Technical Appendix D1

Quarantine Expert Panel Advice

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

QUARANTINE EXPERT PANEL
ADVICE TO THE GORGON JOINT VENTURE

TECHNICAL APPENDIX D1

Prepared for:

ChevronTexaco Australia Pty. Ltd.
250 St Georges Terrace
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Prepared by:

Dr. Bernard Bowen
Chairman,
Quarantine Expert Panel

30th September 2004

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30 September 2004

Mr Paul Oen
General Manager
ChevronTexaco Australia Pty Ltd
PO Box S1580
PERTH WA 6845

Dear Paul

I have pleasure in presenting to you a report of the Gorgon Quarantine Expert Panel.

The purpose of the report is to provide Gorgon with an overview of the work of the Panel since its establishment by the Gorgon Joint Venture in October 2003. It is timely that this be done as Gorgon is now preparing its Environmental Impact Statement / Environmental Review and Management Programme (EIS/ERMP) document.

The work of the Panel has been greatly assisted by the involvement of Mr Russell Lagdon, Mr Geoff Prior, Mr Sean Reddan and Mr Richard Stoklosa.

The Panel is of the view that with the release of the EIS/ERMP it may have concluded its role, at least for phase 1. However, following its release Gorgon will need to expand its work on the details of an effective quarantine management system and Gorgon may find value in continuing a form of advice from specialists and the community generally.

The Panel requests Gorgon to consider this matter in relation to the form of an advisory panel which Gorgon may need in the next phase of the quarantine management process.

Panel members take this opportunity to express their thanks to Gorgon for the opportunity to provide advice and steer the direction of quarantine management on Barrow Island.

Yours sincerely

Bernard Bowen
(Chairman, Gorgon Quarantine Expert Panel)

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1 Introduction

The Gorgon Joint Venture established a Panel of specialists (Gorgon Quarantine Expert Panel) in October 2003 to advise and steer the direction of quarantine management for Barrow Island to meet the goal of 'no introduced species' on Barrow Island and in the surrounding waters as an essential element in conserving the biodiversity of the area.

Membership of the Panel (Attachment 1) was based on the expert advice each participant could bring to the discussions. Two observers from the State conservation departments also attended the meetings (Attachment 1). Terms of Reference and a Panel Charter were established and are set out in Attachments 2 and 3.

The Panel has been serviced by officers of the Gorgon Joint Venture (see Attachment 1). All participants (Panel members, observers and secretariat) at Panel meetings have entered fully into the discussions and brought the benefit of their expertise to those discussions. However, neither the observers nor the secretariat were involved in the preparation of this report.

The Panel records its thanks for the involvement of and assistance provided by Mr Russell Lagdon, Mr Geoff Prior, Mr Sean Reddan and Mr Richard Stoklosa.

The purpose of this report is to provide Gorgon with an overview of the work of the Panel since its establishment in October 2003. It is timely that this be done as Gorgon is now preparing its Environmental Impact Statement / Environmental Review and Management Programme (EIS/ERMP) document, which is expected to include considerable detail on quarantine management.

The overview is set out below in sections 2 to 8. Section 9 provides advice of the Panel to the Gorgon Joint Venture on the way forward.

2 Meetings and Procedures

The Panel has met on eight occasions. At the conclusion of each meeting, a Brief Summary of the outcomes of the meeting was prepared within one week and made public through the Gorgon website. The record of each meeting has also been made available publicly on the website following confirmation of the record at the next Panel meeting.

The secretariat provided by Gorgon has been very professional. The staff have greatly assisted the work of the Panel and have readily given attention to the advice provided. Most members of the Panel have been available to accept Gorgon's invitation to visit Barrow Island and have benefited from an inspection and a briefing. One member has extensive knowledge of the Island as a research scientist.

3 Terms and Definitions to establish a quarantine and risk glossary

The Panel advised Gorgon that there was a need to have a glossary of terms and definitions to be used in the development the Quarantine Management System (QMS), the Quarantine Management Plan (QMP) and the EIS/ERMP documentation.

The Panel worked with Gorgon and a glossary in now available.

4 The approach to preparing the Quarantine Management System

One of the matters first considered by the Panel was the approach to developing a QMS. The QMS has to provide confidence that there is a very high probability that the goal of 'no introductions' can be met and that if introductions do occur there are appropriate monitoring and contingency arrangements in place.

The Panel advised Gorgon that the following activities should be given high order attention.

- Establishing standards for acceptable risk, which need to be developed in consultation with, and be broadly acceptable to, stakeholders including those within the wider community.

- Identifying the organism groups of concern and undertaking the required baseline surveys (designed to incorporate future surveillance and monitoring).

- Providing the community with the opportunity to engage in the process for setting standards and developing a 'better than' world's best practise QMS.

- Establishing policies and processes and defining responsibilities such that the risk standards are able to be met.

- Establishing surveillance and monitoring programs for detection of introduced species and environmental change and for compliance with system and plan procedures.

- Establishing contingency and response plans.

- Proposing a process for independent (third party) system audits.

5 Risk assessment, QMS and QMP

Risk assessment, including the establishment of standards for acceptable risk, has been a major item of consideration for the Panel. The Panel has contributed to the development of a "How-to Guide" for conducting risk based assessments of quarantine hazards on Barrow Island. Rather than attempt to quantify 'acceptable risk' for Barrow Island in a manner similar to that undertaken for individual risk in relation to, for example, hazardous industrial plants, where risk data are available, the Panel suggested that informed judgements be made following the development of a process for identifying and classifying threats within the context of the likelihood of the introduction, survival, detection and eradication of introduced species.

