphyllum*	-	FACW	Twinner	Vine	Polymorphic leaves
51	*Mariscus alternifolius*	-	FACU	Herb	Groundcover	Adventitious roots
52	*Mariscus flabelliformis*	-	UPL	Herb	Groundcover	Adventitious roots
53	*Melastomastrum capitatum*	-	FACW	Shrub	Groundcover	-
54	*Musa paradisiaca*	Plantain	FACW	Pseudo-tree	Subcanopy	Adventitious roots
55	*Musa sapientum*	Banana	FACW	Pseudo-tree	Subcanopy	Adventitious roots
56	*Musanga cecropiodes*	Umbrella tree	UPL	Tree	Understorey	Stilt roots
57	*Mussaenda spp.*	-	FACU	Shrub	Subcanopy	-
58	*Nephrolepis biserrata*	Sword fern	FAC	Herb	Groundcover/ Epiphyte	Adventitious roots
59	*Nymphaea lotus*	Water lily	OBL	Herb	Aquatic macrophyte	Floating leaves
60	*Palisota hirsuta*	-	UPL	Herb	Groundcover	-
61	*Panicum laxum*	-	FACW	Herb	Groundcover	Adventitious roots
62	*Paspalum scrobiculatum*	Ditch millet	FACU	Herb	Groundcover	Adventitious roots
63	*Pentaclethra marcrophylla*	Oil bean tree	UPL	Tree	Overstorey	-
64	*Pentodon pentandrus*	-	OBL	Herb	Groundcover	-
65	*Pistia stratiotes*	Water lettuce	OBL	Herb	Aquatic macrophyte	Floating leaves,adventitous roots
66	*Raphia hookeri*	Wine palm	OBL	Tree	Overstorey	Adventitious/peg roots
67	*Rhyncospora corymbosa*	-	OBL	Herb	Groundcover	Adventitious roots
68	*Sacciolepis Africana*	-	OBL	Herb	Groundcover	Adventitious roots
69	*Salvinia nymphellula*	Salvinia	OBL	Herb	Aquatic macrophyte	Floating leaf
70	*Scheria verrucosa*	-	OBL	Herb	Groundcover	Adventitious roots
71	*Scleria naumanniana*	Razor sedge	OBL	Herb	Groundcover	Adventitious roots

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
72	*Smilax anceps*	West African sarsaparilla	UPL	Twinner	Vine	-
73	*Solanun torvum*	Turkey berry	UPL	Shrub	Subcanopy	-
74	*Thalia geniculata*	-	FAC	Shrub	Groundcover	-
75	*Thaumatococcus danielii*	Katemfe	FACU	Herb	Groundcover	-
76	*Treculia africana*	African breadfruit	UPL	Tree	Overstorey	-
77	*Trema orientalis*	Trema	FAC	Tree	Subcanopy	-
78	*Vitex doniana*	Balck plum	UPL	Tree	Overstorey	-
79	*Zornia latifolia*	-	UPL	Herb	Groundcover	-

Appendix 3B
A Checklist of the Vegetation Found in the Inland Upland Areas

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
1	*Aframomum melegueta*	Alligator Pepper	FACU	Herb	Groundcover	-
2	*Aframomum sceptrum*	Grains of Paradise	FACU	Herb	Groundcover	-
3	*Ageratum conyzoides*	Goatweed	UPL	Herb	Groundcover	-
4	*Albizia ferruginea*	-	UPL	Tree	Understorey	-
5	*Albizia zygia*	-	UPL	Tree	Understorey	-
6	*Alchornea cordifolia*	Christmas bush	FAC	Shrub	Subcanopy	Multitrunk,stooling
7	*Alchornea laxiflora*	-	UPL	Shrub	Subcanopy	Multitrunk, stooling
8	*Alternanthera sessilis*	Sessile joyweed	FACW	Herb	Groundcover	-
9	*Anacardium occidentale*	Cashew	UPL	Tree	Overstorey	-
10	*Ananas comosus*	Pineapple	UPL	Herb	Groundcover	-
11	*Anchomanes difformis*	-	FAC	Herb	Subcanopy	-
12	*Andropogon gayanus*	Ganba grass	UPL	Herb	Subcanopy	Adventitious roots
13	*Andropogon tectorum*	Giant blue stem	UPL	Herb	Subcanopy	Adventitious roots
14	*Aneilema*	-	FACU	Herb	Groundcover	Adventitious roots

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
	beniniense					
15	*Anthocleista vogelii*	Cabbage tree	FACW	Tree	Overstorey	Stilt roots (occasionally)
16	*Anthonotha macrophylla*	-	UPL	Shrub/Tree	Understorey	-
17	*Artocarpus communis*	Jack fruit	UPL	Tree	Overstorey	-
18	*Aspilia africana*	Haemorrhage plant	UPL	Herb	Groundcover	-
19	*Asystasia gangetica*	-	UPL	Herb	Groundcover	-
20	*Baphia nitida*	Camwood	UPL	Tree	Understorey	-
21	*Bombax bounopozense*	Red flowered silk-cotton tree	UPL	Tree	Groundcover	Buttresses
22	*Borassus aethiopum*	Borassus palm	FACU	Tree	Overstorey	Adventitious roots
23	*Brachiaria deflexa*	-	UPL	Herb	Groundcover	Adventitious roots
24	*Calopogonium mucunoides*	-	UPL	Twinner	Vine	-
25	*Canna indica*	Canna lily	UPL	Herb	Groundcover	-
26	*Capsicum annum*	Pepper	UPL	Shrub	Subcanopy	-
27	*Carica papaya*	Pawpaw	UPL	Tree	Subcanopy	Adventitious roots
28	*Cassytha filiformis*	-	UPL	Twinner	Vine	Haustoria
29	*Ceiba pentandra*	Silk-cotton tree, kapok	UPL	Tree	Overstorey	Buttresses
30	*Centrosema pubescens*	-	UPL	Twinner	Vine	-
31	*Cercestris afzelii*	-	FACW	Herb	Groundcover/Epiphyte	
32	*Chromolaena odorata*	Siam weed	UPL	Shrub	Subcanopy	-
33	*Clappertonia ficifolia*	-	OBL	Shrub	Subcanopy	-
34	*Clerodendron splendens*	-	UPL	Liana	Vine	-
35	*Cnestis ferruginea*	-	UPL	Shrub	Subcanopy	-
36	*Cocos nucifera*	Coconut	FAC	Tree	Overstorey	Adventitious roots
37	*Cola millenii*	-	UPL	Tree	Understorey	-
38	*Cola nitida*	Kolanut	UPL	Tree	Overstorey	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
39	*Colocasia esculenta*	Cocoyam	UPL	Herb	Groundcover	Adventitious roots
40	*Commelina benghalensis*	Wandering Jew,tropicalspiderwort	UPL	Herb	Groundcover	Adventitious roots
41	*Commelina erecta*	Dayflower	FAC	Herb	Groundcover	Adventitious roots
42	*Conyza sumatrensis*	Fleabane	UPL	Herb	Groundcover	-
43	*Costus afer*	Bushcane	FACW	Herb	Groundcover	-
44	*Cynodon dactylon*	Bahama/Couch grass	UPL	Herb	Groundcover	Adventitious roots
45	*Cyperus haspan*	Flat sedge	OBL	Herb	Groundcover	Adventitious roots
46	*Cyperus iria*	-	FACW	Herb	Groundcover	Adventitious roots
47	*Desmodium ramossissimum*	-	UPL	Herb	Groundcover	-
48	*Desmodium triflorum*	-	UPL	Herb	Grounddcover	-
49	*Dialium guineense*	Velvet tamarind	UPL	Tree	Overstorey	-
50	*Dicrostachys cinerea*	-	UPL	Shrub	Subcanopy	-
51	*Digitaria gayana*	-	UPL	Herb	Groundcover	Adventitious roots
52	*Digitaria horizontalis*	Digit grass	UPL	Herb	Groundcover	-
53	*Diodia sarmentosa*	-	UPL	Herb	Groundcover	-
54	*Dracena drago*	-	UPL	Tree	Understorey	-
55	*Elaeis guineensis*	Oil palm	FAC	Tree	Overstorey	Adventitious roots
56	*Eleusine indica*	Bull grass	UPL	Herb	Groundcover	Adventitious roots
57	*Emilia coccinea*	Yellow tasselflower	UPL	Herb	Groundcover	-
58	*Emilia praetermissa*	Pink tasselflower	UPL	Herb	Groundcover	-
59	*Eriosema psoraleoides*	-	UPL	Shrub	Subcanopy	-
60	*Euphorbia heterophylla*	Wild poinsettia, Spurge weed	UPL	Herb	Groundcover	-
61	*Ficus exasperata*	Sandpaper	UPL	Tree	Understorey	-
62	*Ficus spp.*	-	UPL	Shrub	Subcanopy	-
63	*Fimbristylis ferruginea*	-	FACW	Herb	Groundcover	Adventitious roots

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
64	*Fuirena umbellata*	-	OBL	Herb	Groundcover	Adventitious roots
65	*Gloriosa superba*	-	UPL	Twinner	Vine	-
66	*Gomphrena celosioides*	-	UPL	Herb	Groundcover	-
67	*Harungana madagascariensis*	-	UPL	Shrub	Subcanopy	-
68	*Heterotis rotundifolia*	-	FACW	Herb	Groundcover	-
69	*Hyparrhenia rufa*	Tatching grass	UPL	Herb	Groundcover	Adventitious roots
70	*Hyperthelia dissolute*	Tamborkie grass	UPL	Herb	Groundcover	Adventitious roots
71	*Imperata cylindrica*	Speargrass	UPL	Herb	Groundcover	Adventitious roots
72	*Indigofera hirsuta*	Hairy indigo	UPL	Shrub	Groundcover	-
73	*Ipomoea involucrata*	Morning glory weed	FACU	Twinner	Vine	-
74	*Irvingia gabonensis*	Wild/bush mango, Dikia nut	UPL	Tree	Overstorey	-
75	*Kyllinga bulbosa*	-	FACW	Herb	Groundcover	Adventitious roots
76	*Kyllinga erecta*	-	FACW	Herb	Groundcover	Adventitious roots
77	*Loudetia arundinacea*	-	UPL	Herb	Groundcover	Adventitious roots
78	*Luffa cylindrica*	Loofah gourd	UPL	Twinner	Subcanopy	-
79	*Mangifera indica*	Mango	UPL	Tree	Understorey	-
80	*Manihot esculenta*	Cassava	UPL	Shrub	Subcanopy	Adventitious roots
81	*Mariscus alternifolius*	-	FACU	Herb	Groundcover	Adventitious roots
82	*Mariscus Flabelliformis*	-	UPL	Herb	Groundcover	Adventitious roots
83	*Melanthera scandens*	-	UPL	Herb	Groundcover	-
84	*Melastomastrum capitatum*	-	FACW	Shrub	Groundcover	-
85	*Mitracarpus villosus*	-	UPL	Herb	Groundcover	-
86	*Momordica charantia*	Balsam pear, African Cucumber	UPL	Twinner	Vine	Adventitious roots

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
87	*Musa paradisiaca*	Plantain	FACW	Pseudo-tree	Subcanopy	Adventitious roots
88	*Musa sapientum*	Banana	FACW	Pseudo-tree	Subcanopy	Adventitious roots
89	*Musanga cecropioides*	Umbrella tree	UPL	Tree	Understorey	Stilt roots
90	*Myrianthus arboreus*	-	UPL	Tree	Understorey	-
91	*Nepenthes spp.*	Pitcher plant	FAC	Liana	Climber	Insectivorous
92	*Nephrolepis biserrata*	Sword Fern	FAC	Herb	Groundcover/Epiphyte	Adventitious roots
93	*Newbouldia laevis*	-	UPL	Tree	Subcanopy	-
94	*Oplismenus burmannii*	-	UPL	Herb	Groundcover	Adventitious roots
95	*Palisota hirsuta*	-	UPL	Herb	Groundcover	-
96	*Panicum laxum*	-	UPL	Herb	Groundcover	Adventitious roots
97	*Paspalum conjugatum*	Sourgrass	FACU	Herb	Groundcover	Adventitious roots
98	*Paspalum scrobiculatum*	Ditch millet	FACU	Herb	Groundcover	Adventitious roots
99	*Paulinia pinnata*	-	UPL	Twinner	Vine	-
100	*Pentaclethra macrophylla*	Oil beam tree	UPL	Tree	Overstorey	-
101	*Peperomia pellucida*	-	UPL	Herb	Groundcover	-
102	*Perotis indica*	-	UPL	Herb	Groundcover	Adventitious roots
103	*Phyllanthus amarus*	-	UPL	Herb	Groundcover	-
104	*Physalis angulata*	Wildcape gooseberry	UPL	Herb	Groundcover	-
105	*Piptadeniastrum africanum*	-	UPL	Tree	Overstorey	Buttresses
106	*Psidium guajava*	Guava	UPL	Tree	Understorey	-
107	*Pycnanthus angolensis*	Cardboard	UPL	Tree	Overstorey	-
108	*Pycreus flavescens*	-	OBL	Herb	Groundcover	Adventitious roots
109	*Rauvolfia vomitoria*	Serpentwood	UPL	Tree	Overstorey	-
110	*Reissantia indica*	-	UPL	Liana	Climber	-
111	*Rhynchelytrum repens*	Blanket/Natal grass	UPL	Herb	Groundcover	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
112	*Scleria verrucosa*	-	OBL	Herb	Groundcover	Adventitious roots
113	*Scoparia dulcis*	Sweetbroom weed	FAC	shrubby-herb	Groundcover	-
114	*Senna hirsuta*	Stinking Cassia	UPL	Shrub	Subcanopy	-
115	*Senna obtsusifolia*	-	UPL	Shrub	Subcanopy	-
116	*Senna occidentalis*	Coffee Senna	UPL	Shrub	Subcanopy	-
117	*Sesamum indicum*	Sesame,Benis eed	UPL	Herb	Groundcover	-
118	*Setaria megaphylla*	-	UPL	Herb	Groundcover	-
119	*Sida acuta*	Broomweed	UPL	Shrub	Groundcover	-
120	*Sida linifolia*	-	UPL	Shrub	Groundcover	-
121	*Smilax anceps*	West African Sarsaparilla	UPL	Twinner	Vine	-
122	*Solanum torvum*	Turkey berry	UPL	Shrub	Subcanopy	-
123	*Spermacoce verticillata*	-	UPL	Herb	Groundcover	-
124	*Spondias mombin*	Hog Plum	UPL	Tree	Understorey	-
125	*Sporobulu pyramidalis*	Cat's tailgrass	UPL	Herb	Groundcover	Adventitious roots
126	*Stachytarpheta cayennesis*	Blue rat's tail	UPL	Shrub	Groundcover	-
127	*Synedrella nodiflora*	-	UPL	Herb	Groundcover	-
128	*Talinum triangulare*	Waterleaf	UPL	Herb	Groundcover	-
129	*Talinum triangulare*	Waterleaf	UPL	Herb	Groundcover	-
130	*Tephrosia bracteolata*	-	UPL	Shrub	Groundcover	-
131	*Tephrosia pediccellata*	-	UPL	Herb	Groundcover	-
132	*Thalia geniculata*	-	FAC	Shrub	Groundcover	-
133	*Theobroma cacao*	Cocoa	UPL	Tree	Understorey	-
134	*Treculia africana*	African Breadfruit	UPL	Tree	Overstorey	-
135	*Trema orientalis*	Trema	FAC	Tree	Subcanopy	-
136	*Tridax procumbens*	Tridax, coat buttons	UPL	Herb	Groundcover	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
137	*Triplochiton scleroxylon*	-	UPL	Tree	Overstorey	Buttresses
138	*Triumfetta cordifolia*	-	FACW	Shrub	Subcanopy	Adventitious roots
139	*Triumfetta rhomboidea*	Chinese bar	FAC	Shrub	Groundcover	-
140	*Urena lobata*	Hibiscus bur, Cadillo	UPL	Shrub	Subcanopy	-
141	*Vernonia amygdalina*	Bitter leaf	UPL	Shrub	Groundcover	-
142	*Vernonia cinerea*	Little ironweed	UPL	Herb	Groundcover	-
143	*Vitex doniana*	Black plum	UPL	Tree	Overstorey	-
144	*Waltheria indica*	-	UPL	Shrub	Groundcover	-
145	*Zanthoxyllum zanthoxyloides*	-	UPL	Tree	Understorey	-
146	*Zea mays*	Maize, Corn	UPL	Herb	Groundcover	Adventitious roots
147	*Zornia latifolia*	-	UPL	Herb	Groundcover	-

Appendix 3C
A Checklist of the Coastal Savannah Vegetation in the Inland Areas

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
1	*Bridelia ferruginea*	-	UPL	Shrub	Subcanopy	-
2	*Clappertonia ficifolia*	-	OBL	Shrub	Subcanopy	-
3	*Elaeis guineensis*	Oil palm	UPL	Tree	Overstory	Adventitious roots
4	*Fuirena umbellata*	-	OBL	Herb	Groundcover	Adventitious roots
5	*Heteropogon contortus*	-	UPL	Herb	Groundcover	Adventitious roots
6	*Hyparrhenia rufa*	Thatching grass	UPL	Herb	Groundcover	Adventitious roots
7	*Hyperthelia dissoluta*	Tamborkie grass	UPL	Herb	Groundcover	Adventitious roots
8	*Imperata cylindrica*	Spear grass	UPL	Herb	Groundcover	Adventitious roots
9	*Melastomastrum capitatum*	-	FACW	Shrub	Groundcover	-
10	*Nauclea latifolia*	-	UPL	Shrub	Subcanopy	-
11	*Panicum maximum*	Guinea grass	UPL	Herb	Groundcover	Adventitious

						roots
12	*Pennisetum purpureum*	Elephant grass	FACW	Herb	Groundcover	Adventitious roots
13	*Pycreus flavescens*	-	OBL	Herb	Groundcover	Adventitious roots
14	*Sacciolepis spp.*	-	FAC	Shrub	Groundcover	Adventitious roots
15	*Scoparia dulcis*	Sweet broom weed	FAC	Shrubby herb	Groundcover	-
16	*Spermacoce verticilata*	-	UPL	Herb	Groundcover	-
17	*Vitex doniana*	Black plum	UPL	Tree	Overstory	-
18	*Zanthoxyllum zanthoxyloides*	-	UPL	Tree	Understorey	-
19	*Zornia latifolia*	-	UPL	Herb	Groundcover	-

Appendix 3D
A Checklist of Derived Savannah Vegetation in the Inland Area

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
1	*Aframomum sceptrum*	Grains of Paradise	FACU	Herb	Groundcover	-
2	*Andropogon tectorum*	Giant bluestem	UPL	Herb	Subcanopy	Adventitious roots
3	*Aspilia africana*	Haemorrhage plant	UPL	Herb	Groundcover	-
4	*Borassus aethiopum*	Borassus palm	FACU	Tree	Overstorey	Adventitious roots
5	*Brachiaria deflexa*	-	UPL	Herb	Groundcover	Adventitious roots
6	*Bridelia ferruginea*	-	UPL	Shrub	Subcanopy	-
7	*Bryophyllum pinnatum*	Resurrection plant	UPL	Shrub	Groundcover	-
8	*Capsicum annum*	Pepper	UPL	Shrub	Subcanopy	-
9	*Cassytha filiformis*	-	UPL	Twinner	Vine	Haustoria
10	*Celosia argentea*	-	UPL	Herb	Groundcover	-
11	*Centrosema pubescens*	-	UPL	Twinner	Vine	-
12	*Chromolaena odorata*	Siam weed	UPL	Shrub	Subcanopy	-
13	*Cnestis ferruginea*	-	UPL	Shrub	Subcanopy	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
14	*Commelina benghalensis*	Wandering Jew/Tropical spiderwort	UPL	Herb	Groundcover	Adventitious roots
15	*Commelina erecta*	Dayflower	FAC	Herb	Groundcover	Adventitious roots
16	*Dicrostachys cineria*	-	UPL	Shrub	Subcanopy	-
17	*Digitaria horizontalis*	Digitgrass	UPL	Herb	Groundcover	Adventitious roots
18	*Dioscorea rotundata*	White yam	UPL	Twinner	Vine	
19	*Elaeis guineensis*	Oil palm	FAC	Tree	Overstorey	Adventitious roots
20	*Emilia coccinea*	Yellow tasselflower	UPL	Herb	Groundcover	-
21	*Eragrostis tenela*	Feathery lovegrass	UPL	Herb	Groundcover	Adventitious roots
22	*Eriosema psoraleoides*	-	UPL	Shrub	Subcanopy	-
23	*Imperata cylindrica*	Speargrass	UPL	Herb	Groundcover	Adventitious roots
24	*Ipomoea involucrata*	Morning glory weed	FACU	Twinner	Vine	-
25	*kyllinga bulbosa*	-	FACW	Herb	Groundcover	-
26	*Lophira lanceolata*	Ironwood	UPL	Tree	Understorey	-
27	*Manihot esculenta*	Cassava	UPL	Shrub	Subcanopy	-
28	*Mariscus alternifolius*	-	UPL	Herb	Groundcover	Adventitious roots
29	*Musa sapientum*	Banana	FACW	Pseudo-tree	Subcanopy	Adventitious roots
30	*Ocimum gratissimum*	Scent leaf	UPL	Shrub	Subcanopy	-
31	*Paspalum scrobiculatum*	Ditch millet	FACU	Herb	Groundcover	Adventitious roots
32	*Pennisetum pedicellatum*	-	UPL	Herb	Groundcover	Adventitious roots
33	*Perotis indica*	-	UPL	Herb	Groundcover	Adventitious roots
34	*Ricinus communis*	Castor-Oil plant	UPL	Shrub	Subcanopy	-

S/N	Botanical Name	Common Name	Wetland Status	Habit	Strata	Adaptation
35	*Sida linifolia*	-	UPL	Shrub	Groundcover	-
36	*Smilax anceps*	West African Sarsaparilla	UPL	Twinner	Vine	-
37	*Spermacoce verticillata*	-	UPL	Herb	Groundcover	-
38	*Sporobolus pyramidalis*	Cat's tailgrass	UPL	Herb	Groundcover	Adventitious roots
39	*Talinum triangulare*	Water leaf	UPL	Herb	Groundcover	-
40	*Tephrosia bracteolata*	-	UPL	Shrub	Groundcover	-
41	*Triumfetta rhomboidea*	Chinese bur	FAC	Herb	Groundcover	-
42	*Vernonia amygdalina*	Bitterleaf	UPL	Shrub	Subcanopy	-
43	*Vernonia cinerea*	Little ironweed	UPL	Herb	Groundcover	-
44	*Vitex doniana*	Black plum	UPL	Tree	Overstorey	-
45	*Waltheria indica*	-	UPL	Shrub	Groundcover	-
46	*Zea mays*	Maize, corn	UPL	Herb	Groundcover	Adventitious roots
47	*Zornia latifolia*	-	UPL	Herb	Groundcover	-

Togo
West African Gas Pipeline
Environmental Baseline Survey
Second Season

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

Adotè Blivi
Universite de Lome
Lome, Togo

Table of Contents

Page

CHAPTER 1 INTRODUCTION AND BACKGROUND..1-1

CHAPTER 2 ONSHORE FIELD METHODS...2-1

2.1 Vegetation Sampling...2-1
2.2 Soil Sampling...2-1
2.2.1 Grain Size...2-1
2.2.2 Microbiology...2-1
2.2.3 Entomology..2-1
2.2.4 Chemical...2-3
2.3 In-Situ Methods..2-3
2.3.1 Soil Sample Temperature Determination Method...2-3
2.4 Wildlife and Animal Resources...2-3
2.5 Sample Tracking, Storage, and Shipping..2-5
2.5.1 Grain Size...2-5
2.5.2 Microbiology...2-5
2.5.3 Entomology..2-6
2.5.4 Chemical...2-7

CHAPTER 3 ANALYTICAL METHODS...3-1

3.1 Physical Laboratory Methods..3-1
3.1.1 Grain size...3-1
3.1.2 Organic Matter..3-1
3.1.2.1 Organic Carbon: Direct Colorimetry...3-1
3.1.2.2 Total nitrogen: Kjeldhal method...3-2
3.1.3 Moisture...3-2
3.2 Chemical Laboratory Methods...3-2
3.2.1 pH and Salinity...3-2
3.2.2 Heavy Metals...3-3
3.2.2.1 Simply Drying and Crushing...3-3
3.2.2.2 Acid Attack and Aqueous Solution..3-3
3.2.2.3 Mercury Analysis by Molecular Absorption Spectrophotometry after Complexation and Extraction (Hg)...3-3
3.2.2.4 Chemical Reagent Solutions...3-3
3.2.2.5 Mercury Dithizonate Extraction and Absorbency Measurement.....3-4
3.2.2.6 Analysis of Cadmium, Chromium, Copper, Nickel, Lead, Iron, Zinc, Aluminum, and Vanadium by Atomic Absorption Spectrophotometry (Cr(VI), Ni, Cu, Zn, Cd,Pb, Fe, Al, V)...3-4
3.2.2.7 Preparation of Standard Solutions...3-4
3.2.2.8 Measurement...3-5
3.2.2.9 Validation of Results..3-5
3.2.3 Biological Laboratory Methods...3-6
3.2.3.1 Vegetation..3-6

Table of Contents

Page

3.2.3.2 Microbiology....3-6
3.2.3.3 Entomology....3-7

CHAPTER 4 RESULTS 4-1

4.1 Vegetation 4-1

4.1.1 Floristic Characteristics of the Survey Environment....4-1

4.1.1.1 Floristic Analysis....4-1
4.1.1.2 Frequency of Species....4-4
4.1.1.3 Types of Plant Formations Found....4-7
4.1.1.4 Flora Richness and Plant Variety....4-9
4.1.1.5 Coastal Vegetation....4-10

4.2 Soil Characterization....4-10

4.2.1 Physical....4-10

4.2.1.1 Organic Matter....4-10
4.2.1.2 Grain Size....4-11
4.2.1.3 Temperature and Moisture....4-13

4.2.2 Chemical....4-14

4.2.2.1 pH and Salinity....4-14

4.2.3 Biological....4-18

4.2.3.1 Microbiology....4-18
4.2.3.2 Entomology....4-24

4.3 Wildlife and Animal Resources....4-27

4.3.1 Species Inventoried....4-27

4.3.1.1 Mammals....4-27
4.3.1.2 Birds....4-30
4.3.1.3 Reptiles....4-30
4.3.1.4 Amphibians....4-30
4.3.1.5 Beach-rock Fauna....4-30

4.3.2 Results of the Two Field Survey Campaigns....4-33
4.3.3 Turtle Species....4-34
4.3.4 Nesting....4-35
4.3.5 Human Predation....4-37
4.3.6 Uses....4-37
4.3.7 Physical Threats....4-38
4.3.8 Sensitization, Strengthened Capability, and Rescue Activities....4-38

4.4 Fish and Fisheries Resources....4-39

4.4.1 Fishing Groups....4-40

4.4.1.1 Gbetsogbe Groups....4-40
4.4.1.2 Groups in the Fishing Port....4-41

4.4.2 The Various Fishing Seasons....4-41

4.4.2.1 High Season....4-41
4.4.2.2 Low Season....4-41

Table of Contents

Page

4.4.3 Expenses Associated with Fishing Activities 4-41
4.4.4 Fishing Equipment Used..4-42
4.4.4.1 Types of Nets 4-42
4.4.4.2 Fishing Techniques 4-42
4.4.5 Species of Fish 4-43
4.4.6 Transformation and Marketing Systems 4-46
4.4.6.1 Women Conduction Fish Smoking Activities 4-46
4.5 Climate, Meteorology, and Air Quality 4-47
4.5.1 Climate..4-47
4.5.2 Weather 4-48
4.5.2.1 Winds 4-48
4.5.2.2 Rainfall..4-49
4.5.2.3 Hygrometry 4-50
4.5.2.4 Temperature 4-51
4.5.3 Air Quality 4-51
4.6 Conclusion 4-53
CHAPTER 5 REFERENCES 5-55

List of Appendices

Appendix A Stake Coordinates.. 1

List of Figures

Figure 1-1 Homogeneous Landscape of the Gas Pipeline Route 1-2

Figure 1-2 Study Area Located near the Village of Gbetsogbe... 1-2

Figure 1-3 Geometry of the Gas Pipeline Installation Site Between the Beach and the CTL [Lome Power Plant] 1-3

Figure 2.2-1 Experimental Sampling Array.. 2-2

Figure 4.1-1 General Range of Inventoried Species.. 4-1

Figure 4.1-2 Representation of the Most Frequent Families on the Gas Pipeline Site.......... 4-4

Figure 4.1-3 Hierarchical Classification of Inventoried Species.. 4-8

Figure 4.2-1 Histograms of Sample Frequency 4-13

Figure 4.2-2 Cumulative Sample Curves.. 4-13

Figure 4.2-3 Metallic Elements Content in Soil Samples from Togo (Onshore) 4-17

Table of Contents

Page

Figure 4.2-4 Metallic Elements Content in Soil Samples from Togo (Onshore) 4-17

Figure 4.2-5 Microbiological Analysis of Sand Samples: Evaluation of Total Germs (30°C)4-21

Figure 4.2-6 Microbiological analysis of Sand Samples: Evaluation of Sulfite-reducing Anaerobic Germs 4-22

Figure 4.2-7 Microbiological Analysis of Sand Samples: Evaluation of Microbial Flora (Total Germs 30°C) 4-23

Figure 4.2-8 Microbiological Analysis of Sand Samples: Evaluation of Total Germs (30°C)4-24

Table 4.4-1: Breakdown of Fishing Groups 4-40

Figure 4.4-1 Recent History of Small-scale Maritime Fishing Catch Volumes 4-45

Figure 4.4-2 Recent History of Small-scale Maritime Fishing Catch Values 4-45

Figure 4.5-1 Rainfall-Temperature Chart of Lome.. 4-48

Figure 4.5-2 Gross Cumulative Rainfall at the Lomé-Aéroport Station Compared to the 1961-1990 Norm.. 4-49

Table of Contents

Page

List of Tables

Table 4.1-1 Records and Types of Habitats 4-2

Table 4.1-2 Diversity of families, number of genera and species 4-3

Table 4.1-3 Most Frequent Species (present in at least 10 records) 4-5

Table 4.1-4 Frequent species (present in at least 5 records) 4-6

Table 4.1-5 Least frequent species (present in only 1 record) 4-6

Table 4.1-6 Species Characteristic of the Types of Habitats 4-8

Table 4.2-1 Organic Matter in Soil Samples 4-11

Table 4.2-2 Survey Sample Grain Size Data 4-11

Table 4.2-3 Temperature and Moisture 4-14

Table 4.2-4 Soil Sample pH and Salinity 4-14

Table 4.2-5 Metal Elements Content of the Soils of Togo (Onshore) 4-15

Table 4.2-6 Metal Elements Content of the Soils of Togo (Onshore) 4-15

Table 4.2-7 Microbiological Analysis of Soil Samples 4-20

Table 4.2-8 Site and Sample Characteristics, Arthropods Found 4-24

Table 4.2-9 Diversity and Relative Abundance of Organisms Identified 4-26

Table 4.3-1 List of Marine Species 4-28

Table 4.3-2 List of Land Species 4-29

Table 4.3-3 Average Density of Animal Species Attached to Beach-rock 4-31

Table 4.3-4 Beach-rock Fauna 4-31

Table 4.3-5 List of Endangered Species 4-32

Table 4.3-6 Live Individuals and Shells Inventoried during the 2001/2003 Seasons 4-35

Table 4.3-7 Nests Inventoried during the 2001/2003 Seasons 4-35

Table 4.3-8 Sea Turtle Nesting Period in Togo, 2001/2003 4-36

Table 4.3-9 Number of Nests Inventoried at Agbodrafo during the 2002-2003 Season 4-36

Table of Contents

Page

Table 4.3-10 Incubation of Eggs during the 2002-2003 Season at Agbodrafo 4-37

Table 4.3-11 Individuals Captured Offshore During the 2001/2003 Seasons 4-37

Table 4.4-2 Distribution of Small-Scale Maritime Fishermen According to Nationality in 2001 4-43

Table 4.4-3 Major Fish Species Brought in by Maritime Fishing 4-44

Table 4.4-4 Quantities and Values of Small-scale Maritime Fishing Catches from 1999 to 2002 4-45

Table 4.4-5 Small-scale Maritime Fishing Catch by Prefecture (Golfe and Lacs) from 1999 to 2002 4-46

Table 4.4-6 Volume of Catches at the Fishing Port from 1999 to 2002 4-46

Table 4.5-1 Wind Speeds at Lomé-Aéroport (1986-1995) 4-48

Table 4.5-2 Average Rainfall Distribution on the Togolese Coast 4-49

Table 4.5-3 Monthly Relative Humidity Norms at Lomé-Aéroport 4-50

Table 4.5-4 Average Vapor Tension Data at Lomé-Aéroport 4-50

Table 4.5-5 Average Dew Point Temperature Data at Lomé-Aéroport (°C) 4-51

Table 4.5-6 Monthly Temperature Norms (°C) on the Togolese Coast 4-51

Table 4.5-7 Evaluation of Atmospheric Gas Emissions by Type of Source in 1995 4-52

Table 4.5-8 Quantity of Greenhouse Gases for 1994-1998 in the Energy Sector 4-53

CHAPTER 1
INTRODUCTION AND BACKGROUND

This report presents the results of the second season of data gathering carried out during the wet season of June and July 2003. It is the continuation of the work in the first dry season campaign in December 2002. It contains the results of the physical, chemical, and biological surveys of the site selected for the installation of the gas pipeline and the reports on sea turtles and fishing activities in the area of Gbetsogbe.

The site, measuring 25m wide by 1000m long, has a surface area of 25,000m² (2.5ha). A 12m safety zone is being used on each side of the route. The environmental components are homogeneous and not very diversified (Figures 1-1 and 1-2). Between stake 1 (P1), located mid-tideland and stake 2 (P2), there is an erosion beach for a distance of 20m, where a group of women from the village of Gbetsogbe extract gravel.

For a distance of 60m between P2 and P5 on the old impassable road, the upper beach area is used for drying fish and storing gravel. An unused dilapidated concrete hangar is located on the coastline. From P5 to P9, an 80m field used for sports and recreational activities is characterized by black soil. To the right of the route towards the north is the edge of the village, with a sanctuary located 12m from P7. A waste dump is also located in this segment between stakes P8 and P9.

For a distance of 20m between stakes 9 and 10, cacti separate the village from the vegetable farming area. For 360m from stake 10 to stake 28 there are farmlands (vegetable gardens) and fallow land with water tanks, most of which are rectangular, filtered wells, underground electrical supply systems, small rest shelters, and a few bushes. It is a very homogeneous landscape, divided into plots. Between stakes 28 and 29, the oil pipeline, which is composed of pipe of different sizes, is bordered by grassy vegetation up to stake 30.

The right-of-way of National Highway No. 2 (Lome-Aneho) is located between P30 and P31. Then grassy vegetation borders the road, and vegetable plots for 20m to P32. Vegetable fields and tanks are distributed over a distance of 120m between P32 and P38. There is a tree within the 25m width.

Stake 38 is at the Power Plant perimeter fence. For 240m up to stake 50, inside the fenced area, relatively thick grassy vegetation indicates an unused and rarely cleared site inhabited by a few reptiles and mammals. A coconut palm grove and a few bushes are located on the route. The 25m route width includes a building, other infrastructures, and the eastern perimeter fence of the Power Plant, adjacent to vegetable beds.

Figure 1-1
Homogeneous Landscape of the Gas Pipeline Route

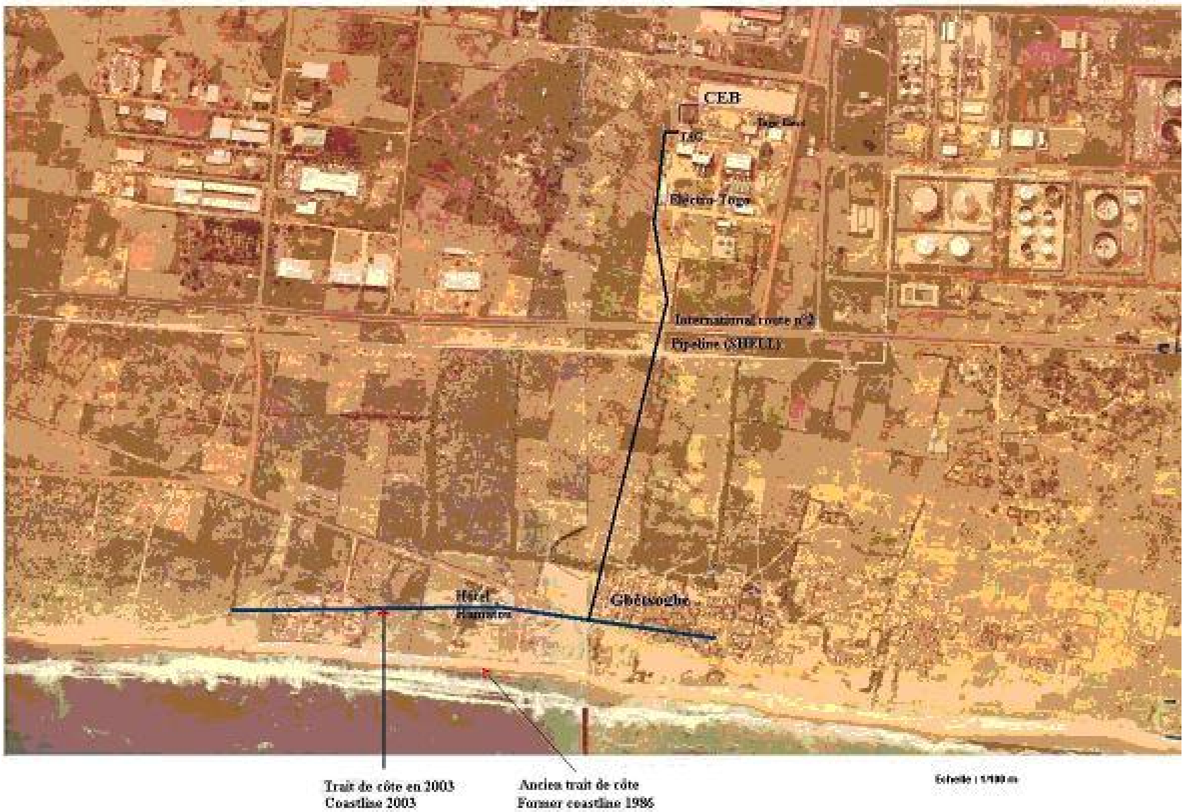
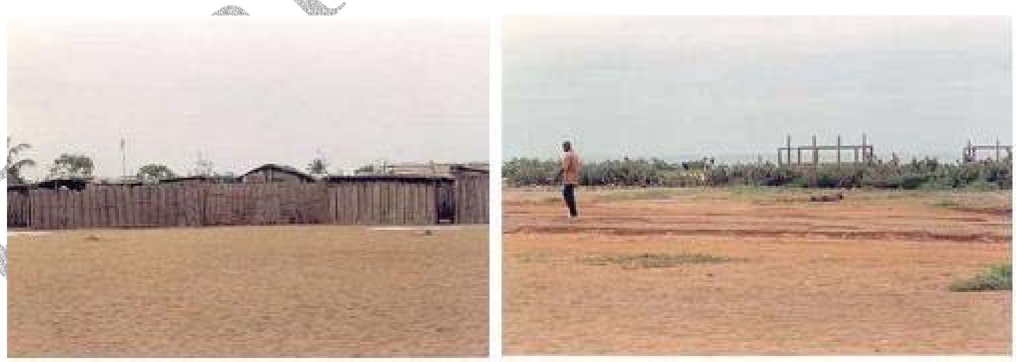
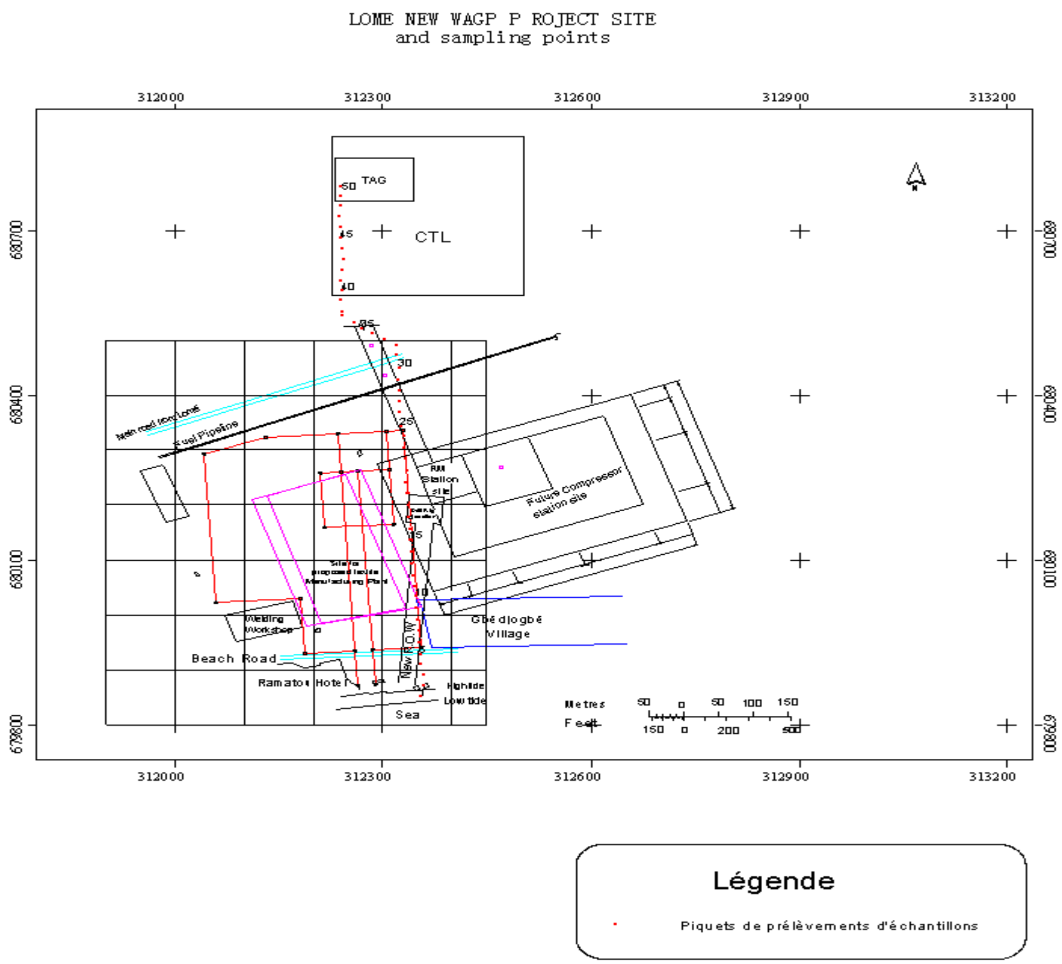


Figure 1-2
Study Area Located near the Village of Gbetsogbe



The gas pipeline route surveyed during the first sampling campaign in December 2002 is different from the route for the second campaign selected on 13 June 2003 by WAGP, PARAGON, RUDAN, and ICF. This three-axis route runs through the markers already set by RUDAN, WAGP 1/02/11, WAGP RT 1/02/10, and WAGP RT 1/02/9. The first axis, which is 640m long, begins at the beach and runs to 20 m north of the road; the second angles to the west for 120m, and the last goes from the Power Plant perimeter fence to the Gas Terminal (TAG).

Figure 1-3
Geometry of the Gas Pipeline Installation Site Between the Beach and the CTL [Lome Power Plant]



The results of the various analyses show the ecological situation and provide conclusions that permit the gas pipeline to be located in the sector without causing major damage to existing structures or the destruction of the relatively homogeneous habitats. The capitalized data will be used as a reference point for monitoring the section as a whole after the gas pipeline is installed, which help provide a measurement of the structure's impact.

CHAPTER 2
ONSHORE FIELD METHODS

2.1 VEGETATION SAMPLING

The initially considered transect has a total length of 140m (a 10m transect located 10m from the beach and two 60m transects from offshore to onshore). In order to better understand the major impact of the route on the coastal vegetation, a systematic species inventory was conducted on 300m² areas. The area considered covers each stake for a width of 10m and a length of 30m as indicated in Figure 2.2-1. On this basis, a transect of approximately 1km was prospected. For each record, all species were noted as present/absent. The size and number of individuals was taken into account for bushes, while for trees the diameter was measured for individuals having a dbh≥7.5cm. Coverage by all species was also noted by visual rating according to the proposed grid. Plant species were identified directly in the field.

The following equipment was used for the survey:

- A compass to establish the transect according to an azimuth perpendicular to the coast
- A survey line and stakes to locate the various record points
- A GPS to record the geographic coordinates of the points
- A clipper to harvest samples in the field for identification in the lab
- A sample recognition guide
- Presses and newspaper for the plant collection
- A camera.

2.2 SOIL SAMPLING

2.2.1 Grain Size

Samples were collected in georeferenced vertical sections at a depth between 15 and 50cm. The nature of the sediments collected is sand. We collected a total of 11 samples, 1 sample per section. The auger was used as sampling tool.

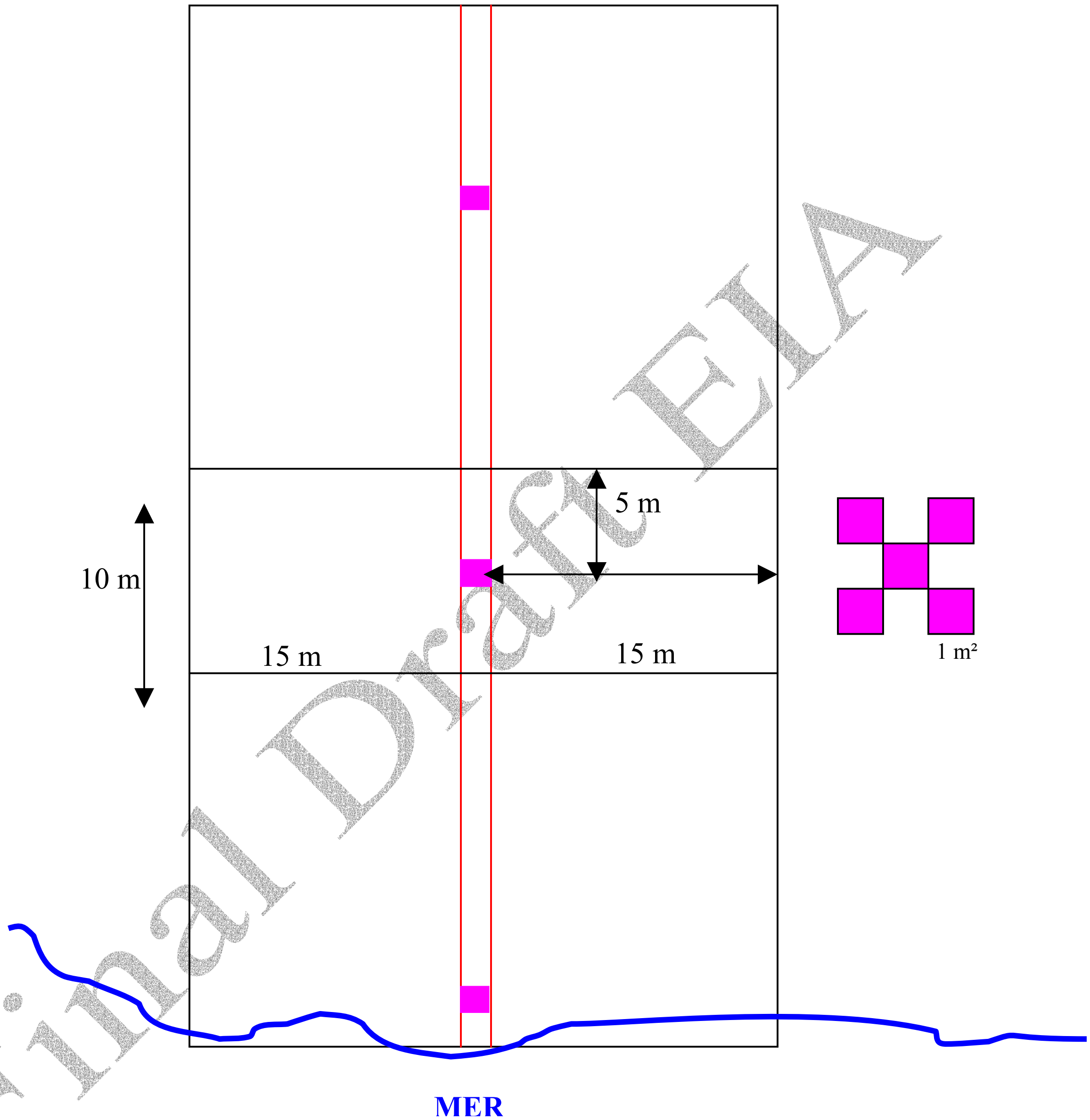
2.2.2 Microbiology

Twenty-two (22) soil samples were collected on Thursday, July 3, 2003 from 7:00 to 11:30 a.m. using a flame-sterilized auger in a 1 m square around each stake at two levels: 0 to 15cm and 15 to 50cm of depth.

2.2.3 Entomology

The sampling sites were selected in collaboration with the members of the other teams. The sampling sites were distributed over three transects. The first transect is 10m long. The two others are 30 and 60 meters respectively. Sampling was done at two depths: 0 to 15cm and 15 to 50cm.

Figure 2.2-1
Experimental Sampling Array



Transect 1 contains 3 sampling points located 0, 5, and 10 meters from the ocean's edge. The three samples from level 1 (0 to 15cm) were mixed to form a single sample. The same was done for the samples from level 2 (15 to 50cm), resulting in a total of 2 samples for the first transect.

Transects 2 and 3 contain 4 sampling points each. Like the first transect, the 4 samples from each of the two levels were also mixed to provide 2 composite samples for each transect. A total of 6 composite samples was therefore obtained to be analyzed for all 11 samples.

All the sampling was done in the morning using an auger approximately 20cm in diameter. When all the samples from a given transect were completed, they were grouped by level. The samples from each level were mixed to form two composite samples per transect. There were 3 sampling points in transect 1 and 4 sampling points in transects 2 and 3, resulting in a total of eleven sampling points, for 6 composite samples.

A second series of 6 composites (2 per transect) was prepared on August 12, 2003 in order to make a second appraisal concerning the soil fauna.

2.2.4 Chemical

Sampling was conducted according to the recommendations taken from the Work plan, at the points selected by all the teams in the three transects selected for this work.

This work was done between 7:30 and 11:00 a.m. The weather during the sampling period was not sunny. Eleven (11) soil samples were collected at a depth of 0 to 15cm for metals, TOC, and TPH analyses. Twenty-two (22) samples for PAH analyses were also collected at a depth of 0 to 15cm for some and 15 to 50cm for the others. For the PAH analyses, the composite samples were prepared in the Laboratory for these twenty-two (22) samples.

The first samples were obtained on the first transect at points $2TT_1$-1, $2TT_1$-2 and $2TT_1$-3, the next on the second transect at points $2TT_2$-1, $2TT_2$-2, $2TT_2$-3 and $2TT_2$-4. The last samples were taken on the third transect at points $2TT_3$-1, $2TT_3$-2, $2TT_3$-3 and $2TT_3$-4. Sample texture and color were first determined in the field and later confirmed in the Lab.

2.3 IN-SITU METHODS

2.3.1 Soil Sample Temperature Determination Method

The temperature of the soil samples was measured *in situ* using a mercury thermometer graduated from – 10 to 110°C.

2.4 WILDLIFE AND ANIMAL RESOURCES

Marine reptile and mammal species identification manuals were used.

Sea Turtles

- *Clé de détermination des tortues marines de l'Atlantique* (Fretey and Pritchard),
- *Guide pratique pour la connaissance et l'identification des espèces menacées et exploitées dans le monde, Guide pratique pour leur connaissance et leur identification: tortues marines* (Fretey, 1983);
- *Identification et biologie des espèces de tortues marines*(Fretey, 2000);
- *The anatomy of sea turtles* (Wyneken, 2001).

Cetaceans

- *Species identification guide, Marine mammals of the world* (Jefferson, Leatherwood and Webber; 1993);

- *Whales, dolphins and porpoises; The visual guide to all the world's cetaceans* (M. Carwardine, 1995)

The method used for inventorying marine reptiles and mammals was essentially based on field surveys and specimen collection. This survey was conducted in the village of Gbetsogbe and in other coastal villages. The survey consisted of looking for trophies (sea turtle skulls, shells, and plastrons, specimens of cetaceans, etc.), turtle eggs, and turtle or whale fat. A few resource people (mainly fishermen) from the villages were also interviewed. This ethnozoological technique consists of showing photographs of animals that might be observed in the area.

The following technical and reference tools were used for the water fowl inventory:

- 2 pair of Nikon Action 8 x 40 8.2° binoculars;
- Notebooks, pencils, erasers;
- Field data cards;
- The following identification guides and keys:
  - *Fiche descriptive des familles* (OMPO, 2000)
  - *Clef de détermination des limicoles* (Hecker, 2000)
  - *Echassiers, canards et limicoles de l'ouest africain* (Girard, 1998)
  - *Les oiseaux de l'ouest-africain* (Serle et Morel, 1993)
  - *Fiche d'entraînement à l'identification* (OMPO, 2000)

In the specific context of this survey, the method used was observation from a fixed point moving along the coastline. Five field outings were conducted between 6:00 a.m. and 12:00 noon. In the field, birds were identified by recording characteristics concerning their morphology, colors, and behavior, according to each individual or group of birds observed.

For the beach-rock fauna, we used:

- A canoe to access the beach rock
- 1-meter long stakes for laying out the squares
- A bucket to contain samples
- Formol for fixing the animals collected
- Knives to remove the animals from the rocky substrate.

For the onshore wildlife survey, a transect of 100m (50m on either side of the new route) over a distance of 700m was covered. When traveling this transect, all reptiles, birds, and mammals were recorded. Some individuals were even captured using traditional traps with the help of farmers along the route. A survey of the population of Gbestogbe was made to supplement the field inventory results.

2.5 SAMPLE TRACKING, STORAGE, AND SHIPPING

2.5.1 Grain Size

The samples were placed in labeled bags, transported by vehicle, and stored at the lab,

Table 2.5-1: List of Samples

Identification			UTM Zone 31		Geographic Coordinates	
Transects	**Stakes**	**Samples**	**Longitudes X**	**Latitudes Y**	**Longitude**	**Latitude**
$2TT_1$-1	1	1	312356	679851	1°18'15.28 E	6°08'52.43 N
$2TT_1$-2	1.5	2	312358	679854	1°18'15.60 E	6°08'52.80 N
$2TT_1$-3	1.10	3	312354	679859	1°18'15.70 E	6°08'53.00 N
$2TT_2$-1	6	4	312353	679951	1°18'15.60 E	6°08'55.70 N
$2TT_2$-2	6.10	5	312353	679961	1°18'15.17 E	6°08'56.30 N
$2TT_2$-3	7	6	312352	679971	1°18'15.17 E	6°08'56.34 N
$2TT_2$-4	7.10	7	312342	679983	1°18'15.40 E	6°08'57.00 N
$2TT_3$-1	14	8	312341	680115	1°18'15.10 E	6°08'57.02 N
$2TT_3$-2	15	9	312341	680138	1°18'15.04 E	6°08'57.70 N
$2TT_3$-3	16	10	312341	680158	1°18'15.07 E	6°08'58.42 N
$2TT_3$-4	17	11	312338	680178	1°18'14.94 E	6°08'59.01 N

2.5.2 Microbiology

The sand samples collected were placed in sterile bottles equipped with stoppers, each bottle marked with the site number. Samples were then taken to the lab in a cooler and analyzed the same day.

Table 2.5-2: List of Samples

Site	Distance from the ocean	Code	* Coordinates		Number of samples and type of analysis		
			Latitude	Longitude	Tempe-rature	Humidity	Micro-biology
$2TT_1$-1	10m	$2TT_1$-C1	6° 08’ 52.43 N	1° 18’ 15.28 E	2	2	
$2TT_1$-2	15m		6° 08’ 52.80 N	1° 18’ 15.60 E	2	2	2
$2TT_1$-3	20m	$2TT_1$-C2	6° 08’ 53.00 N	1° 18’ 15.70 E	2	2	
$2TT_2$-1	120m	$2TT_2$-C1	6° 08’ 55.70 N	1° 18’ 15.60 E	2	2	
$2TT_2$-2	130m		6° 08’ 56.30 N	1° 18’ 15.17 E	2	2	2
$2TT_2$-3	140m	$2TT_2$-C2	6° 08’ 56.34 N	1° 18’ 15.17 E	2	2	
$2TT_2$-4	150m		6° 08’ 57.00 N	1° 18’ 15.40 E	2	2	
$2TT_3$-1	280m	$2TT_3$-C1	6° 08’ 57.02 N	1° 18’ 15.10 E	2	2	
$2TT_3$-2	300m		6° 08’ 57.70 N	1° 18’ 15.04 E	2	2	2
$2TT_3$-3	320m	$2TT_3$-C2	6° 08’ 58.42 N	1° 18’ 15.07 E	2	2	
$2TT_3$-4	340m		6° 08’ 59.01 N	1° 18’ 14.94 E	2	2	
Total					**22**	**22**	**06**

* Data from July 3, 2003 Records, attached

$2TT_1$-C1=0-15cm level composite from first Transect; $2TT_1$-C2=15-50cm level composite from first Transect;

$2TT_2$-C1=0-15cm level composite from second Transect; $2TT_2$-C2=15-50cm level composite of second Transect;

$2TT_3$-C1=0-15cm level composite from third Transect; $2TT_3$-C2=15-50cm level composite from third Transect.

2.5.3 Entomology

The composite samples were kept in labeled bags. They were transported in the vehicle and stored at the lab.

Table 2.5-3: List of Composite Samples

Sample	Composition
$2TT_1$-C_1	Mixture of the 3 samples from level 1 (0–15cm)
$2TT_1$-C_2	Mixture of the 3 samples from level 2 (15–50cm)
$2TT_2$-C_1	Mixture of the 4 samples from level 1 (0–15cm)
$2TT_2$-C_2	Mixture of the 4 samples from level 2 (15–50cm)
$2TT_3$-C_1	Mixture of the 4 samples from level 1 (0–15cm)
$2TT_3$-C_2	Mixture of the 4 samples from level 2 (15–50cm)

The 6 composites from the second series were labeled ($2TT_1$-C1, $2TT_1$-C2, $2TT_2$-C1, $2TT_2$-C2, $2TT_3$-C1, $2TT_3$-C2) and taken by car to the entomology lab at Abomey-Calavi University in Cotonou.

2.5.4 Chemical

All the samples were collected in glass jars with an approximate capacity of 500ml. They were labeled as indicated above, and taken to the lab in a cooler.

Table 2.5-4: List of Samples

Sampling Point Number	Distance from the ocean (m)	Longitude	Latitude
$2TT_1$-1	10	1°18’15.28	6°08’52.43
$2TT_1$-2	15	1°18’15.60	6°08’52.80
$2TT_1$-3	20	1°18’15.70	6°08’53.00
$2TT_2$-1	120	1°18’15.60	6°08’55.70
$2TT_2$-2	130	1°18’15.17	6°08’56.30
$2TT_2$-3	140	1°18’15.17	6°08’56.34
$2TT_2$-4	150	1°18’15.40	6°08’57.00
$2TT_3$-1	280	1°18’15.10	6°08’57.02
$2TT_3$-2	300	1°18’15.04	6°08’57.70
$2TT_3$-3	320	1°18’15.07	6°08’58.42
$2TT_3$-4	340	1°18’14.94	6°08’59.01

CHAPTER 3
ANALYTICAL METHODS

3.1 PHYSICAL LABORATORY METHODS

3.1.1 Grain size

A 100 g portion was taken from each sample. The sieving method used the AFNOR (Association Francaise de Normalisation) series. The column was composed of 5 sieves of geometrically decreasing mesh size: 2mm, 1mm, 0.500mm, 0.200mm, and 0.050mm.

This geometrically decreasing progression of meshes provides a normal length graph with a logarithmic mesh size scale on the abscissa.

Each sample was sieved by electromagnetic agitation for 15 minutes, and results were weighed using a Shimazzu BX 3200 D balance.

The following classification was used:

≥2	mm	gravel
≥1	mm	very coarse sand
≥0.500	mm	coarse sand
≥0.200	mm	medium sand
≥0.050	mm	fine sand

Based on grain size, a data base of actual weight, percent, and cumulative percent was created. This grain size-based classification permits the construction of two types of grain size graphs (frequency and cumulative) from which the grain deposition conditions are interpreted.

3.1.2 Organic Matter

3.1.2.1 Organic Carbon: Direct Colorimetry

The carbon in the organic matter is oxidized by a mixture of potassium bichromate and sulfuric acid. The oxygen consumed is assumed to be proportional to the carbon to be determined. Instead of determining the unused bichromate by volumetrics, a direct colorimetric determination is made of the blue green cr^{3+} ions formed during the reaction, which are proportional to the equivalent oxidized carbon.

The colorimetry titration curve is constructed using a glucose solution with a known carbon content.

The advantages of this method are the elimination of back-titration using Mohr salt, and the fact that some interferences such as chlorine are not involved.

3.1.2.2 Total nitrogen: Kjeldhal method

- Weigh out 5g of crushed soil in a 150cc matrass.
- Add 2.5g of catalyst and 6 glass marbles.
- Shake well to mix soil and catalyst.
- Then add 20cc of sulfuric acide, mix well so the solid portion is uniformly moistened.
- Heat gently for ½ hour in a sand bath.
- Increase heat to maximum, but do not permit the white sulfuric vapors to reach the neck of the matrass.
- Continue until the residue is completely white (generally 3 hours).
- Then continue heating for another ½ hour.
- Allow to cool.
- With each series of determinations, make a control by placing 10cc of accurately measured N/10 ammonium sulfate, catalyst, and acid as for the samples.

3.1.3 Moisture

Soil sample moisture was determined by the oven-drying method.

An aliquot of 100g of sand (P1) is placed in a container of known weight (P0). The prepared specimen is incubated in the oven at 105°C for two (2) hours and then cooled in a dessicator.

The dry weight (P2) of the aliquot is evaluated by weighing it and the moisture is determined by calculation using the following formula:

$$\text{Percent moisture (\%)} = \frac{P1 - P2}{P2} \times 100$$

3.2 CHEMICAL LABORATORY METHODS

3.2.1 pH and Salinity

The pH and salinity of soil suspensions on the order of 1g/ml were measured: Place approximately 25g of soil in an Erlenmeyer flask and add 25mL of distilled water. Shake for about 15 minutes, then measure the pH using a pH-meter and the salinity using a salinity meter.

3.2.2 Heavy Metals

The samples underwent no processing in the lab before the pH and moisture analyses. After the analyses, the samples were kept in their packaging at room temperature (28-32°C).

3.2.2.1 Simply Drying and Crushing

A fraction of the soil samples was dried and finely ground using porcelain or glass mortars. The powders obtained were recovered in small plastic bags.

3.2.2.2 Acid Attack and Aqueous Solution

The chemical reagent used is a mixture of three acids (mixture of perchloric acid ($HClO_4$), hydrofluoric acid (HF), and nitric acid (HNO_3).

For a volume V = 4v of reagent, mix the three acids in the following proportion:

$HClO_4$=1.0v HF=1.5v HNO_3=1.5v

For example, for 1000mL:

$HClO_4$=250mL HF=375mL HNO_3=375mL

The acid attack and solubilization procedure is as follows:

Place 2.5g of sediment or soil in a teflon jar, moisten slightly with distilled water, add 30ml of reagent and allow to react overnight (at least 6 hours), then heat gently on a sand bath until abundant white smoke appears (approximately 3 hours).

Add approximately 2mL of HNO_3, then 25mL of distilled water. Recover all residue. Filter on Whatman paper (glass microfiber filter paper) and recover the filtrate in a 100mL graduated flask. Adjust to 100mL.

3.2.2.3 Mercury Analysis by Molecular Absorption Spectrophotometry after Complexation and Extraction (Hg)

The mercury was analyzed by molecular absorption spectrophotometry after formation of mercury dithizonate.

3.2.2.4 Chemical Reagent Solutions

1g/L Organic Dithizone Solution

- Dissolve 0.1g of dithizone in 100mL of pure chloroform.
- From this mother solution, prepare dilutions of 10mg/L in chloroform.

Aqueous Acetic Acid Buffer pH 4.5

- Dissolve 560g of hydrated trisodium acetate in approximately 250mL of distilled water, add 240mL of pure acetic acid and bring the volume up to 1000mL with distilled water.

Aqueous Solution of Disodium Salt of EDTA Acid

- Dissolve 50g of disodium salt of EDTA acid in approximately 250mL of water, then fill up to 1000mL with distilled water.

Standard Solutions of Mercury

- Using the 1.0g/L mother solution of mercury in water, prepare second-generation standard solutions in the anticipated concentration range. The mercury salt used is mercury sulfate ($HgSO_4$).

3.2.2.5 Mercury Dithizonate Extraction and Absorbency Measurement

- Place 25mL of the subject solution in decanters. Add 10mL of acetic buffer solution, 5ml of EDTA solution, then adjust pH to 4.5 with a 0.1mole/L aqueous soda solution.

- Add 5mL of 10mg/L dithizone chloroform solution. Shake adequately (10 minutes). Separate the phases and recover the organic phase.

- Measure the optical density of the organic phase at 465nm after resetting with pure chloroform.

3.2.2.6 Analysis of Cadmium, Chromium, Copper, Nickel, Lead, Iron, Zinc, Aluminum, and Vanadium by Atomic Absorption Spectrophotometry (Cr(VI), Ni, Cu, Zn, Cd,Pb, Fe, Al, V)

Equipment used: Perkin Elmer model 2308 atomic absorption spectrophotometer with hollow cathode lamps (Perkin Elmer lamps) appropriate to the elements to be determined, a non-specific absorbancy correction lamp, and an acetylene-air nebulizer-burner unit.

3.2.2.7 Preparation of Standard Solutions

These solutions are prepared just before use by diluting the standard mother solutions.

- Prepare a second-generation solution of each element (100mL at 100mg/L in distilled water)

- Prepare a diluted solution mixture (in the desired range of concentration) from the 100mg/L second-generation solutions in the presence of nitric acid.

- The standard solutions are prepared from commercial 1000ppm standard solutions (Riedel-de Haen Fixanal products sold by Merck, or Perkin Elmer product for vanadium).

3.2.2.8 Measurement

- Adjust the apparatus.
- Make measurements element by element using the appropriate hollow cathode lamp.
- Adjust gas flows by suctioning the approximately N/10 nitric acid solution.
- Rinse the nebulizer-burner unit with nitric acid solution after the passage of each solution.

3.2.2.9 Validation of Results

To validate the measurement results, we used the following multi-step procedure for each element analyzed.

- Calibration and detection threshold: Dilutions and apparatus adjustments must be handled with care to obtain good analytical conditions. Start measurements when the calibration curve indicates good linearity between the signal value (absorbancy) and the element concentration. Apparatus adjustment is frequently emphasized in order to obtain a very low detection threshold.
- Multiple injections: When analyzing elements by atomic absorption spectrophotometry, the solution of each sample is injected three times after validating the calibration curve. The average value (arithmetic average) is used.
- Dilution step: Samples with high absorbency values were diluted. The dilution factor is calculated so as to obtain a signal within the concentration range of the calibration curve. If there is proportionality between the dilution factor and the absorbency value, the result is validated; if not, injections are repeated. This method is supported by the fact that the matrix effect of the samples is greater in a concentrated medium.
- Confirmation step: When analyses of the series are completed, the results of the measurements obtained are closely analyzed. Over all, the relatively more concentrated samples and relatively less concentrated samples are selected and analyzed again. The more concentrated are of course diluted to one or two dilution factors. If the results are very different from the previous results, the results of this step are used because when there are only a small number of samples to be analyzed injection and reinjection can be repeated several times. It is assumed that there is no significant decomposition or contamination of the samples during storage.

3.2.3 Biological Laboratory Methods

3.2.3.1 Vegetation

Some plants not identified in the field had to be harvested in order to identify them at the University of Lome herbarium. The nomenclature used was Hutchison and Dalziel (1954-1972) and Brunel *et al.* (1984).

A list of all the species found on the gas pipeline route was prepared based on the field data gathered. The frequency calculation, done directly by micro-computer using the "records x species" table, helped determine for each species the absolute frequency or "species-contact" number, which is the number of records in which the species is observed and the relative frequency, which is the ratio between the absolute frequency and the total number of records in the survey area. The data are then processed using the Statistica 6.0 program.

3.2.3.2 Microbiology

The germs were counted using the solid medium counting method recommended by the guidelines of NF V08-011, 1973 and NF V08-012, 1974.

Preparation of Mother Solution and Decimal Dilutions

- 10g of sand from each sample were diluted in 90mL of tryptone-salt broth. After homogenization by shaking for 5 minutes, 0.1mL of the mixture is diluted in 9.9mL of tryptone-salt to obtain a 10^{-2} dilution.
- The same dilutant is used to make decimal solutions up to $10^{-8.}$

Seeding

1mL of each dilution is double-seeded in sterile Petri dishes. Specific surfused agar-agar media were mixed with the inocula. The Agar Nutrient medium is used to determine total germs; potato dextrose agar for fungal flora, 1% desoxycholate gelose for coliforms, Drigalski gelose for enterobacteria, and tryptone sulfate neomycin (TSN) gelose for anaerobic sulfite-reducing germs.

Incubation and Determination

The seeded dishes were incubated at 30°C for 48 hours and the colonies were counted in the dishes, indicating between 30 and 300 colonies. The sulfite-reducing anaerobic germs were incubated at 44°C for 48 hours and the black colonies characteristic of tubes with between 10 and 30 colonies were counted.

Calculation of the Number of Germs per gram of Soil

The number of germs per gram of soil was calculated using the dilution factor.

3.2.3.3 Entomology

The soil arthropod fauna were detected and identified in several steps:

- Step 1
  The Berlese method is based on the photofugal behavior of organisms living in soil. This step consists of lighting the soil sample contained in a metal funnel with a 60-watt electric bulb for 48 hours. The edaphic organisms, mainly insects that flee from light and heat will migrate down into the tube of the funnel and fall into an anesthetic jar placed under the tube. The organisms that fall into the anesthetic jar are recovered, stored, and prepared for identification.

- Step 2
  The soil samples resulting from the Berlese method are picked up and examined with a magnifier to recover any arthropods that are dead or were unable to migrate into the anesthetic jar.

- Step 3
  The arthropods recovered in steps 1 and 2 are successively sorted to group them by order and then by family. Those that are determined are stored. Those that could not be determined are prepared to be sent to a specialized taxonomy lab for identification.

Analysis protocol for the second series of composites.

2kg of sand was sieved over a column of two sieves, 200µm et 500µm mesh. The sand and organisms recovered are directly poured into small bottles, then fixed with 4% formol.

The formol-fixed sample is washed over a column of 4 sieves, 2mm to 200µm mesh. The organisms trapped in each sieve are transferred into sorting bins, where they are sorted for determination.

The organisms were identified with the naked eye when possible, or with a Pierron binocular magnifier when necessary, using the following identification guides:

- Atachi P., 1983. *Clé de classification des insectes. Collection de planches de travaux pratiques*, Agro 3, FSA Bénin.

- Brown D.S. and Kristensen T.K., 1993. A field guide to African freshwater snails. 1. West African species. Danish Bilharziasis Laboratory. 55p.

- Fischer, W. (Ed.), 1973. Rome, FAO, pag. Var. *Fiches FAO d'identification des espèces pour les besoins de la pêche. Méditerranée et Mer Noire (Zone de pêche 37).* Volume 2

- Fischer, W. (Ed.), 1981. Rome, FAO, pag. Var. *Fiches FAO d'identification des espèces pour les besoins de la pêche. Zone de pêche34, 47 (en partie).* Volumes 3 and 4.

- Maslin J.-L., 1985. *Les peuplements de mollusques benthiques d'une lagune du Sud-Bénin (le lac Ahémé): facteurs de leur répartition et impact des variations des conditions du milieu.* Verh. Internat. Verein. Limnol. 22. pp. 3300-3305.

- Micha J-C et Noiset J-L, 1982. *Evaluation biologique de la pollution des ruisseaux et rivières par les invertébrés aquatiques.* PROBIO REVUE, quarterly publication, vol.5 n°1. 143 p.

- Nicklès M. 1953. *Scaphodes et Lamellibranches récoltés dans l'Ouest Africain.* 94-237.

- Nicklès M., 1950. *Mollusques testacés marins de la côte occidentale d'Afrique.* 269p.

- Tachet H., Bournaud M. et Richoux P., 1980. *Introduction à l'étude des macroinvertébrés des eaux douces (Systématique élémentaire et aperçu écologique).* Association Française de Limnologie. 151p

CHAPTER 4
RESULTS

4.1 VEGETATION

4.1.1 Floristic Characteristics of the Survey Environment

4.1.1.1 Floristic Analysis

A total of 50 records were made on a 1 km transect. The various records and corresponding units are shown in Table 4.1-1. A total of 125 species was inventoried, including 108 herbaceous species, 8 bushes, and 10 trees. They are represented by 101 genera grouped in 47 families, with 7 monocotyledons and 40 dicotyledons (Table 4.1-2). Several families, including Amaranthaceae, Asteraceae, Solanaceae, Cucurbitaceae, Cyperaceae, and Tiliaceae, are represented by at least 4 species, while the other families are represented by no more than 3 species (Table 4.1-2).

Figure 4.1-1 shows that the herbaceous species (86%) are clearly dominant. Bushes (6%) are not widely represented in the area, while trees account for only 8%. The best-represented herbaceous families are the Poaceae (17 species), followed by the Fabaceae (11 species) and Euphorbiaceae (9 species) (Table 4.1-2).

Figure 4.1-1
General Range of Inventoried Species

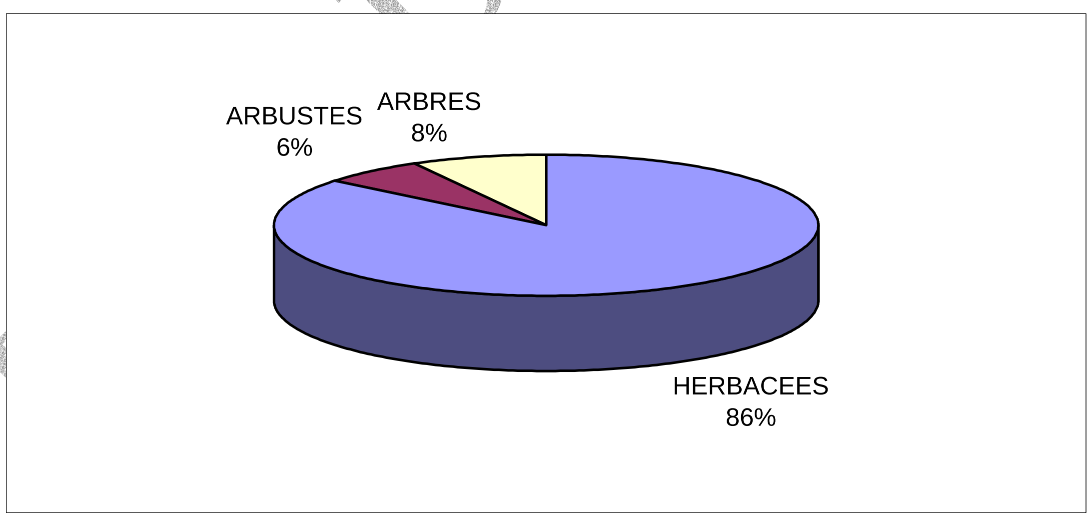


Table 4.1-1
Records and Types of Habitats

Unit	Record n°	Type of habitat
1 (beach)	1	Beach
2 (upper beach to marker 11)	2	Beach
	3	Grass with *Sporobolus virginicus*
	4	Field
	5	Field
3 (empty field)	6	Field
	7	Field
	8	Field
4 (dump)	9	Field-dump mosaic
	10	Hedge of *Opuntia dillenii*
5 (farm)	11	Farm
	12	Farm
	13	Farm
	14	Farm
6 (fallow land)	15	Fallow field
	16	Fallow field
7 (fallow land-farm land mosaic up to pipeline)	17	Farm
	18	Fallow-farm mosaic
	19	Fallow-farm mosaic
	20	Fallow-farm mosaic
	21	Fallow-farm mosaic
	22	Farm
	23	Cleared fallow field
	24	Farm
	25	Farm
	26	Farm
	27	Farm
	28	Farm
	29	Fallow-farm mosaic
8 (between pipeline and RN2)	30	Fallow field
	31	Fallow field
	32	Fallow field
9 (between RN2 and the CEB perimeter fence)	33	Farm
	34	Farm
	35	Farm
	36	Farm
	37	Farm
	38	Farm
10 (CEB power plant enclosure)	39	Fallow
	40	Fallow
	41	Fallow
	42	Fallow
	43	Fallow
	44	Fallow
	45	Fallow

Unit	Record n°	Type of habitat
	46	Fallow
	47	Field of *Ipomoea batatas*
	48	Garden
	49	Garden
	50	Garden

Table 4.1-2
Diversity of families, number of genera and species

Class	Family	Genera	Species	Family Total
DICOTYLEDONS	Acanthaceae	1	1	
	Aizoaceae	1	1	
	Amaranthaceae	4	6	
	Anacardiaceae	1	1	
	Annonaceae	1	1	
	Apocynaceae	1	1	
	Asclepiadaceae	3	3	
	Asteraceae	5	5	
	Bignoniaceae	1	1	
	Bombacaceae	1	1	
	Cactaceae	3	3	
	Caesalpiniaceae	1	3	
	Capparidaceae	2	2	
	Caricaceae	1	1	
	Combretaceae	1	1	
	Connaraceae	1	1	
	Convolvulaceae	2	2	
	Cucurbitaceae	4	5	
	Euphorbiaceae	6	9	
	Fabaceae	8	11	
	Lauraceae	1	1	
	Malvaceae	3	4	
	Meliaceae	1	1	
	Menispermaceae	1	1	
	Mimosaceae	4	4	40
	Molluginaceae	2	2	
	Moraceae	1	2	
	Nyctaginaceae	1	2	
	Oleaceae	1	1	
	Passifloraceae	1	1	
	Pedaliaceae	2	2	
	Portulacaceae	2	2	
	Rubiaceae	1	1	
	Rutaceae	1	1	
	Solanaceae	3	5	

Class	Family	Genera	Species	Family Total
	Sterculiaceae	1	1	
	Tiliaceae	2	4	
	Umbelliferae	1	1	
	Verbenaceae	1	1	
	Zygophyllaceae	1	1	
MONOCOTYLEDONS	Agavaceae	1	1	
	Araceae	1	1	
	Commelinaceae	1	2	
	Cyperaceae	2	4	7
	Liliaceae	1	1	
	Palmae	2	2	
	Poaceae	14	17	
TOTAL		**101**	**125**	**47**

4.1.1.2 Frequency of Species

An analysis of Table 4.1-3 shows that the most frequent species are herbaceous. Of these, 80% are dicotyledons. Table 4.1-4 shows the species present in at least 5 records, while Table 4.1-5 indicates the least frequent species or those observed in only one record. These belong to 20 different families, 2 monocotyledons and 18 dicotyledons. Figure 4.1-2 shows that the Poaceae are the most frequent, followed by the Fabaceae and the Euphorbiaceae.

Figure 4.1-2
Representation of the Most Frequent Families on the Gas Pipeline Site

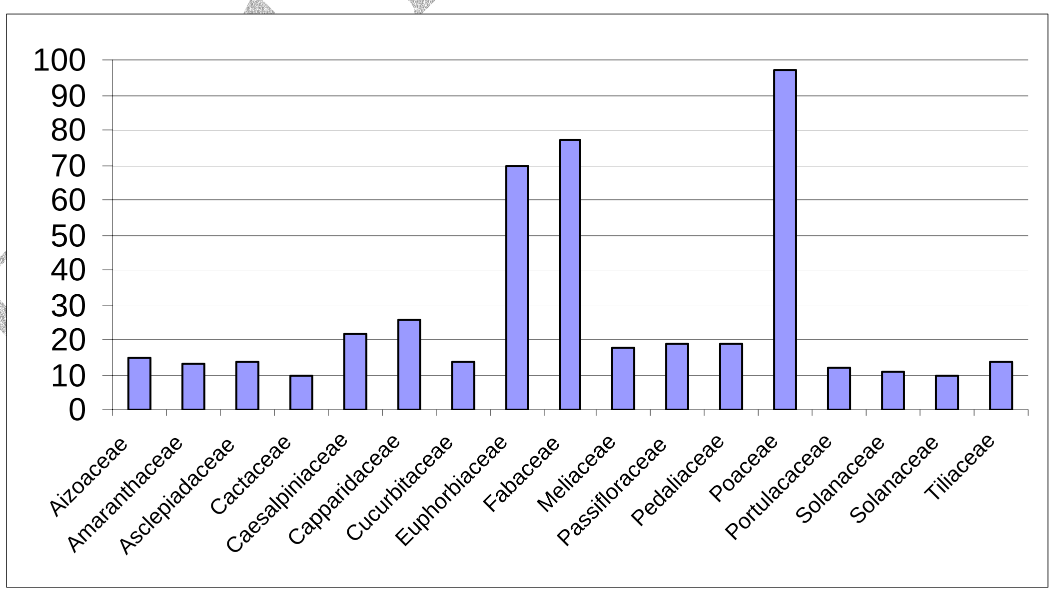


Table 4.1-3
Most Frequent Species (present in at least 10 records)

Species	Family	Frequency	
		Absolute	Relative
Tephrosia purpurea	Fabaceae	30	6.3
Cleome viscosa	Capparidaceae	26	5.5
Boerhavia erecta	Nyctagynaceae	23	4.8
Euphorbia hyssopifolia	Euphorbiaceae	23	4.8
Eragrostis tenella	Poaceae	21	4.4
Passiflora foetida	Passifloraceae	19	4.0
Pedalium murex	Pedaliaceae	19	4.0
Azadirachta indica	Meliaceae	18	3.8
Indigofera arrecta	Fabaceae	17	3.6
Anthephora cristata	Poaceae	15	3.2
Trianthema portulacastrum	Aizoaceae	15	3.2
Corchorus olitorius	Tiliaceae	14	2.9
Momordica charantia	Cucurbitaceae	14	2.9
Pergularia daemia	Asclepiadaceae	14	2.9
Amaranthus cruentus	Amaranthaceae	13	2.7
Dactyloctenium aegyptium	Poaceae	13	2.7
Digitaria horizontalis	Poaceae	13	2.7
Phyllanthus pentandrus	Euphorbiaceae	13	2.7
Commelina erecta subsp. erecta	Commelinaceae	12	2.5
Croton lobatus	Euphorbiaceae	12	2.5
Portulaca oleracea	Portulacaceae	12	2.5
Cassia occidentalis	Caesalpiniceae	11	2.3
Cassia rotundifolia	Caesalpiniceae	11	2.3
Euphorbia heterophylla	Euphorbiaceae	11	2.3
Phyllanthus amarus	Euphorbiaceae	11	2.3
Solanum lycopersicum	Solanaceae	11	2.3
Alysicarpus glumaceus	Fabaceae	10	2.1
Indigofera hirsuta	Fabaceae	10	2.1
Opuntia dillenii	Cactaceae	10	2.1
Solanum macrocarpum	Solanaceae	10	2.1
Tephrosia villosa	Fabaceae	10	2.1

Table 4.1-4
Frequent species (present in at least 5 records)

Species	Family	Frequency
Daucus carota	Umbelliferae	9
Euphorbia hirta	Euphorbiaceae	9
Merremia tridentata	Convolvulaceae	9
Panicum lindleyanum	Poaceae	9
Abelmoschus esculentus	Malvaceae	8
Brachiaria deflexa	Poaceae	8
Cenchrus biflorus	Poaceae	8
Cyperus compressus	Cyperaceae	8
Eleusine indica	Poaceae	8
Leptadenia hastata	Asclepiadaceae	8
Tribulus terrestris	Zygophyllaceae	8
Cucumis melo var. *agrestis*	Cucurbitaceae	7
Cymbopogon citratus	Poaceae	7
Gynandropsis gynandra	Capparidaceae	7
Mollugo nudicaulis	Molluginaceae	6
Ricinus communis	Euphorbiaceae	6
Triumfetta rhomboidea	Tiliaceae	6
Zea mays	Poaceae	6
Brachiaria distichophylla	Poaceae	5
Manihot esculenta	Euphorbiaceae	5
Pupalia lappacea	Amaranthaceae	5
Setaria megaphylla	Poaceae	5
Tridax procumbens	Asteraceae	5
Vernonia amygdalina	Asteraceae	5
Vigna unguiculata	Fabaceae	5
Ceratotheca sesamoides	Pedaliaceae	5
Physalis angolensis	Solanaceae	5

Table 4.1-5
Least frequent species (present in only 1 record)

Species	Family	Frequency
Acantocereus sp.	Cactaceae	1
Capsicum annuum	Solanaceae	1
Celosia sp.	Amaranthaceae	1
Corchorus aestuans	Tiliaceae	1
Crotalaria pallida	Fabaceae	1
Dracaena arborea	Agavaceae	1
Heteropogon contortus	Poaceae	1
Jasminum sp.	Oleaceae	1
Lactuca sativa	Asteraceae	1

Species	Family	Frequency
Mariscus cylindristachyus	Cyperaceae	1
Terminalia catappa	Combretaceae	1
Vitex doniana	Verbenaceae	1
Zantosoma mafaffa	Araceae	1
Cyperus rotundus	Cyperaceae	1
Indigofera spicata	Fabaceae	1
Annona senegalensis	Annonaceae	1
Sida cordifolia	Malvaceae	1
Urena lobata	Malvaceae	1
Launea taraxacifolia	Asteraceae	1
Mangifera indica	Anacardiaceae	1
Adansonia digitata	Bombacaceae	1
Acacia auriculiformis	Mimosaceae	1
Cassytha filiformis	Lauraceae	1
Sida acuta	Malvaceae	1
Gomphrena celosioides	Amaranthaceae	1

4.1.1.3 Types of Plant Formations Found

As in the first phase, the various units on the gas pipeline route are nearly the same. Processing the data using Statistica software made it possible to construct the hierarchical species tree as shown in Figure 4.1-3. This makes it possible to determine groups of species as a function of the various habitats (Table 4.1-6).

These include the barren beach, the upper onshore beach where a *Sporobollus virginicus* grassland is found, with *Opuntia dillenii, Tephrosia purpurea, Pedalium murex, Boerhavia erecta*, and *Citrullus colocynthis* in places (stakes 1, 2, 3 and 4). In units 4 and 5, waste dump and fallow land respectively, a ruderal flora is observed, with *O. dillenii* predominating. A mosaic of fallow land and farm crops (units 5, 6, and 7) is observed along the route up to the CEB power plant perimeter fence.

Figure 4.1-3
Hierarchical Classification of Inventoried Species

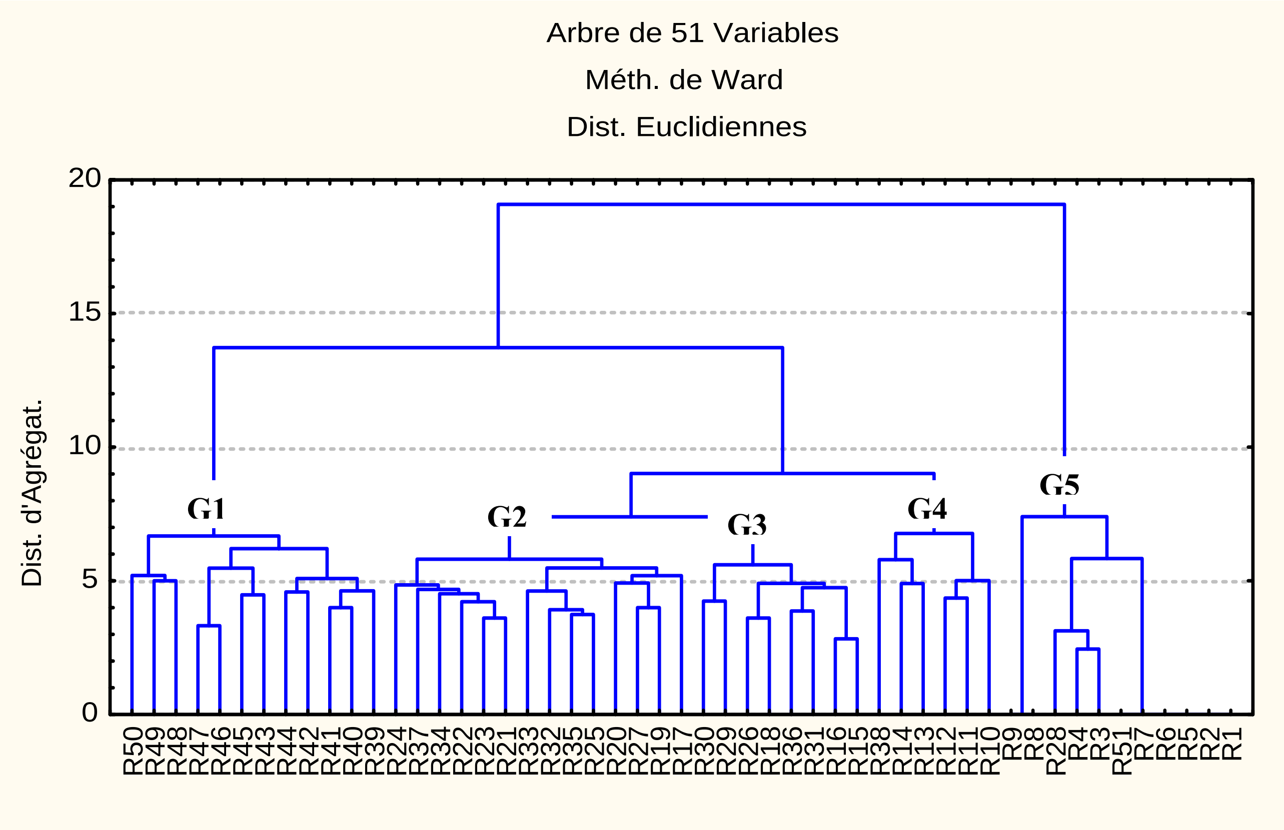


Table 4.1-6
Species Characteristic of the Types of Habitats

Group	Characteristic Species	Type of Habitat
G1	Azadirachta indica, Cassia occidentalis, *Cleome viscosa*, *Commelina erecta*, *Croton lobatus*, *Euphorbia hyssopifolia*, *Momordica charantia*, *Pedalium murex*, *Pergularia daemia*, *Phyllanthus pentandrus.*	Old farmlands (inside CEB power plant enclosure)
G2	*Corchorus olitorius*, *Indigofera arrecta*, *Tephrosia purpurea*, *Trianthema portulacastrum*, Graminées	Farmland perimeters
G3	Tephrosia purpurea, Tribulus terrestris.	Young fallow fields

Group	Characteristic Species	Type of Habitat
G4	*Azadirachta indica,* *Digitaria horizontalis,* *Opuntia dillenii.*	Edges of farm plots
G5	*Colocynthis citrullus*	Unused field (between beach and dump)

In this parade of flora, crops such as the following are predominant: *Daucus carota, Abelmoschus esculentus, Zea mays, Manihot esculenta, Cymbopogon citratus, Cucumis melo var agrestis, Allium cepa, Solanum macrocarpum, Solanum lycopersicum* and *Corchorus olitorius*. Weeds are also represented, including *Tephrosia purpurea, Cleome viscosa, Boerhavia erecta, Euphorbia hyssopifolia, Eragrostis tenella, Passiflora foetida, Pedalium murex, Indigofera arrecta, Anthephora cristata, Trianthema portulacastrum, Momordica charantia, Pergularia daemia, Amaranthus cruentus, Dactyloctenium aegyptium, Digitaria horizontalis, Phyllanthus pentandrus, Commelina erecta subsp. erecta, Croton lobatus, Portulaca oleracea, Cassia occidentalis, Cassia rotundifolia, Euphorbia heterophylla, Phyllanthus amarus,* etc. The CEB power plant enclosure, unit 8, includes stakes 39 to 50. It contains a fallow field, then a garden with *Ipomoea batatas* and a row of *Citrus aurantium* in the lengthwise direction and another row of *Polyaltia longifolia* in the crosswise direction of the route.

4.1.1.4 Flora Richness and Plant Variety

Compared to the first phase, the herbaceae (86%) are the best-represented species. They are also the most frequent, and the Poaceae, Fabaceae, and Euphorbiaceae are still the best-represented families. This heavy dominance of herbaceae is a sign of the heavy anthropization of the environment, essentially indicated by farm crops. Species such as *Daucus carota* (carrot), *Allium cepa* (onion), *Abelmoschus esculentus* (okra), *Zea mays* (corn), *Manihot esculenta* (manioc), *Cymbopogon citratus* (citronella), *Cucumis melo* var. *agrestis* (melon), *Solanum macrocarpum* (spinach), *Solanum lycopersicum* (tomato), *Cucumis sativus* (cucumber) et *Corchorus olitorius* are the species of herbaceae grown on the gas pipeline route. Among these, *Daucus carota* (carrot), *Solanum macrocarpum* (spinach), *Solanum lycopersicum* (tomato) and *Corchorus olitorius* are most dominant. *Carica papaya, Citrus aurantium, Vernonia amygdalina* and *Cocos nucifera* are the bushes and trees that are farmed here. All these crops were also in a vigorous state during the second evaluation.

The number of species of flora inventoried in the second phase (125 species) is far greater than in the first season (59 species). This considerable difference can be attributed to the new survey method, which permitted a systematic sweep of all the species encountered along the gas pipeline transect. The different formations found here are practically the same except that the safety perimeter could include part of the village of Gbetsogbe. In both the first and the second survey phases, the thin ligneous cover of the area is a sign of the extreme deterioration of the environment.