The Panel's advice on risk assessment assisted the Gorgon team to establish:

- A community consultation strategy with respect to quarantine management risks and strategies;

- A series of IMEA (infection modes and effects analysis) and HAZOP (hazard and operability) workshops to identify major groups of organisms of quarantine concern, possible infection pathways to Barrow Island, how infection might occur and the array of barriers that should be developed to reduce the risks; and

- A draft Quarantine Policy for the Gorgon Joint Venture.

The outcomes of the Panel discussions, the HAZOP/IMEA workshops and the community consultations have been:

- Recognition that in practical terms the goal of ‘no introductions’ would not be achieved. It was agreed, however, noting the island’s very high biodiversity and conservation values, that the establishment of an introduced species on Barrow Island Nature Reserve, which includes a number of surrounding islands, or its surrounding waters would be unacceptable.

- Recognition that the introduction of micro-organisms will occur every time people and fresh food enter the Island. While many of these may not survive in the natural environment, the extent to which some species may establish on Barrow Island is unknown.

- A report from the community to the Gorgon Joint Venture and to the Environmental Protection Authority on acceptable quarantine risk standards for Barrow Island (Risk Standards Report). The report set out that the risk of establishment of introduced species is acceptably low if it conforms to the Risk Standard Framework described in the report. However, it was recognised that the proposed development would not be able to meet the Risk Standard Framework in so far as micro-organisms and marine species are concerned.

- Recognition that the connectivity of the marine environment is likely to lead to introduced species near the coast also being found in the waters around Barrow Island.

- Identification of the most important pathways to be considered for quarantine management, noting that Gorgon’s schedule and the availability of relevant experts has not yet permitted detailed examination of all of the identified infection pathways.

- Progress towards the development of a Quarantine Management System and a Quarantine Management Plan, which would apply to the existing ChevronTexaco activities and the proposed Gorgon venture as well as to all other people visiting Barrow Island.

- A Contents Table for the Quarantine Management Plan.

- Recognition that whilst pre-border quarantine would be the prime activity, border and post border segments of the quarantine (biosecurity) framework (inspection, surveillance, monitoring, eradication responses) are also essential elements of the Quarantine Management System. Whilst animals such as introduced rats and mice are readily identified as having major consequences should incursions occur, it was recognised that it would not be possible to predict the consequences of most other potential incursions. Accordingly, all species of plants and animals were included in the statement that the establishment of an introduced species on Barrow Island would be unacceptable.

- Recognition that species of plants and animals may arrive on Barrow Island in a manner which is outside the control of Gorgon (eg. birds or air-borne organisms), and that such incursions will need to be given attention in the Quarantine Management System.

- A worked example of the quarantine management specifications, termed Design Guides, required for the pathway of raw materials (aggregate and sand) so as to give effect to the standards set out in the Risk Standards Report.

- Progress towards the development of Design Guides for two further pathways of 'Food and Perishables' and 'People' which will need to be included in the appendices to the EIS/ERMP document.

- A review by Gorgon of some of the pathways leading to a change in project design such that road base material will now not be taken to Barrow Island and consideration is being given to precasting concrete wherever possible to reduce the transport of aggregate and sand.

- Recognition that the details of the quarantine management measures (barriers) necessary for addressing many pathways cannot be formalised until the project's procedural and engineering processes are well advanced.

- Recognition that the development of the quarantine management programs is an iterative process, and that this process must include independent reviews by specialists to assess the effectiveness of the detailed quarantine measures proposed by Gorgon in relation to the risk standards set out in the Risk Standards Report.

- Advice to Gorgon that baseline surveys of the marine and terrestrial environments are essential elements of a Quarantine Management System and should be well underway before the operational phase of the proposed development.

- Recognition that the current paucity of information concerning most organism groups that occur on and adjacent to the Barrow Island Nature Reserve (including lack of taxonomic research and lack of experts capable of identifying specimens) and the short development time frame means that baseline data collection will not have progressed to a stage that the Panel would consider desirable before construction is proposed to commence.

- An annotated outline of the quarantine chapter in the EIS/ERMP document.

Gorgon has made good progress towards the preparation of a Quarantine Management Plan. The Company has the potential to achieve international recognition for the quarantine standards and management measures being planned for an industrial development on an island with very high biodiversity and conservation values. In addition, Gorgon has developed a community consultation process which provides an opportunity through meetings and workshops for considerable public input.

6 A transparent process

The Panel has provided advice on the need for a high degree of transparency in relation to the meeting records not only for the meetings of the Panel, as set out above in Section 2, but also for the Gorgon Community Consultation meetings and the associated Workshops.

Draft Meeting Records have been prepared by the secretariat for each Community Consultation meeting and for each Workshop. These drafts were distributed to each participant and suggested amendments invited. Following receipt of the suggested amendments the Meeting Records were finalised by the meeting chairman. The Meeting Records were then distributed to each participant and also made available on the Gorgon website. At each Community Consultation Meeting and Workshop participants had a further opportunity to comment on the previous Meeting Record. If a participant so desired, the chairman accepted comments on the meeting record in writing and these then became an attachment to the subsequent meeting record.

7 Information gathering

The Panel has provided advice to Gorgon on the need for additional information in relation to the development and long term operation of a Quarantine Management System. This has included advice on the adequacy of surveys of the marine environment as well as giving attention to the potential for introductions of invertebrates and micro-organisms.