4.1.1.5 Coastal Vegetation

The results obtained show that Togo's coastal plant formations have been extremely damaged by man. Their greatly reduced area due to coastal erosion is compounded by farming activities, aggravating the deterioration. On the new gas pipeline route, there is practically no natural vegetation characteristic of the seacoast. The coastal herbaceous communities observed are essentially the most dominant ones, and occupy more than 80% of the survey area. This was also noted in the first phase. Since the heavy anthropization of the environment prevents a demonstration of the dynamic of the environment's characteristic vegetation, it would be desirable to continue monitoring during and after the gas pipeline is installed. This will assist in a better understanding of any change in the physiognomy of the area vegetation.

The conclusions of the first phase remain valid for this second survey phase. The new gas pipeline route runs through a highly anthropized area, mainly due to farmlands. No species that is rare or endangered in Togo was found on the new gas pipeline route, if we refer to the work of Akpagana (1992) and Akpagana & Bouchet (1997). All species indicated as less frequent are observed elsewhere. The littoral grassland and the old coconut palm grove are now replaced by a mosaic of fallow lands and farm lands. In these conditions, the construction of the gas pipeline will not have any serious effect on the natural flora and vegetation, which have already been impoverished by farming and other human activities.

4.2 SOIL CHARACTERIZATION

4.2.1 Physical

TOC and grain size
include groundwater resources summary for Nigeria and Benin

4.2.1.1 Organic Matter

The standards established by the Togolese Agronomical Research Institute (ITRA) were used in the interpretation of the soil analysis results.

The organic content of the soil varies between 0.06 and 0.86%. It rarely exceeds 1%. These rates reveal that the soils are very poor in organic matter (Table 4.2-1).

Nitrogen reserves are between 0.02 and 0.05%, not exceeding 0.05%. These values show that the soils are very poor in nitrogen.

The C/N ratios are very low, varying from 1 to 10. They are indicative of the dominant mineral character of soils with a low organic content.

In conclusion, the soils surveyed are very poor in organic matter (less than 1%) and in nitrogen (less than 0.05%). The very low C/N ratios (less than 10) demonstrate the dominant mineral nature of the soils. In general, the soil has a predominance of mineral particles and little organic matter.

Table 4.2-1
Organic Matter in Soil Samples

Sample		P1-0	P1-5	P1-10	P6-0	P6-10	P6-20
Organic matter	%	0.11	0.25	0.11	0.34	0.24	0.06
Carbon C	%	0.06	0.15	0.10	0.20	0.14	0.04
Total nitrogen N	%	0.03	0.02	0.03	0.02	0.03	0.02
C/N	%	2	7	3	10	4	2

Sample		P6-30	P14	P15	P16	P17	
Organic matter	%	0.06	0.25	0.86	0.24	0.20	
Carbon C	%	0.04	0.15	0.50	0.14	0.12	
Total nitrogen N	%	0.04	0.05	0.05	0.02	0.04	
C/N	%	1	3	10	7	3	

4.2.1.2 Grain Size

The sedimentary volume, deposited in very uniform conditions, is quite homogeneous around coarse and medium grains. The frequency graphs and cumulative curves attest to the evolution of coastal sedimentation (Figures 4.2-1 and 4.2-2). This identification strengthens the state of knowledge about this loose coastal sedimentary relief, constituting a well-compacted substrate (Blilvi, 1993 a and 2002). The analytical data are shown in Table 4.2-2.

Table 4.2-2
Survey Sample Grain Size Data

	Sample 1				**Sample 2**			
Sediment Size	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**
2 mm	1.47	0.38	0.38	0.38	1.4	0.31	0.31	0.31
1 mm	4.95	3.86	3.86	4.24	3.16	2.07	2.07	2.38
0.500 mm	51.45	50.16	50.13	54.37	40.2	39.11	39.13	41.51
0.200 mm	45.75	44.66	44.63	99.00	59.28	58.19	58.21	99.72
0.050 mm	1.89	0.8	0.80	99.80	1.37	0.28	0.28	100.00

	Sample 3				**Sample 4**			
Sediment Size	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**
2 mm	1.86	0.77	0.77	0.77	2.21	1.12	1.12	1.1
1 mm	6.07	4.98	5.00	5.77	5.66	4.57	4.58	5.7
0.500 mm	49.42	48.33	48.56	54.33	49.45	48.36	48.45	54.1
0.200 mm	46.39	45.3	45.51	99.85	46.53	45.44	45.52	99.6
0.050 mm	1.24	0.15	0.15	100.00	1.42	0.33	0.33	100.0

	Sample 5				Sample 6			
Sediment Size	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**
2 mm	1.4	0.31	0.3	0.3	1.69	0.6	0.6	0.6
1 mm	5.17	4.08	4.1	4.4	3.42	2.33	2.3	2.9
0.500 mm	52.82	51.63	51.6	56.0	34.74	33.65	33.7	36.6
0.200 mm	44.8	43.71	43.7	99.7	63.37	62.28	62.4	99.0
0.050 mm	1.29	0.2	0.2	99.9	2.1	1.01	1.0	100.0

	Sample 7				Sample 8			
Sediment Size	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**
2 mm	1.3	0.21	0.2	0.2	1.09	0	0.0	0
1 mm	3.8	2.71	2.7	2.9	3.51	2.42	2.4	2.4
0.500 mm	55.86	54.77	55.2	58.2	47.6	46.51	46.6	49.0
0.200 mm	41.86	40.77	41.1	99.3	50.53	49.44	49.5	98.5
0.050 mm	1.81	0.72	0.7	100.0	2.55	1.46	1.5	100.0

	Sample 9				Sample 10			
Sediment Size	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**	**Overall Weight**	**Actual Weight**	**%**	**Cumul. %**
2 mm	1.26	0.17	0.2	0.2	1.13	0.04	0.0	0
1 mm	3.03	1.94	1.9	2.1	2.41	1.32	1.3	1.3
0,500 mm	31.44	30.35	30.4	32.5	31.13	30.04	30.3	31.6
0,200 mm	64.74	63.65	63.7	96.3	67.07	65.98	66.5	98.1
0,050 mm	4.82	3.73	3.7	100.0	2.99	1.9	1.9	100.0

Sample 11			
Overall Weight	**Actual Weight**	**%**	**Cumul. %**
1.98	0.89	0.9	0.9
1.65	0.56	0.6	1.5
26.85	25.76	25.9	27.4
70.18	69.09	69.5	96.9
4.16	3.07	3.1	100.0

Figure 4.2-1
Histograms of Sample Frequency

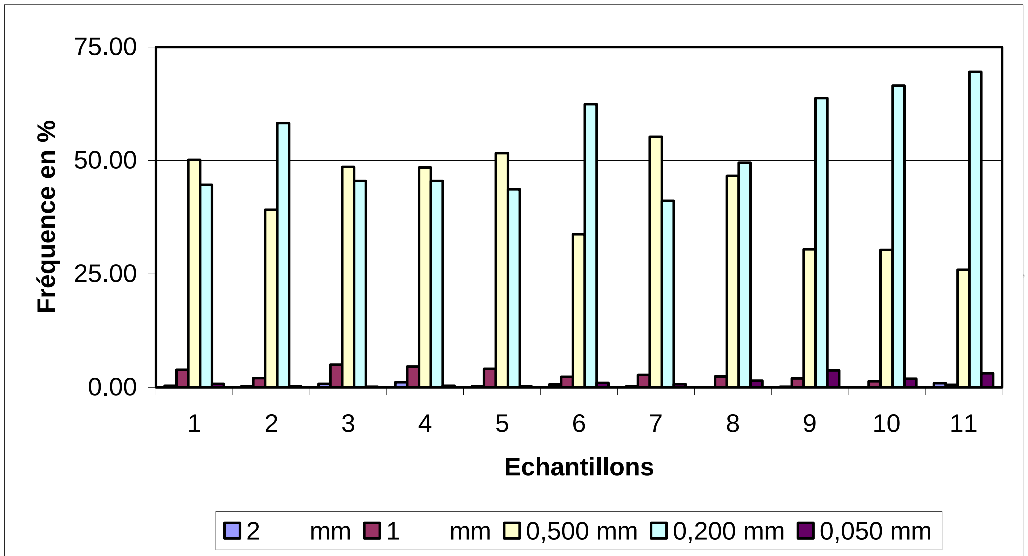
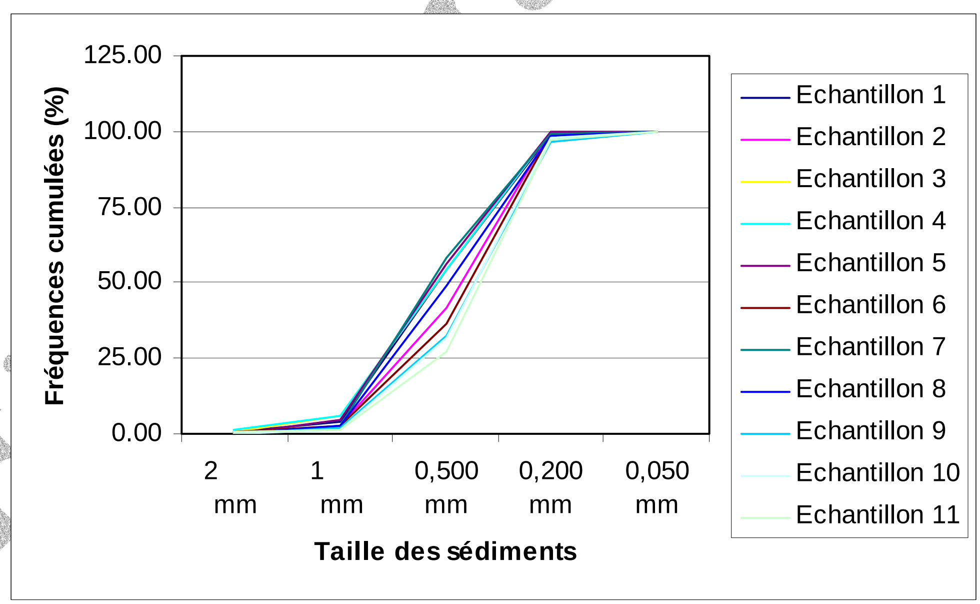


Figure 4.2-2
Cumulative Sample Curves



4.2.1.3 Temperature and Moisture

The temperatures at the various sites were between 21.8°C and 31°C. The moisture readings are shown in Table 4.2-3.

Table 4.2-3
Temperature and Moisture

Measurement Site	CODE	Level	Temperature (°C)	Moisture (%)
No. 1	2TT$_1$-1	0-15cm	22°2C	6.35
6°08'52.43N/ 1°18'15.28E		15-50cm	24°2C	1.35
No. 2	2TT$_1$-2	0-15cm	24°5	1.71
6°08'52.80N/ 1°18'15.60E		15-50cm	21°8C	14.33
No. 3	2TT$_1$-3	0-15cm	25°C	2.29
6°08'53.00N/ 1°18'15.70E		15-50cm	31°C	2.75
Composite N°1- N°2- N°3	2TT$_1$-C1	0-15cm	NS	2.13
	2TT$_1$-C2	15-50cm	NS	5.15
No. 4	2TT$_2$-1	0-15cm	28°C	2.8
6°08'55.70N/ 1°18'15.60E		15-50cm	28°2C	3.29
No. 5	2TT$_2$-2	0-15cm	28°8C	2.56
6°08'56.30N/ 1°18'15.17E		15-50cm	31°C	2.69
No. 6	2TT$_2$-3	0–15cm	28°C	2.46
6°08'56.34N/ 1°18'15.17E		15-50cm	29°C	1.88
No. 7	2TT$_2$-4	0-15cm	30°C	3.73
6°08'57.00N/ 1°18'15.40E		15-50cm	30°C	3.04
Composite Nos. 4- 5- 6- 7	2TT$_2$-C1	0-15cm	NS	2.71
	2TT$_2$-C2	15-50cm	NS	3.27

4.2.2 Chemical

4.2.2.1 pH and Salinity

The pH and salinity values of the soil samples are shown in Table 4.2-4.

In the first and third transects, the pH of the analyzed samples is above 7, while in the second transect it is below 7. The highest pH is at point 2TT1-2, for sample No. 2.

The salinity value is higher in the transect directly in contact with ocean waters. Salinity drops noticeably in the second transect. It is higher in the third transect than in the second. The salinity value observed in the third transect is probably associated with the agricultural activities (vegetable farming) conducted in this area.

Table 4.2-4
Soil Sample pH and Salinity

Sample Number	Code	Longitude	Latitude	pH	Salinity (mg/L)
1	2TT$_1$-1	1°18'15.28	6°08'52.43	7.70	4358.5

2	2TT$_1$-2	1°18'15.60	6°08'52.80	8.04	2039.0
3	2TT$_1$-3	1°18'15.70	6°08'53.00	8.42	389.7
4	2TT$_2$-1	1°18'15.60	6°08'55.70	6.71	59.1
5	2TT$_2$-2	1°18'15.17	6°08'56.30	6.44	48.0
6	2TT$_2$-3	1°18'15.17	6°08'56.34	5.71	47.6
7	2TT$_2$-4	1°18'15.40	6°08'57.00	6.83	52.7
8	2TT$_3$-1	1°18'15.10	6°08'57.02	7.15	180.7
9	2TT$_3$-2	1°18'15.04	6°08'57.70	7.69	66.7
10	2TT$_3$-3	1°18’15.07	6°08'58.42	8.08	159.9
11	2TT$_3$-4	1°18’14.94	6°08’59.01	7.45	77.7

The results are indicated in Tables 4.2-5 and 4.2-6. The tables show the sample, collection date, elements analyzed, and units of concentration used (µg/L or mg/L). Figures 4.2-3 and 4.2-4 show the different concentrations, among which magnesium, aluminum, and iron are the highest.

Table 4.2-5
Metal Elements Content of the Soils of Togo (Onshore)

Sample Number Limit	Collection Date -	Lead Pb µg/g)	Iron Fe (mg/g)	Cadmium Cd (µg/g)	Chromium Cr (µg/g)	Nickel Ni (µg/g)	Aluminum Al (mg/g)
		20	1.0	0.8	1.0	4.0	0.6
2TT$_1$-1	03/07/03	<20	14.6	< 0.8	29.7	6.2	8.04
2TT$_1$-2	03/07/03	<20	10.6	< 0.8	22.8	6.2	5.15
2TT$_1$-3	03/07/03	<20	6.7	< 0.8	16.0	4.0	4.87
2TT$_2$-1	03/07/03	<20	10.3	< 0.8	20.6	5.6	6.20
2TT$_2$-2	03/07/03	<20	9.8	< 0.8	22.8	4.0	6.31
2TT$_2$-3	03/07/03	<20	7.7	< 0.8	10.3	5.0	7.40
2TT$_2$-4	03/07/03	<20	9.5	< 0.8	21.7	5.0	5.06
2TT$_3$-1	03/07/03	<20	8.2	< 0.8	11.4	5.6	7.55
2TT$_3$-2	03/07/03	<20	8.5	< 0.8	17.1	5.0	5.67
2TT$_3$-3	03/07/03	<20	8.0	< 0.8	18.3	4.3	5.68
2TT$_3$-4	03/07/03	<20	9.0	< 0.8	19.4	5.0	7.00

Table 4.2-6
Metal Elements Content of the Soils of Togo (Onshore)

Sample Number	Collection Date	Copper Cu µg/g)	Mercury Hg µg/g)	Vanadium V µg/g)	Zinc Zn µg/g)	Magnesium Mg (mg/g)
Limit	-	2.0	1.0	0.04	1.0	0.0004

Sample Number	**Collection Date**	**Copper Cu µg/g)**	**Mercury Hg µg/g)**	**Vanadium V µg/g)**	**Zinc Zn µg/g)**	**Magnesium Mg (mg/g)**
$2TT_1$-1	03/07/03	7.27	4.6	2.1	23.5	23.6
$2TT_1$-2	03/07/03	4.24	1.4	1.1	28.6	13.8
$2TT_1$-3	03/07/03	3.63	0.7	<0.04	14.1	10.0
$2TT_2$-1	03/07/03	5.45	3.4	1.1	19.5	12.2
$2TT_2$-2	03/07/03	4.24	3.8	1.1	16.7	11.4
$2TT_2$-3	03/07/03	4.24	3.6	<0.04	16.1	10.6
$2TT_2$-4	03/07/03	5.45	0.0	1.1	24.1	13.4
$2TT_3$-1	03/07/03	7.87	5.5	<0.04	35.5	13.0
$2TT_3$-2	03/07/03	4.24	4.8	<0.04	20.1	16.8
$2TT_3$-3	03/07/03	5.45	2.7	<0.04	28.3	13.4
$2TT_3$-4	03/07/03	4.24	2.1	<0.04	28.3	14.4

Figure 4.2-3
Metallic Elements Content in Soil Samples from Togo (Onshore)

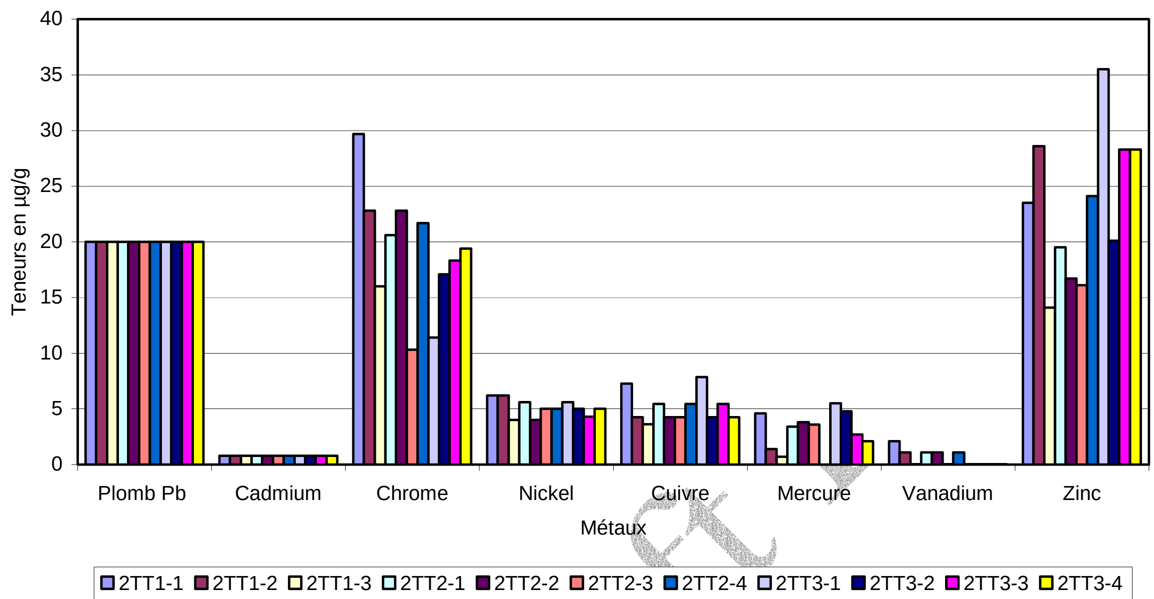
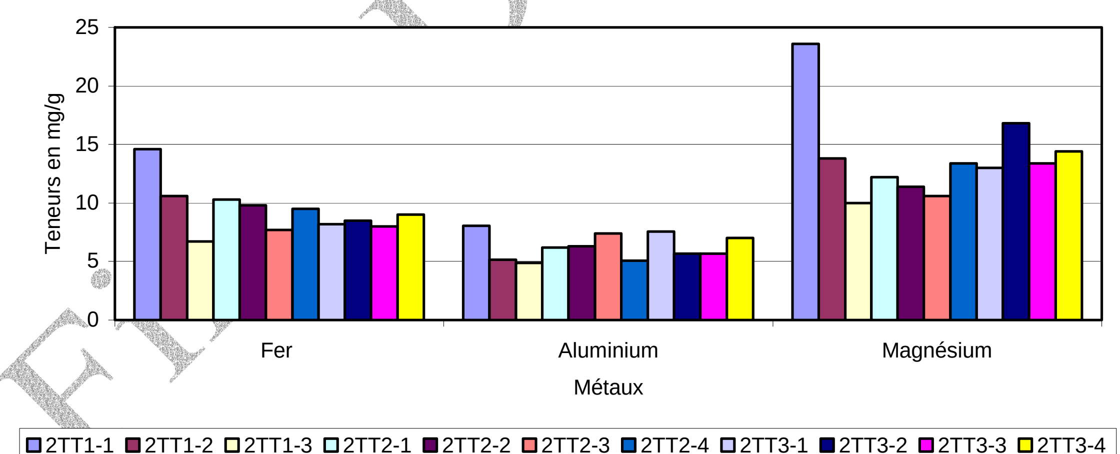


Figure 4.2-4
Metallic Elements Content in Soil Samples from Togo (Onshore)



These results show that the soils analyzed contain practically no lead or cadmium. They also indicate that the samples have a very low vanadium and mercury content. The zinc content of the samples analyzed exceeds 14µg/g. The maximum zinc content is on the order of 28µg/g. The analysis showed that lead and cadmium content respectively was below 20µgPb/g and 0.8 µgCd/g. Magnesium and iron content is higher than the other elements analyzed.

The limits of detection obtained for this second survey campaign changed for some elements. This change is attributable to the analysis conditions, which may vary from one analysis to another. In general, the order of magnitude of metal content is the same in the two campaigns.

4.2.3 Biological

Soil Ecology and Microbiology

4.2.3.1 Microbiology

The results are given in Table 4.2-7 and Figures 4.2-5 to 4.2-8.

Microflora at the 0-15 cm depth level of the soil analyzed.

Total germs (30°C)

All the sites contain these germs. This flora is most concentrated in composite 2TT3-C1 (mixture of samples 8, 9, 10, and 11) followed by composites 2TT2-C1 (mixture of samples 4, 5, 6, and 7) and 2TT1-C1 (mixture of samples 1, 2, and 3).

Total Coliforms

None of the composites analyzed contains these germs.

Enterobacteria

Composite $2TT_1$-C1 contains no enterobacteria. Their presence in composites $2TT_2$-C1 et $2TT_3$-C1 is valued respectively at $155x10^5$ and $25x10^5$ per gram of soil.

Molds

All the composites contain these germs. This flora is composed of *Aspergillus flavus*, *Aspergillus niger*, and *Penicillium sp*. for composites $2TT_1$-C1 and $2TT_2$-C1. Composite $2TT_3$-C1 contains only *Aspergillus flavus* and *Rhizopus sp.*

Sulfite-reducing Anaerobic Germs

This flora is present in all the composites analyzed. It is evaluated at 120 germs/g of soil, 110 germs/g of soil, et 100 germs/g of soil respectively for composites $2TT_2$-C1, $2TT_3$-C1, and $2TT_1$-C1.

In summary, at the 0-15cm depth level, the microflora of samples of all composites is composed of Total Germs (30°C), Yeasts and Molds, and Sulfite-reducing Anaerobic Germs. The total coliform enterobacteria were counted only in composites $2TT_2$-C1 and $2TT_3$-C1. At this depth, coliforms were not found.

Microflora at the 15-50 cm depth level of the soil analyzed.

Total Germs (30°C)

These germs are present to varying degrees at all the collection points. The flora of composite $2TT_3$-C2 is most numerous, followed by composites $2TT_2$-C2 and $2TT_1$-C2 respectively.

Total Coliforms

Total coliforms are not counted in these composites.

Enterobacteria

This flora does not exist at this depth.

Molds

Molds were counted in all the composite samples analyzed. The flora from Composites $2TT_1$-C2, $2TT_2$-C2 and $2TT_3$-C2 are $81x10^5$, $46x10^5$ et $64x10^5$ germs/gram of soil respectively. These molds are composed of *Aspergillus flavus*, *Aspergillus niger* and *Penicillium* sp.

Sulfite-reducing Anaerobic Germs

This flora is present in all the composites analyzed. It is evaluated at 50 germs/g of soil, 80 germs/g of soil and 70 germs/g of soil respectively for composites $2TT_2$-C2, $2TT_3$-C2, and $2TT_1$-C2.

In summary, at the 15-50cm depth level, total germs, sulfite-reducing anaerobic germs and molds are found in the flora of all the composites. However, total coliforms and enterobacteria are not found in the samples of these composites. Also note that the soil samples analyzed contain no yeasts.

The profile of the microbial flora of the soil samples analyzed reveals the germs usually found in soils. The same categories of germs are found in both the selected levels (0-15cm and 15-50cm) except for enterobacteria, which are found only in the 0-15cm level of composites $2TT_2$-C1 and $2TT_3$-C1. The presence of enterobacteria in composites $2TT_2$-C1 et $2TT_3$-C1 would be due to human activities on the sites of composite $2TT_2$-C1 (soccer field) and composite $2TT_3$-C1 (gardening).

The absence of total coliforms in the flora of all the composites analyzed would be associated with their proximity to the ocean. The germs counted and the soil depths selected for the survey will make it possible to detect any change in the microflora.

The temperatures observed at the various sites are generally those indicated for the development of the germs found in the composites. A significant temperature change could alter the composition of the microbial flora of the sites.

The moisture results indicate that for the two depths surveyed (0-15cm and 15-50cm), the moisture of the soil samples analyzed is in keeping with soils of this nature (2 to 20%). This rate is also compatible with the microbial flora revealed by the microbiological analyses. Any major change in the moisture could affect the growth of the various categories of germs in the microflora. Moisture is therefore an indicative parameter for monitoring the gas pipeline's impact on the soil at the selected installation site.

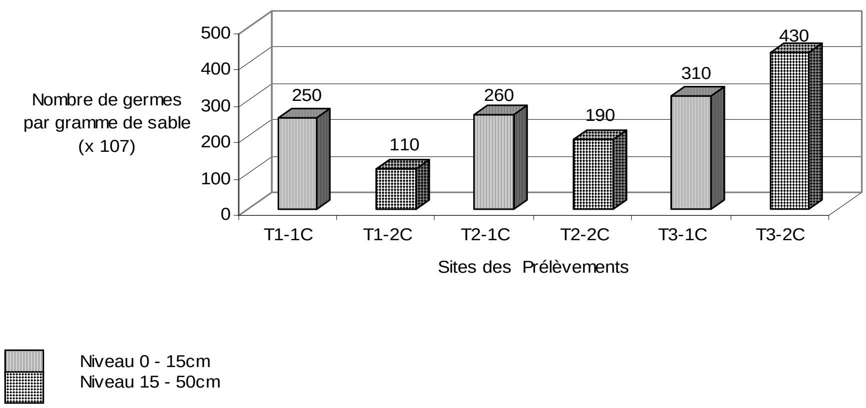
Table 4.2-7
Microbiological Analysis of Soil Samples

			Number of germs / gram of sand				
Collection Site	**Code**	**Level**	**Total Germs (30°C)**	**Total Coliforms**	**Enterobacteria**	**Sulfite-reducing Anaerobic Germs**	**Molds ***
Composite Nos. 1, 2, 3	$2TT_1$-C1	0-15cm	$250x10^7$	0	0	100	$25x10^5$
	$2TT_1$-C2	15-50cm	$110x10^7$	0	0	50	$81x10^5$
Composite Nos. 4, 5, 6, 7	$2TT_2$-C1	0-15cm	$260x10^7$	0	$155x10^5$	120	$75x10^5$
	$2TT_2$-C2	15-50cm	$190x10^7$	0	0	80	$46x10^5$
Composite Nos. 8, 9, 10, 11	$2TT_3$-C1	0-15cm	$310x10^7$	0	$25x10^5$	110	$83x10^5$
	$2TT_3$-C2	15-50cm	$430x10^7$	0	0	70	$64x10^5$

NOTES:
$2TT_1$-C1=0-15cm level composite of first Transect
$2TT_1$-C2=15-50cm level composite of first Transect
$2TT_2$-C1=0-15cm level composite of second Transect;
$2TT_2$-C2=15-50cm level composite of second Transect
$2TT_3$-C1=0-15cm level of third Transect;
$2TT_3$-C2=15-50cm level of third Transect
* The samples do no contain any yeasts.

Figure 4.2-5
Microbiological Analysis of Sand Samples: Evaluation of Total Germs (30°C)

Figure N°1 : **Analyse microbiologique des échantillons de sable : Evaluation des Germes totaux (30°C)**



NOTES:
T1-1C = Composite niveau 0 - 15cm du 1er Transect ; T1-2C = Composite niveau 15-50cm du 1er Transect.
T2-1C = Composite niveau 0-15cm du 2ème Transect; T2-2C = Composite niveau 15-50cm du 2ème Transect.
T3-1C = Composite niveau 0-15cm du 3ème Transect; T3-2C = Composite niveau 15-50cm du 3ème Transect.

Figure 4.2-6
Microbiological analysis of Sand Samples: Evaluation of Sulfite-reducing Anaerobic Germs

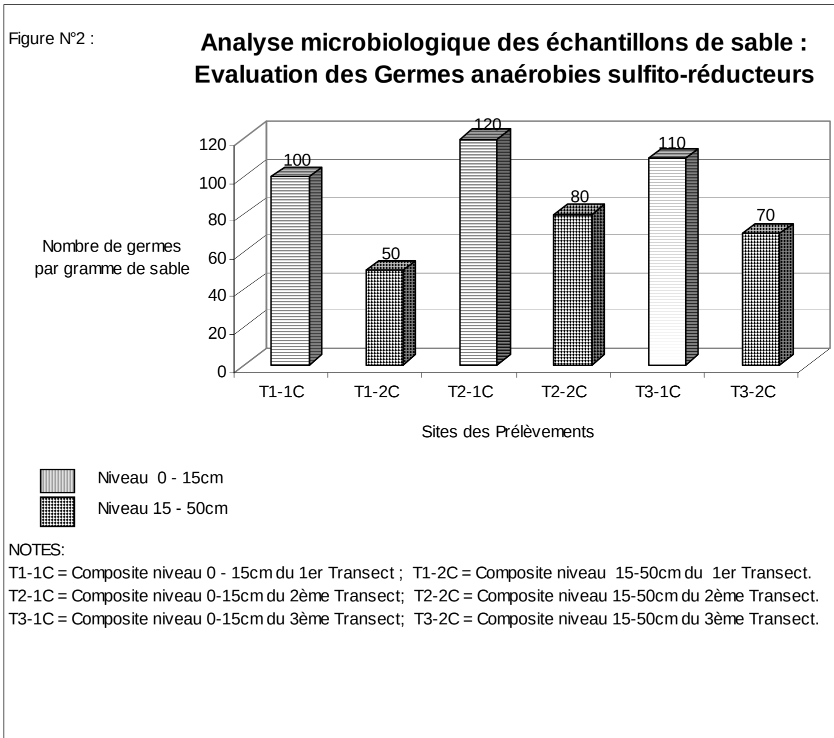


Figure 4.2-7
Microbiological Analysis of Sand Samples: Evaluation of Microbial Flora (Total Germs 30°C)

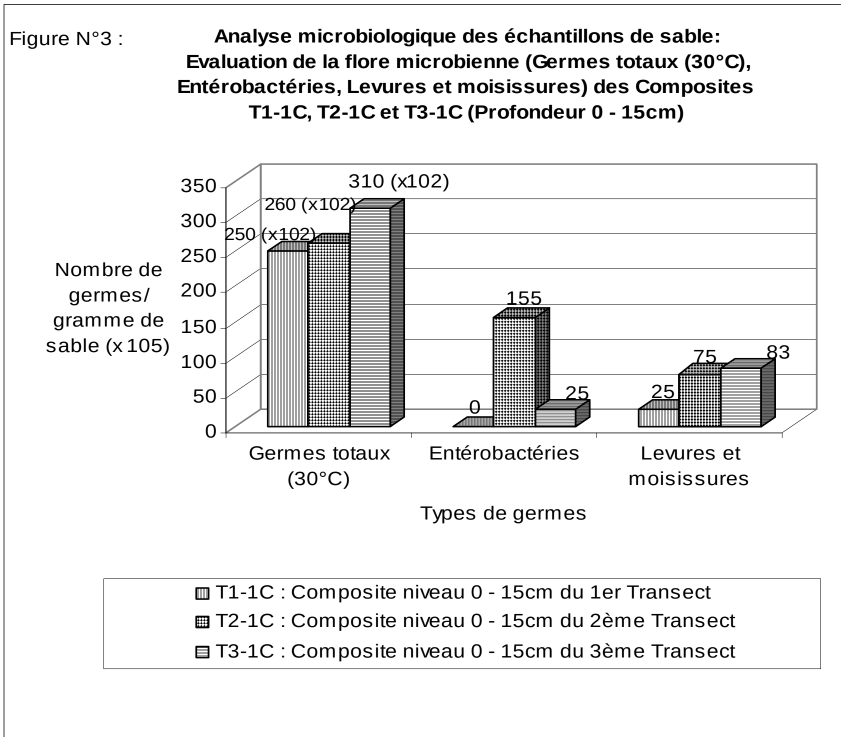
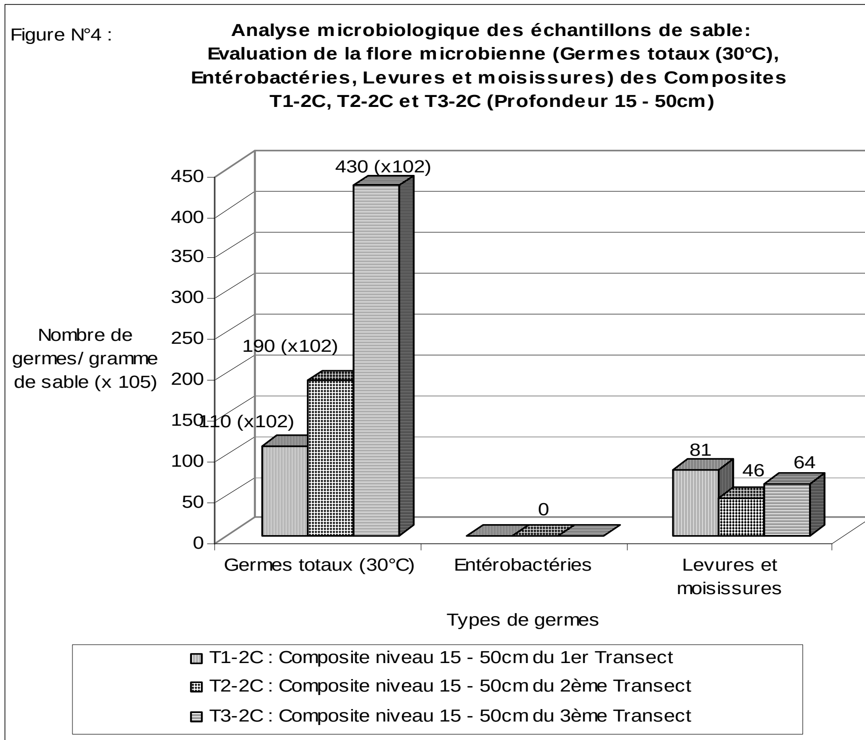


Figure 4.2-8
Microbiological Analysis of Sand Samples: Evaluation of Total Germs (30°C)



4.2.3.2 Entomology

Two expert appraisals provided the entomological situation in the survey area.

* The first results are summarized in Table 4.2.8. The last column of the table indicates the various species observed; a species is counted only once.

Table 4.2-8
Site and Sample Characteristics, Arthropods Found

Sample	Site Condition	Nature of Sample	Arthropod Taxonomic Group: Order	Family	Species	Number of Species
$2TT_1$-C_1	Immediately adjacent to coast	Clean Ocean Sand	Acarians			1
			Coleoptera			1
			Diptera	Culicidae		1 1 1
			Hymenoptera	Tenthredinidae		1
			Homoptera			2
			Lepidoptera			1
$2TT_1$-C_2	Ditto		Acaria	Same as previous sample		

Sample	**Site Condition**	**Nature of Sample**	**Arthropod Taxonomic Group** **Order**	 **Family**	 **Species**	**Number of Species**
		Clean Ocean Sand	Coleoptera	Melyridae Curculionidae	Collops quadrimaculatus	1 1 1
			Diptera	Mycetophylidae Cecidomyiidae		1 1 1
$2TT_2$-C_1	Playing Field	Brown Sand	Coleoptera	Chrysomelidae		1
			Diptera	Cecidomyiidae	Same species as above	1
			Homoptera			1
			Orthoptera			1
$2TT_2$-C_2	Ditto	Brown Sand	Acaria	Same species as $2TT_1$-C_1		
			Hymenoptera			1
			Homoptera			1
			Isoptera			1
$2T\ T_3$-C_1	Vegetable farming plot	Slightly ashy sand, with some organic matter	Coleoptera	Staphylinidae Chrysomelidae		2 1
			Diptera	Culicidae	Same species as $2TT_1$-C_1 1	
			Homoptera		Same species as $2TT_1$-C_1	
			Lepidoptera			1
$2TT_3$-C_2	Ditto	Yellowish-brown Sand	Coleoptera	Pselaphidae Cicindelidae Staphylinidae	 Same as above	1 1 1
			Diptera		Same as 2TT1-C1	
			Heteroptera	Pentatomidae	Nezara viridula	1
			Hymenoptera			1
			Lepidoptera			1

On the athletic field, tunnels of crabs from the family Ocypodidae were collected. These are *Ocypode africana.* On the immediate coast, *Ocypode cursor* was found.

Note that the tunnels of the former species on the playing field are noticeable very early in the morning by the wet sand ejected by the crabs. When the temperature warms up, the sand ejected by the crabs dries up and the tunnels can no longer be distinguished.

A total of 34 different species of arthropods were identified, including 14 in Transect 1 immediately on the coast ($2TT_1$), 9 in Transect 2 ($2TT_2$) on the athletic field, and 11 in Transect 3 located in the farming plots.

Since the transects are located at different sites, they are differentiated by their distance from the coastline, degree of disturbance by human activity, and the moisture and temperature of the samples collected.

Since the samples analyzed were mixtures of various samplings, the only factor that can affect the abundance, distribution, and frequency of the arthropods in the soil in the survey area is the degree of disturbance by human activity.

In conclusion, the arthropods inventoried in this survey were distinguished by species. They will be fully identified by a specialist in each taxonomic group. Our results do indicate the initial species diversity of the sector where the pipeline will be installed. The pipeline installation work is considered a disturbance whose impact may result in a reduction of the species diversity of arthropods. A decrease in this diversity may be observed for a time, the duration of which will be associated with the degree of disturbance caused to the biotope during the pipeline construction work. The period after pipeline installation will be considered relatively calm. It will permit arthropods to reoccupy the area and gradually increase the species diversity, while the pipeline and its contents do not represent a major change in this environment.

* The six soil samples composed from the second survey are generally poor in organisms, indicating that they have been exposed to various forms of pollution (Table 4.2-9). For example, the beach, which is used heavily by tourists and therefore subject to trampling and noise, is poor in organisms. Essentially, the shells of bivalves and a few rare fly larvae are observed on the surface of this ocean sand ($2TT_1$-C1), probably attracted by the products of fishing. In addition to bivalve shells, the deep layers of this sand ($2TT_1$-C2) also contain Annelida Polychaeta and Oligochaeta worms. The same observations are made on the onshore samples from the athletic field. A rare Homoptera individual of the family Aphididae was identified at the surface ($2TT_2$-C1) and the deeper moist soil ($2TT_2$-C2) also contains Alhpididae and also an Annelida Oligochaeta.

The pollution of the farming soils subjected to pesticides and mineral fertilizers is particularly severe. A single bivalve shell is observed in this soil sampled at the surface ($2TT_3$-C1) and two ants known to be resistant (Formicidae, Myrmicidae) are observed at depth ($2TT_3$-C3).

Table 4.2-9
Diversity and Relative Abundance of Organisms Identified

	$2TT_1C1$		**$2TT_1C2$**		**$2TT_2C1$**		**$2TT_2C2$**		**$2TT_3C1$**		**$2TT_3C2$**	
	N	**AR**	**N**	**AR**	**N**	**AR**	**N**	**AR**	**N**	**AR**	**N**	**AR**
ANNELIDS												
Polychaeta												
Nereidae			1	16.7								
Oligochètes												
Lumbriculidae			2	33.3			1	50				
MOLLUSKS												

	2TT$_1$C1		2TT$_1$C2		2TT$_2$C1		2TT$_2$C2		2TT$_3$C1		2TT$_3$C2	
	N	**AR**	**N**	**AR**	**N**	**AR**	**N**	**AR**	**N**	**AR**	**N**	**AR**
Bivalves (shells)												
Donax rugosus L.			1	16.7								
Donax pulchellus Hanley											1	33.3
Pitaria tumens (Gmelin)	1	33.3										
Diplodonta diaphana (Gmelin)	1	33.3										
Ensis goreensis Clessin			1	16.7								
Solen guinnensis Gray			1	16.7								
Tagelus angulatus Sowerby									1	100		
ARTHROPODS												
Insects												
Diptera												
Sepsidae	1	33.3										
Homoptera												
Aphididae					1	100	1	50				
Hymenoptera												
Formicidae											1	33.3
Myrmicidae											1	33.3
TOTAL	**3**		**6**		**1**		**2**		**1**		**3**	

N = number, AR = relative abundance

4.3 WILDLIFE AND ANIMAL RESOURCES

including turtle survey

4.3.1 Species Inventoried

4.3.1.1 Mammals

A total of 11 species of marine mammals (Table 4.3-1) belonging to 8 genera and 3 families were inventoried. Their presence is signaled by the specimens inventoried in the coastal villages or by surveys of coastal fishermen. Land mammals are represented by 11 species (Table 4.3-2) belonging to 11 genera and 3 families. The marine species are migratory and visit the coast of Togo at a given time of year (July to December, Report on the cetaceans in Togo, Directorate of Wildlife and Hunting, July 2003). These are endangered species (Table 4.3-5) registered in Annex I of the CITES (Convention on the International Trade of Endangered plant and wildlife Species).

Table 4.3-1
List of Marine Species

Date	FAMILY	SPECIES	Common Name	Local Name	OBSERV./ interview
MAMMALS					
25/06/03	*Blaenopteridae*	*Balaenoptera edeni*	Bryde's Whale	Bosso	Photo observed, taken at fishing port
25/06/03	*Balaenopteridae*	*Megaptera novaengliae*	Megaptera	Bosso	Specimens observed at Baguida
	Delphinidae	*Delphinus delphis*	Common dolphin	Takpe	Interview at Gbetsogbe
25/06/03	Delphinidae	*Delphinus capensis*	Common long-rostrum dolphin	Takpe	Skull observed at Kotokoucondji
25/06/03	Delphinidae	*Stenella longirostris*	Longirostral dolphin	Takpe	Interview at Gbetsogbe
25/06/03	Delphinidae	Stenella frontalis	Spotted Atlantic dolphin	Takpe	
03/07/03	Delphinidae	Stenella attenuata	Spotted pantropical dolphin	Giga	Skull observed at Gbetsogbe
25/06/03	Delphinidae	*Orcinus orca*	Orca	Gagadolo	Interview at fishing port
25/06/03	Delphinidae	*Globicepahalus macrorhynchus*	Tropical pilot whale	Gagadolo	
03/07/03	Delphinidae	***Tursiops truncatus***	Great dolphin	Gogadolo	Specimens observed at Gbetsogbe
03/07/03	Physeteridae	***Physeter macrocephalus***	Sperm whale	Bosso	Skull observed at Adissen
REPTILES					
23/06/03	Cheloniidae	*Chelonia mydas*	Green turtle	Eklo	Back shells observed in coastal villages
23/06/03	Cheloniidae	*Eretmochelys imbricata*	Imbricated turtle	Adeklo	
23/06/03	Cheloniidae	*Lepidochelys olivacea*	Olive turtle	Eklo	
23/06/03	Dermochelyidae	*Dermochelys coriacea*	Leathery turtle	Agbo-zegue	

Table 4.3-2
List of Land Species

Date	FAMILY	SPECIES	Common Name	Local Name	Observation/Interview along the transect or at Gbétsogbé
MAMMALS					
23/06/03	Crecetidae	*Cricetomys gambianus*	Gambian rat	Kissi	Interview
23/06/03	Leporidae	*Lepus crawshayi*	Rabbit-eared hare	Azui	Interview
23/06/03	Muridae	*Arvicantis niloticus*	Nile rat	Afi edei	Observed
23/06/03	Muridae	*Mastomys natalensis*		Afi	Observed
23/06/03	Muridae	*Acomys acatririnus*	White-breasted mouse	Afi	Interview
23/06/03	Muridae	*Lemnicomys striatus*	Striped mouse	Togbefi	Observed
23/06/03	Muridae	*Graphiurus spirelli*	Tufted-tail mouse	Afi	Interview
23/06/03	Muridae	*Dendromis mesomela*	Dwarf mouse	Afi	Observed
23/06/03	Muridae	*Mus haussa*	Mouse	Afi	Observed
23/06/03	Muridae	*Taterab kempi*	Mouse	Afi	Observed
23/06/03	Muridae	*Taterillus gracilis*	Mouses	Afi	Interview
BIRDS					
25/06/03	Columbidae	***Streptopelia senegalensis***	**Speckled dove**	Peplelou	Observed
25/06/03	Cuculidae	*Centropus senegalensis*	Senegal coucal	Wuitoutou	Interview
25/06/03	Estrildidae	*Lonchura cucullata*	Spermète-nonette	Ayiroèvi	Observed
25/06/03	Estrildidae	*Lagonosticta senegala*	Common African finch	Blinti	Interview
25/06/03	Nectariniidae	*Nectarinia sp*	Soui-manga	Titi	Observed
25/06/03	Ploceidae	*Ploceus cuculatus*	Gendarme weaver-bird	Ewli	Observed
25/06/03	Ploceidae	*Passer griseus*	Grey sparrow	Assisroè	Observed
25/06/03	Phasianidae	*Francolinus bicalcaratus*	Common francolin [black partridge]	Tegli	Interview
25/06/03	Phycnonotidae	*Pycnonotus barbatus*	Common bulbul	Voplè	Observed
25/06/03	Proceidae	*Vidua macroura*	Dominican widow bird		Observed
25/06/03	Strigidae	*Otus leucotis*	Small white-faced owl	Kpokpo	Interview
25/06/03	Strigidae	*Tyto alba*	African screech-owl	Adjehe	Interview
25/06/03	Timalidae	*Camaroptera brachyura*	Grey-backed camaroptera		Observed
REPTILES					
25/06/03	Agamidae	*Agama agama*	Gray lizard	Adoglo	Observed
25/06/03	Agamidae	*Agama sp*	Field lizard	Agbodogli	Observed
25/06/03	Chameleonidae	*Chameleo gracilis*	Chameleon	Agama	Interview
25/06/03	Colubridae	*Meizodon regularis*	Grass snake	Gbodro	Observed
25/06/03	Elapidae	*Naja melanoleuca*	Cobra	Flibo	Interview
25/06/03	Gekkonidae	*Hemidactylus brooki*	Household gecko	Hominyaté	Observed
25/06/03	Gekkonidae	*Hemithconyx caudicinctus*	Big-tailed gecko	Hominyaté	Observed
25/06/03	Pythonidae	*Python reguis*	Royal python	Dangbe	Interview
25/06/03	Scincidae	*Mabuya perodotti*	Red skink	Adinbolo	Observed
25/06/03	Scincidae	*Mabuya quinquetaeniata*	Blue skink	Adinbolo	Observed
25/06/03	Scincidae	*Mabuya striata*	Skink	Adinbolo	Observed
25/06/03	Scincidae	*Riopa fernandi*	Black skink	Adinbolo	Observed
25/06/03	Varanidae	*Varanus niloticus*	Nile monitor	Eve	Interview

Date	FAMILY	SPECIES	Common Name	Local Name	Observation/Interview along the transect or at Gbétsogbé
25/06/03	Viperidae	*Bitis arietans*	Puff adder	Djakpatra	Interview
AMPHIBIANS					
25/06/03	Buforidae	*Bbufo regularis*	Toad	Abito	Observed
25/06/03		*rana sp.*	Frog	Adjiin	Observed

4.3.1.2 Birds

During the field work in the second campaign, 13 species of birds belonging to 13 genera and 10 families were inventoried in the Gbetsogbe area (Table 4.3-3). Unlike the first campagne, no palearctic migrators were observed.

4.3.1.3 Reptiles

Marine reptiles are represented by the sea turtles. Four (4) species (Table 4.3-2) divided into 4 genera grouped in 2 families (Cheloniidae and Dermochelyidae) were inventoried. A total of 14 land species were inventoried, representing 11 genera and 9 families. Sea turtles, like cetaceans, are fully-protected migratory species (CITES, UICN, CMS). They lay their eggs on the Gbetsogbe beach and their spawning period lasts from September to February. In spite of the current status of sea turtle species, they are subject to heavy human exploitation in the coastal fishing community. Conservation efforts led by the AGBO-ZEGUE Association in partnership with the Directorate of Wildlife and Hunting are in progress.

The other 14 reptile species inventoried are land reptiles. They are small animals whose habitat is severely damaged by vegetable farming activities.

4.3.1.4 Amphibians

Amphibians are represented by 2 species, *Bufo regularis* and *Rana sp*, divided into 2 genera and 2 families. The site is poor in amphibians; of the 39 species inventoried in Togo, only 2 are inventoried in the project area (PNAE, 2002).

4.3.1.5 Beach-rock Fauna

The beach-rock fauna is highly diversified. The solid anchoring opportunities make beach-rock an ideal habitat for algae, which represent the food of herbivorous animals such as Mollusks, Gasteropods, and Bivalves, Cirrate crustaceans, Echinoderms, Porifera, and Cnidaria. The field work during this survey identified:

- 9 species of Gasteropod Mollusks
- 2 species of Bivalve Mollusks
- 2 species of Cirrate Crustaceans
- 1 species of Echinoderm
- 1 species of Cnidaria

Several other species belonging to the Cnidaria, Porifera, and Bryozoaria have been reported in the literature, but have not yet been determined. The average density per square meter of the species collected is shown in Table 4.3-3 below.

Table 4.3-3
Average Density of Animal Species Attached to Beach-rock

GROUP	Species	Average density (m^2)
GASTEROPOD MOLLUSKS	***Thais heamastoma***	27
	Thias nodosa	21
	Patella safiana	14
	Patella lugubris	9
	Siphonaria grisea	2
	Fissurella nubecula	3
	Littorina punctata	22
	Littorina neritoides	12
	Nerita senegalensis	2
BIVALVE MOLLUSKS	*Mytelus perna*	13
	Arca noe	1
CIRRATE CRUSTACEANS	*Chthamalus stellatus*	13
	Balanus tintinnabulum	11
ECHINODERMS	*Echionometra lucunter*	67
CNIDARIA	*Actina equina*	5

For safety reasons, all the compartiments of the beach-rock (both flanks) were not explored. However, the existing literature and the collections of the University of Lome Zoology and Animal Biology Lab helped to complete the results (Table 4.3-4). A total of 38 species of marine invertebrates (Mollusks, Crustaceans, Echinoderms, Bryozoaria, Porifera, and Cnidaria, etc.) were inventoried on the beach-rock. On the sandy upper beach of the site, 2 species of ocypod crabs are observed: *Ocypode cursor* and *Ocypode africana.*

Table 4.3-4
Beach-rock Fauna

GROUPS	Species
GASTEROPOD MOLLUSKS	***Thais heamastoma***
	Thias nodosa
	Murex rosarium
	Murex cornutus
	Patella safiana
	Patella lugubris
	Siphonaria grisea

GROUPS	Species
	Fissurella nubecula
	Littorina punctata
	Littorina neritoides
	Nerita senegalensis
	Monodonta puctulatus
	Oliva flamulata
	Olivencillaria sp
	Harpa doris
BIVALVE MOLLUSKS	*Mytelus perna*
	Arca noe
CEPHALOPOD MOLLUSKS	*Octopus vulgaris*
	Sepia officinalis
POLYPLACOPHORA MOLLUSKS	***Chiton canariensis***
CIRRATE CRUSTACEANS	*Chthamalus stellatus*
	Chthamalus dentatus
	Balanus tintinnabulum
BRACHYURA CRUSTACEANS	*Grapsus grapsus*
	Plagusia depressa
ECHINODERMS	*Echinometra lucunter*
	Eucidaris tribuloides
PORIFERA AND CNIDARIA	*Actina equina*
	Polythoa monodi
	Anemonia sulcata
	Goronia cavolini
	Eunicella singularis
	Corallium sp
	Alcionium sp
	Obelia sp
	Sertularia sp
BRYOZOARIA	*Electra sp*
	Spirula sp

Table 4.3-5
List of Endangered Species

Species	Current Status	Legal Status	
		CITES	In Togo
Balaenoptera edeni	Endangered	Annex I	Class A
Megaptera novaengliae	Endangered	Annex I	Class A
Delphinus delphis	Endangered	Annex I	Class A
Delphinus capensis	Endangered	Annex I	Class A
Stenella longirostris	Endangered	Annex I	Class A

Species	Current Status	Legal Status	
		CITES	In Togo
Stenella frontalis	Endangered	Annex I	Class A
Stenella attenuata	Endangered	Annex I	Class A
Orcinus orca	Endangered	Annex I	Class A
Globicepahalus macrorhynchus	Endangered	Annex I	Class A
Tursiops truncatus	Endangered	Annex I	Class A
Physeter macrocephalus	Endangered	Annex I	Class A
Chelonia mydas	Endangered	Annex I	Class A
Eretmochelys imbricata	Endangered	Annex I	Class A
Lepidochelys olivacea	Endangered	Annex I	Class A
Dermochelys coriacea	Endangered	Annex I	Class A
Python regus	Endangered	Annex II	Class B
Bitis arientans	Endangered	Annex II	Class B

A: Class A species fully protected in Togo (Ordinance No. 4 of 16 January 1968)
I: Annex I of the CITES (species in danger of imminent extinction due to trade)

4.3.2 Results of the Two Field Survey Campaigns

The results of this second fieldwork campaign made it possible to increase the list of cetacean species that visit the Togolese coast. To the 4 species of cetaceans inventoried in the first season (*Balaenoptera edeni, Megaptera novaeangliae, Physeter macrocephalus, Delphnis capensis*) were added *Stenella attenuata, Tursiops truncatus.* Of these two new species, *Stenella attenuata* was accidentally captured in fishermen's nets on June 6, 2003. However, the cetacean visiting period is from July to December in Togolese waters.

Nocturnal species such as *Otus leucotis* and *Tyto alba* were inventoried. The absence of these species in the first report is due to the fact that no observations were made at night.

The list of reptiles has not changed. However, the live animals had been observed in the first campaign, but only specimens were invetoried in the second. The sea turtle spawning period on our coasts is from September to February.

The beach-rock is an ideal habitat, offering potential fastening opportunities for living organisms. The marine invertebrates that colonize this environment are a food source, especially for migratory birds as they pass along the Togolese coast.

No waterfowl (palearctic migrators) were observed during this second phase; the current counting season is not propitious to their presence along the coast, which is from November to February.

The land animal species, rodents, birds, reptiles, and amphibians inventoried in the Gbetsogbe area are relatively frequent throughout the Togolese coast. In addition, this land wildlife is threatened by vegetable farming activities, which are significantly destroying its habitat. The construction of the gas pipeline will therefore have little impact on the area's land fauna.

The beach-rock exhibits a relatively abundant species diversity. Its importance in the socioeconomic life of the neighboring populations must be emphasized. Some species, particularly Atlantic dogwinkles and urchins, are eaten or sold. However, the nearly homogeneous distribution of these species along this rocky substrate implies that the impact of gas pipeline construction will be less on the fauna in this envirojment. Furthermore, no rare or endangered species has been reported there.

The marine wildlife species (mammals and reptiles) and palearctic migrators that visit the Togolese coast are endangered. They are fully protected (CITES, UICN, CMS). Aside from their status, it is therefore very important, in order not to comprimise the current conservation efforts, to take account of the period when these animals are present on the Togolese coast and in the waters of the Gulf of Guinea, before any gas pipeline construction activity. The necessary precautions must be taken to preserve marine ecosystems during the installation work, because the Togolese waters and coastal habitats are very important to the reproduction and growth of these species.

The highly diversified marine wildlife of the Togolese coast needs to be preserved during the installation of the gas pipeline. Considering the period when migratory species visit Togolese waters, the gas pipeline installation should be done between February and July in order to minimize the risks of impacts on biological diversity, particularly turtles.

4.3.3 Turtle Species

Several interviews of fishermen and shell collections gathered from coastal fishermen and vendors in the markets made it possible to inventory four species of recognized sea turtles in Togo:

* C*helonia mydas*, the green turtle, the local name of which is Klo or Eklo, is caught with maritime fishing gear. The biometric data indicate that the size of the individuals varies from 38 to 102cm. This confirms the presence of juveniles, sub-adults, and adults within the population of *Chelonia mydas*. Male individuals of this species have also been observed on the Togolese coast.

* *Lepidochelys olivacea*, the olive turtle, is also called Klo or Eklo. It is the species most used in Togo. The populations gather the eggs and capture the females on the beaches. Fishermen capture the species offshore. The size of individuals varies from 56 to 75cm; these are essentially adult individuals. The morphology of the shells makes it impossible to say whether they are exclusively from females.

* *Eretmochelys imbricata*, the imbricated turtle (Adeklo or Eklo) is captured with beach seines. The population of *Eretmochelys imbricata* contains juveniles, sub-adults, and adults varying in size from 31 to 72cm.

* *Dermochelys coriacea* or the leathery turtle is called Agbo-zegue or Agbossegue in Togo. Based on information gathered from fishermen, captures mainly involve females coming to spawn on the beaches at night. No male individual of this species has been observed on the beaches.

The results of the recent field work indicate a relative abundance of *Chelonia mydas* on the Togolese coast and the presence of immature individuals of *Chelonia mydas* and *Eretmochelys imbricata.* The presence of young green turtles (*Chelonia mydas*) seems to be dependent upon the abundant food source in the form of plants they can find on the rocks.

The frequency of species of sea turtles on the Togolese coast is indicated in Table 4.3-6 *Dochelys olivacea* is the most abundant species, followed by *Chelonia mydas.*

Table 4.3-6
Live Individuals and Shells Inventoried during the 2001/2003 Seasons

Species	*Chelonia mydas*	*Lepidochelys olivacea*	*Eretmochelys imbricata*	*Dermochelys coriacea*	Total
Individuals inventoried	40	38	11	49	138
Shells inventoried	31	94	8	6	139
Total	71	132	19	55	277

4.3.4 Nesting

Of the 4 species of sea turtles present in Togo, only *Eretmochelys imbricata* is not a nester. *Chelonia mydas, Lepidochelys olivacea,* and *Dermochelys coriacea* build nests on the Togolese beaches. *Dermochelys coriacea* is the species that nests the most on Togolese beaches (Table 4.3-7). There is also a large number of *Lepidochelys olivacea* nests. The total number of nests inventoried for the 3 nesting species on the Togolese coast during the 2001/2003 seasons is 63.

Table 4.3-7
Nests Inventoried during the 2001/2003 Seasons

Species	*Chelonia mydas*	*Lepidochelys olivacea*	*Eretmochelys imbricata*	*Dermochelys coriacea*
Nests	3	17	0	43

The spawning period of sea turtles on the Togolese coast is from September to February (Table 4.3-8). This table shows the monthly distribution of live individuals inventoried during the two years of activity and indicates the frequency and spawning periods of sea turtles.

Table 4.3-8
Sea Turtle Nesting Period in Togo, 2001/2003

Month	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Number of turtles inventoried	7	15	13	23	48	5	13	7	4	0	0	3

Since the Togolese coast is essentially sandy, various nesting sites are found there. The main sea turtle nesting sites are distributed in four areas:

- The Lome Area has a 10-km beach due to the installation of the main jetty of the port of Lome. There is practically no vegetation in the western portion. This area offers very good nesting opportunities for sea turtles;
- The Gbetsogbe-Agbavi Area has been significantly altered due to coastal erosion. The beach has practically disappeared, and varies in width from 10 to 15m depending on location. The sandy upper beach is absent. Fishing is also absent due to the unearthing of beach-rock;
- The Agbodrafo Area is as eroded as the above zone, but the beach-rock is on topographic continuity with the beach. The width of the beach varies from 20 to 30m. However, much of this beach is used as a dump for clay waste from phosphate processing. This dumping is causing the pollution of ocean waters even beyond the Togo-Benin border;
- The Aneho Area: Coastal erosion is highly visible at the ends of this area. There is a beach protected by riprap structures.

Activities Conducted at Agbodrafo

During the 2002-2003 season, turtle monitoring activities were conducted at all the sites, particularly Agbodrafo. The number of nests inventoried at Agbodrafo is shown in Table 4.4-9. These nests are frequently poached. The number of rescued nests from which the eggs will be incubated is shown in Table 4.3-9.

Table 4.3-9
Number of Nests Inventoried at Agbodrafo during the 2002-2003 Season

Nests	N.N.E	N.N. B	N.N.S.I
Numbers	40	25	15

N.N.E = number of nests recorded; N.N.B = number of nests poached; N.N.S.I = number of nests rescued and incubated.

Table 4.3-10 shows the results achieved from the incubation of turtle eggs on the Agbodrafo beach and the number of newborn turtles released into the ocean during the 2002-2003 season.

Table 4.3-10
Incubation of Eggs during the 2002-2003 Season at Agbodrafo

Eggs and newborns	N.O.I	N.O.N.E	N.B.M	N.B.V.L
Numbers	1858	982	72	804

N.O.I = number of eggs incubated; N.O.N.E = number of eggs incubated and not hatched; N.B.M = number of dead babies; N.B.V.L = number of live babies released

4.3.5 Human Predation

Human predation occurs through captures of individuals offshore with fishing gear and captures of females on the beaches. Table 4.3-11 indicates the number of captures inventoried during the two spawning seasons, and shows that *Chelonia mydas* and *Lepidochelys olivacea* are the species captured most. Captures of *Chelonia mydas* and *Eretmochelys imbricata* occur offshore, while captures of *Lepidochelys olivacea* and *Demochelys coriacea* occur both on the beach and offshore.

Table 4.3-11
Individuals Captured Offshore During the 2001/2003 Seasons

Species	*Chelonia mydas*	*Eretmochelys imbricata*	*Lepidochelys olivacea*	*Dermochelys coriacea*	Total
Number of cases of capture	37	11	22	6	76

However, human predation on sea turtle populations is also expressed in the number of shells inventoried (Table 4.4-6), essentially *Lepidochelys olivacea.*

4.3.6 Uses

According to the surveys conducted, sea turtles have long been used in Togo for their flesh, eggs, fat, and skulls. Most coastal fishermen eat and sell the flesh and eggs. The price of the live animal varies from 5,000 to 60,000 FCFA depending on the species and size of the animal.

Dermochelys coriacea oil is extracted from the fat of the captured female. Approximately 40 liters of oil can be recovered. The Ewe people use leatherback oil in the traditional pharmacopaeia to treat asthma, fainting, and malaria. The grease is spread over the patient's body and ingested orally, which causes vomiting.

Shells are mainly sold as trophies or souvenirs on the markets with prices varying from 500 to 20,000 FCFA. They are ground up and mixed with certain medicinal plants to be used against migraines. The powdered skulls of the various species are also consumed in traditional medical treatments and by the worshipers of ancestral gods (juju priests). These preparations are reportedly used mainly against stiffness. Among the Adan people (ethnic group of the coast of the Gulf of Guinea), sea turtles are totemic, and are therefore respected and not killed.

4.3.7 Physical Threats

There are numerous physical threats to these marine reptiles in Togo:

- The occupation of spawning sites: Lighting from homes and industry influences the behavior of the females that come to spawn on the beaches and that of the newborns, which are disoriented when trying to return to the marine environment, especially at night.

- Pollution by domestic, industrial, and agricultural waste: In 1993 the UICN indicated that water pollution was increasing due to the dumping of untreated industrial waste. There are no waste disposal centers. Pollution due to discharges of clays from phosphates, rich in organic materials and metal compounds, causes significant disturbance of the marine ecosystem. The company is currently storing phosphate sludges at the spawning sites. The scouring of these materials produces pollutants (cadmium, strontium, zircon, etc.).

- Coastal erosion has fostered the unearthing of the beach-rock, which is a threat to sea turtles; females take advantage of the high tide to get to the beach for spawning. It is difficult for them to return to the water, especially at low tide. They are therefore trapped in the water between the beach-rock and the upper beach and become the prey of neighboring populations.

- Gravel extraction destroys sea turtle spawning sites. In addition, according to the surveys, sand extraction is often an opportunity for the women who load the trucks to dig up turtle eggs. They eat them.

4.3.8 Sensitization, Strengthened Capability, and Rescue Activities

Marine biology educational programs are offered in the academic establishments and at the University of Lome. They put an emphasis on sea turtles. Sensitization activities conducted in the coastal villages have made the following possible:

- The official installation of 8 rescue committees in the villages neighboring the coast. Each committee is composed of at least five ecological monitors, who are local actors. On sensitization days there is significant participation by the public and students, and great interest in the turtles, conservation actions, and support for development. Many people have visited the turtle village of Agbodrafo, and even follow the activities of the local ecological monitors.

- The organization of open-door days from January 27 to February 8, 2003 at the French Cultural Center. Nearly 700 visitors, including many adults and children, particularly 35 classes from 10 public or private academic establishments, participated in these open-door days.

- The association has participated in international conferences and seminars in places such as Benin, France, Miami, and Dakar on the improvement and management of international sea turtle data bases.

The organization of night patrols, daytime monitoring, fish-net inspections, the construction of incubation enclosures and turtle holding tanks, nest monitoring, and turtle releases are the major rescue activities. They are mainly conducted by the village ecological monitors. These ecological monitors have acquired various types of practical knowledge, including but not limited to identification criteria, measurement and marking techniques, nest location, gathering techniques, egg transplantation, and the release of baby turtles on the beach.

A turtle egg incubation enclosure was built on the beach at Agbodrafo and two tanks were constructed for temporary holding of captured turtles and baby turtles awaiting release or for ecotourism purposes. The ecological monitors know how to conduct themselves with the fishing communities and sea turtle poachers, and receive weekly technical support from the association.

The agents from the Directorate of Wildlife and Hunting and the Fisheries Service support the association in strengthening capabilities and sensitizing local populations.

Lepidochelys olivacea and *Dermochelys coriacea* are the most common species that nest on Togolese beaches, and *Lepidochelys olivacea* is the most abundant species.

The use of sea turtles and their eggs is systematic. Total ignorance of the regulations in force and the generalized poverty of the coastal populations lead them to kill any wild animal, regardless of whether it is protected by the legislation in force.

There are other threats to sea turtle survival in Togo. These are mainly physical threats such as coastal erosion, massive sand and gravel extraction, and essentially industrial pollution.

4.4 FISH AND FISHERIES RESOURCES

A survey of fishing activities was conducted around the gas pipeline construction area of the village of Gbetsogbe at the fishing port. The survey was aimed at listing the various ocean-related activities. This involved gathering the necessary information on the various fishing groups as well as on the women's structures that transform or market the products of fishing or conduct other ocean-related income-generating activities.

4.4.1 Fishing Groups

4.4.1.1 Gbetsogbe Groups

Located southeast of Lome, Gbetsogbe is a village of the commune of Lome. It is bounded on the north by the Kagome district, on the south by the Atlantic Ocean, on the east by the village of Baguida, and on the west by the port zone. Founded in 1845 by the ancestor Togbui Gbetsogbe, today it is led by Togbui Gbetsogbe Afandina Mandjani. Note that the village has been moved three times already due to coastal erosion, which has taken about 1 km of ground.

Although the Katanga district (fishing port), essentially populated by fishermen from elsewhere (Ghana, Benin), is under the authority of the chief of Gbetsogbe, it is not considered to be a social entity integrated in the history of the foundation and settlement of the village, for which reason it is classified as an economic transition area by the population of Gbetsogbe. The population of Gbetsogbe, which is part of the Ewe cultural group that migrated from *Notse* (approx. 100km towards the country's interior), belongs to the *ajatado* cultural area.

Today, the establishment of the port and the growing urbanization of these people's space have deprived them of their arable lands. Farmers and fishermen from the beginning, the inhabitants of Gbetsogbe now have only fishing, farming, and gravel extraction as income-generating activities at the local level. There are a total of sixteen (16) fishing groups and units. The number of group members varies from 5 to 30 people, according to the type of nets. Table 4.4-1 shows the breakdown of the different fishing groups.

Table 4.4-1: Breakdown of Fishing Groups

Organization	Name	Comments
Fishing Groups	1. GAPG (small-scale fishing group of Gbetsogbe 2. TONYEVIADJI 3. Wait and see (Ténéténé) 4. DOVI everyone 5. BOUDEGANTO 6. Ayaovi Assimétiadio , 7. Zogbèdè 8. Kodzo Danou Koumako 9. KOFFI 10. MICHEL 11. Gamgbé 12. Holali 13. Robert 14. Kponyi 15. Komlavi Kodjao 16. Ayawo Agblomé	Note that if some groups are named after a person, that person is generally the one who financed the purchase of the boat and nets.
TOTAL	**16**	

For each of the groups, high season activity can generate a profit between 5 and 15 million after deduction of investments such as repairs, maintenance, and payments of 1,000 to 30,000 FCFA per fishing trip. This profit is divided among the members of the group at the end of the season, but the lion's share goes to the owner of the canoe. Part of the profit is kept in the treasury. This enables the groups to assist members in case of need (loans, aid in case of illness, death, etc.) If a member dies, the group may even purchase the coffin. In the low season, fishing activities generally generate insignificant profit, so members often return home with 1,000 or 0 F at the end of a fishing trip.

4.4.1.2 Groups in the Fishing Port

There are about 300 to 407 canoes, with as many groups. These groups are mainly composed of foreigners, mainly Adan and Fanti people from GHANA. Note that of the 300 to 407 canoes that dock at the fishing port barely 100 belong to Togolese (including the Gbetsogbe canoes). In general, these canoes are not stable in the fishing port. The move around like migratory birds. It's enough for fishermen to find that there are abundant fish elsewhere for them to leave the fishing port for that location and sometimes stay there for long periods (1 to 5 months), so these are highly mobile groups. The management of these groups' funds is the same as for the Gbetsogbe groups. Some of the groups in the fishing port: God is God, No smoking, Nana Beleve, nohry in life; God First; who known Zebaot, God is time, Dadji Massada, Ayata, Dynamo, S'Boys, See never dry, etc.

The vessels or canoes are monoxylic [made from a single piece of wood]. They are used regardless of the fishing technique. In 2001, 46% of these canoes were motorized (framework survey, 2001). The number of canoes, fishermen, and women participating in the fishing trade on the Togolese coast in 2001 was 401, 5551, and 2366 respectively (framework survey, 2001).

4.4.2 The Various Fishing Seasons

4.4.2.1 High Season

High season begins in June and ends in September. During this season, fishing fluorishes, with good catches.

4.4.2.2 Low Season

Low season starts at the end of September and ends in late May. During this period, the groups mainly practice what can be called semi-commercial and semi-subsistence fishing, because often the catch is below average.

All the canoes depart from the fishing port. In addition, they all dock at the port for an annual fee of 30,000 F called dock fee or mooring fee.

4.4.3 Expenses Associated with Fishing Activities

Obtaining a canoe with all the equipment (machinery, nets, paddles, accessories) requires a minimum expenditure of 15 million francs. As for repairs and miscellaneous maintenance, it should be noted that canoe accidents (net snagged on a wreck) can cost up to 500,000 F and maintenance (Dobabla) can also cost up to 500,000 F. These types of maintenance are done once every three years and can take up to four months. Weekly maintenance is estimated at 25,000 or 30,000 F.

4.4.4 Fishing Equipment Used

4.4.4.1 Types of Nets

- Watcha and Watchagan used on 10-15 man canoes
- Tounga, net used on 5-7 man canoes. There are also the Agla, Deyido, Nisanisodo.

4.4.4.2 Fishing Techniques

Inland fishing is little known in Togo. Estimated at 5,000 tons per year in 1996, there have been no other estimates of inland fishing to date. It is not monitored like maritime fishing, which is prevalent due to the size and value of the catch.

There are two major categories of maritime fishing:

Small-scale Maritime Fishing

Small-scale maritime fishing is essentially seasonal, and is characterized by two periods: a high season and a low season. The high season runs from July to October during the period of cold waters due to upwelling, while the low season runs from November to June. Small-scale maritime fishing uses six different types of gear:

- *The "Watsa" rotating running seine*, 600 to 1000m long, is used on board 18-20m long monoxylic canoes equipped with 20-40 CV outboard motors. The crew varies from 15-20 people and the trips are daily, sometimes twice a day. The target species are pelagic species such as sardines, anchovies, cavally, etc.).

- *Line or hook fishing, or Akpon in Ewe,* is done from motorized monoxylic canoes equipped with an ice supply. A crew of 6-8 people makes a trip of about 3 days, fishing dorado, grouper, snapper, etc. in the fossil reef areas at depths of 50-60m.

- *The beach seine, or Yovodo in Ewe,* 200 to 1000m long, is used all year long on all the beaches by unmotorized 12-18m monoxylic canoes. It is pulled by both ends from the shore and yields catches composed of sardines, anchovies, razor fish, sea-perch, etc.

- *Bottom gill nets, or Tonga in Ewe, and surface gill nets, or Awli in Ewe, and shark nets or Gbowledo* are used by 6-12m monoxylic canoes that are often equipped with motors. Gill nets are used all year and are several hundred meters long with a drop of 2m. The mesh is from 40 to 200mm (stretched) and these nets are mainly used to fish for small thread-fins, otoliths, sole, flying fish, and large pelagic species (tuna, shark, sailfish, and swordfish).

More than 50% of small-scale maritime fishing is by foreigners, essentially from Ghana. The most represented ethnic groups are the Adan, Fanti, Gan, and Ahlan. The Adan, the most numerous in the fishing port, come from a region located to the west of the mouth of the Volta. The Ahlans, specialized in beach seine fishing and surface gill net fishing, are a sub-group of the Ewe from southeastern Ghana.

The number of fishermen in 2001 (Table 4.4-2) is 5551, of which 281 are canoe owners, 3322 are professional fishermen, and 1948 fishermen's helpers (framework survey, 2001). In order of decreasing number, they are from Ghana (59%), Togo (40%) and Benin (1%).

Small-scale maritime fishing, the most active, uses an average of 500 6-18 meter monoxylic canoes per year, equippoed with bottom gill nets, surface gill nets, shark nets, floating nets, rotating sienes, beach seines, and lines. The percentage of these vessels with motors, by horsepower, is: 40 CV (84%), 25 CV (15%), and 8 CV is 47%.

Table 4.4-2
Distribution of Small-Scale Maritime Fishermen According to Nationality in 2001

Nationality	Number
Togolese	2261
Ghanean	3278
Benin	12
Total	5551

Source : Division of Fishing and Aquaculture Promotion

Industrial Fishing

Since 1999, industrial offshore fishing has been reduced to the activity of a single ship with a total length of 24m and 400 CV in power. It operates very little due to frequent breakdowns and the annual volume of its catch is approximately 300 tons.

The species brought in by industrial fishing are generally: *Dentex* spp., *Epinephelus* spp, Sciandiae, Lutjanus spp, etc. (Table 4.3-3).

4.4.5 Species of Fish

The annual small-scale maritime fishing production represents more than 70% of the nation's halieutic production (Table 4.4-4, Figures 4.4-1 and 4.4-2). The production of the Lacs prefecture is always lower than that of the Golfe prefecture (Table 4.4-5). The reason for this is the very high production registered at the fishing port.

The annual catches of small-scale fishing brought in to the fishing port represent a very large portion of the annual catch brought in along the entire Togolese coast (Table 4.4-6). In 2002, for example, 13,840 tons of fish were brought in to the fishing port, or 87% of the volume of that year's catch for small-scale maritime fishing. This is explained by the fact that there are more fishing units and fishermen at the fishing port than at other camps. It should also be noted that the small-scale maritime fishing units of other fishing camps sometimes unload their products at the fishing port; rotating running seines, more than 99% of which are at the fishing port, produce more than half the total catch registered at the fishing port.

The catch made by these seines is mainly composed of anchovies, called Abobi in Ewe (the local language). More than fifty different species of fish are brought in by maritime fishing Table 4.4-3). The major species are indicated in the following table:

Table 4.4-3
Major Fish Species Brought in by Maritime Fishing

Scientific Name	Local French Name
Brachydeuterus auritus	Friture - Fry fish
Trichiurus lepturus	Poisson ceinture - Belt fish
Sardinella aurita	Sardinelle - Sardine
Sardinella maderensis	Hareng - Herring
Caranx spp	Carangue - Cavally
Trachurus spp	Chinchard - Scad
Engraulis encrasicolus	Anchois - Anchovy
Sarda sarda	Bonite - Bonita
Scomber japonicus	Maquereau - Mackerel
Ethmalosa fimbriata	Ethmalose - Shad or herring
Scomberomorus tritor	Thazard blanc - West African Spanish mackerel
Pagellus bogaraveo	Dorade rose - Pink dorado
Spondyliosoma cantharus	Dorade grise - Grey dorado
Lutjanus spp	Carpe rouge - Red carp
Epinephelus spp	Mérou - Grouper
Hemiramphus spp	½ Bec - Half-beak
Coryphena africana	Caméléon - Chameleon
Sphyraena africana	Brochet - Pike
Pagellus spp	Pageot - Porgy
Ilisha africana	Rasoir - Razor fish
Pomadasys jubelini	Pristipoma - Sompat grunt
Exocoetus spp	Poisson volant - Flying fish
Belonidae	Orphie - Garfish (Family)
Boops boops	Bogue - Bo-ops
Psettodes belcheri	Turbot - Flounder
Drepane africana	Disque - African sicklefish
Balistes spp	Baliste - Triggerfish
Galeodes decadactylus	Petit capitaine ou Hornose - Smaller threadfish
Polydactylus quadrifilis	Gros capitaine - Threadfish
Soleidae	Sole (Family)
Xiphias gladius	Espadon - Swordfish
Pseudotolithus spp	Bar
Penaeus spp	Crevette - Shrimp
Squalidae	Requin - Shark (Family)
Raja spp	Raie - Ray
Mugil spp	Mulet - Mullet

Scientific Name	Local French Name
Elegatis bipinulata Raja spp	Faut mulet - Rainbow runner Raie - Ray

Table 4.4-4
Quantities and Values of Small-scale Maritime Fishing Catches from 1999 to 2002

Year	1999	2000	2001	2002
Quantity (tons)	21,877	17,277	18,163	15,946
Value (1000 FCFA)	4,062,349	3,359,084	3,771,524	3,442,640

Source : Division of Fishing and Aquaculture Promotion

Figure 4.4-1
Recent History of Small-scale Maritime Fishing Catch Volumes

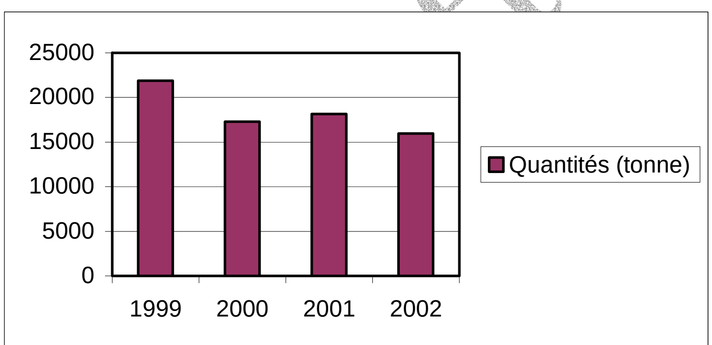


Figure 4.4-2
Recent History of Small-scale Maritime Fishing Catch Values

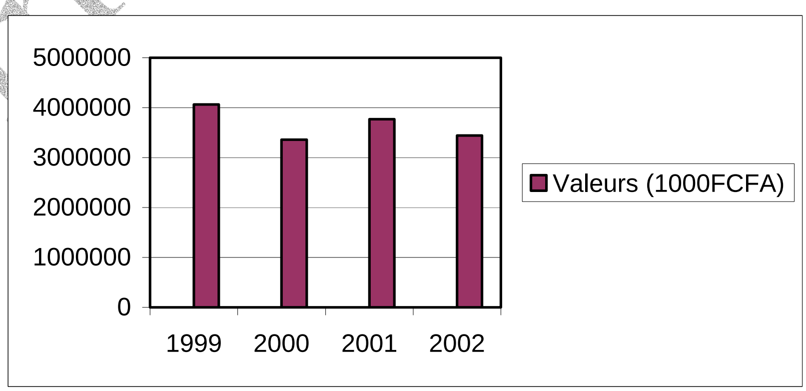


Table 4.4-5
Small-scale Maritime Fishing Catch by Prefecture (Golfe and Lacs) from 1999 to 2002

	1999		2000		2001		2002	
Quantity of catch (tons)	Golfe	Lacs	Golfe	Lacs	Golfe	Lacs	Golfe	Lacs
	17565	4312	14506	2770	15785	2377	14536	1410

Source : Division of Fishing and Aquaculture Promotion

Table 4.4-6
Volume of Catches at the Fishing Port from 1999 to 2002

	1999	2000	2001	2002
Total volumes (tons)	16,709	13,498	14,870	13,840
Volumes of anchovies (tons)	8,522	6,360	5,664	6,602

Source : Division of Fishing and Aquaculture Promotion

4.4.6 Transformation and Marketing Systems

Maritime fishing in Togo provides employment to more than 10,000 people (natives and foreigners). The major activity of the coastal villages is fishing. Maritime fishing production represents approximately 4% of the GIP of the primary sector each year. The fishing permits applied for annually by fishing boat owners are subject to a fee. Canoe owners that operate at the fishing port pay the Autonomous Port of Lome an annual fee of 20,000 to 40,000 FCFA per canoe. Women's access to the fishing port is subject to payment of a daily fee of 100 FCFA. The women who operate at Katanga pay the Autonomous Port of Lome a monthly fee of 500 FCFA for a 20m² parcel. It should be noted that this distribution or activity is conducted exclusively by women.

4.4.6.1 Women Conduction Fish Smoking Activities

Gbétsogbé

There is one group of women who smoke fish. This group includes all the women of this locality. There is a council of six (6) members, with a chairwoman and deputy chairwoman. The group members conduct their activities individually. After receiving a loan, for example, the management divides it up based on the individual request of each member. Each one conducts her own activities separately. At the end of the fiscal year the group holds a meeting during which it adds up expenses for reimbursement.

Katanga

This is an extension of Gbetsogbe that is under the authority of the chief of Gbetsogbe. In this locality, closer to the fishing port, there are thirty-six (36) groups in a single association called FETRAPO (Femmes Transformatrices de Poissons). This association began in 1978 when the fish-smoking women were seen in the area of the Mercure Sarakawa Hotel. In effect, these businesswomen were displaced by the State for reasons of security in the area around the hotels. They formed FETRAPO at that time. Thanks to the FETRAPO movement, the women were able to get the State to authorize them to set up at Katanga. FETRAPO now has a council of eleven (11) members, with a chairwoman, deputy chairwoman, secretary and deputy secretary, treasurer and deputy treasurer, and five (5) councilwomen. The association now has 610 women members. Among the 36 groups making up FETRAPO are GFTP (Groupements des Femmes Transformatrices de Poissons), GFMP (Groupement de femmes Marailleuses Transformatrice de poissons). Other fish marketing groups include: *Amen, Kékéli, Main de Dieu, Puissance de Dieu, Lonlonyo, Boussomékpo, Manowogomé, Assilassimé, Pieton, Déla, Novikpokpo, Djiyewanou,* and *Miwonovi.*

These groups have an average membership of 10 to 20. Most have no legal documentation (bylaws, internal regulations). When FETRAPO receives loans, it divides them up among the groups, which in turn divide them among their various members who, like the women of Gbetsogbe, conduct their activities individually. For the reimbursement of these loans, the groups collect the funds from the members and turn them over to the FETRAPO managing committee, which handles the reimbursement. Most women work by storing fish in the high season in order to sell them in the low season.

4.5 CLIMATE, METEOROLOGY, AND AIR QUALITY

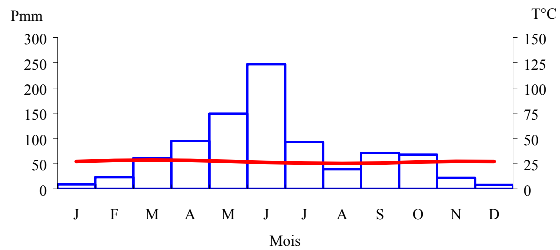
There was no activity concerning these factors during this second season of information and data gathering. The indications below are from the documentation.

4.5.1 Climate

The climate of the coastal region where the gas pipeline field is located is subject to two air masses: the harmattan or dry, hot continental tradewinds from the northeast resulting from the high pressures in the Sahara in December-January, and the hot, humid monsoon from the southwest from June to September, which brings rain. These two air masses come into contact at the intertropical convergence zone in which the InterTropical Front (ITF) is located. The movements of this front determine the seasons throughout the year on the coast. According to the rain and temperature chart of Lome (Figure 4.5-1), the seasons alternate as follows:

- A long dry season (November to mid-March))
- A long rainy season (mid-March to mid-July))
- A short dry season (mid-July to August)
- A short rainy season (September to October)

Figure 4.5-1
Rainfall-Temperature Chart of Lome



The distribution of the rains is bimodal. The long rainy season of 2003 was very wet, reaching its peak in June at 203.6mm. The data show enormous disparities between monthly rainfall, illustrating a fluctuation early in the season with 82.5mm in January and 8.0 in February, and a regular rise from March (78.7mm) to June.

The short dry season, which is very short, is centered in the month of August. It has the particular feature of being less severe, especially with the emergence of the coastal upwelling, which attenuates the temperatures of the ocean's surface, creating a convective anomaly. The rainfall during this period is greater than in the first dry season, 37.1mm.

4.5.2 Weather

4.5.2.1 Winds

The major winds on the Togo coast, measured at the Lomé-Aéroport station, (approx. altitude 20 m) are:

- The SSW and SW winds, parallel to the coast, which blow in all seasons at an average monthly velocity of 2 to 4m/s. The monthly data calculated over the past decade between 1986-1995 confirm this distribution (Table 4.5-1).
- The local winds due to differential warming of the ocean waters and the continent. They are added to the winds resulting from the air masses, and are commonly called sea breeze or land breeze, depending on their direction.
- The NE winds called "Harmattan", bringing in the dry haze and fine particles from the savannas or more arid regions.

Table 4.5-1
Wind Speeds at Lomé-Aéroport (1986-1995)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Speed in $m.s^{-1}$	2.5	3.0	3.2	3.1	2.7	2.9	3.6	3.9	3.3	2.6	2.3	3.0

Source: National Weather Directorate

4.5.2.2 Rainfall

A series of rainfall measurement sites is available along the coast, as indicated in the Table 4.5-2.

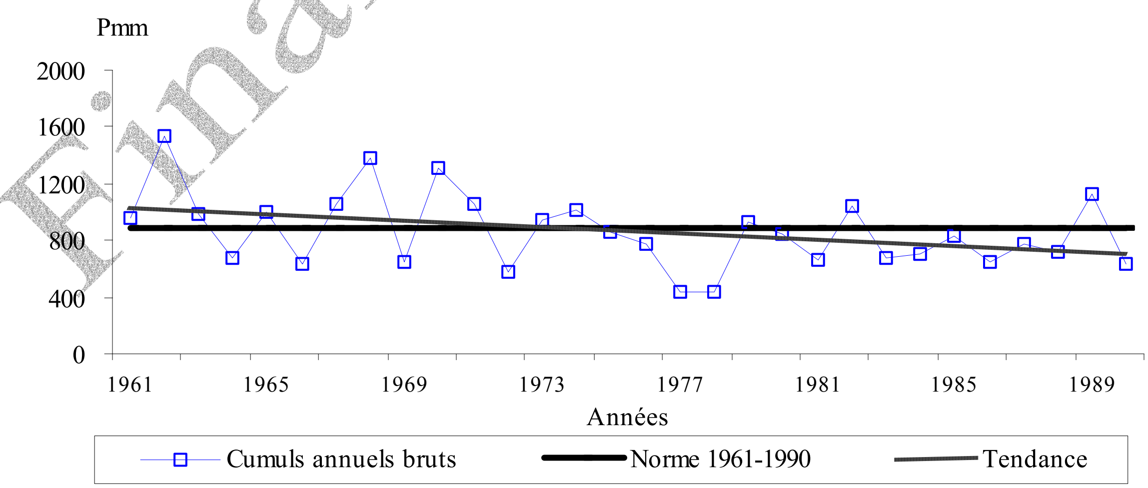
Table 4.5-2
Average Rainfall Distribution on the Togolese Coast

Station \ Month	J	F	M	A	M	J	J	A	S	O	N	D
Lomé-Ville	11.3	48.2	53.5	95.2	140.5	208.8	69.2	20.9	36.0	84.2	30.3	9.6
Lomé-Aéro	12.5	26.7	62.0	99.1	154.1	246.6	88.1	24.9	46.9	89.4	24.8	6.9
Lomé-FDS	3.1	28.8	32.5	112.4	158.0	165.5	92.6	48.4	92.6	81.7	16.0	10.9
Baguida	10.2	20.4	54.4	105.5	151.3	242.8	69.0	27.1	54.5	88.4	26.8	7.4
Kpémé	0.0	24.2	35.1	95.3	76.4	156.4	61.4	18.1	73.0	110.3	15.0	12.1
Aného	12.5	30.1	62.7	110.9	152.2	245.1	85.1	22.2	45.4	87.1	34.8	9.8

Source: National Weather Directorate

On the multi-annual scale from 1961 to 1990, a gradual decrease in the 10-year average cumulative rainfall is observed at the Lomé-Aéroport station: 1018.4mm (1961-70), 789.4mm (1971-1980), and 784.6mm (1981-1990). The decade from 1961-1970 was very wet: 1962 and 1968 registered more than 1350mm. In addition, in the second decade 1977 was very dry, only 440mm (Figure 4.5-2).

Figure 4.5-2
Gross Cumulative Rainfall at the Lomé-Aéroport Station
Compared to the 1961-1990 Norm



Rainfall on the average is between 800 and 950mm per year. The major characteristic of this climatic domain is the negative rainfall anomaly. It is an ensemble governed by the anticyclones of Ste. Helene in the south and the Azores in the north.

4.5.2.3 Hygrometry

Humidity data are very rarely measured at the various stations; the Lomé-Aéroport station has hygrometry data (Table 4.5-3).

The average relative humidity is above 75%. This is explained by the considerable impact of the ocean waters on the climate of Lome. The average minimum monthly values fluctuate around 57-58% during the harmattan period and 71-73% in the rainy season.

Table 4.5-3
Monthly Relative Humidity Norms at Lomé-Aéroport

Month	J	F	M	A	M	J	J	A	S	O	N	D
H%	77	78	78	80	82	85	85	87	83	82	81	78

Source: National Weather Directorate

The vapor tension data from the Lome station help explain the variation of atmospheric pressure on the Togolese coast (Table 4.5-4). The partial pressure due to the presence of water vapor in the air is at its peak between February and April with values between 30 and 31mb. These data are shown in the following table, where the average values are completed by hourly values at 6 am, 12 noon, and 6 pm.

Table 4.5-4
Average Vapor Tension Data at Lomé-Aéroport

Time \ Month	J	F	M	A	M	J	J	A	S	O	N	D
6 am	27.7	29.3	29.7	29.6	28.8	27.8	26.6	26.0	27.5	27.5	27.6	27.4
12 noon	27.5	29.8	29.8	30.4	30.4	29.2	27.1	26.6	27.5	28.6	29.2	27.0
6 pm	30.2	31.2	31.0	31.0	30.4	29.0	26.9	26.4	27.5	29.1	30.1	29.4
Average	28.5	30.1	30.2	30.3	29.9	28.7	26.9	26.3	27.2	28.4	29.0	27.9

Source: National Weather Directorate

The dew point temperature data at the Lome Station are given in Table 4.5-5 below. The maximum is between February and May (24.0-24.2°C), and the minimum in the low rainfall period of July-August is approximately 22°C.

Table 4.5-5
Average Dew Point Temperature Data at Lomé-Aéroport (°C)

Month / Time	J	F	M	A	M	J	J	A	S	O	N	D
6 am	22.5	23.7	23.9	23.8	23.4	22.8	22.0	21.7	22.5	22.5	22.7	22.4
12 noon	22.2	23.6	24.1	24.2	24.2	23.6	22.9	22.1	22.6	23.3	23.6	22.6
6 pm	24.1	24.7	24.6	24.6	24.4	23.5	22.3	21.9	22.6	23.5	24.1	23.7
Average	23.9	24.0	24.2	24.2	24.0	23.3	22.3	21.9	22.6	23.1	23.5	22.9

Source: National Weather Directorate

4.5.2.4 Temperature

On the coast, the Lome station and the Kpeme station (located on the phosphate wharf) regularly supply atmospheric temperature data as indicated in Table 4.5-6 below:

Table 4.5-6
Monthly Temperature Norms (°C) on the Togolese Coast

Month / Station	J	F	M	A	M	J	J	A	S	O	N	D
Lomé-Aéro	27.0	27.9	28.1	27.8	27.1	25.9	25.1	24.9	25.6	26.2	26.9	26.9
Lomé-Ville	27.0	27.9	28.1	27.8	27.5	25.9	25.1	24.9	25.6	26.2	26.9	26.9
Kpémé (air)	26.4	27.5	27.4	27.5	27.3	26.5	25.0	24.6	25.3	26.2	26.5	25.9
Kpémé (sea side)	27.2	28.0	28.5	28.7	28.6	27.9	25.9	25.1	25.9	27.0	27.9	27.2

Source: National Weather Directorate

The temperature data show that the maximum highs are registered in the dry season (February-March) and the minimum lows in the rainy season (July-August). The greatest deviations during the year are between 28.5°C at 25.2°C at Lome.

4.5.3 Air Quality

There is no assessment of the composition of the air in Togo based on laboratory measurements, but estimates have been made of the emissions of some gases into the air. They involve many compounds from industrial facilities, transportation, and other human activities. There has been a theoretical quantification of emissions of compounds such as carbon dioxide, sulfur dioxide, nitrogen oxides (NO_x), and organic products. The work done involves three types of pollutant load emission sources: fixed, mobile, and industrial sources.

The studies conducted by a group of researchers in 1998 at the request of the FAO showed: approximately 15,595 tons of SO_2 per year, 9491 tons of NO_x per year, 14,558 tons of hydrocarbons per year, and 40,111 tons of CO per year (Table 4.5-7).

Table 4.5-7
Evaluation of Atmospheric Gas Emissions by Type of Source in 1995

Source	SO_2		NOx		Hydrocarbures		CO	
	tons/an	%	tons/an	%	tons/an	%	tons/an	%
Domestic sources	730	45.3	7320	77.1	1462	10.1	367	0.9
Industrial sources	435	27.3	1219	12.9	8	≈ 0.0	11	≈ 0.0
Power Plant	3	0.2	100	1.1	1	≈ 0.0	5	≈ 0.0
Road traffic	381	23.9	772	8.1	12953	89.0	39648	98.9
Air traffic	5	0.3	32	0.3	104	0.7	36	0.1
Maritime traffic	41	2.5	48	0.5	31	0.2	44	0.1
Total	**1595**	**100**	**9491**	**100**	**14558**	**100**	**40111**	**100**

Source: EP/INT/068/UEP/ FAO/ WACAF II) Project

Through these results it can be seen that the major SO_2 emission sources are domestic and industrial sources. The pollutant load from domestic sources is essentially due to the consumption of firewood. The highest contribution for these emissions could well come from the domestic and industrial sources of cities. Particularly at Lome, with a high population density and increasing needs for the use of firewood or coal by the populations living there, higher emissions are observed.

As for industrial sources and road traffic, studies show respective SO_2 contributions of 27.3 and 23.9%. There is a great deal of vehicle traffic in the port zone. The large number of vehicles traveling in the port zone and the high industrial concentration of Lome compared to the rest of the country could result in high SO_2 pollution in this area. With respect to NO_x, 77% is emitted by domestic sources, while most of the hydrocarbons and CO emissions are from road traffic.

Other studies conducted from 1994 to 1998 permitted an estimate of the emissions of certain gases in the Energy sector. Table 4.5-8 shows the various gas emissions surveyed. Emissions from energy industries, manufacturing and construction, transportation, residential activities, and small-scale (cottage industry) and commercial sources were estimated.

Table 4.5-8
Quantity of Greenhouse Gases for 1994-1998 in the Energy Sector

Gas (Gigagrams)	Year				
	1994	**1995**	**1996**	**1997**	**1998**
CO_2	516	567	620	727	1010
CH_4	16	17	18	19	19
N_2O	0.12	0.13	0.14	0.14	0.15
CO	250	270	291	294	305
NO_x	7	8	8	9	10
Non-methane volatile organic compounds	35	37	41	41	43

This estimate shows a gradual increase in emissions over the study period. This change is particularly noticeable with carbon dioxide, which is the compound emitted most. Estimates made for the years from 1994 to 1998 show a 68% increase in carbon dioxide emissions. The transportation and industry segments are essentially responsible for the increases in carbon dioxide emissions. Most of the emissions of this type come from Lome, because most activities and nearly all the industrial sectors are developing in that city.

Carbon monoxide or CO is the major compound, showing an increase of about 22%. The increase in the number of automobiles in the country is at the root of this increase. The engines of these automobiles are very often poorly adjusted, resulting in incomplete combustion with emissions of carbon monoxide. Annual NO_x emissions are nearly constant over the period covered by this study. Nitrous oxide N_2O emissions are low, while methane CH_4 and non-methane organic compound emissions are significant. All these emissions are higher at Lome because of the higher number of activities producing these gases.

4.6 CONCLUSION

The gas pipeline installation site, located between the Gbetsogbe village beach and the Lome Power Plant, is characterized by a homogeneous landscape that was the subject of a geometric survey on the basis of which the other field applications were conducted. The results of the various surveys illustrate the current situation of the ecology and the functioning of the habitats studied in the two campaign seasons.

With respect to flora, a total of 125 species was inventoried, with a strong predominance of herbaceous species (85%). The various types of habitats found along the gas pipeline route include fallow lands and vegetable garden beds. These crops and a few ligneous species, particularly *Cocos nucifera,* are proof of the area's high degree of anthropization. No rare or endangered species were found. The construction of the gas pipeline will therefore not have any impact on the area's natural flora and vegetation.

The substrate, composed of coarse and medium grain materials, is well-compacted. The soil's low organic content and the low concentrations of lead (< 20µg/g), cadmium (<0,8µg/g) and mercury (0,0-05,5 µg/g) are indicative of the low level of soil pollution.

The microbial flora of the soils studied revealed total germs, yeasts and molds, and sulfite-reducing aerobic germs, and at times Enterobacteria whose presence appears to be due to human activity. The absence of total Coliforms would be due to the proximity to the ocean. The soil temperatures, between 21.8° C and 31°C, are those generally indicated for the development of these germs. A significant change in these temperatures could change the composition of the microbial flora. The moisture level of the soil, between 2 and 20%, is compatible with the microbial flora identified. A change in moisture level could affect the growth of microbial flora.

The soil fauna study in the first campaign revealed the presence of 34 species of Arthropods belonging to the orders Acariae, Coleoptera, Diptera, Hymenoptera, Homoptera, Lepidoptera, and Isoptera. The results of the second campaign showed the presence of Polychaeta and Oligochaeta Annelids, Bivalve Mollusks, and also Arthropods belonging to the orders Diptera, Homoptera, and Hymenoptera. These results indicate soils disturbed by human activities. Other damage caused by the gas pipeline installation work would result in the species reduction of Arthropods. After the gas pipeline is installed, the soil fauna will certainly recolonize the environment.

With respect to animal wildlife, 11 species of marine mammals, 11 species of land mammals, 4 species of sea turtles, 14 species of land reptiles, 13 species of birds, and 2 species of amphibians were inventoried in the two campaign seasons. The beach-rock fauna, rich in Mollusks, Crustaceans, Echinoderms, Cnidaria, and Bryozoaria, was also inventoried. The construction of the gas pipeline will have little impact on the land wildlife. The impact of the gas pipeline construction on the beach-rock fauna would be less due to the nearly homogeneous distribution of species along the substrate.

The periods when the various marine and land species are present, when they reproduce, and when they grow are a very important factor that must be taken into account in scheduling construction operations so as to minimize the impacts on biological diversity. The installation work should be done between February and July.

Based on all these results, it should be noted that the homogeneous nature of the components of the sector surveyed and of the entire coastal area is a significant point of evidence indicating that the gas pipeline work will have no effect on the marine and coastal environment, which contains no sensitive elements.

CHAPTER 5
REFERENCES

Akpagana K, 1992. – Quelques espèces rares ou menacées de disparition du Togo. 1- Le cordon littoral. *Ann. Univ. Bénin Togo*, sect. sci., 10, 33-36.

Akpagana K. & Bouchet P., 1997. - Les espèces en voie de disparition et leur utilisation en thérapeutique. *In* Les phytomédicaments éthiques. *Les Presses de l'UB :63-70.*

Brunel J. F., Scholz H. & Hiepko P., 1984. - *Flore analytique du TOGO. Phanérogames.* GTZ, Eschborn, 751 p.

Hutchinson J. and Dalziel L. M, 1954-1972.- *Flora of West Tropical Africa.* 2nd ed., revised by Keay and Hepper, 3 vol.

Blivi, A.B., Anthony, E.J. & Oyede L.M., 2002. – Sand barrier development in the bight of Benin, West Africa. Journal : *Ocean and Coastal Management*, vol : 45(2-3) pp 185-200.

Blivi, A.B., 2001. – Impact de l'érosion côtière et éléments d'étude de vulnérabilité : exemple du Togo (Golfe de Guinée). *Revue de l'Université de Moncton*, vol.32, n° 1-2, 2001, 289-308.

Blivi, A.B., 1993. - Géomorphologie et dynamique actuelle du littoral du golfe du Bénin, Afrique de l'Ouest. Thèse de Doctorat, Université de Bordeaux 3, p 463

APPENDIX A
STAKE COORDINATES

Sampling Site Stake Coordinates				
	UTM Zone 31		Geographic Coordinates	
Stake	**Longitude X**	**Latitude Y**	**Longitude**	**Latitude**
1	312356	679851	1° 18' 15.28 E	6° 08' 52.43 N
2	312360	679871	1° 18' 15.41 E	6° 08' 53.08 N
3	312359	679891	1° 18' 15.38 E	6° 08' 53.73 N
4	312356	679910	1° 18' 15.28 E	6° 08' 54.35 N
5	312356	679929	1° 18' 15.27 E	6° 08' 54.97 N
6	312354	679951	1° 18' 15.21 E	6° 08' 55.69 N
7	312353	679971	1° 18' 15.17 E	6° 08' 56.34 N
8	312351	679992	1° 18' 15.10 E	6° 08' 57.02 N
9	312349	680013	1° 18' 15.04 E	6° 08' 57.70 N
10	312350	680035	1° 18' 15.07 E	6° 08' 58.42 N
11	312346	680053	1° 18' 14.94 E	6° 08' 59.01 N
12	312345	680071	1° 18' 14.90 E	6° 08' 59.59 N
13	312343	680094	1° 18' 14.83 E	6° 09' 00.34 N
14	312342	680115	1° 18' 14.80 E	6° 09' 01.02 N
15	312341	680138	1° 18' 14.76 E	6° 09' 01.77 N
16	312341	680158	1° 18' 14.76 E	6° 09' 02.42 N
17	312338	680178	1° 18' 14.66 E	6° 09' 03.07 N
18	312338	680199	1° 18' 14.66 E	6° 09' 03.76 N
19	312335	680221	1° 18' 14.56 E	6° 09' 04.47 N
20	312334	680239	1° 18' 14.53 E	6° 09' 05.06 N
21	312335	680262	1° 18' 14.56 E	6° 09' 05.81 N
22	312333	680283	1° 18' 14.49 E	6° 09' 06.49 N
23	312331	680304	1° 18' 14.42 E	6° 09' 07.18 N
24	312331	680324	1° 18' 14.42 E	6° 09' 07.83 N
25	312328	680343	1° 18' 14.32 E	6° 09' 08.44 N
26	312326	680369	1° 18' 14.25 E	6° 09' 09.29 N
27	312325	680388	1° 18' 14.22 E	6° 09' 09.91 N
28	312324	680408	1° 18' 14.18 E	6° 09' 10.56 N
29	312323	680427	1° 18' 14.15 E	6° 09' 11.18 N
30	312325	680450	1° 18' 14.21 E	6° 09' 11.93 N
31	312321	680474	1° 18' 14.08 E	6° 09' 12.71 N
32	312321	680490	1° 18' 14.08 E	6° 09' 13.23 N
33	312303	680501	1° 18' 13.49 E	6° 09' 13.59 N
34	312286	680513	1° 18' 12.94 E	6° 09' 13.97 N
35	312271	680522	1° 18' 12.45 E	6° 09' 14.27 N
36	312260	680531	1° 18' 12.09 E	6° 09' 14.56 N
37	312243	680545	1° 18' 11.54 E	6° 09' 15.01 N
38	312242	680552	1° 18' 11.5 E	6° 09' 15.24 N
39	312241	680573	1° 18' 11.47 E	6° 09' 15.92 N
40	312242	680590	1° 18' 11.5 E	6° 09' 16.47 N

Sampling Site Stake Coordinates				
	UTM Zone 31		Geographic Coordinates	
Stake	Longitude X	Latitude Y	Longitude	Latitude
41	312240	680609	1° 18' 11.43 E	6° 09' 17.09 N
42	312243	680628	1° 18' 11.53 E	6° 09' 17.71 N
43	312244	680647	1° 18' 11.56 E	6° 09' 18.33 N
44	312242	680667	1° 18' 11.49 E	6° 09' 18.98 N
45	312239	680686	1° 18' 11.39 E	6° 09' 19.60 N
46	312241	680706	1° 18' 11.45 E	6° 09' 20.25 N
47	312237	680727	1° 18' 11.32 E	6° 09' 20.93 N
48	312240	680745	1° 18' 11.42 E	6° 09' 21.52 N
49	312239	680764	1° 18' 11.38 E	6° 09' 22.14 N
50	312241	680780	1° 18' 11.45 E	6° 09' 22.66 N

Offshore West African Gas Pipeline Environmental Baseline Survey Second Season

Prepared for

Prepared for:
Chevron West African Gas Limited & Chevron Nigeria Limited
on behalf of the
West African Gas Pipeline (WAGP) Joint Venture

14 November 2003

ICF Consulting
33 Hayden Ave.
Lexington, MA 02421 USA
(781)676-4000

ICF Reference 022483.3.002.**07**

Prepared by:

ICF Consulting Services, LLC
33 Hayden Avenue
Lexington, MA 02421 USA
(781) 676-4000

Environmental Solutions (ESL), LTD
Accra, Ghana

Table of Contents

Page

Chapter 1 Introduction and Background **1-1**
1.1 Physical Setting 1-1
1.2 Offshore Biological Setting 1-4
1.2.1 Plankton 1-4
1.2.2 Benthic Organisms 1-5
1.2.3 Fisheries 1-5
1.2.4 Marine Birds, Mammals, Reptiles and Amphibians 1-7
1.3 Meterology background 1-8
1.4 Study Design 1-9
1.4.1 Offshore Study Design 1-9
1.4.1.1 Sampling Station Layout 1-9
1.4.1.2 Sediment Biological Characterization Design 1-10
Chapter 2 Offshore Methods **2-1**
2.1 Operations, Station Location, and Navigation 2-1
2.2 Mobilization and Pre-Sampling Preparations 2-2
2.3 Seabed Sample Collection 2-4
2.4 Water Column Sampling 2-4
2.5 Offshore *In-Situ* Methods 2-5
2.6 Offshore Benthic Community Characterization 2-5
2.7 Plankton Community Characterization 2-5
2.7.1 Phytoplankton Sample Processing 2-7
2.7.2 Zooplankton Sample Processing 2-7
2.7.3 Data Analysis 2-7
2.8 Fish Population Characterization 2-7
2.9 Aquatic Macrophyte Sampling 2-8
2.10 Marine Birds, Mammals, Reptiles 2-9
2.11 Meteorological Conditions and Ocean Currents 2-9
2.12 Documentation, Sample Tracking, Storage, and Shipping 2-9
2.12.1 Documentation 2-9
2.12.2 Documentation, Sample Tracking, Storage and Shipping 2-10
Chapter 3 Analytical Methods **3-1**
3.1 Physical Laboratory Methods 3-1
3.2 Chemical Laboratory Methods 3-2
3.2.1 Alkalinity 3-2
3.2.2 Biochemical Oxygen Demand (BOD5) 3-2
3.2.3 Chemical Oxygen Demand (COD) 3-2
3.2.4 Electrical Conductivity 3-3
3.2.5 Exchangeable Acidity 3-3
3.2.6 Nitrogen forms (Nitrate, Nitrite, Ammonia Nitrogen, Total Nitrogen) 3-3

Table of Contents

Page

3.2.7 Phosphorus forms (phosphate, orthophosphate, reactive phosphorus, total phosphorus) 3-3
3.2.8 Polyaromatic Hydrocarbons (PAHs) 3-4
3.2.9 Solids (Total Suspended Solids, Total Dissolved Solids) 3-4
3.2.10 Sulfate 3-4
3.2.11 Total Petroleum Hydrocarbons (TPH) 3-4
3.2.12 Total Organic Carbon 3-5
3.2.13 Turbidity 3-5
3.3 Biological Laboratory Methods 3-5
3.3.1 Plankton and Productivity 3-5
3.3.2 Macrobenthic infauna 3-6
3.4 Data Analysis and Reporting 3-7
3.5 Data Quality Objective for Chemical and Physical Analyses 3-8
3.5.1 Data Quality Objectives 3-9
3.5.1.1 Precision 3-9
3.5.1.2 Accuracy 3-9
3.5.1.3 Completeness 3-11
3.5.1.4 Representativeness 3-11
3.5.1.5 Comparability 3-12
3.5.1.6 Sensitivity 3-12
3.5.2 Field Quality Control Samples 3-12
3.5.2.1 Equipment Blanks 3-12
3.5.2.2 Field Blanks 3-12
3.5.2.3 Replicate Samples (Field Duplicates) 3-13
3.5.2.4 Split Samples 3-13

Chapter 4 Offshore Sediment Characterization 4-1

4.1 Chemical Results 4-1
4.1.1 Total Organic Carbon (TOC) 4-1
4.1.1.1 Main Pipeline Route 4-1
4.1.1.2 Laterals 4-1
4.2 Physical Results 4-4
4.2.1 Sediment Particle Size 4-4
4.2.1.1 Main pipeline route 4-4
4.2.1.2 Laterals 4-5
4.2.2 Discussion 4-8

Chapter 5 Offshore Water Characterization 5-1

5.1.1 Discrete Water Samples 5-1
5.1.2 CTD Results 5-7

Table of Contents

Page

Chapter 6 Offshore Biological Characterization 6-1
6.1.1 Benthic Infauna..6-1
6.1.1.1 Ghana 6-1
6.1.1.2 Togo 6-5
6.1.1.3 Benin 6-8
6.1.1.4 Nigeria..6-11
6.1.1.5 Discussion 6-14
6.1.2 Offshore Plankton Community Characterization...............................6-19
6.1.3 Fish Population 6-35
6.1.3.1 Species Composition and Catch Rates..6-35
6.1.3.2 Laterals and Mainline Stations..6-39
6.1.3.3 Discussion 6-42
6.1.4 Marine Birds, Mammals and Reptiles 6-45
6.1.5 Offshore Primary Production...6-46
Chapter 7 Meterological Conditions and Ocean Currents 7-1
Chapter 8 References 8-1

List of Appendices

Appendix A 9-1

List of Figures

Figure 1.1-1: Offshore Map showing WAGP Pipeline Route 1-2

Table 3.5-1 Summary of Data Quality Objectives and Levels 3-8

Figure 4.1-1 Distribution of Total Organic Carbon along the Main Pipeline Route 4-1

Figure 4.1-2 Distribution of Offshore Total Organic Carbon along Nigeria Diagonal 4-2

Figure 4.1-3 Distribution of Offshore Total Organic Carbon along Benin Lateral 4-2

Figure 4.1-4 Distribution of Offshore Total Organic Carbon along Togo Lateral 4-3

Figure 4.1-5 Distribution of Offshore Total Organic Carbon along Tema Lateral 4-3

Figure 4.1-6 Distribution of Offshore Total Organic Carbon along Takoradi Lateral 4-4

Figure 4.2-1 Distribution of Offshore Sediment Parameters along Main Pipeline Route 4-5

Figure 4.2-2 Distribution of Offshore Sediment Parameters Along Nigeria Diagonal 4-6

Table of Contents

Page

Figure 4.2-3 Distribution of Offshore Sediment Parameters Along Benin Lateral 4-6

Figure 4.2-4 Distribution of Offshore Sediment Parameters Along Togo Lateral 4-7

Figure 4.2-5 Distribution of Offshore Sediment Parameters Along Tema Lateral................ 4-7

Figure 4.2-6 Distribution of Offshore Sediment Parameters Along Takoradi Lateral 4-8

Figure 5.1-1 Offshore Stations' Surface Water NH_3-N Concentrations............................... 5-1

Figure 5.1-2 Offshore Stations' Bottom Water NH_3-N Concentrations 5-2

Figure 5.1-3 Offshore Stations' Surface Water NO_3-N Concentrations............................... 5-2

Figure 5.1-4 Offshore Stations' Bottom Water NO_3-N Concentrations 5-3

Figure 5.1-5 Offshore Stations Surface Water Total Nitrogen Concentrations..................... 5-3

Figure 5.1-6 Offshore Stations Bottom Water Total Nitrogen Concentrations 5-4

Figure 5.1-7 Offshore Stations' Surface Water Phosphate Concentrations........................... 5-4

Figure 5.1-8 Offshore Stations' Bottom Water Phosphate Concentrations 5-5

Figure 5.1-9 Offshore Stations' Surface Water Total Phosphorous Concentrations 5-5

Figure 5.1-10 Offshore Stations' Bottom Water Total Phosphorous Concentrations 5-6

Figure 5.1-11 Offshore Stations' Surface Water Sulphate Concentrations 5-6

Figure 5.1-12 Offshore Stations' Bottom Water Sulphate Concentrations 5-7

Figure 5.1-13 Example of Temperature vs Depth Profile in Benin...................................... 5-9

Figure 5.1-14 Example of Temperature vs Depth Profile in Ghana 5-10

Figure 5.1-15 Example of Temperature vs Depth Profile in Nigeria 5-11

Figure 5.1-16 Example of Temperature vs Depth Profile in Togo 5-12

Figure 6.3-1 Offshore Benthic Macrofauna Distribution on Main Pipeline Route in Ghana 6-2

Figure 6.3-2 Offshore Benthic Macrofauna Diversity index Distribution on Main Pipeline Route in Ghana 6-2

Figure 6.3-3 Offshore Benthic Macrofauna Distributions along Tema Lateral..................... 6-3

Figure 6.3-4 Offshore Benthic Macrofauna Diversity index Distribution along the Tema Lateral 6-3

Table of Contents

Page

Figure 6.3-5 Offshore Benthic Macrofauna Distributions along Takoradi Lateral 6-4

Figure 6.3-6 Offshore Benthic Macrofauna Diversity index Distribution along the Takoradi Lateral 6-4

Figure 6.3-7 Offshore Benthic Macrofauna Distributions along Main Pipeline Route of Togo 6-5

Figure 6.3-8 Offshore Benthic Macrofauna Diversity index Distribution along the Main Pipeline Route of Togo 6-6

Figure 6.3-9 Offshore Benthic Macrofauna Distribution along the Togo Lateral 6-7

Figure 6.3-10 Offshore Benthic Macrofauna Diversity index Distribution along the Togo Lateral 6-7

Figure 6.3-11 Offshore Benthic Macrofauna Distribution along the Main Pipeline Route of Benin 6-8

Figure 6.3-12 Offshore Benthic Macrofauna Diversity index Distribution along the Main Pipeline Route of Benin 6-9

Figure 6.3-13 Offshore Benthic Macrofauna Distribution along the Lateral of Benin 6-10

Figure 6.3-14 Offshore Benthic Macrofauna Diversity index Distribution along the Benin Lateral 6-10

Figure 6.3-15 Offshore Benthic Macrofauna Distribution along the Diagonal of Nigeria.. 6-11

Figure 6.3-16 Offshore Benthic Macrofauna Diversity index Distribution along the Nigeria Diagonal 6-12

Figure 6.3-17 Abundance and Distribution of Major Macrobenthic Fauna Group at Random Stations across the Countries Sampled 6-13

Figure 6.3-18 Distribution of Diversity at Random Stations along Countries Main Pipeline Route 6-13

Figure 6.3-19 Group-average dendrogram of Bray-Curtis similarity Showing Clustering of Random stations and the Stations Replicates.. 6-14

Figure 6.3-20 Occurrence of Dominant Sedentary Polychaetes across Ghana 6-15

Figure 6.3-21 Occurrence of Dominant Errant Polychaetes across Ghana 6-15

Figure 6.3-22 Occurrence of Dominant Sedentary Polychaetes across Togo 6-16

Figure 6.3-23 Occurrence of Dominant Errant Polychaetes across Togo 6-16

Figure 6.3-24 Occurrence of Dominant Sedentary Polychaetes across Benin 6-16

Figure 6.3-25 Occurrence of Dominant Errant Polychaetes across Benin 6-17

Figure 6.3-26 Occurrence of Dominant Sedentary Polychaetes across Nigeria.................. 6-17

Figure 6.3-27 Occurrence of Dominant Errant Polychaetes across Nigeria........................ 6-18

Figure 6.3-28 Occurrence of Dominant Errant Polychaetes across Countries 6-18

Figure 6.3-29 Occurrence of Dominant Errant Polychaetes across Countries 6-19

Figure 6.3-30 Distribution of Species Richness (S) by Country 6-27

Figure 6.3-31 Mean Distribution of Plankton Collected from Sampling Stations off Ghana, Togo, Benin and Nigeria in July, 2003 6-28

Figure 6.3-32 Distribution of Total Abundance of Zooplankton Collected using Step Oblique and Vertical Methods 6-32

Figure 6.3-33 Dendrogram for Hierarchical Clustering of Plankton Sites, using Group-Average Linking of Bray-Curtis Similarities Calculated on Fourth Root Transformed Abundance Data 6-33

Figure 6.3-34 Catch Rates at Stations off Ghana... 6-35

Figure 6.3-35 Catch Rates at Stations off Togo... 6-36

Figure 6.3-36 Catch Rates at Stations off Benin.. 6-36

Figure 6.3-37 Catch Rates at Stations off Nigeria 6-37

Figure 6.3-38 Catch Rates at Stations along Main Pipeline Route..................................... 6-37

Figure 6.3-39 Catch Rates by Depth Range on the Laterals... 6-38

Figure 6.3-40 Distribution of *Chlamys purpuratus* 6-41

Figure 6.3-41 Calculated Values of the Shannon Diversity Index 6-42

Figure 6.3-42 Black Tern... 6-45

Figure 6.3- 43 Royal Tern.. 6-45

Figure 6.3-44 Variations in Primary Productivity at Stations along the WAGP Pipeline (Bar Charts) with 2 Step Running Averages (Line Chart). Stations with Asterisks Indicate those along the Laterals. (Stations Have been Arranged From West To East)............ 6-47

Table of Contents

Page

Figure 6.3-45 Variation in Primary Productivity Averaged According to WAGP Countries . 6-48

Figure A-1 2B01C Temperature vs Depth ... 9-1

Figure A-2 2B02C Temperature vs Depth ... 9-2

Figure A-3 2B03C Temperature vs Depth ... 9-3

Figure A-4 2B04C Temperature vs Depth ... 9-4

Figure A-5 2B05C Temperature vs Depth ... 9-5

Figure A-6 2B06C Temperature vs Depth ... 9-6

Figure A-7 2B07C Temperature vs Depth ... 9-7

Figure A-8 2B08C Temperature vs Depth ... 9-8

Figure A-9 2B09C Temperature vs Depth ... 9-9

Figure A-10 2B10C Temperature vs Depth ... 9-10

Figure A-11 2G01C Temperature vs Depth ... 9-11

Figure A-12 2G10C Temperature vs Depth ... 9-12

Figure A13-1 2G11C Temperature vs Depth ... 9-13

Figure A-14 2G20C Temperature vs Depth ... 9-13

Figure A-14 2G20C Temperature vs Depth ... 9-14

Figure A-15 2G21C Temperature vs Depth ... 9-14

Figure A-15 2G21C Temperature vs Depth ... 9-15

Figure A-16 2G22C Temperature vs Depth ... 9-15

Figure A-16 2G22C Temperature vs Depth ... 9-16

Figure A-17 2G23C Temperature vs Depth ... 9-16

Figure A-17 2G23C Temperature vs Depth ... 9-17

Figure A-18 2G24C Temperature vs Depth ... 9-17

Figure A-18 2G24C Temperature vs Depth ... 9-18

Table of Contents

Page

Figure A-19 2G35C Temperature vs Depth........ 9-18

Figure A-19 2G35C Temperature vs Depth........ 9-19

Figure A-20 2ND01C Temperature vs Depth........ 9-19

Figure A-20 2ND01C Temperature vs Depth........ 9-20

Figure A-21 2ND02C Temperature vs Depth........ 9-21

Figure A-22 2ND03C Temperature vs Depth........ 9-22

Figure A-23 2ND04C Temperature vs Depth 9-23

Figure A-24 2ND05C Temperature vs Depth........ 9-24

Figure A-25 2ND06C Temperature vs Depth........ 9-25

Figure A-26 2T01C Temperature vs Depth........ 9-26

Figure A-27 2T02C Temperature vs Depth........ 9-27

Figure A-28 2T03C Temperature vs Depth........ 9-28

Figure A-29 2T04C Temperature vs Depth........ 9-29

Figure A-30 2T05C Temperature vs Depth........ 9-30

Figure A-31 2T06C Temperature vs Depth........ 9-31

Figure A-32 2T07C Temperature vs Depth........ 9-32

Figure A-332T08C Temperature vs Depth........ 9-33

List of Tables

Table 2.7-1 Plankton Sampling Protocol during Second Season of the Environmental Baseline Survey (EBS) 2-5

Table 6.3-1 Abundance of Major Groups of Benthic Infauna........ 6-1

Table 6.3-2 Plankton taxa identified from samples collected off Ghana, Togo, Benin and Nigeria in July, 2003: (a) Phytoplanton, (b) Zooplankton (oblique tow), and (c) Zooplankton (vertical haul)........ 6-20

Table 6.3-3 Calculation of Suite of Diversity Indices for Plankton Collected Off Ghana, Togo, Benin And Nigeria In July, 2003. (S, Species Richness; N, Number Of

Individuals; D, Margalef's Index; J', Pielou's Evenness Index; H', Shannon-Wiener Index) 6-25

Table 6.3-4 Results of Analysis of Similarity (ANOSIM) between Plankton Communities. (0 < R < 1 Reflects Degree Of Discrimination Between Areas) 6-34

Table 6.3-5 Dominant Species Recorded at the Laterals and along the Main Pipeline Route with the Catch Rates 6-39

Table 6.3-6 Results of Primary Productivity Recorded at Stations along the WAGP Pipeline in July, 2003 6-46

Table 7.1-1: Offshore Stations and meteorological observations 7-1

CHAPTER 1
INTRODUCTION AND BACKGROUND

This report presents the results of the Second Season Environmental Baseline Survey (EBS) offshore survey conducted as part of an Environmental Impact Assessment (EIA) for the proposed West African Gas Pipeline (WAGP) project. The EBS was conducted in accordance with established standard operating procedures (SOPs) and participating governments' guidelines. The first season represented dry conditions; while the second represents wet, or rainy conditions.

This report provides physical, chemical and biological data for the study area, which is located offshore of Benin, Ghana, Nigeria, and Togo. In conjunction with the reviewed regional information presented in the Preliminary Draft EIA Reports (ICF, 2003) and summarized below, these site-specific data provide the initial basis for examining potential impacts from constructing, operating and decommissioning the proposed gas pipeline. An in-depth analysis and interpretation of the First and Second Season EBS data will be included in the EIA submittals.

1.1 PHYSICAL SETTING

The project area is within the Gulf of Guinea. The entire Gulf spans 2,500km of coastline from Cape Palmas in Liberia to Port Gentil in Gabon, and includes the following nations: Angola, Benin Republic, Cameroon, Equatorial Guinea (including the Islands of Principe and Sao Tome), Congo, Cote d'Ivoire, Gabon, Ghana, Liberia, Nigeria, Togo, and Zaire. The project area lies on the sandy, continental shelf. The average width of this plateau is approximately 27km from the shore to the 100m isobath.

Bathymetry and Coastal Geology

The project area from Nigeria to Ghana lies along the Gulf of Guinea shelf. The continental shelf is narrow in the project area, ranging from 10km to 90km in width. The shelf breaks into the slope at approximately the 100m isobath. A reef of dead madreporarian coral lines the seaward edge of the continental shelf throughout the project area.

The shelf historically has been considered seismically stable, but recent tremors in Ghana and Nigeria suggest the presence of some crustal instability. In Ghana, there is active faulting, especially near the intersection of the east-west Coastal Boundary Fault Zone and the northeast to southeast Akwapim Fault Zone (Tsidzi et al., 1995). The first major reported seismic activity in Ghana was in Elmina (Central Region) in 1615 (Armah and Amlalo, 1998). Subsequent seismic events took place in 1636, 1862, 1906, 1939, and 1997. In 1997, seismic events were recorded in January, February, and March with magnitudes on the Richter scale of 3.8, 4.1, and 4.8, respectively. Burke (1969b) associated the seismic activities of the Accra and Kribi regions with the Romanche and Chain fracture regions. Along the coastline, currents move sands from west to east, forming a barrier beach system along much of the coastline. This littoral drift is interrupted at Lome and Cotonou by groynes built to reduce shoreline erosion.

Figure 1.1-1: Offshore Map showing WAGP Pipeline Route

Currents and Tidal Patterns

The oceanography of the region is influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral currents (Merle and Arnault, 1985; Fontaine et al., 1999). The cold Canary and Benguela Currents are warmed as they flow toward the equator along the coastal margins. These currents then turn westward near the equator and diverge as the North and South Equatorial Currents (Longhurst, 1962). Between the North and South Equatorial Currents flows the ECC. This ECC becomes known as the Guinea Current as it runs from Senegal to Nigeria. The Guinea Current flows the whole length of the coast, as far as the Bight of Biafra, year-round. It maintains its highest velocities during the season of the southwesterly winds from June to October (Longhurst, 1962).

The ECC is driven by westward wind stress. When this subsides during February to April and October to November, it is reversed (Garzoli and Katz, 1983; Richardson, 1984; Merle and Arnault, 1985). A small westward-flowing countercurrent lies beneath the Guinea Current. Below a depth of 40m, it appears to turn to the southwest with velocities ranging between 0.5m/s to 1.0m/s and 0.05m/s to 1.02m/s near the bottom (Akpati, 1975; Binet et al., 1991). The cold subsurface water could be a branch of the Benguela Current that penetrates and dominates the ECC.

The coastal waters experience seasonal changes at the surface of the Tropical Surface Water (TSW). There is little change in the subsurface waters. The TSW layer is characterized by warm, well-mixed water that extends from the surface to the depth of the thermocline (about 30m to 40m). Seasonal changes in the hydrographic regime come in the form of minor and major upwelling, alternating with periods of stratification. Between January and February, the surface waters tend to be slightly cooler, indicating a minor upwelling. By the end of June, there is an increase in the easterly wind in the western equatorial Atlantic that brings up cold South Atlantic Central Water (SACW) to replace the TSW (Moore et al., 1978). When the thermocline breaks, it signals the onset of the major upwelling. The sea surface temperature can fall from 30°C in May to 18°C in August.

Water Quality and Water Column Characteristics

In the tropical regions of the Atlantic, a thin stratum of warm, relatively low salinity water called TSW overlies cooler, higher density water to form a thermocline. Where the south-flowing TSW converges with a north-flowing SACW, a zone called the tropical convergence is formed. This zone is generally located at about latitude 10°S in the eastern half of the Atlantic Ocean, but can be as far south as 25°S.

There are three other types of water masses below the SACW: the Arctic Intermediate Water (AIW), North Atlantic Deep Water (NADW), and Antarctic bottom water. The NADW is more saline and denser than the AIW, which is Antarctic surface water that sinks as it moves towards the equator.

Bottom Hazards and Areas of Existing Pollution

Abandoned ships are present along the rocky banks of the Port of Lomé within the project area. There is another shipwreck further seaward, in the ship sailing zone off the Port of Lomé. This is known by the harbormaster's office at the Port of Lomé, and was recently located by the French navy during the last ocean floor survey carried out in November 2002.

In general, pollution exists only along the beach. Other various sources of marine pollution originating from the city and industries have been identified. Little existing data are available on pollution farther out at sea.

1.2 OFFSHORE BIOLOGICAL SETTING

The offshore waters off the coast of Benin, Ghana, Nigeria and Togo are part of the Gulf of Guinea. This region is classified as a Large Marine Ecosystem (LME) by the United Nations Conference on the Environment and Development. As an LME, the Gulf of Guinea encompasses the onshore river basins and estuaries and the offshore environment extending to the continental shelf and seaward margin of the coastal current system. The northern subsystem of this marine ecosystem is thermally unstable and undergoes intensive seasonal upwellings. The southern half, which is thermally stable, depends on nutrient input that originates from land drainage, river flows, and wave turbulence. Although less intensive, periodic upwellings have been reported. These characteristics combine to make this area one of the world's most productive marine areas, rich in fishery resources and biological diversity.

1.2.1 Plankton

Species diversity and abundance is linked to seasonal variation of the oceanographic regime. During periods of thermal stability of the water column, the abundance of zooplankton is low but species diversity is high. During the upwelling, zooplankton is more abundant but have lower species diversity (Wiafe, 2002). *Calanoides carinatus*, a cold-water copepod species, tends to be the most abundant during the upwelling periods. Other common holoplankton found during the upwelling period are *Oikopleura longicauda*, *Euconchoecia chierchiea*, *Lucifer faxoni,* and *Sagitta enflata*. The Cladocera, an ephemeral form, can be found during all seasons. *Penilia avirostris* and *Evadne tergestina* become abundant during the upwelling and dominate the zooplankton community for a brief period.

The diatoms normally dominate the phytoplankton community, especially during the major upwelling season when the water temperature is relatively cold (20°C to 25°C) and conducive for their growth. Dinoflagellates, on the other hand, thrive well when the temperature is above 25°C. The principal species of diatoms recorded in Ghana during the upwelling belong to the genera *Skeletonema*, *Nitzschia*, *Chaetoceros*, *Rhizosolenia,* and *Thalassiosira*. In Nigeria, the most prevalent species are of the genera *Bidulphai, Coscinodiscus, Chaetoceros, and Ditylium*. Dinoflagellates are better adapted to survive under conditions of low nutrient levels (Harris, 1986), and thus abound during periods of thermal stability. For example, *Ceratium* spp. exhibit slow growth rate and have low nutrient requirements. The species most commonly recorded off Ghana and Nigeria are *C. extensum, C. trichoceros, C. massiliense,* and *C. vultur*.

In Ghana, it has been observed that Chaetognaths are sparse most of the year, but become prolific September to November. Thaliaceans, mainly *Thalia democratica,* become prolific only in December and July, and Appendicularians are often abundant in June and October (Thiriot, 1977).

1.2.2 Benthic Organisms

Offshore benthic organisms have been described by Buchanan (1957 and 1958). They include a range of polychaete worms, ribbon worms, amphipods, bivalves, gastropods, and decapod crustaceans.

The macrobenthic fauna in this region are comprised of essentially three phyla: Annelida (exclusively Polychaetes), Mollusca, and Crustacea. Rijavec (1980) found that the hard bottom substrate had substantially higher invertebrate biomass than soft bottom substrates. Crustaceans are the most abundant macrofauna. Crustaceans of primary commercial importance in this ecosystem are *Penaeus notialis, P. kerathurus, Parapeneus longirostis*, and *P. atlantica.* The juveniles of these species are caught in the estuaries, mangroves, and on the beach with beach seines during the upwelling season. In near-shore areas, the older peneids are caught by inshore trawlers.

Macrobenthic algae, along with the microalgae, are the primary producers in the marine environment and key players in the ecosystem of the Gulf of Guinea. In general, macro benthic algae have low species diversity in the study area. Typically, species of Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae) are present. Populations are sparsely distributed in three potential habitats: brackish water, marine inter tidal, and sub tidal. In Ghana, the brackish water habitat has 10 recorded species, the marine inter tidal has 116, and the sub-tidal has 80 species. These represent 112 taxonomic genera (John and Lawson, 1997). Macro benthic algae grow among piles of dead coral branches, on dead portions of coral heads, and mixed with sea grasses (sea grasses form thin stands on sandy bottoms near the shore).

The three lobster species of high commercial value are *Panulirus argus* and *P. regius* (spiny lobster), and *Scyllares herklotsii* (slipper lobster). These are captured with bottom nets set by small canoes on rocky grounds. By far, the most widely occurring species is the deep-water rose shrimp, *Parapeanus longirostris*. In general, many more species are present during the rainy season than during the dry season. Five species are restricted to the rainy season, while only one species, *Callinectes pallidus,* is restricted to the dry season. Catches generally decrease with increasing distance from shore, both in number and weight.

1.2.3 Fisheries

Fish production in the Gulf of Guinea is high. The migration of important fish stocks is dependent on upwelling events and the movement of climatic fronts and ocean currents that has been described above. More than 400 species of both cartilaginous and bony fishes have been recorded in the Gulf of Guinea. The most common and abundant are pelagics and semi-pelagic. The families Clupeidae, represented by *Sardinella* sp and *Ethmalosa fimbriata,* Scombridae, and Carangidae are the families in which most of the species are caught. Others are the demersal species. The most abundant of these is the Sciaenidae, represented by *Pseudotolithus* spp., and the Sparidae, represented by *Dentex* spp. Others are the Serranidae, the Pleuronectiformes (Flatfishes), and Lutjanidae.

This rich fishery resource supports artisan fisheries, local industrial fleets, and large commercial offshore fishing fleets from the European Union, Eastern Europe, Korea, and Japan. Since the 1960s, the offshore commercial fishing has negatively affected the resource catch per unit effort by exceeding sustainable yields in some countries (Ajaji, 1994) and species diversity and average total body length of the most important fish species has declined.

Small pelagic fish species that inhabit coastal areas are highly diverse. Four species have the highest economic value: *Sardinella aurita* (round sardine), *S. maderensis* ('herring'), *Engraulis encrasicolus* (anchovy), and *Scomber japonicus* (chub mackerel). Other species caught in smaller quantities include *Ilisha africana*, *Brachydeuterus auritus,* and several small carangids. The resource is exploited using various types of netting (e.g. encircling nets and beach seines).

In the coastal pelagic fishery, economically important species are linked to the availability of phytoplankton and zooplankton. In Ghana, for example, small pelagic fish species contribute over 50 percent to the total marine production of the fisheries yield indicating their importance to food security of the region. The target species off the coast of Ghana and Togo are *Sardinelia aurita*, *Sardinelia maderensis*, *Scomber japonicus,* and *Engraulis encrasicolus*. Further south from Benin to Democratic Republic of the Congo, the target species are *Ethmalosa fimbriata, Sardinella maderensis,* and *Ilisha africana*.

This group is made up of mainly tunas: *Thunnus albacares* (yellowfin), *T. obesus* (bigeye), *Katsuwonus pelamis* (skipjack), and *Euthynnus alleterratus* (black skipjack). Other large pelagic species of commercial importance include *Istiophorus albicans* (Atlantic sailfish), *Xiphias glaudius* (swordfish), *Makaira nigricans* (blue marlin), and *Tetrapturus albidus* (white marlin). Harvesting is either industrial or artisan, using pole and line, purse seine, and gillnets.

Demersal fisheries are of higher economic value than pelagics. The target species are the croakers, (*Pseudotolithus elongatus*, *Psendotholitus senegalensis*, *Pseudotholitus typus)*, Polymenids, (*Galeoides decadactylus*, *Polydactylus quadrifilis)*, perches, big eye tuna, (*Brachydeuterus auritus)*, catfish, (*Arius* spp., *Pomadasys* spp.*),* soles and *Cynoglossus* sp. In the highly lucrative coastal demersal shrimp fishery, the pink shrimp (*Paenus notialis)* is dominant but other target species include the *Parapenaeopsis atlantical* and *Penacus kerathurus*. Shrimping grounds cover 2,500 square miles off Nigeria, 190 square miles off Cameroon, and 180 square miles off Benin. White shrimp (*Nematopalaemon hastatus*), exclusively exploited by small-scale operators with passive cane or netting gear in the estuaries or with miniature trawls in the surf zone, is a major fishery resource off the Gulf of Guinea. The potential yield is about 150,000 tons per year off the coast of Nigeria. The shrimp are an important export species in this region.

In addition to the economically important fishes, there are several pelagic and demersal species that are important to maintaining the marine ecosystem balance. Four species of sharks, *Mustelus* sp., *Paragaleus gruveli* (*P. pectoralis*), *Rhizoprionodon acutus*, and *Squatina aculata*, occur throughout the Gulf of Guinea. Four species of rays, *Torpedo torpedo*, *Raja miraletus*, *Rhinobatos albomacutus*, and *Dasyatis margarita* occur in the region as well. In addition, families such as Elopidae, Albulidae, and Mugilidae are highly valued fish in the market, but are not caught in large quantity.

1.2.4 Marine Birds, Mammals, Reptiles and Amphibians

The aquatic birds of the Gulf of Guinea comprise two distinct groups: creek birds (waterfowl, waders, and fish-eating birds) and oceanic birds, shearwaters, storm petrels, tropicbirds, frigate birds, gannets, and boobies, that are rarely seen near the seashore. These oceanic birds do not appear to be as abundant in the Gulf as the coastal species. For instance, records dating back to the 1960s reveal only limited sightings of a few species (Elgood et al, 1994). The rarity of oceanic birds may be attributable to the absence of suitable breeding sites (e.g. remote islands and rocky cliffs) in the Gulf of Guinea.

There have been a few records of dolphins and whales being spotted at different places along the coastline in Ghana. In a survey by Waerbeek and Ofori-Danson (1999), six cetacean species were recorded: clymene dolphin (*Stenella clymene*); rough-toothed dolphin (*Steno bredanensis*); bottlenose dolphin (Tursiops truncates); dwarf sperm whale (*Kogia simus*); sperm whale (*Physeter macrocephalus*); and the humpback whale (*Megaptera novaeangliae*). Small cetaceans are regularly caught in artisan gillnet fisheries operating from Apam in the Central Region to Kpone in the Greater Accra Region. Annual catches have been estimated to be in the low hundreds. During the December 2002 Offshore EBS, two Humpback whales and a calf were spotted and identified at N5°41.78" E0°53.32" as noted in the Offshore EBS Daily Shift Report for 12 December 2002.

The Atlantic coast of West Africa (approximately 14,000km), including the four countries addressed in this project, serves as a very important migration route, feeding ground, and nesting site for marine turtles. In the Gulf of Guinea, six species have been identified: the loggerhead (*Caretta caretta*); the olive ridley (*Lepidochelys olivacea*); the kemp ridley (*Lepidochelys kempii*); the hawksbill (*Erectmochelys imbricata*); the green turtle (*Chelonia mydas)*; and the leatherback (*Dermochelys coriacea*) (Armah et al., 1997a). The hawksbill is very rare and only seen occasionally. Sea turtles nest on sandy beaches beyond or at the high tide mark and always return to the same area to nest.

In Ghana, sandy beaches constitute about 70 percent of the coastline and stretch from the western border with Cote d'Ivoire to Axim, and from the east of Tema to the border with Togo. The prime turtle nesting sites are located within the rapidly eroding sites between Tema and the Volta estuary. The nesting period is reported to be between July and December, with a peak in November (Armah et al., 1997b). In Togo, however, the nesting periods are from September through February in the sandy beaches of Agbodrafo to Aneho. Sea turtles are a protected species under several international treaties ratified by the four West African countries covered in this project. However, in reality, populations have decreased due to poaching and habitat destruction. The young turtles begin to appear in the sea from April. In Nigeria, these species breed along the coast from Badagry to Eket, especially in relatively undisturbed secluded sandy beaches found in some coastal states, notably Akwa, Ibom, Rivers, Delta, and Lagos States.

1.3 METEROLOGY BACKGROUND

The onshore and offshore climates are similar in the region. The climate is an equatorial bimodal system with an alternating rainy and dry season. The climate in the Gulf of Guinea and Central Eastern Atlantic is influenced largely by the inter-tropical convergence zone (ITCZ) weather patterns (also known as the inter-tropical discontinuity and the inter-tropical front). Maritime tropical air masses, characterized by warm, humid southwesterly winds and continental air mass, characterized by hot, dry northeasterly winds, converge in the ITCZ. The alternating rainy season and dry season phenomenon is determined by the north-south oscillation of air masses in the ITCZ. Winds from the southwest and south-southwest blow year round with monthly averages between 2 meters per second (m/s) to 4m/s. While there are two main seasons during the course of the year, the annual weather patterns are somewhat more complicated due to a short break in rainy season in August.

The typical weather is as follows:

- Long rainy period (southern summer monsoon season) stretches from April to July and starts with storms and humid SW winds of between 15m/s and 25m/s. There is an upwelling event along the shoreline in July;

- Short dry period occurs in August as rainfall amounts suddenly decline about 75 percent;

- Short rainy period is associated with decreasing winds and a weak upwelling during October and November. Ocean surface temperatures increase during September, reaching 28°C; and

- Long dry season stretches from December to March and is characterized by persistent Harmattan winds, which derive from anticyclone systems in the north.

Mean annual rainfall in the region ranges from 500 millimeters (mm) to 2,000mm. During the rainy season, daily rainfalls of 50 to 140mm can occur. High temperatures throughout the year, common to regions near sea level in the equatorial zone, prevail in the project area. Mean annual temperatures oscillate between 30.4°C and 32°C. During the extreme hot weather period from November to January, temperatures vary between 32°C and 34°C. Low temperatures of about 28°C occur during July and August. During the rainy season, relative humidity can be greater than 80 percent in the morning and 60 percent in the afternoon. During the dry season relative humidity tends to be lower than 50 percent in the morning and 25 percent in the afternoon.

1.4 STUDY DESIGN

The objective of the offshore and onshore study design was to provide an analytical basis for the WAGP EIA, that is, to provide an accurate and comprehensive analysis of the existing environment as it relates to the proposed construction and operation of the project, and to do so in the most efficient and cost-effective manner. The ICF Scientific Team designed the first season EBS based upon the expertise of its scientists and the experience it has derived from past experience and surveys in West Africa and elsewhere.

The sample design was intended to evaluate spatial patterns of physical, chemical, and biological conditions that are of particular significance to the proposed project and that may be adversely affected. It provided physical, chemical and biological characterizations of the seabed, water column, terrestrial vegetation, terrestrial soil, groundwater, onshore surface water, and onshore sediment environments. Due to the nature of the proposed project, the study emphasized the baseline biological conditions. However, the chosen study design was comprehensive and generated over 14,000 chemical, physical, and biological data points for analysis and interpretation.

The ICF EBS Scientific Team subsequently made an assessment for each of the EBS questions regarding whether sufficient data were collected to produce valid statistical results. Graphs, such as species-areas curves, were plotted to indicate whether the addition of new sampling points would add significantly new information to the survey results. Resulting data deficiencies have been flagged for further investigation--mainly this includes focusing the second season study design on closing these data gaps.

A system of monitoring, tracking, and data quality control that was described in the EBS work plan and followed during the EBS ensured that field sampling and laboratory testing were performed adequately.

Before the EBS was implemented, the study design was critically evaluated and presented to WAGP and regulatory bodies. It was evaluated as to whether the design met the study objectives and tests the appropriate hypothesis and whether the technical and statistical elements of the design are appropriate. This section, Study Design, is intended to provide an overview of how the EBS was designed to provide appropriate information and analysis to adequately address the EBS objectives.

1.4.1 Offshore Study Design

1.4.1.1 Sampling Station Layout

A total of 50 offshore sampling stations were sampled during July-August 2003, using a research vessel. The timing was chosen to represent wet season conditions. Thirty-five of the stations were placed along the main pipeline route: Nigeria (3), Benin (7), Togo (5), and Ghana (20). The remaining 15 stations were on the laterals that bring the pipeline onshore in Nigeria (3), Benin (3), Togo (3), and Ghana (6). See Plate 1.8-1: West African Gas Pipeline Proposed Pipeline Route and 2002 Offshore Sampling Stations for placement of the sampling stations.

In order to perform statistical analysis of the collected data, it was necessary that there be an element of randomisation in the placement of sampling points. Sampling points were located using a stratified random method as follows: For the main pipeline, the route was divided into 18km segments. Then a random number generator was used to select a number between one and 36. This random number indicated at which half-kilometer interval along the route, starting at the beginning of the 18km segment, the sampling point was to be placed.

For the laterals, a similar approach to sampling station placement was used; however, in these cases the length of the segments depended upon the water contour depth. Sampling points on the lateral routes corresponded to the following (also see Section 2.1):

- The 15m contour depth;
- A water depth 15m deeper than the water depth at the intersection with the main pipeline route or 5km south of the intersection with the principal pipeline route, whichever is the shorter distance;
- The depth-midpoint between the intersection with the main pipeline route and the 15m contour depth.

1.4.1.2 Sediment Biological Characterization Design

To address the benthic and seabed questions presented above, sediment grab samples were collected at each of the 50 sampling stations for biological, physical, and chemical characterization. Two replicate samples for benthic infaunal community analyses were taken at each of the 35 main pipeline stations. Only one of two replicate samples collected along the main pipeline route was analyzed in the laboratory. On the laterals, four replicate samples were taken at each of the 15 stations; but only one of the replicate samples collected along the pipeline laterals was analyzed in the laboratory.

Macrobenthic infauna was identified to the lowest possible taxon and from this was determined abundance (number of individuals of each taxon per grab sample) and frequency (as proportion of how many times that taxon occurred in the grab samples out of the total number of grab samples analyzed).

The justification using the analytical flow decision tree stems from the main purpose of the benthic infauna analysis, which is to define broad regional conditions and the range of regional variability and, given a fixed budget, doing so by using a large spatial coverage and non-replicated samples. The approach follows Cuff and Coleman "Optimal Survey Design: Lessons from a Stratified Random Sample of Macrobenthos" (J. Fish. Res. Bd. Can. 36: 351-361, 1975) and optimizes our sampling effort for geographic coverage with consideration of the limitation of the available time and cost resources. Cuff and Coleman found that preferable results were derived from the same total number of grab samples by increasing the number of stations at the expense of the number of grabs per station. They concluded the optimum number of grabs, given the regional objective, was one per station to maximize the area covered.

Macrobenthic infauna sampling data was analyzed to derive measures of species diversity and evenness. Species diversity indices to be useful must address both the measures of abundance and evenness of species present. The Shannon diversity index (*H*), which takes both into account, was calculated. In the Shannon index, the proportion of species *i* relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by (–1).

$$H = -\sum_{j=1}^{S} p_i \ln p_i$$

Evenness (J) was determined using the following formula:

$$J = H/\ln(S)$$

Where H is the Shannon Diversity Index, ln is the log base (e), and S is equal to the number of taxa. This index expresses H relative to the maximum value that H can obtain when all the species in the sample are perfectly even with one individual per species.

Sediment Physical and Chemical Characterization

In addition to the biological characterization, sediment samples were at each station collected specifically for laboratory analysis to determine key physical and chemical parameters.

Water Quality Characterization

Water sampling was carried out at each of the 50 offshore sampling stations on the proposed pipeline route, as close as practical to the locations where the sediments were taken. *In-situ* measurements were made using a CTD and water samples were collected at two depths: near the water surface (<1m) and at 1m above the bottom; and submitted for laboratory analysis.

Fish and Plankton Characterization

Trawl sampling at 25 stations in the study area were conducted for fish, ichthyoplankton, phytoplankton, and zooplankton during July-August 2003. Trawls were conducted at approximately the same locations as the sediment sampling stations described above. In addition, 10 trawls were conducted at approximately 50km intervals along the main pipeline route. Trawl depths were chosen to collect representative samples of fish and plankton assemblages.

Marine Birds, Mammals, And Reptiles Characterization

Information on marine birds, mammals, and reptiles was obtained during field operations from deliberate observations of species distributions, estimated numbers, and behavior. Special attention was given observing whales, dolphins, sea turtles, and West African manatees that were known to be of concern in the study area.

Meteorological Characterization

Measurements of meteorological conditions, i.e., air temperature, wind speed and direction, and wave height were carried out during field sampling and trawling operations.

CHAPTER 2
OFFSHORE METHODS

2.1 OPERATIONS, STATION LOCATION, AND NAVIGATION

Operations

Field operations were conducted from the vessel R/V GeoExplorer, a 44m research vessel subcontracted by TDI-Brooks International. The vessel was outfitted with a hydraulic winch spooled with 9/16th stainless-steel wire and a starboard-mounted A frame used for gear deployment. Smaller diameter wire was used to deploy plankton and water sampling gear. The GeoExplorer was also equipped with enclosed laboratory spaces, sheltered work deck, and refrigerator and freezer space. The vessel was equipped with Differential Global Positioning System (DGPS) receivers and propulsion systems capable of positioning and navigating to an accuracy of ±5m during sampling and WinFrog™ navigation software.

Station Location

Fifty offshore sampling station transects were visited during the Offshore EBS. Of these 35 were along the main pipeline route: Nigeria (3), Benin (7), Togo (5), and Ghana (20) and 15 along the 5 laterals. Along the main pipeline route sampling transects were located using a stratified random method as follows: the main pipeline route was divided into 18km segments. Each 18km segment was subdivided into 36 half-kilometer segments, one of which was randomly chosen to be the center station for the sampling transect. The two additional sampling stations were then positioned 1km North and South of the center station The element of randomization was added to the method of station location to facilitate statistical analysis of the data, as described in Appendix H, WAGP Offshore and Onshore Environmental Baseline Survey Work Plan.

Along the laterals, three transects were established perpendicular to each lateral using a different method. The center station of each transect was positioned using a different method. The vessel navigated to the intersection of a lateral and the main pipeline route (the *intersection*) and marked the depth, *D1*. The center station of each transect was then located as follows:

- The center station of the northern-most transect on a lateral was located by navigating the vessel from the *intersection*, along the lateral route, towards shore until the first sustained (1/2 kilometer) 15m depth was found.

- The center station of the seaward most transect on each lateral was located by navigating along the lateral, past the *intersection,* until the depth was D1 + 15m or a distance of 5km had be covered, whichever occurred first.

- The center station of the middle transect on each lateral was located by navigating the vessel from the *intersection* towards shore until the depth was equal to (D1-15)/2, which located the station at the depth-midpoint between the northern-most transect and the main pipeline route.

A list of sampling stations, locations, and water depth at each station is presented in Table 2.1-1. A map of the proposed pipeline route and all the offshore sampling stations is shown in Figure 2.1-1.

Navigation

Station locations were plotted in a geographic information system (GIS). The stations were then located by transferring the Latitude and Longitude of the station from the GIS into the WinFrog™ navigation system as waypoints, which then used DGPS to navigate to, and position the vessel directly over the station. The offset of the A-frame from the GPS antenna was recorded and programmed into the navigation system so that the position recorded was the position of the A-frame, rather than the position of the GPS antenna.

2.2 MOBILIZATION AND PRE-SAMPLING PREPARATIONS

Mobilization

The scientists from the United States arrived in Accra, Ghana on the evening of 10 July 2003. The scientists from Nigeria, Benin, and Togo arrived in Accra on the afternoon of 12 July 2003. On 13 July 2003, a cruise kickoff meeting was held at the WAGP offices in Accra, Ghana to review the objectives of the 2nd season offshore EBS and the best way to achieve these objectives. The meeting reviewed the work plan, procedures for sampling, preserving samples, health and safety issues, and the roles of each person on the cruise. All of the scientists who were to sail with the GeoExplorer attended. A list of scientists, their nationality, and role on the EBS Cruise is presented in Table 2.1-2.

Name	Nationality	Position/Expertise
Henry **Camp**	USA	Chief Scientist
Theodore Havemeyer **Coogan**	USA	Shift Leader
Gavin **Hogge**	USA	Benthos
Cossi Georges Epiphane **Degbe**	Benin	Benthos
Youssouf **Abou**	Benin	Plankton
Emmanuel **Lamptey**	Ghana	Shift Leader
Selorm Dzako **Ababio**	Ghana	Water Chemistry, Benthos
Samuel Nii Kpakpa **Quaatey**	Ghana	Plankton
Emmanuel **Klubi**	Ghana	Benthos

Audrey Kweinorki **Quaye**	Ghana	Benthos
Anthony Oppan **Bentil**	Ghana	Benthos
Kwame Adu **Agyekum**	Ghana	Benthos
Peter Lanre **Olorunda**	Nigeria	Sediment Chemistry
Isah Ibrahim **Attah**	Nigeria	Water Chemistry
Olumide Goriola **Omisore**	Nigeria	Sediment Chemistry
Therese **Edorh**	Togo	Plankton

For on-board work, the scientific staff was divided into 3 shifts:

00:00 – 12:00: Water Chemistry, Sediment Chemistry, Benthos

12:00 – 24:00: Water Chemistry, Sediment Chemistry, Benthos

06:00 – 18:00: Trawls (Plankton, Fisheries)

On the morning of 14 July, Coogan and Hogge conducted an inspection of the GeoExplorer, according to the client's checklist for hired vessels. A copy of the completed vessel inspection checklist is included with this report in Attachment A. Upon completion of the inspection, the scientific staff mobilized their scientific equipment on the R/V GeoExplorer.

The GeoExplorer departed Tema, Ghana at 15:30 on 15 July 2002, with a compliment of 16 scientists and a vessel crew of 12. All members of the scientific team went through a 45-minute vessel orientation and safety tour/briefing conducted by the vessel crew. Ship operation and safety procedures were also covered at this time. Each member of the scientific party signed the Vessel Introduction and Safety form after completion of the tour and briefing.

Pre-Sampling Preparation

Participants of the offshore EBS met for a series of meetings that were held on 13 July 2003 in Accra to review the objectives of the studies, review the on-board work plan, and determine how to best achieve the work objectives. All of the scientists who participated on the offshore EBS attended these meetings. A summary of the principal topics covered in the meetings follows:

- Scope of EBS Program- Overview and Goals
- Health & Safety Briefing
- Roles and Responsibilities

- Daily schedule, Shifts and shift assignments
- Review of Health & Safety Issues
- Personal and Protective Gear
- Review of Generalized Sampling Procedures
- SPI
- Water and Sediment Chemistry
- Benthos, Plankton, and Fisheries
- Cruise and Sampling Plan (Station ID, Sampling Process, etc.)
- Data Management and Chain-of-Custody forms
- QA/QC issues
- Sample archiving, storage and transportation
- Laboratory Studies– on-board versus land-based

During the pre-sampling meetings numerous administrative issues that pertained to departure formalities and vessel requirements were also addressed.

2.3 SEABED SAMPLE COLLECTION

Seabed sediment samples were collected using a 30cm x 30cm x 60cm GOMEX-type box corer deployed and retrieved on the 9/16th inch stainless steel cable over the starboard side of the GeoExplorer with the hydraulic A-frame. When the box corer was returned to the deck of the ship, the sample was inspected to determine if it was adequate for collection. Examples of inadequate samples include over-penetration of the box corer and partial or complete washout or disturbance of the sample while the box corer was being returned to the surface. If the sample was determined to be inadequate, it was discarded and the box corer redeployed until a good sample was collected. The sediment was sub sampled from the box corer by removing the top 2cm of the sediment using a Kynar™-coated scoop and placing the sample in pre-cleaned glass containers for chemistry analyses.

After chemistry samples were collected, the box corer was deployed 2 additional times at each station (4 times on the lateral stations) to collect sediment for benthic infauna analysis

2.4 WATER COLUMN SAMPLING

The water column was sampled using both electronic profiling instruments and discrete water samples. Comprehensive water column profiles were collected using an electronic YSI 6600 Sonde™ conductivity, temperature and depth (CTD) profiler. The YSI 6600™ profiler was augmented with additional sensors for dissolved oxygen, pH, turbidity, oxidation-reduction potential (ORP) and chlorophyll-*a*. The YSI 6600 was attached to the weighted 9/16th inch cable for deployment. Data were collected from 1 m below the water surface to approximately 5 m above the seafloor at a frequency of 2 samples per second and stored in memory and retrieved and reviewed upon each cast completion. The YSI 6600 is multi-parameter instrument, designed for both short and long-term in-situ monitoring and profiling. The YSI 6600™ profiler uses standard YSI 6-Series probes, including YSI's Rapid Pulse™ stirring-independent dissolved oxygen sensor, and self-cleaning turbidity probe excludes variations in ambient light resulting in hydrographic data for the 50 stations for depth, temperature, turbidity, chlorophyll-*a*, dissolved oxygen saturation, pH, and ORP. All results archived represent the full cast data collection. The down cast data were reviewed and trimmed for data display, due to operational interferences affecting the specific conductance probe.

In-situ measurements were collected at the 50 stations along the proposed pipeline route from July 15-21 2002. Discrete water samples were collected using two 5-L Niskin™ polycarbonate samplers deployed on the winch cable to collect surface (< 3m) and near-bottom (1 m above seabed) samples. Sample bottles were deployed open and then closed with a brass messenger at the targeted depth. The samplers were decontaminated with Alconox™ and rinsed with deionised water before each deployment.

2.5 OFFSHORE *IN-SITU* METHODS

The offshore in-*situ* methods were used to determine measurements of different aspects of sediment and water. The different aspects of water measurements done in the field were done with the CTD or in the on-board lab.

2.6 OFFSHORE BENTHIC COMMUNITY CHARACTERIZATION

Offshore macrobenthic fauna was sampled with a 0.30m x 0.30m x 0.60m box corer. Two replicate samples were taken at the stations along the main pipeline route labeled as center stations. At the spur laterals, four replicate samples were taken. Two replicate samples were also taken at a kilometer interval either north and south or east and west of stations along the main pipeline route. Each replicate sample at each station was split. The samples were emptied into sample trays, washed and screened through a sieve with a mesh size of 0.5mm. The resulting samples were put into plastic containers, fixed in 10% formalin solution and taken to the laboratory for sorting and identified to species where possible, using a Leica Zoom 2000 dissecting microscope and a Leica Gallen III microscope.

2.7 PLANKTON COMMUNITY CHARACTERIZATION

Phytoplankton and zooplankton samples were collected from 15th to 25th July at 25 different stations of the gas pipeline route. Table 2.7-1 shows the stations samples and their sampling dates and times.

Table 2.7-1
Plankton Sampling Protocol during Second Season of the Environmental Baseline Survey (EBS)

Country	Station	Sampling depth (m)	Date	Sampling time (GMT)		
				Phytoplankton	Zooplankton (vertical haul)	Zooplankton (step oblique)
Ghana	G01	15.4	17-Jul	0920	0910	0839
	G02	21.2	17-Jul	0957	1010	1025
	G03	32.7	17-Jul	1301	1313	1335
	G04	29.8	17-Jul	1436	1452	1507
	G05	31.0	16-Jul	1735	1750	1812
	G06	41.0	16-Jul	0956	1010	1033
	G07	50.0	16-Jul	0705	0720	0745
	G08	62.1	18-Jul	1045	0957	1022
	G09	60.4	18-Jul	1805	1820	1844
	G010	34.3	15-Jul	1813	1850	1820
	G011	16.3	15-Jul	1615	1630	1715
	G012	12.6	19-Jul	1145	1218	1235
Togo	T01	16.3	20-Jul	0735	0721	0740
	T02	34.5	20-Jul	0915	0840	0927
	T03	67.2	20-Jul	1115	1050	1125
	T04	50.0	20-Jul	1307	1245	1318
Benin	B01	55.0	25-Jul	0636	0610	0645
	B02	37.0	25-Jul	1045	1128	1136
	B03	25.0	23-Jul	1757	1707	1726
	B04	46.1	21-Jul	0929	0906	0931
	B05	60.0	20-Jul	1635	1648	1613
Nigeria	N01	67.0	24-Jul	1315	1245	1322
	N02	15.0	24-Jul	0800	0700	0738
	N03	82.0	24-Jul	1636	1840	1644
	N04	35.0	24-Jul	0956	0930	1005

(a) Phytoplankton communities were sampled with a 64µm mesh net of 34cm ring diameter. The samples were collected by towing the net in a horizontal manner for about five minutes. The towing speed was 1.5 knots.

(b) Zooplankton samples (referred to as ichthyoplankton) were collected with a 300µm mesh of 34cm ring diameter. This was towed in a step oblique manner in three steps, by paying out 10m of wire after each 5–minutes of tow. The towing speed was 1.3–1.5 knots.

(c) Zooplankton samples were collected with a 200µm mesh net of 34cm ring diameter. The net was hauled in a vertical manner from above 5metres of the water bottom at each sampling station. Four replicates were taken at each station and pooled together as one sample.

The amount of water filtered by each net was calculated from the readings of the respective flowmeters attached to the nets. Phytoplankton samples were fixed with acidic Lugol's solution and zooplankton with buffered formaldehyde of 4% strength.

2.7.1 Phytoplankton Sample Processing

Phytoplankton samples collected from the field were concentrated using 20microns mesh and the contents made up to 400ml in a round-bottomed flask. After shaking the contents of the flask vigorously, 1.0ml aliquot was taken and poured into a Sedgewick-Rafter cell counting chamber. The phytoplankton species were identified and counted under a Leica compound microscope. Species identification was carried out using taxonomic keys of Tomas (1997) and ICES (1992).

2.7.2 Zooplankton Sample Processing

For each zooplankton collected, the samples were concentrated using 60µm mesh and the formalin used in fixing the samples was drained. Depending on the amount of sample collected, a fraction of the sample was prepared for analysis using a Folsom splitter (Omori and Ikeda, 1984). This was made up to 400ml with water in a round-bottomed flask. The contents in the flask were shaken to ensure uniform distribution in the flask after which three aliquots of 2.5 ml each were taken with a Stempel pipette. All individuals in each Stempel pipette were identified to the lowest possible taxon, and counted using a Leica dissecting microscope.

Species abundance from the three aliquots was averaged for each sample. The aliquots were taken on the premise that at least 300-500 specimens would be present (Omori and Ikeda, 1984). The flow meter readings were used to estimate zooplankton counts per cubic meter of seawater. Species identification was carried out using various identification guides and taxonomic keys including Wilson (1932); Owre and Foyo (1967); ICES (1992); Wiafe and Frid (2001).

2.7.3 Data Analysis

A suite of multivariate statistical procedures was employed in analysing the data. Species/taxa abundance was converted as number of individuals per metre cube of seawater. Data used in the community characterisation comprised those, which represented at least 2% of the total abundance in at least one sample. This criterion for selecting taxa to be used in data analyses became necessary due to sporadic occurrence in low abundance of some taxa, which could have biased statistical analyses.

Bray-Curtis similarity matrix was computed from fourth-root transformed ($\sqrt{\sqrt{x}}$) data, and standardized as zero mean and unit standard deviation. The matrix was used via principal component analysis to construct a hierarchical dendrogram of the communities. One-way analysis of similarity test (ANOSIM) (Clarke and Warwick, 1994) was carried out on the similarity matrix and the test statistic (R), was computed from 5000 permutations.

2.8 FISH POPULATION CHARACTERIZATION

A second (wet season) survey was conducted between 22nd and 31st July 2003 to coincide with the upwelling season that occurs in the western Gulf of Guinea. One of the aims of the survey was to document the fish population in the wet season. As in the dry season survey, twenty-six (26) trawl hauls were made comprising three (3) hauls on each of the five laterals and eleven (11) along the proposed main pipeline route at approximately 50 km intervals. The trawls were conducted using a 7.6m (25ft) Marinovich Otter Trawl sampler equipped with a cod-end mesh size of 2cm. Each trawl was deployed along a predetermined transect with at scope of at least 3:1 (wire length:depth) ratio, with the starting point being recorded as when the net is fully deployed on the bottom. The net was towed at a rate of 3 knots for 10 minutes and retrieved while the GeoExplorer maintained a speed of 5 knots. The end point of the trawl was recorded as when the retrieval commenced. The start and end points of each trawl were determined by the vessels DGPS and recorded in both the ship's log and on the Chief Scientist's Station Log.

Upon net retrieval, the contents of the net were transferred to plastic tubs where the organisms were sorted by species and identified to the lowest possible taxon, counted, photographed, measured for length, width, weighed, and sexed where possible. Representatives of each species were preserved for future reference. Species diversity along the laterals and the main line was calculated using the Shannon Diversity Index.

During the dry season survey a scallop (*Chlamys purpuratus*) bed was identified at station T26 in Ghanaian waters. In order to confirm its distribution and delineate its boundaries, four (4) additional trawl hauls were made at 1 km radius from the station, in angular displacements of 90 degrees.

2.9 AQUATIC MACROPHYTE SAMPLING

An initial survey for the occurrence and abundance of marine algae in the rocky intertidal zone was carried out along transects that are coincident with the laterals. This early reconnaissance of the study area suggested that these habitats, which tend to support macroalgae, are only present on the two Ghanaian laterals, whereas the other sites had sandy bottom substrates. Therefore, even though this habitat is an offshore one, the sampling was done in association with the onshore fieldwork (correspondingly, the results can be found within the Ghana onshore results, Section 4). Sampling was not conducted in the freshwater areas since freshwater aquatic macrophytes were low in density. Two of the 60m onshore transects with four sampling points each at 20m interval, starting at the high tide mark, but randomly located laterally in the pipeline ROW, were used to sample these two habitats in Ghana.

The high and low water marks' coordinates were determined using a GPS and recorded. The habitat, shore type, biotope and community of macroalgae in the general shore area was described for a 10m-line transect drawn from where macroalgae cover begins and move seawards. The intertidal area was divided into lower and upper shores and abundance or cover was estimated. One-meter square quadrats were placed at the 1, 5, 7 and 9-meter marks on the line transect drawn. The algal species within the bare ground and their percentage cover/abundance were estimated by eye. Algae observed while sampling were collected, photographed, preserved, and identified to as low a taxon as possible. The presence of faunal forms and other characteristic species in the general quadrat area were noted and recorded, as well.

2.10 MARINE BIRDS, MAMMALS, REPTILES

Information on the local populations of marine Birds, Mammals, and Reptiles was obtained primarily from the literature. However, deliberate observations of species distributions, estimated numbers, and behavior was recorded whenever available during the cruise. These observations were recorded by the Chief Scientist or Shift Leader in the Daily (Shift) Report. The deliberate observations made included marine bird surveys, which were carried out at 0600hrs GMT each day, employing a pair of binoculars. Birds in the field of view within a 200m radius were identified and their numbers estimated.

2.11 METEOROLOGICAL CONDITIONS AND OCEAN CURRENTS

Meteorological conditions and ocean currents were recorded during sampling activities on each Station Log and on the GeoExplorer's Bridge Log. The observations recorded include:

- Wind Speed
- Wind Direction
- Wave Height
- Current Speed
- Current Direction

All observations were originally recorded by the ship's crew into the Bridge Log and transcribed onto the Station Logs by the Chief Scientist or Shift Leader.

2.12 DOCUMENTATION, SAMPLE TRACKING, STORAGE, AND SHIPPING

2.12.1 Documentation

Documentation included the following:

- Daily (Shift) Reports
- Station Logs
- Fish Trawl Logs
- Plankton Trawl Logs
- Bridge Logs
- Field Notebooks (for on-board laboratory results)
- Chain-of-Custody Forms
- Photographs

Daily Reports and Station Logs were maintained by either the Chief Scientist or the appropriate Shift Leader. Trawl Logs were maintained by the Trawl Master. Bridge Logs were maintained by the crew of the GeoExplorer. Field notebooks, used to record the results of shipboard analyses were filled out by the laboratory staff. ICF has maintained custody of all original field documentation, notebooks, electronic navigation logs, still and video photography. Chain-of-Custody (CoC) forms were used to record the identification of each sample along with the preservation method, required analyses and were signed by scientific party personnel.

The CoC forms accompanied the samples at all times during transport from the vessel to the laboratory where analyses were to be conducted. The Offshore EBS Cruise is documented in narrative form in a comprehensive Cruise Report submitted by the Chief Scientist and is included with this document as Appendix I.

2.12.2 Documentation, Sample Tracking, Storage and Shipping

All samples were placed in appropriate storage containers immediately after collection and affixed with a unique label containing the following information:

- sample identification number
- date and time of collection
- person responsible's initials
- type of analysis (e.g., metals), and
- preservative.

This information was used to generate sample chain-of-custody forms and shipping manifests for sample transfer and shipment to the analytical laboratories. Sediment chemistry samples were then transferred to freezers. Benthic samples were fixed in borax buffered 15 percent formalin and stored at room temperature. Water column samples were refrigerated or processed onboard.

Samples designated for analysis at laboratories in the US and archived samples were stored frozen and then placed in coolers with blue ice for transport via international airfreight. Samples analyzed in West African laboratories were transported from the vessel to the analytical laboratories in a similar manner. Shipping coolers included an adequate coolant to sample ratio to maintain stable temperatures during transport. Each shipping cooler included a chain-of-custody form and a copy of the shipping manifest.

CHAPTER 3
ANALYTICAL METHODS

3.1 PHYSICAL LABORATORY METHODS

Grain Size/particle Size Distribution

Mechanical sieving of larger size particles and hydrometer separation of finer particles were used to determine the grain size and/or particle size distribution of soils and sediments. The methods referenced include the Bouyoucous (1951) method, sieve/hydrometer methodology equivalent to ASTM D-422, or by the semi quantitative Page et al.(1987) method measuring settling of particles against standard published rates. The methods are considered to provide data of comparable quality although direct comparison of the data may be difficult depending on the series of sieve sizes used and the relative particle size distribution of the soil samples. All methods produce comparably usable information at larger grain sizes. The hydrometer method is preferred over the Page et al. (1987) method at small grain sizes (less then 50 μm).

Sieve Method

This test method covers the quantitative determination of the distribution of particle sizes in soils. The sieve method determines size constituents based on passing the dried material through sieve screens of various sizes and weight determinations of the fractions retained on each the sieve. In most cases the addition of a dispersion agent (sodium hexametaphosphate) aids uniformity of the soil mixture and accurate sieving. The accuracy and division of this data is based on the number and division of screens employed which can vary widely. The distribution of particle sizes larger than approximately 75 μm (retained on the No. 200 sieve) is determined by sieving.

Hydrometer Method

The distribution of particle sizes smaller than approximately 75 μm is determined by a sedimentation process, using a hydrometer. The hydrometer methodology quantitatively determines the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer. The hydrometer method of estimating particle size analysis (sand, silt and clay content) is based on the dispersion of soil aggregates using a sodium hexametaphosphate solution and subsequent measurement based on changes in suspension density. The use of the ASTM 152 H-Type hydrometer is based on a standard temperature of 20°C and a particle density of 2.65 g cm-3 and units are expressed as grams of soil per liter. Corrections for temperature and for solution viscosity may be made by taking a hydrometer reading of a blank solution. The method has a detection limit of 1% sand, silt and clay (dry soil basis) and is generally reproducible within 8% (relative). In the Page (1987) settling method, after sieve fractionation, the finer silt and clay particles are suspended and allowed to settle. Given published rates of migration of known particle sizes pipette samples are taken, dried and weighed to estimate the mass of clay and (by difference) the mass of silt. Accuracy of this method is lower and considered only semi-quantitative.

pH/Soil reaction

The pHs of soil samples were determined using the saturated paste and pH meter. This quantitative but screening level method determines the pH of soil, using a saturated paste prepared from the soil and a pH meter. It is most applicable to soils with a pH ranging from 4.0 to 9.0. It is not possible to determine the total acidity or alkalinity of the soil from pH because of the nature of the colloidal system and junction potential. This method does however provide information on the disassociated H-ions affecting the sensing electrode. The method is generally reproducible within 0.2 pH units.

3.2 CHEMICAL LABORATORY METHODS

3.2.1 Alkalinity

Onshore and offshore surface water samples were analyzed for alkalinity. Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity of water is due primarily to the presence of bicarbonate, carbonate, and hydroxide ions. Salts of weak acids, such as borates, silicates, and phosphates, may also contribute. Salts of certain organic acids may contribute to alkalinity in polluted or anaerobic water. Bicarbonate is the major form of alkalinity. Carbonates and hydroxide may be significant when algal activity is high, and in certain industrial water and wastewater, such as boiler water. Alkalinity is expressed as phenolphthalein alkalinity or total alkalinity. Both types can be determined by titration (APHA 2310 STD Method, 19th ed. 1995) with a standard sulfuric acid solution to an end point pH, evidenced by the color change of a standard indicator solution (generally methyl orange) or by pH meter.

3.2.2 Biochemical Oxygen Demand (BOD5)

Onshore surface water samples were analyzed for BOD5 to determine the extent to which oxygen within a sample can support microbial life. Analyses were performed according to the Winkler titration method equivalent to APHA 422 (STD Method 19th ed., 1995). Initially samples are initially seeded with microorganisms and supplied with a carbon nutrient source of glucose-glutamic acid. The sample is then introduced to an environment suitable for bacterial growth at reproducible temperatures, nutrient sources, and light within a 20^{o}C incubator such that oxygen will be consumed. Quality controls, standards and dilutions are also run to test for accuracy and precision. Determination of the dissolved oxygen within the sample can be determined through Winkler titration methods. The difference in initial DO readings (prior to incubation) and final DO readings (after 5 days of incubation) predicts the BOD of the sample.

3.2.3 Chemical Oxygen Demand (COD)

Onshore and offshore surface water samples were analyzed for COD. The mg/L COD results are defined as the mg of O_2 consumed per liter of sample under conditions of this procedure. The samples are analyzed using the closed reflux method with spectrophotometric or titrimetric determination equivalent to APHA 5220D (STD Method 19th ed., 1995) or APHA 5220D (STD Method 19th ed., 1995). In the reactor digestion method, the sample is heated for two hours with a strong oxidizing agent, potassium dichromate. Oxidizable organic compounds react, reducing the dichromate ion (Cr2O72-) to green chromic ion (Cr3+). Mercuric sulfate addition is critical to removal of chloride interferences. Spectrophotometer or titration measurement provide essentially equivalent quantitation of the concentration of chromic ion.

3.2.4 Electrical Conductivity

Onshore surface water samples were analyzed for electrical conductivity in certain countries. Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, and valence; and on the temperature of measurement. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all. Electrical conductivity was measured *in situ* in surface water samples using standard conductivity meters.

3.2.5 Exchangeable Acidity

Onshore and offshore sediment samples were analyzed for exchangeable acidity to provide a measure of the cation exchange capacity of the soils in combination with alkaline metal analyses. Cation exchange capacity is a criterion in assessment for disposal or utilization of organic or industrial wastes for agricultural crops. Exchangeable acidity is determined by titration relative to known buffer solutions.

3.2.6 Nitrogen forms (Nitrate, Nitrite, Ammonia Nitrogen, Total Nitrogen)

Various measurements of nitrogen were analyzed for in onshore and offshore surface water, sediment, and soil samples. The forms of nitrogen measured include nitrate, nitrite, ammonia nitrogen, total nitrogen, although in cases only specific forms of nitrogen were measured in the same series of samples. The analyses of the various forms rely on chemical reaction of the samples with catalyzing agents (for example cadmium metal in the analysis of nitrate nitrogen reduces nitrate in the sample to nitrite) to ensure or distinguish chemical forms of nitrogen. Then reaction with color forming agents (for example sulfanic acid in nitrate analysis) to form specifically colored complexes and/or compounds. Measurements of the concentrations of the nitrogen form are then made spectrophotometrically at specific wavelengths against standard concentration curves.

3.2.7 Phosphorus forms (phosphate, orthophosphate, reactive phosphorus, total phosphorus)

Onshore and offshore water samples were analyzed for forms of phosphorus. Phosphates are important nutrients at low concentration, at higher levels can be an indicator of discharges, and at high levels can lead to eutrophication under certain conditions. Phosphorus analyses APHA 4500-PE (STD Methods 19th ed) consist of two general procedural steps: (*a*+) conversion of the phosphorus form of interest to dissolved orthophosphate, and (*b*) colorimetric/spectrophotometric determination of dissolved orthophosphate. The primary forms determined in this program were reactive phosphorus and total phosphorus. Phosphates that respond to colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample are termed ‘‘reactive phosphorus.’’ While reactive phosphorus is largely a measure of orthophosphate, a small fraction of any condensed phosphate present usually is hydrolyzed unavoidably in the procedure. Reactive phosphorus occurs in both dissolved and suspended forms. Total phosphorus (orthophosphate, condensed, and organically bound) can be determined by acid oxidation with persulfate, followed by the reactive phosphorus test. Organically bound phosphate can then be determined by subtracting the acid-hydrolyzable phosphorus.

3.2.8 Polyaromatic Hydrocarbons (PAHs)

PAH analysis was performed on soil, sediment, and surface water samples. PAH analysis provides a measure of higher molecular weight organic compounds often related to petroleum products or contamination or combustion products. Measurements of total PAHs involve preparation of the sample to concentrate the PAHs, and analysis by gas chromatography typically by flame ionization although possibly also by mass spectrometry (MS) for verification of specific compound identification with minimal loss of sensitivity. Additional extract clean ups may precede analysis where other suspected interfering compounds may be present. Quantitation of the results as total PAHs provides a relative measure of the concentrations of PAH compounds where identification of specific PAH compounds can add to the interpretation of the source of elevated PAHs.

3.2.9 Solids (Total Suspended Solids, Total Dissolved Solids)

Measurements of solid components (TSS and TDS) were determined in offshore and onshore water samples. TDS/TSS provides a measure of the total water soluble/insoluble fraction and do not reveal the quantity or type of individual contaminants in the sample TDS analyses were determined using in situ meter determinations calculated at reference conditions from conductance. TDS laboratory measurements were determined from gravimetric procedures equivalent to APHA 2540 C (STD Method, 19th ed, 1995). TSS was determined using gravimetric procedures equivalent to APHA 2540 D (STD Method, 19th ed, 1995).

3.2.10 Sulfate

Determination of sulfate in surface water samples was based on the barium chloride turbidity method equivalent to APHA 4500-Si (STD Method, 19th ed, 1995). Barium chloride is added and turbidity caused by barium sulfate suspension which is proportional to sulfate concentration is measured either spectrophotometrically or using a turbidimeter.

3.2.11 Total Petroleum Hydrocarbons (TPH)

TPH analysis was performed on soil, sediment, and surface water samples. TPH analysis provides a determination of organic petroleum –related compounds. Measurements of TPH involve preparation of the sample to concentrate the compounds of concern, and analysis by gas chromatography typically by flame ionization. Additional extract clean ups may precede analysis where other suspected interfering compounds may be present. Quantitation of the results as TPH provides a relative measure of the petroleum related concentrations.

3.2.12 Total Organic Carbon

Determination of total organic carbon in sediment and soil samples was by the Walkley and Black (1934) method modified by Nelson and Somners (1982) using potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement. This method quantifies the amount of oxidizable organic matter in which OM is oxidized with a known amount of $Cr_2O7_2^-$ in the presence of sulfuric acid. The remaining Cr_3^+ chromate is determined spectrophotometrically at 600nm wavelength. The calculation of organic matter is based on organic matter containing 58% carbon. The method has a detection limit of approximately 0.01% and is generally reproducible within 8%. Alternatively the loss of ignition method (Page et al., 1987) was utilized which is not directly comparable but provides sufficient data quality when compared with data using the same methodology.

3.2.13 Turbidity

Turbidity was measured in offshore and onshore surface water samples. Measurements varied from in situ determination via Secchi disk method to APHA 2130 B (STD Method 19th ed., 1995). Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. Although the methods are not comparable, the determinations are internally comparable and consistent. For clarification the Secchi disk determinations will be termed clarity while turbidity will be applied only to optical scattering instrumental determinations (nephelometer). Secchi disk measurement provides field screening level determination of clarity. Nephelometer measurements are considered fully quantitative.

3.3 BIOLOGICAL LABORATORY METHODS

Biological laboratory methods for assessment of phytoplankton, zooplankton, phytoplankton productivity, microbiology identifications, and macrobenthic identification and diversity were performed to characterize the biological baseline conditions.

3.3.1 Plankton and Productivity

In the laboratory known values of water samples for phytoplankton analysis were analyzed using a microscope at multiple magnifications. Sedimentation was carried out in counting chambers, cell counts were made in duplicate and average cell counts per ml computed.

Filamentous and colonial forms were counted as individuals and their numbers multiplied by the average numbers of cells for filament or colony (determined for some 20 individuals) as carried out by Lund et al. (1958). Identifications were carried out standard reference materials that may have differed based on accepted country standards.

The formulas used for estimation of respiration, photosynthesis and relative productivity were as per Wetzel and Likens (1990).

1. Respiratory activity per unit volume
   Per time interval ($mg0_2/L/hr$)
   IB - DB (IB = initial oxygen)
   (DB = 0_2 Dark bottle)

2. Net photosynthetic activity per unit
   Volume per time interval ($mg0_2/L/hr$)
   LB - IB (IB = initial oxygen)
   (LB = 0_2 light bottle)

3. Gross photosynthetic activity ($mg0_2/L/hr$)
   (LB - IB) + (IB - DB) = Net photosynthesis + Respiration

4. Relative production ($mg\ C/m^3/hr$)

$$\frac{[(0_2\ LB) - (0_2\ DB)]\ \times (1000)\ (0.375)}{(PQ)\ t}$$

0.375 = ratio of moles of carbon to moles of oxygen ($12\ mgC/32\ mg0_2$)
t = time of exposure = 12 hrs

PQ = 1.2 = Dimensionless number indicating the relative amount of carbon Involved in the processes of photosynthesis and the constant is given as 1.2

Relative productivity ranges are

$1.0mgC/hr/m^3$/ for sea (Doty and Oguri, 1957)
11(- 29) ($mg\ C/hr/m^3$) for Inland water (Elster, 1965)

3.3.2 Macrobenthic infauna

In the laboratory, each of the macrobenthic samples was emptied into a Petri-dish and examined under the dissecting microscope. The recorded organisms were sorted out, identified and counted. Identification was done as much as possible to species level using relevant literature. Where fragmented animals were found, only those with heads were counted. The determination of diversity (species richness and diversity indices) of the original macrobenthic communities were based on the measurements made. Taxa richness was computed using Margalef's index (D) expressed as

$$D = \frac{S-1}{InN}$$

Where S = number of taxa
N = total number of all individuals
In = natural logarithm

General species diversity using Shannon Wiener (H) index was computed as

$$H' = \frac{N \log N - \sum_{i=1}^{k} n_i \log n_i}{N}$$

where: n = total number of individuals
ni = number of individuals in species
k = total number of species

Evenness index (E) expresses the degree of uniformity in the distribution of individuals among the taxa in the collection was also calculated as follows:

$$E = \frac{H'}{H_{max}}$$

where: H' = Shannon-Wiener index
H_{max} = maximum expected diversity expressed as logs
S = number of taxa

Besides the application of the diversity indices, interstation comparisons were carried out to test for significant differences in the faunal abundance using one-way analysis of variance (ANOVA) according to Zar (1984).

3.4 DATA ANALYSIS AND REPORTING

Management of the environmental data was distributed across the project teams with ICF playing a central and coordinating role. The initial responsibility for data management and quality resided in the individual participating organizations and laboratories. For the onshore programs, overall field and final laboratory was managed by the individual teams, who also verified data quality in terms of the project goals. ICF performed a back up role. For the offshore program, ICF played a central role in managing and reporting the field and laboratory data, although the laboratories conducting the analyses were key to this process.

Relative to management of chemical data for this report, data were managed electronically, mainly in the form of computer spreadsheet applications (e.g., Microsoft Excel), which reduced the need for transcription and potential for errors. A database was used to track and monitor the sample analyses from the onshore and offshore programs while they were in progress. It is intended that the final laboratory results for the chemical and biological parameters from this survey, as well as additional data collected in the second season of data acquisition, be managed in a project–specific database.

Data analyses in this report are presented essentially as reported by the participating organizations and laboratories. These same organizations provided brief interpretation of the data and in some case conducted some data analysis and limited statistics.

3.5 DATA QUALITY OBJECTIVE FOR CHEMICAL AND PHYSICAL ANALYSES

To ensure data quality, a comprehensive quality program was implemented. Elements of the quality program include the following:

- Development of planning documents including work plan and SOPs
- Audits of the participating laboratories and organizations prior to and following the project
- Oversight of field sampling operations
- Collection of field quality control samples (Equipment blanks, field blanks, field replicates)
- Analysis of laboratory quality control samples (Laboratory Blanks, duplicates, matrix spikes, interference control samples

These elements of the quality program are intended to ensure that the data generated in the studies are usable for intended purposes and meet minimum data quality standards. Data quality objective standards vary based on the expected use of the data and on the data generation process. The different levels are by convention discussed as DQO Levels I through III as described in table below varying from low data quality requirements and concomitant low data usability (DQO I) through highest level of data quality and widespread data usability (DQO III).

These standards are typically interpreted in terms of data quality indicators: precision, accuracy, representativeness, completeness, comparability and sensitivity (PARCCS). These elements are described further below.

Table 3.5-1
Summary of Data Quality Objectives and Levels

Data Quality/Usability	DQO Level	Method
High	Level III	Standard, accepted methods with fully implemented QA/QC according to the methods (for example APHA, SW846, ASTM, NIOSH, etc.)
Moderate	Level II	Field analyses or laboratory analyses with minimal quality control (for example Hach kits, turbidity, colorimetric methods, titrimetric methods, gravimetric methods)
Low	Level I	Field analysis, meters with limited or no quality control (for example ph, temperature, dissolved oxygen, etc.)

3.5.1 Data Quality Objectives

3.5.1.1 Precision

Precision is defined in as a measure of agreement among individual measurements of the same property. For this program, high precision was obtained by:

- Use of standardized sampling procedures
- Linear or consistent instrument calibration
- Field and laboratory QC sample analysis

Field samples collected to assess precision include field duplicates and replicates, which may be spiked with compounds of interest prior to analysis. Laboratory QC samples which are used to assess precision include laboratory duplicates and replicate analyses. In addition to these QC samples, surrogate recovery can be used as a relative measure of precision. The types and frequency of QC sample collection and analysis is detailed below. The following three items are key components of precision evaluations.

Standardized Sampling Procedures

Field sampling procedures were detailed in the approved work plan that guided all field operations. The procedures were based on accepted procedures for sample collection and standardized forms were used to document the field work. These elements helped insure a high degree of precision.

Analysis of Calibration Standards

Analysis of calibration standards are method specific. Guidelines for calibration were based on DQO level. DQO level I field analyses required analysis of a minimum one point calibration and regular (once per day) calibration check. DQO level II field analyses utilized at least a multi-point calibration curve. Fixed laboratory analyses at DQO levels III normally require a multi-point calibration.

Analysis of Field and Laboratory Duplicates and Replicates

The relative percent difference (RPD) is calculated from the results of field sample replicates (spiked or unspiked) to assess precision. The DQO Level III methods required matrix spike analysis or laboratory control spike (i.e., blank spike) and laboratory control spike duplicate. Acceptable RPDs are differentiated by media, method, analyte, and concentration level (it is more difficult to be precise for example at very low spike levels) although generally acceptable RPDs are 25% for aqueous matrices and 50 % for other matrices.