In response, the following reports have either been completed or are in the process of completion. The Panel understands that Gorgon will make the reports available on the Gorgon website prior to the release of the EIS/ERMP document and will form part of the Appendices of that document.

- Baseline Studies and Data Gaps.
- Micro-organism threats to terrestrial vertebrate fauna of Barrow Island.
- Micro-organism threats to Barrow Island flora.
- Micro-organism threats to Barrow Island marine environment.
- Quarantine Procedural Review – Benchmarking Study.

Gorgon has also funded the Department of Conservation and Land Management (CALM) to prepare a comprehensive Barrow Island bibliography, and it is anticipated that this will be made public through a CALM publication.

8 The Panel in relation to the release of the EIS/ERMP document

The Panel is aware that the proposed release date for the EIS/ERMP document was amended during the year from August to December 2004. This decision took into account advice received from the Panel and the discussions at the Community Consultation meetings. The Panel is conscious of the size and difficulty of the task of developing an effective Quarantine Management System, particularly because of the very high biodiversity and conservation importance of Barrow Island. The Panel has worked closely with Gorgon to provide advice to assist in developing risk standards, a Quarantine Management System and a Quarantine Management Plan.

The Panel will not be in a position to provide advice on the text of the draft EIS/ERMP document, but the Panel has endeavoured to provide advice which has assisted Gorgon in giving attention to the matters of high priority in relation to the development of an effective Quarantine Management System.

9 Advice of the Panel to the Gorgon Joint Venture on the way forward

Coordination of the biological surveys

Comprehensive knowledge of the plants, animals and micro-organisms of Barrow Island and surrounding waters is an essential element of an effective quarantine management system in relation to the detection of introduced species as well as assessments of ecological change. The Panel is of the view that surveys to gain the required knowledge over time can best be achieved by engaging lead specialists in three broad areas of flora, vertebrates and invertebrates. However, a coordinating mechanism is essential and this will require the services of a suitably qualified, experienced person, or team, to be responsible for integrating the surveys and the data flowing from those surveys.

Protocol for action in the event of an incursion being detected

A process needs to be established at an early stage that defines the protocols to be adopted in the event that an incursion of an introduced species is detected. The protocol would include the communication required, the authority to act, the principles supporting the methods to be employed, the equipment that needs to be available and the mechanisms to verify outcomes.

Conclusion of the work of the Panel

The Panel is of the view that with the release of the EIS/ERMP document it may have concluded its role, at least for phase 1. However, following release of the EIS/ERMP document Gorgon will need to expand its work on the details of an effective quarantine management system and Gorgon may find value in continuing a form of advice from specialists and the community generally.

The Panel requests Gorgon to consider this matter in relation to the form of an advisory panel which Gorgon may need in the next phase of the quarantine management process.

Panel members take this opportunity to express their thanks to Gorgon for the opportunity to provide advice and steer the direction of quarantine management on Barrow Island.

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Attachment 1

Gorgon Quarantine Expert Panel Membership

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Gorgon Quarantine Expert Panel

'To advise and steer the direction of quarantine management for Barrow Island, to meet the goal of no introduced species on Barrow Island and in the surrounding waters as an essential element in conserving the biodiversity of the area.'

Members

Bernard Bowen	Chairperson
Andrew Burbidge	Conservation Specialist
David Carter	Commonwealth Department of Environment and Heritage
Keith Collins	Risk Management Specialist
Diana Jones	WA Museum
Malcolm Nairn	Biosecurity Consultant
Greg Pickles	WA Department of Agriculture
Sandra Potter	Australian Antarctic Division
Andre Schmitz	Australian Wildlife Conservancy
John Scott	CSIRO Entomology

Observers

Warren Tacey	WA Department of Environment
Norm Caporn	WA Department of Conservation & Land Management

Secretariat

Russell Lagdon	Gorgon Joint Venture, (HES Manager)
Sean Reddan	Gorgon Joint Venture, (Environmental Advisor)
Richard Stoklosa	Gorgon Joint Venture, (Risk Specialist)
Geoff Prior	Gorgon Joint Venture, (Construction and Logistics Advisor)

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Attachment 2

Gorgon Quarantine Expert Panel

Terms of Reference

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Gorgon Quarantine Expert Panel
Terms of Reference

Preamble

The establishment of a Quarantine Management System (QMS) to meet the goal of no introduced species on Barrow Island and in the surrounding waters is a critical element of a referral document by the Gorgon Joint Venture to the Environmental Protection Authority (EPA) under Part IV of the Environmental Protection Act.

The EPA set out in its Bulletin 1101 that if the Western Australian Government ("Government") gave in-principle approval for access to Barrow Island, the Gorgon Joint Venture would need to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island, and that the process would need to include appropriate technical experts as well as ensuring a high level of transparency and community involvement.

The Government has given in-principle approval for access to Barrow Island.

The QMS would set new benchmarks in best practice conservation performance and would include the set of standards for the performance of the quarantine measures. The Gorgon Joint Venture would also be required to demonstrate that it could meet the risk standards with a very high degree of confidence.

The Joint Venture has established a Gorgon Quarantine Expert Panel to assist in the development of the QMS and to ensure that this is undertaken in a transparent manner with community involvement. However, the Gorgon Joint Venture recognises that the final responsibility for the QMS resides with the Joint Venture Company in relation to the preparation of the referral document to the EPA.

The purpose of the Expert Panel is to advise and steer the direction of quarantine management for Barrow Island, to meet the goal of no introduced species on Barrow Island and in the surrounding waters, as an essential element in conserving the biodiversity of the area.

Composition of the panel is based on the expert advice each participant can provide.

Terms of Reference

1 Agree upon the 'boundary conditions' and precise outputs expected from the Expert Panel in relation to the QMS.

2 Define roles, responsibilities and expectations of members of the Expert Panel (eg. meeting attendance, continuity of support).

3 Gain appreciation of existing quarantine operations, procedures and performance history.

4 Define the focus for the development of the QMS noting the requirements for best practice outcomes.

5 Discuss and agree on the work, schedule and resources required to develop the criteria for acceptable quarantine risks, performance standards, baseline surveys, contingency planning, monitoring/audit requirements, and transparency of operation, including reporting, and external review of performance.

6 Discuss and agree on mechanisms and protocols for communication of the work of the Expert Panel.

7 Develop a 'road map' of work to be undertaken and the scheduling of that work.

8 Review and comment on documentation proposed, including risk management strategies, in relation to the preparation of the QMS.

9 Provide high-level advice to the Gorgon Joint Venture which will contribute to the development of an effective QMS.

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Attachment 3

Gorgon Quarantine Expert Panel

Charter

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Gorgon Quarantine Expert Panel Charter

Purpose

"To advise and steer the direction of quarantine management for Barrow Island, to meet the goal of no introduced species on Barrow Island and in the surrounding waters as an essential element in conserving the biodiversity of the area."

Clarification notes:

- "No introduced species" relates to all activities of ChevronTexaco, including those of existing oilfield operations, as operator of the Gorgon Development, and its contractors.
- The term "introduced species" relates not only to species that are exotic to Australia but also to species that occur on the mainland but not on Barrow Island.
- Including the surrounding Islands of Boodie, Middle, Pasco, Boomerang, Double and Prince Rock.
- The Quarantine Management System will apply to the construction, operation and decommissioning phases of the Gorgon Development, as well as any other person travelling to Barrow Island.
- The Panel will provide advice on a set of biosecurity measures designed to achieve the purpose.
- In the case of micro-organisms, the principle of preventing the introduction of species not already present on Barrow Island can best be addressed by adopting a risk management approach to each of the operational pathways so that material likely to harbour potentially harmful micro-organisms are prevented where ever possible from entering the island. Such an approach recognises the difficulty of identifying the enormous range of micro-organisms which currently exist on the island as well as those that could enter via a variety of avenues some of which have nothing to do with human intervention. It also recognises that micro-organisms will have entered and will continue to enter Barrow Island in or on humans and their food, most of which are unlikely to affect the indigenous biodiversity. The pre-border, border and post-border quarantine (biosecurity) management measures will take into account those micro-organisms known, or expected to be harmful to the biodiversity of Barrow Island.

Objectives are to:

- Establish standards for acceptable risk which are developed in consultation with stakeholders and which are broadly acceptable for the purpose of establishing an effective quarantine management system
- Identify the major organism groups of concern and the required baseline surveys (designed to incorporate future monitoring)
- Provide the community with the opportunity to engage in the process for setting standards and delivering a world's best practice Quarantine Management System
- Establish practicable policies, processes, and responsibilities which meet the risk standards
- Establish monitoring programs for detection of introduced species and compliance with procedures
- Establish contingency and response plans

To achieve our purpose and objectives we commit to:

- Every point of view is important and is to be respected by others
- Where our opinions differ, we will respect those differences but strive to resolve them through an agreed process
- Talk freely (i.e. contribute our input and opinion freely)
- Be aware of the different roles and positions we hold or represent (i.e. beyond the Expert Panel) and find a way to handle them (i.e. to ensure we contribute our expertise to the Panel)

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Technical Appendix D2

How-to Guide for Conducting Risk-based Assessments of Quarantine Threats to Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

HOW-TO GUIDE FOR CONDUCTING RISK-BASED ASSESSMENTS OF QUARANTINE THREATS TO BARROW ISLAND

TECHNICAL APPENDIX D2

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April 2005

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How-to Guide for Conducting Risk-based Assessments of Quarantine Threats to Barrow Island

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Preferred citation:

E-Systems, 2005. *How-to guide for conducting risk-based assessments of quarantine threats to Barrow Island*, Rev. 5, prepared for ChevronTexaco Australia, Perth, Western Australia.

Revision History:

Revision 0	**26 November 2003**	**Draft for review**
Revision 1	**10 December 2003**	**Incorporating Quarantine Expert Panel comments**
Revision 2	**10 February 2004**	**Released for community consultation**
Revision 3	**12 March 2004**	**Incorporating stakeholder comments and released for risk assessment workshop support**
Revision 4	**30 July 2004**	**Incorporating stakeholder comments and workshop experience**
Revision 5	**29 April 2005**	**Incorporating stakeholder comments and workshop experience, and defining the acronyms PBA and QHAZ**

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This "How to Guide" has benefitted from substantial consultation with technical experts and stakeholders. I wish to thank the Quarantine Expert Panel, in particular, for their strategic advice and useful suggestions in their reviews of this risk-based approach toward managing quarantine threats to Barrow Island: Bernard Bowen (Chairman), Andrew Burbidge, Norm Caporn (Observer), David Carter, Keith Collins, Diana Jones, Malcolm Nairn, Greg Pickles, Sandra Potter, Andre Schmitz, John Scott and Warren Tacey (Observer).