3.5.1.2 Accuracy

Accuracy is defined as the degree of agreement of a measurement or average of measurements with an accepted reference or true value. For this program high accuracy was attained by:

- Use of standardized sampling procedures
- Collection of field blanks and equipment blanks
- Use of high quality analytical reference materials
- Instrumental performance
- Laboratory QC sample analysis

Field samples collected to assess accuracy include matrix spike samples, matrix spike duplicates for organic analyses, field blanks (bottle, trip, and equipment), and Performance Evaluation (PE) samples. Laboratory QC samples which are used to assess accuracy include matrix spikes, matrix spike duplicates, laboratory control spikes, method blanks, and instrument blanks. In addition to these QC samples, surrogate recovery can be used as a relative measure of accuracy. The following items are key components of accuracy evaluations.

Reference Materials

All reference materials used for calibration standards or spiking solutions were the highest purity available. Where possible, reference materials independent of the calibration standard material were utilized to insure accurate calibration.

Instrument Performance

Each instrument used on a project was required to be checked on each day that it is used to demonstrate acceptable performance. For example, the gas chromatography methodologies included daily calibration, and system performance checks. Comparable requirements exist for other analyses. The specific instrument performance requirements had to meet the appropriate DQO level and the analytical method specifications.

Recovery of Spiked Analytes

Either the field sample matrix or a standard matrix, such as deionized distilled water or blank soil, is spiked with a known amount of the analyte. The recovery are calculated for each spiked analyte using the results of the analysis. The choice of spiked samples versus standard matrices is based on the method selected. In order to assess accuracy, analysis of spiked samples or standard matrices should be utilized wherever possible based on the DQO level and according to the analytical method. Acceptable recoveries are differentiated by media, method, analyte, and concentration level (it is more difficult to be accurately recover at very low spike levels) and no common standard exists for all applications. Evaluation of spike results will rely on documented method criteria.

All samples for GC/MS analysis are spiked with known amounts of surrogate compounds. The recovery and bias are calculated for each spiked surrogate using the results of the analysis. Surrogate limits are based on well established analytical methods. Evaluation of surrogate results will rely on documented method criteria.

3.5.1.3 Completeness

Completeness is defined as a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under average conditions. Valid data are defined as data meeting the DQOs specified in the site-specific QAPjP. The project objective for completeness is 90%.

3.5.1.4 Representativeness

Representativeness is defined as an expression of the degree to which the data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Samples collected for the purpose of chemical or physical characterization of a population must be representative of the populations they are intended to characterize. The results obtained from the analysis of the sample will be used to assess the character of the whole, and frequently these results will be used to determine whether a process, a product, or a condition is acceptable as compared with some predetermined standard or regulation. Therefore, sample selection, collection, and handling methodologies must be based on or derived from procedures or practices that will either deliver a portion of the whole either as it originally existed or altered in a controlled manner.

For this project, the principal sources of uncertainty with respect to representativeness are sample collection and handling methods, temporal variations, and spatial variations. Variability associated with location (spatial) is generally expected to be the largest source of uncertainty.

Objectives for representativeness are based on the proper implementation of a well thought out and defined sampling plan. To minimize the uncertainty, the sampling plan was designed with consideration of the following:

1. The purpose of collecting the sample;
2. The ultimate use of the data;
3. The important components or aspects of the source (or process) being studied;
4. Sample collection methods;
5. Sample location strategy, including, where appropriate, a statistical assessment of the probabilities of either under or over estimating the extent or level of contamination;
6. Timing and frequency of sample collections;
7. Individual sample size;
8. Sample preservation and control procedures; and

9. Quality control sample needs (co-located and replicate samples, split samples, trip and equipment blanks, or matrix spikes).

Evaluation of representativeness is a qualitative judgment based on overview of the entire program including field sample oversight, auditing, and planning documents. An assessment of data represetativeness is made and discussed in Section 8.

3.5.1.5 Comparability

Comparability is defined as an expression of the confidence with which one data set can be compared to another. Comparability is assured by development and specification of reporting requirements so that the analytical methods used for analysis are clear and that data results are easily interpreted (e.g., data units expressed uniformly).

3.5.1.6 Sensitivity

Sensitivity is the capacity of the methods used to meet decision criteria that may be based on regulatory standards or scientific need. Demonstration and documentation of method sensitivity limits were required from the participating laboratories.

3.5.2 Field Quality Control Samples

Specific field quality control samples were added to the EBS program to help assess the data relative to the data quality objectives.

3.5.2.1 Equipment Blanks

Equipment blanks are collected when sampling involves use of collection equipment that comes into direct contact with the sample (i.e., the modified Van-Veen grab) during or following the collection of sediment chemistry samples. The equipment blank is representative of potential contamination associated with the equipment.

For the EBS, blanks were collected as part of the offshore survey. To collect the equipment blanks, the grab was first decontaminated according to the procedure outlined in the work plan. Then the inside of the bucket is rinsed with high-purity, deionized water and the reinstate is collected directly into a clean, pre-labeled water sample container. The rinsate was refrigerated at 4°C and analyzed for metals and organic parameters.

3.5.2.2 Field Blanks

Field blanks are collected, which are representative of any atmospheric or other contamination that the field samples may be subject to and also of any potential contamination associated with the glassware.

For the EBS, blanks were collected as part of the offshore survey. A clean, pre-labeled sample jar of the same batch used for sample collection was opened during the collection of one sample and returned to the laboratory with the field samples and analyzed for metals and organic parameters.

3.5.2.3 Replicate Samples (Field Duplicates)

Field replicates are samples collected at the same location and time. The collection frequency and station designation for replicate samples was assigned by Chief Field Scientist and guided by the work plan. The number and type of samples wad based on site observations, daily sampling method frequency, and analytical aliquots collected. For the offshore survey, five replicates were collected.

3.5.2.4 Split Samples

Split samples are replicate samples collected according to the SOP and work plan requirements for replicate samples that are then analyzed independently by separate laboratories. The analysis of split samples allows for interlaboratory comparison to understand the relative comparability and overall data quality of the individual laboratories. For the project, split samples were collected during the offshore survey and analyzed by both the in-region, primary laboratory and a US laboratory.

CHAPTER 4
OFFSHORE SEDIMENT CHARACTERIZATION

4.1 CHEMICAL RESULTS

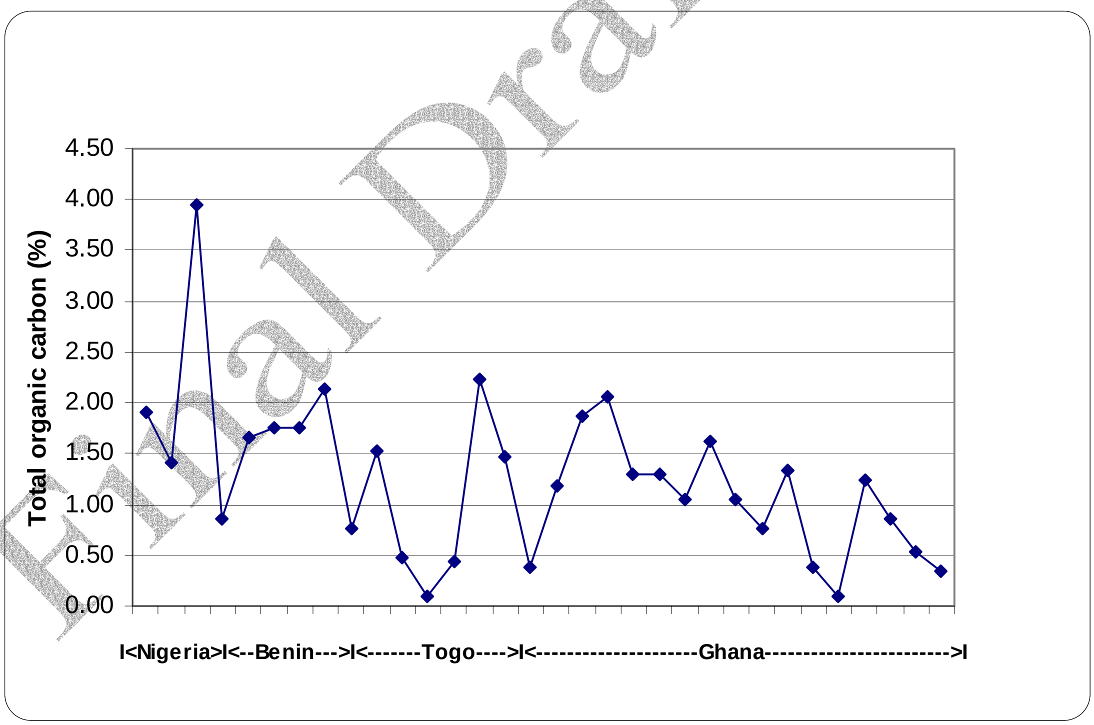
4.1.1 Total Organic Carbon (TOC)

Figure 4.1-1 shows the levels of TOC measured along the main pipeline route. The distribution along the laterals are depicted in Figures 4.1-2, 4.1-3, 4.1-4, 4.1-5, and 4.1-6 respectively for Nigeria (diagonal), Benin, Togo, Tema and Takoradi.

4.1.1.1 Main Pipeline Route

The TOC levels showed a general increase from west to east closely mirroring the pattern of clay distribution (Figure 4.2-1). All the stations recorded concentrations below 2.5% apart from Station 2B01C which was almost 4%.

Figure 4.1-1
Distribution of Total Organic Carbon along the Main Pipeline Route



4.1.1.2 Laterals

The percentage concentrations of TOC along the laterals portrayed a general decrease in concentration from deeper waters to shallow waters.

Figure 4.1-2
Distribution of Offshore Total Organic Carbon along Nigeria Diagonal

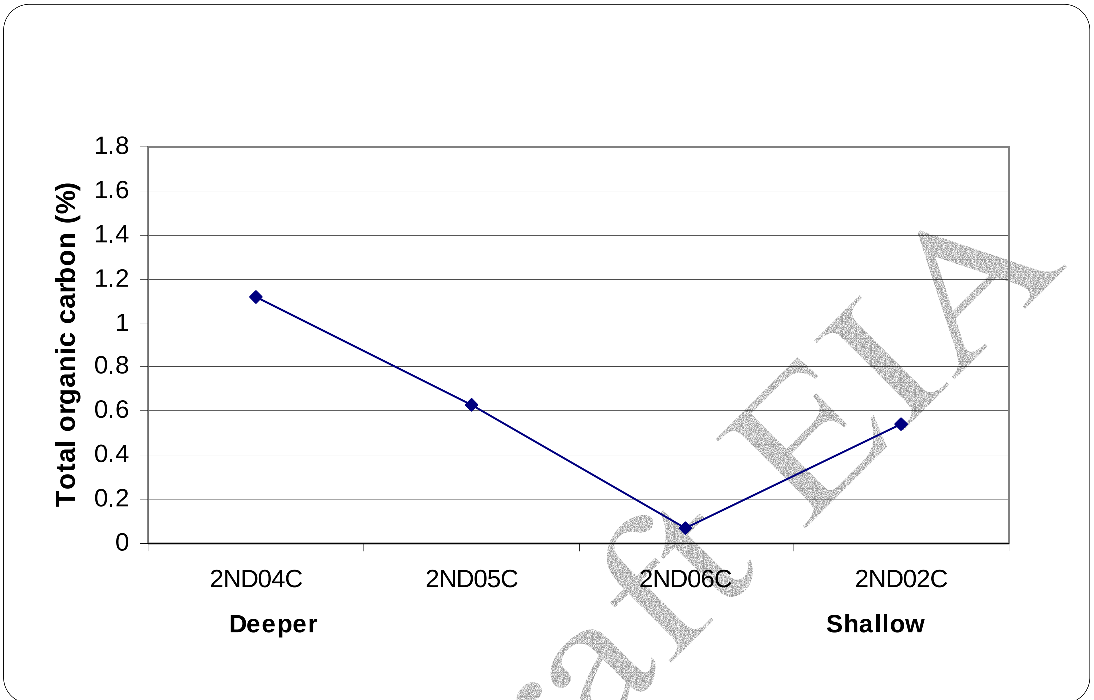


Figure 4.1-3
Distribution of Offshore Total Organic Carbon along Benin Lateral

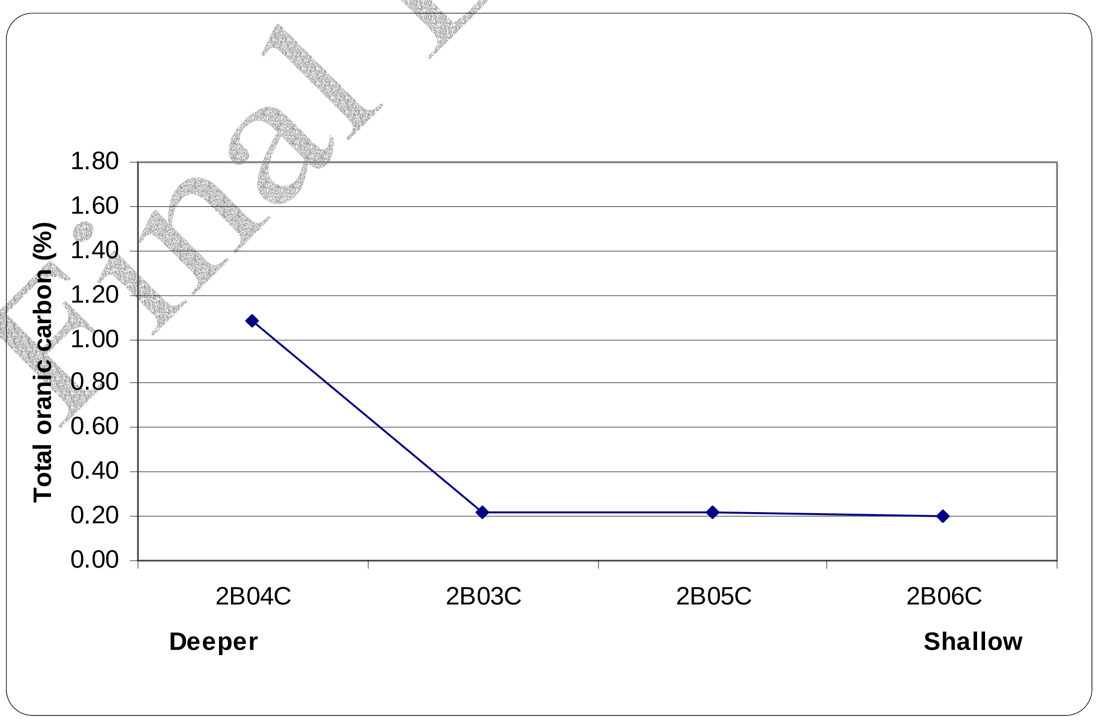


Figure 4.1-4
Distribution of Offshore Total Organic Carbon along Togo Lateral

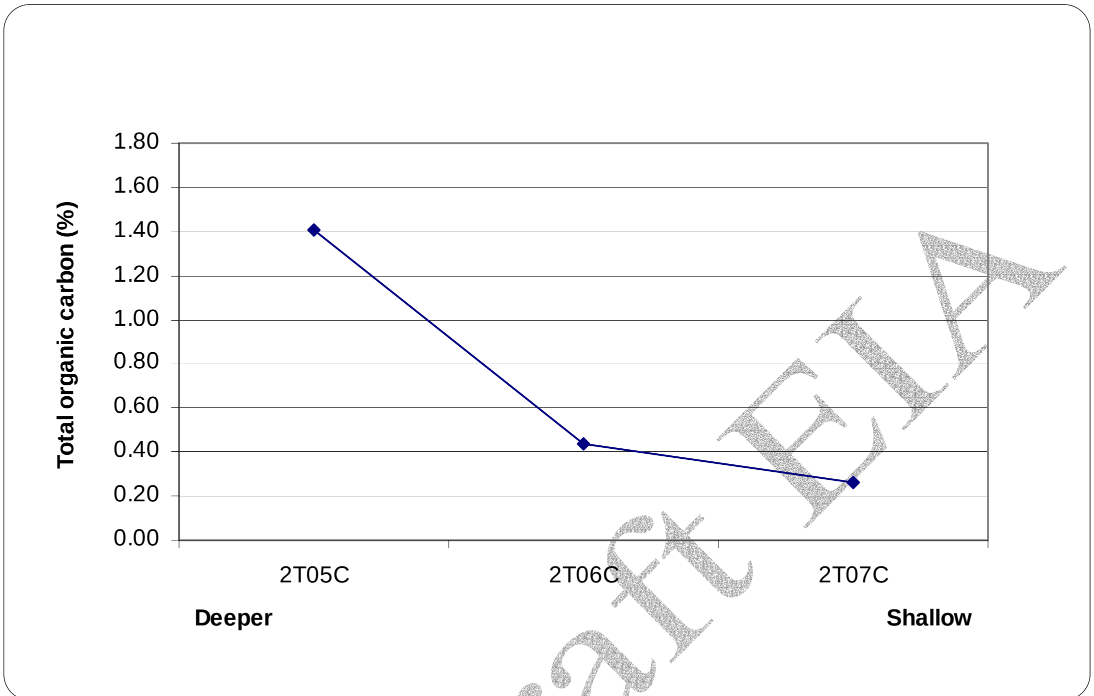


Figure 4.1-5
Distribution of Offshore Total Organic Carbon along Tema Lateral

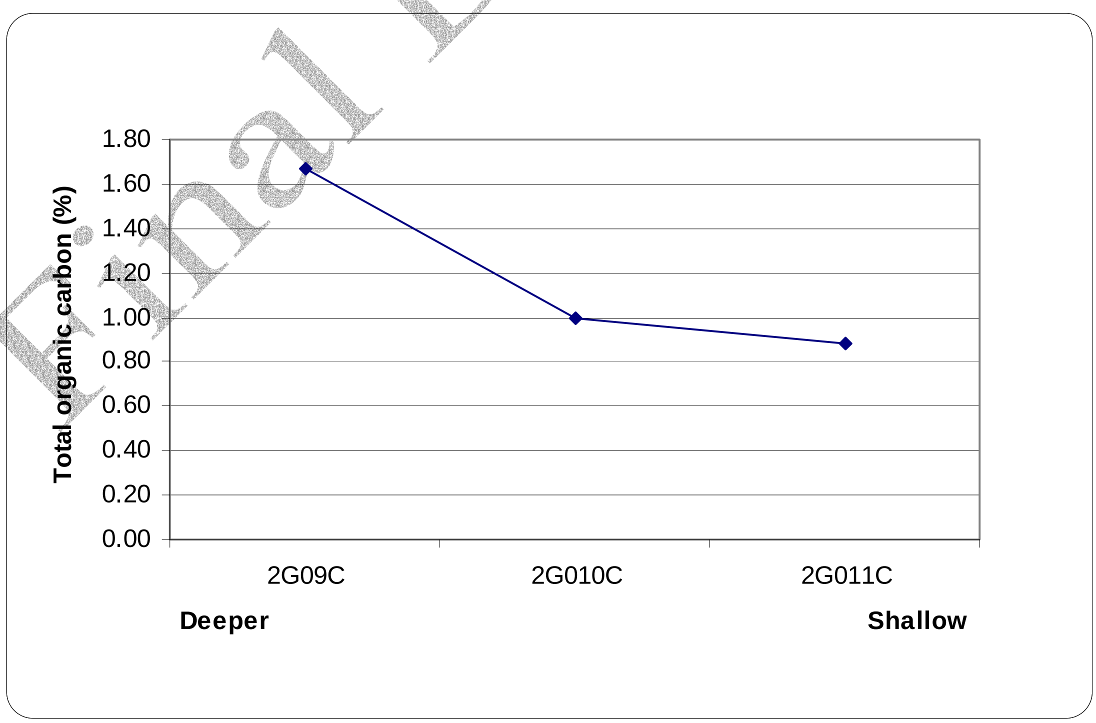
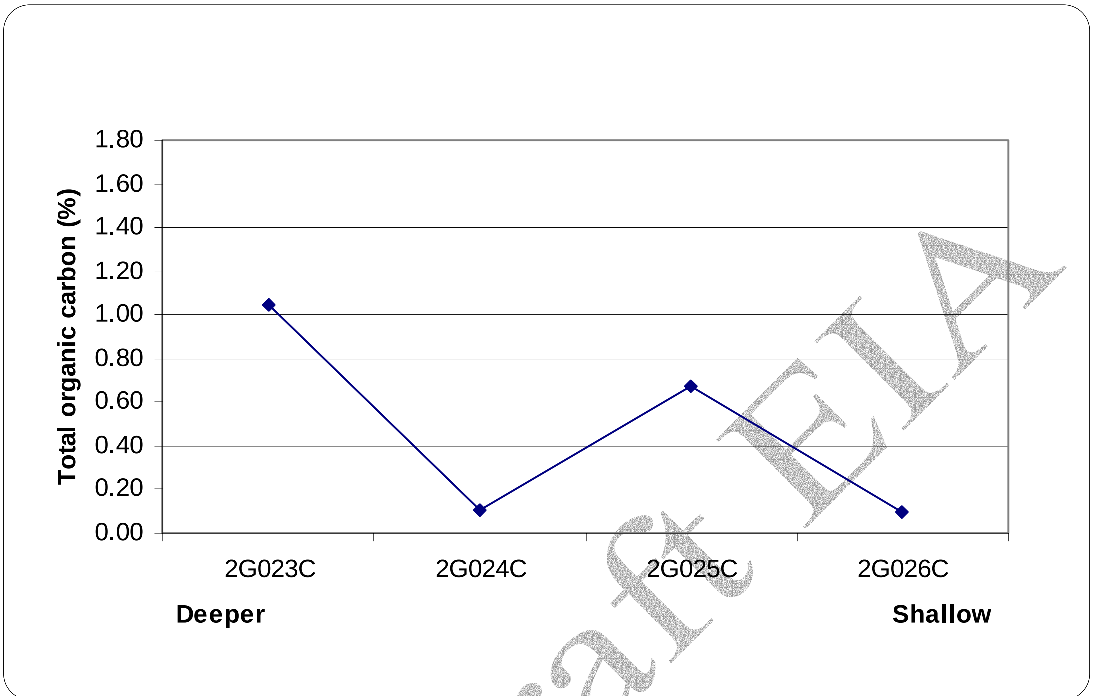


Figure 4.1-6
Distribution of Offshore Total Organic Carbon along Takoradi Lateral



In nearshore environments, the TOC of the sediment typically increases with the fineness of the deposit. This well known observation is reflected in the levels ascertained from deeper waters to the shallow offshore waters where deeper waters have relatively finer sediments. Thus construction activities in the deeper waters will introduce more organic carbon into the system than in the shallower waters.

4.2 PHYSICAL RESULTS

4.2.1 Sediment Particle Size

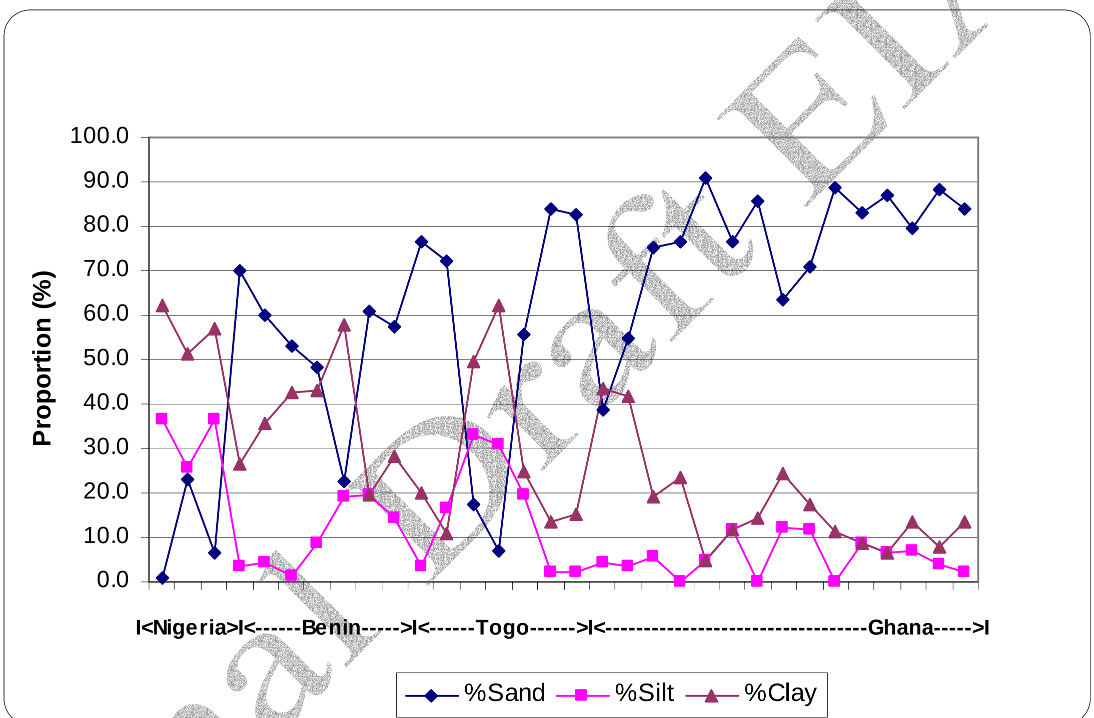
The bulk properties of sediment were determined using the grain-size distribution. Since sediment properties generally change with depth, the grain size analysis was done separately for the main pipeline route and for the laterals branching from the main pipeline to the shores in Benin, Togo, Ghana and Nigeria (Figures 4.2-1 to 4.2-6). The proportions of the sand, silt and clay determine the texture of the sediment. From the result, the texture of the offshore sediment along the main pipeline route and the laterals fell under seven categories namely: clayey sand, sand, clay, silty sand, silty clay, clayey mud and sandy mud.

4.2.1.1 Main pipeline route

The order of dominance of sediment texture in the 32 stations along the main pipeline route were 55% clayey sand, 21% sand, 12% silty clay and the rest clay, clayey mud, silty sand and sandy mud contributed about 12%.

From Figure 4.2-1, sand was appreciably high in the sediment along the main pipeline route in offshore sections of Ghana, whereas silt and clay were generally low. The other countries exhibited considerable variability in the proportions of sand, clay and silt distribution along the offshore pipeline corridor. On the whole, the sand component was generally high across the countries, the exceptions being Station 2ND04C (Nigeria) where clay particle dominated, and Stations 2ND03C, 2ND01C (Nigeria), 2B01C (Benin), 2T08C (Togo) and 2G01C (Ghana) where the dominant particle size was silty clay. In general, the proportions of silt and clayey sediment increased from west to east and sand from east to west.

Figure 4.2-1
Distribution of Offshore Sediment Parameters along Main Pipeline Route



4.2.1.2 Laterals

The description of the laterals includes the Nigerian diagonal and the terminal landward branch of the main pipeline at Takoradi. The proportions of the sand particle size generally increase toward shallower waters along the laterals. The other particle sizes (silt and clay) relatively decrease toward shallow waters (Figures 4.2-2, 4.2-3, 4.2-4, 4.2-5, and 4.2-6). A phenomenon explained by the stronger energy associated with waves and currents closer to the land.

Figure 4.2-2
Distribution of Offshore Sediment Parameters Along Nigeria Diagonal

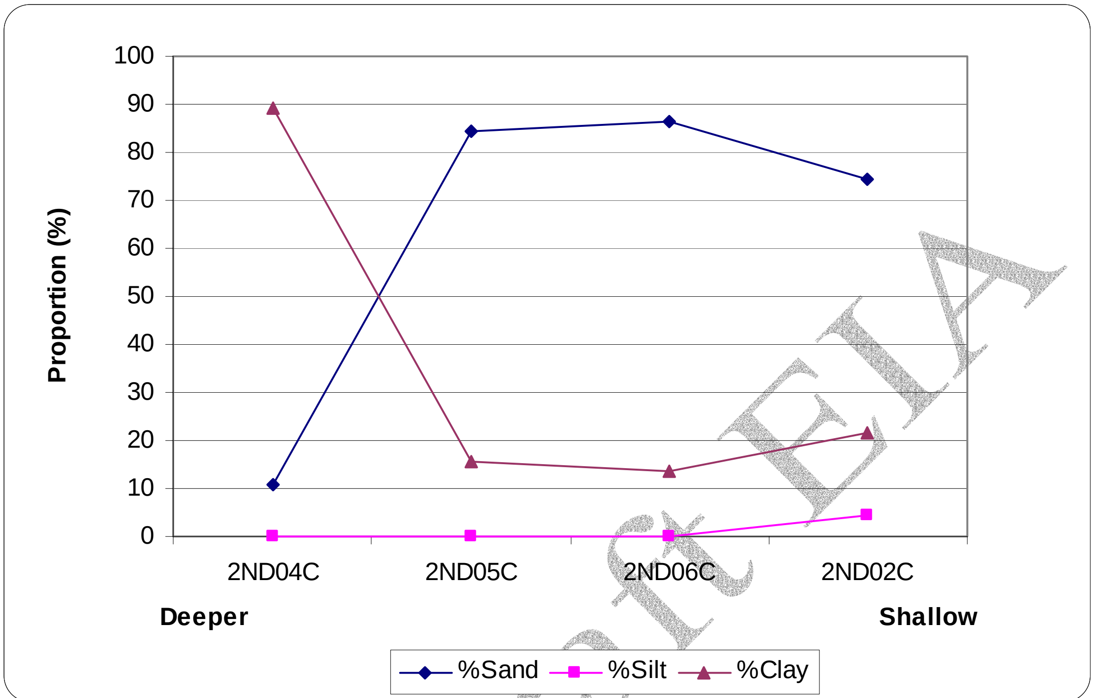


Figure 4.2-3
Distribution of Offshore Sediment Parameters Along Benin Lateral

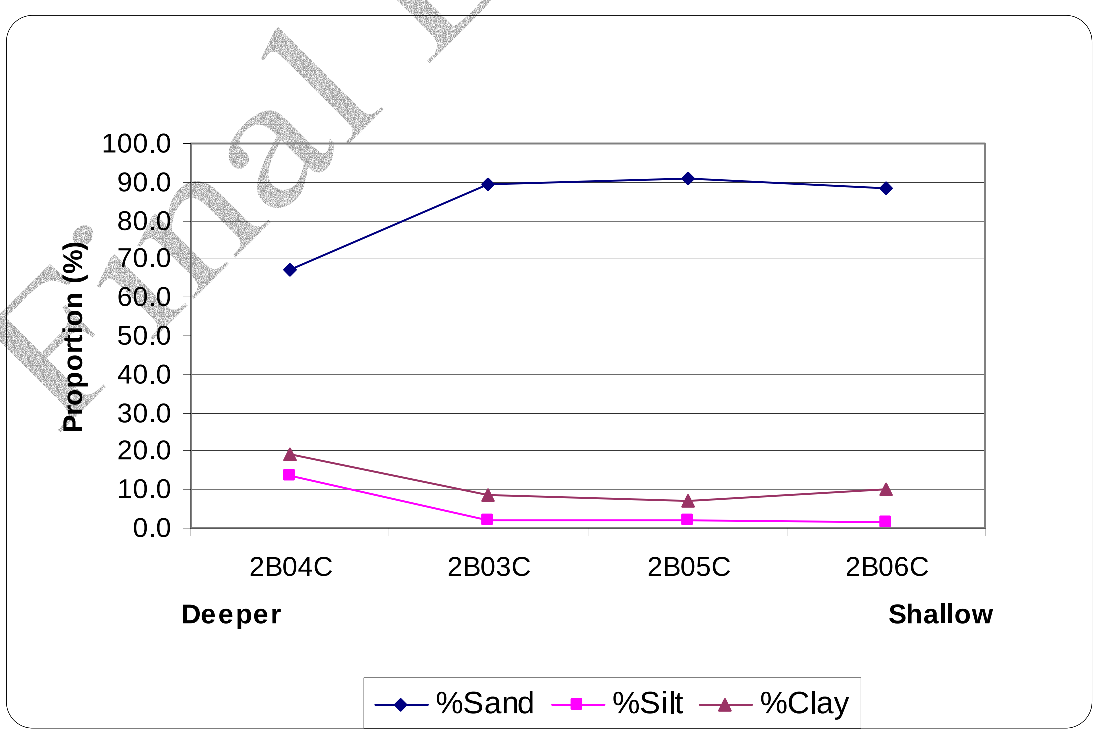


Figure 4.2-4
Distribution of Offshore Sediment Parameters Along Togo Lateral

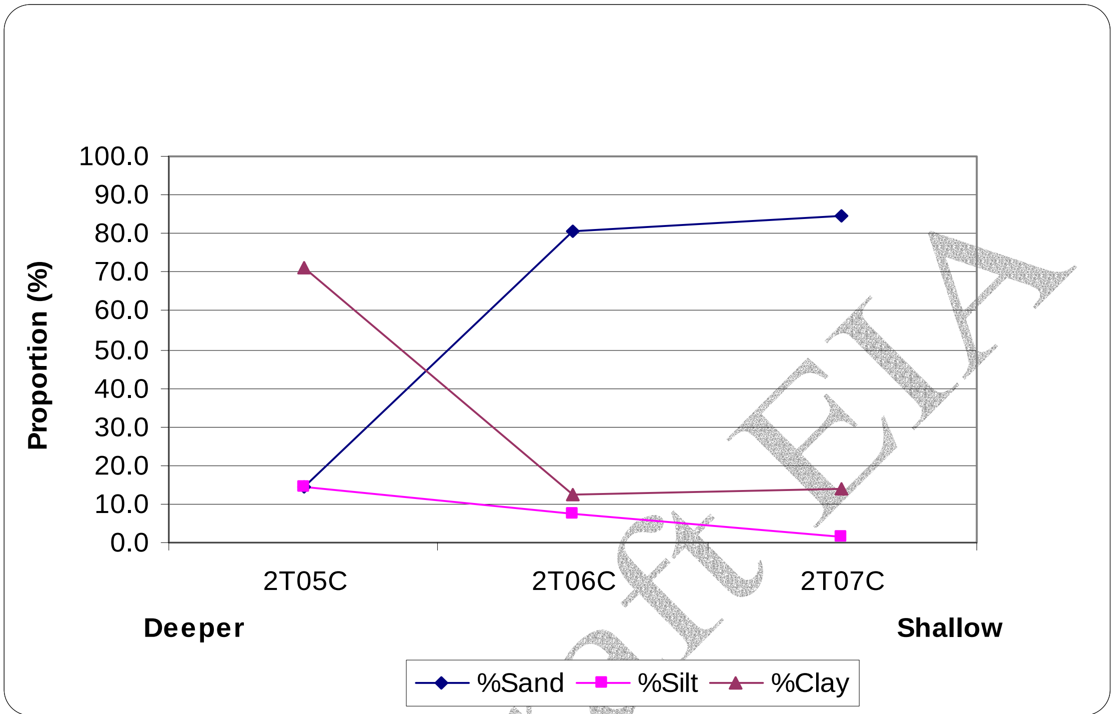


Figure 4.2-5
Distribution of Offshore Sediment Parameters Along Tema Lateral

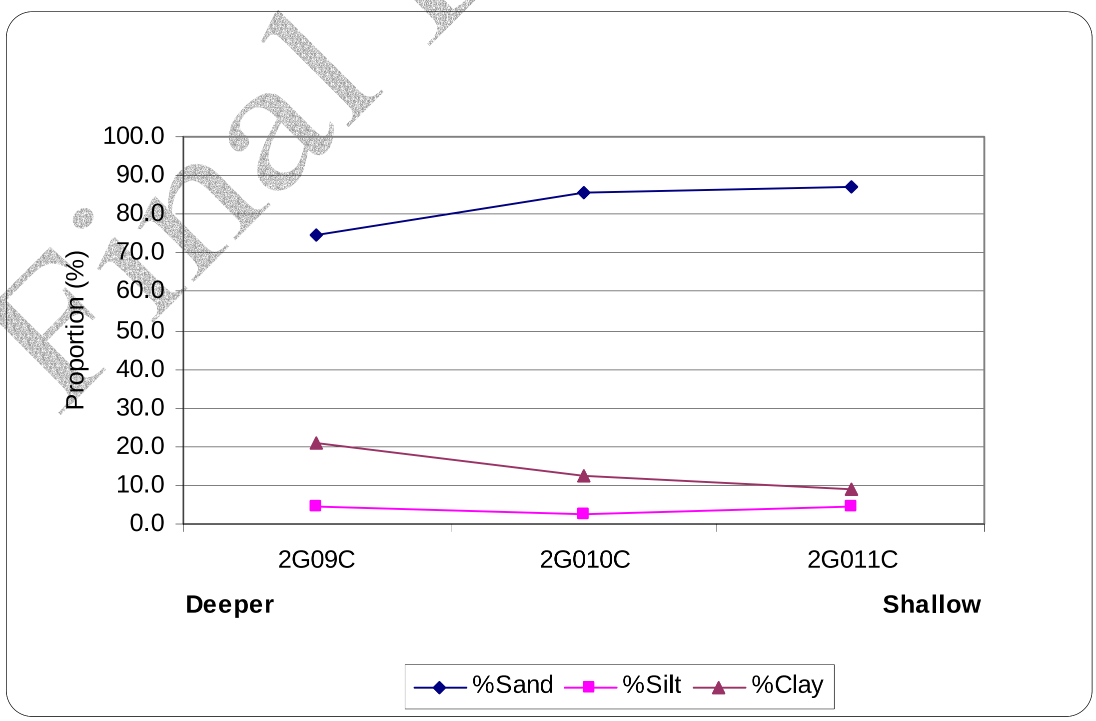
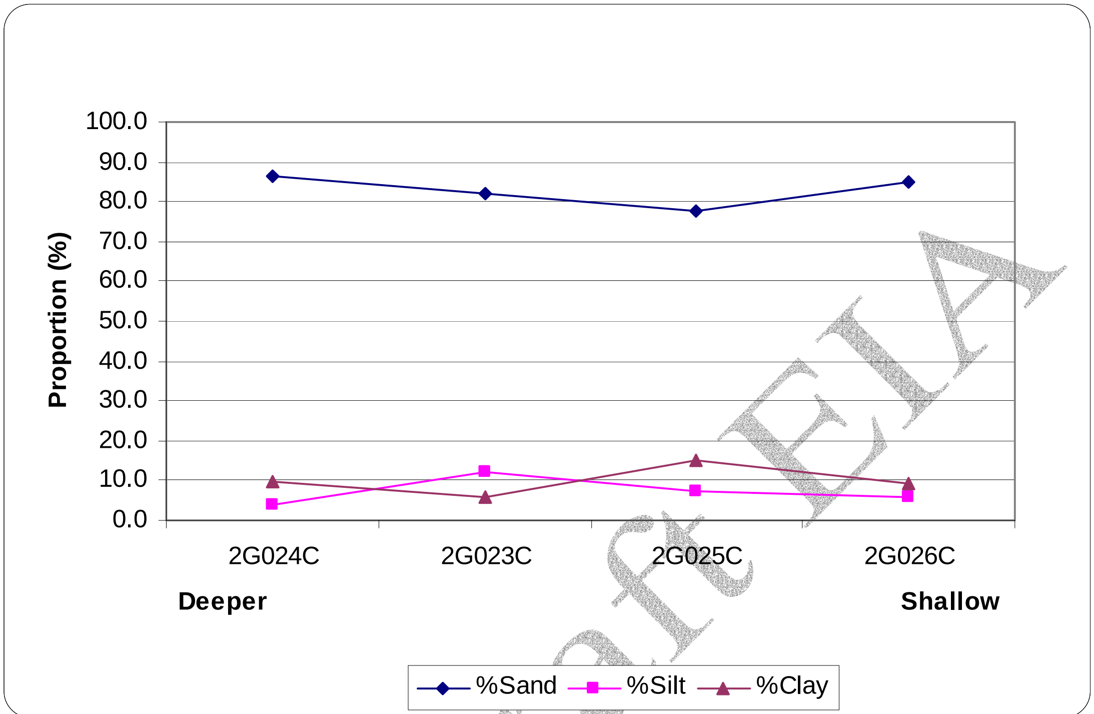


Figure 4.2-6
Distribution of Offshore Sediment Parameters Along Takoradi Lateral



High levels of clay (70-90%) characterised the sediments samples from Stations 2TO5C (Togo) and 2NDO4C (Nigeria). These stations are in relatively deeper waters (>40m) where water movement is slower and encouraging the accumulation of lighter particles.

4.2.2 Discussion

Sediment texture and composition greatly affect the distribution of marine benthic organisms and the community structure. The correlation between a particular grain-size and marine benthic species had amply been demonstrated in many findings. The feeding type of the benthic community is considered as an adaptation to the sediment characteristics. Thus the analysis of sediment properties and/or parameters is of utmost important to the understanding of benthic ecology and the effects of impacts arising out of construction disturbances of the ocean floor.

CHAPTER 5
OFFSHORE WATER CHARACTERIZATION

5.1.1 Discrete Water Samples

The concentrations and the ranges of the discrete water samples are presented in Figures 5.1-1 to 5.1-12 below.

The range of concentration for ammonia (0.02mg/L to 0.13mg/L) was relatively the same for bottom water samples. However, the concentrations determined for the surface waters generally increased eastwards. However, Station 2G26C in the west recorded the highest concentration for the bottom water samples while Station 2ND04C recorded the highest level for the surface waters (Figures 5.1-1 and 5.1-2).

Figure 5.1-1
Offshore Stations' Surface Water NH_3-N Concentrations

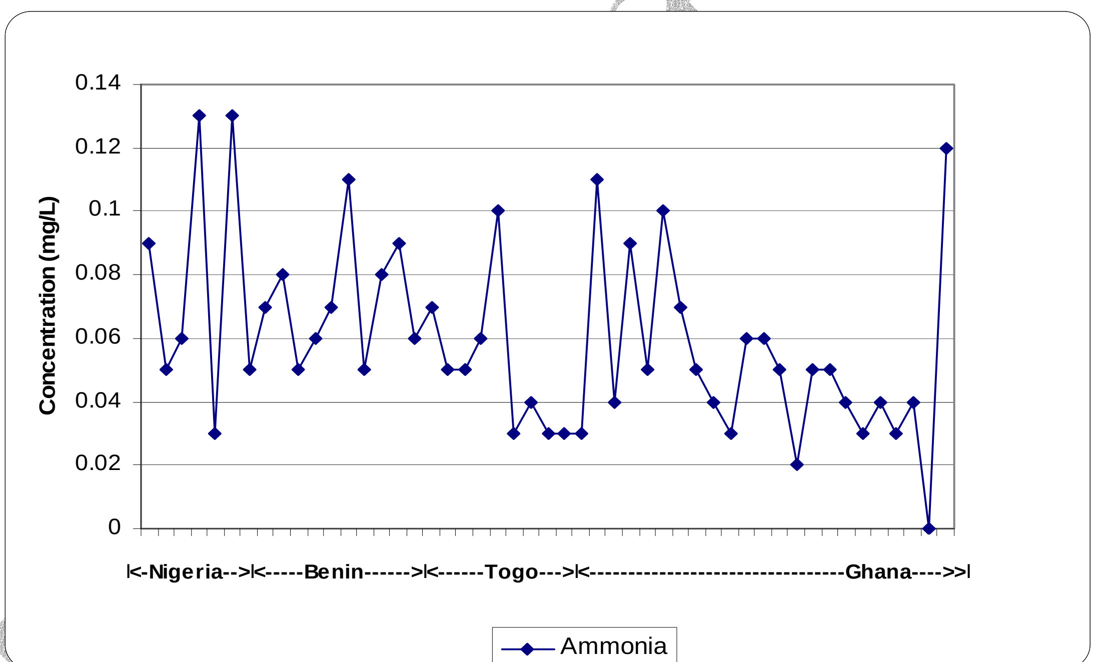
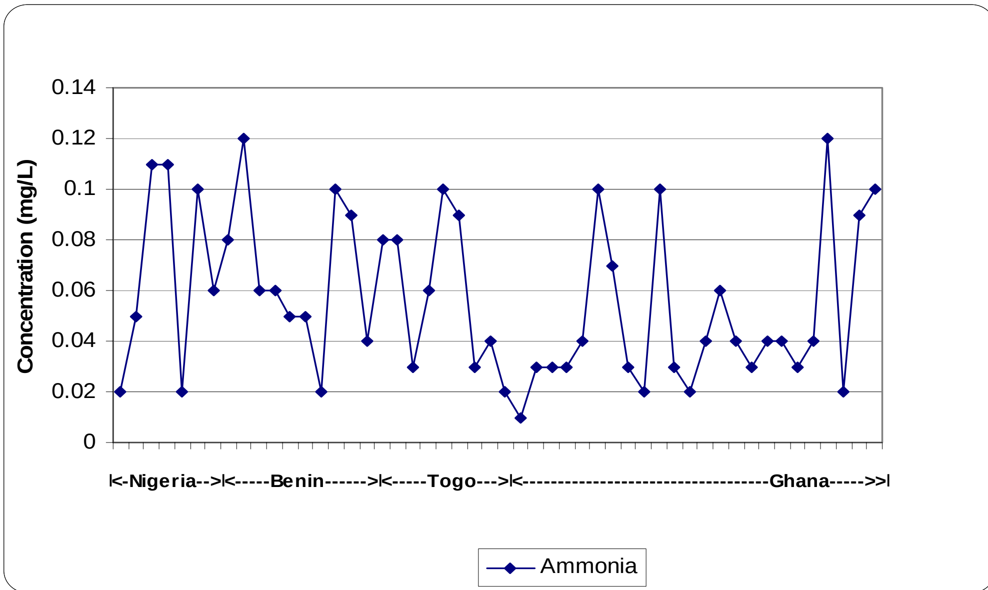


Figure 5.1-2
Offshore Stations' Bottom Water NH_3-N Concentrations



The concentration of nitrate was slightly higher in bottom samples than surface water samples for the offshore waters located in Ghana to the west. Again, greater variability in nitrate concentrations was evident in the offshore waters of Ghana (Figures 5.1-3 and 5.1-4).

Figure 5.1-3
Offshore Stations' Surface Water NO_3-N Concentrations

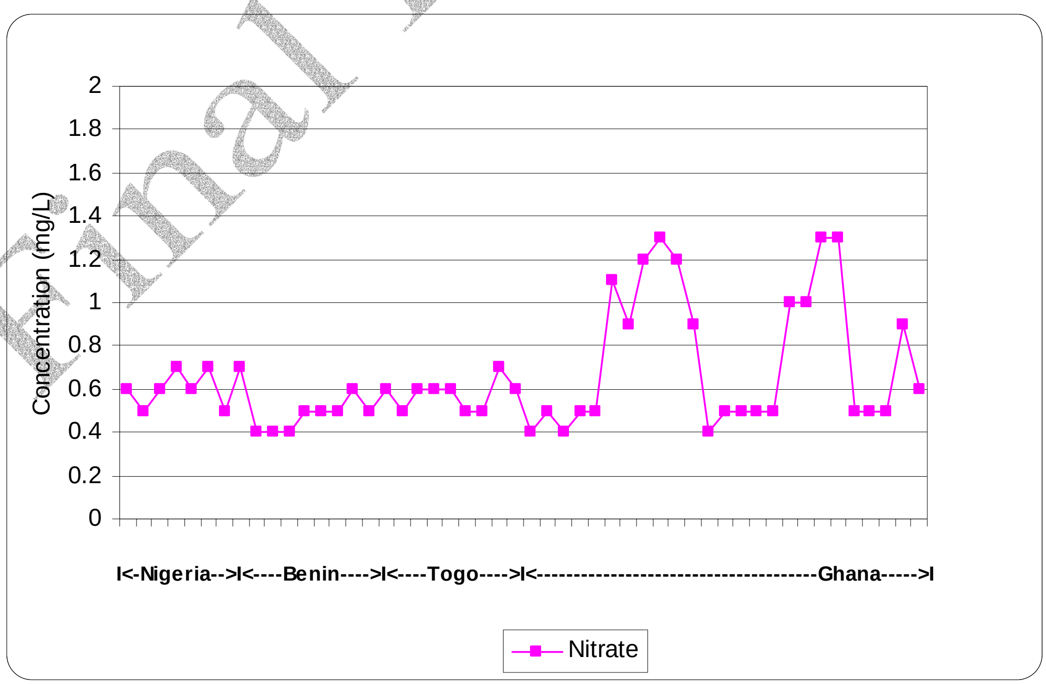
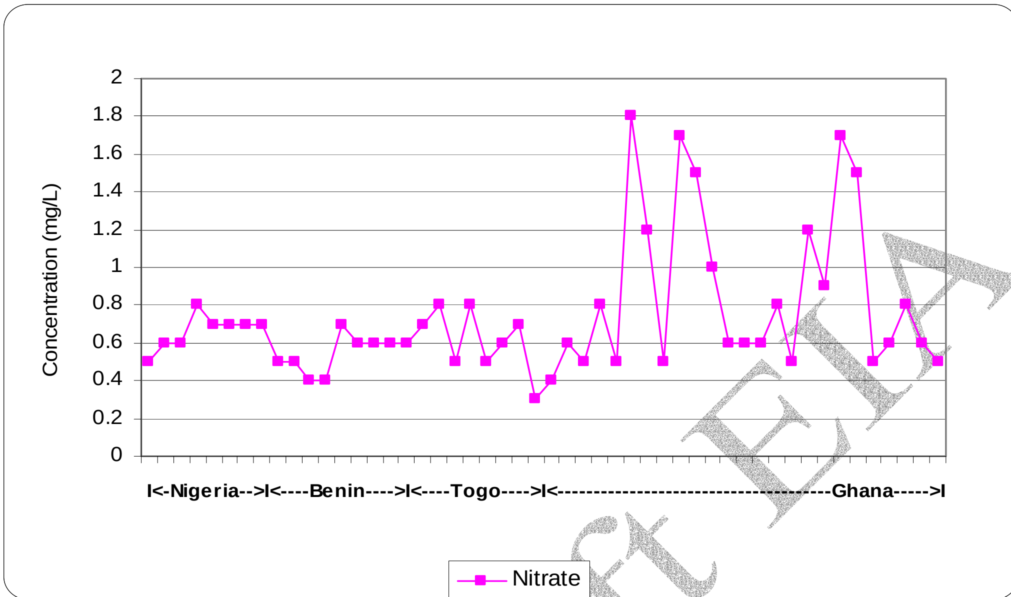


Figure 5.1-4
Offshore Stations' Bottom Water NO_3-N Concentrations



Total nitrogen concentration in the study area ranged from 0.006mg/L (at Station 2B07C) to 1.82mg/L (at Station 2G24C) for both the surface and bottom water samples analysed. The concentrations were quite similar with marked variability in the study area. This observation was quite marked in the surface water samples to the west of Ghana (Figures 5.1-5 and 5.1-6).

Figure 5.1-5
Offshore Stations Surface Water Total Nitrogen Concentrations

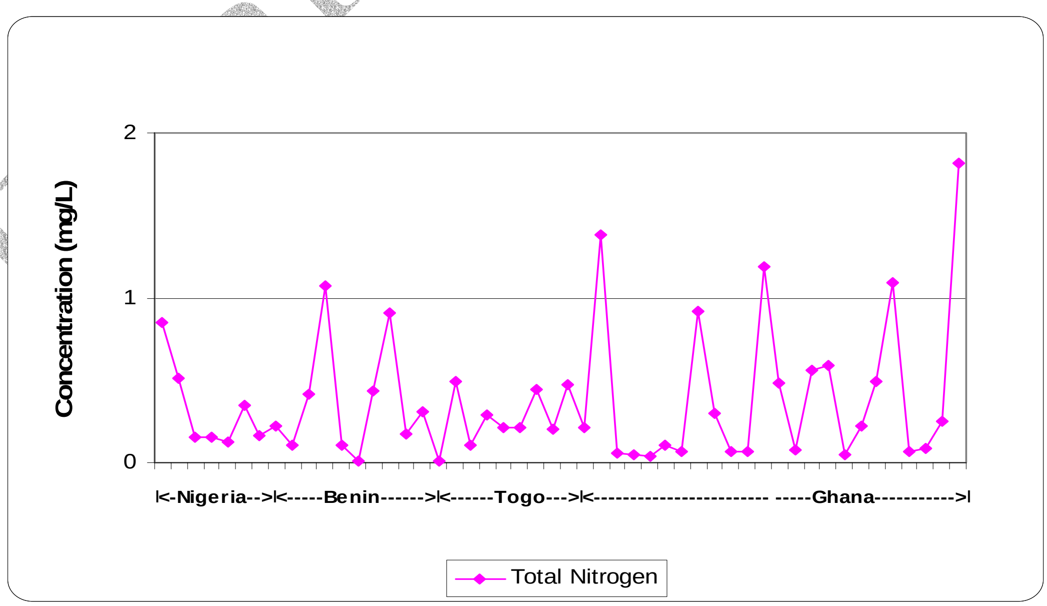
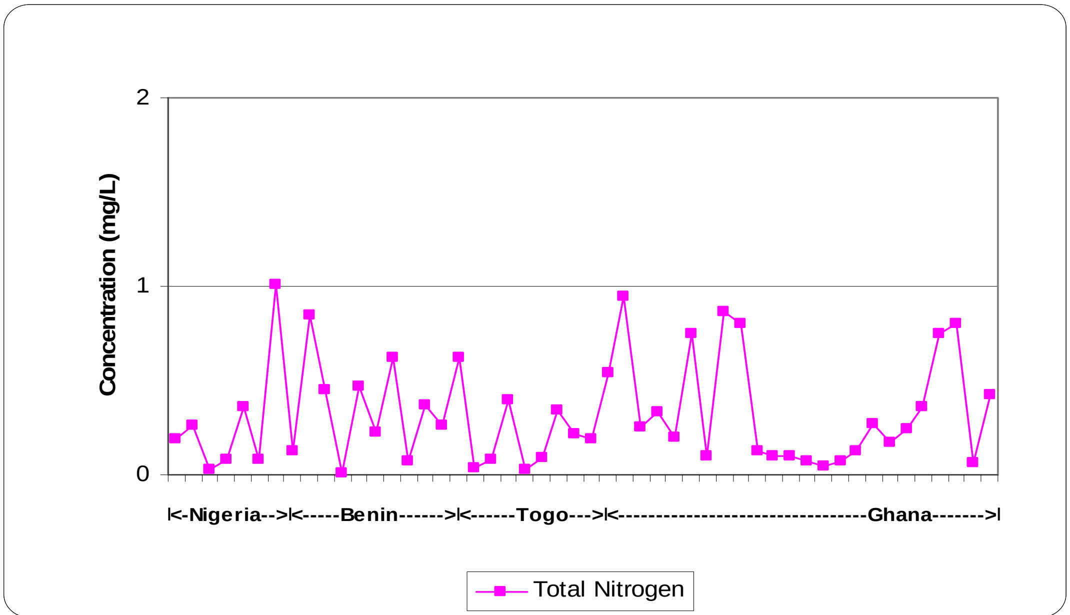


Figure 5.1-6
Offshore Stations Bottom Water Total Nitrogen Concentrations



Phosphate concentrations were generally similar in range for both the surface and the bottom water samples. The concentrations ranged between <0.01mg/L to 0.40 mg/L. Greater variability and comparatively higher levels were evident in the bottom water samples between Togo and Nigeria than the surface waters for the same area (Figures 5.1-7 and 5.1-8).

Figure 5.1-7
Offshore Stations' Surface Water Phosphate Concentrations

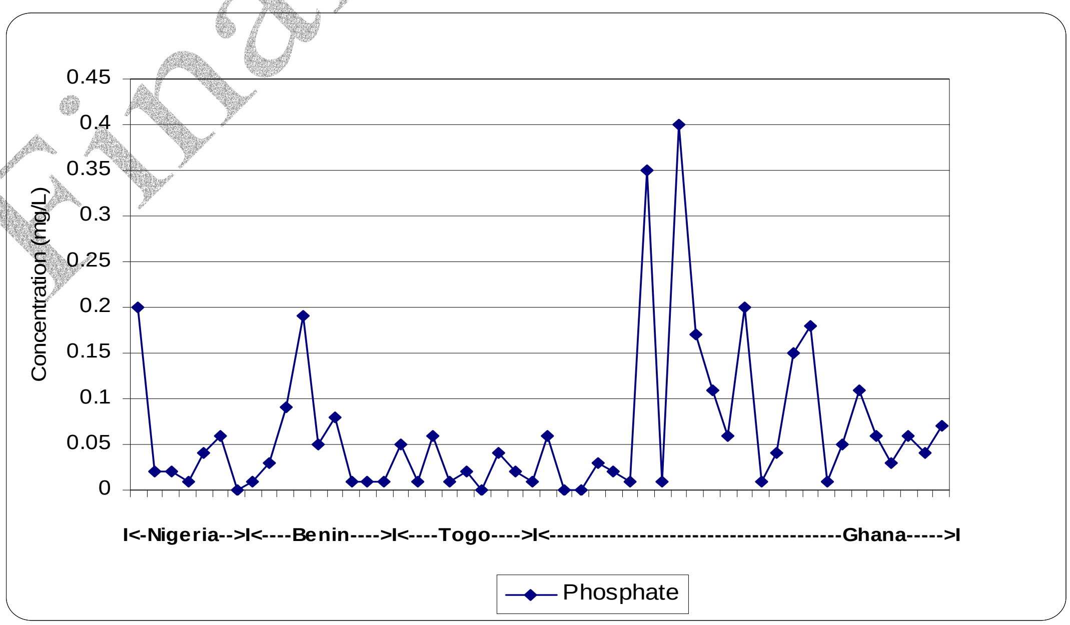
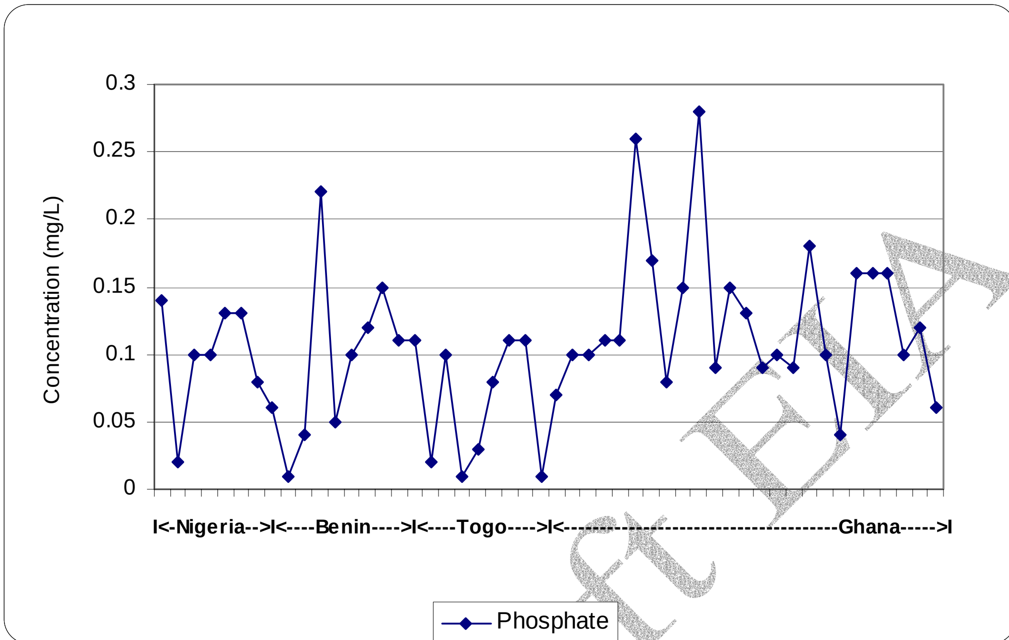


Figure 5.1-8
Offshore Stations' Bottom Water Phosphate Concentrations



The concentrations for the total phosphorus in the surface water samples ranged from 0.063mg/L (at Station 2G17C) to 3.83mg/L (at Station 2ND02C). In the bottom water samples, the concentrations were quite similar with a range between 0.05m/L to 3.99mg/L for total phosphorus (Figures 5.1-9 and 5.1-10).

Figure 5.1-9
Offshore Stations' Surface Water Total Phosphorous Concentrations

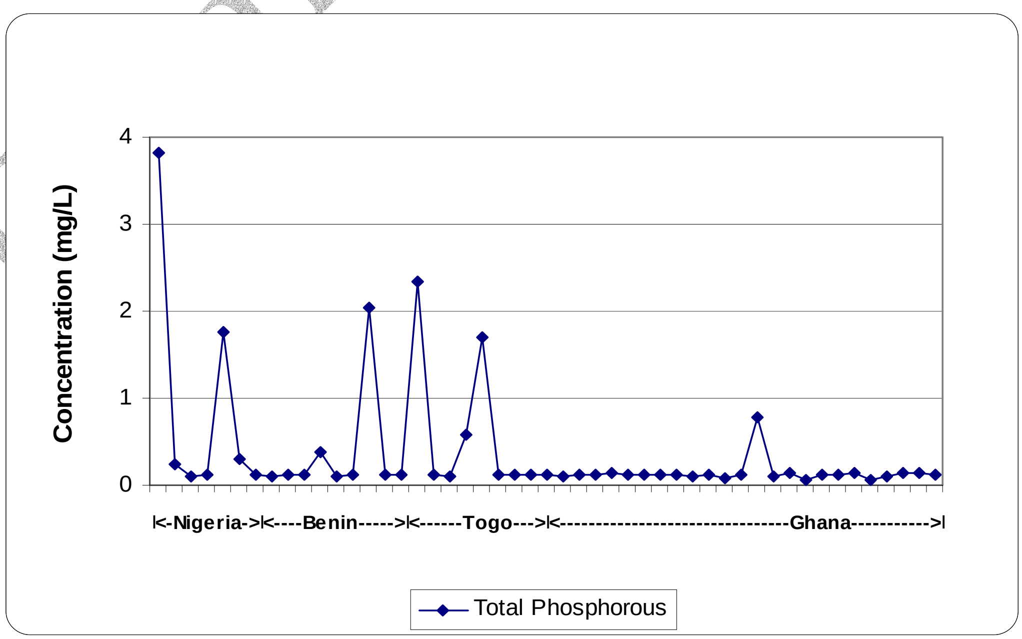
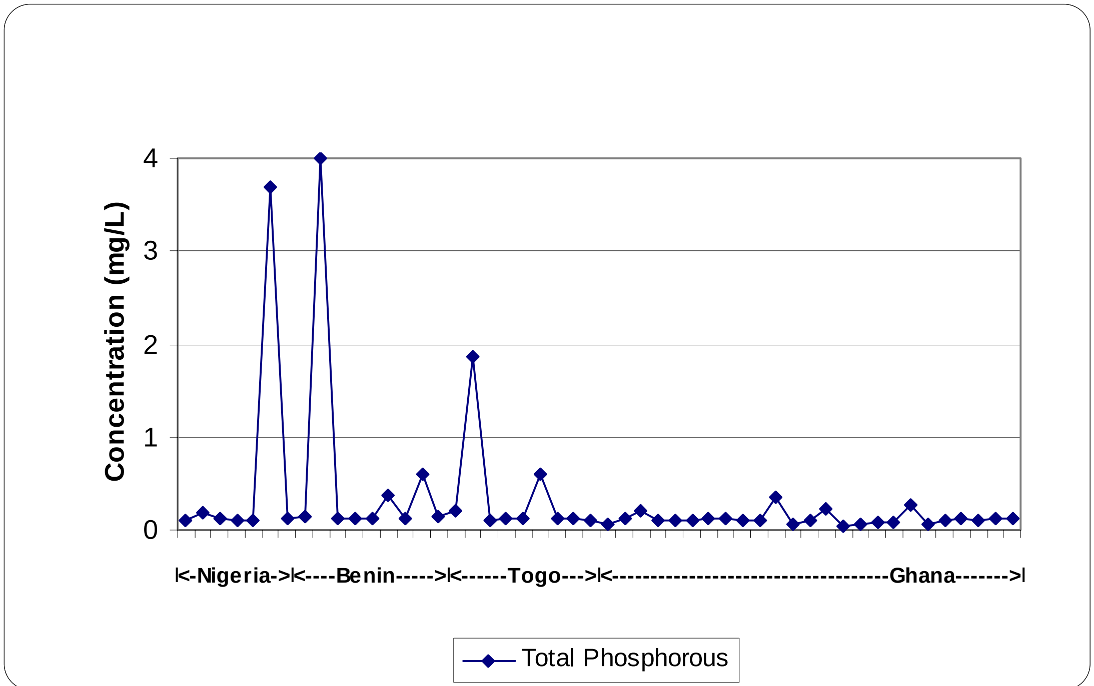


Figure 5.1-10
Offshore Stations' Bottom Water Total Phosphorous Concentrations



Sulphate concentrations (ranged between 2100mg/L to 3550m/L.). No major trends in levels for both surface and bottom water samples were evident (Figures 5.1-11 and 5.1-12).

Figure 5.1-11
Offshore Stations' Surface Water Sulphate Concentrations

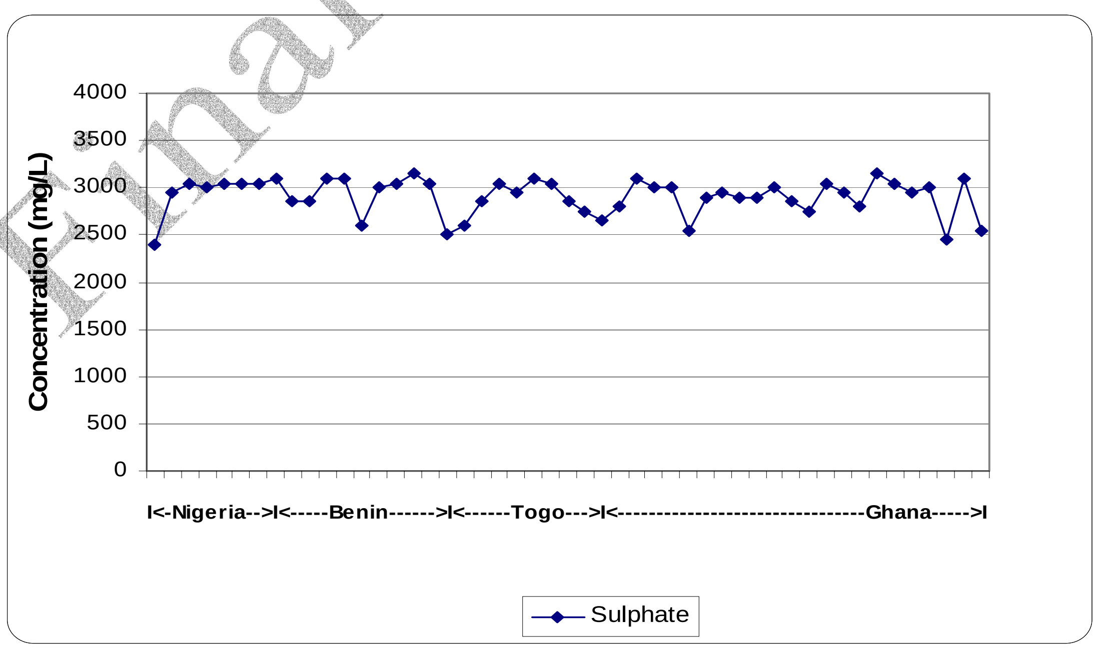
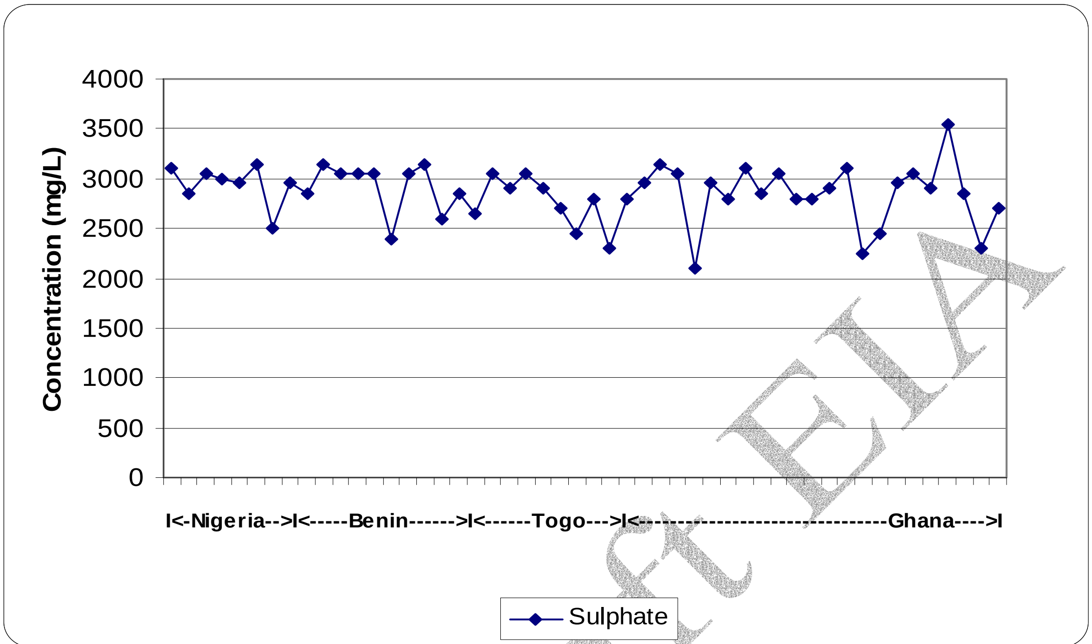


Figure 5.1-12
Offshore Stations' Bottom Water Sulphate Concentrations



Discussion

Greater variability was observed in concentrations of nitrates and phosphates in both the surface and bottom waters off the Ghanaian coast of the study area. In contrast, greater variability was observed for total phosphorus in the eastern section between Togo and Nigeria. These differences might be due to higher flow regimes of major rivers and sporadic upwellings normally experienced along the western and central coasts of Ghana during the period of the year when the study was conducted. The greater variability observed for phosphate in the bottom water samples between Togo and Nigeria as well as in the total phosphorus for both surface and bottom samples could be a consequence of the phosphate factory effluents discharged near the beach in Togo.

5.1.2 CTD Results

The offshore water profiling was done using a YSI 6600 CTD data sonde. Measurements including depth, temperature, conductivity, chlorophyll a, and dissolved oxygen were recorded at each of the stations. The temperature profile at depth was the greatest concern, to examine the possible change in the depth of the thermocline with the upwelling season later in the year. The laterals showed no drastic change in temperature that would indicate the profile of a thermocline, which can be mostly attributed to the shallow depth of the stations. The deeper stations regularly demonstrated a thermocline between 15 and 20 meters, and having an average decline in temperature between two and five degree Celcius. Beyond the thermocline, there was a gradual decline in temperature for those stations whose depth greatly exceeded the 20-meter mark, as exemplified by Figure 5.1-13 through 5.1-16. The change in temperature over depth can be seen in Appendix A. A second thermocline was not observed, even at the stations exceeding 50 meters in depth. This could result from an upwelling event that brings the cooler water from the abyssal plain, up to the continental shelf, creating a consistant decrease in temperature with the increase in depth. The lateral stations, closer to the shoreline, are removed from the influence of the upwelling, due to the distance from the stations. The stations situated along the mainline are closer to the influence from the upwelling; these stations are close to the continental slope, where the cooler waters rise to meet the warmer waters of the continental shelf.

The upwelling creates an increase in the chlorophyll content in the water column. The cold, nutrient rich waters provide an excellent environment for chlorophyll containing organisms to become prolific. One station in Nigeria noted a 617% increase in the chlorophyll content (1.7 increase to 10.5 µg/L). While the increase nutrients may be good for photosynthetic organisms, the overall affect is an increase in turbidity as well. With the greater chlorophyll content, equivocally an increase in turbidty is expected. The same station in Nigeria had an increase in turbidity of 282% (-0.1 to 28.2 NTU).

Figure 5.1-13
Example of Temperature vs Depth Profile in Benin

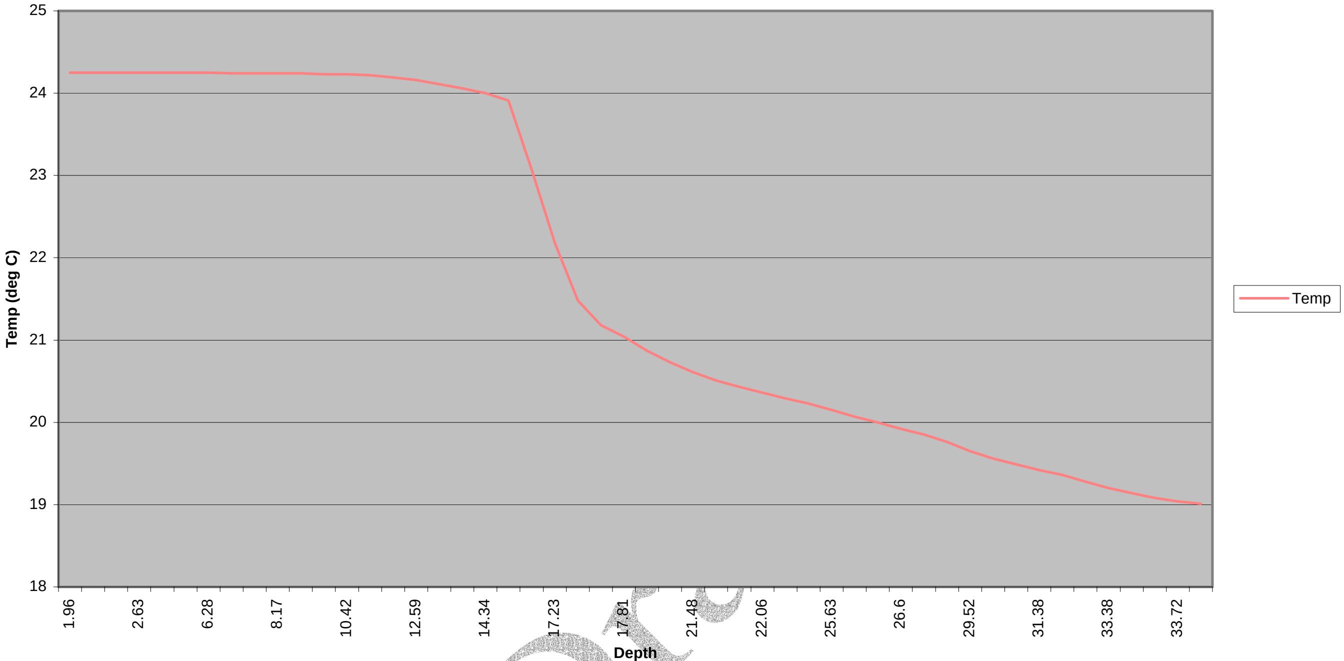


Figure 5.1-14
Example of Temperature vs Depth Profile in Ghana

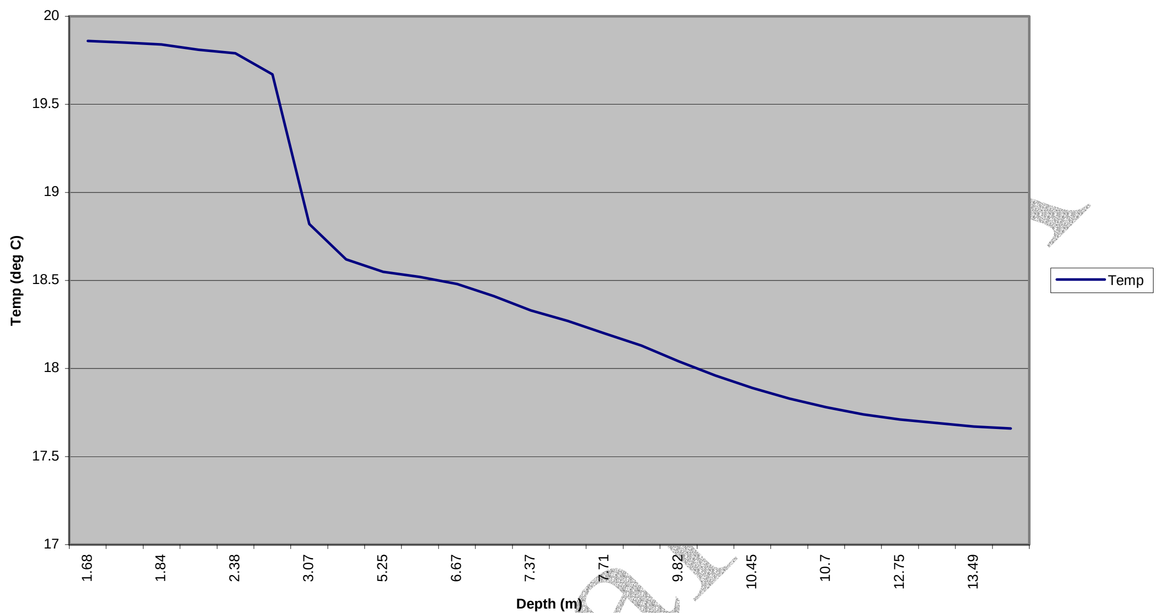


Figure 5.1-15
Example of Temperature vs Depth Profile in Nigeria

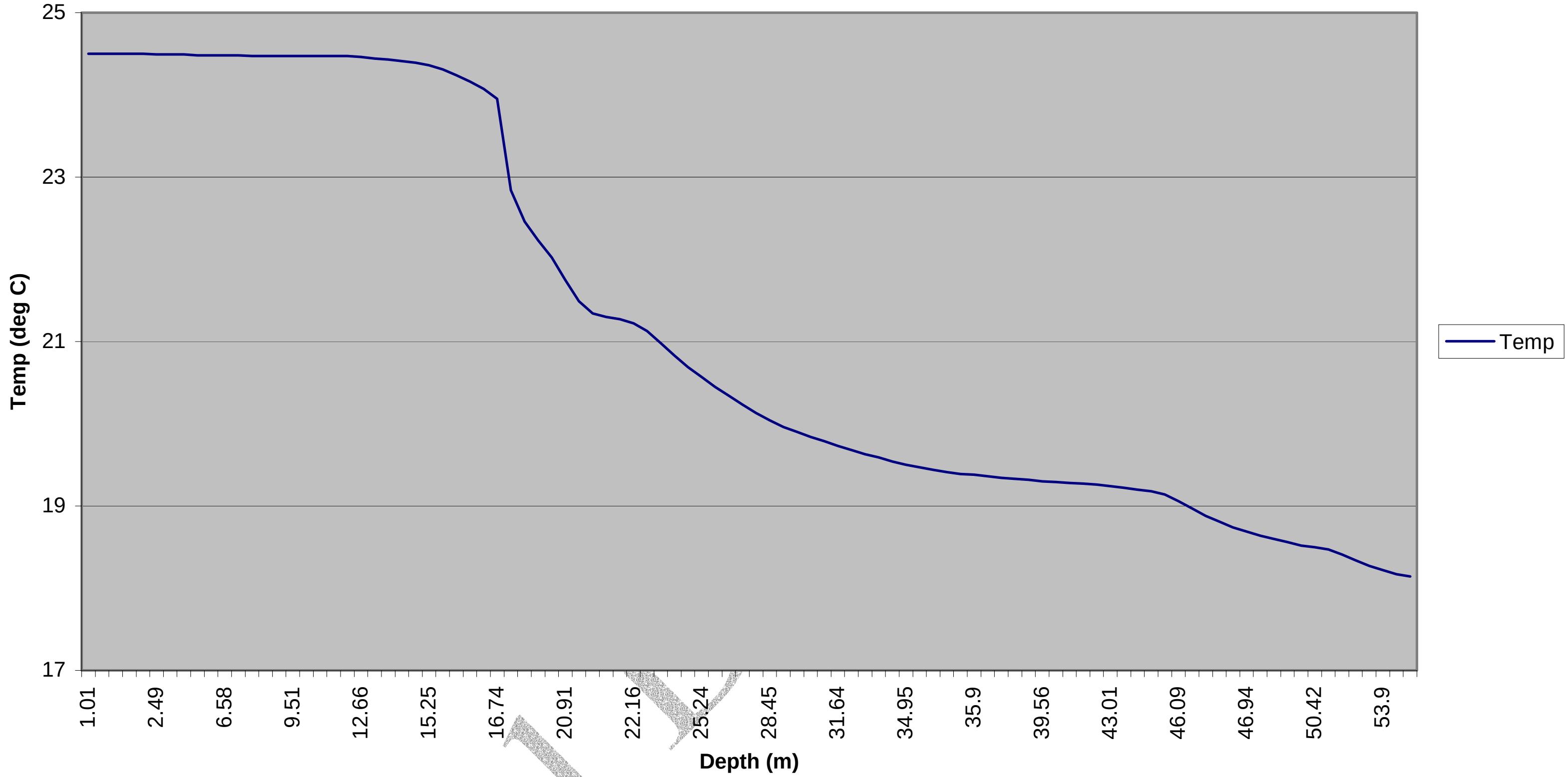
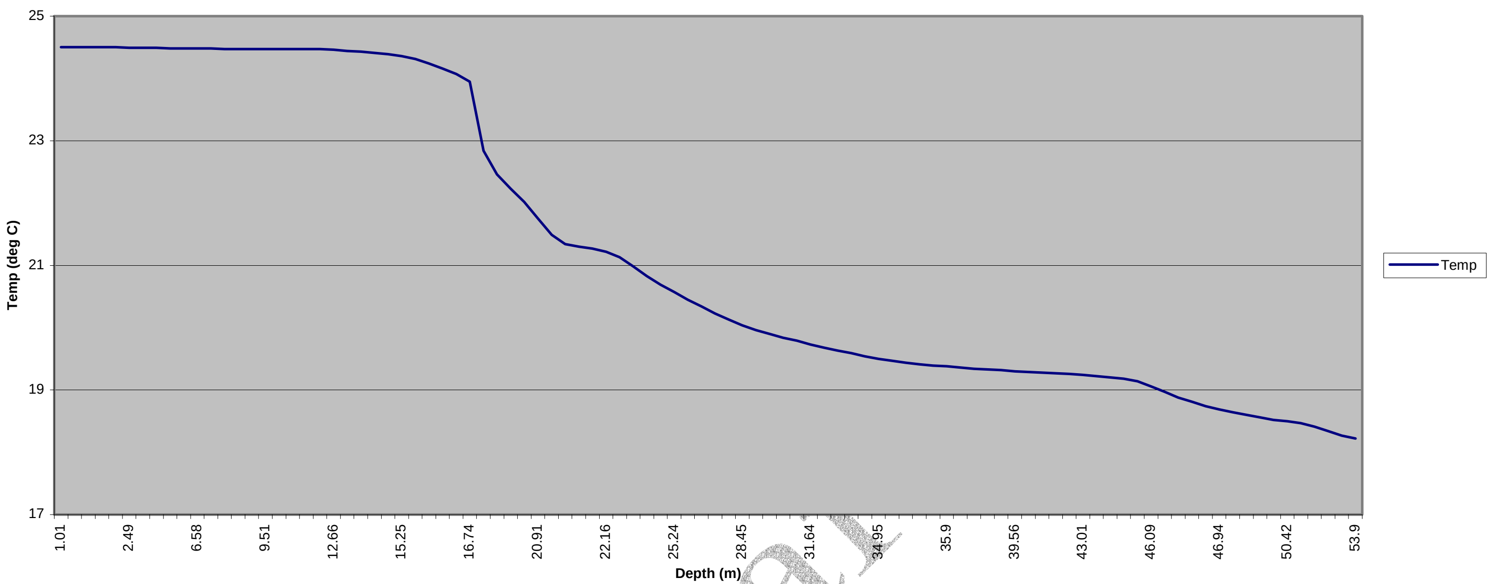


Figure 5.1-16
Example of Temperature vs Depth Profile in Togo



CHAPTER 6
OFFSHORE BIOLOGICAL CHARACTERIZATION

6.1.1 Benthic Infauna

Of the 75 benthic samples analyzed, a total of 3663 individual organisms were identified. These include Polychaeta, Crustacea, Mollusca and species grouped as 'others'. Table 6.3-1 shows the total number of the major benthic taxonomic groups and the respective percentage contributions. Polychaetes were the most dominant taxonomic group contributing 65.30%, followed by the crustacean (18.90%) and 'others' category contributed 12.70%. Molluscs were the least abundant group constituting 3.10%.

Table 6.3-1
Abundance of Major Groups of Benthic Infauna

Major Species	Ghana	Togo	Benin	Nigeria	TOTAL	Percentage
Polychaeta	1417	433	438	103	**2391**	65.30%
Crustacea	423	138	90	43	**693**	18.90%
Mollusca	100	6	7	1	**114**	3.10%
Others	179	94	154	38	**465**	12.70%
TOTAL	**2119**	**671**	**689**	**184**	**3663**	

The species grouped as 'others' category were mainly echinoderms, oligochaete, sipunculids etc.) (Appendix B). The number of species and the diversity indices calculated per station for each country along the main pipeline route and the laterals are presented in Figures 6.3-1 to 6.3-18. Stations are arranged from west to east along the main pipeline route, and from south to north (generally corresponding to a trend of deeper water to shallower water) on the laterals. The diversity indices calculated included species richness (d) Margalef's Species richness, and the Shannon-Wiener Diversity Index (H' loge). Species richness (as per Margalef) is a measure of the number of species present, taking into account the number of individuals present. These are useful quantitative tools for determining changes that might occur in the future.

6.1.1.1 Ghana

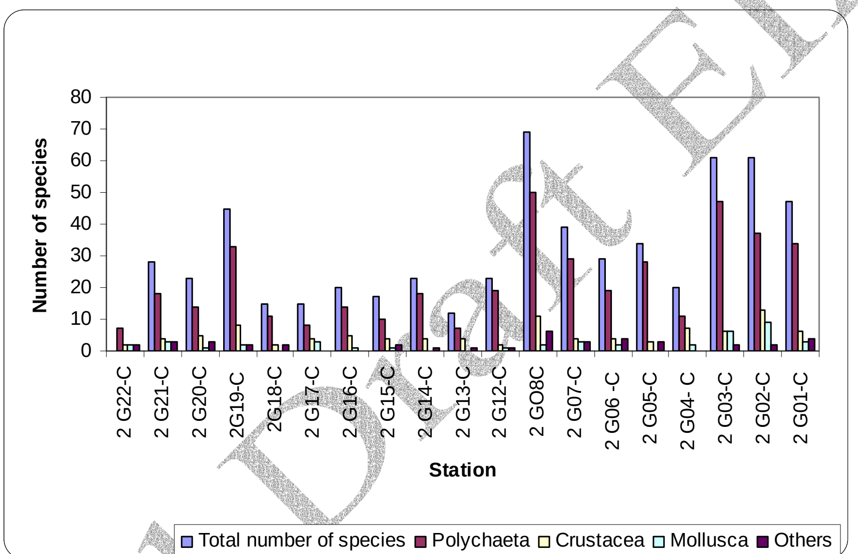
In the Ghanaian waters, 359 taxa were identified, made up of 255 polychaete species, 49 crustacean species 36 molluscan species and 19 species placed in the 'others' category. Nineteen stations were sampled along the main pipeline route, three stations along the Tema lateral, and four stations along the Takoradi lateral.

Main Pipeline Route

Figures 6.3-1 and 6.3-2 show the number of species and the diversity indices estimated for the stations along the main pipeline route of Ghana. The main pipeline route ranges in depth from 50 to 80m. The species count per station show slight east-west increase with station 2G08-C ranking high, followed closely by stations 2G03-C, 2G02-C and 2G01-C.

Low species counts were observed at Stations 2G18-CS and 2G13-C. The dominant taxonomic group in all the stations was polychaetes. Crustacean species were not recorded at four stations (2G18-C, 2G14-C, 2G13-C and 2G05-C), while two stations (2G16-C and 2G04-C) did not record any organisms for the ‘others’ group.

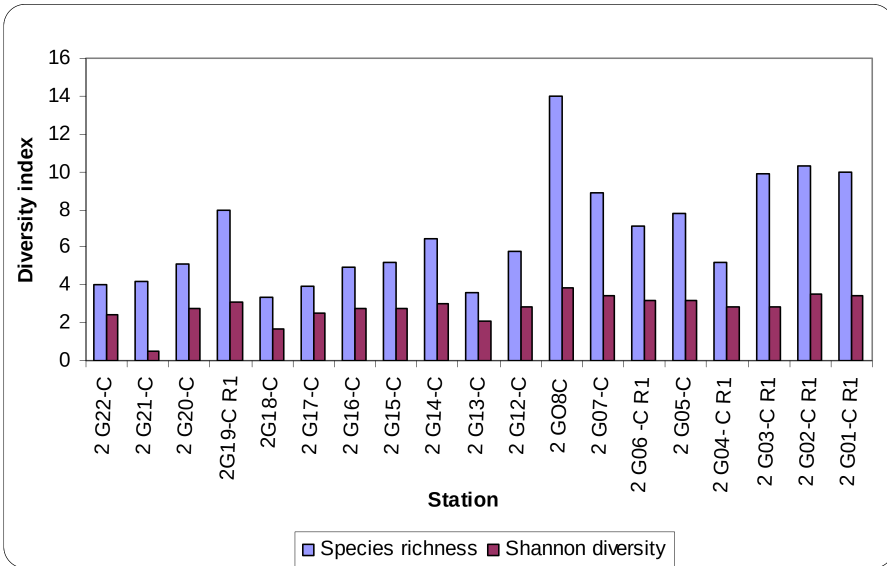
Figure 6.3-1
Offshore Benthic Macrofauna Distribution on Main Pipeline Route in Ghana



Offshore Benthic Macrofauna Distribution on Main Pipeline Route in Ghana

The diversity index distributions showed a trend reminiscent of the species count distribution. Species richness was highest at Station 2G08-C, closely followed by Stations 2G03-C, 2G02-C and 2G01-C, whilst the lowest were recorded at Station 2G18-C and 2G13-C. However, Station 2G21-C ranked very low in species diversity.

Figure 6.3-2
Offshore Benthic Macrofauna Diversity index Distribution on Main Pipeline Route in Ghana



Lateral Route

Figures 6.3-3 to 6.3-6 show the species count per station and the diversity indices calculated for the Tema and Takoradi laterals. The distribution of polychaetes in the lateral stations was relatively the same except slight decrease at Station 2G11-C. However, crustacean species and species in ‘others’ category showed opposing relationships. As the former decrease from deeper waters to shallow waters (i.e. from 2G09-C to 2G11-C), the latter showed an upward trend.

Figure 6.3-3
Offshore Benthic Macrofauna Distributions along Tema Lateral

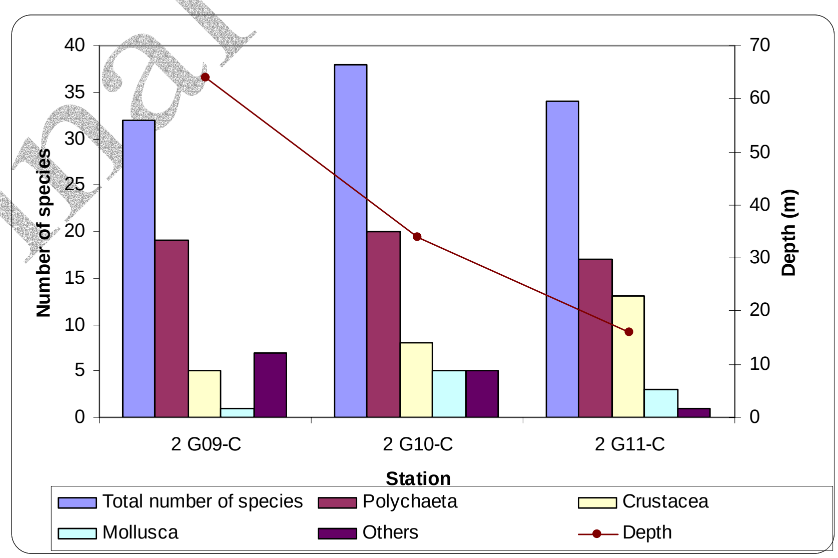
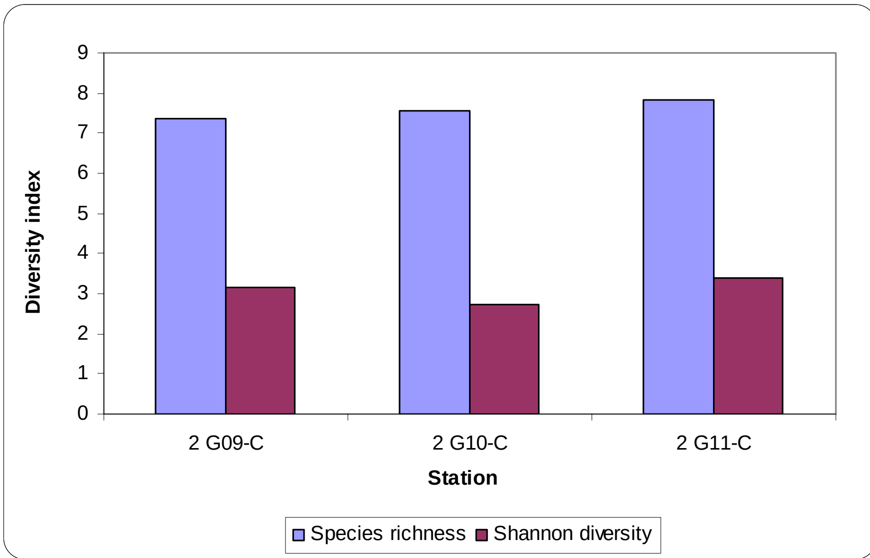


Figure 6.3-4
Offshore Benthic Macrofauna Diversity index Distribution along the Tema Lateral



The dominant species along the Takoradi lateral were polychaetes. Generally, there was a decrease in numbers of polychaetes and crustaceans from deep water to shallow waters, the exception being Station 2G24-C. The number of species counted was higher at Station 2G23-C than at the other stations along the transect. A striking feature here was the absent of molluscs at Station 2G23-C and 'others' group at Station 2G26-C.