The participation and useful observations of 45 technical specialists in 17 workshops through April 2005 is acknowledged. Many of these specialists attended several workshop sessions, and to them I am grateful for their commitment and enthusiasm. Their involvement has advanced the methodology and laid the foundations for continuing progress.

Numerous community stakeholders who attended eight public meetings and workshops have offered constructive and insightful comments on this methodology, and the difficult task of setting standards for acceptable risk.

Finally, I wish to recognise the commitment of ChevronTexaco Australia and the Gorgon Joint Venture for their support of this risk-based approach and the development of a rigorous methodology to underpin it.

Richard Stoklosa

1 Introduction

This document has been prepared to outline the methodology for conducting a risk-based assessment of potential quarantine threats on Barrow Island. There is a need to address the potential hazards of introduced terrestrial and marine pests during the construction and operation of the proposed Gorgon LNG gas plant, and associated marine terminal and CO_2 re-injection facilities. Increased movements of personnel and material on aircraft and marine vessels present a threat to the unique conservation values of the Island as a Class A Nature Reserve. The development of a Quarantine Management System (QMS) is being undertaken with advice from the Gorgon Quarantine Expert Panel. The outcomes of the risk-based assessment are to contribute to the development of the QMS.

Ecological risk assessment is rapidly becoming an appealing discipline for best practice environmental management. Regulatory authorities use risk assessment to manage a variety of ecological hazards, including non-indigenous species and genetically modified organisms. Given the complexity of ecological systems, there are few 'off-the-shelf' guidelines which apply to the wide range of environmental assessments that are undertaken. Substantial efforts are underway by numerous regulatory authorities to develop environmental risk assessment methods and techniques suitable for a wider variety of assessments.

It is the aim of this How-to Guide to draw upon the best practices for ecological risk assessment and apply them in a transparent and repeatable manner. The objective is the assessment of threats to the conservation values of Barrow Island, however the approach could be applied to nature reserves in general, or locations otherwise having high conservation value. This document will address the early activities of a staged risk assessment process, in which potential hazards will be subjected to a screening process to identify those which present risks that must be managed in a QMS. More sophisticated risk analysis may be necessary for hazards which pose significant risks to the conservation values of native species. Future adjustments to the approach and methodologies suggested here are likely based on experience, and will be reflected in revisions of this document to improve the quality of the risk assessment process.

The risk assessment and risk management of quarantine issues will continue through the proposed Gorgon Development lifecycle. It is necessary to structure the initial stages of this risk-based assessment to enable Gorgon to outline the essential elements of the QMS during the environmental impact assessment process to the Western Australian government for community consultation and project approval.

2 Background

A risk-based management framework is being used to address the threat of introducing non-indigenous species to Barrow Island. The management framework will be developed directly from the risk-based assessment of potential quarantine threats. The risk assessment is undertaken in accordance with AS/NZS 4360, *Risk management*, and incorporates the guidelines contained in the related handbook for environmental risk management (HB203 2004).

The focus areas addressed by the Expert Panel which will form the basis for the QMS are:

- Performing a risk assessment of potentially invasive terrestrial and marine species from project construction and operational activities. A systematic hazard evaluation of potential 'invasion pathways' will be undertaken. Risk analysis may be undertaken at various levels of complexity in a staged approach, initially starting with a pathway-driven analysis of potentially invasive biological groups. This first level may be used for qualitative estimates of the likelihood of a non-indigenous species arriving at Barrow Island. Subsequent levels of the risk analysis, if required, could qualitatively and/or quantitatively address the ecological risk of a potentially invasive species establishing, persisting and competing with native species. A staged approach to risk assessment is desirable to initially screen out hazards which are clearly manageable, and to apply more sophisticated risk analysis techniques (where available) to hazards which appear to represent more significant threats. Advice of the Expert Panel and community points to a qualitative risk assessment in the absence of data and knowledge of complex ecological systems.

- Identifying the biological groups of interest and undertaking a literature search with regard to their ecological functioning and potential 'invasiveness' in an arid sub-tropical setting such as found on Barrow Island. Conducting baseline studies of flora and fauna, and identifying data gaps which should be rectified to improve the quality of the management plans to be developed. Planning future monitoring requirements as a result of knowledge gained from baseline studies.

- Providing the community with the opportunity to engage in the process for delivering a QMS which will protect the conservation values of Barrow Island. The methodology and proposed standards for acceptable risk will be communicated with stakeholders and the public, and consultation will be undertaken to ensure that relevant concerns are fully considered.

- Establishing policies, organisational and administrative processes and responsibilities which ensure that standards for acceptable risk are achieved. Training and induction requirements for personnel and visitors will be addressed.

- Establishing monitoring programs for the rapid and effective detection of introduced species, and compliance with QMS procedures. Requirements for independent auditing of the QMS will be addressed to ensure that the system achieves its performance objectives and is continuously improved.

- Establishing contingency and response plans in the event of a quarantine breach. These will include 'rapid response decision guides' which rely on advice from technical specialists to formulate an appropriate response to the detection of a non-indigenous species.

The QMS developed through this framework will evolve during the project approvals process, and will be designed to address specific threats throughout the project lifecycle. Potential quarantine threats will be identified as major equipment is sourced and ongoing logistics arrangements are contemplated. The risk-based QMS will be designed to incorporate new information as it becomes available so that potential quarantine threats are effectively managed.