Figure 6.3-5
Offshore Benthic Macrofauna Distributions along Takoradi Lateral

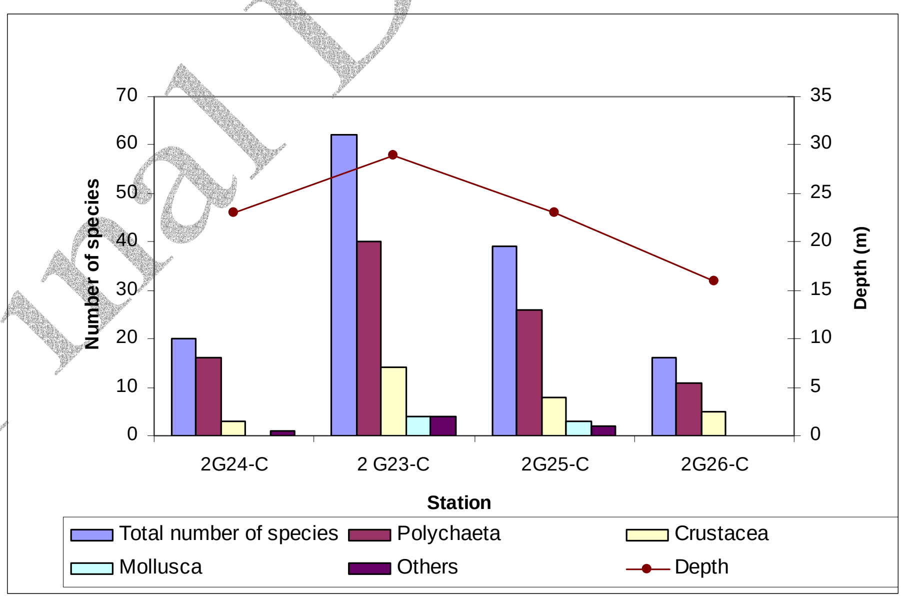
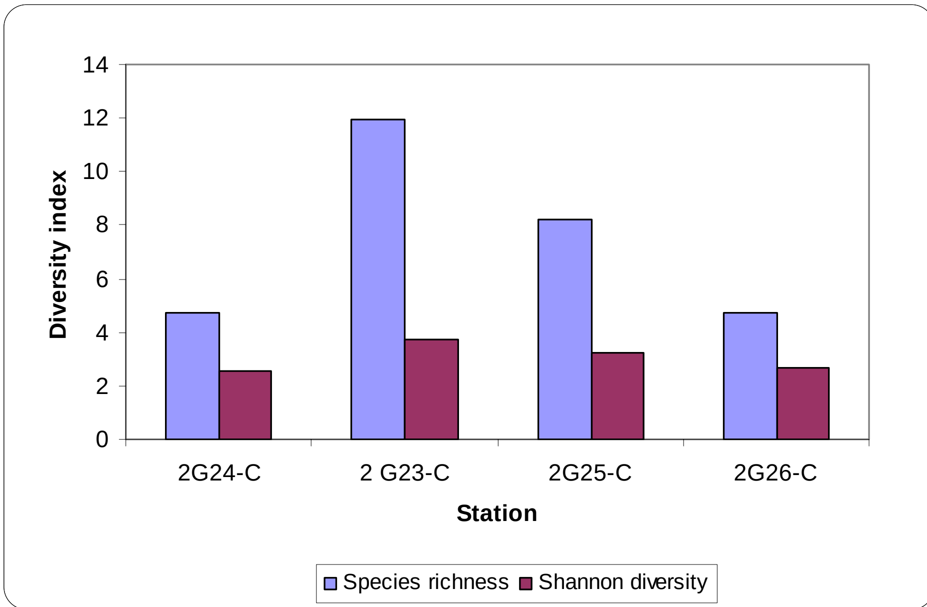


Figure 6.3-6
Offshore Benthic Macrofauna Diversity index Distribution along the Takoradi Lateral



The lateral stations at Tema did not show any trend moving from deep waters to shallow waters. All the three lateral stations at Tema showed an equal strength in species richness and diversity.

6.1.1.2 Togo

Two hundred and three taxa belonging to 4 major taxonomic groups were identified off Togo. This consisted of 142 polychaete species, 29 crustacean species, 7 mollusc species, and 9 species classified as 'others'. Five stations were sampled along the main pipeline route and four stations along the lateral.

Main Pipeline Route

Figures 6.3-7 and 6.3-8 show the number of species and the diversity indices estimated for the stations along the main pipeline route in Togo. The main pipeline route off Togo ranges in depth from 45 to 65m. The number of species identified per station did not show any clear east-west trend. However total species observed and polychaete counts were highest for Station 2T02-C, though did not record any molluscan species, and lowest for Station 2T04-C. The lowest crustacean count was also recorded at Station 2T04-C. The molluscan group did not show up at Stations 2T02-C, 2T03-C and 2T04-C. Generally, there was an increase from west to east in species classified into the 'others' category, though Station 2T04-C recorded the lowest. The polychaete species were dominant in all the stations sampled.

Figure 6.3-7
Offshore Benthic Macrofauna Distributions along Main Pipeline Route of Togo

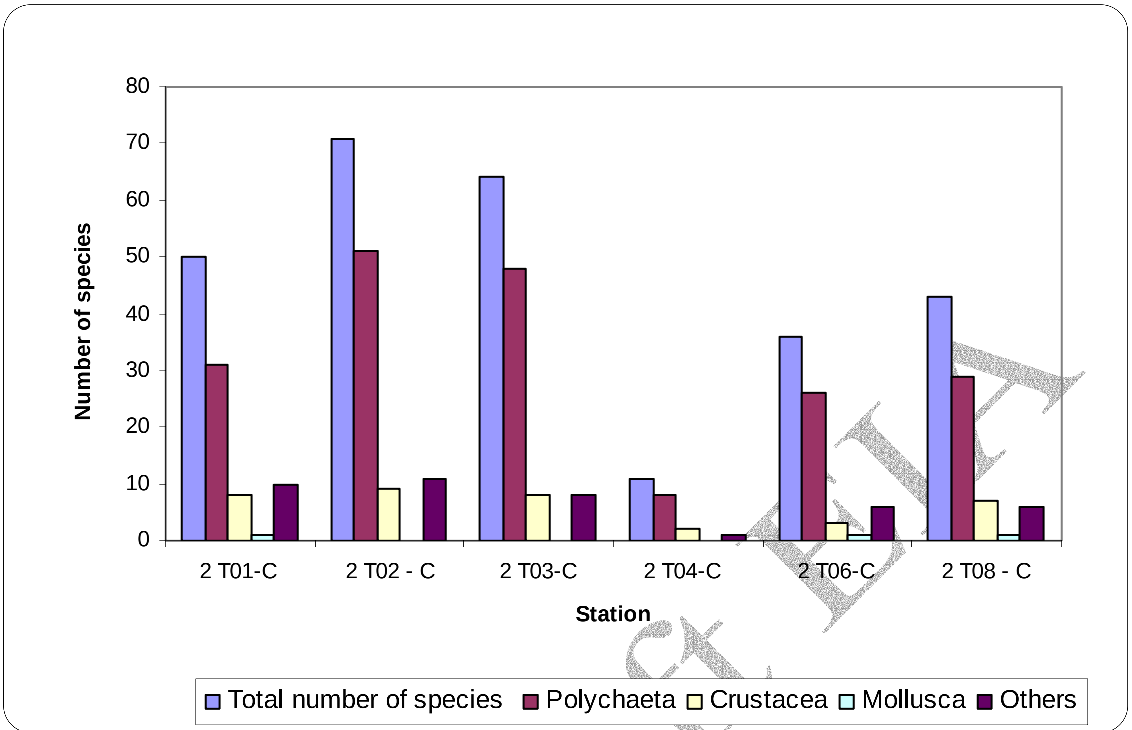
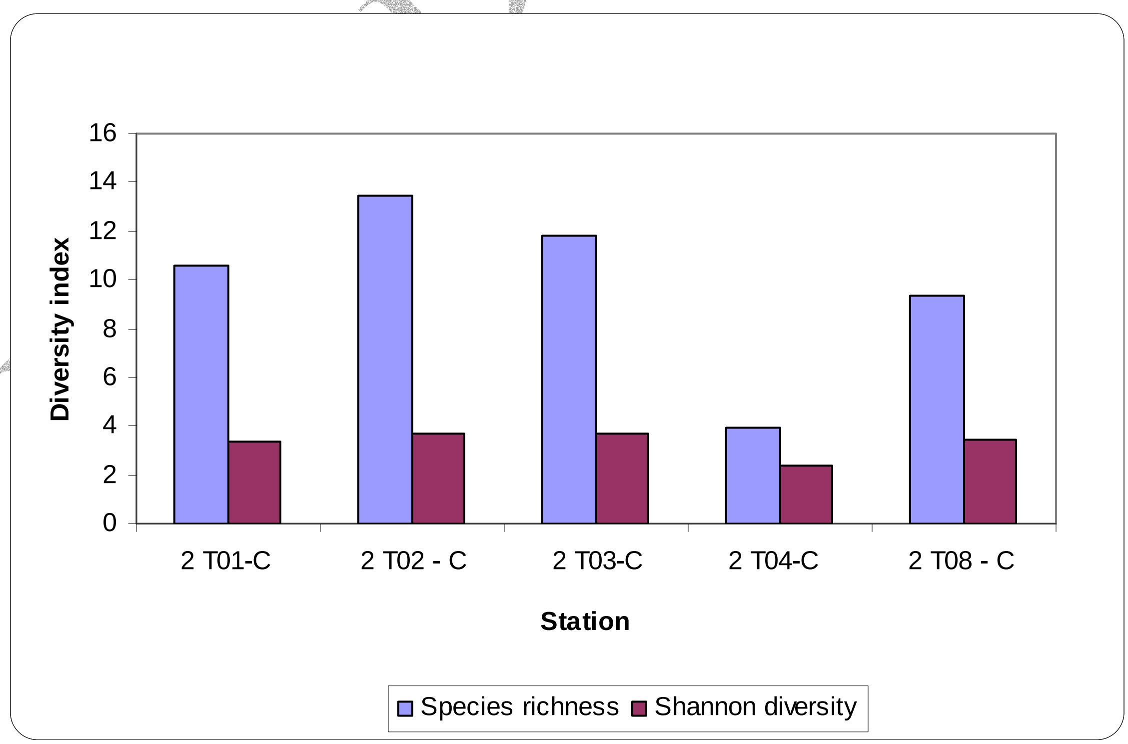


Figure 6.3-8
Offshore Benthic Macrofauna Diversity index Distribution along the Main Pipeline Route of Togo

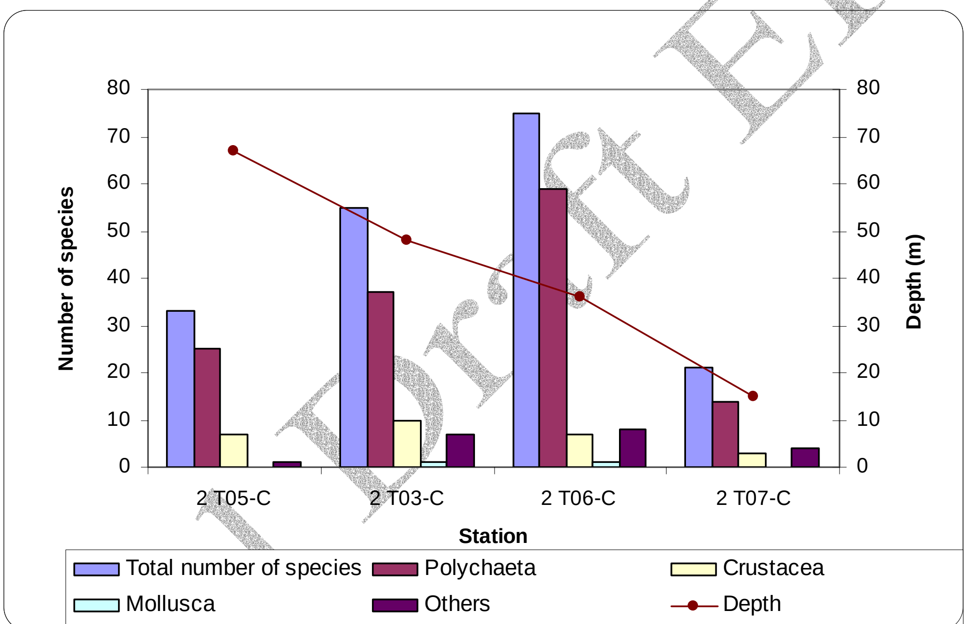


The diversity index showed a trend similar to the species diversity with Station 2T02-C having the highest species richness. The Shannon-Wiener Index was relatively the same in all the stations except Station 2TO4-C.

Lateral Route

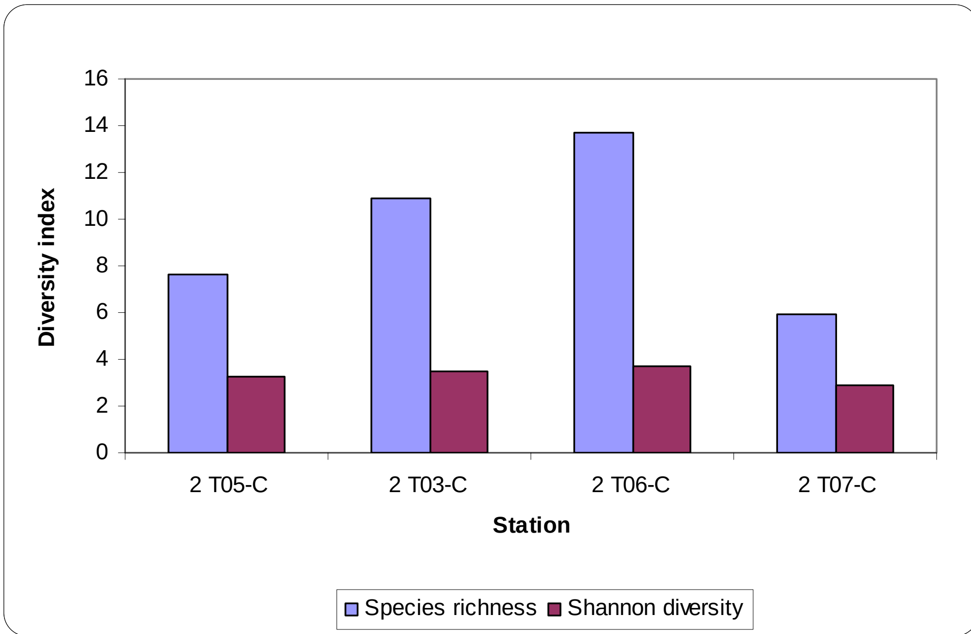
The number of species recorded along the lateral (Figure 6.3-9) showed a northward increase in number of species between Stations 2T05-C and 2T06-C. Station 2TO6-C exhibited the highest species count along the lateral. There was also southward increase in species placed in ‘others’ group. Stations 2T05-C and 2T07 did not record any molluscan species.

Figure 6.3-9
Offshore Benthic Macrofauna Distribution along the Togo Lateral



The Margalef’s species richness (d) and Shannon-Wiener Index showed distributions (Figure 3.3-10) similar to the number of species counted for each station.

Figure 6.3-10
Offshore Benthic Macrofauna Diversity index Distribution along the Togo Lateral



6.1.1.3 Benin

One hundred and ninety three (193) taxa were identified, made up of 135 polychaete species, 26 crustacean species, 11 molluscan species and 21 species classified as 'others'. Seven stations were sampled along the main pipeline route off Benin and four stations along the laterals.

Main Pipeline Route

Figures 6.3-11 and 6.3-12 show the number of species and the diversity indices estimated for the stations off the main pipeline route. The main pipeline route off Benin ranges in depth from 50 to 70m. From the graph, the number of species per station showed a fluctuating trend. There was a gradual increase westward up to station 2B03-C, then another increase eastward from Stations 2B10-C to 2B08-C. Station B07-C, which is centrally placed, exhibited low number of species. Polychaetes were dominant in all the stations sampled. Only Stations 2B03-C and 2B08-C recorded molluscan species.

Figure 6.3-11
Offshore Benthic Macrofauna Distribution along the Main Pipeline Route of Benin

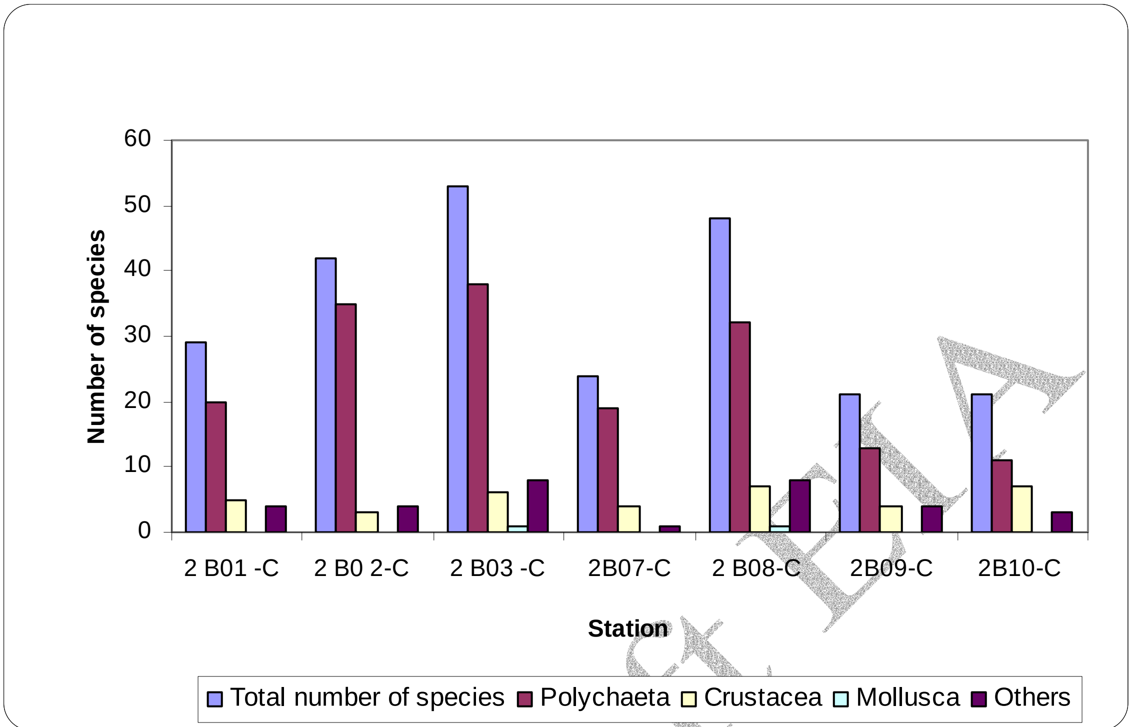
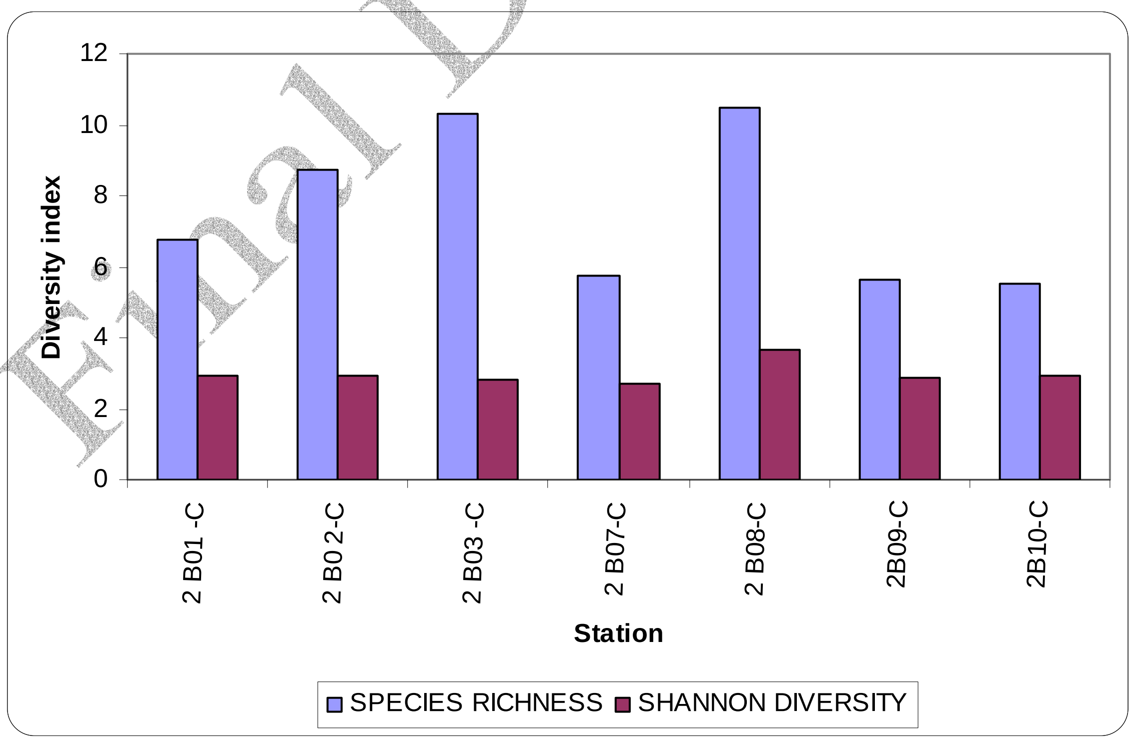


Figure 6.3-12
Offshore Benthic Macrofauna Diversity index Distribution along the Main Pipeline Route of Benin



The diversity index showed a trend similar to the number of species.

Lateral Route

The number of species recorded along the lateral (Figure 6.3-13) show that Station 2B06-C, which was shallowest and closest to land, recorded the lowest count for total species observed and polychaetes, and no value for the mollusc group. Stations 2B03-C on the other hand recorded the highest numbers for the total species observed and the number of polychaetes observed as well as the other groups. The species richness (d) and Shannon-Wiener Index showed distributions similar to the number of species counted for each station.

Figure 6.3-13
Offshore Benthic Macrofauna Distribution along the Lateral of Benin

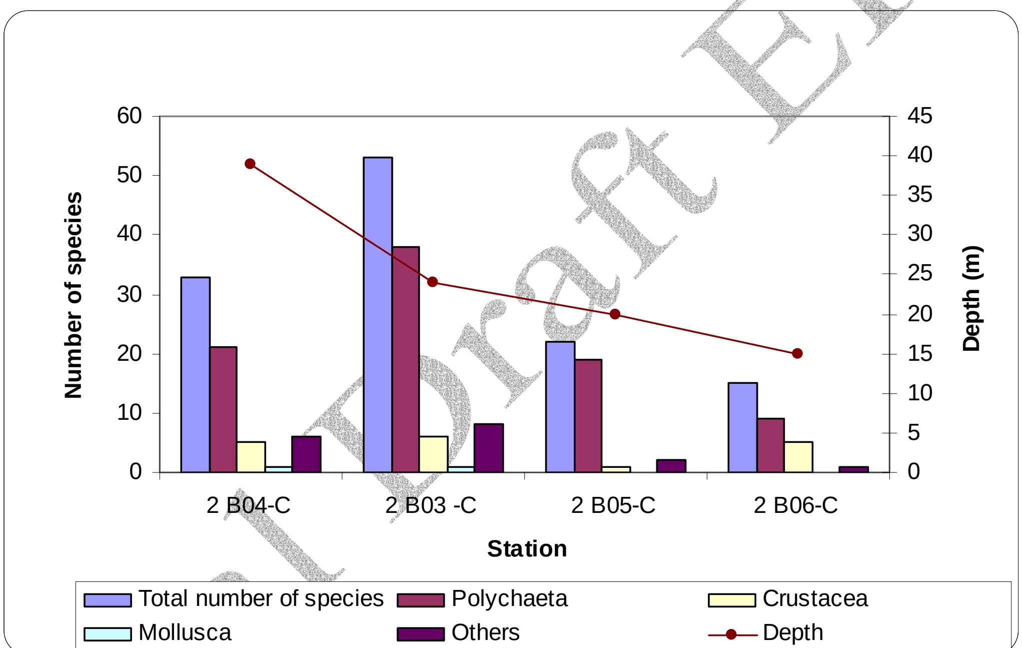
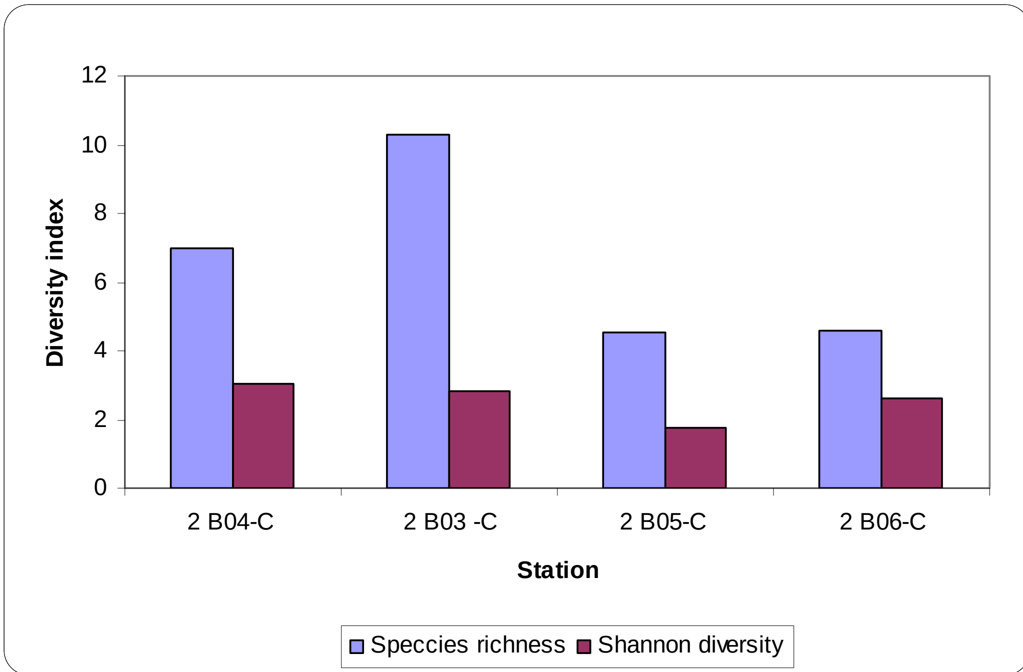


Figure 6.3-14
Offshore Benthic Macrofauna Diversity index Distribution along the Benin Lateral



6.1.1.4 Nigeria

One hundred and sixteen taxa were identified. These comprised 79 polychaete species, 22 crustacean species, 3 molluscan species and 12 species classified as 'others.' Six stations were samples on a diagonal, which extended from the subtidal to deeper waters.

Main Pipeline Route

Figures 6.3-15 and 6.3-16 show the number of species and the diversity indices estimated for the stations off the main pipeline route. The main pipeline route off Nigeria diagonal ranges in depth from 50 to 80m. No clear spatial distribution pattern was observed for the number of species enumerated. Station 2ND04-C showed the highest total species and polychaete counts while Station 2ND06-C, the deepest station, showed the least counts. Benthic macrofauna grouped under 'others' was absent in samples from stations 2ND01-C and 2ND06-C. Polychaete species were dominant in all the stations sampled.

The diversity index also showed a trend similar to the species diversity.

Figure 6.3-15
Offshore Benthic Macrofauna Distribution along the Diagonal of Nigeria

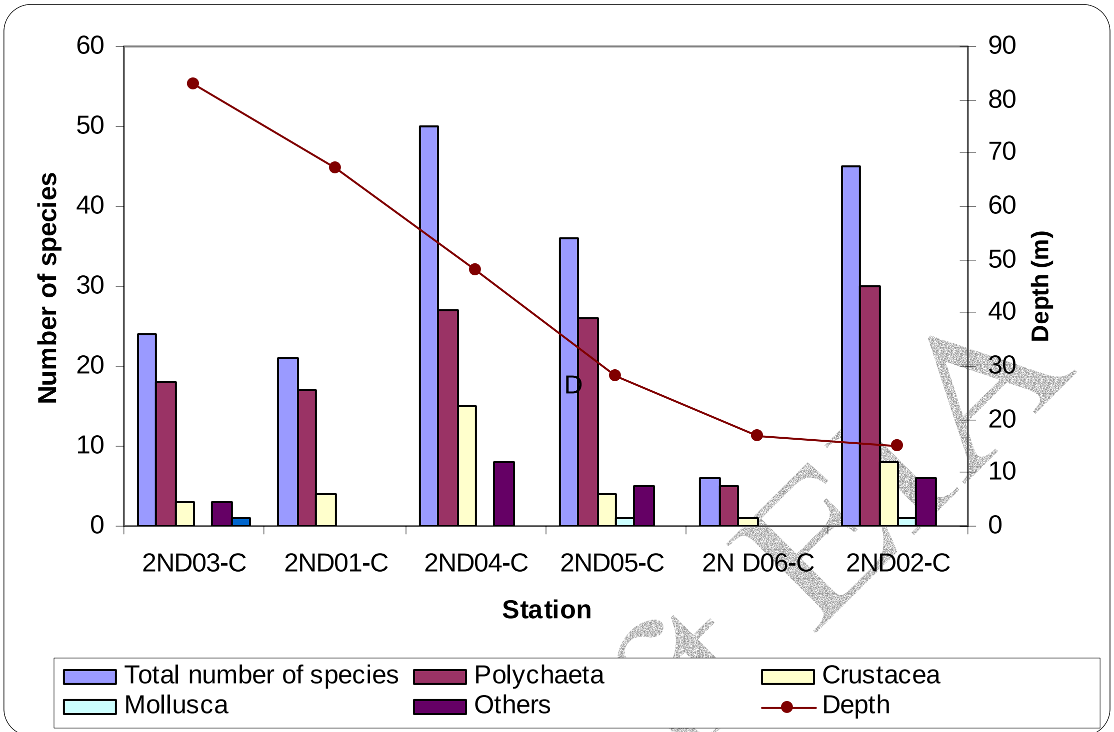
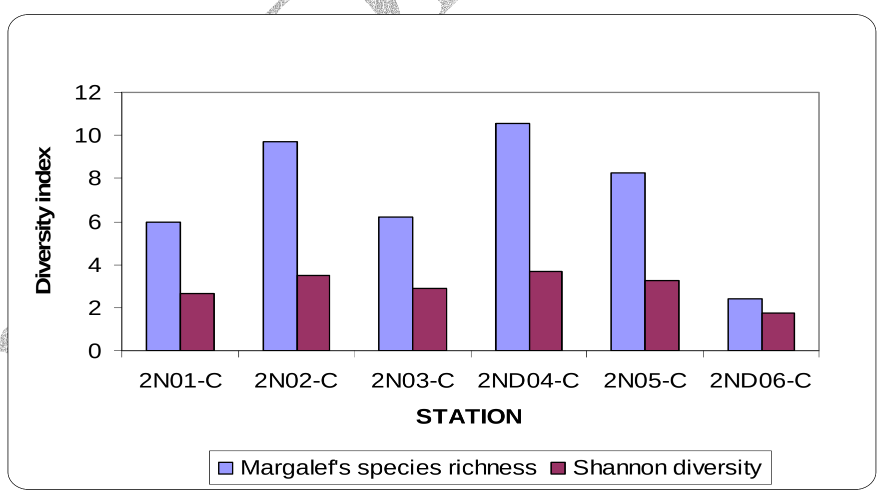


Figure 6.3-16
Offshore Benthic Macrofauna Diversity index Distribution along the Nigeria Diagonal



Random Stations along the Main Pipeline Route

Replicate analyses were performed for four random stations.

Figures 6.3-17 and 6.3-18 show the number of species and the diversity indices estimated for the random stations along the main pipeline across the countries. The highest numbers of species were recorded at Station 2T03-C for replicates one and two (R1 & R2). Polychaetes were the dominant species in these random stations, closely followed by the crustacean species, 'others' group and the molluscan species in the order. Molluscan species were absent in 50% of the stations.

Figure 6.3-17
Abundance and Distribution of Major Macrobenthic Fauna Group at Random Stations across the Countries Sampled

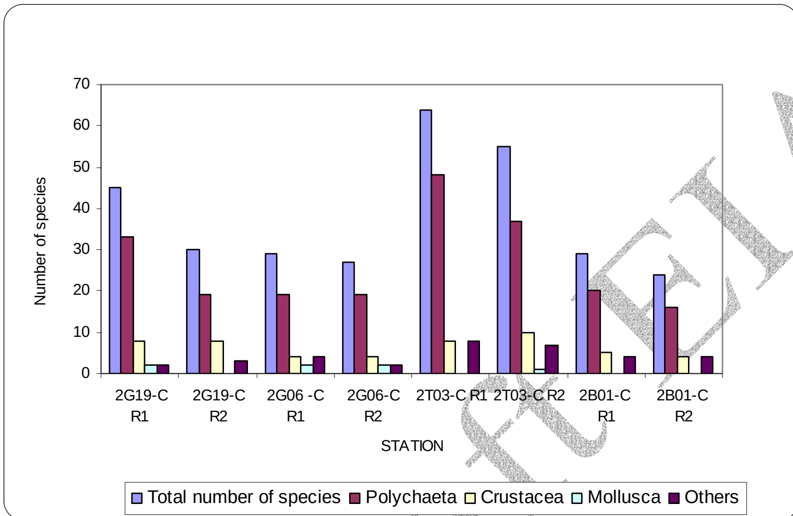


Figure 6.3-18
Distribution of Diversity at Random Stations along Countries Main Pipeline Route

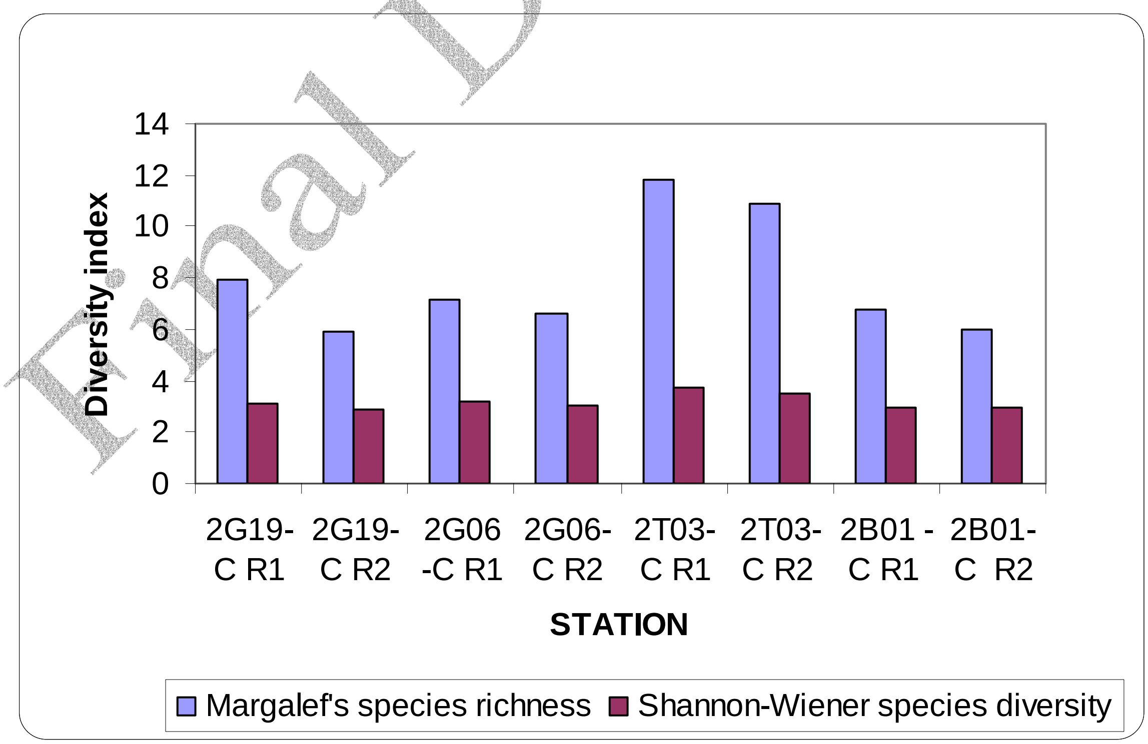
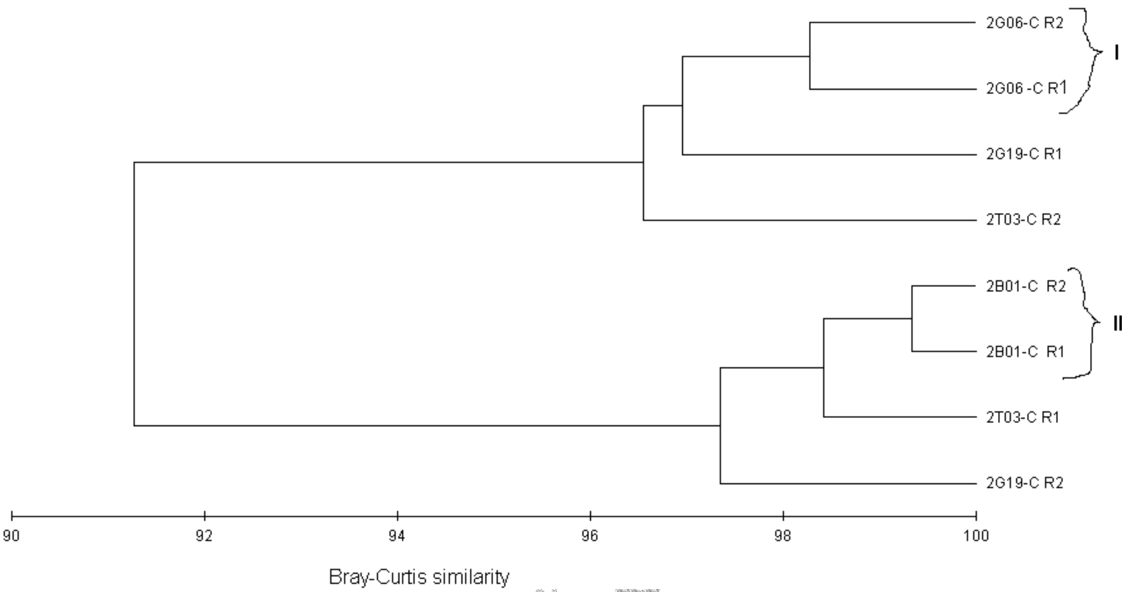


Figure 3.3-19 shows the group-average dendrogram clustering of the random stations.

Figure 6.3-19
Group-average dendrogram of Bray-Curtis similarity Showing Clustering of Random stations and the Stations Replicates



Two stations, Stations 2G06-C and 2B01-C named I and II on the dendrogram plot showed a high Bray-Curtis similarity with their respective replicates (i.e.R1 and R2). This means that 50% of these stations exhibited a very high homogeneity. Conversely, 50% of the stations also depicted a very high heterogeneity. However, the highest similarity in station replicate was recorded at Station 2B01-C which recorded a Bray-Curtis similarity of 99%. The less similar stations were 2G19-C and 2T03-C with Bray-Curtis similarity of 91% that is appreciably high. This possibly suggests that most of the stations sampled have similar species abundances.

6.1.1.5 Discussion

Polychaetes constituted the dominant organisms of the benthic infauna analysed. Polychaetes occur in two basic forms, errant and sedentary types, based on habits. Errant types are generally mobile predators with jaws for catching prey. Sedentary types are tube dwellers and generally are detritivores or filter feeders.

A total of 1797 individual polychaetes belonging to 40 families were recorded in the offshore waters. Of this number, a total of 482 individuals (27% of the polychaetes by number) belonging to 12 families were errant polychaetes, while the sedentary polychaetes included 1315 individuals (73% of the polychaetes by number) comprising 28 families. Polychaete families with counts exceeding 50, 30, 20 and 5 individuals were classified as ‘dominant’ for Ghana, Togo, Benin and Nigeria respectively. Based on this classification, the dominant families among the errrants were the Eunicidae, Nephtyidae, Phyllocidae and the Glyceridae, and comprised 68% of the entire errant forms. Among the sedentary types, the dominant forms included the Spionidae, Ampharetidae, Maldanidae, Lumbrinereidae, Onuphidae and Cirratulidae. They constituted 61 percent of the sedentary forms.

Figure 6.3-20
Occurrence of Dominant Sedentary Polychaetes across Ghana

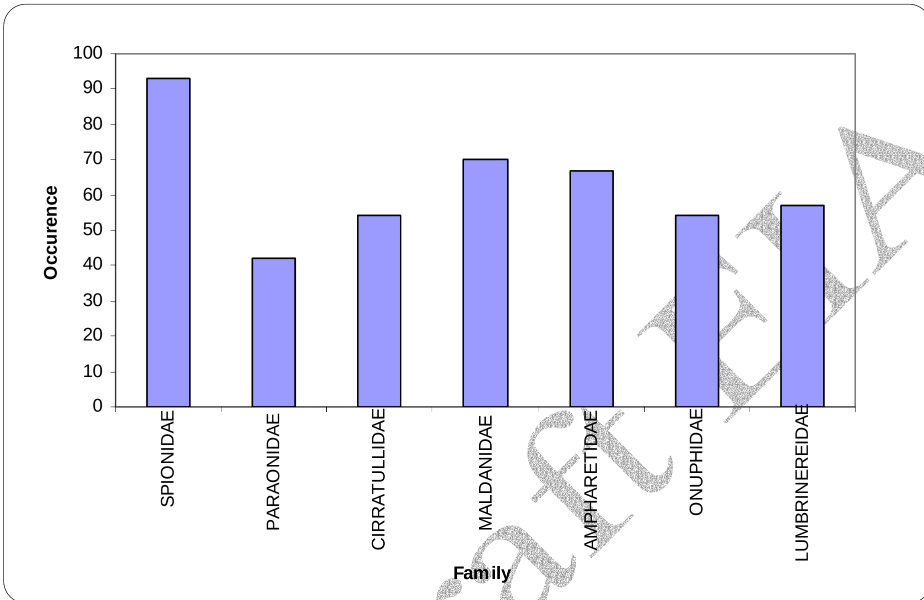


Figure 6.3-21
Occurrence of Dominant Errant Polychaetes across Ghana

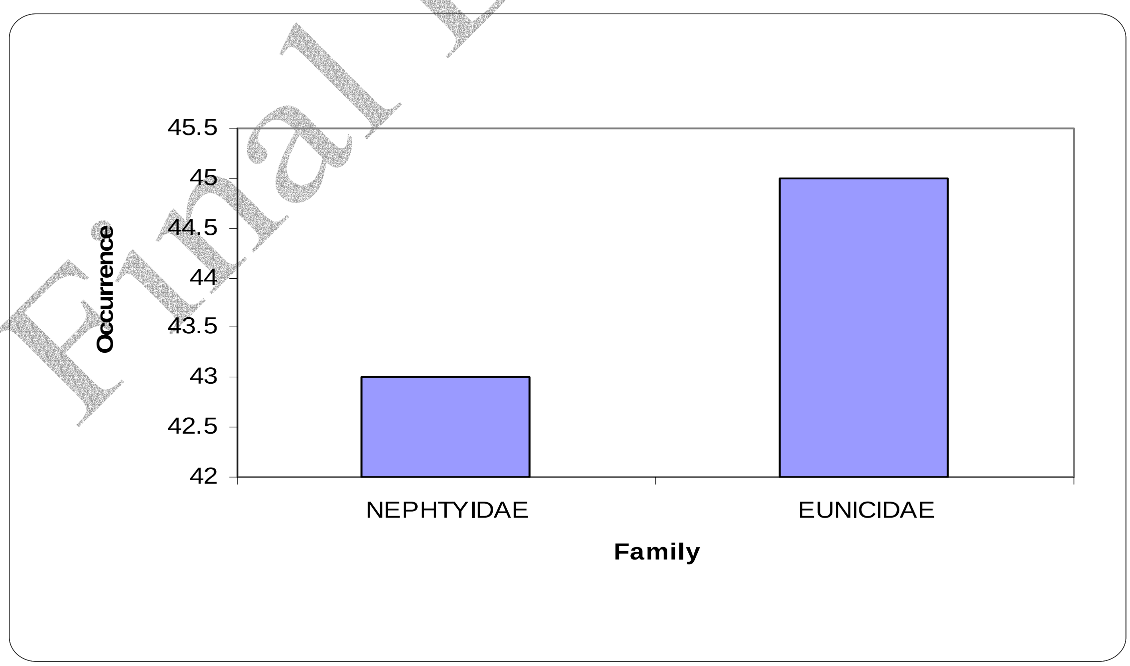


Figure 6.3-22
Occurrence of Dominant Sedentary Polychaetes across Togo

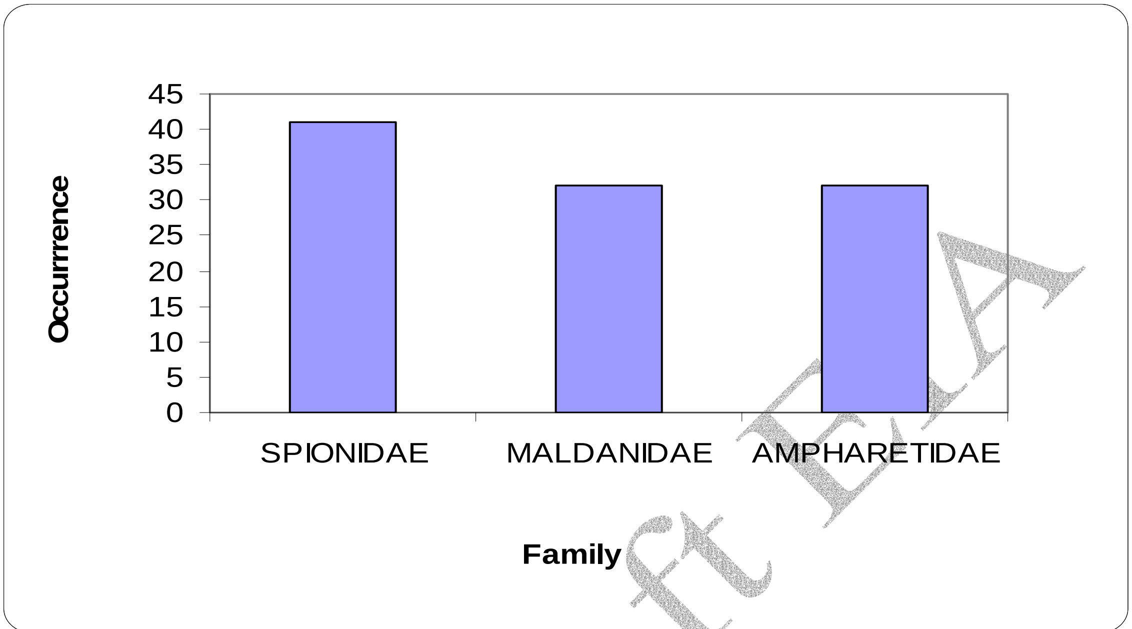


Figure 6.3-23
Occurrence of Dominant Errant Polychaetes across Togo

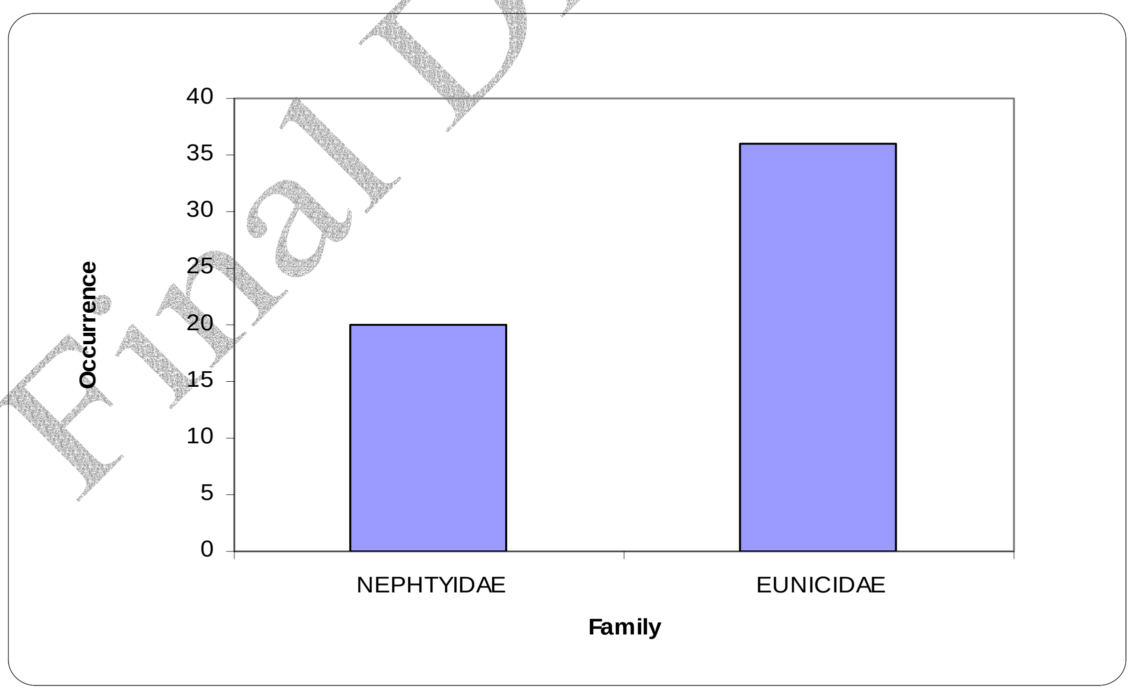


Figure 6.3-24
Occurrence of Dominant Sedentary Polychaetes across Benin

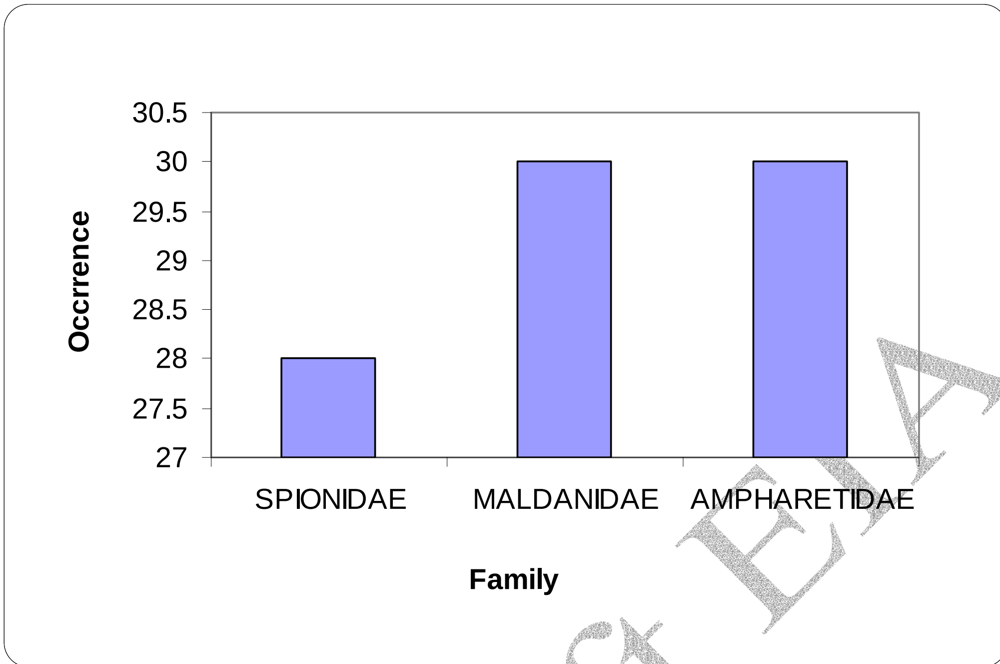


Figure 6.3-25
Occurrence of Dominant Errant Polychaetes across Benin

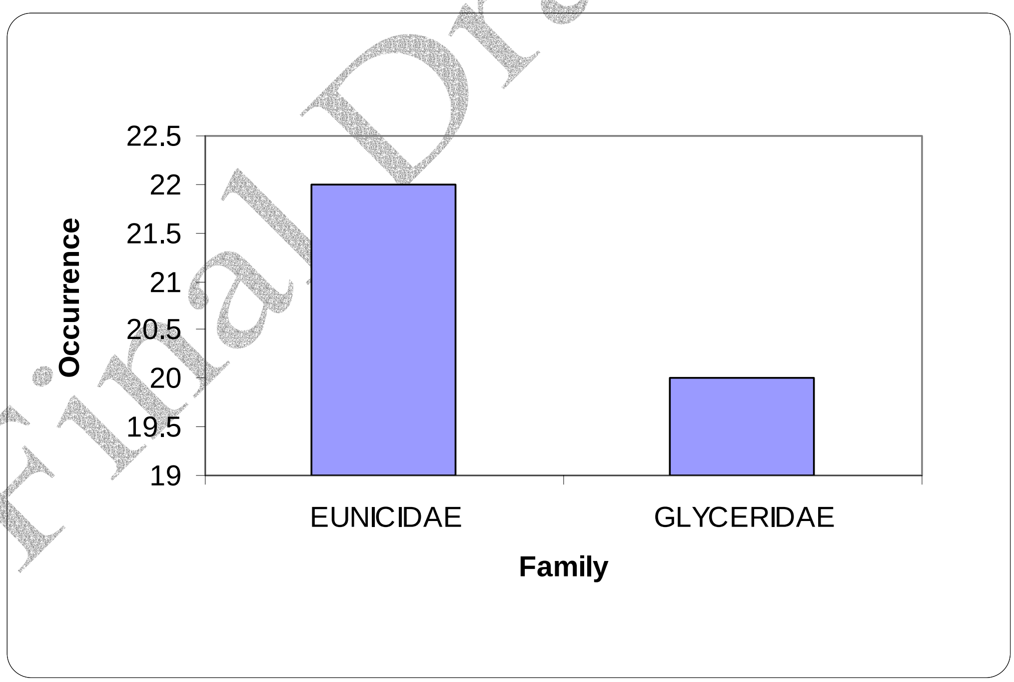


Figure 6.3-26
Occurrence of Dominant Sedentary Polychaetes across Nigeria

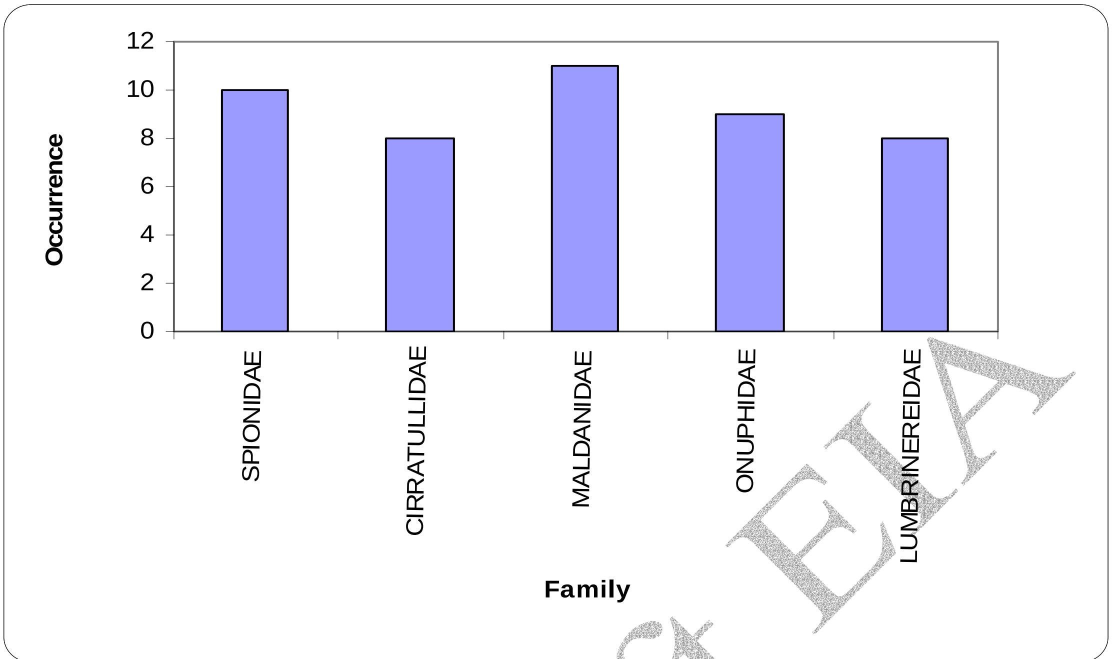
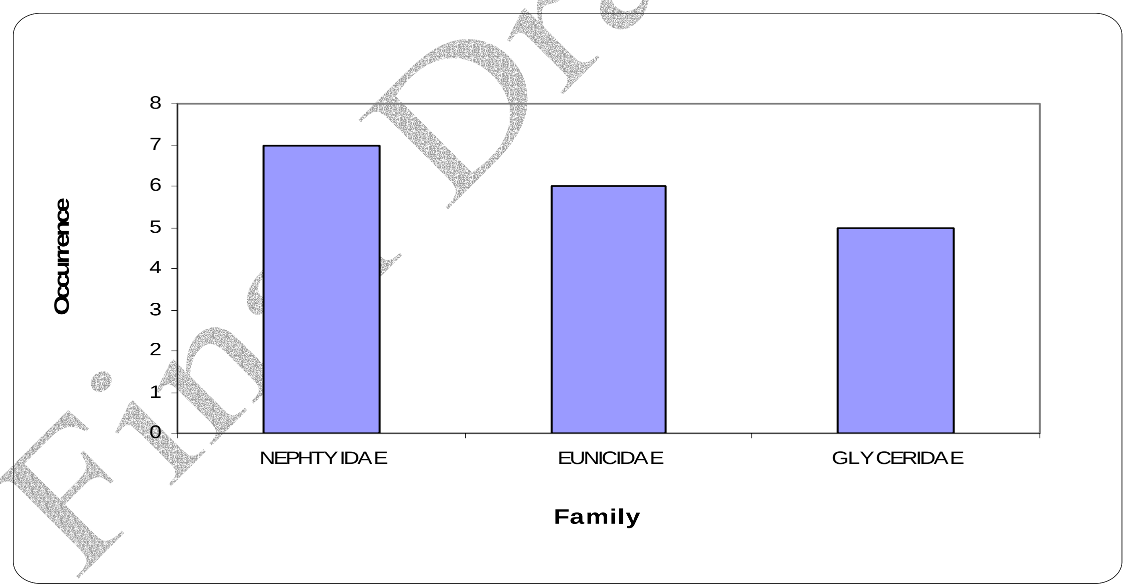


Figure 6.3-27
Occurrence of Dominant Errant Polychaetes across Nigeria



The relative occurrences of the 'dominant' errant and 'dominant' sedentary polychaetes are presented in Figures 6.3-20 and 6.3-27 on country-by-country basis. Figures 6.3-28 and 6.3-29 also show the hierarchical dominant errant and sedentary families for the entire offshore study area. The Maldanidae and Spionidae families were the most common, while the Ampharetidae was the least abundant in the hierarchical order.

Figure 6.3-28
Occurrence of Dominant Errant Polychaetes across Countries

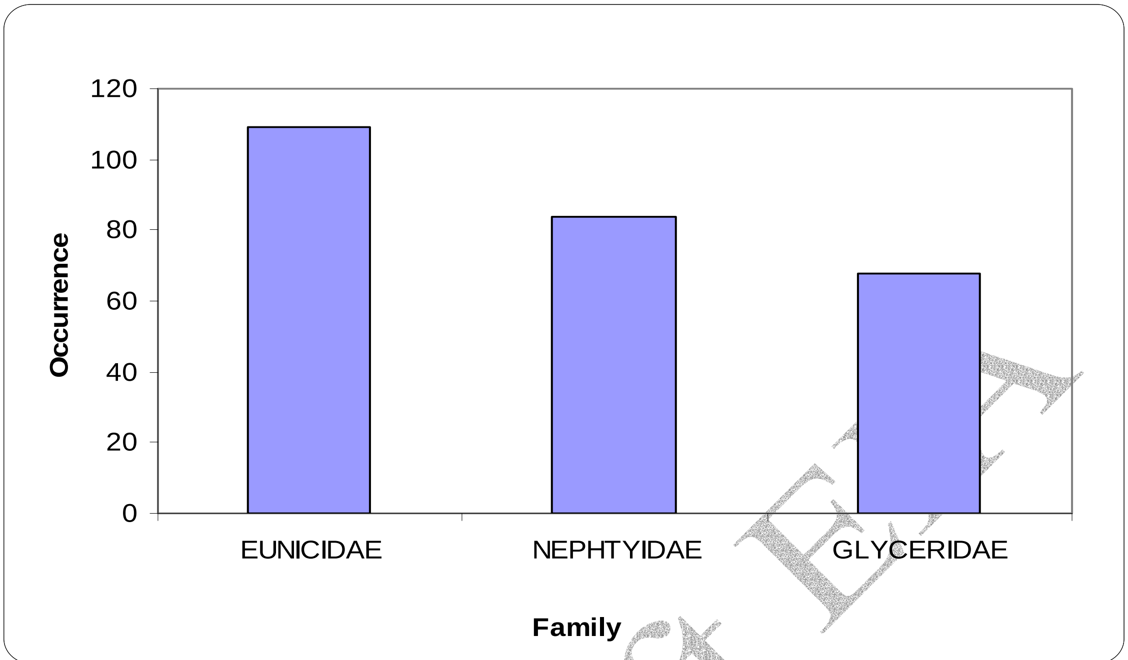
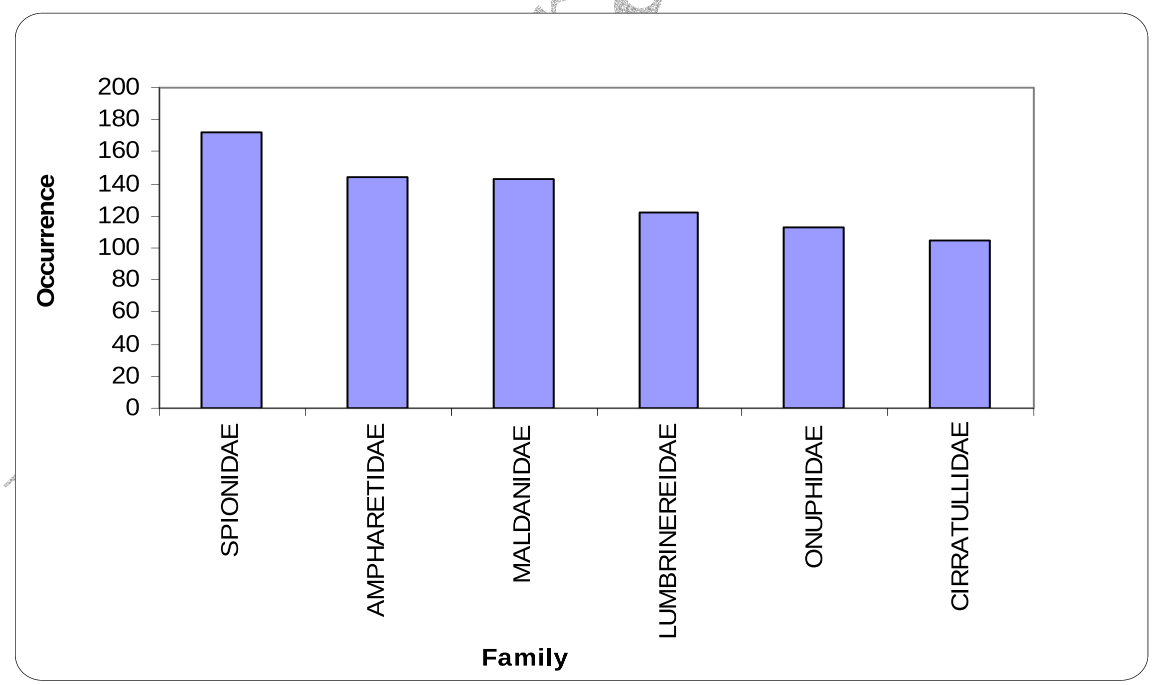


Figure 6.3-29
Occurrence of Dominant Errant Polychaetes across Countries



6.1.2 Offshore Plankton Community Characterization

A total of sixty-three phytoplankton, sixty-three zooplankton (oblique tow) and sixty-five zooplankton (vertical haul) taxa were identified in the samples (Table 6.3-2). The phytoplankton community was dominated by *Chaetoceros* spp. while *Penilia avirostris,* *Temora stylifera* and *Para-Clausocalanus spp* dominated the zooplankton community. The density of zooplankton obtained by oblique and vertical tows was higher in the latter (Table 6.3- 2 b, c). *P. avirostris* ranked highest, in terms of abundance, in the oblique tow but was second highest in the vertical haul. This species is mostly epipelagic (Bainbridge, 1972), and the oblique tow, by its design, samples the upper water column.

Table 6.3-2
Plankton taxa identified from samples collected off Ghana, Togo, Benin and Nigeria in July, 2003: (a) Phytoplanton, (b) Zooplankton (oblique tow), and (c) Zooplankton (vertical haul)

(a) Phytoplankton

Taxa	Mean (Cells m^{-3})	Std. Error
Chaetoceros spp.	62,227.10	16,856.90
Trichodesmium (Oscillatoria)	24,460.20	9,539.60
Ceratium extensum	14,421.90	4,426.10
Rhizosolenia calcar avis	13,925.20	7,551.50
Rhizosolenia spp	12,653.00	7,552.60
Thalassionema nitzschioides	9,926.30	6,141.70
Fragilaria spp.	8,952.90	5,026.00
Dinoflagellate cysts	8,761.30	5,366.70
Rhizosolenia hebetata semispina	8,001.60	2,940.90
Ceratium vultur	6,245.00	2,706.50
Ceratium trichoceros	6,165.30	2,579.10
Ceratium massiliense	6,106.90	2,104.80
Thalassiosira spp.	5,850.30	2,845.20
Bacteriastrum spp.	5,304.70	2,692.50
Dinophysis spp.	5,020.70	1,662.20
Coccolithaceae	4,743.50	2,463.90
Blue green algae	4,210.90	1,726.00
Rhizosolenia alata alata	3,916.70	1,972.50
Nitzschia spp.	3,460.40	1,172.60
Climacodium spp.	3,355.40	2,437.40
Thalassiothrix longissima	2,729.00	981
Acantharia	2,713.70	1,362.70
Ceratium contortum	2,526.50	2,342.50
Ceratocorys spp.	2,212.80	878.3
Ceratium pentagonum	1,982.20	1,282.20
Ceratium fusus	1,980.70	669.4
Coscinodiscus spp.	1,779.50	561.1
Ceratium furca	1,626.50	861.5

Taxa	Mean (Cells m^{-3})	Std. Error
Dactyliosolen mediterraneus	1,582.50	1,272.50
Silicoflagellate	1,573.20	678.3
Ceratium macroceros	1,463.00	916.3
Skeletonema costatum	1,350.30	755.6
Ceratium bucephalum	1,288.90	550.2
Ceratium hexacanthum	1,242.00	491.7
Asterionella japonica	1,191.80	581.7
Thalassionema fraunfeldii	909.1	862.6
Hemiaulus spp.	880	414.1
Ceratium teres	850.5	425
Ceratium horridum	842.1	836.6
Ditylum brightwelli	833	330.4
Rhizosolenia setigera	733.9	733.9
Ornithocercus spp.	701.3	371.7
Ceratium carriense	600.9	570.1
Navicula spp.	585.1	350.6
Biddulphia aurita	544.9	299.3
Corethron	502	302.3
Gonyaulax spp.	456.5	233.2
Podolampas spp.	314.2	305.3
Amphsolenia spp.	306.7	205.3
Prorocenturm spp.	235.6	185.1
Ceratium tripos	233.7	121.3
Ceratium arietinum	204.2	181.7
Ceratium breve	197.6	183.3
Peridinium spp.	190.7	166.3
Lithodesmium undulatum	189.6	171.7
Paralia spp.	100.9	69.2
Exuviaella spp.	92.6	65.9
Detonula confervacea	69.7	61
Dictyocha spp.	58.2	58.2
Ceratium candelabrum	31	19
Lauderia spp.	22.8	18.2
Ceratium lineatum	16.6	16.6
Ceratium minutum	4.9	4.9

(b) Zooplankton (oblique tow)

Taxa	Mean (individuals m^{-3})	Std. Error

Taxa	Mean (individuals m^{-3})	Std. Error
Penilia avirostris	369.5	163.8
Temora stylifera	221.5	44.8
Para-Clausocalanus	196.8	33.4
Oncaea spp.	108.3	20.2
Oikopleura longicaudata	90.3	21.5
Eucalanus pileatus	87.6	20
Corycaeus spp.	62.5	19.3
Oithona spp./Lubbockia spp.	49.8	9.7
Decapod	22.8	5.5
Sagitta spp.	21.8	4.8
Centropages furcatus	21.7	5.8
Euterpina acutifrons	17.2	10.6
Nauplii	16.1	5.8
Acartia spp.	15	2.7
Cyprid	14.2	11.2
Thecosomata	12.4	6
Conchoecia spp.	12.4	5.5
Thaliacea	11.6	3.8
Evadne spp.	10.8	4.1
Lucifer faxoni	9.4	2.9
Medusae	7	5.2
Muggiaea spp.	6.8	2.4
Euchaeta paraconcina	6.6	1.9
Pluteus	6.1	2.3
Polychaeta	5.4	2.4
Corycaeus speciosus	5	1.8
Fish larvae	4.9	2
Undinula vulgaris	4.7	1.2
Macrosetella gracilis	3.7	2.3
Tintinnid	3.5	1.6
Foraminifera	3.4	1.3
Hyperidea	3.1	1
Sagitta enflata	3.1	1.2
Calocalanus spp.	3	1.3
Lamellibranchia	2.9	1.3
Nannocalanus minor	2.6	1.2
Fish eggs	2.5	1.3
Cyphonautes	2.3	1.4
Siphonophore	2.2	1.1

Taxa	Mean (individuals m^{-3})	Std. Error
Asteroidea	1.9	1
Rhincalanus cornutus	1.2	0.6
Eucalanus attenuatus	1.2	1
Farranula gracilis	1.1	1.1
Centropages chierchiae	1	0.7
Scolecithrix danae	1	0.7
Sapphirina spp.	0.8	0.4
Euchaeta marina	0.7	0.5
Neocalanus gracilis	0.7	0.5
Candacia spp.	0.7	0.5
Sagitta friederici	0.5	0.5
Euphausiacea	0.5	0.5
Sagitta hispida	0.3	0.3
Podon sp.	0.2	0.2
Membranipora membranacea	0.2	0.2
Sepia sp.	<0.1	<0.1
Beroe Cucumis	<0.1	<0.1
Pontellina plumata	<0.1	<0.1
Pleuromamma spp.	<0.1	<0.1
Pleurobrachia pileus	<0.1	<0.1
Harpaticoida	<0.1	<0.1
Eucalanus crassus	<0.1	<0.1
Echinoderm larvae	<0.1	<0.1
Copilia spp.	<0.1	<0.1

(c) Zooplankton (vertical haul)

Taxa	Mean (individuals m^{-3})	Std. Error
Para-Clausocalanus	1,475.80	214.1
Penilia avirostris	1,398.20	750.1
Temora stylifera	1,006.20	165.9
Oncaea spp.	711.5	105.3
Oikopleura longicaudata	673.6	100.4
Eucalanus pileatus	469.2	108.1
Oithona spp./Lubbockia spp.	429.2	75.9
Nauplii	393.2	190.1
Corycaeus spp.	243.9	37.2

Taxa	Mean (individuals m^{-3})	Std. Error
Polychaeta	170	116.4
Thaliacea	166.3	70
Sagitta spp.	125.3	23.1
Euterpina acutifrons	100	37
Conchoecia spp.	87.4	42.3
Pluteus	86.4	23.4
Decapod	78.8	14.3
Sagitta enflata	59.6	22.5
Euchaeta paraconcina	54.5	15.5
Siphonophore	53.1	34.7
Medusae	51	28.1
Calocalanus spp.	47.5	21.1
Evadne spp.	41.2	15.8
Acartia spp.	35.6	10.4
Centropages furcatus	33.2	8
Foraminifera	32.8	12.4
Thecosomata	31.6	9.3
Cyprid	29.4	21.7
Lucifer faxoni	26.7	11.7
Asteroidea	25.5	12.7
Hyperidea	20.7	13.6
Sagitta friederici	15.9	13.6
Farranula gracilis	14.8	10.8
Sapphirina spp.	14.4	7.7
Fish larvae	14.1	8.5
Muggiaea spp.	13.6	7.2
Nannocalanus minor	12.5	4
Rhincalanus cornutus	7.3	5.5
Lamellibranchia	7.1	3.1
Neocalanus gracilis	7	3.6
Sagitta hispida	6.8	6.8
Beroe cucumis	6.8	6.8
Membranipora membranacea	6.1	3
Tintinnid	5.3	3.3
Corycaeus speciosus	5.2	2.8
Undinula vulgaris	3.3	1.9
Macrosetella gracilis	1.8	1.8
Fish eggs	1.5	1.1

Taxa	Mean (individuals m^{-3})	Std. Error
Euphausiacea	1	1
Eucalanus crassus	1	1
Eucalanus attenuatus	1	1
Aetideus armatus	<0.1	<0.1
Scolecithrix danae	<0.1	<0.1
Pontellina plumata	<0.1	<0.1
Scolecithrix danae	<0.1	<0.1
Podon sp.	<0.1	<0.1
Pleuromamma spp.	<0.1	<0.1
Pleurobrachia pileus	<0.1	<0.1
Mysid	<0.1	<0.1
Harpaticoida	<0.1	<0.1
Euchaeta marina	<0.1	<0.1
Echinoderm larvae	<0.1	<0.1
Cyphonautes	<0.1	<0.1
Copilia spp.	<0.1	<0.1
Centropages chierchiae	<0.1	<0.1
Candacia spp.	<0.1	<0.1

Phytoplankton species diversity was highest off Ghana (Stations G01 and G02) whilst in the case of zooplankton, Benin recorded the highest diversity (Table 6.3-3). By pooling data together, Ghana recorded highest diversity in species with respect to phytoplankton and zooplankton (oblique tow). Benin showed highest diversity with respect to zooplankton (vertical haul) (Figure 6.3-30).

With regard to zooplankton vertical haul, all stations off Benin were never less than 25 m (Table 6.3-1). It is possible depth of water at those stations contributed to the high diversity (pooled data) in zooplankton (vertical haul) recorded off Benin.

Table 6.3-3
Calculation of Suite of Diversity Indices for Plankton Collected Off Ghana, Togo, Benin And Nigeria In July, 2003.
(S, Species Richness; N, Number Of Individuals; D, Margalef's Index; J', Pielou's Evenness Index; H', Shannon-Wiener Index)

(a) Phytoplankton

Station	S	N	d	J'	H'(loge)
2G01	28	375,938.5	2.1	0.6	2.2
2G02	26	680,327.5	1.9	0.6	1.8
2N01	23	145,125.9	1.9	0.7	2.1

2G06	22	469,365.1	1.6	0.8	2.5
2T02	22	311,384.6	1.7	0.7	2.2
2G03	21	254,979.3	1.6	0.6	1.8
2B03	21	230,139.8	1.6	0.8	2.5
2N02	21	789,642.4	1.5	0.6	1.9
2T04	20	106,393.7	1.6	0.8	2.3
2N04	20	177,093.6	1.6	0.7	2.2
2G05	19	139,693.9	1.5	0.8	2.5
2G07	19	92,540.4	1.6	0.6	1.9
2T03	18	163,777.5	1.4	0.7	1.9
2B01	18	100,308.8	1.5	0.8	2.3
2B02	18	160,859.9	1.4	0.8	2.3
2G09	17	90,722.5	1.4	0.7	2.1
2G04	16	57,690.7	1.4	0.7	2.0
2G10	16	578,275.8	1.1	0.7	1.8
2B04	16	117,394.1	1.3	0.7	2.1
2G11	14	148,079.0	1.1	0.7	1.9
2G12	14	416,857.6	1.0	0.6	1.5
2T01	14	114,861.4	1.1	0.8	2.1
2N03	14	310,593.0	1.0	0.8	2.0
2G08	12	171,433.3	0.9	0.6	1.4
2B05	12	188,034.0	0.9	0.7	1.8

(b) Zooplankton (oblique tow)

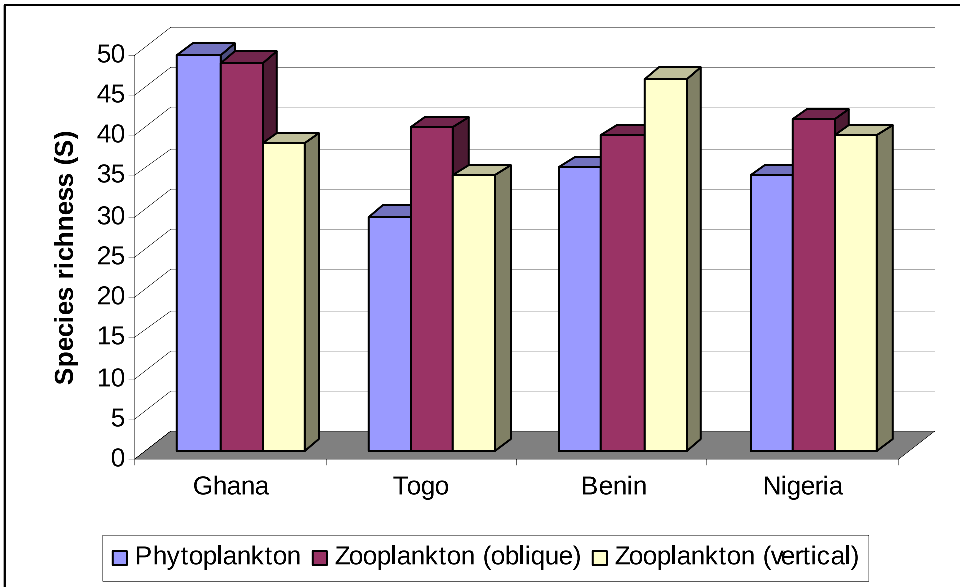
Station	S	N	d	J'	H'(loge)
2B05	32	472.4	5.0	0.8	2.7
2N01	31	1,554.4	4.1	0.7	2.4
2T04	27	1,144.5	3.7	0.8	2.5
2T03	26	1,088.2	3.6	0.8	2.5
2N03	26	2,235.1	3.2	0.7	2.2
2G01	24	7,737.6	2.6	0.6	1.9
2G12	24	3,158.1	2.9	0.7	2.3
2B01	24	2,435.1	2.9	0.7	2.3
2B02	24	1,954.6	3.0	0.8	2.4
2G03	22	811.8	3.1	0.8	2.6
2G05	22	1,976.6	2.8	0.9	2.6
2B03	22	588.0	3.3	0.8	2.4
2N04	22	2,263.1	2.7	0.7	2.2
2G09	20	704.9	2.9	0.8	2.5
2G06	19	1,189.4	2.5	0.7	2.0
2G11	19	2,257.4	2.3	0.8	2.4
2T02	19	825.2	2.7	0.8	2.5
2G02	17	650.7	2.5	0.8	2.4

Station	S	N	d	J'	H'(loge)
2G08	17	769.5	2.4	0.8	2.4
2G10	15	452.5	2.3	0.9	2.4
2N02	15	525.1	2.2	0.7	2.0
2T01	14	529.6	2.1	0.7	1.9
2G04	13	309.1	2.1	0.7	1.9
2G07	11	716.1	1.5	0.8	2.0
2B04	11	220.1	1.9	0.8	2.0

(c) Zooplankton (vertical haul)

Station	S	N	d	J'	H'(loge)
2B01	32	6,887.5	3.5	0.7	2.5
2N01	30	3,906.0	3.5	0.7	2.5
2T03	27	3,162.7	3.2	0.8	2.5
2N03	27	6,534.1	3.0	0.7	2.4
2N04	26	5,218.5	2.9	0.8	2.5
2B05	25	2,534.6	3.1	0.8	2.5
2B03	24	8,605.5	2.5	0.7	2.2
2G01	23	40,288.9	2.1	0.7	2.1
2G05	22	17,938.1	2.1	0.8	2.6
2G09	22	7,700.3	2.3	0.8	2.6
2G03	21	13,697.9	2.1	0.9	2.7
2G06	20	5,765.2	2.2	0.9	2.7
2T01	19	4,979.7	2.1	0.7	1.9
2B02	19	4,896.4	2.1	0.8	2.3
2G02	18	11,230.2	1.8	0.8	2.4
2G10	17	7,279.9	1.8	0.8	2.4
2B04	17	3,117.9	2.0	0.8	2.3
2G08	16	12,025.1	1.6	0.8	2.3
2G11	16	6,533.2	1.7	0.8	2.3
2G12	16	6,434.5	1.7	0.8	2.1
2G04	15	8,128.6	1.6	0.8	2.3
2G07	12	1,767.7	1.5	0.9	2.2
2T02	12	2,366.7	1.4	0.8	1.9

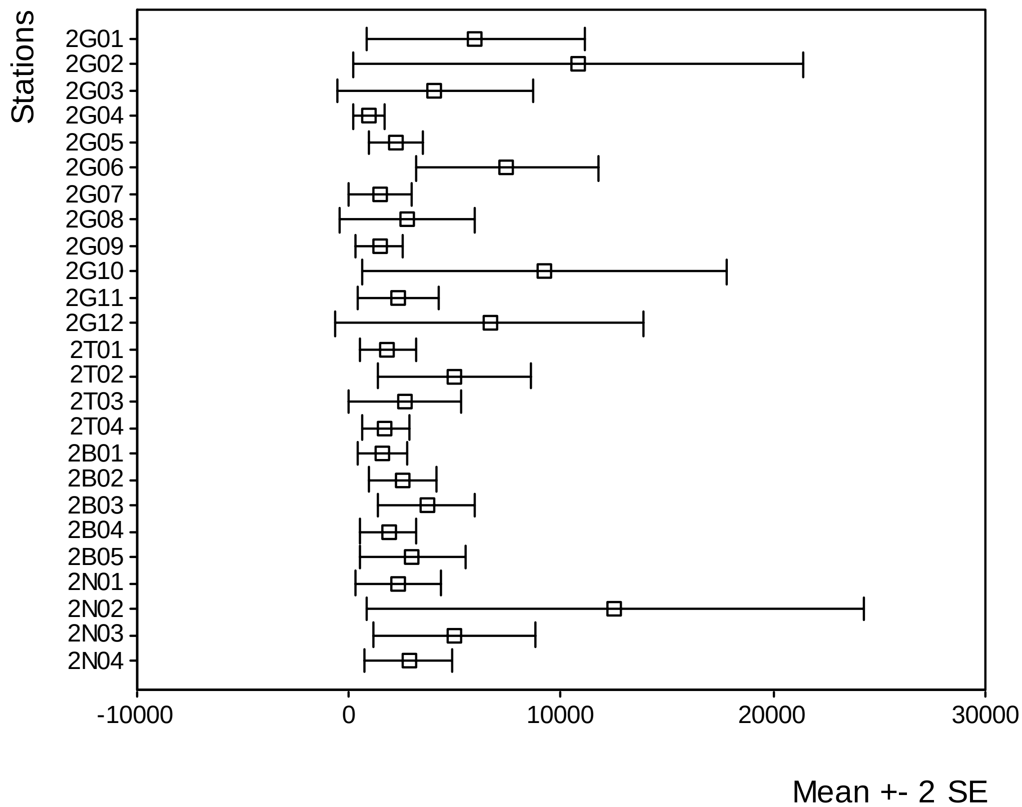
Figure 6.3-30
Distribution of Species Richness (S) by Country



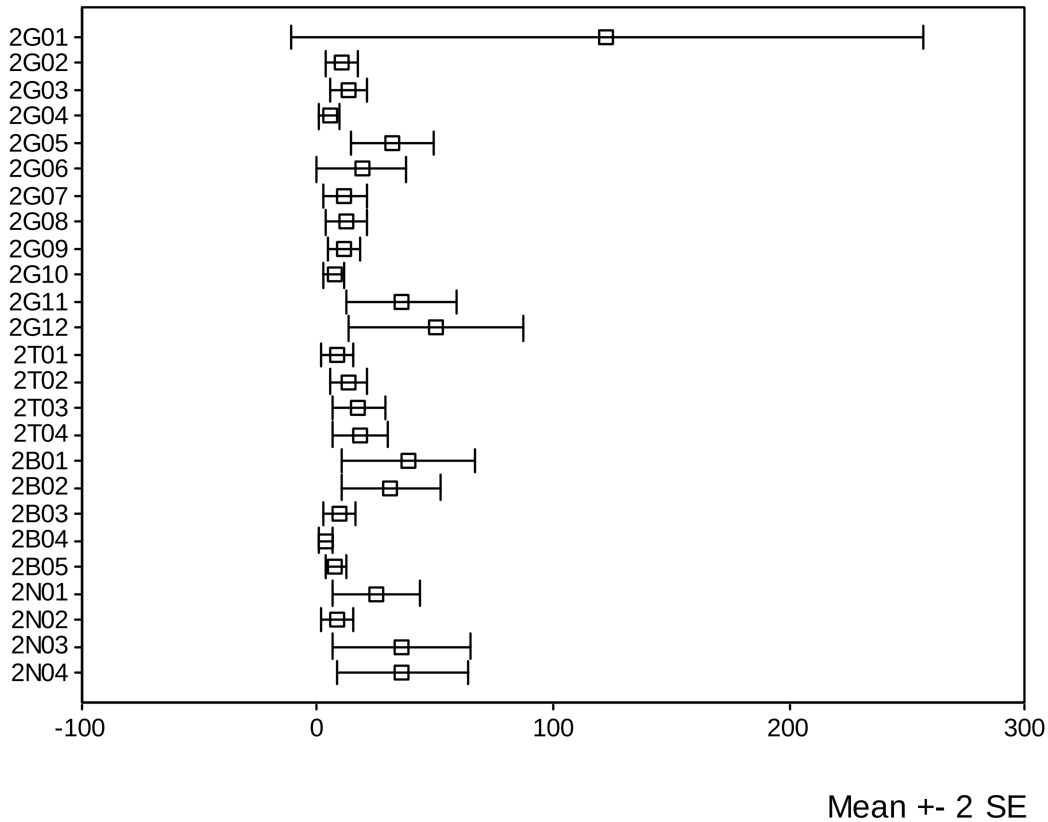
Whereas phytoplankton abundance was highest off Station G02, zooplankton abundance (vertical and step oblique) was highest off Station G01 (Figure 6.3-31). By pooling data together for all stations, total abundance of zooplankton collected by vertical haul was relatively higher than that collected by step oblique (Figure 6.3-32). This could be attributed to the effect of diel vertical migration in zooplankton distribution (i.e. zooplankton move to greater depths with rising of the sun and returns to the upper layers during dusk).

Figure 6.3-31
Mean Distribution of Plankton Collected from Sampling Stations off Ghana, Togo, Benin and Nigeria in July, 2003

(a) Phytoplankton


Stations
2G01
2G02
2G03
2G04
2G05
2G06
2G07
2G08
2G09
2G10
2G11
2G12
2T01
2T02
2T03
2T04
2B01
2B02
2B03
2B04
2B05
2N01
2N02
2N03
2N04
-10000
0
10000
20000
30000
Mean +- 2 SE

(b) Zooplankton (step oblique)



(c) Zooplankton (vertical haul)

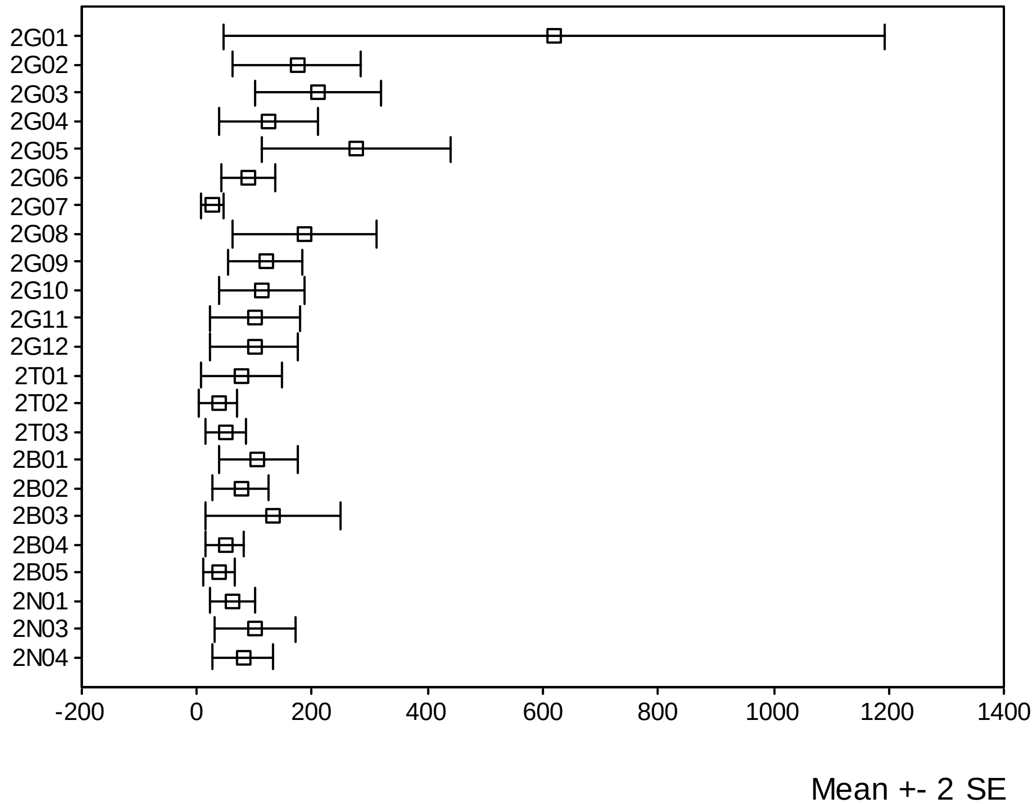
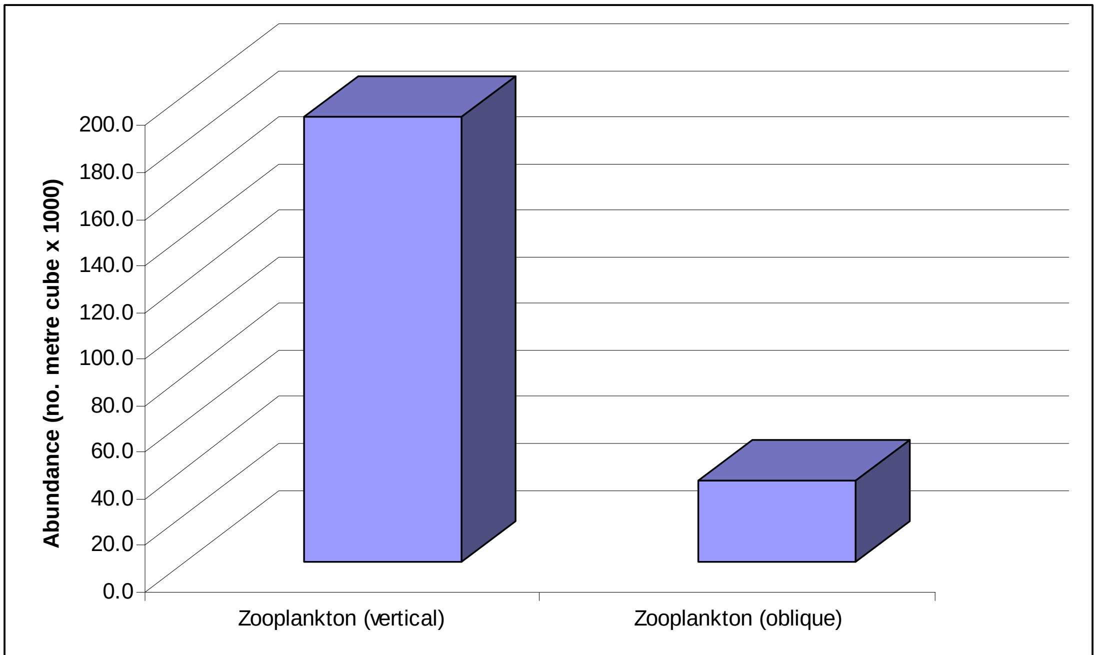


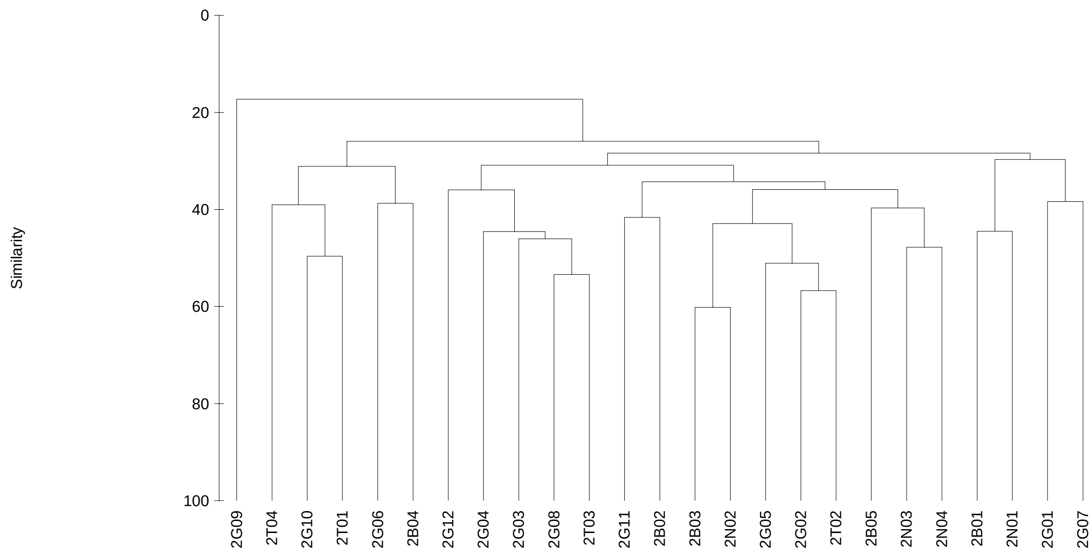
Figure 6.3-32
Distribution of Total Abundance of Zooplankton Collected using Step Oblique and Vertical Methods



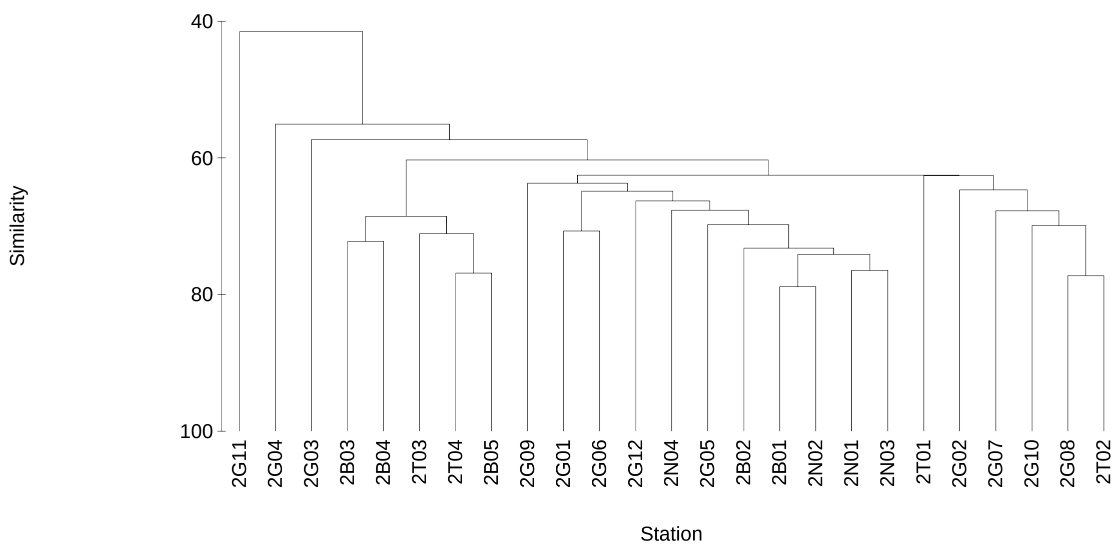
Hierarchical clustering with group-average linking based on Bray-Curtis similarity matrices was performed for all communities. Homogeneity in phytoplankton community was achieved at Bray-Curtis similarity of about 20% (Figure 6.3-33a). This is an indication that the communities from the various stations were very different in terms of species composition and abundance. However, with respect to zooplankton, homogeneity was achieved above 40% and 50% respectively for vertical and oblique methods of sampling (Figure 6.3-33 b, c).

Figure 6.3-33
Dendrogram for Hierarchical Clustering of Plankton Sites, using Group-Average Linking of Bray-Curtis Similarities Calculated on Fourth Root Transformed Abundance Data

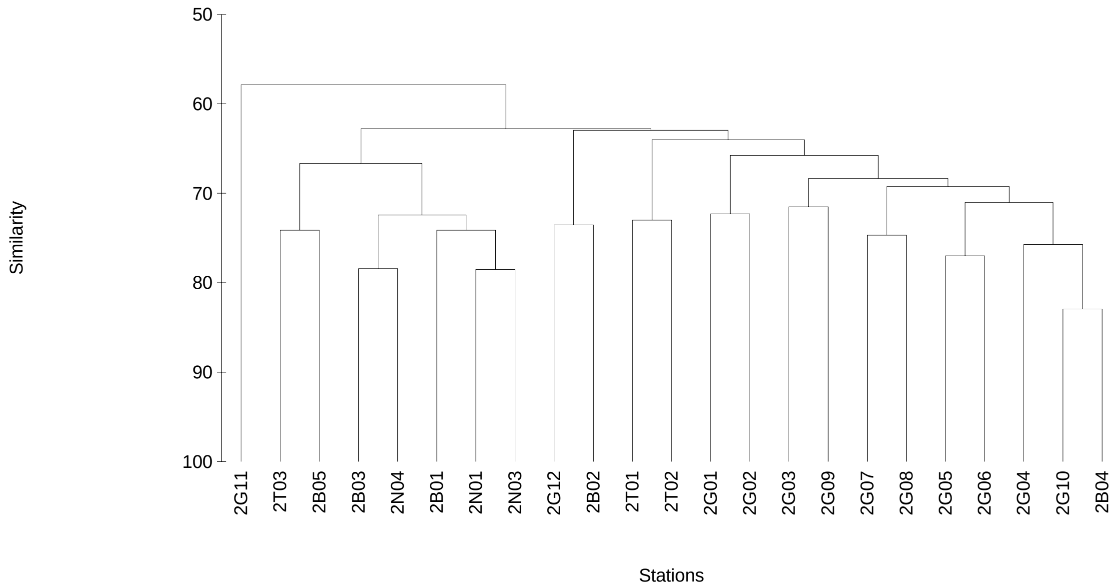
(a) Phytoplankton



(b) Zooplankton (oblique tow)



(c) Zooplankton (vertical haul)



Analysis of similarity (ANOSIM) was performed between the communities from the various countries. None of the pairings was significant at 0.05 level of significance. This means that, on the whole, the spatio-temporal patterns of species contributing to the community structure in Figure 4 were significantly different. An indication of the highly dynamic hydrography that characterises the Gulf of Guinea prior to the major upwelling. However, at a significant level of 0.06, the R-statistic of 0.37 between Ghana and Togo can be considered as ecologically significant and this suggests that the community structure within and between stations from Ghana and Togo (i.e. 12 from Ghana and 4 from Togo) were similar (Table 6.3-4).

Table 6.3-4
Results of Analysis of Similarity (ANOSIM) between Plankton Communities.
(0 < R < 1 Reflects Degree Of Discrimination Between Areas)

Countries	Phytoplankton (Global R = -0.093; α = 0.82)		Zooplankton (vertical haul) (Global R = 0.109; α = 0.19)		Zooplankton (oblique tow) (Global R = -0.023; α = 0.57)	
	R-Statistic	Significant level	R-Statistic	Significant level	R-Statistic	Significant level
Ghana vs. Togo	-0.14	0.8	0.37	0.06	0.09	0.27
Ghana vs. Benin	-0.02	0.52	0.13	0.19	0.1	0.23
Ghana vs. Nigeria	-0.11	0.72	0.02	0.44	-0.15	0.79
Togo vs. Benin	-0.08	0.72	0.19	0.23	-0.17	0.84
Togo vs. Nigeria	0.26	0.11	0.33	0.3	0.23	0.14
Benin vs. Nigeria	-0.16	0.84	-0.45	1	0.09	0.2

Based on community characterisation observed for the zooplankton, with regard to vertical haul and step oblique tow, it is recommended that any future monitoring should consider the method of vertical haul for sampling the zooplankton.

6.1.3 Fish Population

6.1.3.1 Species Composition and Catch Rates

The species composition, catch rates (kg/haul) and number of individual species by stations for Ghana, Togo, Benin and Nigeria are presented in Appendix B3. Figures 6.3-34 to 6.3-37 are graphical representation of the catch rates. Figure 6.3-38 gives the catch rates along the main pipeline route while Figure 6.3-39 gives the catch rates by depth range along the laterals

Figure 6.3-34
Catch Rates at Stations off Ghana

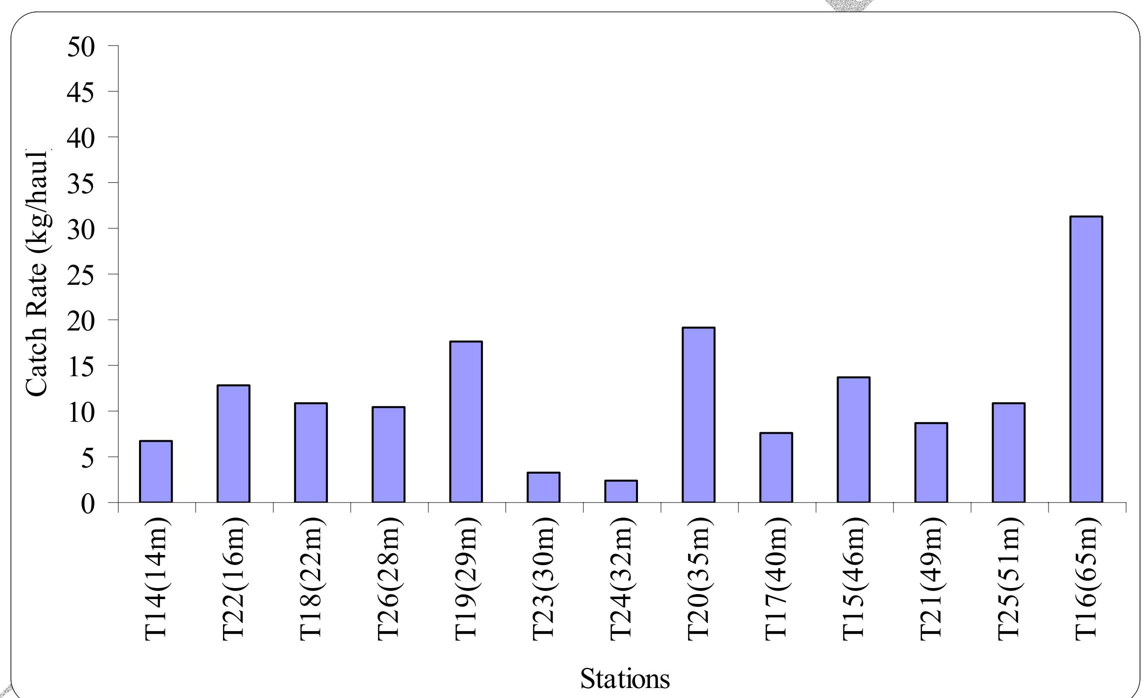


Figure 6.3-35
Catch Rates at Stations off Togo

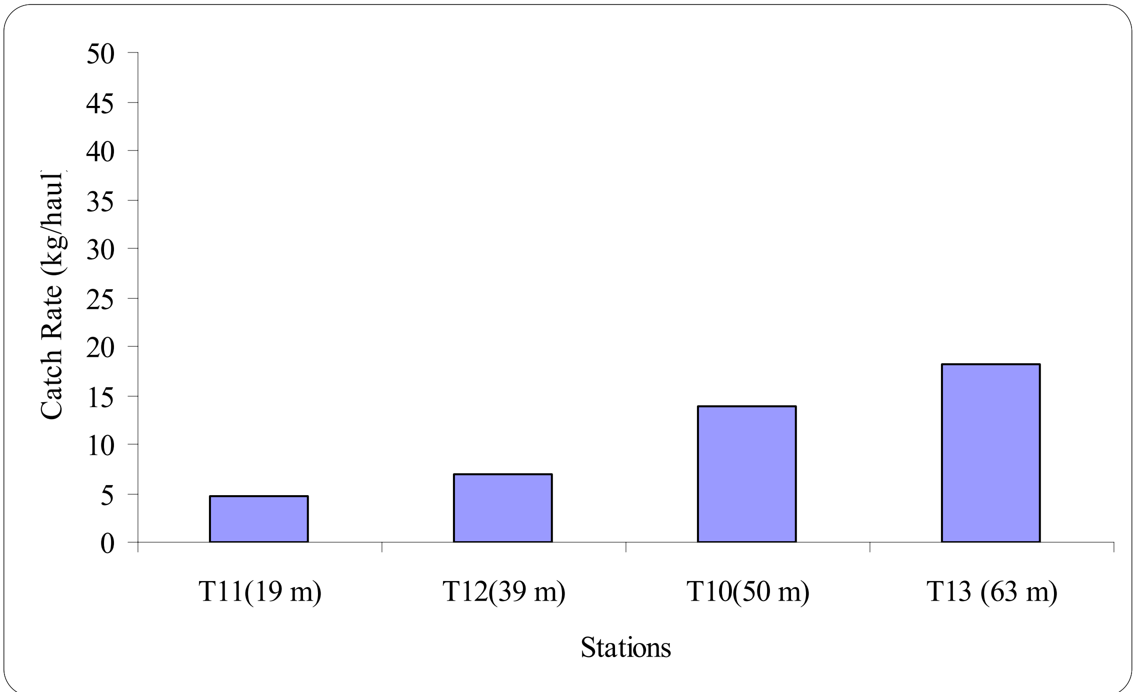


Figure 6.3-36
Catch Rates at Stations off Benin

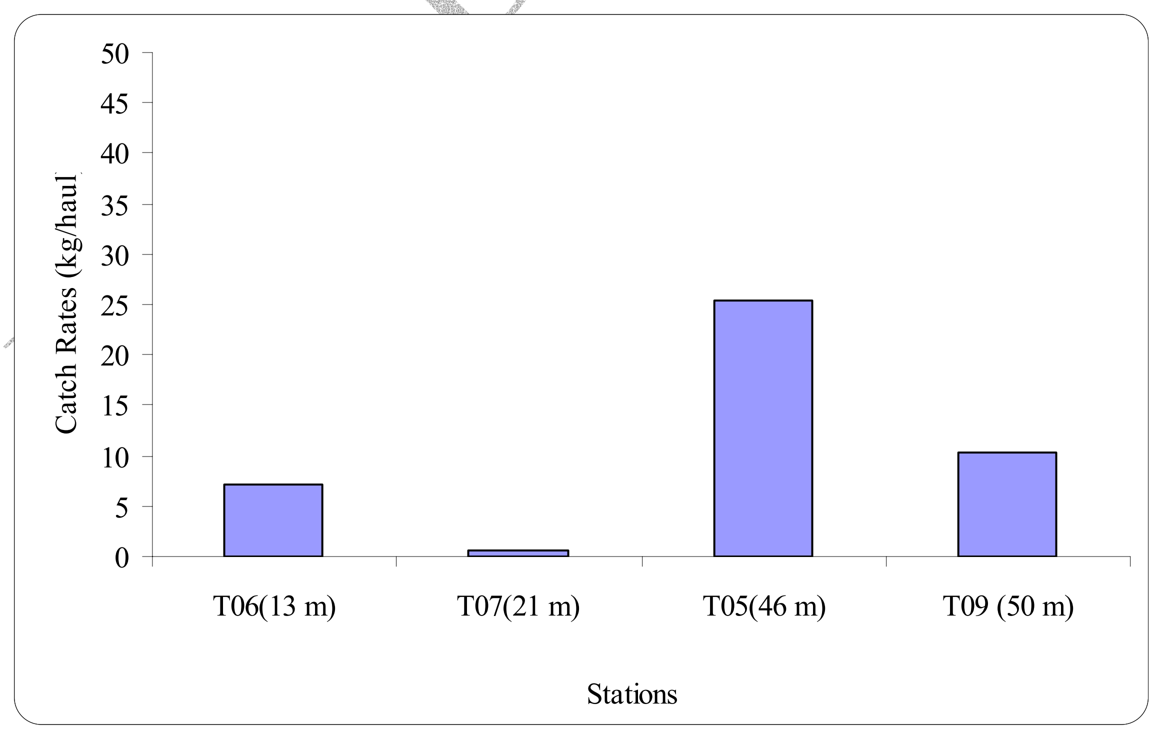


Figure 6.3-37
Catch Rates at Stations off Nigeria

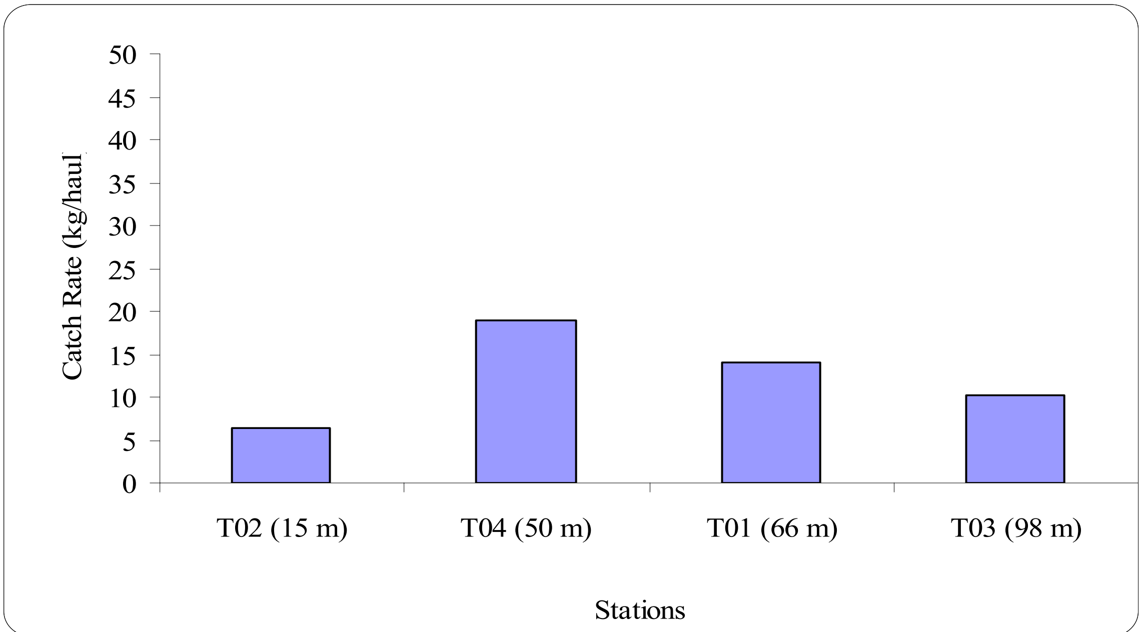


Figure 6.3-38
Catch Rates at Stations along Main Pipeline Route

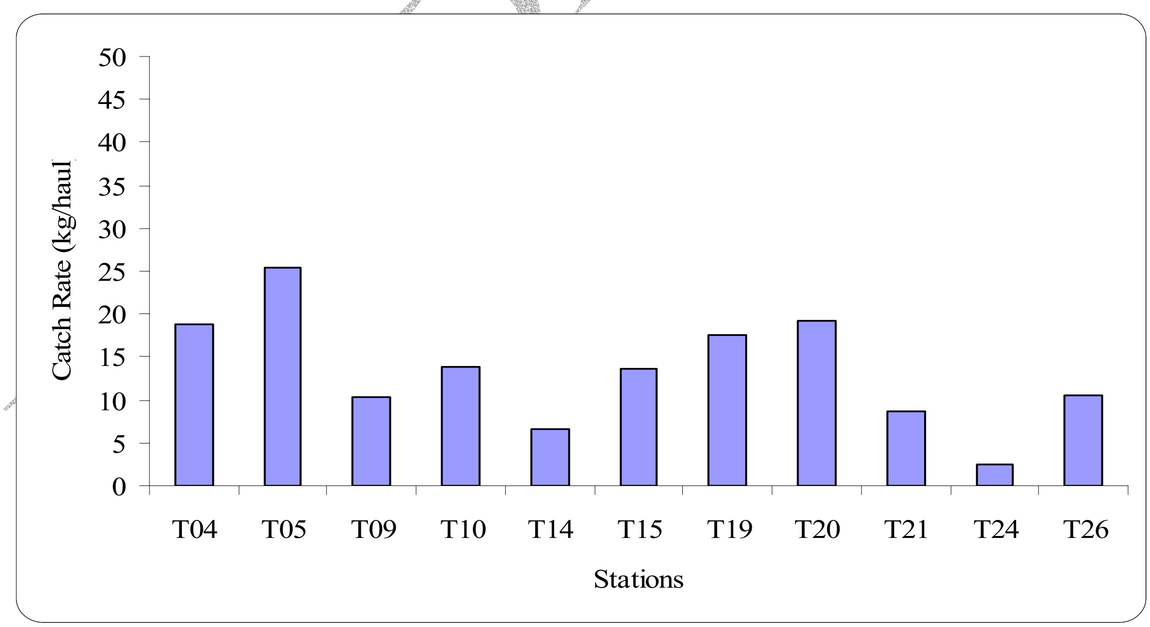
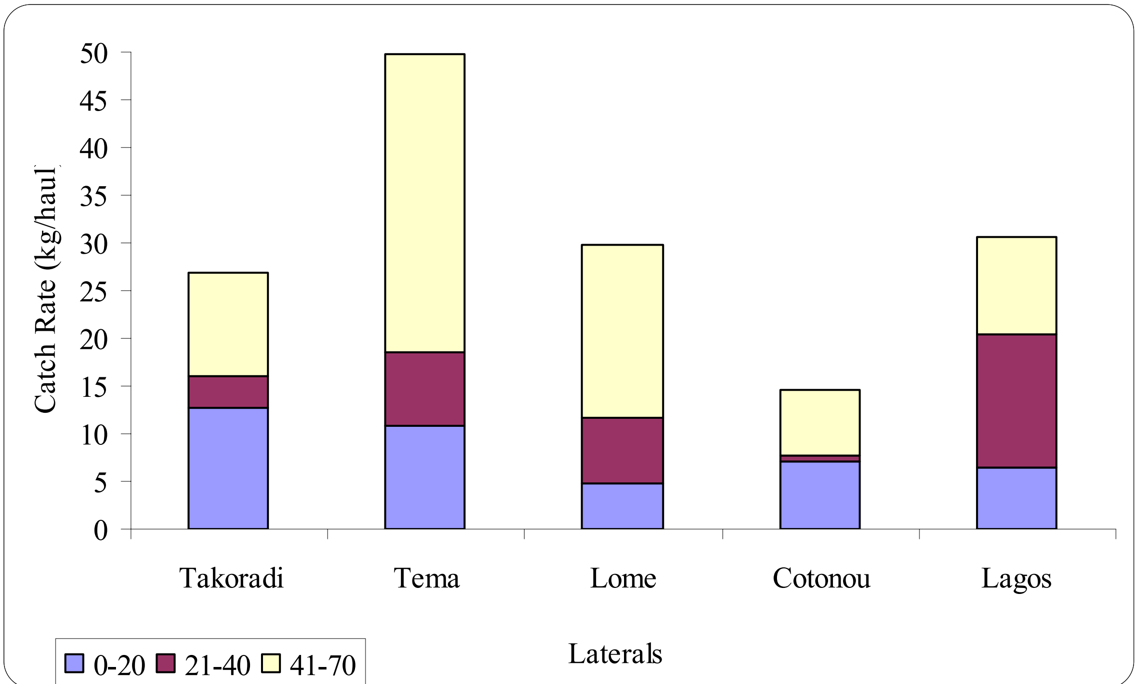


Figure 6.3-39
Catch Rates by Depth Range on the Laterals



Ghana

A total of 106 species belonging to 62 families were caught in Ghanaian waters during the survey (Appendix B3). Of these, 15 were crustaceans, 5 molluscs, 12 other invertebrates and 74 fish species. The crustaceans were mainly crabs, lobster and shrimps while the molluscs were cuttlefish, squid, octopus, snails and bivalves. Almost the same molluscs and crustaceans were found in the other countries.

The dominant species recorded were *Umbrina canariensis* (1.19 kg/haul), *Pseudupeneus prayensis* (1.03 kg/haul), *Syacium micrurum* (1.02 kg/haul), *Chelidonichthys lastoviza* (0.95 kg/haul), *Sepia officinalis* (0.64 kg haul), *Octopus vulgaris* (0.42 kg/haul) and *Grammoplites gruveli* (0.41 kg/haul).

Togo

A total of 45 species belonging to 27 families were caught off Togo (Appendix B3). There was 1 crustacean, 4 molluscs, 8 other invertebrates and 32 fish species.

The most abundant species were Sea Fern (1.27kg/haul), *Octopus vulgaris* (1.04kg/haul), *Dentex angolensis* (1.02kg/haul), *Dentex congoensis* (0.95kg/haul), *Sepia officinalis* (0.75kg/haul), *Pseudupeneus prayensis* (0.50kg/haul), and *Syacium micrurum* (0.48kg/haul).

Benin

A total of 63 species belonging to 43 families were recorded off Benin during the survey (Appendix B3). There were 8 crustacean, 5 mollusc, 7 other invertebrate, and 43 fish species.

The dominant species were *Squatina oculata* (2.13kg/haul), *Chelidonichthys lastoviza* (1.98 kg/haul), *Grammoplites gruveli* (0.80kg/haul), *Sepia officinalis* (0.72kg/haul), *Serranus accraensis* (0.72kg/haul), *Drepane africana* (0.44kg/haul) and *Raja miraletus* (0.42kg/haul).

Nigeria

Off Nigeria, a total of 60 species belonging to 41 families were recorded. There were 7 crustacean, 5 mollusc, 5 other invertebrate, and 43 fish species.

The species were dominated by *Dentex angolensis* (1.95kg/haul), *Brachydeuterus auritus* (1.00kg/haul), *Sepia officinalis* (0.80kg/haul), *Dentex congoensis* (0.68kg/haul), *Pagellus bellottii* (0.52kg/haul), *Grammoplites gruveli* (0.52kg/haul) and *Serranus accraensis* (0.42kg/haul).

6.1.3.2 Laterals and Mainline Stations

The dominant species recorded on each of the five laterals and along the mainline route, together with the catch rates, are presented in Table 6.3-5.

Table 6.3-5
Dominant Species Recorded at the Laterals and along the Main Pipeline Route with the Catch Rates

Lateral	Species	Catch rate (kg/haul)
Takoradi	*Illisha africana*	1.5
	Syacium micrurum	1.2
	Selene dorsalis	0.73
	Pseudotolithus senegalensis	0.57
	Sepia officinalis	0.45
	Pteroscion peli	0.37
	Aurelia sp.	0.37
Tema	*Umbrina canariensis*	5.16
	Chelidonichthys lastoviza	2.3
	Acanthostracion guineensis	1.03
	Pseudupeneus prayensis	0.9
	Sepia officinalis	0.68
	Echinometra sp.	0.67
	Aurelia sp.	0.5

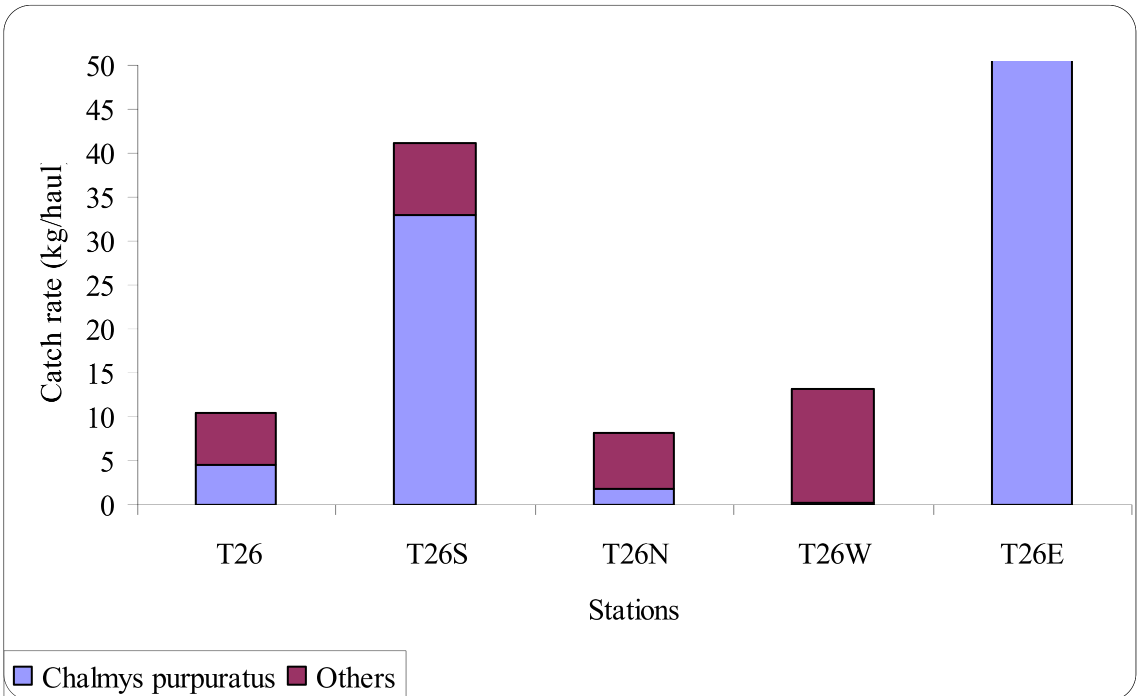
Lateral	Species	Catch rate (kg/haul)
Lome	*Octopus vulgaris*	1.39
	Dentex angolensis	1.37
	Dentex congoensis	1.27
	Sepia officinalis	0.8
	Pseudupeneus prayensis	0.63
	Xyrichthys novacula	0.53
	Chelidonichthys lastoviza	0.47
Cotonou	*Drepane africana*	0.73
	Chelidonichthys lastoviza	0.47
	Grammoplites gruveli	0.43
	Raja miraletus	0.37
	Galeoides decadactylus	0.33
	Fistularia petimba	0.23
	Brachydeuterus auritus	0.2
Lagos	*Dentex angolensis*	2.6
	Dentex congoensis	0.9
	Chelidonichthys lastoviza	0.53
	Galeoides decadactylus	0.53
	Brotula barbata	0.5
	Squatina oculata	0.47
	Sepia officinalis	0.44
Main Pipeline Route	*Chelidonichthys lastoviza*	1.21
	Squatina oculata	1.12
	Sepia officinalis	0.95
	Syacium micrurum	0.95
	Pseudupeneus prayensis	0.84
	Grammoplites gruveli	0.72
	Serranus accraensis	0.61

The following species occurred at almost all the stations on the mainline: *Chelidonichthys lastoviza, Sepia officinalis, Alloteuthis africana, Pseudupeneus prayensis, Grammoplites gruveli, Syacium micrurum* and *Astropecten sp*.

Distribution of *Chlamys purpuratus* off Ghana

The importance of *Chlamys purpuratus* in the catches at and around station T26 is depicted in Figure 6.3-40. The Figure indicates that the species was most abundant on east and north of station T26 and almost absent towards the south and west of the station.

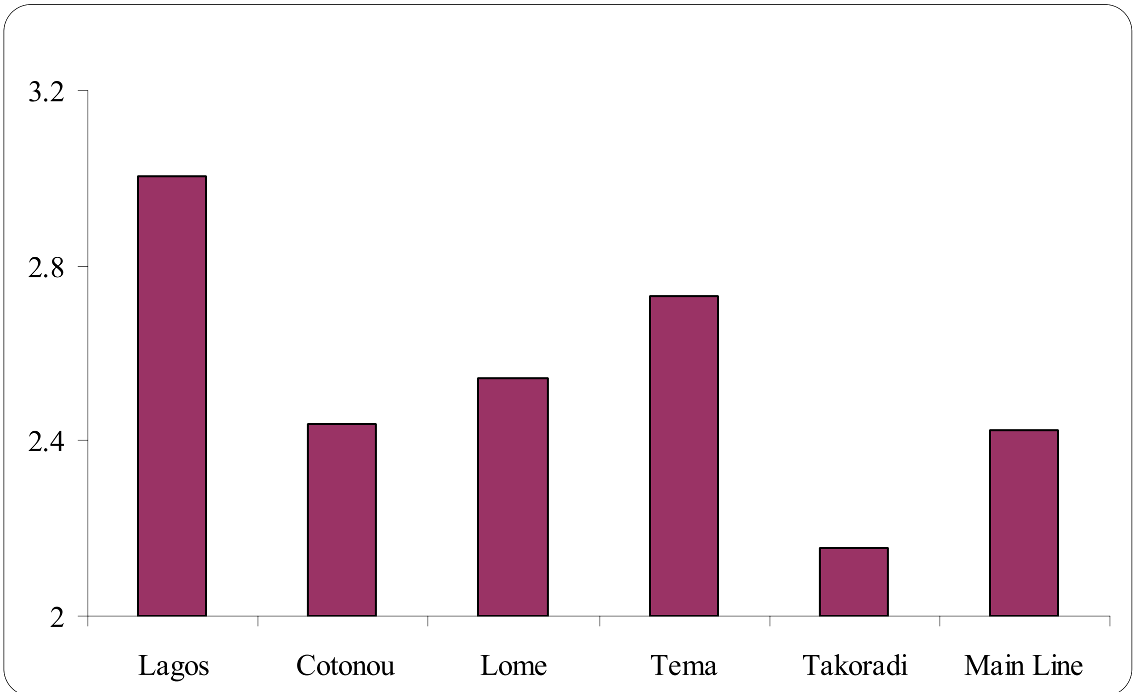
Figure 6.3-40
Distribution of *Chlamys purpuratus*



Species Diversity

The calculated values of the Shannon Diversity Index are presented in Figure 6.3-41. The figure shows that species diversity was highest off Lagos followed by Tema and the lowest was off Takoradi and Cotonou.

Figure 6.3-41
Calculated Values of the Shannon Diversity Index



6.1.3.3 Discussion

Species Composition

Ghana

The composition of species in the hauls varied from station to station. However, *Syacium micrurum, Grammoplites gruveli, Bothus podas africanus, Sepia officinalis*, *Allotheuthis africana*, *Pseudupeneus prayensis, Chelidonichthys lastoviza*, *Aurelia sp*. and *Astropecten sp*. occurred almost at all the stations in Ghanaian waters.

The observed differences in species composition between stations are expected and may be attributed, among others, to depth and nature of the seabed at the stations (Williams, 1968; Koranteng, 2001; Mensah & Quaatey, 2002).

Togo

As observed in Ghana, the species composition also varied from station to station with the differences attributable to the same reasons as for Ghana. Out of 45 species, 7 species, namely *Sepia officinalis, Allotheuthis africana, Chelidonichthys lastoviza, Grammoplites gruveli, Citharus linguatula, Priacanthus arenatus* and *Syacium micrurum, Astropecten sp*. and *Echinometra sp*. occurred almost at all the stations.

Benin

Variation in species composition from station to station were observed but *Sepia officinalis, Allotheuthis africana, Serranus accraensis, Pagellus bellottii, Scorpaena scrofa, Grammoplites gruveli, Syacuim micrurum, Chelidonichthys lastoviza, Microchirus frechkopi,* and *Citharus linguatula* occurred almost at all the stations.

Nigeria

Differences in species composition between stations were also observed and may be attributed, among others, to differences in depths and nature of the seabed at the stations. However, *Sepia officinalis, Chelidonichthys lastoviza, Dicologoglossa cuneata,* Gobid *sp*., *Grammoplites gruveli, Syacium micrurum, Trigla lyra, Brachydeuterus auritus* and *Aurelia sp.* occurred almost at all the stations.

Catch Rates

Differences in the distribution and abundance of demersal species may also be due to factors including the amount of organic mud in the bottom deposits, the occurrence of isolated patches of rocky bottom, the occurrence of estuarine condition associated with lagoons and rivers and the nature of oceanic water masses lying over the continental shelf (Longhurst and Pauly, 1987). As these factors varied from area to area so were the species compositions, catch rates and diversity of species. The differences in the four countries, as observed in the wet season survey, are discussed below.

Ghana

The catch rates of the species varied with stations and depth (Figure 3.3-39). Generally, the lowest catch rates were recorded in inshore waters (i.e. 21–40m). The highest catch rates were recorded in deep waters (41-70m), followed by coastal waters (0–29m). Similar trend was found during the dry season surveys. Thus, the most productive areas recorded in the surveys off Ghana are in deep waters in the vicinity of the main pipeline route.

Togo

The catch rates varied with stations. Generally, the catch rates increased with increasing depth peaking in deep waters where the proposed main pipeline would run (Figure 6.3-39).

Benin

In Benin, the catch rates also varied with depth. On the average the catch rate increased with increasing depth (13 to 45m), followed by a decrease (50m). Similar trend was found during the 2002 R/V Dr. Fridtjof Nansen survey in the western Gulf of Guinea (Mehl et. al., 2002).

Nigeria

The catch rates varied with station and depths. The catch rates generally increased from coastal waters to deeper waters. However, the depth range, 41-70m, recorded a slight decrease in fish population from the 21-40m depth-range. Thus, the most abundant areas in terms of fish population are in deep waters along the main pipeline route.

Catch Rates along Laterals

Generally, the catch rates, hence abundance of the demersal species, were highest on the laterals off Ghana (Tema and Takoradi), followed by Togo (Lome), Nigeria (Lagos) and Benin (Cotonou).

For the same lateral, the catch rates varied with depth. Off the Takoradi and Cotonou laterals the highest catch rates were recorded in coastal waters (i.e. 0–20m) (Figure 6.3-39), while that off Tema and Lome were recorded in deep waters (41–70m). The highest catch rate off Lagos was recorded in the inshore waters (21–40m).

Species Diversity

All the calculated values of the Shannon Diversity Index fall within the acceptable range of 1–3.5 (Magurran, 1991). The highest diversity was for the Lagos lateral (Figure 6.3–41).

Conclusion

In total, 124 fish and invertebrate species from 71 families were represented in the wet season trawl survey. Eight fish species dominated the catches in terms of numbers and frequency of occurrence in the hauls. When ranked by catch rate in the whole region, *Chelidonichthys lastoviza* emerged the most abundant and *Serranus accraensis* the least abundant of the eight species.

The species composition varied from country to country with the highest number of species recorded in Ghanaian waters. The number of species also varied from lateral to lateral with the highest number recorded on the Tema Lateral. However, the Shannon Diversity Index was highest off Lagos.

Mean catch rates also varied according to depth with the highest values recorded in deep waters off Ghana, Togo and Nigeria whereas in Benin the catch rates were highest in inshore waters.

Five out of the 8 dominant fish species found in the entire region were present in the hauls made off Ghana and 3 each off Togo, Benin and Nigeria. It is suggested from these results that at the regional level, five fish species namely; *S. officinalis, S. micrurum, G. gruveli, C. lastoviza* and *P. prayensis* be used as bio-indicators for future monitoring of potential environmental impacts, though country-specific dominant fish species must also be considered.

It appears that the bed of the scallop (*Chlamys purpuratus*) does not extend towards the south and west of station T26. On the other hand, appreciable quantities were recorded towards the north and east of the station. However, further hauls are required to know the extent of spread of the species.

6.1.4 Marine Birds, Mammals and Reptiles

During the second season, the survey crew recorded several sightings of black terns (*Chlidonias niger*) (Figure 6.3-42), royal terns (*Sterna maxima*) (Figure 6.3-43), common tern (*Sterna hirundo*) few sandwich terns (*Sterna sandvicensis*). The black terns were recorded mainly at offshore locations close to estuaries and/or lagoons (e.g. 2G02- Keta lagoon, 2G03– Volta estuary, 2G13- Korle lagoon). These species leave the onshore areas to feed at sea during the afternoon. Few sea gulls were recorded during the fish trawl at Station 2T23. (Note: the photographs shown are representative of the species, but were not taken during the survey).

Figure 6.3-42
Black Tern

Figure 6.3- 43
Royal Tern

On 16 July 03, at 1330 and 30 July 03, three unidentified whales were sighted at approximately 1.2km and 1.0 respectively off the bow of the R/V GeoExplorer ™ at N04 58.77.7, W000 50.27.0 and trawl station 2T23 respectively. On 20 July 03, at 0535, 4 common dolphins were spotted at Station 2T06C.

No reptiles were found during the study.

6.1.5 Offshore Primary Production

The results of primary productivity, measured in milligrams of carbon per unit area per day, showed that Station 2G06 recorded the highest level followed by Station 2T04 (Table 6.3-6). By referring to the nautical chart of the Project area, only Station 2G06 was located within an area with depth beyond 60m.

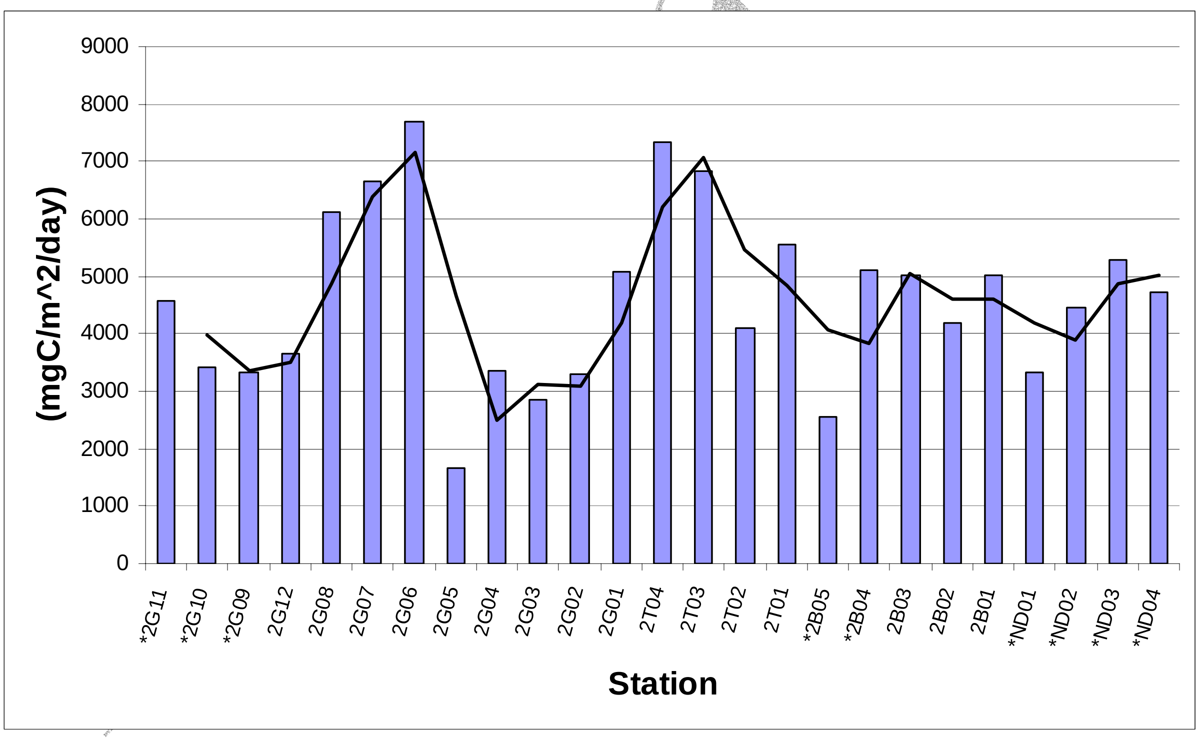
Table 6.3-6
Results of Primary Productivity Recorded at Stations along the WAGP Pipeline in July, 2003

Country	Station	(mgC/m^2/day)	Country mean productivity ± Standard error (mgC/m^2/day)
Ghana	2G01	5080.0	4305 ± 508
	2G02	3297.1	
	2G03	2857.5	
	2G04	3370.4	
	2G05	1648.6	
	2G06	7693.3	
	2G07	6643.1	
	2G08	6105.8	
	2G09	3333.8	
	2G10	3407.0	
	2G11	4567.1	
	2G12	3651.3	
Togo	2T01	5568.5	5956 ± 720
	2T02	4103.1	
	2T03	6826.3	
	2T04	7326.9	
Benin	2B01	5011.6	4374 ± 483
	2B02	4176.4	
	2B03	5011.6	
	2B04	5104.4	
	2B05	2564.4	
Nigeria	ND01	3341.1	4455 ± 410
	ND02	4454.8	
	ND03	5290.1	

Country	Station	(mgC/m^2/day)	Country mean productivity ± Standard error (mgC/m^2/day)
	ND04	4733.2	

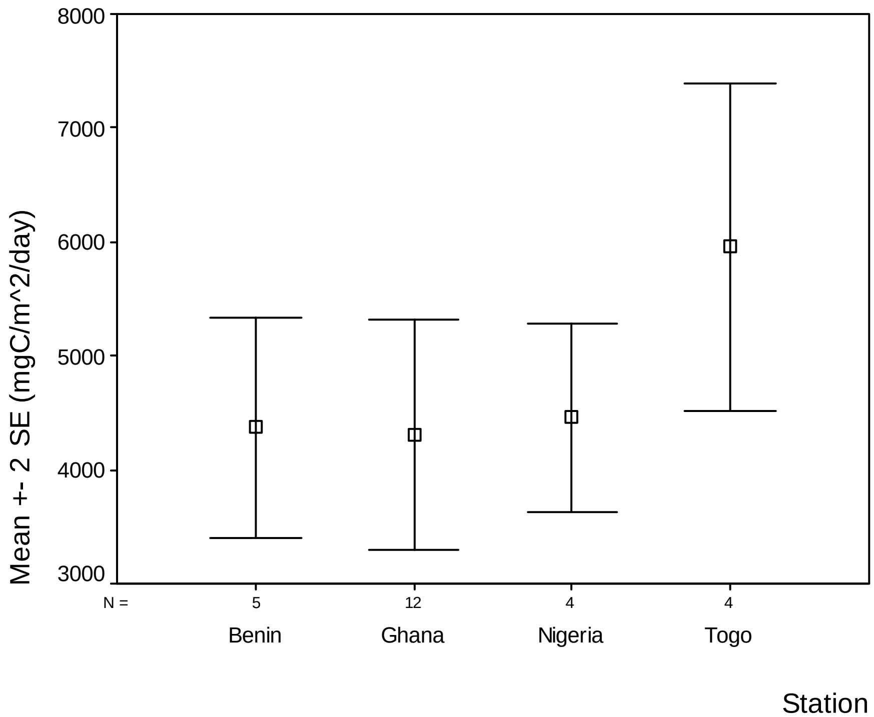
Distribution of productivity at each station, displayed on a chart, from West to East of the gas pipe line route showed a gradual increase from Station 2G12 to a peak at Station 2G06 (Figure 3.3-44). Thereafter, there was a rapid fall in productivity at Station 2G05 followed by a gradual increase to a peak at Station 2T04. There was fluctuation in productivity levels from 2T04 to ND04.

Figure 6.3-44
Variations in Primary Productivity at Stations along the WAGP Pipeline (Bar Charts) with 2 Step Running Averages (Line Chart). Stations with Asterisks Indicate those along the Laterals. (Stations Have been Arranged From West To East)



Productivity measurements recorded at the various stations were averaged for each country and plotted. Togo recorded the highest level of productivity and also showed the highest variability about the mean (Figure 6.3-45, see also Table 6.3-44).

Figure 6.3-45
Variation in Primary Productivity Averaged According to WAGP Countries



Discussion

Primary production is linked to the amount of inorganic carbon assimilated by phytoplankton via the process of photosynthesis in a given volume of water or an area over a given time period. Typically, productivity in offshore ecosystems range from 10-100 mg C m^{-3} day^{-1} in terms of volume, or from 75-1000mg C m^{-2} day^{-1} in terms of area. Thus, the values obtained for the Project area (i.e. 4305–5956mg C m^{-2} day^{-1}) indicate a system of high productivity. This is not surprising since the coastal ecosystem of the Project area undergo seasonal upwelling that commences in July. It should be noted that the samples were collected in July and thus marked the period for the commencement of the upwelling.

The upwelling phenomenon brings nutrients from the deeper layers of the water body and makes them available to phytoplankton at the surface. The phenomenon of bringing nutrient from the deeper layers which is characteristic of the upwelling could be more pronounced at Station 2G06, being located beyond 60m depth. This probably led to the observed highest record.

The nutrient-rich waters brought to the surface stimulates phytoplankton productivity in the coastal waters. This available food results in an increase in zooplankton production, especially of copepods. The upwelling period also coincides with the spawning of *Sardinella aurita*, a major species of the commercial inshore fisheries. Because of the available copepod in great abundance, there is no shortage of food for the larvae of *S. aurita*.

In addition to nutrients brought from the deeper layers, land-based nutrients (phosphates and nitrates) are also carried into the sea resulting in an increase in the overall nutrient level during the upwelling. This is particularly significant for Togo where the existence of phosphorus mining activity in the coastal areas led to a high level of productivity.

CHAPTER 7
METEROLOGICAL CONDITIONS AND OCEAN CURRENTS

Wind speed and direction, wave height, and water depth were recorded in the GeoExplorer™ bridge log. Water depths at the locations sampled ranged from 15 to approximately 84m. The prevailing wind direction during the survey was from the southwest with wind speeds ranging from zero to approximately 15 knots, with an average velocity of 6 knots. Wave heights ranged from zero to approximately 1.5m. Late night and early morning fog was frequently observed during the time offshore. Most days were sunny with less than a fifty percent cloud cover, and a light rain was observed only once. Extracts from the bridge log detailing these conditions are listed in Table 7.1-1.

Table 7.1-1: Offshore Stations and meteorological observations

Date	Station Number	Time On Station	Wind Speed	Wind Direction	Wave Height	Water Depth (m)
7/15/2003	2G10C	19:15	5.0	SSW	2	
7/15/2003	2G11C	21:18	5.0	SSW	2	
7/17/2003	2G24C	1:05	1-2	E	0.5-1	33
7/17/2003	2G23C	2:15	1-2	E	0.5	29
7/17/2003	2G25C	4:30	0.5	E	0-0.5	22
7/17/2003	2G21C	19:38				20.6
7/17/2003	2G19C	20:17	12.0	W	1-2	30.7
7/17/2003	2G20C	21:38				
7/17/2003	2G18C	21:40	12.0	W	1-2	30.7
7/17/2003	2G22C	23:50	2.0	NE	1-1.5	30
7/17/2003	2G26E		1-2	E	0	15
7/17/2003	2G26W		1.0	E	0	15.6
7/17/2003	G26C		1-2	E	0	15
7/18/2003	2G17C	0:25	3-4	E	1-2	29
7/18/2003	2G16C	3:25	2-3	NE	1-2	41

Date	Station Number	Time On Station	Wind Speed	Wind Direction	Wave Height	Water Depth (m)
7/18/2003	2G14C	7:35	1.0	E	1-2	54
7/18/2003	2G12C	14:42	4-5	SW	1-2	50.4
7/18/2003	2G08C	16:22	4-5	SW	1-3	52.1
7/18/2003	2G09C	19:50	4-5	SW	1-2	64.4
7/18/2003	2G07C		4-5	W	1-2	57.2
7/18/2003	2G13C		0-0.5	E	1	62
7/18/2003	2G15C		1-2	E	0.5-1	49
7/19/2003	2G06C	1:17	1-2	E	1	66
7/19/2003	2G06C	2:31	1.0	E	1	75
7/19/2003	2G06N	3:10	2.0	E	1-2	58
7/19/2003	2G05C	6:04	1-2	E	1	41
7/19/2003	2G02C	14:00	10-15	SW	2-4	20.4
7/19/2003	2G01C	15:58	10-12	SW	2-3	48.3
7/19/2003	2T08C	19:28	12.0	W	1-2	63.4
7/19/2003	2T04C	20:25	12.0	W	1-2	60.7
7/19/2003	2T05C	22:50	12.0	W	1-2	67.1
7/19/2003	2G03C		1-2	E	1	15
7/19/2003	2G04C		2-4	E	1-2	24
7/20/2003	2T03C	0:00	1-2	W	1-2	47
7/20/2003	2T02C	2:29	1-2	SW	1	49
7/20/2003	2T06C	5:17	1.0	SW	0.5	33
7/20/2003	2T01C	15:00	12.0	SW	2-3	50.7
7/20/2003	2B10C	17:00	10-15	SW	2-4	60.6
7/20/2003	2B09C	19:22	12.0	SW	2-3	57.5

Date	Station Number	Time On Station	Wind Speed	Wind Direction	Wave Height	Water Depth (m)
7/20/2003	2B08C	21:21	10.0	SW	3	61.9
7/20/2003	2T07C		0-1	SW	0-1	15
7/21/2003	2ND03C	0:01	10-12	SE	1-3	83
7/21/2003	2B07C	0:12	2-4	SW	1-2	46
7/21/2003	2B04C	2:03	4-6	SW	1-2	39
7/21/2003	2B03C	3:07	4-6	W	2-3	25
7/21/2003	2B05C	4:07	4-6	W	1-1.5	20
7/21/2003	2B06C	4:55	4-6	SW	1-1.5	15
7/21/2003	2B02C	7:16	8-10	W	1-2	38
7/21/2003	2ND02C	16:25	10-15	SW	2-3	15.2
7/21/2003	2ND06C	17:35	10-15	SW	2-3	17.4
7/21/2003	2ND05C	18:53	8.0	SW	2	27.8
7/21/2003	2ND04C	20:46	8.0	SW	2-3	49.3
7/21/2003	2ND01C	22:30	5.0	SW	2	67.4
7/21/2003	2B01C		2-4	SW	1-1.5	55
7/21/2003	2B02N		6-8	W	1-2	
Fisheries Leg						
7/23/2003	2T06	14:00	10.0	SSW	2-3	
7/23/2003	2T07	16:00	8.0	SW	2-3	
7/24/2003	2T02	6:02	7.0	SW	2-3	15
7/24/2003	2T04	10:50	7.0	SW	2	50
7/24/2003	2T03	14:30	10-12	SW	1-2	84
7/24/2003	2T01	17:44	5.0	SW	1-2	68
7/25/2003	2T05	8:30	5.0	SW	2-3	46

Date	Station Number	Time On Station	Wind Speed	Wind Direction	Wave Height	Water Depth (m)
7/25/2003	2T08	13:09	10-12	SW	1-2	37
7/25/2003	2T11	16:30	15-20	SW	3-5	18
7/26/2003	2T09	6:11	9.0	W	3	54
7/26/2003	2T10	11:00	4-5	NE	2	49
7/26/2003	2T12	16:30	10.0	SW	2-3	
7/27/2003	2T13	6:30				
7/27/2003	2T14		5.0	W	2-3	
7/28/2003	2T15	6:00	5.0	SW	2-3	
7/28/2003	2T17	10:43				
7/28/2003	2T18	12:00				
7/28/2003	2T21	16:00				
7/29/2003	2T16	6:00	5.0	SW	2-3	
7/29/2003	2T20	13:00	4.0	W	2	
7/29/2003	2T19	17:50	5.0	SW	2	
7/30/2003	2T25	6:00	6.0	W	3	
7/30/2003	2T24	7:30	5.0	W	1-2	
7/30/2003	2T22	11:20				
7/30/2003	2T23	13:20				
7/31/2003	2T26C	6:00	3.0	SW	2	28
7/31/2003	2T26S	7:20	7.0	W	1-2	29
7/31/2003	2T26N	8:20	3.0	SW	2	26
7/31/2003	2T26W	9:30	3.0	SW	1	26
7/31/2003	2T26E	11:45	5.0	SW	1	28

CHAPTER 8
REFERENCES

Adam, K. S (1986) Man's impact on the geomorphological evolution of the coastal plain in the Gulf of Benin. *in* Thalassas, University of Santiago, Spain.

Adam, K. S. & N. Devine (1993) Quantification of risk to Benin from an Accelerated Sea Level Rise. International Sea-Level Rise Studies Project, Rutgers University New Jersey, USA.

Adam, K. S. (1991) The Gulf of Benin: Present environment and future Sea-Level Rise. International SLR Studies Project. Institute of Marine and Coastal Sciences. The State University of New Jersey. USA.

Adam, K. S. (1996) Towards Integrated Coastal Zone Management in the Gulf of Guinea / Vers une gestionn intégrée de la zone côtière dans lle Golfe de Guinée, Editions du Flamboyant. 200 pp.

Adejuwon (1974)

Adeniyi (1991)

Adité A. (2002) Diversity and management of mangrove fishes in the coastal zone. Research Project Funded by the International Foundation for Science (IFS) under Research Grant IFS No. A/2913-1.

Adjakidjè V. (1984) Contribution à l'étude botanique des savanes guinéennes de la République Populaire du Bénin. Thèse 3ème Cycle. Univ. Bordeaux III. 301 p.

Adjakpa, J. B. (1999) Etude de la faune aviaire des zones humides du Bénin: Inventaire faunique, habitats et cycles migratoires. CEROE/CPU Benin.

Adjakpa, J. B., Coubeou, Th. P., Hagemeijer, J. M. W. (1996) Inventaire de la faune aviaire des zones humides du Sud-Bénin. PAZH, Ambassade Royale des Pays Bas, Cotonou, 70 pp.

Adjakpa, J. B., Tchabi, A. & Ogouvide, F. T. (2002) Oiseaux utilisés en pharmacopée traditionnelle au Bénin. Malimbus 24:1-24.

Adjanohoun E. (1965) Comparaison entre les savanes côtières de la Côte d'Ivoire et du Dahomey. Ann. Univ. Abidjan, t.1, pp. 1-60.

Adjanohoun E. (1966) Existence au Dahomey de savanes côtières analogues à celle de la Côte d'Ivoire. Etude Dahoméenne, 6-7, pp. 48-7.

Adjanohoun E. (1968) Le Dahomey. (Cons. Vég. Afr. South of the Sahara, Symp. AET FAT, Acta phyt. Suecica, 54:86-91.

Adokpo S., Fanou T. (1992) Rapport sur l'inventaire et l'analyse de la législation environnementale au Bénin. MEHU, 1992, Cotonou, 108 pp.

Adomeko and Armale (1981)

Afoakwa, S.N., Agbodaze, D. and Abrahams, C.A. (1988) Microbiological quality of the coastal waters of Ghana: a bacteriological appraisal. Accra: GNC/IOC Seminar on the Conservation and Utilisation of Marine Resources.

Agassounon L. C. (2002) Evolution pédosédimentaire du géosystème margino-littoral de l'Ouémé-Sô au cours de l'holocène (Bénin-Afrique de l'Ouest) Thèse de Doctorat en Sciences de la Terre et de l'Environnement. 425 pp.

Agbo-zegue (2002)

Ajaji (1994) The Status of marine Fishery Resources of the Gulf of Guinea: In: Proc. 10th Session FAO, CECAF, Accra, Ghana, 10-13 October.

Ajavon A. L (2000) . Stratégie nationale de la lutte contre la pollution atmosphérique en République du Bénin. MEHU, 70 pp.

Ajavon A. L., Amegankpoé A. (1998) Contribution à l'évaluation de la pollution de l'air à Cotonou.

Akintola (1986)

Akoègninou A. (1984) Contribution à l'étude botanique des îlots de forêts denses humides semi-décidues en République Populaire du Bénin. Thèse 3ème cycle. Univ. Bordeaux III. 250 pp.

Akoègninou A. (1999) Rapport final des travaux du groupe Mangrove Bénin. 34 pp.

Akoègninou A., Oyede L. M. & Toffi M. (1993) La mangrove du Benin: Environment physique, vegetation, et essais de gestion. Document technique no2. FAST-UNB.

Akpagana, K. & Bouchet, P. (1997) Les espèces en voie de disparition et leur utilisation en thérapeutique. In Les phytomédicaments éthiques. Les Presses de l'UB, pp. 63-70.

Akpagana, K. (1992) Quelques espèces rares ou menacées de disparition sur le cordon littoral du Togo. ral. Ann. Univ. Bénin Togo, sect. sci., 10, p. 33-36.

Akpati, B. N. (1975) Source and dispersal of Holocene sediments on the continental shelf of Ghana, West Africa., p.44. Accra: Research report of UNESCO. Contract SC/RP600.874.

Akpiti S., Clauer, N., Houessou A., Lang J. and Tisserand D. (1985) Datation isotopique K-Ar d'un niveau de sable glauconieux à la limite Paléocène- Eocène dans le bassin côtier béninois (Afrique de l'Ouest) Journal of African Earth Sciences. 3(4): 487-490.

Alassane M. A., (2000) .Contribution à l'étude hydrochimique de l'aquifère du Continental Terminal du plateau de Sakété dans le bassin sédimentaire côtier du Bénin. Mémoire de DEA. UCAD. Dakar, Sénégal.

Albatet J-J & Diouf P. S. (1994) Diversité des poissons des lagunes et des estuaires Ouest-africains. Ann. Mus. r. Afr. Centr. Zool. 275: 165-177.

Alidou S. et Oyede L. M. (1984) Quaternaire du Bénin. ASEQUA, Bull. Liaison, no. 72-73, 42-43. Dakar.

Alidou S., Boukari M., Oyede L. M., Gaye C. B., Faye A., Gelinas P., Isabel D. et Locat J., (1994) Rapport technique final du projet "hydrogéologie du Quaternaire du Sud-Bénin", phase 2. CRDI 3-P-89-1017. Tomes I, II, III et IV. Univ. Nat. Bénin, Univ. CA. Diop, Dakar, Univ. Laval Québec.

Allen and Wells (1962)

Allersma, E. and Tilmans, W. M. K. (1993) Coastal conditions in West Africa: a review. Ocean and Coastal Management 19, p. 199-240.

Amusan and Ashaye (1989)

Anderson, D.M., Anderson, P., Bricelj, V.M., Cullen, J.J. and Rensel, J.E. (2001) Monitoring and management strategies for harmful algal blooms in coastal waters, APEC #201 – MR-01.1, Asia Pacific Economic Program, Singapore, and Intergovernmental Oceanographic Commission Technical Series No. 59, Paris.

Aravomo (1991)

Archambault J. (1953) Les eaux souterraines de l'Afrique Occidentale, BURGEAP-BCEOM, Paris.

Archambault J. (1960) . Etudes hydrogéologiques pour l'alimentation en eau des divers centres urbains du Dahomey. BURGEAP, Paris.

Armah, A. K. and Amlalo, D. S. (1998) Coastal zone profile of Ghana. In Gulf of Guinea Large Marine Ecosystem Project, pp. vii + 111. Accra: Ministry of Environment, Science and Technology.

Armah, A.K., Darpaah, G.A., Wiafe, G., Adomako, J.K. and Fiagbedzi, S. (1997a) Save sea turtles: a primer on sea turtle conservation for coastal communities in Ghana. Accra: Royal Crown Press Ltd.

Armah, A.K., Darpaah, G.A., Wiafe, G., Adomako, J.K., Quartey, S.Q., Abotchie, C., Ansah, F. and Fiagbedzi, S. (1997b) Traditional and modern perspectives of marine turtle conservation in Ghana. In Biodiversity Conservation: traditional knowledge and modern concepts. (ed. Amlalo D.S., L. D. Atsiatorme and C. Fiati), EPA/MAB/UNESCO, pp. 80-87.

Ashaye (1967)

Association de Climatologie du Québec (1997) Les défis des changements environnementaux à l'échelle planétaire. Actes du colloque du 63 ème congrès de l'ACFAS, Québec, 212 pp.

Asubre (1993)

Awosika, L.F., and Ibe, A.C. (1994) Geomorphic features of the Gulf of Guinea shelf and littoral drift dynamics. In Proc. International symposium on the results of the first IOCEA cruise in the Gulf of Guinea, May 1994, p. 17-20.

Awosika, L.F., Ibe, A.C., and Ibe, C.E. (1993) Anthropogenic Activities affecting sediment load balance along the West Africa Coastline. In Coastlines of western Africa, Coastlines of the world series. Pub. American Society of Civil Engineers N.Y., 1993, pp. 26-35.

Azontonde A. (2000) Dynamique de la matière organique et de l'azote dans le système Mucuna-Maïs sur un sol ferralitique (terre de barre) au Sud-Bénin. Thèse de Doctorat ENSAM-Université de Montpellier, Montpellier, 235 pp.

Baba-Moussa A. (1994) Etude de la pollution bactériologique de la nappe phréatique à partir d'une latrine en Afrique subtropicale. Thèse de Doctorat ès Sciences Techniques. Ecole Polytechnique Fédérale de Lausane.EPFL. 252 pp.

Badejo (1990)

Badejo (1999)

Badejo M.A. and Lasebikan, B.A (1988) Comparative studies of the acarine populations of a secondary regrowth forest and a cassava plantation in Ile-Ife, Nigeria. Pedobiologia, 32:111-116.

Badejo, M.A. (1998) Introduction to the General Classification of Crustaceans of Wetlands, Freshwaters and Coastal Regions in Nigeria. College Press, Ibadan & Enproct Consultants Lagos. 45pp. Badejo.

Badejo, M.A., Tian, G., and Okoh, I.O. (in press) Litter transformers as ecosystem engineers in sustainable agroecosystems. In: Badejo M.A. and Togun A.O. (eds) Strategies and Tactics of Sustainable Agriculture in the tropics. Volume 2. College Press & Enproct Consultants.

Bainbridge, V. (1972) The zooplankton of the Gulf of Guinea. Bulletin of Marine Ecology 8:61-97.

Baize D. et Girard, M.-C. (1995) Référence pédologique. AFES, Paris, 332 pp.

Bassindale, R. (1961) On the marine fauna of Ghana. Proceedings of the Zoological Society of London 137, pp. 481-510.

Batawila, K., (1997) Recherches sur les formations dégradées et jachères de la plaine côtière du sud Togo. Mém. DEA. Biol. Dév. Univ. Lomé. 65 pp.

Belfield (1956)

BURGEAP (1985) Préparation d'un programme d'hydraulique villageoise dans lesprovinces de l'Atlantique et de l'Ouémé. DH. Cotonou Bénin.

Benner, B. A., Gordon, G. E. and Wise, S.A. (1989) Mobile sources of atmospheric polycyclic aromatic hydrocarbons: a roadway tunnel study, Environ Sci Technol., 23:1269-1278.

Bernacsek, G. M. (1986) Profile of the Marine Resources of Ghana. CECAF/TECH/86/71. CECAF Program. FAO, Dakar, Senegal.

Bijker E. W., Radu, M. (1981) Sur l'application de l'analogie entre l'équation de la chaleur et celle développée par Pelnard-Considère à l'étude d'un littoral. XIX ème Congrès AIHR New Delhi, India.

Binet, D., Marchal, E. and Pezennec, O. (1991) Sardinella aurita de Cote d'Ivoire et du Ghana: fluctuations halientiques et changements climatiques. In Pecheries Ouest Africaines: varibilite, instabilite et changement. (ed. P. Cury and C. Roy) ORSTOM.

Biney, C.A. (1986) The state of pollution of the west and central African marine environment: aspects of the Ghanaian situation., 24pp. Accra: Institute of Aquatic Biology.

BOAD (2001) Etude sur l'impact du transport urbain par les véhicules à deux roues et perspectives de développement dans les pays de l'UEMOA (Bénin, Niger, Togo) Rapport de synthèse provisoire.

BOAD. (2001) :. Etude sur l'impact du transport urbain par les véhicules à deux roues et perspectives de développement dans les pays de l'UEMOA (bénin, Niger, Togo) Rapport de synthèse provisoire.

Boko M. (1975) . La plaine côtière du Dahomey à l'Ouest de Cotonou. Thèse de Doctorat de 3ème cycle. Géographie tropicale. Univ. de Dijon, 225 p.

Boko M. (1975) La plaine côtière du Dahomey à l'Ouest de Cotonou. Thèse de Doctorat de 3ème cycle. Géographie tropicale. Univ. de Dijon, 225 pp.

Bokonon-Ganta E. (1987) Les climats de la région du Golfe du Bénin. Thèse de 3ème cycle. Univ. de Paris IV. Sorbone. 248 pp.

Boukari Boukari M., (1998) . Fonctionnement du système aquifère exploité pour l’approvisionnement en eau de la ville de Cotonou sur le littoral béninois. Impact du développement urbain sur la qualité des ressources. Thése de Doctorat d’Etat ès Sciences. UCAD. Dakar, Sénégal.

Boukari M., (1984) Rapport de synthèse sur les connaissances géologiques et hydrogéologiques du bassin sédimentaire côtier de la République Populaire du Bénin. Université Nationale du Bénin. FAST, Cotonou. Bénin.

Boukari M., (1996) Caractérisation hydrodynamique et hydrochimique du système aquifère du panneau d’Allada dans le bassin sédimentaire côtier du Bénin. Africa Groundwater Resources ‘96. Résumé. 7.

Boukari M., Alidou S., Oyede L,. M. Gaye C.B, et Maliki R., (1995) Identification des aquifères de la zone littorale du Bénin (Afrique de l'Ouest) hyrdynamique, hydrochimie et problèmes d'alimentation en eau de la ville de Cotonou. African Geoscience Review, Paris France. Vol. 2(1):139-157.

Boukari M., Gaye C. B., Faye A. et Faye S., (1996) The impact of urban development on coastal aquifers near Cotonou, Benin. Journal of African Earth Sciences. 22(4)

Bourgeois M. (1978) Carte de planification des ressources en eau: Côte-d’Ivoire, Ghana, Togo et Bénin. CIEH, Ouagadougou, Burkina Faso.

Bourrelly P. (1981) Les Algues d'eau douce: Initiation à la systématique Tome II Les Algues jaunes et brunes. 517 pp.

Bourrelly P. (1985) Les Algues d'eau douce: Initiation à la systématique Tome III: Les Algues bleues et rouges. 606 pp.

Bourrelly P. (1990) Les Algues d'eau douce: Initiation à la systématique Tome I: Les Algues Vertes. 572 pp.

Bouzid M. (1967) Données hydrogéologiques sur le bassin sédimentaire côtier du Dahomey. Projet DAH3, FAO, Rome.

Bowessidjaou E. J., Fretey J., Formia A., Segniagbeto H., (2002) Observations biométriques et ethnozoologies préliminaires sur les tortues marines au Togo, 2e journées scientifiques internationales de l'Université de Lomé, 6 pp. (non-publié)

Brl/gersar-Beture (1995) Alimentation en eau potable: Plan d'investissementdans les villes de Cotonou, Porto-Novo et Djougou ; Tome 1: Cotonou. SBEE. Cotonou.

Brunel, J.F., Scholz, H. & Hiepko, P. (1984) Flore analytique du TOGO. Phanérogames. GTZ, Eschorn, 751 pp.

Buchanan JB and Anderson M.M. (1955) Additional records to the marine molluscan fauna of the Gold Coast. J.West Afr..Sci. Ass. 3(2):10-11.

Buchanan, J.B. (1957) Benthic fauna of the continental edge off Accra, Ghana. Nature 179:634-635.

Buchanan, J.B. (1958) The bottom fauna communities across the continental shelf off Accra, Ghana (Gold Coast) Proceedings of the Zoological Society of London 130(Part 1):1-56.

BURGEAP- GEOHYDRAULIQUE, (1988) Projet d'hydraulique villageoise BOAD-Atlantique. DH, Cotonou, Bénin. Paris, France.

Burton M., (1978) Reptiles et amphibiens . Edition Atlas S.a.r.l ; Paris. pp 44-45.

Butcher et al. (1971)

Calamari & Naere (1994)

Chapman, P. J., Edwards, A.C., Reynolds, B., Cresser, M.S. and Neal, C. (1998) The nitrogen content of rivers in upland Britain: The significance of organic nitrogen. Hydrology, Water Resources and Ecology in Headwaters. 248:443-450.

Cheke R. A. & Walsh J.F.. (1996) The birds of Togo. British Ornithologists Union, BOU Check List No. 14. pp.63-80.

Chelboldaeff M. et Trichet J. (1990) The Continental Terminal in West Africa. Journal of African Earth Sciences, 10(1/2):79-99.

Chippaux J.P. (2001) Les serpents d'Afrique Occidentale et Centrale. Edition de l'IRD (Ex ORSTOM) 292 p.

Church Harrison, R.J. (1980) West Africa. London, Longman.

Clarke, K. R., and R. M. Warwick. (1994) Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Plymouth Marine Laboratory, Plymouth.

Clason, E.W.H., Tellegen, B.D.H., Friijlink, H.C., Thijsse, J.Th., Jansen, P.Ph., and Schijf, J.B. (1954) Report on the Western Niger Delta by the Netherlands Engineering Consultants to the Government of Nigeria.Lagos: The Hague; NEDECO. 143 pp.

CMS/CMS. Technical Series Publication No. 5. Abidjan-Côte d'Ivoire, Mai (1999) Mesures de conservation pour les Tortues Marines de la côte atlantique de l'Afrique.

Colleuil B. (1984) Un modèle d'environnement lagunaire soumis aux conditions de climat équatorial tempéré: le lac Nokoué (République Populaire du Bénin) Thèse de l'Univ. de Bordeaux 1. no.158, 135 pp.

Colombani, (1967) Premiers résultats des mesures de qualité de l'eau au Togo et au Dahomey. Cahiers ORSTOM. Série hydrologie (Fr.), 4(2):3-25.

Crosnier and Berritt (1966)

Darboux-Afouda R., Locat J. et Gelinas P. (1997) Localisation géoélectrique des biseaux salés dans la région côtière au Bénin: Exemple de terrain. Bulletin de l'Assoc. Intern. De Géol. De l'Ingénieur. 55:83-97.

Day, J. H. (1967) A Monograph on the Polychaete of Southern Africa. Part 1 & 2. Errantia & Sedentaria. Trustees of the British Museum (Natural History), London.

de Baize & Girard (1995)

De Foucault, B., Akpagana, K., Batawila, K. et Bouchet, P. (2000) Contribution à une étude phytosociologique du littoral sableux du Togo. Acta Bot. Gallica. 147(4):333-344.

DFC Togo/OMPO (2002) Suivi des oiseaux migrateurs et des oiseaux d'eau du Togo, cahier de la formation Lomé (Togo).

DFC(MERF)/ DEP(MAEP) PNUE/CMS. Marine Education Research, Projet WAFCET-3 GHANA-TOGO, Etude d'exploitation, de distribution et d'histoire naturelle des cétacés au Togo.

DFC/MERF, (2002) Les zones humides les plus importantes du Togo. Rapport provisoire.

DFC/OMPO (2001)

Direction de l'Environnement/MEHU (2001) Communication nationale initiale du Bénin, Cotonou, 92 pp.

Dorst J., (1985) Qui mange qui, la lutte pour la vie dans le monde animal. p. 639.

Dossou-Bodrenou, J., Hoekert,W.E.J., Fretey. (2000) Atelier international de formation sur les techniques de conservation des tortues marines et évaluation du programme de sauvegarde des tortues marines au Bénin. Rapport intérimaire No. 2, p. 8.

Doty & Oguni (1957)

DPR (2002)

Durand J. R. & Levêque C. (1980) Flore et faune aquatique de l'Afrique sahélo-soudanienne. Ed. de l'ORSTOM. Paris, 389 pp.

Dussart (1996)

Dussart B. (1966) Limnologie. Etude des eaux continentales. Géologie – Ecologie – Aménagement. Paris, 676 pp.

Edmunds, J. (1978) Sea shells and other mollusks found on West African Coast and Estuaries. Ghana Universities Press. 164 pp.

Edwards, R.A., Whitmarsh, R.B., and Scrutton, R.A. (1997) Synthesis of the crustal structure of the transform continental margin off Ghana, northern Gulf of Guinea. Geophysical Marine Letters 17:12-20.

Ekundayo (1977)

Elgood et al. (1994)

Elster (1965)

Ern, H. (1979) Die Vegetation Togos. Gliederrung, Gefährdung, Erhaltung. Willdenowia 9:295-312.

Evans, S.M., Gill, M.E., Hardy, F.G., and Seku, F.O.K. (1993) Evidence of change in some rocky shore communities on the coast of Ghana. Journal of Experimental Marine Biology and Ecology 172:129-141.

Faggianelli J.D., Faggianelli E. (1984) Pêche maritime artisanale au Togo: Caractéristiques générales et résultats statistiques pour la saison p. 80.

Fiogbe (2000)

Fischer et al. (1981)

FishBase (2000)

Fontaine, B., Janicot, S., and Roucou, P. (1999) Coupled ocean-atmosphere surface variability and its climate in the tropical Atlantic region. Climate Dynamics 15:451-473.

Foster, S., Huettle, M. and Ziebis, W. (1996) Impact of boundary layer flow velocity on oxygen utilisation in coastal sediments. Marine Ecology Progress Series. 143:173-185.

Fretey J. (1998) Marine Turtles of the Atlantic Coast of Africa / Tortues Marines de la façade Atlantique de l'Afrique. UNEP Technical Publication No. 1.

Fretey J. (2001) Biogeography and conservation of marines turtles of the Altlantic coast of Africa / Biogéographie et conservation des tortues marines de la cote Atlantique de l'Afrique. CMS Technical Série Publication No. 6 pp. 209-207.

Gaillard M. et M., Lang J. et Lucas J. (1982) Etude des milieux de mangrove du Bénin occidental (Afrique de l'Ouest) Océanologica Acta. no. sp., 129-137

Garzoli, S.L. and Katz, E.J. (1983) The forced annual reversal of the Atlantic North Equatorial Counter Current. Journal of Physical Oceanography 13:2082.

Gbaguidi & Pfeiffer (1998)

GEOHYDRAULIQUE. (1985) Note explicative de la carte hydrogéologique à 1/200 000 du bassin sédimentaire côtier du Bénin. MET. DH. FED. 23 pp.

GEOHYDRAULIQUE-BURGEAP (1988) Projet d' hydraulique villageoise BOAD: Provinces de l'Atlantique et du Sud du Zou, Rapport final.DH, Cotonou, Bénin.

GIGG ou IGIP - GKW- GRAS (1989) Plans directeurs et étude d'ingénierie pour l'alimentation en eau potable et l'évacuation des eaux pluviales, des eaux usées et déchets solides. Ville de Cotonou. SBEE. Cotonou, Bénin. 90 pp.

GIGG ou IGIP-GKW-GRAS (1983) Plan directeur alimentation en eau potable ville de Cotonou. Les ressources en eau. Ministère de l'Industrie des Mines et de l'Energie- SBEE. Vol. 2 .

GIGG ou IGIP-GKW-GRAS (1987) Plans directeurs et étude d'ingénierie pour l'alimentation en eau potable et évacuation des eaux pluviales, des eaux usées et des déchets solides, ville de Cotonou. Tome 1, les ressources en eau.

Girard O. (1998) Echassiers, Canards et limicoles de l'Ouest-africain. p. 136.

Gnaha E.F.C. & Adjadji Ch. A. (2001) Evolution quantitative et qualitative des eaux souterraines captées dans le périmètre de pompage intensif de Godomey: impact sur l'approvisionnement en eau potable de l'agglomération de Cotonou . UAC ; Cotonou. Bénin.

Guedegge B. (1999) Programme de Gestion de la faune non aviaire dans les zones humides du littoral du Bénin. Rapport provisoire-PAZH, 39 p.

Guendéhou S. (2001) Résultats des inventaires des gaz à effet de serre au Bénin. In actes de l'atelier des journées de restitution de l'atelier régional sur les inventaires des gaz à effet de serre, Accra. 11 pp.

Guilcher A. (1959) La région côtière du bas-Dahomey occidental. Bull. IFAN, XXI (3/4), pp. 357-424.

Guinko S. (1974) Contribution à l'étude des savanes marécageuses du Bas-Dahomey. Thèse 3ème cycle, Fac. Sc. Abidjan, p. 142.

HACEMEIJER, W., POOT, M. & ADJAKPA, J. B. 2000. Suivi des oiseaux d'eau dans les zones humides du Sud-Bénin 1996-1997, CEROE & SOVON, 70 pp.

Halliday I. A., & Young W.R. 1996. Density, biomass and species composition of fish in a subtropical Rhizophora stylosa Mangrove forest. Mar. Freshwater Res., 47:609-15.

Hansel (1965)

Harris, G.P. (1986) Phytoplankton ecology: structure, function, and fluctuation, p. ix, 384. New York: Chapman and Hall.

Hill, M.B. and Webb, J.E. (1958a) The Ecology of Lagos lagoon. 1.The lagoon of the Guinea coast. Philosophical transactions of the Royal Society of London. 241:308-319.

Hill, M.B. and Webb, J.E. (1958b) The ecology of Lagos Lagoon, topography and physical features of Lagos Harbour and the Lagos lagoon. Phil. Trans. Roy. Soc. London. Ser. B. 241:319-333.

Houghton, R.W. (1983) Seasonal variations of the subsurface thermal structure in the Gulf of Guinea. Journal of Physical Oceanography 13:2070-2081.

Houndénou C. (1999) Variabilité climatique et maïsiculture en milieu tropical humide. Thèse pour le Doctorat d'Université: Option géographie Spécialité: Climatologie. Centre de Recherches de Climatologie. UMR 5080 du CNRS « Climatologie de l'Espace Tropical ». Université de Bourgogne, Dijon, 390 pp.

Houndénou C. et ABE (2002) Tableau de bord du kiosque informations et produits du SISEI-Bénin: indicateurs environnementaux et statistiques (compendia) ABE pour l'environnement, 236 pp.

Huettel, M., W. Ziebis, and S. Forster. (1996) Flow-induced uptake of particulate matter in permeable sediments. Limnol. Oceanogr. 41:309-322.

Hutchinson, J. and Dalziel, L.M (1954-1972) Flora of West Tropical Africa. 2nd ed., revised by Keay and Hepper, 3 vol.

Ibadan (1979)

ICF (2003a) Benin Preliminary Draft West African Gas Pipeline Environmental Impact Assessment Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by the Centre pour l'Environnement, le

Dèveloppement et l'Amènagement durables, CEDA Consult (Benin) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.0.

ICF (2003b) Ghana Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Environmental Solutions (ESL), LTD (Ghana) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

ICF (2003c) Nigeria Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Environmental Resources Managers Limited (ERML, Nigeria) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

ICF (2003d) Regional Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Adote Blivi, University de Lome (Togo); Centre pour l'Environnement, le Dèveloppement et l'Amènagement durables, CEDA Consult (Benin); Environmental Resources Managers Limited (ERML, Nigeria); Environmental Solutions (ESL), LTD (Ghana); and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

ICF (2003e) Togo Preliminary Draft West African Gas Pipeline Environmental Impact Assessment. Prepared for Chevron Nigeria Limited on behalf of the West African Gas Pipeline (WAGP) Joint Venture. Prepared by Adote Blivi, University de Lome (Togo) and ICF Consulting Services, LLC (ICF, USA) ICF Reference 022483.6.006.00.

IGIP (1984) Adduction d'eau dans 13 chefs-lieux de district. Ministère de l'Industrie des Mines et de l'Energie - SBEE Rapport de fin de travaux.

IGIP (1987) Rapport final sur les forages F8 et F19 à Godomey et le forage FAC à Abomey-Calavi. SBEE.

Ihenyen, A.E. (1998) Appraisal of heavy metal concentrations in bottom sediments of the Gulf of Guinea. In Nearshore dynamics and sedimentology of the Gulf of Guinea (ed. Ibe, A.C., Awosika, L.F. and Aka, A.), p. 93-98. Cotonou: IOC-UNESCO/UNIDO.

Imevbore, A. et al. (1993) Environmental Impact Assessment of the Activities of Shell Petroleum Development Company Ltd. in the South Forcados Development Area. Institute of Ecology, Obafemi Awolowo University, Ile-Ife, Nigeria.

INSAE. (2000) Résultats provisoires du recensement de la population et de l'habitat.

IRB, (1987) Etude de cartographie géologique et prospection minièrede reconnaissance au Sud du 9ème parallèle. Rap. Istituto Recerche Breda. FED- OBEMINES. 80 pp.

Iverson (1972)

Janicot S. (1990) Variabilité des précipitations en Afrique de l'ouest et circulations quasi-stationnaires durant une phase de transition climatique. Thèse de Doctorat d'Etat, Paris, 178 pp.

Janicot S. (1990) Variabilité des précipitations en Afrique de l'ouest et circulations.

Jefferson, T.A., Leatherwood, J. & Weber M.A. (1993) Marine mammals of the word. FAO Species identification guide, p. 319.

John, D.M. and Lawson, G.W. (1997) Seaweed biodiversity in West Africa: a criterion for designating marine protected areas. In The coastal zone of West Africa: problems and management. (ed. S. M. Evans, C. J. Vanderpuye and A. K. Armah), London: Penshaw Press, pp. 111-123.

John, D.M., Lawson G.W. & Ameka G.K. (2001) Seaweeds of the Tropical West Africa Sub-region, Identification manual. Marine Biodiversity capacity Building in the West African-Region, 161 pp.

Joiris, C.R., Otchere, F.A., Azokwu, M.I. and Ali, I.B. (1997) Total and organic mercury, and organochlorides in a bivalve from Ghana and Nigeria in the coastal zone of West Africa: problems and management (ed. Evans, S.M., Vanderpuye, C.J., and Armah, A.K.), pp. 89-92.

Jones & Hockey (1964)

Keay (1959)

Kent, N and Coker, P. (1992) Vegetation Description and Analysis. Wiley, Chichester.

Kerbyson, J. D. and Schandorf, J.R.H. (1966) Chemical Analysis of Ghana Rocks, Ores and Minerals, 1945-1965, Geological Survey Bulletin 42: Accra, Ghana.

Kirkegaard, J. B. (1988) The Polychaeta of West Africa. Part 2. Errantia species. In: J. Knudsen and T. Wolff (eds.) Atlantide Report 14. E.J. Brill/ Scandinavian Science Press Ltd.

Kogbe C. A. (1978) Revision of Continental terminal concept in Africa. 2nd Working Conference IGCP-IUGS Project 127. Occasional Publ., no. 7, Ahmadou Bello University, Zaria, Nigeria.

Kokou, K. et. al. (1999) Les ilôts forestiers au Sud du Togo : Dynamique et relation avec les végétations périphériques. Rev. Ecol. (Terre Vie), 54:301-314.

Koranteng, K.A. (2001) Structure and Dynamics of Dermersal Assemblages on the Continental Shelf and Upper Slope off Ghana, West Africa. Mar-Ecol-Prog-Ser. 2001 Sep 27. 220:1-12.

Laboratoire de delft: Port de Cotonou. (1977) Influence d'un épi d'arrêt et d'un barrage sur la côte. p.1241.

Laegdsgaard P. & Johnson C.R. (1995) Mangrove habitats as nurseries: unique assemblages of juvenile fish in subtropical mangroves in eastern Australia. Mar. ecol – Prog ser. 126:67-81.

Lamouroux m. (1953) Etude pédologique de la vallée de l'Ouémé, rive droite de la Sô. Rapport ORSTOM, Paris, 32 pp.

Lang J. and Paradis G, (1977) Un exemple d'environnement sédimentaire, biodétritique, non carbonaté, marin et continental, holocène en climat intertropical: le domaine margino-littoral du Bénin (ex. Dahomey) Rev. Géogr. Phys. Géol. Dynam. (2), XIX, fasc. 3:295-312.

Lang J. and Paradis G, (1984) Le quaternaire margino-littoral béninois (Afrique de l'Ouest); synthèse des datations au carbone 14. Paleoecology of Africa. Ed. J.A. Coetze et E. M. Van Zinderen Baker - A.A. Balkema Publ., Rotterdam, Pays- Bas.

Lang J., Kogbe C., Alidou S., Alzouma K., Dubois D., Houessou A. et Trichet J. (1986) Le Sidérolithique du Tertiaire ouest africain et le concept de Continental terminal. Bull. Soc. Géol. Fr., 8(4, II):605-622.

Lang J., Paradis G. and Oyede, L. M. (1988) Le domaine margino-littoral du Bénin (Golfe de Guinée, Afrique de l'Ouest) Age holocène et mise en place marine des "Sables jaunes". Journal of African Earth Sciences, Vol. 7(5/6):829-833.

Lang, J Kogbe C. A Alidou S Alzouma K. Bellion C. Dubois D., Durand A., Guiraud R, Houessou A. Klasz I. Roman E., Salard- Lang J. et Oyede L. M. (1991) Discontinuities in the recent and quaternary margino-littoral sedimentation of Benin (humid tropical zone) Journal of African Harth Sciences. 12(1/2):217-228.

Le Barbe l., Ale G., Millet B., Borel Y. et Gualde R. (1993) Les ressources en eau superficielles de la République du Bénin. ORSTOM Editions, Paris.

Le Barbe l., Ale G., Millet B., Borel Y. et Gualde R. (1993) Les ressources en eau superficielles de la République du Bénin. ORSTOM Editions, Paris.

Leveque C., Paugy D. & Teugels G. G. (1990a) Faunes des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 1. Editions ORTOM/MDRAC, Paris.

Leveque C., Paugy D. & Teugels G. G. (1990b) Faunes des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 2. Editions ORTOM/MDRAC, Paris.

Levi C., Cotillon P. (1990) Campagne Biocal: Environnement bathyal actuel et récent aux abords de la Nouvelle Calédonie. In Tour du Monde (Jean Charcot), Ocean. Act., 10:163-171.

LIFAD/ABE. (2000) Inventaire et diagnostic pour la préparation du SDAL. Cotonou

Longhurst, A.R. (1962) A review of the oceanography of the Gulf of Guinea. Bulletin d'Institute franc Africain noire, 24:633-663.

Longhurst, E.R & D. Pauly (1987) Ecology of Tropical Ocean. Academic Press Inc. Harcourt Brace Jovanovich Publishers, San Diego. 407 pp.

Lund (1958)

Magurran A. (1991) Ecological Diversity and its measurement. London,Chapman and Hall.

Maliki R., (1993) Etude hydrogéologique du littoral béninois dans la région de Cotonou (A.O.) Thèse de Doctorat de 3ème cycle. Version provisoire. UCAD; Dakar, Sénégal. 162 pp.

Marche-Marchad J. (1969) Le monde animal en Afrique intertropicale. pp. 514-519.

Maslin J. L. (1983) Les mollusques bentiques d'une lagune du Sud-Bénin, le lac Ahémé: les facteurs de leur répartition, dynamique de population et estimation de la production de Corbula trigona. Thèse doct. 3ème cycle, Univ. de Lyon, 152 pp.

McColl (1972)

McCune B. and Mefford M. J. (1995) Multivariate analysis of ecological data. Version 2.0. MJM Software design, Gleneden Beach, Oregon, USA.

MEHU/GTZ (2001) Pollution atmosphérique urbaine au Bénin. Tractebel (2000) Etude sur la qualité de l'air en milieu urbain: cas de Cotonou. 49 pp.

Mensah, M.A. (1991) The influence of climatic changes on the coastal oceanography of Ghana. In Pecheries ouest Africaines: variabilite, instabilite et changement (ed. C. Phillipe and C. Roy), pp. 67-79.

Merle, J. and Arnault, S. (1985) Seasonal variability of the surface dynamic topography in the Tropical Atlantic Ocean. Journal of Marine Research 43:267-288.

Miller & Tiller (1971)

Mondjanagni A. (1969) Contribution à l'étude des paysages végétaux du Bas-Dahomey. Ann. Univ. Abidjan. t. 1, fasc.. 2:191.

Moore, D.W., Hisard, P., McCreary, J.P., Merle, J., O'Brien, J.J., Picaut, J., Verstraete, J.M., and Wunsch, C. (1978) Equatorial adjustment in the eastern Atlantic ocean. Geophysical Research Letters 5:637-640.

Morton R. M. (1990) Community structure, density, and standing crop of fishes in a subtropical Australian mangrove area. Marine Biology. 105:385-394.

Moss (1957)

Nason, A. (1992) Discovering Birds: An Introduction to the Birds of Nigeria. Pisces Publications, the Nature Conservation Bureau Ltd., UK.

Nations Unies (1979) Seminaire-Atelier sur les problèmes de l'érosion Gouvernements du Togodes côtes du Togo et du Bénin. Lomé.

NEDECO/HASKONING (1984) Complément de formation de l'unité hydrographique Laboratoire de Delft. Evaluation et Interprétation des données morpho.

NEDECO/HASKONING Port Autonome de Cotonou. (1983) Etude du littoral. Laboratoire de Delft.

NEDECO: République togolaise. Etude détaillée de l'érosion.

Nelson & Sommers (1982)

NISSAKU Co. LTD. (1994) Projet pour l'exploitation des eaux souterraines du Bénin, phase III. Rapport final. 204 pp.

Northridge S.P. (1985) Etude des interactions entre les mammifères marins et les pêches au niveau mondial. FAO. pp. 60-78.

NU. (1987) Plan directeur d'utilisation des ressources en eau: la plaine côtière du Bénin, une reconnaissance hydrochimique. Rapport informel UN/DTCP No. 1. Projet BEN 85/004, Cotonou, Bénin. 12 pp.

Nunoo, F. K. E. (2003) Biotic, abiotic and anthropogenic controls of nearshore marine fish assemblage caught in beach seines in Sakumono, Ghana, and their management implications. Ph.D. Dissertation. University of Ghana, Legon. 142 pp.

Nwankwo (1990a)

Nwankwo (1990b)

Nyarko, E. and Evans, S.M. (1997) Impacts of tributyltin pollution and human food gathering on populations of gastropods Thais haemastoma and Thais nodosa along the Ghana coast. *In* The coastal zone of West Africa: problems and management (Eds., Evans, S.M., Vanderpuye, C.J. and Armah, A.K.), London: Penshaw Press, pp. 93-101.

Odeyemi, O.O., et al. (1994) The effect of drill slot on aquatic life in Belema field in the eastern operational area of the Shell Petroleum Company of Nigeria Limited. Environmental Pollution Studies and Technology Team, Dept of Microbiology, Obafemi Awolowo University, Ile-Ife, Nigeria. 154 pp.

Okoye et al. (1991)

Olaniyan (1961)

Olaniyan (1975)

OMI/UNNEP : Rapport de mission concernant l'élaboration d'un projet de plan d'intervention d'urgence en cas de situation critique pour l'environnement marin et côtier, République Populaire du Bénin.

Omori, M. and Ikeda, T. (1984) Methods in marine plankton ecology, pp. xiii, 332. New York: Wiley.

Onudi. (1999) Organisation des Nations Unies pour le Dévéloppement et l'Industrie. Rapport.

Oteng-Yeboah, A.A. (1994) Biodiversity in three traditional groves in Guinea savannah,Ghana, in L. J.G. Van deer Maesen et al.(eds.) The Biodiversity of African plants , Kluwer AcademicPublishers, Dordrecht. pp. 188-197.

Owre, H. B. and Foyo, M. (1967) Copepods of the Florida Current. In Fauna Caribaea. No.1 Crustacea, Part1: Copepoda. Miami: University of Miami. 137 pp.

Oyede L. M. (1983) Un exemple de sédimentation biodétritique quaternaire dans le domaine margino-littoral en climat tropical humide: le « lac » Ahémé (Bénin – Afrique de l'Ouest) Thèse Doctorat 3ème cycle, Université Nationale du énin – Université de Bourgogne, Dijon, 171 p.Oyede L.M., Kaki C. & Yessoufou S. (2001) Reconnaissance géologique d'un site de décharge et de valorisation des véhicules hors d'usage: étude d'impact environnemental sur le milieu physique. DST/UNB, 17 p.

Oyede L. M. (1991) Dynamique sédimentaire actuelle et messages enregistrés dans les séquences quaternaires et néogènes du domaine margino-littoral du Bénin (Afrique de l'Ouest) Thèse de Doctorat. Univ. de Bourgogne et Univ. Nat. du Bénin. 302 pp.