A staged approach will address the EPA requirements for submission of a strategic management plan at the time when the ERMP is submitted for review. Detail of specific policies, procedures and administrative details will be incorporated in the QMS prior to project construction. This staged approach will allow improvements and incorporate new information as it becomes available, supporting the desired world-class standard of the management system.

This risk assessment methodology outlines the methods to be used to perform comprehensive and systematic identification of potential quarantine threats (hazards), which is the most important part of any risk assessment. Without a thorough and complete understanding of the threats, risks could be underestimated or the QMS could fail to recognise and control risks to acceptable levels.

3 Guiding principles

Environment Protection Authority Bulletin 1101 (EPA 2003) recommended to the Western Australian government that if the proposed development of a gas plant on Barrow Island was to proceed, "it could only be with a policy of 'zero tolerance of invasions' target and an associated quarantine regime of sufficient, demonstrated rigour to achieve this." In view of the government's in-principle approval to proceed with the assessment of the proposal, the EPA has advised environmental requirements including independent expert advice and transparent public processes to decide the acceptable risk to conservation values of Barrow Island. To accomplish this, the proponent is required to develop a set of standards for acceptable risks, and to demonstrate that the risk standards can be met with a very high level of confidence. The approach is to adopt a risk-based assessment process, using the guidance contained in AS/NZS 4360 and applying it to ecological systems with regard to best practices.

Following a thorough literature search in 2003, there were no known risk assessment methods which would address the threat of invasive alien species to the conservation values of native animals and plants on a Nature Reserve and surrounding waters, to meet the EPA guidelines. It was necessary, then, to adopt the best practices from methods which have proven to be valuable in the analysis of biological stressors (Suter 1993; Beer & Ziolkowski 1995), introduction of non-indigenous species (Bomford 2003; CSIRO 2001; Hayes & Hewitt 1998; Pheloung 2001; USDA 2000), quarantine risk assessment (Biosecurity Australia 2001, 2002 and 2003; FAO 1996), the release of genetically modified organisms (OGTR 2003b; RCEP 1991), and relevant industry experience (Stoklosa 1988 and 1999). Independent reviews of quarantine risk assessment practices were also considered (eg 'The Nairn Report', DPIE 1996).

Since the initial literature search in November 2003, at least one relevant example of environmental risk assessment for the protection of island conservation values has emerged. The Department of Environment and Heritage (DEH) identified that the potential introduction of marine and terrestrial species to The Ashmore Reef National Nature Reserve and the Cartier Island Marine Reserve, due to the high level of vessel traffic and visitation, represented a significant threat to the natural values and conservation objectives of these Reserves. A risk-based assessment of the threat of introductions has been proposed by Russell *et al* (2003). This recent work supports the argument for the risk-based approach described here.

The full range of potential pests which could threaten the conservation values of Barrow Island must be considered. It would be desirable to be able to identify every potential pest species in all biological groups. Clearly this cannot be achieved in the short term. Prior to approval of the Gorgon Development, the suppliers of major plant and equipment have not yet been identified, and the potential pests originating from the locations of suppliers, or vessels used for transport, cannot be determined. Even without this knowledge, a risk-based assessment can commence by considering the 'biological groups' (or perhaps phenotypes) which may pose a threat of introduced species within the usual ICZN taxonomic classification scheme (eg Phylum, Class, Order, Family, Genus, Species). It would be practical to consider biological groups at the Family level wherever possible (eg Muridae—mice and rats), or to identify convenient subgroups of Orders (eg winged arthropods). Using such a taxonomic classification to identify potential pests ensures comprehensive consideration of organisms of interest, and allows experts in various disciplines to contribute to the risk assessment in a structured manner. Advice to be considered will include characteristics of the lifecycle stages of these biological groups, the environmental parameters which affect survival and persistence (eg temperature, salinity, rainfall, soils, habitat structure, seasonal events, etc), and the competency to survive the journey and establish viable populations at the recipient port. In some cases, it may be possible to specifically consider one or more 'indicator species' within a wider biological group, which could be used for assessment purposes if its activity and management regime is protective of the wider organisms represented in the group.

The exception to direct hazard identification and risk assessment of potential pests would be micro-organisms. Some specific bacteria, viruses, fungi, or other pathogens might be identified as known threats to native species in the general region, carried by airborne spores or vectors such as seabirds which routinely visit offshore islands in the area. It would be an impossible task to identify all potential pathogens, as only a fraction of micro-organisms are even described by the scientific community. Instead, it would be more productive to consider any special circumstances where specific pathogens of known concern could be associated with host species, or entrained in cargoes or people arriving at Barrow Island (eg temperature controlled containers, goods and conditions which might provide a culture medium, unique types of equipment packaging, luggage, etc).

Hazard evaluation is the most important part of any risk assessment, and must be systematic, rigorous and transparent. Failure to identify potential hazards can result in risk estimates which are too low, or management practices which fail to recognise and control risks to acceptable levels. It is desirable for hazard evaluation to involve a range of technical disciplines and specialists with operational experience, making use of 'inductive' techniques which are designed to identify hazards which may lie outside the professional experience of the individual analysts involved. The selection of appropriate techniques to address these guiding principles is discussed in Section 4 of this document.

Pathway-driven hazard evaluations are the most useful starting point for assessing the risks of introduced alien species, as there are a limited number of inspection facilities where goods are packaged prior to shipment to Barrow Island (eg Welshpool, Dampier). Other pathways of interest include personnel and small articles arriving from airports in passenger aircraft, originating at commercial airports and other nearby facilities (eg Varanus Island, Thevenard Island). Pathway-driven hazard evaluations must also consider major equipment arriving in Australia from foreign ports which will require special arrangements for quarantine inspections and clearance prior to delivery to Barrow Island, specialised vessels to be used for construction activities (eg survey vessels, dredges, etc), and product tanker vessels.