Oyede L. M., Lang. J. and Carbonnel G. (1986) Phénomènes biosédimentaires actuels et subactuels dans le domaine margino-littoral sud-béninois (Bénin, Afrique de l'Ouest) Workshop projet no. 210. PICG. Jos, Nigeria. pp. 47-48.

Oyede L. M., Lang. J. and Tsawlassou. (1988) - Un exemple de sédimentation biodétrique holocène en climat tropical humide: le lac Ahémé (Bénin, Afrique de l'Ouest) Journal of African Earth Sciences, 7(5/6):835-855.

Oyede L. M., Prichonnet G., Alidou S. and Preda M. (1987) Les minéraux lourds et argileux dans la stratigraphie du Quaternaire littoral du Bénin (Afrique de l'Ouest) XIIème Congrès INQUA. Montréal., 237 pp.

P.N.U.E. (1985) Erosion Côtière en Afrique de l'Ouest et du Centre, (avec la collaboration des Nations Unies et de l'UNESCO) Paris.

Page et al. (1987)

Pallas P. (1988) Contribution à l'étude des ressources en eau souterraine du bassin côtier du Bénin. Confrontation ressources-besoins. (Projet PNUD) 29 pp.

Papadakis (1965)

Paradis G. & Adjanohoun E. (1974) L'impact de la fabrication de sel sur la végétation de mangrove et la géomorphologie dans le Bas-Dahomey. Univ. Abidjan, Sér. E, Ecologie, VII, 1.

Paradis G. (1975) Physionomie, composition floristique et dynamisme des formations végétales d'une partie de la basse vallée de l'Ouémé (Dahomey) Ann. Univ. Abidjan, Sér. C, Sc., t.XI, p. 35-101.

Paradis G., (1976) Recherches sur le Quaternaire récent du Sud de la République du Bénin. Thèse 3ème cycle. Univ. Paris Sud. Orsay, 174 pp.

Pelnard Considère, R. (1956) Essai de théorie de l'évolution des formes de rivage en plages de sables et de galets. Ves journées de l'hydraulique. Paris.

Per Roed, J. (1989) Coastal erosion in the Bight of Benin; national and regional aspects. Commission of the European Community, p. 381.

Pereira J. J. (1978) Le Crétacé dans le bassin sédimentaire côtier du Bénin (Afique de l'Ouest) 6ème Réun. Ann. Sci. Terre. Orsay. 305.

Pliya J.1980. La pêche dans le Sud-Ouest du Bénin, ACCT,1980, 296 pp.

PNAE/MERF, (2002) Monographie nationale sur la diversité biologique. Document préliminaire, p. 191.

PNUD (1987) Plan directeur d'utilisation des ressources en eau du Bénin. Projet UN/DTCD BEN 85/004. DH. Cotonou, Bénin.

Port Autonome de Cotonou- Direction du bureau d'études: Erosion Côtière. Etude et suivi de l'évolution de la côte béninoise (phase 1) Rapport de l'étude.

Prichonnet G., Oyede L. M. et al., (1987) Les bas niveaux marins du Pleistocène supérieur au Sud du Bénin et dans les zones adjascentes de l'Afrique de l'Ouest.

Profizi J. P. (1982) Essai de quantification du dynamisme d'une mosaïque forêt-savane du savane Sud-Bénin par photo-interprétation. Ann. Univ. Abidjan, Sér. E., E. (Ecol.), t. XV, pp. 95-101.

Purser B.H. (1980) Sédimentation et diagenèse des carbones néritiques récents. Technip., Paris, 366 pp.

Ramsar Convention on Wetlands (2000) Workplan.

Richardson, P.L. (1984) Moored current meter measurements in the Atlantic North Equatorial Counter Current during 1983. Geophysical Research Letters 11, pp. 749-752.

Rijavec, L. (1980) A survey of the demersal fish resources of Ghana. CECAF/TECH/80/25.

Roberston A. I. & Duke N.C. (1987) Mangrove as a nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. Marine Biology. 96: 193-206.

S.G.I., (1983) Etude de la nappe aquifère de Godomey. Rapport complémentaire sur les piézomètres. Société Générale pour l'Industrie. Banque Africaine de Développement, Abidjan, Côte d'Ivoire. SBEE, Cotonou. Genève, Suisse.

Sagbo O. M. (2000) Pollution des nappes alimentant la ville de Cotonou en eau de consommation: vulnérabilité et urgence des mesures de protection des aquifères. UAC, Cotonou, Bénin.

SBEE (1995) - Adduction d'eau des villes de Cotonou et Porto-Novo. Rapport final.S.G.I., (1981) Etude de la nappe aquifère de Godomey. Société Générale pour l'Industrie Banque Africaine de Développement-SBEE. Cotonou.

Schneider (1990)

SERHAU-BURGEAP (1987) Expérimentation sur l'assainissement à Cotonou: potentialité d'infiltration dans le sol. FAC, France, MET, Bénin.

Serle W. & Morek G. J. (1993) Les oiseaux de l'Ouest-africain ; Guide du naturaliste.

SERRES G. (1987) Coupe hydrogéologique à travers le Nord-Ouest du plateau d'Allada. DH. Cotonou. Inédit.

Sitarz, ( ) Côtes africaines, études des profils d'équilibre de plages. Travaux du Centre d'Etudes.

Slansky M. (1968) Contibution à l'étude géologique du bassin sédimentaire côtier du Dahomey et du Togo. Thèse . Univ. Nancy, série 59, n° 165 et 1962, Mém. BRGM, No. 11, 170 pp.

Sogreah (1990) Etude sur modèle mathématique de l'évolution du littoral béninois entre la frontière togolaise et l'est de l'embouchure du fleuve Mono.

Sogreah (1991) Etude des problèmes sédimentologiques et programmation des campagnes de dragages du chenal d'accès et du bassin portuaire.

Sogreah, and Delft (1983) Travaux de Protection de la Zone de « la Crique » à Cotonou. Pièce annexe au dossier d'Appel d'Offres (Projet) Mémoire justificatif des ouvrages.

Sogreah, and Delft (1989) Instiut danois d'Hydraulique Expertise Régionale pour le Projet Pilote Régional de Lutte contre l'Erosion en Afrique de l'Ouest et du Centre.

Sogreah/SCET-Tunisie, (1997) Etude de la stratégie nationale de gestion des ressources en eau du Bénin. Rapports R1 à R7. Cotonou, Bénin.

Steentoft, M. (1986) Flowering plants in West Africa. In: (G.W. Lawson, Ed.) Plant Ecology in West Africa, Systems and processes. Chichester. John Wiley.

Syreyjol, P (1964) Communication sur la construction du port de Cotonou (Dahomey) Coastal Engieneering Conference, Lisbon.

Syreyjol, P. (1964) Communication sur la construction du port de Cotonou (Dahomey) Coastal Engieneering Conference, Lisbon.

T&T Associates Ltd. (1991)

Tastet J. P. (1981) Morphologie des littoraux sédimentaires liés aux variations du niveau de la mer: exemple du Golfe de Guinée. Océanis, 7, Fasc. 4:455-472.

TEE Associates Environmental Consultants (1991)

Thayer G. W., Colby D. R. & Hettler W.F. Jr. (1987) Utilization of the red mangrove prop root habitat by fishes in south Florida. Marine Ecology Progress Series. 35:25-38.

Thiriot, A. (1977) Zooplankton in the upwelling zones of the African Atlantic littoral. Document Scientifique Centre Recherche Oceanographique (ORSTOM) 8:1-72.

Thomas (1959)

Tomas, C. R. (1997) Identifying Marine Phytoplankton. San Diego: Academic Press. 858 pp.

TROADEC and Coll. (1979)

Tsidzi, K. E. N., Akoto, M. A. and Iddrisu, Y. (1995) Geological hazards mitigation in Ghana: the state of the art. Ghana Mining Journal 1.

TurkPak International-SCET -Tunisie, (1991) Inventaire des ressources en eaux souterraines au Bénin. Rapport final. V.1 284 p. + Annexes.UN, (1987) La plaine côtière du Bénin: une reconnaissance hydrochimique. Rapport informel No. 1. Projet BEN 85/OO4 PNUD, Cotonou, Bénin.

UN, (1990) Plan directeur d'utilisation des ressources en eau du Bénin. Projet BEN 85/OO4 PNUD, Cotonou, Bénin.

UNB-UQAM (1987) Aquifère du Quaternaire côtier du Bénin. Projet CRDI (1ère phase) n° 3-P-84-1056-03..

UNEP Tzeng W-N. & Wang Y.T. (1992) Structure, composition and seasonal dynamics of the larval and juvenile fish community in the mangrove estuary of Tanshui River, Taiwan. Marine Biology. 113:481-490.

UNESCO/UN (DIESA) (1984) Projet Erosion Côtière en Afrique Centrale et de l'Ouest. WACAF/3. Réunion au B.R.G.M. Orléans.

Van Thielen R. , Hounkpe C., Agon G. & Dagba L. (1987) Guide de détermination des poissons et crustacés des lagunes et lacs du Bas Benin. Deutsche Gesellschaft Fur Technische Zusammenarbeit (GTZ)GMBH & Direction des Pêches, Cotonou.

Vance D. J., Haywood M.D.E., Heales D.S., Kenyon R.A. & Loneragan N.R. (1990) How far prawns and fish move into mangroves? Distribution of juvenile banana praws Penaeus merguiensis and fish in a tropical mangrove forest in northern Australia. Marine Ecology Progress Series. 131:115-124.

Vanden Bossche, J.P. and Bernaesek, G.M. (1990) Source book for the inland Fishery resources of Africa. CIFA Technical Paper 18/2 Rome, 240 pp.

Van-Thielen et al (1987)

Vinje, J.J. et W.M.K. Tilmans ( ) Expertise sur l'Erosion Côtière et les Techniques de Protection du Littoral de la République du Togo.

VOLKOFF B. (1976) Carte pédologique de reconnaissance de la République Populaire du Bénin. ORSTOM, Paris, Inédit.

Waerbeek, K. V. and Ofori-Danson, P. K. (1999) Exploratory survey of cetaceans and their interactions with fisheries in Ghana and Togo, the Gulf of Guinea. Chicago Zoological Society and Leopold III Fonds Voor Natuuronderzoek en Natuurbehoud. 15 pp.

Webb (1958)

Welcomme, R. L. 1971. A description of certain indigenous fishing methods from Southern Dahomey. Afr.J.Trop.Hydrobiol.Fish., 1: 129-40.

Wetzel & Likens (1990)

Wiafe G. & Frid C.L.J. (2001) Marine zooplankton of West African. Marine Biodiversity capacity Building in the West African-Region, 120 p., Recherches Océanographiques. Vol. 3, fasc. 4.1960 Construction, No 9, 1967 XIIème. Congrès INQUA. Montréal. Résumé. 245. 80, 125-160.

Wiafe G. and Quist, M. (2002) Nutrient Pollution in Ghana., p. 31. Accra: UNIDO Thematic Area Paper For Stocktaking Meeting (PDF-B).

Wiafe, G. (2002) Spatial and temporal dynamics of plankton communities in the Gulf of Guinea ecosystem. In: Oceanography and Fisheries, pp. 188. Legon: University of Ghana.

Wiafe, G. and Frid, C. L. J. (2001) Marine plankton of West Africa, pp. 120. with CD-ROM Published by Darwin Initiative, U.K.

Williams, F. (1968) Report on the Guinean Trawling Survey, Organisation Of African Unity Scientific and Technical Research Commission (99)

Yankson and Kendall (2001)

Zar (1984)

Ziebis, W., M. Huettel, and S. Forster (1996) Impact of biogenic sediment topography on oxygen fluxes in permeable seabeds. Mar. Ecol. Prog. Ser. 140: 227-2.

CHAPTER 9
APPENDIX A

Figure A-1 2B01C Temperature vs Depth

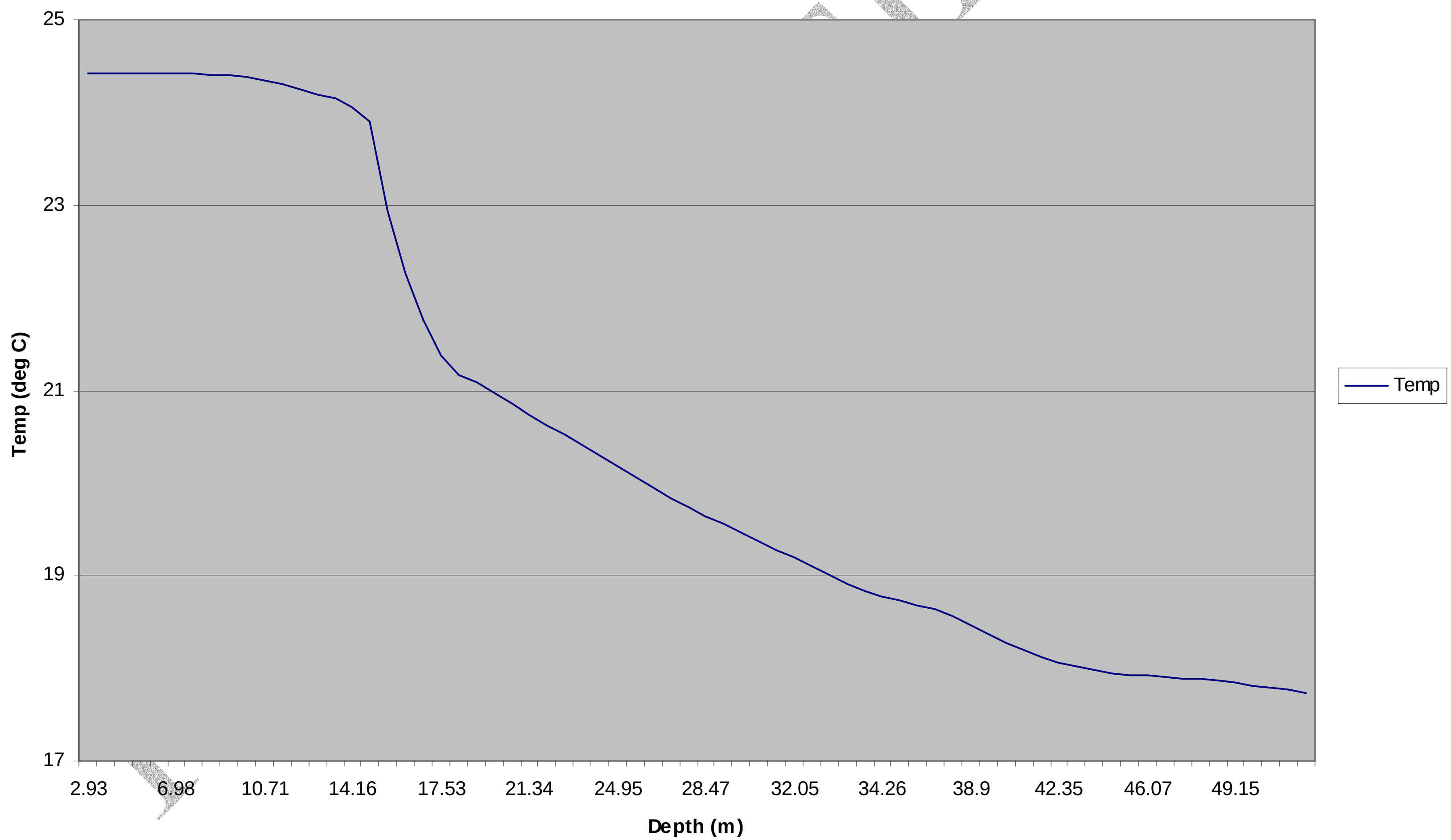


Figure A-2 2B02C Temperature vs Depth

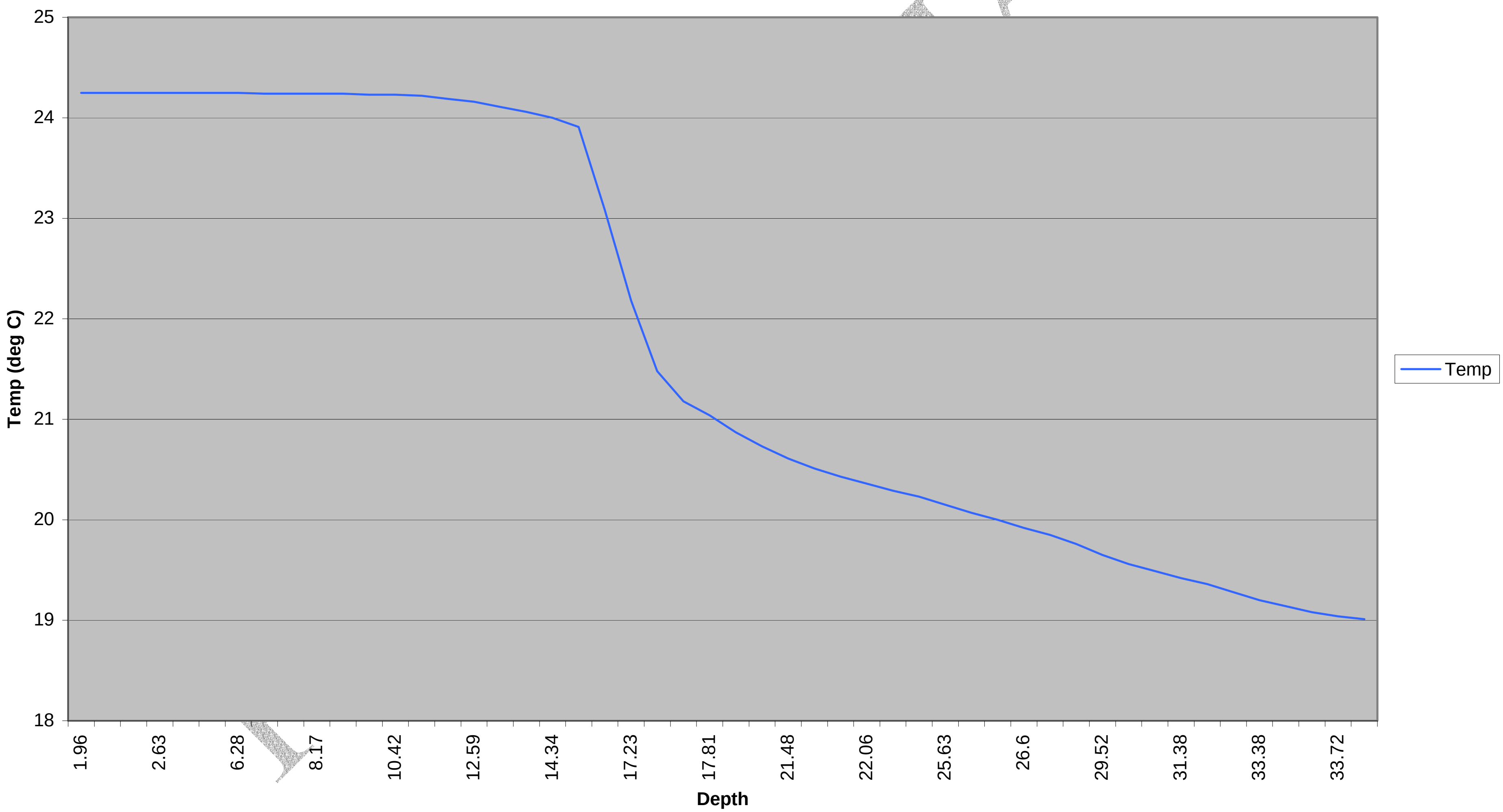


Figure A-3 2B03C Temperature vs Depth

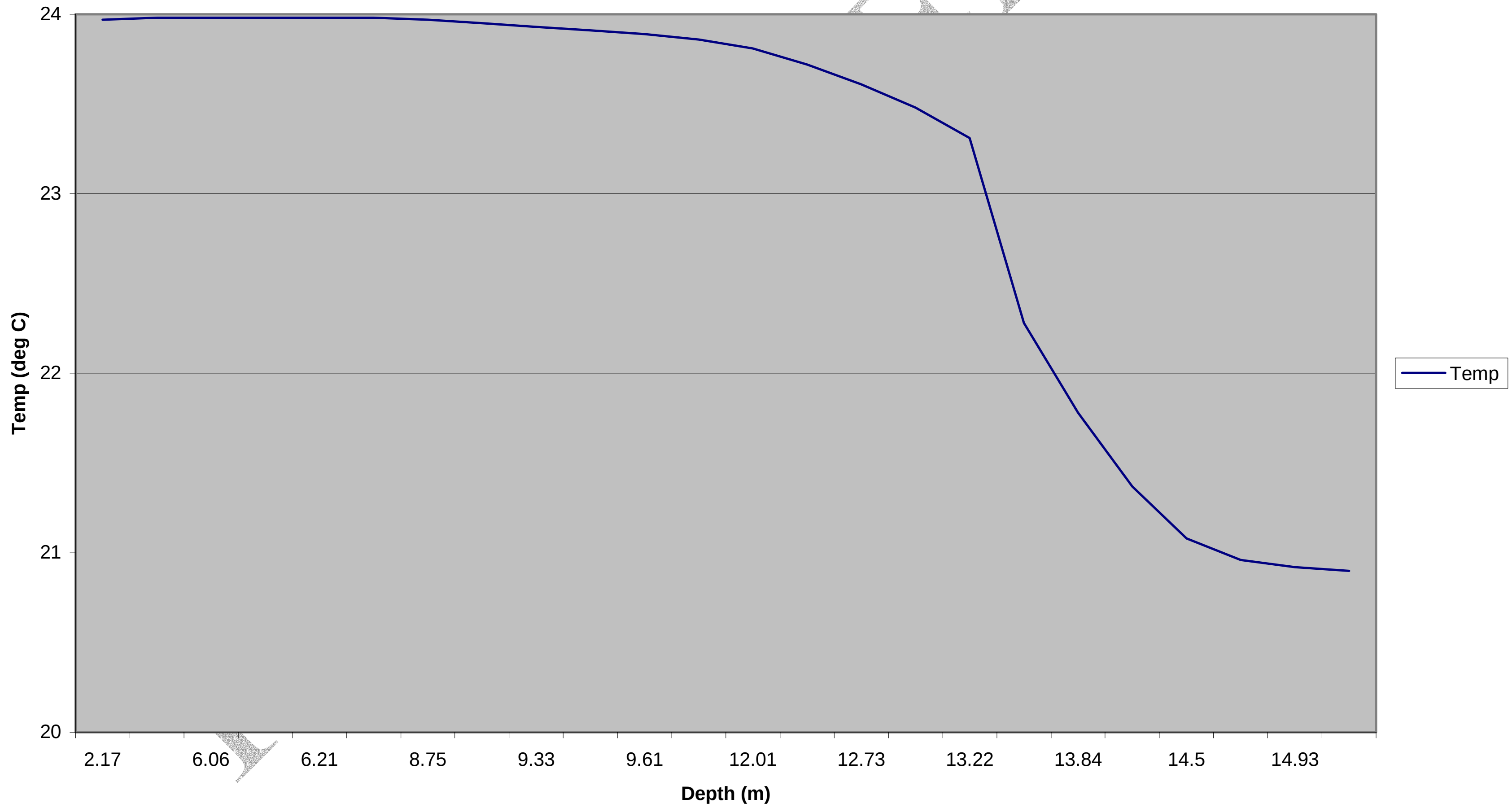


Figure A-4 2B04C Temperature vs Depth

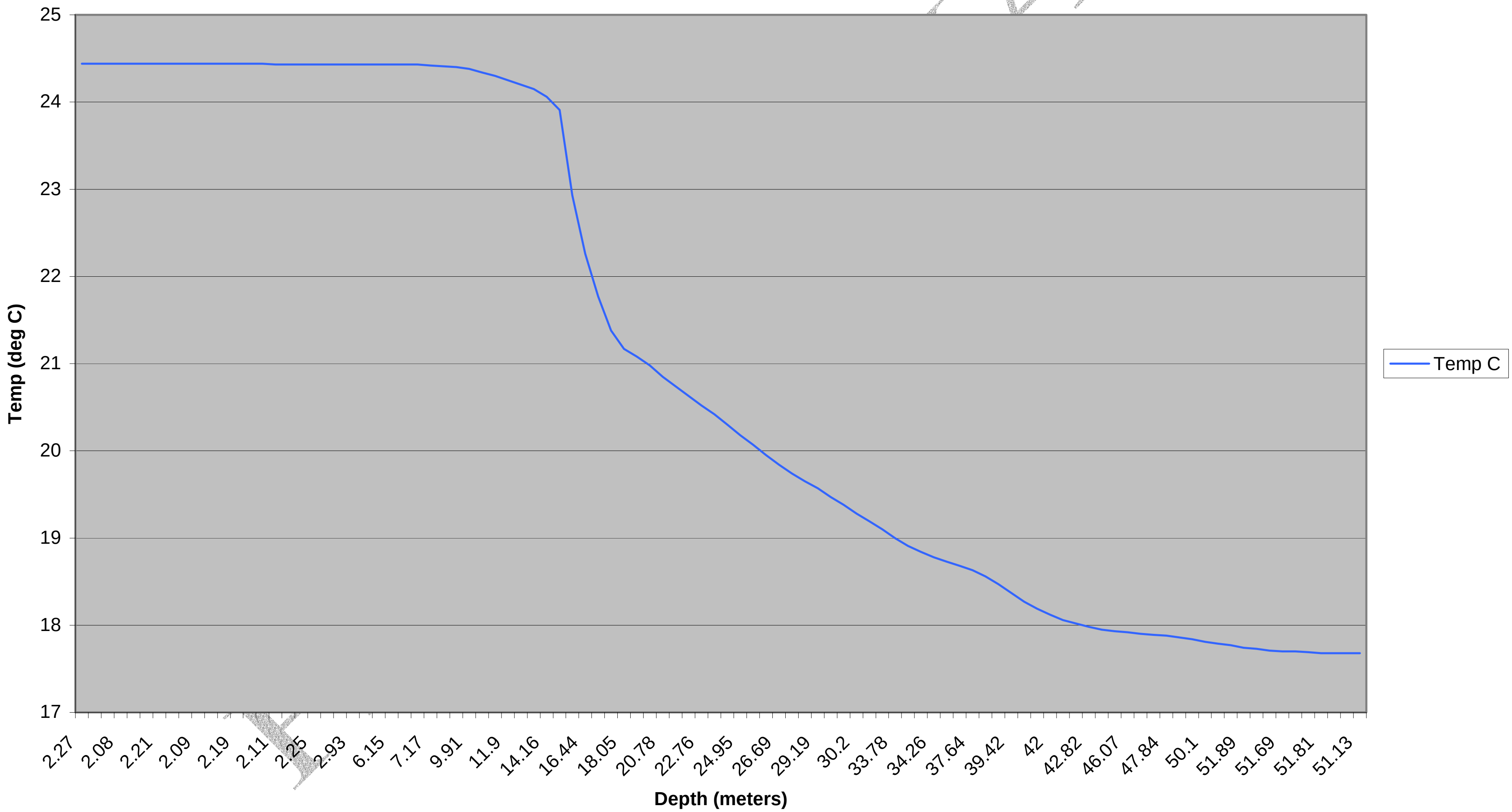


Figure A-5 2B05C Temperature vs Depth

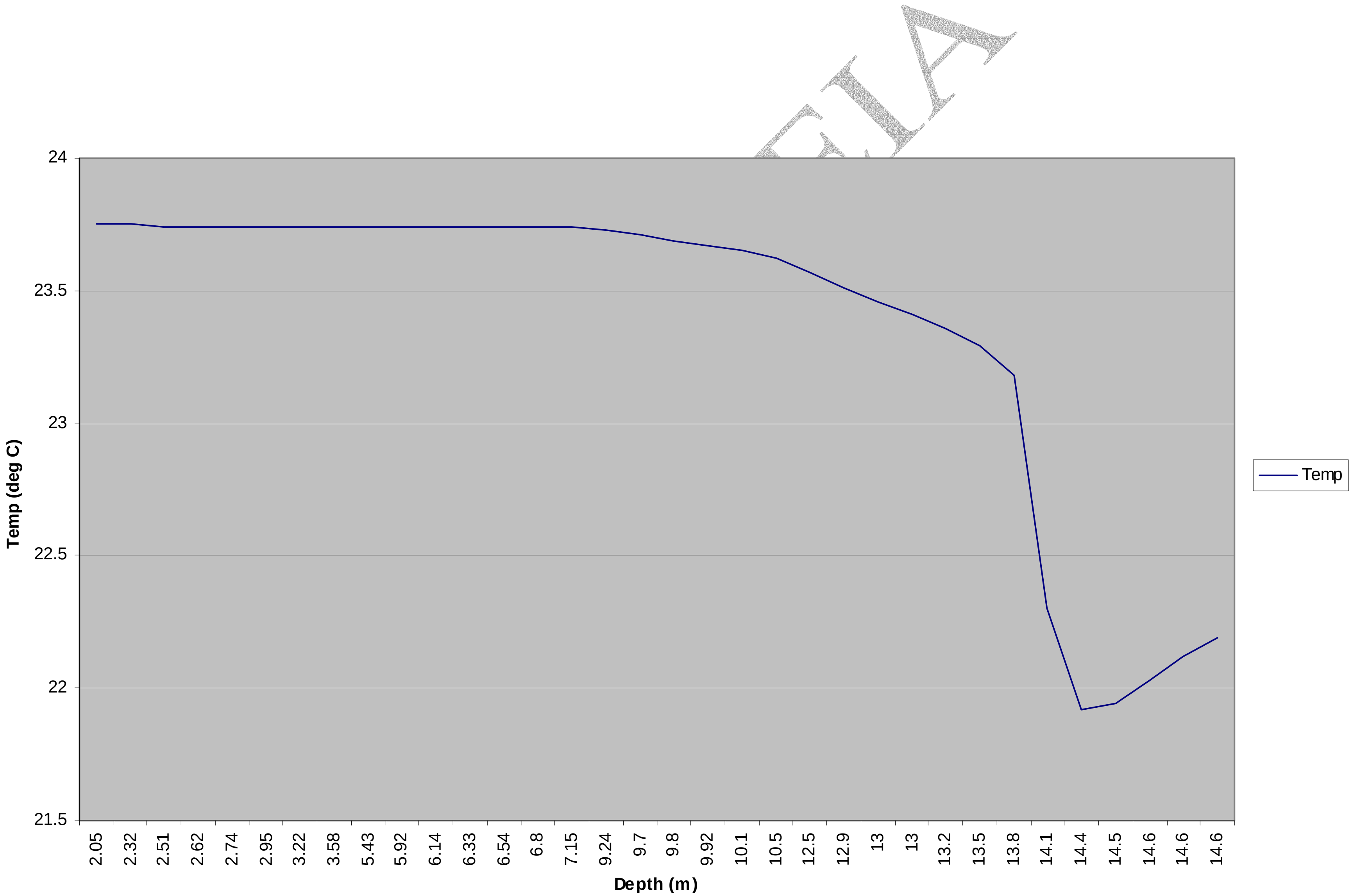


Figure A-6 2B06C Temperature vs Depth

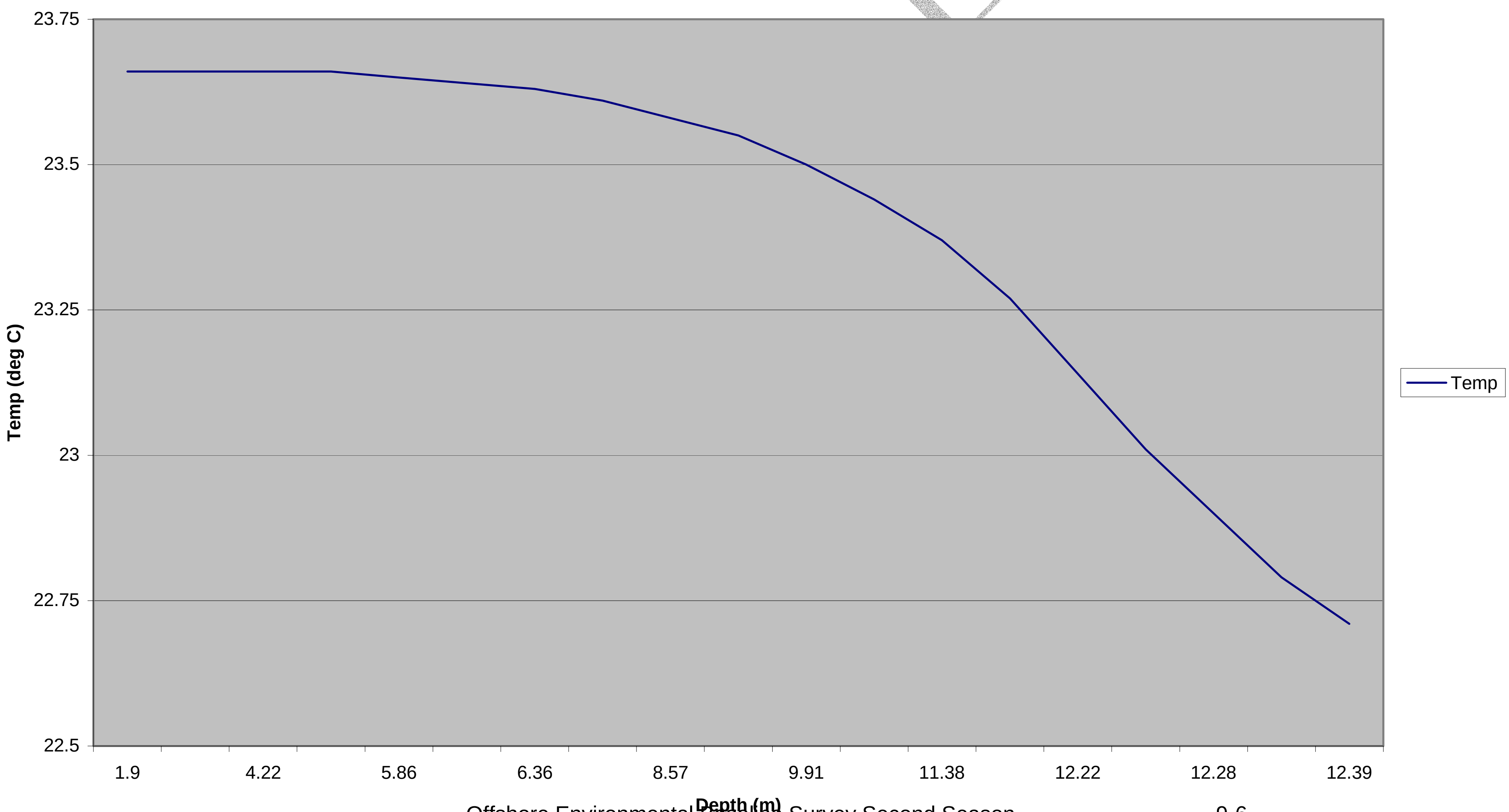


Figure A-7 2B07C Temperature vs Depth

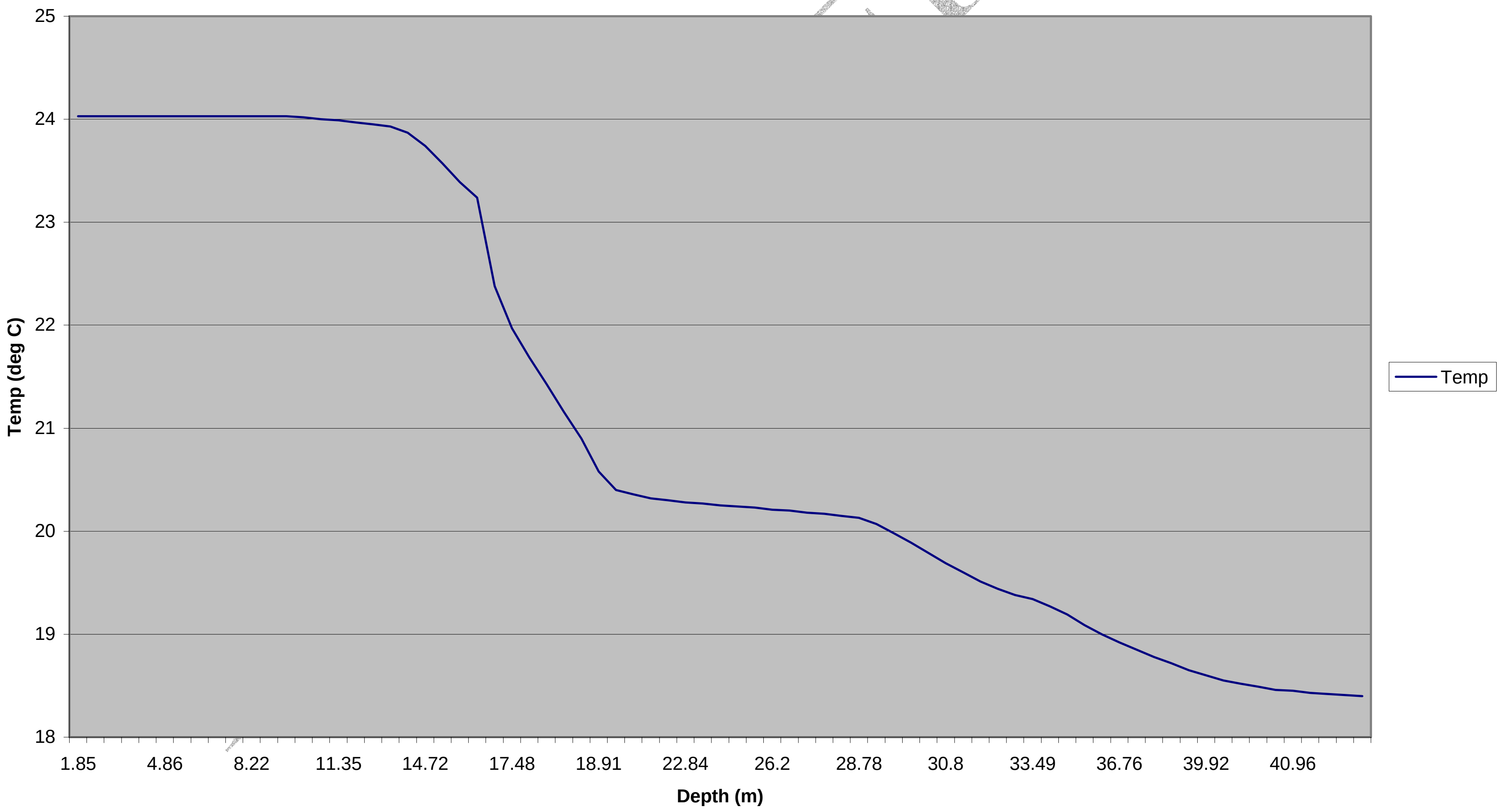


Figure A-8 2B08C Temperature vs Depth

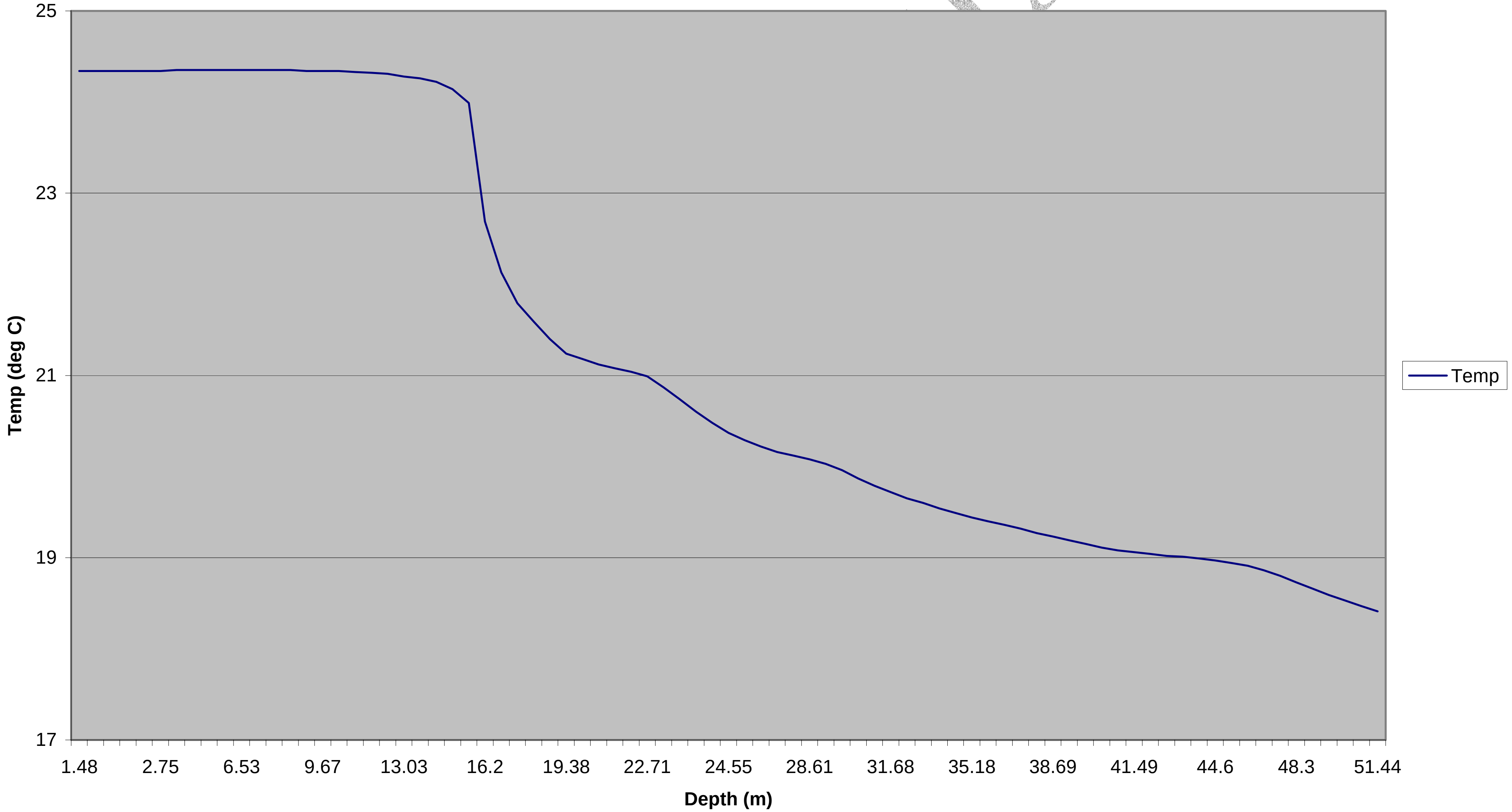


Figure A-9 2B09C Temperature vs Depth

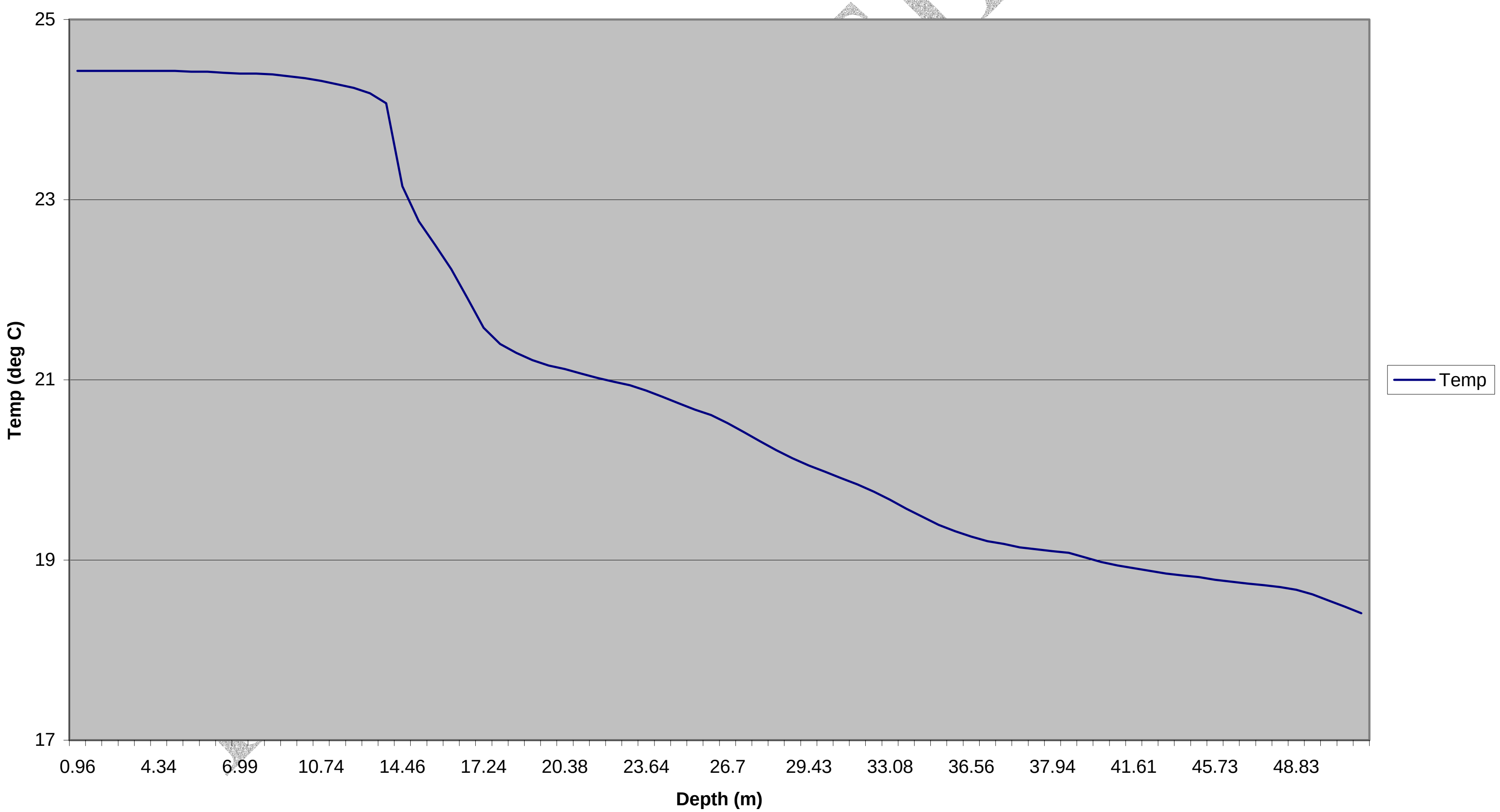


Figure A-10 2B10C Temperature vs Depth

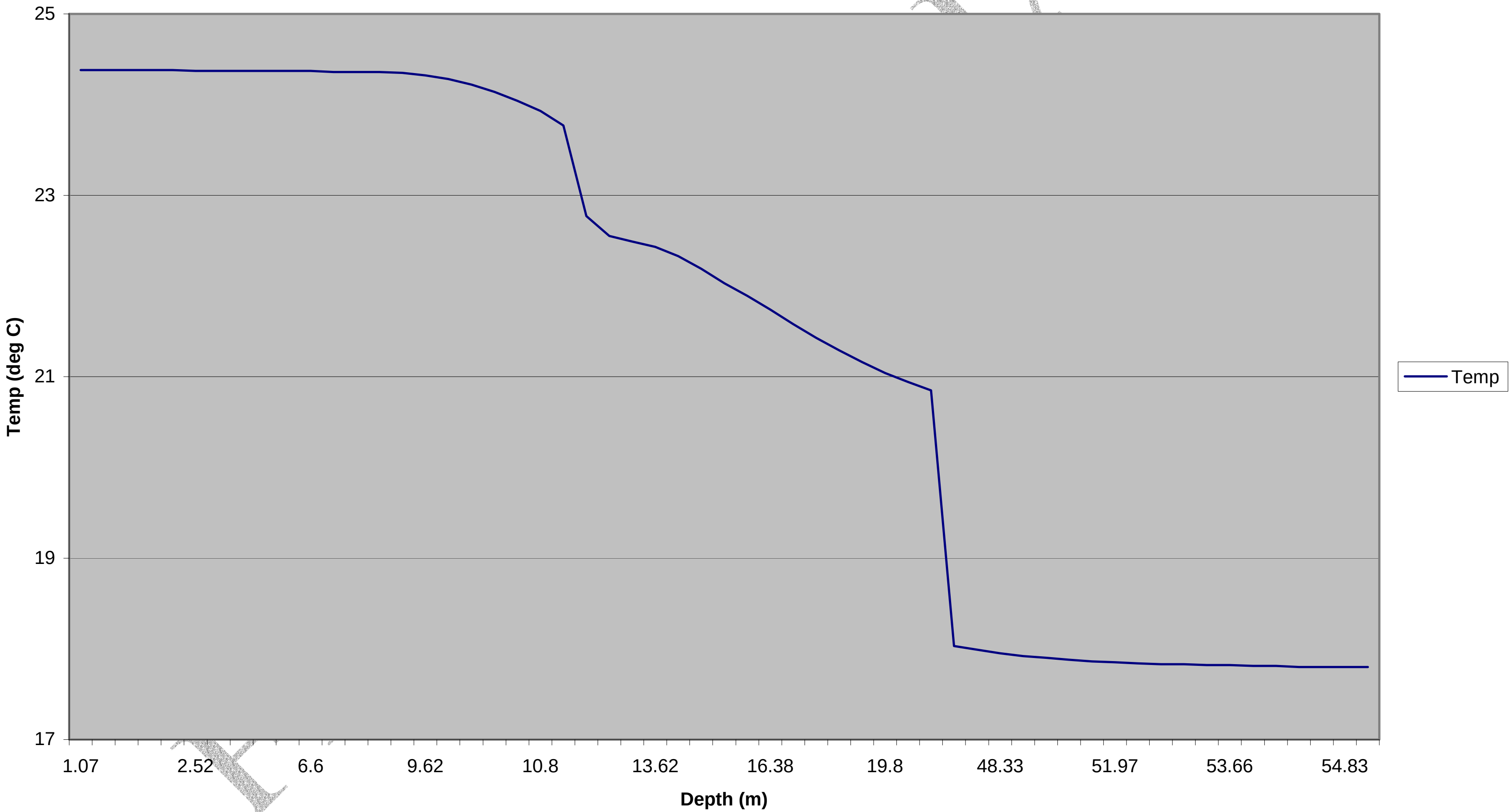


Figure A-11 2G01C Temperature vs Depth

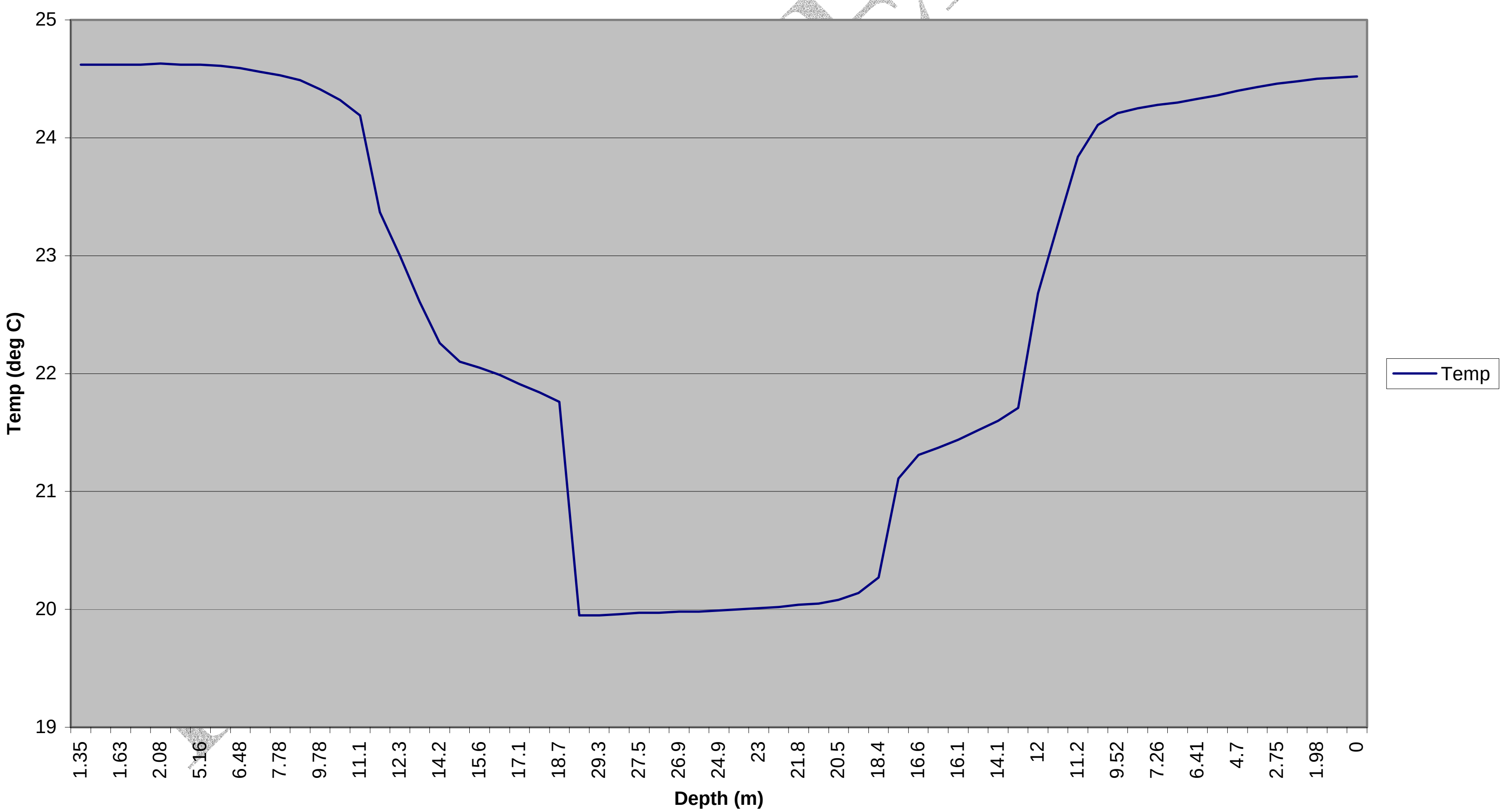


Figure A-12 2G10C Temperature vs Depth

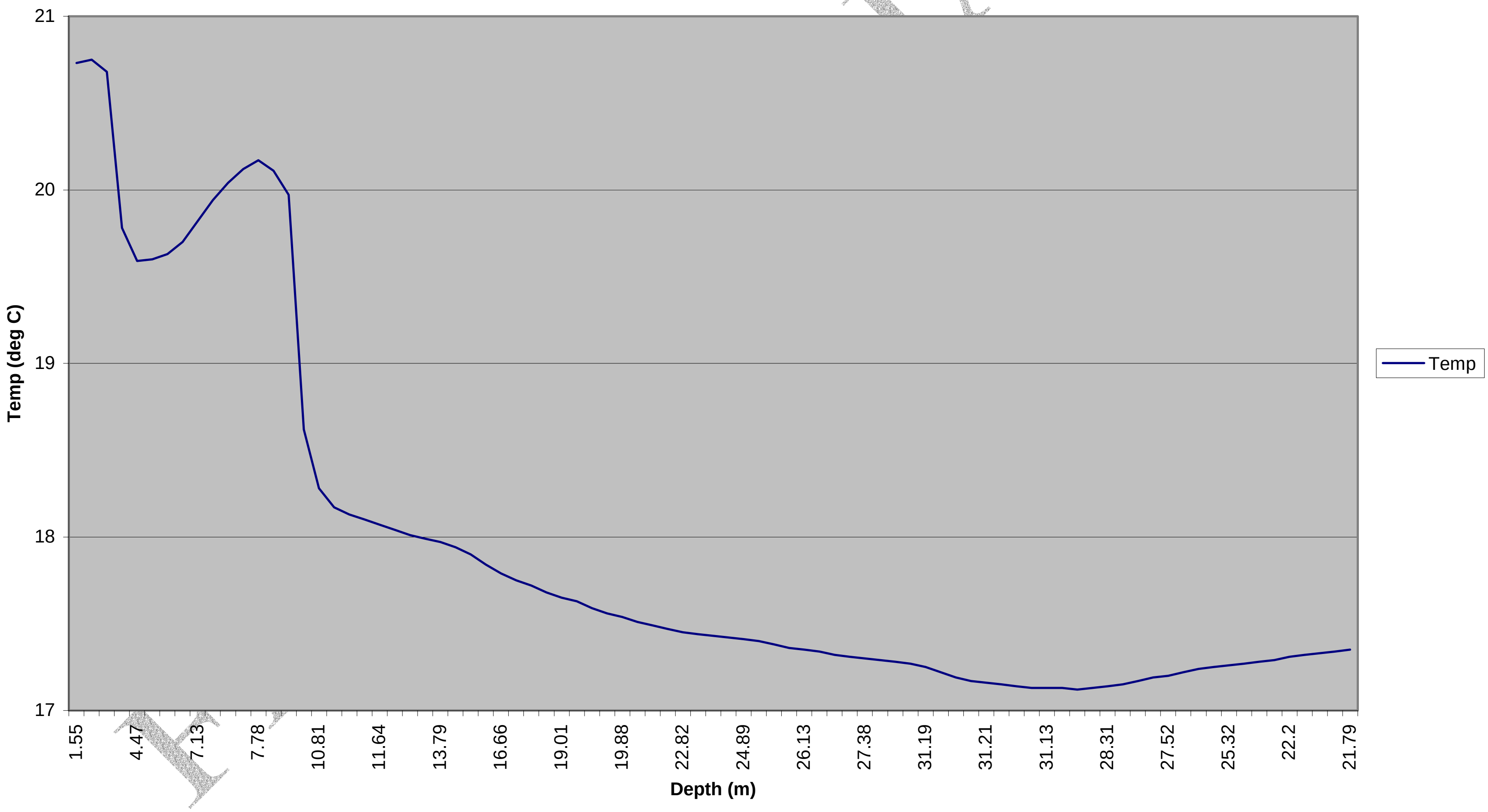


Figure A13-1 2G11C Temperature vs Depth

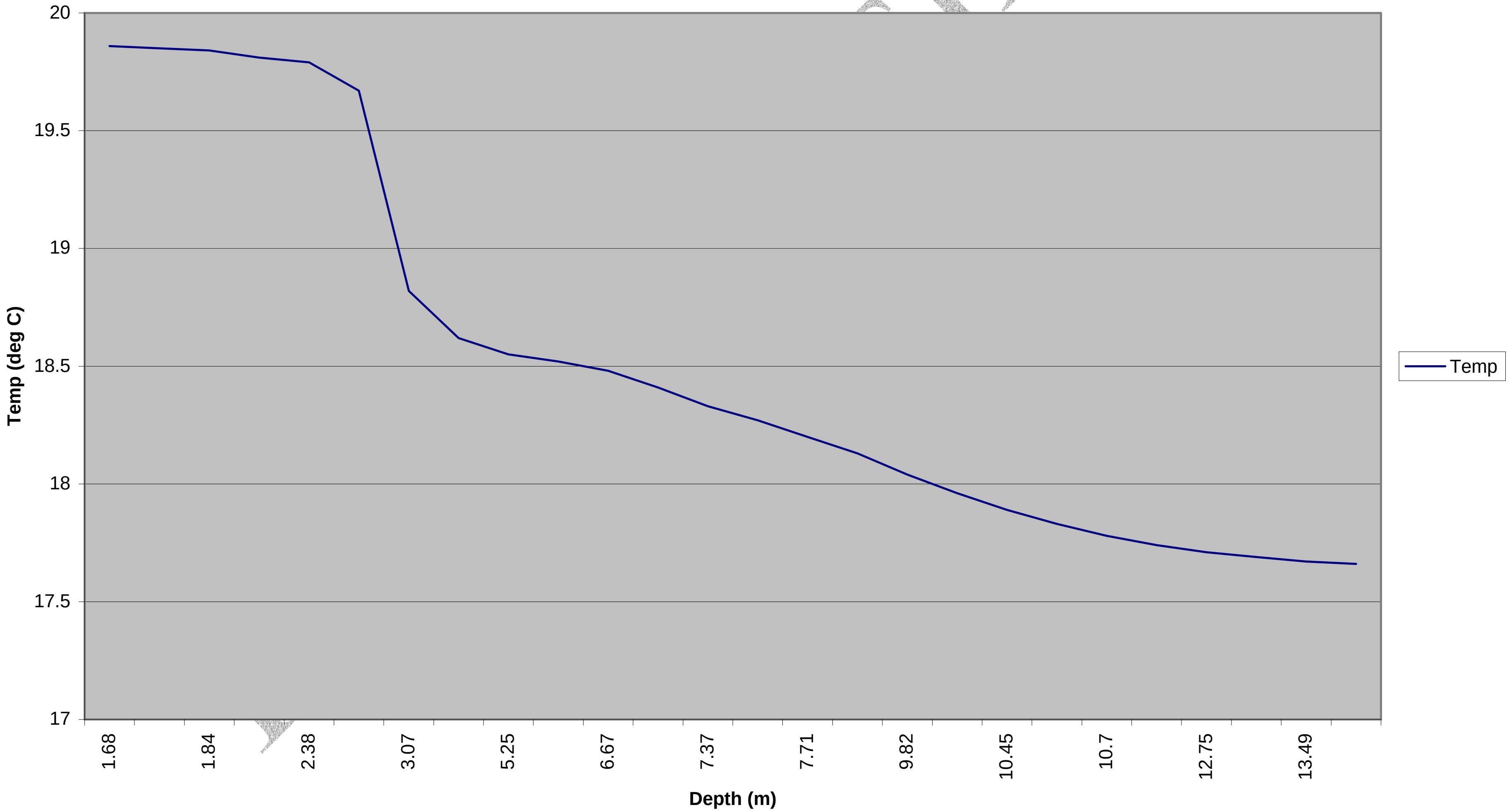


Figure A-14 2G20C Temperature vs Depth

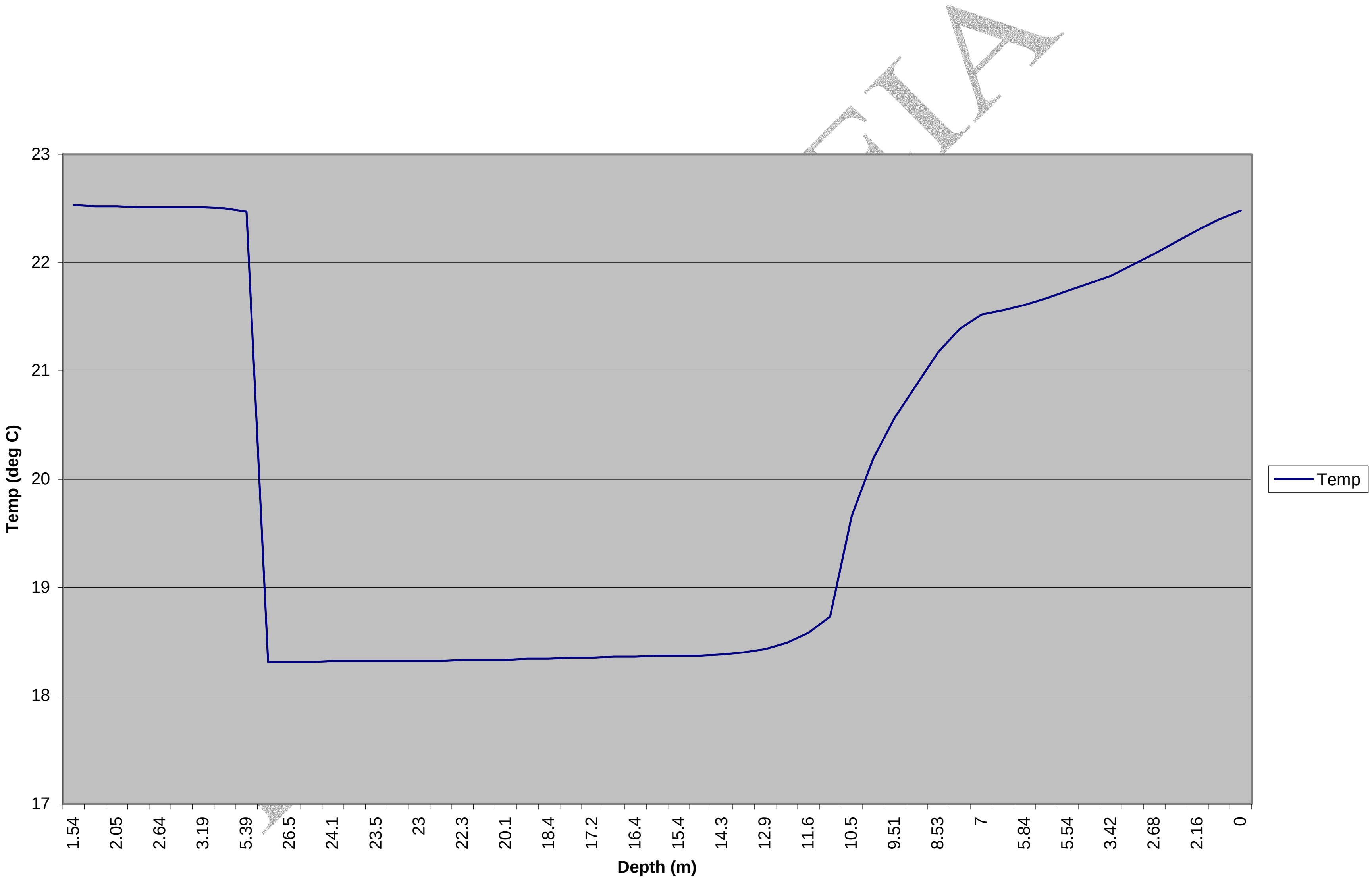


Figure A-15 2G21C Temperature vs Depth

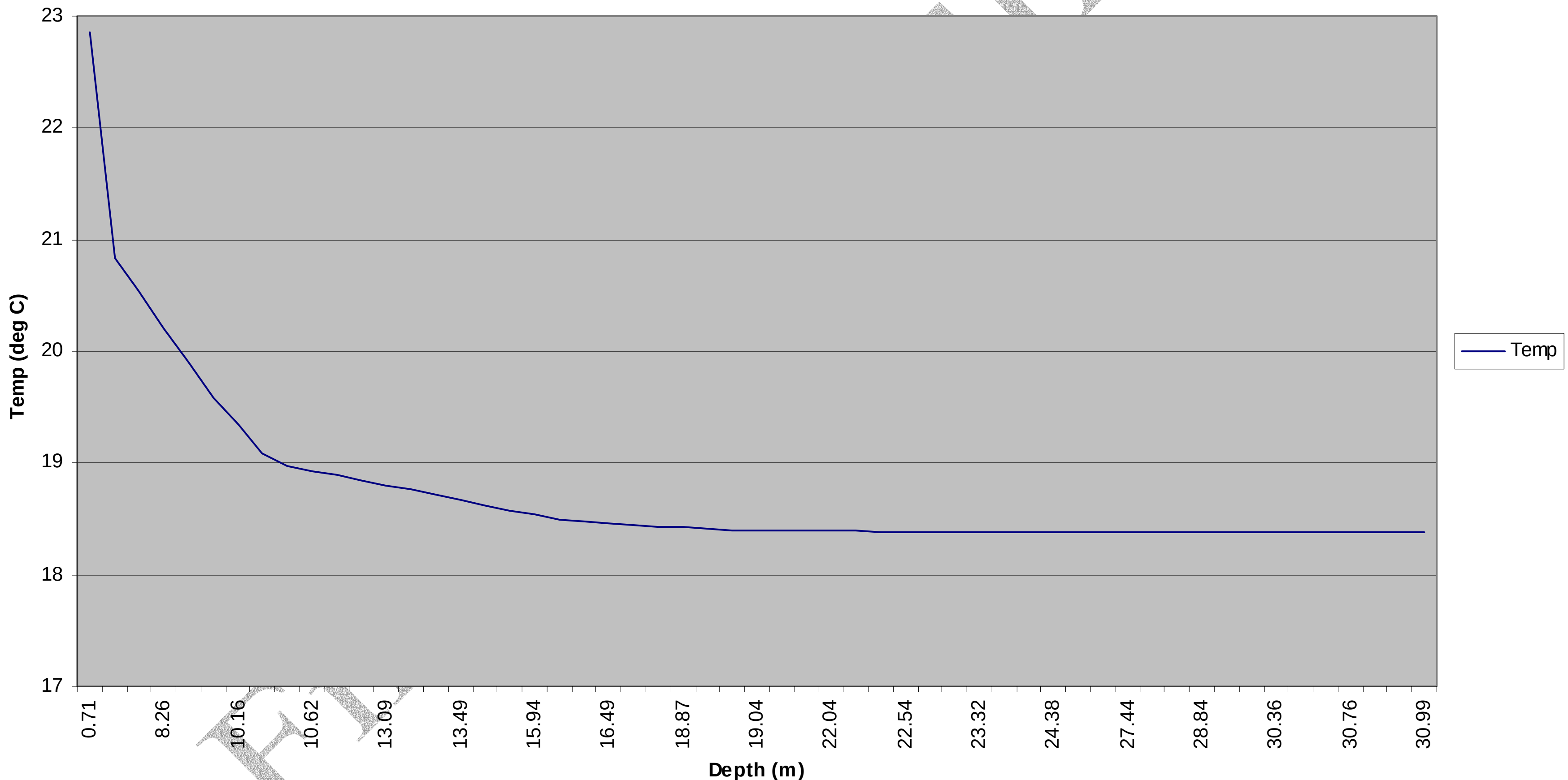


Figure A-16 2G22C Temperature vs Depth

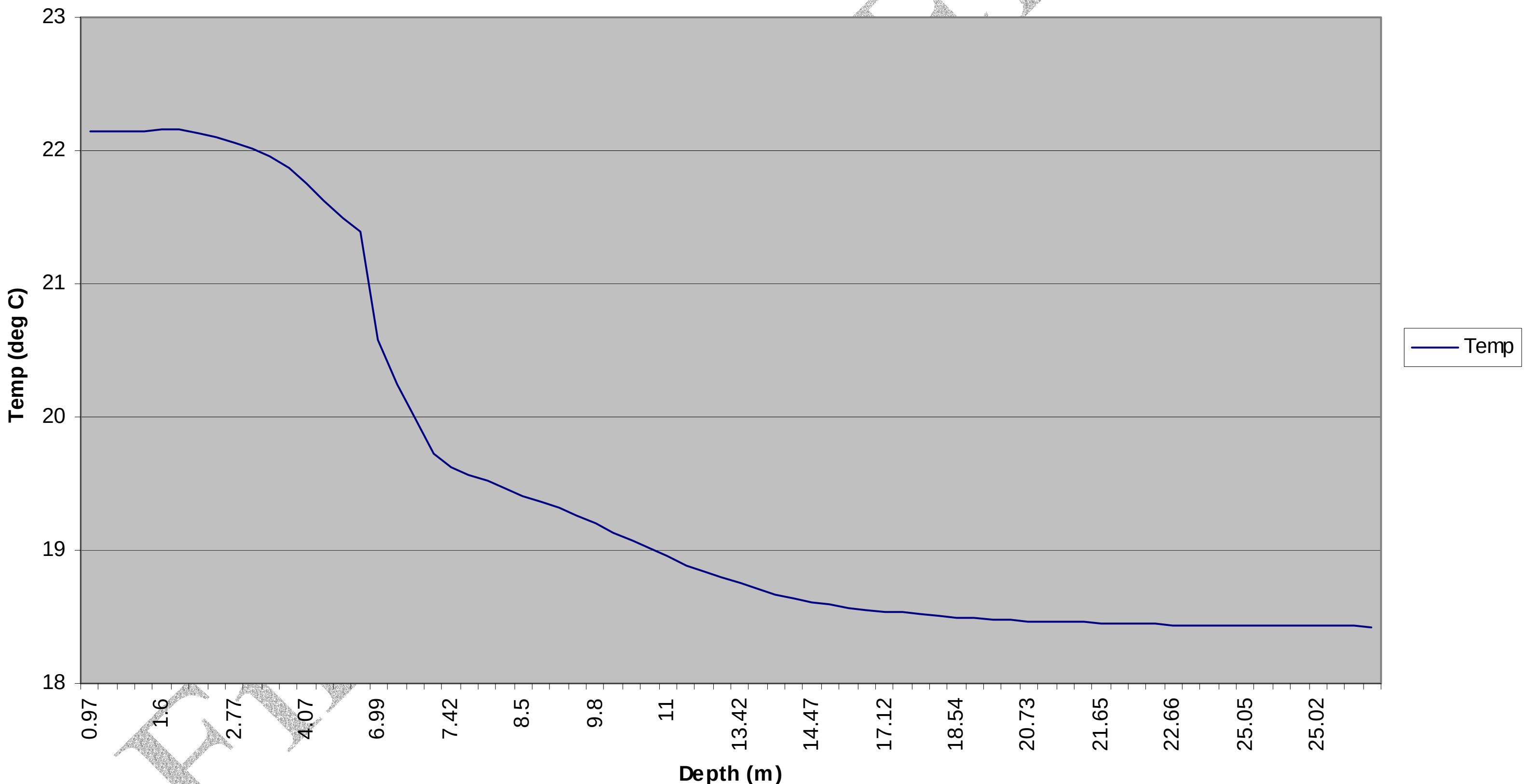


Figure A-17 2G23C Temperature vs Depth

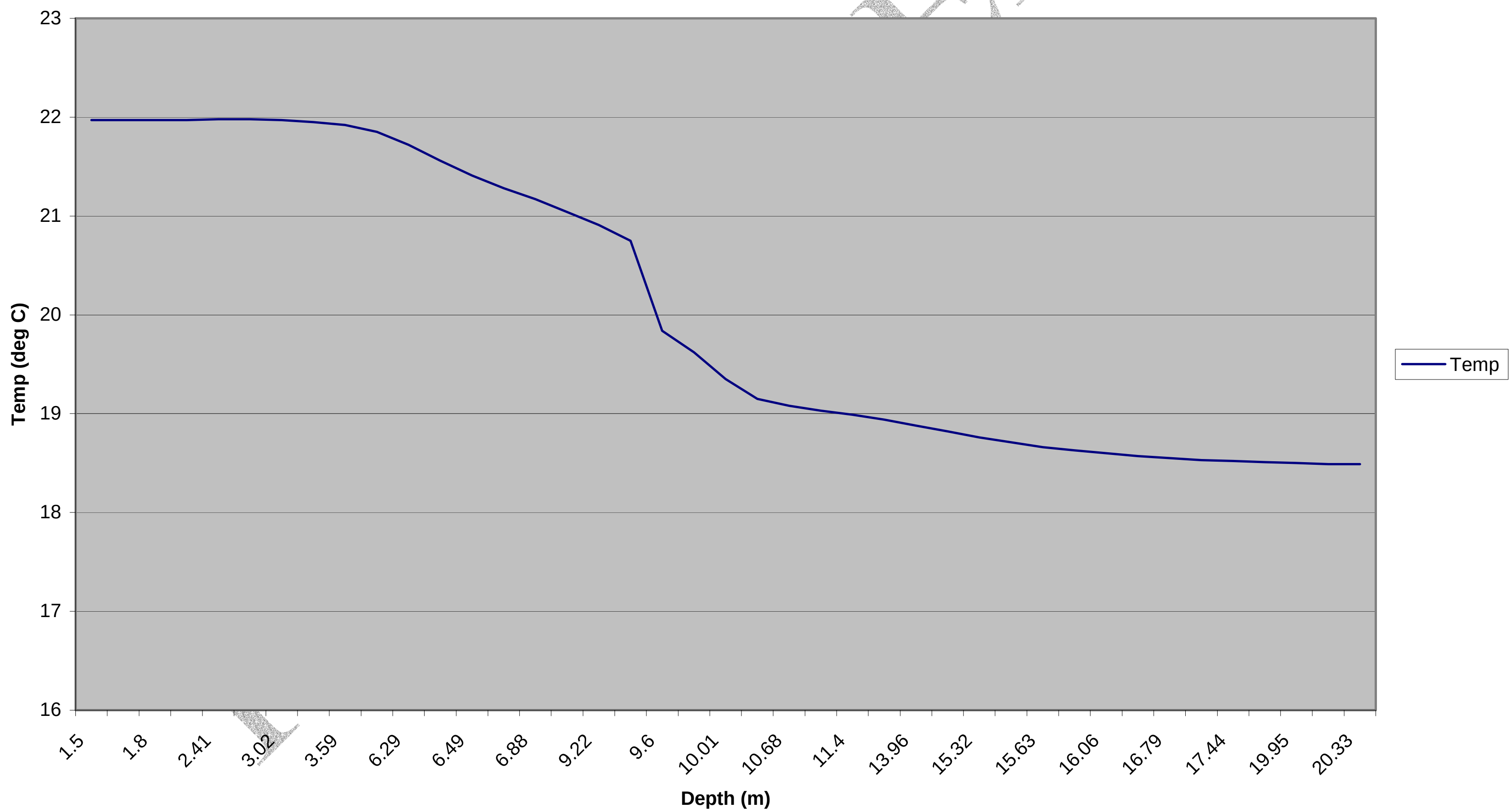


Figure A-18 2G24C Temperature vs Depth

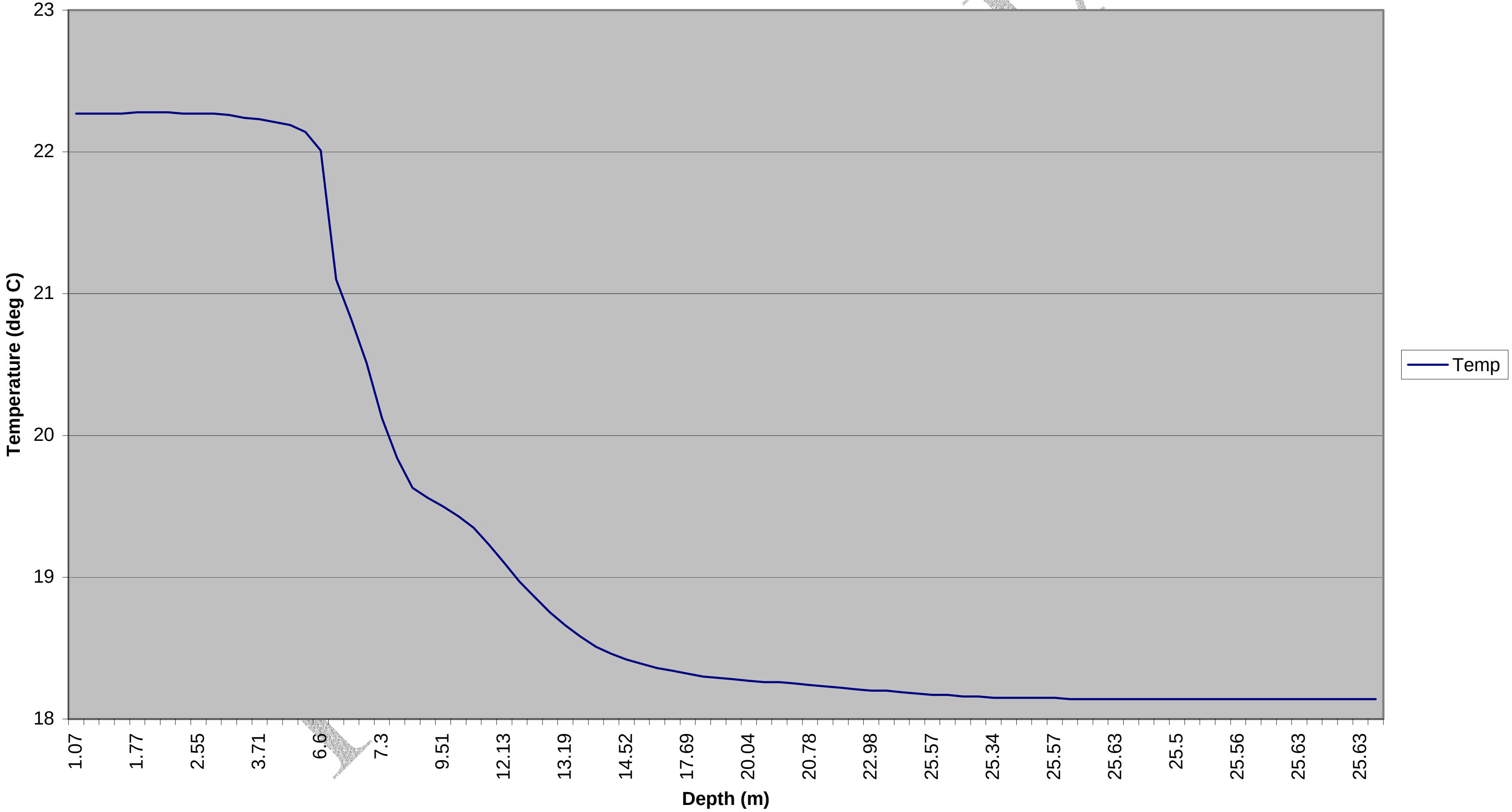


Figure A-19 2G35C Temperature vs Depth

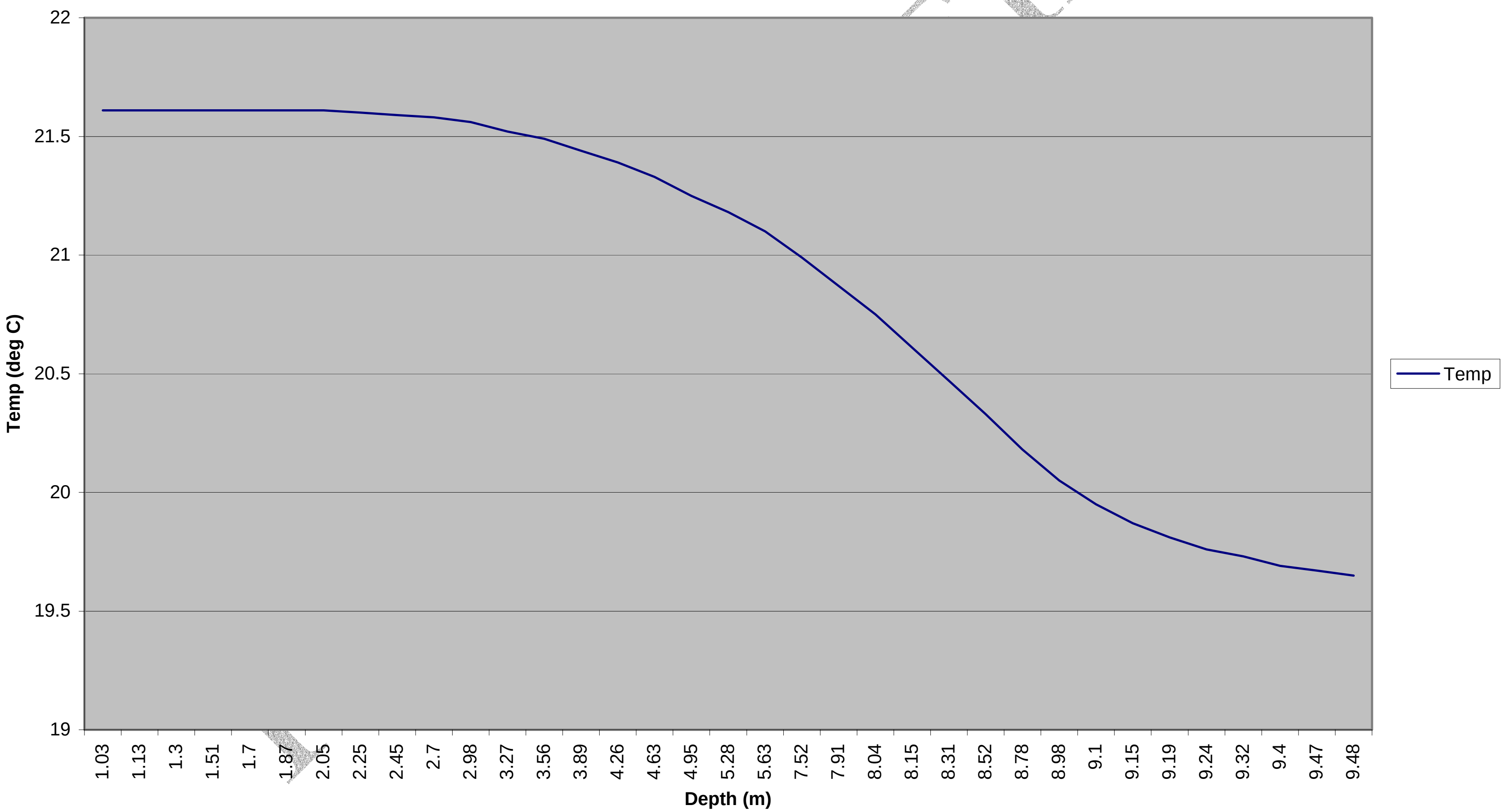


Figure A-20 2ND01C Temperature vs Depth

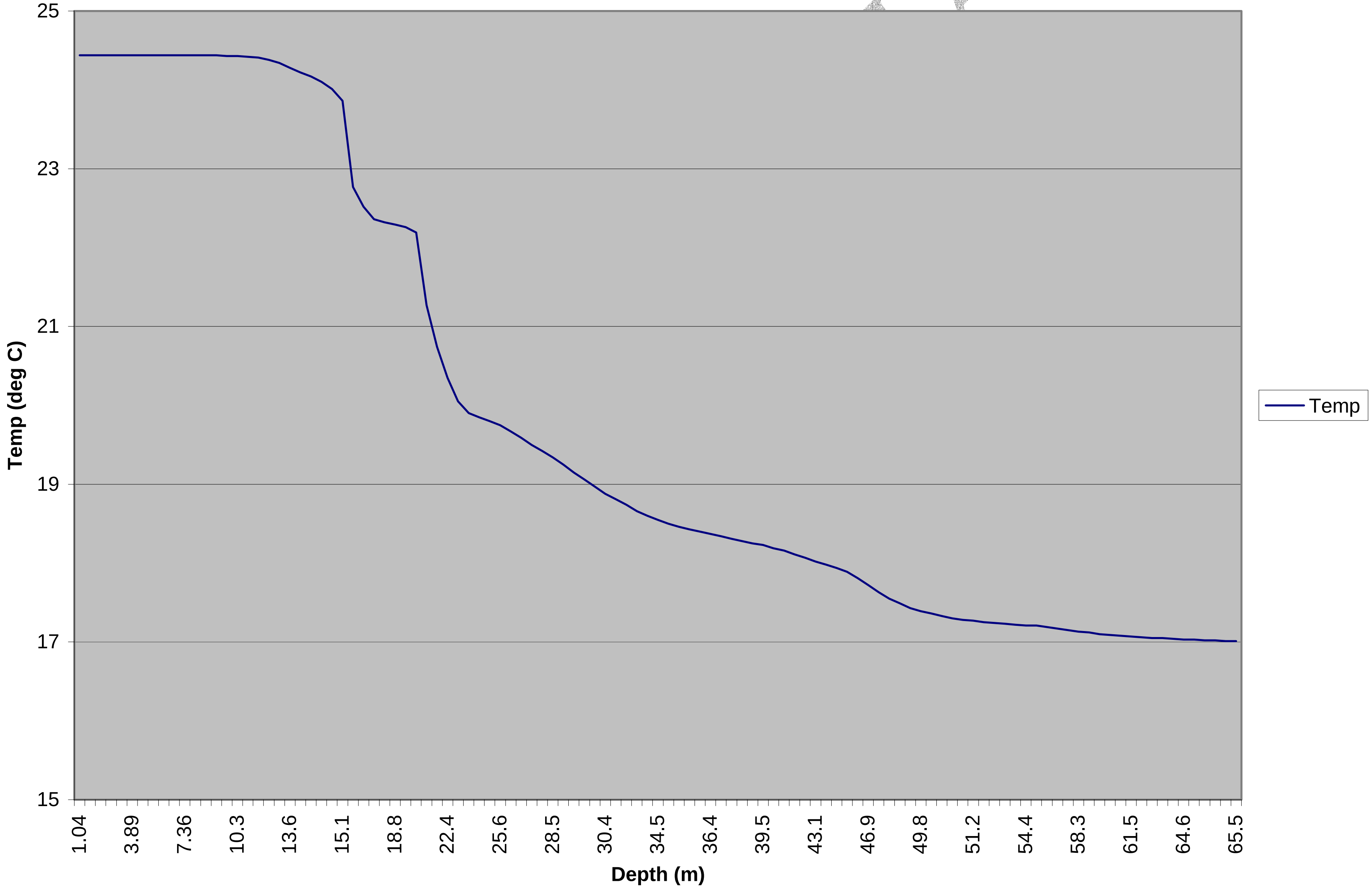


Figure A-21 2ND02C Temperature vs Depth

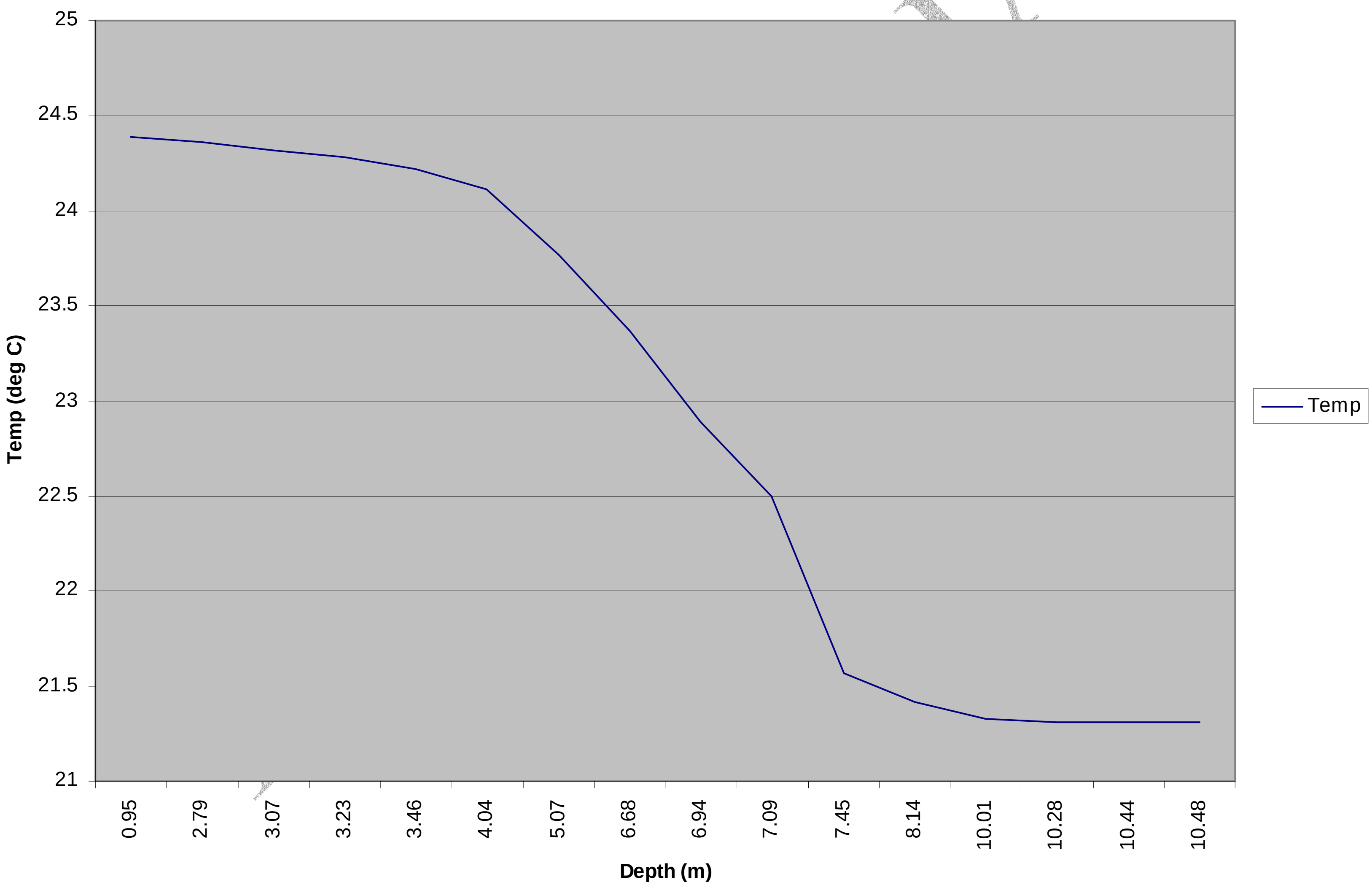


Figure A-22 2ND03C Temperature vs Depth

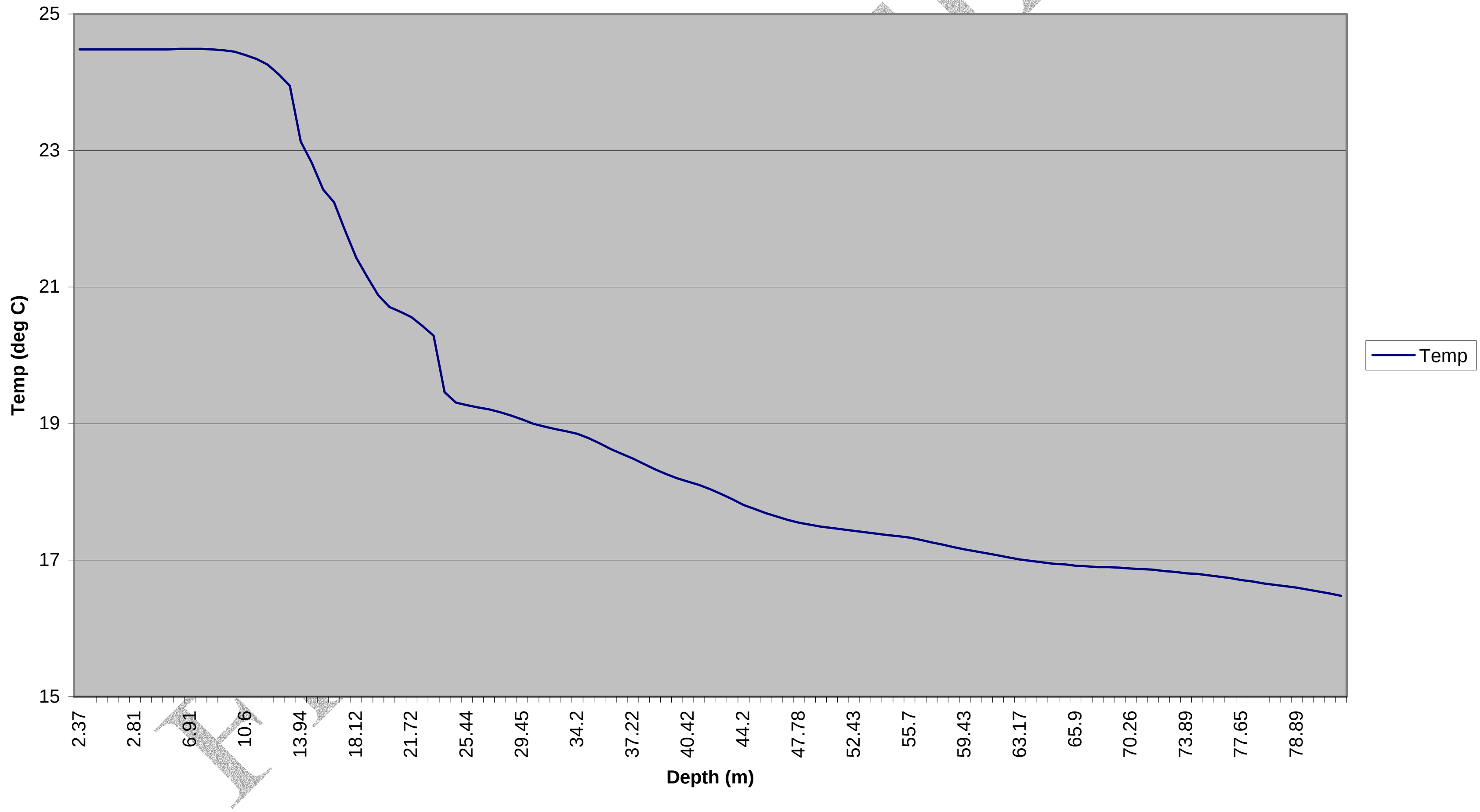


Figure A-23 2ND04C Temperature vs Depth

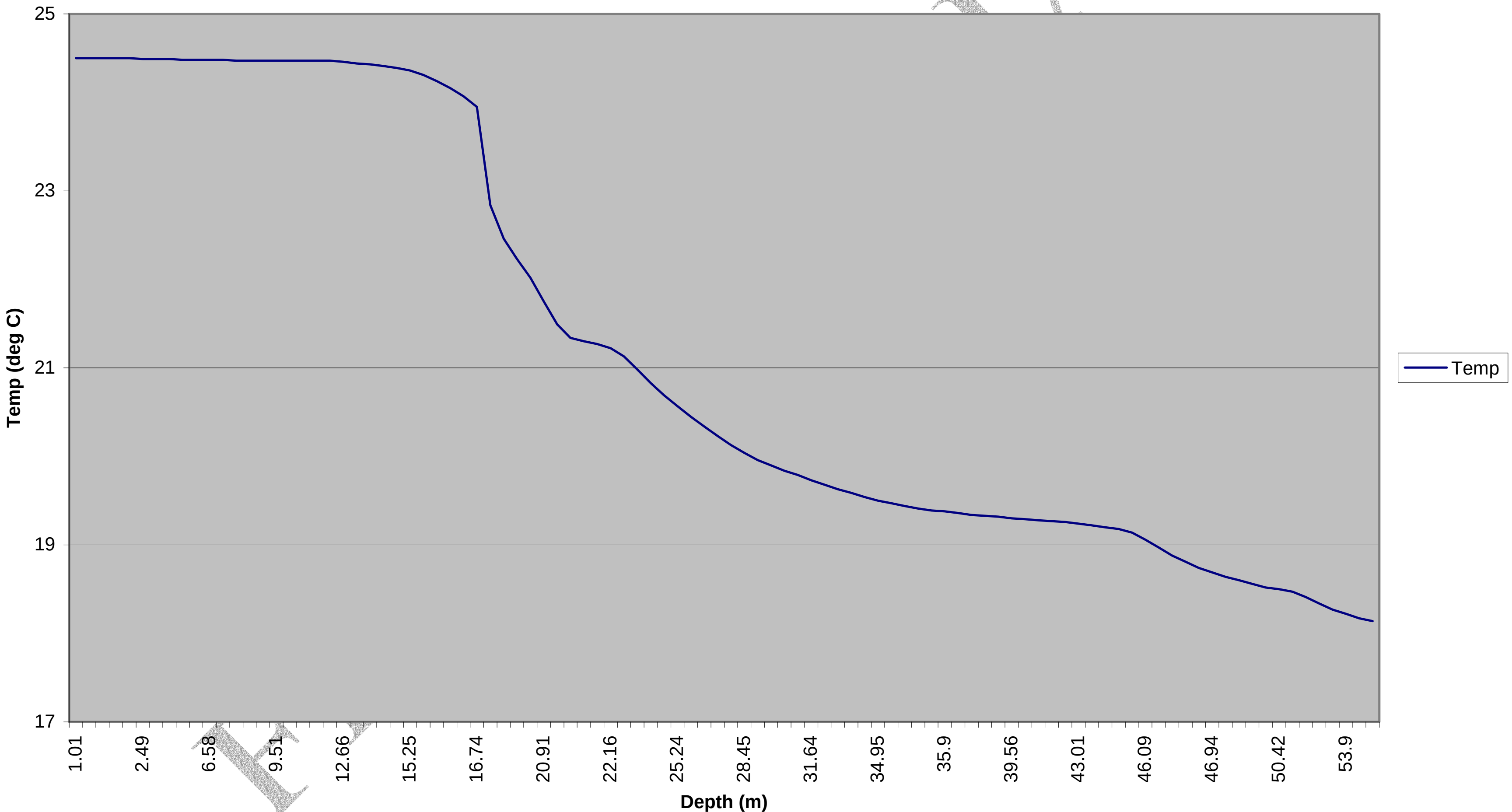
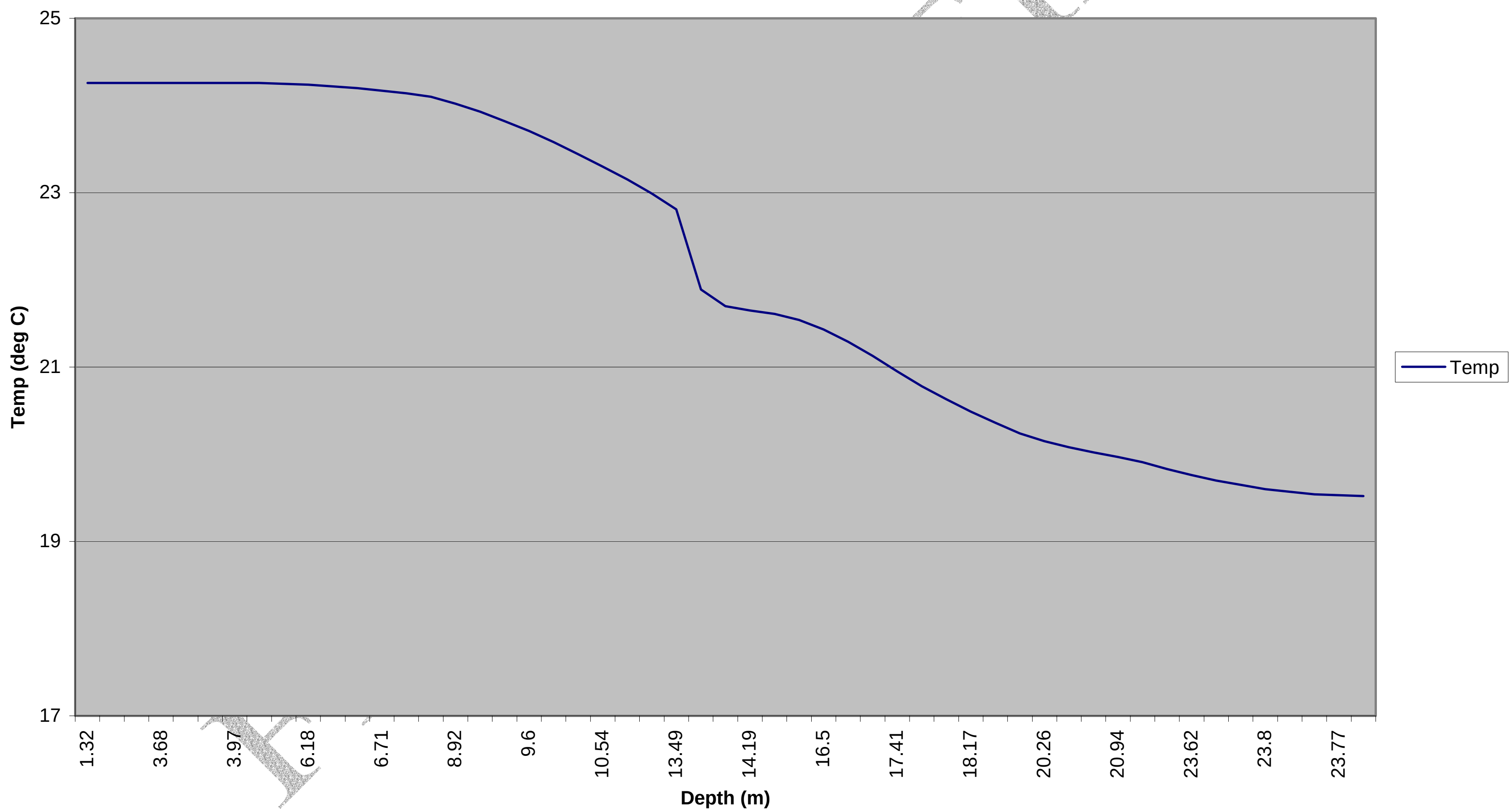


Figure A-24 2ND05C Temperature vs Depth



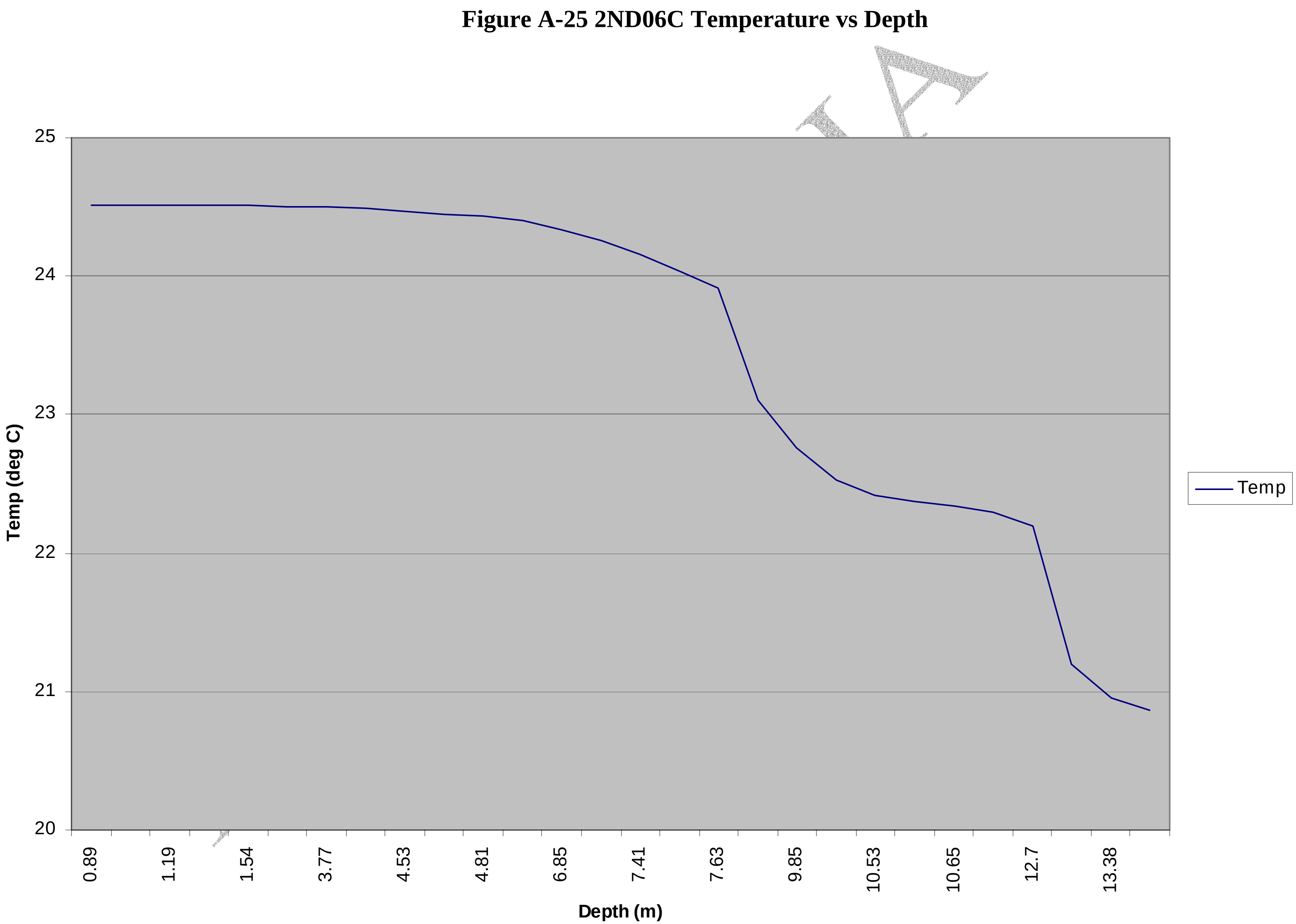


Figure A-25 2ND06C Temperature vs Depth
25
24
23
22
21
20
Temp (deg C)
0.89
1.19
1.54
3.77
4.53
4.81
6.85
7.41
7.63
9.85
10.53
10.65
12.7
13.38
Depth (m)
Temp

Figure A-26 2T01C Temperature vs Depth

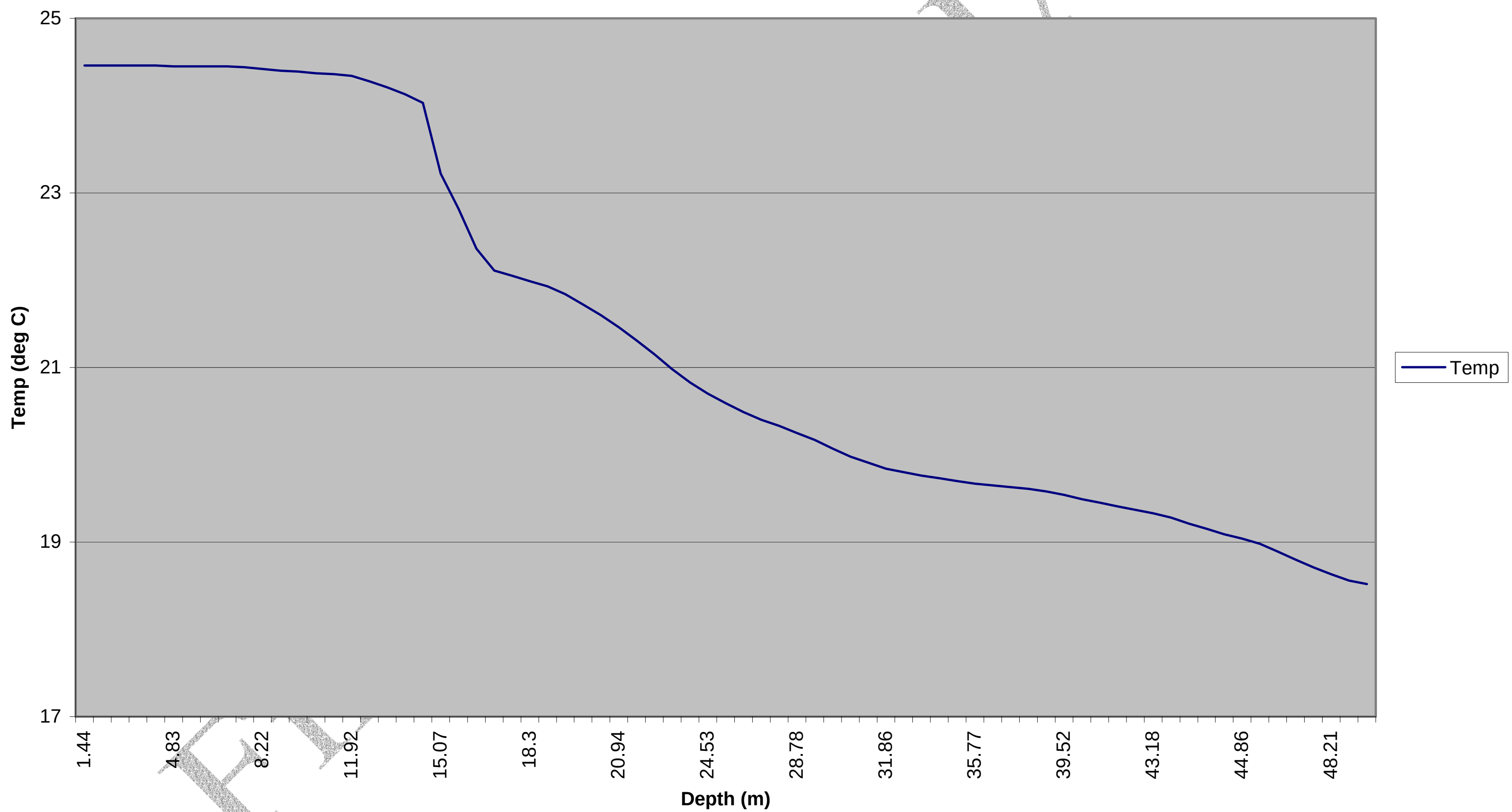


Figure A-27 2T02C Temperature vs Depth

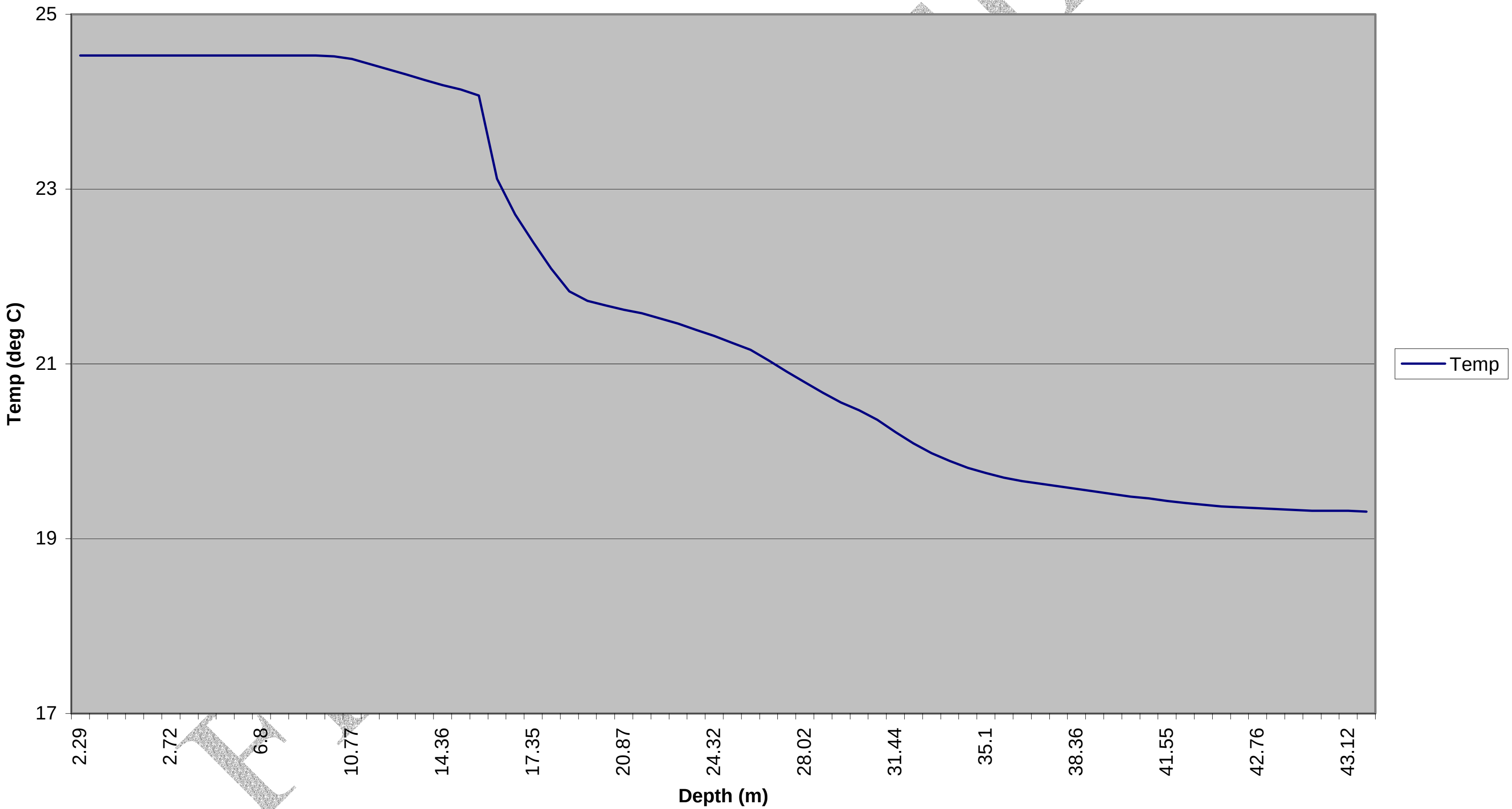
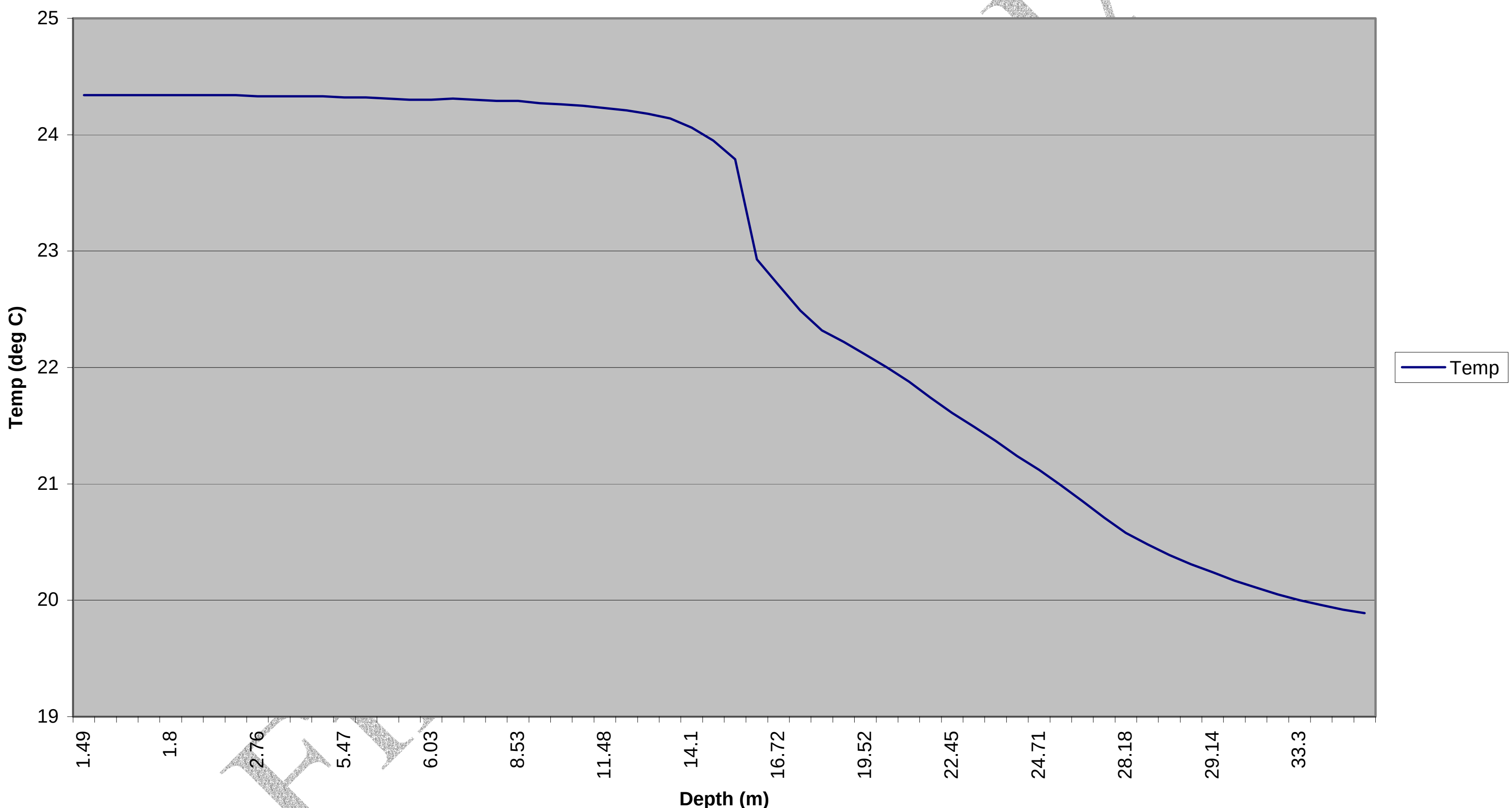


Figure A-28 2T03C Temperature vs Depth



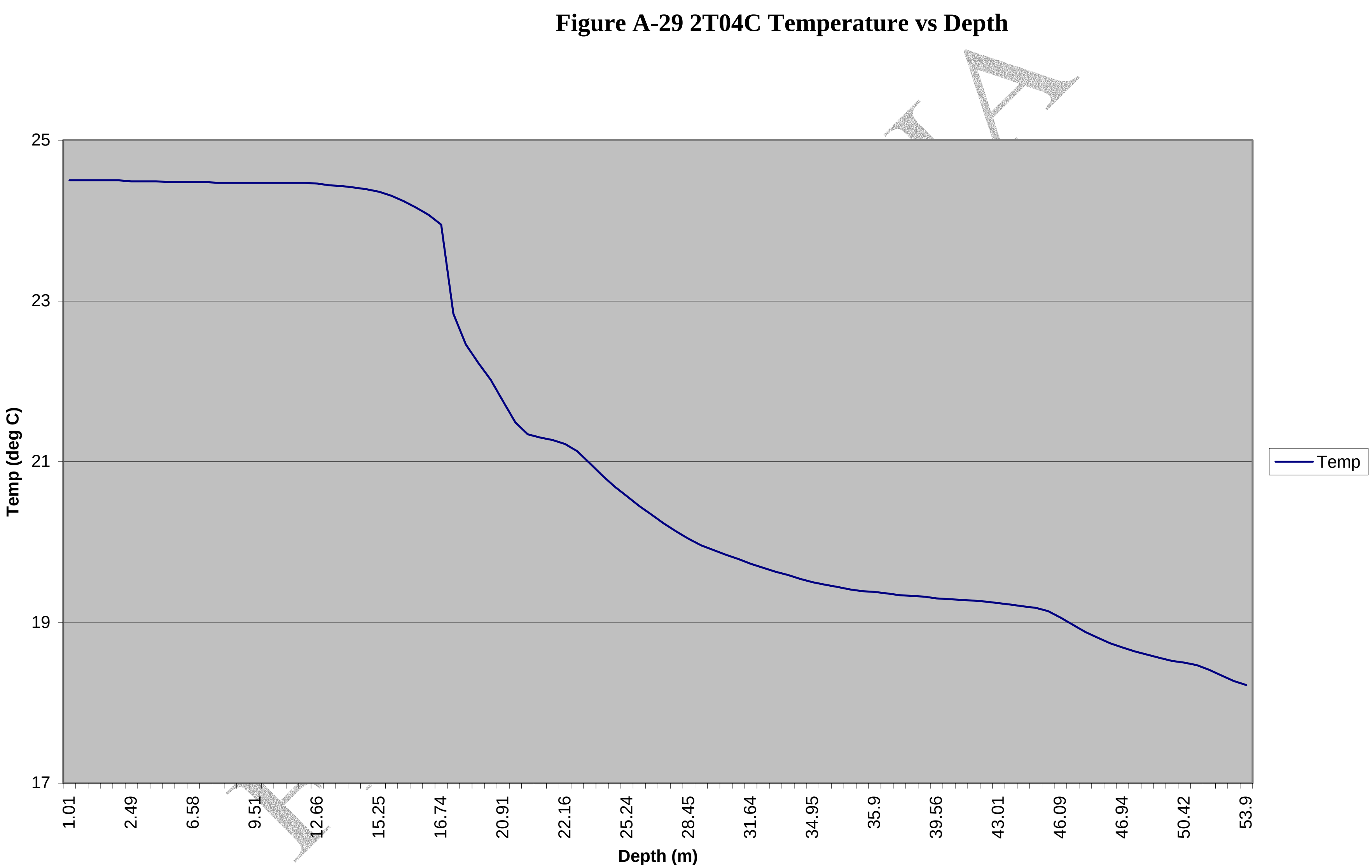


Figure A-29 2T04C Temperature vs Depth
25
23
21
19
17
Temp (deg C)
1.01
2.49
6.58
9.51
12.66
15.25
16.74
20.91
22.16
25.24
28.45
31.64
34.95
35.9
39.56
43.01
46.09
46.94
50.42
53.9
Depth (m)
Temp

Figure A-30 2T05C Temperature vs Depth

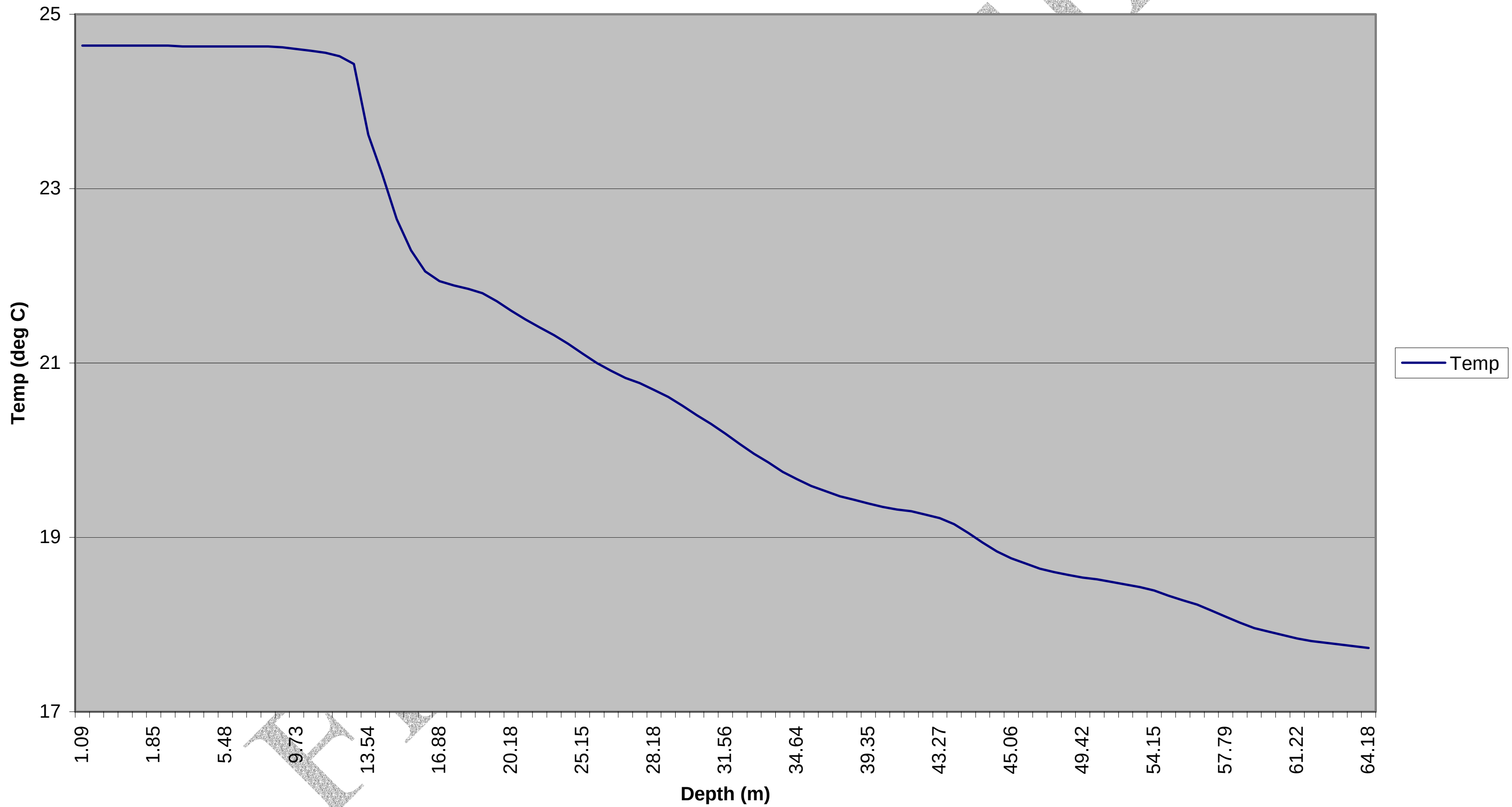


Figure A-31 2T06C Temperature vs Depth

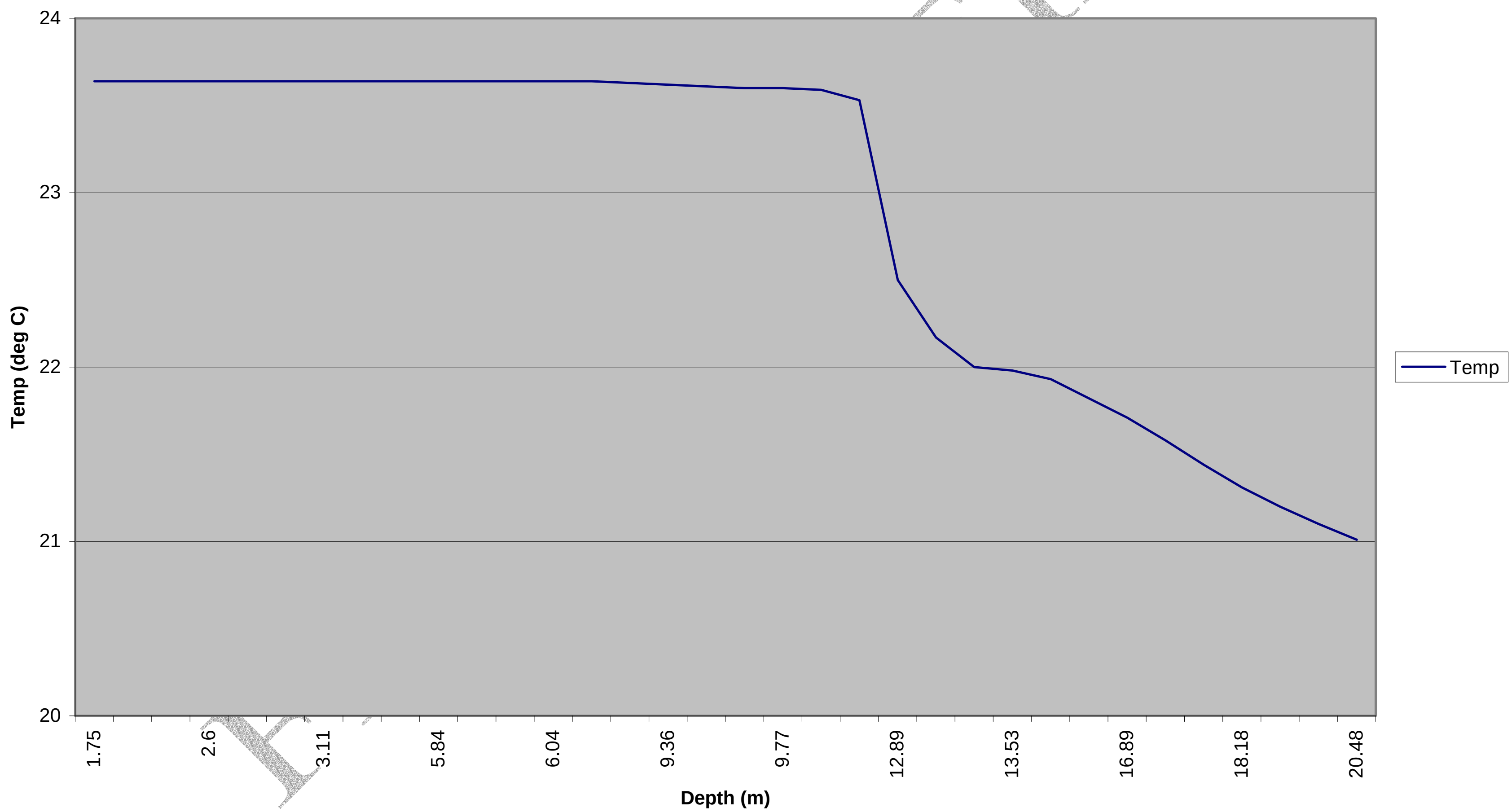


Figure A-32 2T07C Temperature vs Depth

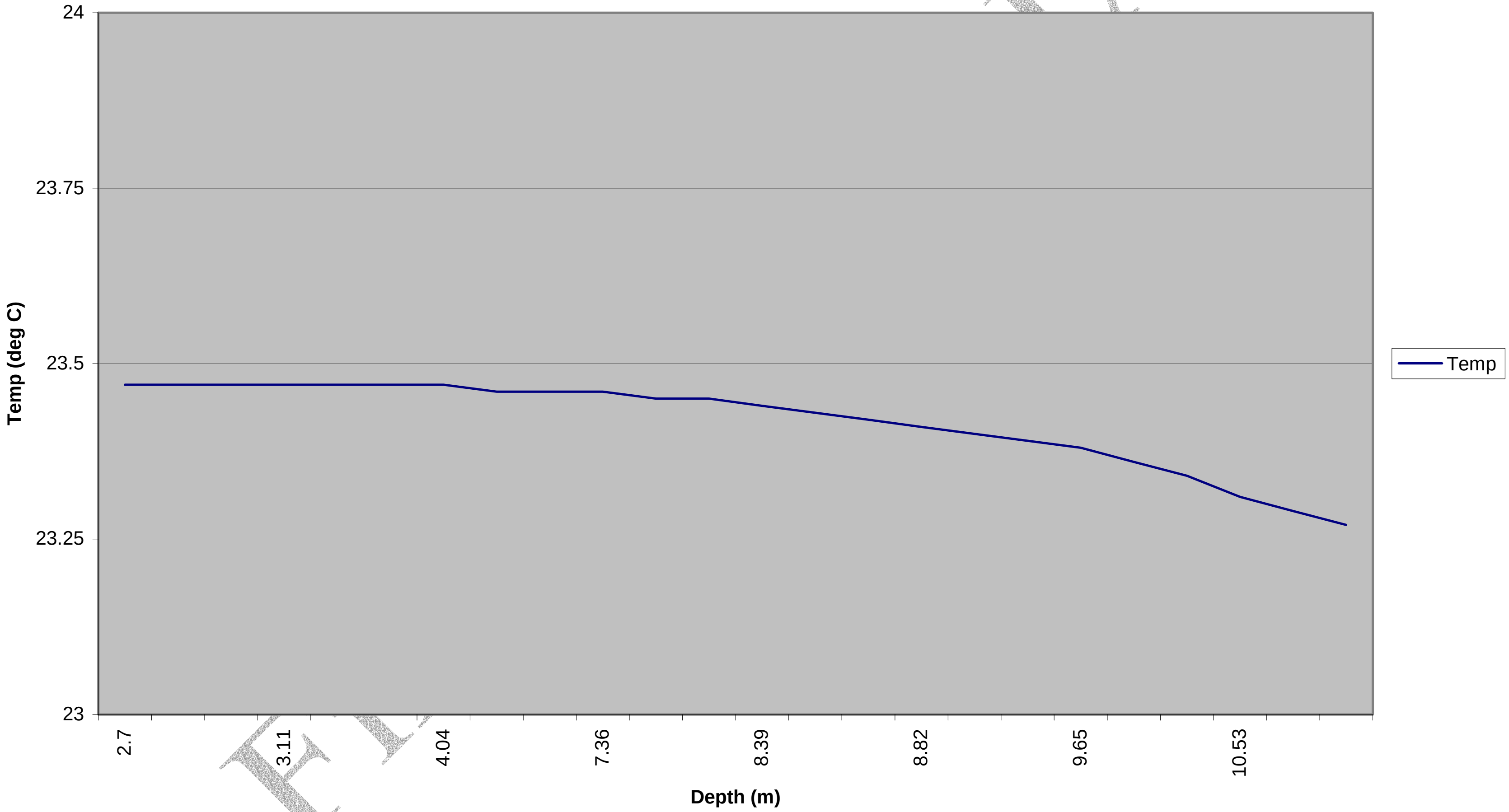
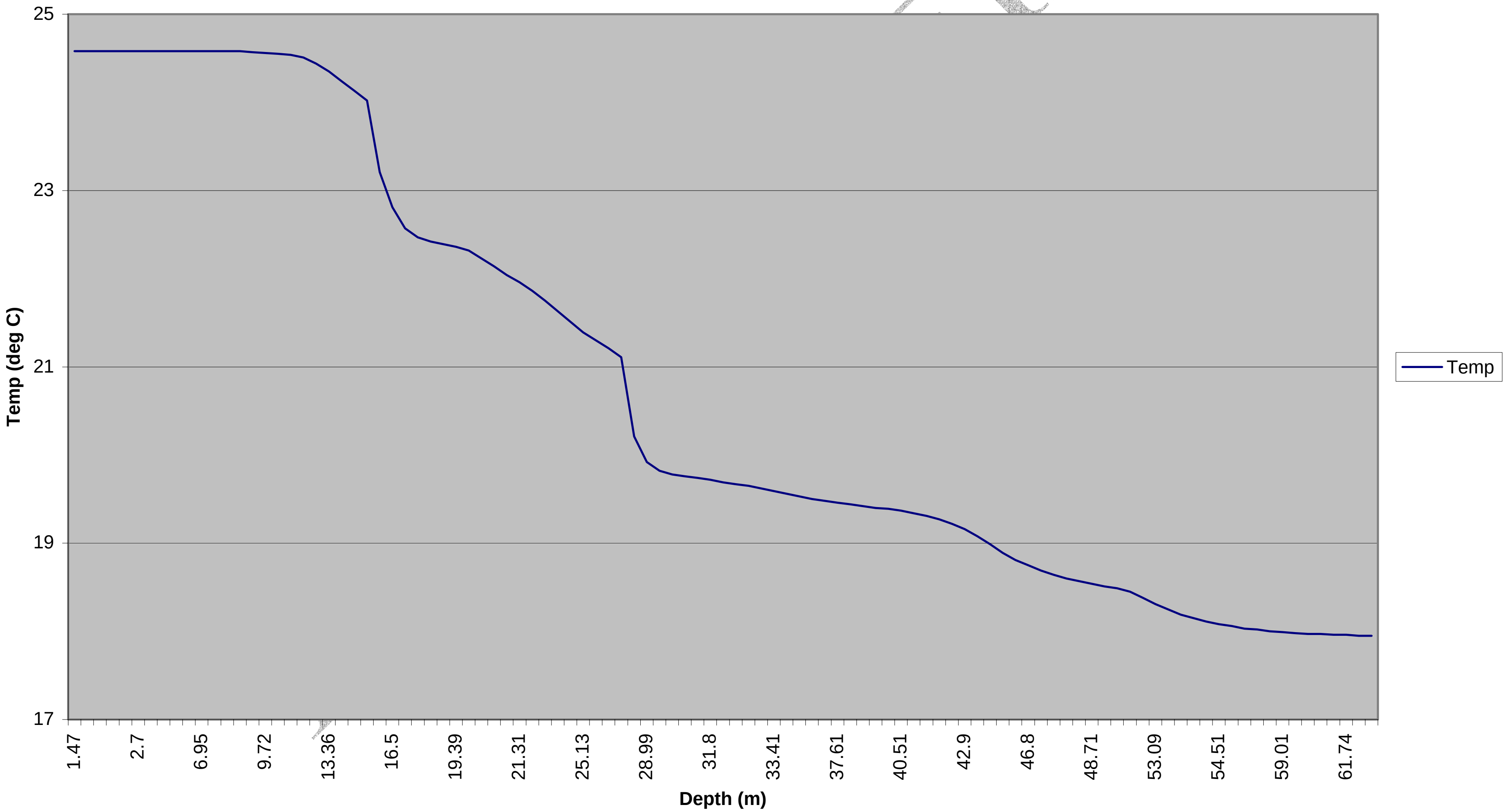


Figure A-332T08C Temperature vs Depth



Cruise Report Second Season (Wet Season) Environmental Baseline Survey of the Offshore Environment Conducted July 15 to August 2, 2003

Prepared for

Client Name Goes Here

ICF Consulting
33 Hayden Ave.
Lexington, MA 02421 USA
(781)676-4000

ICF Reference 000000

powered by perspective

Table of Contents

Page

Kickoff Meeting **1**
Vessel Audit and Departure **1**
Data Collection and Stations Visited **2**
Summary of Data Collected **2**
Water Quality Measurements **3**
Sediment Chemistry **3**
Benthic Fauna **3**
Plankton Tows **4**
Additional Data Collection **4**
Technology Transfer and Training **4**
Health and Safety **5**
Demobilization **5**

Attachment A: Vessel Audit Checklist **A-1**

1.0 Certification and Documentation **A-1**
2.0 Crew Qualification **A-2**
2.1 Officers A-2
2.2 Staff A-2
3.0 Safety **A-3**
4.0 Bridge and Navigation Equipment **A-4**
5.0 Pollution Control **A-5**
6.0 Vessel Integrity **A-5**
7.0 Life Saving **A-6**
8.0 Mooring Equipment **A-7**
9.0 Communications and Electronics **A-7**
10.0 Vessel Machinery/Plants **A-8**
11.0 Back Deck Equipment **A-9**
12.0 General Vessel Condition **A-9**

Kickoff Meeting

On 13 July 2003, a cruise kickoff meeting was held at the WAGP offices in Accra, Ghana to review the objectives of the 2nd season offshore EBS and the best way to achieve these objectives. The meeting reviewed the work plan, procedures for sampling, preserving samples, health and safety issues, and the roles of each person on the cruise. All of the scientists who were to sail with the GeoExplorer attended.

Vessel Audit and Departure

On the morning of 14 July, Coogan and Hogge conducted an inspection of the GeoExplorer, according to the client's checklist for hired vessels. A copy of the completed vessel inspection checklist is included with this report in Attachment A. Upon completion of the inspection, the scientific staff mobilized their scientific equipment on the R/V GeoExplorer.

The GeoExplorer departed Tema, Ghana at 15:30 on 15 July 2002, with a compliment of 16 scientists and a vessel crew of 12. A list of scientific staff is presented below in Table 1.

Table 1: Scientific Crew List

Name	Nationality	Position/Expertise
Henry **Camp**	USA	Chief Scientist
Theodore Havemeyer **Coogan**	USA	Shift Leader
Gavin **Hogge**	USA	Benthos
Cossi Georges Epiphane **Degbe**	Benin	Benthos
Youssouf **Abou**	Benin	Plankton
Emmanuel **Lamptey**	Ghana	Shift Leader
Selorm Dzako **Ababio**	Ghana	Water Chemistry, Benthos
Samuel Nii Kpakpa **Quaatey**	Ghana	Plankton
Emmanuel **Klubi**	Ghana	Benthos
Audrey Kweinorki **Quaye**	Ghana	Benthos
Anthony Oppan **Bentil**	Ghana	Benthos
Kwame Adu **Agyekum**	Ghana	Benthos
Peter Lanre **Olorunda**	Nigeria	Sediment Chemistry
Isah Ibrahim **Attah**	Nigeria	Water Chemistry
Olumide Goriola **Omisore**	Nigeria	Sediment Chemistry
Therese **Edorh**	Togo	Plankton

The scientific staff was divided into 3 shifts:

00:00 – 12:00: Water Chemistry, Sediment Chemistry, Benthos

12:00 – 24:00: Water Chemistry, Sediment Chemistry, Benthos

06:00 – 18:00: Trawls (Plankton, Fisheries)

Data Collection and Stations Visited

Data collection started on 15 July. A total of 50 water chemistry, sediment chemistry, and benthic biology stations and 25 phytoplankton and zooplankton stations were visited.

All stations were positioned identically to the first Season EBS using the ship's navigation systems, with the exception of Nigerian stations ND01C – ND06C, which were positioned according to WAGP's revised pipeline route.

All plankton trawls were conducted during daylight hours, 06:00 to 18:00 in order to follow the methodology used during the first season. Seven trawls were not conducted on the first leg of the EBS cruise, in order to comply with schedule; these plankton trawls were collected along with the fish trawls on the second leg of the EBS cruise.

Table 2: Stations Visited

Date	Stations Visited
7/15/03	2G11C, 2G11 P, 2G10C, 2G10P
7/16/03	2G07P, 2G06P, 2G05P, 2G20C, 2G21C, 2G22C
7/17/03	2G22C, 2G23C, 2G24C, 2G25C, 2G26E, 2G26W, 2G26C, 2G01P, 2G02P, 2G03P, 2G04P, 2G19C, 2G18C
7/18/03	2G17C, 2G16C, 2G15C, 2G14C, 2G08P, 2G13C, 2G12C, 2G08C, 2G08P, 2G09C, 2G07C
7/19/03	2G06C, 2G06S, 2G06N, 2G05C, 2G04C, 2G03C, 2G12P, 2G02C, 2G01C, 2T08C, 2T04C, 2T05C
7/20/03	2T03C, 2T02C, 2T06C, 2T07C, 2T01P, 2T02P, 2T03P, 2T04P, 2T01C, 2B05C, 2B10C, 2B09C, 2B08C
7/21/03	2B07C, 2B04C, 2B03C, 2B05C, 2B06C, 2B02C, 2B02N, 2B04P, 2B01C, ND02C, ND06C, ND05C, ND04C, ND01C, ND03C
7/22/03	ND03C, Dock in Cotonou, Benin

* P - Denotes all Plankton Trawls

Summary of Data Collected

The data were collected according to the work plan submitted by ICF. All data were recorded on data sheets produced and printed by ICF for field use. Station logs had placeholders for sea-state information, meteorological information, station name, collections performed, and collection times. Shift logs were completed by the shift leader, and provided a daily record of the stations performed on each shift.

Duplicate samples were taken at 10 percent of the stations, chosen at random using a random number generator. Equipment blanks were taken at several stations to check the calibration of the equipment. At two stations in Ghana additional samples were collected per the request of the Ghanaian regulators.

Water Quality Measurements

Water quality was measured and collected through two methods. The first was water collection at two depths (surface and bottom) using 5-Liter Niskin bottles. A total of 100 (50 from each depth) Niskin bottle samples were collected.

Water Analyses from Niskin Bottles:

Water samples were collected with Teflon lined 5-l Niskin samplers at two depths--near the water surface (< 1m) and at 1m above the bottom and composited for further shipboard chemical analyses. Samples shall be transferred into clean plastic containers for shipboard analysis and for transfer to the laboratory and refrigerated and preserved appropriately.

CTD:

The CTD was allowed to calibrate near the surface of the water for several minutes and then deployed to within 1 meter from the sea floor. The CTD probe successfully collected temperature, conductivity, redox, pH, dissolved oxygen, turbidity, depth, and chlorophyll α. All the data from the 50 stations for which the YSI 6600 Sonde was deployed was successfully downloaded to the hand-held YSI computer, and from this apparatus to a laptop.

Sediment Chemistry

A 30 cm x 30 cm x 60 cm box core was used to obtain benthic sediment samples for chemistry analysis at each of the 50 stations. The top 2 cm of sediment was removed from the box core using a 2-cm deep Kynar-coated scoop and placed into the following jars:

250 mL glass jar (x2): archive Ziploc bag (x2): grain size analysis

All samples were preserved according to the procedures described in the workplan. In addition, the top layer of sediment collected was analyzed on-board the vessel for Redox, pH, temperature, and conductivity.

Benthic Fauna

Benthic samples were collected using a 30 cm x 30 cm x 60 cm box core. If the box core penetrated into the surface more than 30 cm, then the top 30 cm of the box core was scooped out of the top by use of small hand shovels. If the sample was less than 30 cm deep, then the entire sample was collected. The sediment was then sieved though 500 µm sieves to collect benthic macrofauna. The material collected from the sieve was stored in plastic jars and fixed with 10% buffered formalin. The samples were then transported to a lab in Ghana for sorting, counting and identification for the final report. Benthic samples were collected at the side stations where it was determined from the first season sediment profile imaging (SPI) results, to have high species diversity.

Plankton Tows

Plankton samples were collected at 25 stations distributed along the main pipeline and the laterals. At each plankton station, three different nets and methods were utilized to collect plankton samples. Each net was fitted with a flow meter to measure the amount of water that passed through the mouth of the net to allow for the calculation of volume. At each station the Niskin bottle was used to collect water samples. Three 1.5 L plastic bottles were filled with water collected from 5 m depth and used in a primary productivity study. The clarity of the water was determined by the use of a Secchi disk; the disappearance and reappearance depth of the disk was recorded to determine visibility. Watercolor was determined using a sea color chart, a set of known standard vials that aid in determining the color of the water.

The plankton samples were fixed with Lugol's solution and stored in 250 mL plastic jars. Phytoplankton was collected using a 64 µm Nansen (30cm diameter) net towed at the surface for 5 minutes at 1.5 knots. Zooplankton was collected using two nets and two methods. The step oblique method used a 300 µm Nansen nets (30cm diameter) and the number of steps varied with depth; each tow was 18 minutes long, but the time at each depth varied with the depth. Tow speed was 1.5 knots. Vertical tows were executed using a 200 µm Nansen nets (30 cm diameter) from the bottom to the surface. Knowing the diameter of the nets, the speed of the boat, and the readings of the flow meter, the volume of the water, which passed through the nets can be calculated to help standardize the results.

Additional Data Collection

All sampling locations and the cruise track were recorded on-board using WinFrog™ navigation and positioning software. All navigation and position data will be imported into the project database and GIS before submission to WAGP. Additional data collected during the cruise included meteorological and sea-state conditions.

Technology Transfer and Training

During the offshore survey ICF provided both on-going technology transfer and training for the in-country nationals. On-going technology transfer and training included: decontamination procedures for scientific sampling equipment, deployment and retrieval of the box core; determination of "acceptable or good" benthic sample vs. "poor sample"; sampling of sediments for chemistry; deployment and retrieval of Niskin bottles; deployment, operation and downloading of YSI sonde.

Health and Safety

The Health and Safety Officer and the Mate of the GeoExplorer held health and safety briefings prior to departure. Also periodic H&S briefings were held during the entire duration of the cruise when an issue came to light. Only minor H&S incidents were reported: headaches, seasickness, and jellyfish stings. No major incidents occurred.

Demobilization

The GeoExplorer arrived at the dock in Cotonou, Benin on 22 July at 14:30. Immigration and Customs formalities were completed by 17:00 and equipment, samples, and personal gear, were offloaded. The next group of scientists, whom were part of the fishing leg, boarded the boat. The boat embarked on the fishing leg around 12:00 on 23 July.

Attachment A: Vessel Audit Checklist

Vessel:

Audited by: Date:

1.0 Certification and Documentation

Certification	Yes/No	Comment
Registration of Navigation	Yes	Expires 31 January 2004
International Load Line	Yes	IMO # 8107921
Ship Radio Station License	Yes	Call Sign: NDA6456 (Exp 2011)
International Oil Pollution	Yes	#642135 Exp 07 January 2004
Fire Inspection	Yes	Inspected 20 November 2003
Ships Safety Equipment	Yes	
Lifting Equipment	Yes	#95595
Designation as R/V	Yes	#642135

Documentation	Yes/No	Comment
Operators Procedures		
SOLAS 1974	Yes	
MARPOL 1973/78	Yes	
IMO Ships Routing	Yes	#8107921
COLREGS		
Standards of Training, Certification and Watchkeeping for Seafarers, 1978 amended 1995	Yes	
Search and Rescue Manual	No	
Oil Record Books	Yes	
Waste Log/Waste Receipts	Yes	
Ship's Documents	Yes	

2.0 Crew Qualification

2.1 Officers

Qualification	Master	Mate	Chief Engineer	Engineer
Nationality	US	US	US	Ghana
Certificate Held	500MT	600MT		
Issuing Country	US	US	US	
Years of Experience	12	20	20+	5
Proficient in English	Yes	Yes	Yes	Yes
Drug Test	Yes	Yes	Yes	Yes
HSE Training	Yes	Yes	Yes	Yes
Fire Fighting	Yes	Yes	Yes	Yes
Training Record	Yes – In vessel logs	Yes – In vessel logs	Yes – In vessel logs	Yes – In vessel logs
Safety at Sea	Yes	Yes	Yes	Yes

2.2 Staff

Qualification	Deckhand	Navigator	Bosun	Cook	Messman
HSE Training	Yes	Yes	Yes	Yes	Yes
Safety at Sea	Yes	Yes	Yes	Yes	Yes
Certificates					
Drug Test	Yes	Yes	Yes	Yes	Yes
Proficient in English	Yes	Yes	Yes	Yes	Yes
Training Record	Yes – In vessel logs	Yes – In vessel logs	Yes – In vessel logs	Yes – In vessel logs	Yes – In vessel logs
Experience					

3.0 Safety

Procedure/Information	Documentation (yes/no)	Comment
Ship Orientation/Safety Checklist	Yes	
HSE Manual	Yes	
MSDS Sheets	Yes	
Chemical Inventory	Yes	
Emergency Response Plan	Yes	
Incident Reports	Yes	
Daily Tool Box Meetings	Yes	
Job Safety Analysis	Yes	
TDI-HSE Policy Statement Posted	Yes	
Emergency Procedures	Yes	
Risk Assessment	No	
Confined Space Entry Procedure	Yes	
Hot Work Permit	No	
Station Bill	Yes	
Fire Information	Yes	
Lifting Guidelines	Yes	
Emergency Exit Guide	Yes	Vessel plans posted on each deck, lighted exit signs
Safe Vessel Entry		

Supplies/Equipment	Yes/No	Comments
Eye Wash Stations	Yes	
Hard Hats (expiration date)	Yes	
Work Gloves	Yes	
Laboratory Gloves	Yes	
Protective Clothing	Yes	
Protective Eyewear	Yes	
Closed-toe Footwear	Yes	
Work Vests	Yes	
Safety Harness	Yes	
Hearing Protection	Yes	

4.0 Bridge and Navigation Equipment

Equipment/Procedures	Yes/No/Good Working Order	Date
Bridge Manuals	Yes	
Navigation Procedures	Yes	
Deck Log Book Maintained	Yes	
Written Procedure for Entry into 500 Meter Zone	No	
Standing Order/Master Night Order Book	Yes	
Magnetic Compass	Yes	
Gyro Compass/Repeaters	Yes	
Radar	Yes	
Radar Plotting Equipment	Yes	
Echo Sounders	Yes	
Speed and Distance Indicators	Yes	
Rudder angle, RPM, variable pitch and bow thruster indicators	Yes	
Radio Direction Finder (RDF)	No	
R/T or GMDSS equipment	Yes	
Signal Lamps	Yes	
VHF Radio	Yes	
Navtex	Yes	
Current Navigation Charts, Publications	Yes	Missing detailed charts of Cotonou harbor
Navigation Warnings and Weather Forecasts Available	Yes	

5.0 Pollution Control

Control	Yes/No	Comment
Environmental Management Plan	Yes	
MARPOL Policy Posted	Yes	
Hazardous Waste Plan	Yes	
Garbage Plan	Yes	
Grey Water Policy	Yes	Sewage plant experienced breakdowns
SOPEP	Yes	
Oil Spill Clean Up Materials	Yes	
Any Vessel hydrocarbon Leaks (oil, hydraulic fluid, diesel)	None Noted	
Spill Containment Devices to prevent oil from Entering Water	Yes	
Oil/Water Separator	Yes	15 ppm; 2 slop tank @ 1000gal each
Oil Spill Response	Yes	

6.0 Vessel Integrity

Test/Certification	Yes/No	Comment
Survey Report File	Yes	On load-line report
Vessel Stability Report	Yes	

7.0 Life Saving

Equipment	Yes/No	Comment
Training/Maintenance Manuals	No	
MOB in good order	Yes	Drills monthly
Life Rafts Certified	Yes	4 rafts
EPIRB with Good Batteries	Yes	
Life Bouys, bouy light etc. in good order	Yes	
Adequate Life Jackets (200%) in breathing areas as well as muster area	Yes	
Safety Equipment on :Life Jackets (lights)	Yes	
Stretcher	Yes	
First Aid Supplies	Yes	
First Aid/CPR Training	Yes	
Fire Fighting Equipment in Good Order	Yes	
Inspection Records/ Inventory Lists up to Date	Yes	
Fire Mains, Pumps, Hoses and Nozzles in good order	Yes	
Operating Instructions Posted		
Portable Fire Extinguishers in good order	Yes	
Engine Room Fire Equipment	Yes	
Maintenance Log of Fire Fighting Equipment	Yes	
Fixed Fire Detection and Alarm System in Good Working Order	Yes	
Smoke Detectors in Good Working Order	Yes	

8.0 Mooring Equipment

Equipment	Yes/No	Comment
Mooring Lines good repair/proper position		
Anchors, cables and securing Equipment in Good condition		

9.0 Communications and Electronics

Equipment/Procedure	Yes/No	Comment
Inmarsat	**Yes**	
Mini M	**Yes**	
Others (list)		
Iridium	Yes	
SSB	Yes	
Lists of Radio Signals	Yes	
Operating Instructions for Emergency Transmitter Displayed	Yes	
Emergency Lifeboat Transmitter	Yes	
Emergency Batteries	Yes	
GMDSS	Yes	
Radio Logs	No	
GMOSS Log	Yes	

10.0 Vessel Machinery/Plants

Equipment/Procedure	Yes/No	Comment
Propulsion/Steering Equipment in Good Order	Yes	Operating on 2 of 3 main engines, do not use bow thruster
HVAC System in Good Working Order	**Yes**	
Sanitary/Domestic Waste System in Good Working Order	Yes	
Fluid Transfer and Storage Systems leak-free (hydraulic oil, water, fuel oil and etc).	Yes	
Recommended Maintenance Programs followed	Yes	
Engine Log Book	Yes	
Bilge System in Good Working Order	Yes	
Emergency Electrical Power in Good Working Order	Yes	
Engine/Machinery Alarms	Yes	
Safe Machinery Space Practices	Yes	
Eye Protection	Yes	
Guards	Yes	
Emergency Escape Routes	Yes	
Engine Room Emergency Shut Off	Yes	
Engineer's Alarm	Yes	
Gauge glass closing Devices on Oil Tanks Self-closing	No	
Chief Engineer's Standing Orders Posted	No	
Watertight Doors in Good Working Order	Yes	
Steering/Gear Compartment in Good Working Order	Yes	
Machinery Spaces Clean and Free from Leaks		**Vessel is greasy and oily in machinery and working spaces**
Safe and Efficient Handling of Ballast	Yes	
Transfer System for Ballast and Cargo in Good Working Order	Yes	

11.0 Back Deck Equipment

Equipment	Yes/No	Comments
Crane Safe Working Loads Marked	**Yes**	
Crane Controls Labeled	**Yes**	
Certificates for all Rigging and Lifting Equipment	Yes	
Certified Lifting Equipment Marked	Yes	

12.0 General Vessel Condition

Item	Yes/No	Comment
Hull	**Yes**	
Hull Markings	Yes	
Weather Decks	Yes	
Deck Openings in Good Condition	Yes	
Vents, Air Pipes on Freeboard Deck in Good Condition, Filled with Closing Devices	Yes	
General Condition of Superstructure	Yes	
Accommodations Clean	Yes	
Food Storerooms, handling, refrigerated spaces, galleys, mess rooms and pantries Clean	Yes	
Railings and Stairs in Good Condition	Yes	

Cruise Report
Second Season Fish Trawl Survey
Component of the
Environmental Baseline Survey (EBS)

Conducted by R/V Geoexplorer
from 22ND July to 1ST August 2003

Prepared by:

Environmental Solutions (ESL), LTD
Accra, Ghana

Table of Contents

Page

1.0 Introduction **1**

2.0 Objective of Survey **1**

3.0 Survey Design **2**

4.0 Vessel Audit, Equipment Mobilization and Departure **2**

5.0 Survey Protocol **4**

5.1 Fish Trawl Survey 4
5.2 Plankton Survey 5

6.0 Data Collection at Fish Trawl Stations **6**

6.1 Data Collection off Benin 6
6.2 Data Collection off Nigeria 6
6.3 Data Collection off Togo 7
6.4 Data collection off Ghana 8

7.0 Plankton Data **9**

8.0 Completion of Survey **11**

9.0 Demobilization **11**

10.0 Departure of Scientists **12**

11.0 Conclusion **12**

List of Tables

Table 1: Trawl Stations in Each Country 2
Table 2: Crew List for Scientific Staff 3
Table 3: Summary of Trawl Information and Data on Stations off Benin 6
Table 4: Summary of Trawl Information and Data on Stations off Nigeria 7
Table 5: Summary of Trawl Information and Data on Stations off Togo 7
Table 6: Summary of Trawl Information and Data on Stations off Ghana 8
Table 7: A Summary of Plankton Data 10

1.0 Introduction

The West African Gas Pipeline Consortium (WAGP) proposes to construct, operate and maintain an onshore and offshore natural gas transmission pipeline from Nigeria through Benin and Togo to Ghana. The proposed pipeline is 617km long with delivery laterals from the main pipeline that will extend into Cotonou (Benin) Lome (Togo), Tema and Takoradi (Ghana). The offshore pipeline installation is anticipated to be in 30-100m of water depths at an approximate distance of 15km from shore. The gas delivery points are anticipated to extend onshore only to the degree necessary to install Regulations and Metering stations (about 1-2km).

In compliance with the legislative and regulatory provisions of the affected countries, the proposed project will be subjected to an Environmental Impact Assessment (EIA). The proposed EIA by WAGP include, among others, a comprehensive Environmental Baseline Survey (EBS) for the offshore portion of the gas pipeline. The main aim of EBS is to describe the current state of the offshore environmental based on literature review and field data collection. It is in fulfillment of the aim of the EBS that a first season (dry season) and second season (wet season) Fish Trawl Surveys were planned and executed between 3rd and 14th March 2003 and 22nd July and 1st August 2003 respectively using the research vessel, R/V GeoExplorer. The purpose of conducting the survey during two different seasons is to assess any significant seasonal changes in the data collected. This reports highlights the activities of the second season (wet season) fish trawl survey. It also covers some aspects of the second season plankton survey that was conducted during survey period.

2.0 Objective of Survey

The overall objective of the survey is to obtain data on the abundance, biomass, diversity and disease prevalence of demersal fish and incidental invertebrate assemblages. This information is useful in characterizing the extent and impact of the project on demersal fish and invertebrate populations in relation to natural conditions. The specific objectives of the second season survey are as follows:

- Fill gaps of the first season survey
- Document wet season conditions
- Further explore results of the first season
- Offer on the job training to scientists

3.0 Survey Design

The survey area and location of the trawl stations are shown in figure 1. There are twenty-six (26) predetermined trawl stations located along the entire lateral and main pipelines. Trawl depths have been chosen to collect representative samples of fish assemblage. Three (3) stations are located on the each of the five (5) lateral lines and the depth distributions of the stations on each lateral line are one each at 10-20m, 31-40m and 50-60m depth contours. In addition there are eleven stations along the main line located at approximately 50km intervals. A scallop bed was identified off station T26 in Ghanaian waters during the first season survey. In order to delineate this habitat, four (4) additional fish trawls at 1km radius from the station, in angular displacements of 90 degrees were to be conducted. The break down of the stations by country is presented in Table 1.

Table 1: Trawl Stations in Each Country

Country	Nigeria	Benin	Togo	Ghana	Additional Trawls in Ghana
Length of Coastline (km)	30	120	50	330	
Number of Trawl Stations	4	5	4	13	4

4.0 Vessel Audit, Equipment Mobilization and Departure

The vessel, R/V GeoExplorer berthed at Tema Port in Ghana on 14th July 2003. The Chief Scientist, Samuel Quaatey conducted an audit of the vessel in the afternoon of that day. Mobilization of equipment from the ESL store to the vessel was done in the morning of 15th July 2003 under the supervision of the Chief Scientist and Emmanuel Lamptey. The Chief scientist, Messrs Selorm Ababio, Anthony Bentil, Kwame Agyekum and Ms. Audrey Quaye boarded the vessel on 15th July 2003 at Tema Port. They were part of the scientific crew for the first leg of the second EBS. The vessel berthed at Cotonou Port in Benin on 22nd July 2003 at end of the first leg of the second EBS. The rest of the scientific crew for the fish trawl survey boarded the vessel on that same day.

A pre-survey meeting was held in the morning of 23rd July 2003 on board the vessel for the scientific crew. The Chief Scientist explained the objectives of the survey, the schedule of work and the protocol for data collection and documentation and preservation of specimen to the scientific crew during the meeting. Scientists were also informed of outstanding data on plankton and productivity to be collected at seven stations off Benin and Nigeria during the survey. Personnel to take charge of specific samples were designated at the meeting. The Party Chief and ICF Fisheries Observer (Gavin Hogge) briefed the scientists on health and safety regulations during the meeting.

The vessel, R/V GeoExplorer departed Cotonou Port in the morning of 23rd July 2003 with a scientific crew of 13 and vessel crew of 11. The list of scientists is presented in Table 2.

Table 2: Crew List for Scientific Staff

Name	Nationality	Position/Expertise	Address	Tel. & Email
Samuel Nii Kpakpa Quaatey	Ghana	Chief Scientist	P.O. Box BT 62, Tema, Ghana	Tel.: 00-233-22-202346 Cell: 00-233-20-8164312 samquaatey@yahoo.com
Gavin Hogge	USA	ICF Fisheries Observer	1331 Lamar Suite 1360 Houston, TX 77010, USA	Tel: 01-713-445-2003 Cell: 01-409-370-7691 ghogge@icfconsulting.com
Daniel Ofori-Adu	Ghana	Fisheries	P.O. Box BT 78, Tema, Ghana	Tel: 00-233-22-205286
Selorm Dazako Ababio	Ghana	Chemist/Fisheries	P.O. Box LG 239, Legon, Ghana	Tel: 00-233-21-514614 00-233-24-770155
Audrey Kweinorki Quaye	Ghana	Intern, Student of the University of Ghana	P. O. Box 1593, Tema, Ghana	Tel: 00-233-21-514614 Cell:00-233-24-273322
Anthony Oppan Bentil	Ghana	Intern, Student of the University of Ghana	P. O. Box DK 278, Darkuman, Ghana	Tel: 00-233-21-514614 Cell:00-233-24-273
Kwame Adu Agyekum	Ghana	Intern, Student of the University of Ghana	P. O. Box AN 101616, Accra North, Ghana	Tel: 00-233-21-514614 Cell:00-233-24-273
Wilson Kwadzo Tamakloe	Ghana	EPA Observer	P. O. Box MB 326, Accra, Ghana.	Tel: 00-233-24-227099
Yaovi Sevi Acakpo-Addra	Togo	Fisheries	B.P. 7334, Lome Togo	Tel: 228-225-19-92 Fax: 228-221-85-95
Kossi Aheodo	Togo	Fisheries	B.P. 1515, Lome Togo	Tel: 228-905-39-14 : 228-221-68-17
Etse Gatogo	Togo	Fisheries	B.P. 1515, Lome Togo	Tel: 228-225-19-92 : 228-221-68-17
Zacharie Sohou	Benin	Fisheries	Service Oceanologie/CBRST, Cotonou,	

Name	Nationality	Position/Expertise	Address	Tel. & Email
			Benin	
Dunsin Abimdola Bolaji	Nigeria	Fisheries	P.M.B. 12729, Victoria Island, Lagos, Nigeria.	Tel: 234-803-402-3677

There was only one shift for the scientific crew and it was from 0600 – 1800 hours. This period coincided with the times of the day when trawling was executed at the stations.

5.0 Survey Protocol

5.1 Fish Trawl Survey

Fish trawl hauls were to be conducted at the same locations sampled during the first season survey. The use of the Chirp bottom penetrating sonar during the first season survey gave an idea of the suitability of the bottom at each station for trawling. Thus, the Chirp was used only at stations that were known to have bad bottom. Trawling was carried-out at the stations using a semi-balloon otter trawl net with the following specifications:

- Length of Head Rope 7.6 m
- Length of Foot Rope 8.8 m
- Mesh Size of Body 3.8 cm
- Mesh Size of Cod End 2.0 cm
- Length of Bridle 22.9 m

Duration of a trawl at a station was 30 minutes and the trawling speed was about 3.0 knots. A trawl catch was not accepted if the duration was less than 10 minutes or the net was hauled-in badly damaged or there was evidence that the net did not touch the bottom or the mouth of the net did not open properly as a result of collapse or flipping of the doors. The trawl was repeated at a station if any of the aforementioned cases occurred.

The trawl catch was sorted into the different species composition, weighed and lengths of the individuals for a species measured. Species that were not identified at sea were preserved for identification in the laboratory. Length measurement was to the cm below except for shrimps that was below mm. The measurement was either fork length (FL) or total length (TL) for finfish depending on the shape of the tail fin, or mantle length for cuttlefish and squid or carapace length for shrimps and crabs. The species were examined for gross pathology during sorting, species identification and length measurement. Indexes of gross pathology include erosion of fins, tumors, external parasites, lesions and colour anomalies.

Information on the weights of the different species and the number of individuals of a species in a trawl for a station was recorded in the Fish and Macro-Invertebrate Trawl Log Sheet (Fish Observation and Measurement). Also recorded on the sheet were navigational positions, nature of bottom, station depths, trawling speed, warp out and duration of tow. Information on length measurement of the different species was recorded on the Fish and Macro-Invertebrate Trawl Log Sheet (Fish Observation and Measurement: Fish Length Measurement).

In addition to the trawling, the spotting of sea birds, marine mammal (whales, dolphins etc) and fishing vessels (canoes, inshore vessels, industrial vessels etc.) at the station were recorded. A summary of activities at a station was recorded in the Station Logsheet and that for a shift activity for the day was recorded in Daily Shift Activity Report sheet.

5.2 Plankton Survey

There were twenty-five (25) predetermined plankton-sampling stations located along the entire lateral and main pipelines. The break down of the plankton-sampling stations by country was 12 in Ghana, 4 in Togo, 5 in Benin and 4 in Nigeria.

Different methods and nets were deployed in sampling of the different plankton communities at each station. An ICITA net with an opening diameter of 34cm and mesh-size of 64µ was used to collect phytoplankton samples. The net was fitted with a flowmeter at the mouth to record the quantity of seawater filtered and a bucket at the base to collect phytoplankton samples. At each station, the initial reading of the flowmeter was recorded and the net lowered just below the surface of the water and towed horizontally for 5 minutes at a speed of 0.5–1.0 knots. The net was hauled-in at the end of the 5 minutes and the final reading of flowmeter recorded. The phytoplankton samples were emptied into plastic containers, preserved with LOGUS solution and labeled.

An ICITA net with an opening diameter of 34cm and mesh-size of 200µ and was fitted with a flowmeter and a bucket was used to collect zooplankton samples. At each station, the initial reading of the flowmeter was recorded and the net lowered to about 5m from the bottom and towed vertically at a rate of 0.5m per second. This was repeated three times and contents emptied into one container, preserved with 10% formalin and labeled. The final reading of flowmeter recorded at the end of the tow.

An ICITA with an opening diameter of 34cm and mesh-size of 300µ and fitted with a flowmeter and a bucket was used to collect ichthyoplankton samples. At each station, the initial readings of the flowmeters were recorded and the net lowered into the water and towed in a step-oblique manner for 18 minutes at a speed of 1–2 knots. At end of the tow, the net was hauled-in and the contents of the two buckets emptied into plastic containers, preserved with 10% formalin solution and labeled. The final reading of flowmeter recorded at the end of the tow.

The Teflon lined 5-1 Niskin samplers was used to collect water samples for productivity studies at each station. The waters samples were put in three (3) one litre plastic bottles, covered with aluminum foil, labeled and stored in fridge. The transparency of the water column was also measured at each station using the Secchi Disc and the sea colour determined.

All these information on the plankton tows, productivity samples, Secchi Disc readings and sea colour are recorded on the Plankton Station Log sheet. Also recorded on the Form is the starting and ending navigational positions at each plankton tow, wind speed and direction and wave height.

6.0 Data Collection at Fish Trawl Stations

6.1 Data Collection off Benin

Data was collected from a total of 5 stations off Benin between 23rd and 26th July 2003. Trawling was executed at stations 2T06 and 2T07 on 23rd July 2003 between 1434 and1630 hours and stations 2T05 and 2T08 25th July 2003 between 0831 and 1339 hours. Trawling was done at station 2T09 on 26th July 2003 between 0616 and 0646 hours. Three canoes were spotted at station 2T06 during trawling. A summary of trawl information and data on stations off Benin is presented in Table 3.

Table 3: Summary of Trawl Information and Data on Stations off Benin

Date	Station ID	Trawl Period	Position		Depth (m)	Catch Rate (kg/30 mins.)	No. of different Species Caught	No. of different Species Measured	Comments
			Latitude	Longitude					
23/07/03	2T06	1434 – 1504 hrs	06°17.7596N 06°17.7633N	002° 19.8309E 002° 21.2341E	13 - 13	7.08	17	15*	Catch Rate higher than in 1st survey. Three (3) Set Net Canoes spotted at sampling location.
23/07/03	2T07	1600 – 1630 hrs	06°14.4011N 06°14.4008N	002° 21.7307E 002° 20.2311E	21 - 21	0.6	7	7	Very poor catch. Catch rate similar to 1st survey. Trawling repeated at station. Catch of first trawl used for analysis.
25/07/03	2T05	0831 – 0901 hrs	06°10.8823N 06°10.8941N	002° 28.7156E 002° 27.2646E	46- 45	25.42	25	22*	Catch Rate higher than in 1st survey.
25/07/03	2T08	1309 – 1339 hrs	06°09.7320N 06°09.7414N	002° 21.3627E 002° 19.8198E	54 - 55	6.81	24	21*	Catch rate lower than in 1st survey.
26/07/03	2T09	0616 – 0646 hrs	06°09.6901N 06°09.6966N	002° 02.0185E 002° 00.4056E	51 - 48	17.59	28	24*	Catch Rate higher than in 1st survey.

*Length measurements of species such as sea fern, sea cucumber, jellyfish, sea urchin and starfish were not taken.

6.2 Data Collection off Nigeria

Fish trawl data were collected from a total of 4 stations off Nigeria on 24th July 2003. Trawling was carried-out at stations 2T02, 2T04, 2T03 and 2T01 between 0602 and 1814 hours on 24th July 2003. A summary of trawl information and data on stations off Nigeria is presented in Table 4.

Table 4: Summary of Trawl Information and Data on Stations off Nigeria

Date	Station ID	Trawl Period	Position		Depth (m)	Catch Rate (kg/30 mins.)	No. of different Species Caught	No. of different Species Measured	Comments
			Latitude	Longitude					
24/07/03	2T02	0602 – 0632 hrs	06°20.8163N 06°20.8046N	002° 55.7774E 002° 57.3440E	15 - 15	6.46	22	22	Catch Rate higher than in 1st survey. However, station T02 during 1st survey was located in deeper waters (63 – 64 m). A lot of juvenile shrimp and fish in catch.
24/07/03	2T04	1102 – 1132 hrs	06°13.2102N 06°13.2068N	002° 48.5383E 002° 46.9984E	50 -50	18.86	28	24*	Catch Rate higher than in 1st survey.
24/07/03	2T03	1423 – 1453 hrs	06°08.4868N 06°08.4787N	002° 43.0620E 002° 41.6270E	84 - 112	10.20	18	14*	Catch Rate higher than in 1st survey. However, station T03 during 1st survey was located in shallow waters (14 – 15 m).
24/07/03	2T01	1744 – 1814 hrs	06°09.9175N 06°09.9219N	002° 44.8799E 002° 43.2985E	67 - 65	14.00	20	16*	Catch Rate higher than in 1st survey. However, station T01 during 1st survey was located in inshore waters (32 m). Catch dominated by sparides.

*Length measurements of species such as sea fern, sea cucumber, jellyfish, sea urchin and starfish were not taken.

6.3 Data Collection off Togo

Trawl data were collected from a total of 4 stations off Togo between 26th July and 27th July 2003. Trawling was carried-out at station 2T10, 2T11and 2T12 on 26th July 2003 between 1114 and 1727 hours and station 2T13 on 27th July 2003 between 0632 and 0652 hours. A summary of trawl information on stations off Togo is presented in Table 5.

Table 5: Summary of Trawl Information and Data on Stations off Togo

Date	Station ID	Trawl Period	Position		Depth (m)	Catch Rate (kg/30 mins.)	No. of different Species Caught	No. of different Species Measured	Comments
			Latitude	Longitude					
26/07/03	2T10	1114 – 1144 hrs	06°05.1481N 06°05.1531N	001° 38.0041E 001° 39.5566E	49 - 51	13.84	27	21*	Catch Rate higher than in 1st survey. Corals found in catch. Samples preserved for further analysis in the USA and Legon laboratories
26/07/03	2T11	1539 – 1609 hrs	06°04.7827N 06°04.7809N	001° 18.7364E 001° 17.0642E	19 - 18	4.7	5	5	Poor catch. However, Catch Rate higher than in 1st survey. No Corals found in catch.
26/07/03	2T12	1657 – 1727 hrs	06°01.6021N 06°01.5702N	001° 17.8655E 001° 19.4754E	37 - 41	7.0	20	15*	Catch Rate lower than in 1st survey. Corals found in catch. Samples preserved for further analysis.
27/07/03	2T13	0632 –	05°57.7967N	001° 19.4808E	61 - 64	1.65	12	Nil	Net hauled-in after 20

Date	Station ID	Trawl Period	Position		Depth (m)	Catch Rate (kg/30 mins.)	No. of different Species Caught	No. of different Species Measured	Comments
			Latitude	Longitude					
		0652 hrs	05°57.7954N	001° 20.5777E					minutes due to bad bottom. Catch Rate higher than in 1st survey. No Corals found in catch.

*Length measurements of species such as sea fern, sea cucumber, jellyfish, sea urchin and starfish were not taken.

6.4 Data collection off Ghana

Fish trawl data was collected from a total of 13 stations off Ghana. Five (5) additional trawls were made off station 2T26 at 1 km radius from the main station. For the purpose of this report the main station is named 2T26C and the additional trawls named as stations 2T26S, 2T26N, 2T26W, 2T26C-NS and 2T26E. The first trawl off Ghana was conducted at station 2T14 on 27th July 2003 between 1400 and 1430 hours. The rest of stations off Ghana were covered between 28th and 31st July 2003. Work at stations 2T15, 2T17, 2T18 and 2T21 were carried out on 28th July 2003 between 0600 and 1658 hours; stations 2T16, 2T20 and 2T19 on 29th July 2003 between 0602–1800 hours; stations 2T25, 2T24, 2T22 and 2T23 on 30th July 2003 between 0602–1354 hours; stations 2T26C, 2T26S, 2T26N, 2T26W, 2T26C-NS and 2T26E on 31st July 2003 between 0606–1215 hours; stations T17 and T18 on 13th March 2003. Trawling was repeated at stations 2T14 and 2T21 due to either snagging of towing wires during trawling or collapse of one of the trawl doors. The results of the first trawl for station 2T14 was used in analysis while that of the second trawl used for station 2T21. Four canoes were spotted off station 2T22. An inshore vessel in distress was spotted off station 2T26. The vessel was towed to shallow waters after completion of scientific work where she had assistance from local canoes operating in the area. A summary of trawl information and data on station off Ghana are presented in Table 6.

Table 6: Summary of Trawl Information and Data on Stations off Ghana

Date	Station ID	Trawl Period	Position		Depth (m)	Catch Rate (kg/30 mins.)	No. of different Species Caught	No. of different Species Measured	Comments
			Latitude	Longitude					
27/07/03	2T14	1400 – 1430 hrs	05°41.8753N 05°41.8691N	000° 52.6325E 000° 53.3082E	13 - 14	6.6	14	11*	Trawl repeated at station. Catch of 2nd trawl used in analysis. Catch Rate lower than in 1st survey. Catch mainly juvenile fishes.
28/07/03	2T15	0600 – 0630 hrs	05°39.9834N 05°39.9839N	000° 24.5755E 000° 22.9678E	46- 45	13.68	26	20*	Catch Rate higher than in 1st survey.
28/07/03	2T17	1041 – 1111 hrs.	05°33.6910N 05°36.6631N	000° 04.6385E 000° 03.0724E	41- 38	7.64	29	26*	Catch Rates similar to 1st survey.
28/07/03	2T18	1209 – 1239 hrs.	05°36.2972N 05°36.2707N	000° 00.3601E 000° 01.9692E	19 - 25	10.84	22	20*	Catch Rates similar to 1st survey
28/07/03	2T21	1628 – 1658 hrs	05°26.4901N 05°26.5002N	00° 00.9829W 00° 00.5962W	50- 47	8.72	16	13*	Trawling repeated at station due to snagging of towing wire during 1st trawl.

Date	Station ID	Trawl Period	Position		Depth (m)	Catch Rate (kg/30 mins.)	No. of different Species Caught	No. of different Species Measured	Comments
			Latitude	Longitude					
									Catch of second trawl used for analysis. Catch Rate higher than in 1st survey.
29/07/03	2T16	0602 – 0630 hrs	05°30.1113N 05°30.1134N	000° 07.0408E 000° 05.4082E	62-67	31.40	31	25*	Catch Rate higher than in 1st survey.
29/07/03	2T20	1247 – 1317 hrs	05°16.7045N 05°16.7089N	00° 21.3383W 00° 22.0936W	34- 35	19.22	43	34*	Catch Rate higher than in 1st survey. Dead corals found in catch.
29/07/03	2T19	1730 – 1800 hrs	05°07.6565N 05°07.6693N	00° 41.2219W 00° 42.9084W	30- 27	17.62	29	25*	Catch Rate higher than in 1st survey.
30/07/03	2T25	0602 – 0632 hrs	04°34.9769N 04°34.9789N	01° 24.0183W 01° 25.5762W	50- 51	10.82	27	21*	Catch Rate higher than in 1st survey.
30/07/03	2T24	0937 – 1007 hrs	04°51.2834N 04°51.2852N	01° 31.2930W 01° 32.9125W	32- 32	2.48	18	14*	Catch Rate lower than in 1st survey.
30/07/03	2T22	1127– 1157 hrs.	04°58.1297N 04°58.1301N	01° 33.7066W 01° 35.2867W	17- 15	12.72	22	19*	Catch Rate higher than in 1st survey. Catch mainly juvenile fishes. 4 canoes spotted at sampling location
30/07/03	2T23	1324 – 1354 hrs.	04°53.0277N 04°53.0297N	01° 31.9152W 01° 33.4458W	30- 30	3.24	19	17*	Catch Rates similar to 1st survey. 20 sea gulls spotted at sampling location.
31/07/03	2T26C	0606 – 0636 hrs	04°59.7561N 04°59.7578N	01° 07.6608W 01° 09.2854W	28- 28	10.48	22	16*	45 % of catch was the scallops, *Chalmys purpuratus*
31/07/03	2T26S	0723 – 0753 hrs	04°59.2079N 04°59.2212N	01° 07.7304W 01° 09.2967W	29- 28	41.07	18	13*	Over 80 % of catch was the scallops, *Chalmys purpuratus*
31/07/03	2T26N	0826 – 0856 hrs	05°00.2318N 05°00.2930N	01° 07.6619W 01° 09.2830W	27- 26	8.05	22	15*	24 % of catch was the scallops, *Chalmys purpuratus*
31/07/03	2T26W	0930 – 1000 hrs	04°58.9956N 05°00.5747N	01° 09.2820W 01° 09.2816W	28- 26	13.18	24	20*	2 % of catch was the scallops, *Chalmys purpuratus*
31/07/03	2T26C-NS	1037 – 1107 hrs	04°58.9462N 05°00.5788N	01° 08.4792W 01° 08.4676W	28- 26	9.86	16	14*	No scallops, *Chalmys purpuratu* in catch
31/07/03	2T26E	1145 – 1215 hrs	04°58.9531N 05°00.5777N	01° 07.6636W 01° 07.6640W	28- 26	99.46	22	18*	Over 91 % of catch was the scallops, *Chalmys purpuratus*

* Length measurements of species such as sea fern, sea cucumber, jellyfish, sea urchin and starfish were not taken.

7.0 Plankton Data

A summary of plankton data collected during first and second leg of the Second Season EBS is presented in Table 7.

Table 7: A Summary of Plankton Data

Date	Time	Station Number	Sample Code	Number of Containers	Type of Sample	Source of Sample
15/07/03	1615 -1733	2G11	2G11PHY 2G11ZOO 2G11ICHY	1 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
15/07/03	1813 -1908	2G10	2G10PHY 2G10ZOO 2G10ICHY	2 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
16/07/03	0705 – 0803	2G07	2G07PHY 2G07ZOO 2G07ICHY	1 2 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
16/07/03	0950 -1051	2G06	2G06PHY 2G06ZOO 2G06ICHY	1 2 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
16/07/03	1730 -1830	2G05	2G05PHY 2G05ZOO 2G05ICHY	1 3 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
17/07/03	0830 -0924	2G01	2G01PHY 2G01ZOO 2G01ICHY	1 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
17/07/03	0957 -1043	2G02	2G02PHY 2G02ZOO 2G02ICHY	1 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
17/07/03	1301 -1352	2G03	2G03PHY 2G03ZOO 2G03ICHY	1 2 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
17/07/03	1436 -1525	2G04	2G04PHY 2G04ZOO 2G04ICHY	1 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
18/07/03	0957-1050	2G08	2G08PHY 2G08ZOO 2G08ICHY	1 3 2	Phyto Zoo Ichthyo	Ghana Ghana Ghana
18/07/03	1800 -1902	2G09	2G09PHY 2G09ZOO 2G09ICHY	1 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
19/07/03	1140 -1256	2G12	2G12PHY 2G12ZOO 2G12ICHY	1 1 1	Phyto Zoo Ichthyo	Ghana Ghana Ghana
20/07/03	0720 -0758	2T01	2T01PHY 2T01ZOO 2T01ICHY	1 1 1	Phyto Zoo Ichthyo	Togo Togo Togo
20/07/03	0830 -0945	2T02	2T02PHY 2T02ZOO 2T02ICHY	1 1 1	Phyto Zoo Ichthyo	Togo Togo Togo
20/07/03	1040 -1150	2T03	2T03PHY 2T03ZOO 2T03ICHY	1 1 1	Phyto Zoo Ichthyo	Togo Togo Togo
20/07/03	1240 -1336	2T04	2T04PHY 2T04ZOO 2T04ICHY	1 1 1	Phyto Zoo Ichthyo	Togo Togo Togo
20/07/03	1613 -1705	2B5	2B05PHY	1	Phyto	Benin

Date	Time	Station Number	Sample Code	Number of Containers	Type of Sample	Source of Sample
			2B05ZOO	1	Zoo	Benin
			2B05ICHY	1	Ichthyo	Benin
21/07/03	0906 -0949	2B04	2B05PHY	1	Phyto	Benin
			2B05ZOO	1	Zoo	Benin
			2B05ICHY	1	Ichthyo	Benin
23/07/03	1707 -1802	2B03	2B03PHY	1	Phyto	Benin
			2B03ZOO	1	Zoo	Benin
			2B03ICHY	1	Ichthyo	Benin
24/07/03	0700 -0805	ND02	ND02PHY	1	Phyto	Nigeria
			ND02ZOO	1	Zoo	Nigeria
			NDO2ICHY	1	Ichthyo	Nigeria
24/07/03	0930-1023	ND04	ND04PHY	1	Phyto	Nigeria
			ND04ZOO	1	Zoo	Nigeria
			NDO4ICHY	1	Ichthyo	Nigeria
24/07/03	1245 -1340	ND01	ND01PHY	1	Phyto	Nigeria
			ND01ZOO	1	Zoo	Nigeria
			NDO1ICHY	1	Ichthyo	Nigeria
24/07/03	1540 -1702	ND03	ND03PHY	1	Phyto	Nigeria
			ND03ZOO	1	Zoo	Nigeria
			NDO3ICHY	1	Ichthyo	Nigeria
25/07/03	0610 -0703	2B01	2B01PHY	1	Phyto	Benin
			2B01ZOO	1	Zoo	Benin
			2B01ICHY	1	Ichthyo	Benin
25/07/03	1045 -1154	2B02	2B02PHY	1	Phyto	Benin
			2B02ZOO	1	Zoo	Benin
			2B02ICHY	1	Ichthyo	Benin

8.0 Completion of Survey

The trawl survey was completed on 31st July 2003 at about 1300 hours. At the end of the survey the Chief Scientist took custody of all Field Notebooks, Fish Trawl Log, Plankton Station Log, Station Log, Daily (Shift) Activity and Chain of Custody Record Forms. All these forms were handed to Gavin Hogge on 1st August 2003 to forward to ICF. The Party Chief of the vessel handed over the vessel Navigational Log to the Gavin Hogge. Gavin Hogge took photographs of fish species and survey activities and he will hand over to ICF.

9.0 Demobilization

The vessel berthed at Tema Port on 1st August 2003 at about 1600 hours. Demobilization of equipment, gear and samples from the vessel started that same day and was completed in the afternoon of 2nd August 2003.

10.0 Departure of Scientists

All scientists disembarked on 1st August 2003. The scientific crew was meet at the port by A. K. Armah of ESL. Participants from Togo, Benin, Nigeria and ICF stayed in hotel organized by Carl Dork on that day. Participants from Togo, Benin and Nigeria left in the same vehicle hired by Carl Dork to their respective countries on 2nd August 2003 while Gavin Hogge left by air to USA in the evening of the same day.

11.0 Conclusion

The survey was successful. All the set objectives were achieved. Trawl data and information were collected from all the targeted 26 stations.