The assessment criteria, or 'endpoint' for the classification of risk is relatively simple, given the EPA recommendations for assessing the project and the Gorgon Venture's objectives for protecting the conservation values of Barrow Island. The assessment standard for acceptable risk can be stated as:

> *A zero tolerance of invasions target, where the risk of introducing an alien species to Barrow Island is sufficiently low to prevent the possibility of establishment and invasion.*

This assessment standard for acceptable risk must be stated in operational terms with advice from technical experts and stakeholders, to enable the assessor to use 'measurement endpoints' to classify risk. The standards for acceptable risk should be established with regard to the analysis of pathways, such that the likelihood of introduction can be estimated for various biological groups, providing a metric which can be monitored and verified with operational experience. Using the likelihood of introducing an alien species to Barrow Island provides a simple, clear and verifiable risk metric, which avoids the complexity of estimating the likelihood of impacts to the conservation values of the Island when little data exists to make informed predictions. The acceptance standard for the introduction of one group of organisms may be different than another, based on expert advice and stakeholder consultation.

The forward plan for improving risk-based assessment of quarantine hazards is to develop more understanding of the suitability of non-indigenous species to survive in the Barrow Island environment, and to determine monitoring and contingency strategies which enable detection and control of any introductions which may occur. As more data becomes available, more confident predictions of survival and detection of alien species may be achievable to characterise risk.

4 Selection of hazard evaluation techniques

Formal hazard evaluation studies have their origins in the chemical process, nuclear and aerospace industries (among others) over a period of more than 40 years. During this time, published guidelines have been developed to describe the techniques used in these studies (CCPS 1992), and there is a wealth of experience in applying them to a variety of industrial risk assessments. The application of the same tools to ecological problems has been attempted to a much lesser extent, however the benefits of performing rigorous hazard evaluation as a basis for an understanding of ecological risk are clear (RCEP 1991; Suter 1992). The general approach is to adapt the familiar tools used in industrial hazard evaluation to their analogies in natural systems.

Hazard evaluation can sometimes be performed by a single person, depending upon the specific need for the analysis, the technique selected, the perceived hazard of the situation being analysed, and the resources available. Clearly, it is preferable for a team of technical and operational specialists to be involved in hazard evaluation and risk analysis than relying on the experience of a single analyst. Whilst the team approach demands a high level of commitment from a number of people, the benefits lie in the exchange of ideas and information which allows for lateral thinking and creative analysis of potential hazards. 'Inductive' techniques—those which involve creatively analysing the ways in which planned activities could fail in their intended purpose—are preferable to 'deductive' techniques in the analysis of ecological risk. Deductive techniques require a precise understanding of the response of a system to well-described events, which are more readily applied to well-understood physical processes (eg industrial equipment, computerised control systems) than the less predictable behaviour of living systems.

There are a number of hazard evaluation techniques which have been applied to industrial situations (CCPS 1992; AS/NZS 3931 1998), and methods used in risk analysis have been noted in the Standards Australia handbook for environmental risk management (HB203 2004 – Appendix G). Of these, the following range of techniques have been published for identifying hazards in ecological systems, particularly with respect to biosecurity and invasion of pest species (in alphabetical order, with references to published applications of each technique in brackets):

- Fault tree analysis (Hayes 2002a);
- Hazard and operability (HAZOP) analysis (RCEP 1991);
- Hazard checklists (OGTR 2003a);
- Hierarchical holographic modelling (HHM), a form of the 'paired comparisons' technique (Hayes *et al* 2004—in preparation);
- Import risk analysis (Biosecurity Australia 2003);
- Infection modes and effects analysis, or IMEA (Hayes 2002b) — the analogy to failure modes and effects analysis, or FMEA, used in the risk analysis of industrial systems;
- Relative ranking, a form of 'hazard indices' (Bomford 2003; Pheloung 2001; USDA 2000); and
- Retrospective analysis, a form of the 'review of historical data' technique (Biosecurity Australia 2001).

Hazard evaluation and risk analysis techniques which may be considered for some types of ecological assessments might also include preliminary hazard analysis (PHA), event tree analysis, human reliability analysis (HRA), and modelling techniques such as Monte-Carlo simulation (Stoklosa 1999). The general limitation of any of these proven industrial methods is in their ability to handle the less certain interactions of biological systems, compared to the well described physics and chemistry of industrial processes.

Of these techniques, six involve inductive reasoning: event tree, IMEA, fault tree, HAZOP, HHM and PHA. The strength of inductive reasoning lies in its ability to discover "what can go wrong?" using the imagination and ingenuity of a group of analysts with appropriate technical and operational expertise. Inductive techniques enable the identification of hazards which lie outside the professional experience of an individual analyst. Hazard identification for all new risk assessment paradigms, such as the risk of introduced species to the conservation values of a nature reserve, must begin with inductive techniques. Only with improved understanding of the performance of operational barriers and the interactions of biological systems, can analysts begin to also adopt deductive approaches such as checklists and unstructured brainstorming techniques. If brainstorming techniques were adopted for each new ecological assessment, hazard identification would become a haphazard process (Suter 1992, page 394). Systematic, inductive hazard evaluation techniques are therefore preferred in the current situation.

The advantages and disadvantages of hazard evaluation techniques which might be applied to the current situation are compared in Table 4.1. Note that the HAZOP and IMEA [FMEA] techniques are described in AS/NZS 3931 as "fundamental" methods for hazard evaluation.

Rather than invent an entirely new hazard evaluation technique, the aim is to select those which are best suited to the analysis of the new risk assessment objectives to be considered here. It is prudent to give higher consideration to those inductive techniques which have proven applications in biosecurity and the invasion of pest species. Techniques must be selected to address pathways of introduction and activities designed to be barriers to introduction along each pathway. Table 4.1 suggests that the focus should be on the proven IMEA, fault tree and HAZOP techniques. These techniques have been applied to introduced species and biosecurity. The PHA technique may also be considered as a precursor to a detailed HAZOP analysis of barriers at the conceptual or preliminary design stage. The selection of appropriate hazard evaluation techniques for the protection of the conservation values of a class A Nature Reserve has not been specifically addressed in the current technical literature, nor have standards for acceptable levels of risk been established in this context.

The fault tree technique is discarded for the initial identification of hazards, however, because of the complexity of the effort to construct detailed and accurate fault trees for every combination of pathways and biological groups of concern. Uncertainties in causal events and circumstances would frustrate the construction of fault trees, as would temporal components of biological systems. This does not mean that a fault tree approach should be excluded categorically, as it may augment the other methods in certain circumstances where such detail could aid the understanding of threats.

Methods currently used for import risk analysis have also been discarded as the basis for this methodology, as these typically require quantitative or semi-quantitative risk analysis techniques which are applied to a very narrow range of organisms and hosts, to determine whether they will become pest species if imported from a foreign country as a result of trade. Import risk analysis is used to establish the types of quarantine barriers that could be adopted to prevent an unfair exclusion of imports among trading nations. Import risk analysis also aims to analyse the economic consequences of an introduction to specific types of agricultural crops (and arguably to a lesser extent environmental consequences). In contrast, the aim of this methodology is to assess the risk of any introduction to Barrow Island, a Class A Nature Reserve, and develop barriers to address specific threats of introduction along pathways where NIS could be introduced.

Table 4.1 Techniques used in hazard evaluation (after AS/NZS 3931).

Hazard evaluation technique	Description and usage	Application to assessment of quarantine hazards	
		Advantages	Drawbacks
Inductive techniques			
Event tree analysis	A hazard identification and frequency analysis technique which employs inductive reasoning to translate different initiating events into possible outcomes.	Potential to augment another hazard evaluation technique to describe ecological consequences from the 'bottom-up', if there is sufficient understanding to predict the behaviour and interactions of an introduced biological group.	Insufficient information to predict outcomes when initiating event is the introduction of non-indigenous species whose behaviour is not well described. Limited usefulness outside of well-understood species interactions.
Infection modes and effects analysis (IMEA) *Analogous to failure modes and effects analysis (FMEA)*	A **fundamental** hazard identification and frequency analysis technique which analyses all the fault modes of a given equipment item for their effects both on other components and the system.	Proven technique for introduced pests (Hayes, 2002b). Highly structured, has the potential to identify all potential hazards, prioritises hazards on the basis of causes and consequences.	Time consuming when used to identify an exhaustive list of combinations of failures which lead to accidental introductions.
Fault tree analysis	A hazard identification and frequency analysis technique which starts with the undesired event and determines all the ways in which it could occur (displayed graphically).	Proven technique for introduced pests (Hayes, 2002a) and incident investigation. Highly structured, 'top-down' analysis of undesirable events.	Analysis for all types of accidental introductions among all biological groups would be an impossible task. A highly complex fault tree would be required for each pathway and organism
Hazard and operability (HAZOP) analysis	A **fundamental** hazard identification technique which systematically evaluates each part of the system to see how deviations from the design intent can occur, and whether they can cause problems.	Proven technique for introduced pests (RCEP. 1991). Highly structured, has the potential to identify all potential hazards, captures existing safeguards and corrective/ preventive measures.	Classical application of this technique does not prioritise hazards. This limitation can be overcome, however, if estimates of likelihood and consequences are included in the analysis.
Paired comparisons — Hierarchical holographic modelling (HHM)	A means of estimation and ranking of a set of risks by looking at pairs of risks and evaluating just one pair at a time.	Considers pair-wise interactions of all components of the system.	Data to support such an analysis for all biological groups is lacking. Analysis would have low confidence.
Preliminary hazard analysis (PHA)	A hazard identification and frequency analysis technique that can be used early in the design stage to identify hazards and assess their criticality.	Commonly carried out during conceptual development of a project when there is little information on design details or operating procedures. Can be a precursor to further hazard identification and risk analysis (such as a HAZOP when detailed design is available).	Provides results which are subject to further analysis when more detailed information becomes available.

Table 4.1 Techniques used in hazard evaluation (after AS/NZS 3931), concluded.

Hazard evaluation technique	Description and usage	Application to assessment of quarantine hazards	
		Advantages	Drawbacks
Non-inductive techniques			
Checklists	A hazard identification technique which provides a listing of typical hazardous substances and/or potential accident sources with need to be considered. Can evaluate conformance with codes and standards.	None for the current situation, as potential hazards cannot be identified by any 'standard' rules or mechanisms.	'Typical' sources of hazards and/or potential introduction scenarios are not well understood in the system under study. Under these circumstances, checklists fail to assist the analyst to be thorough.
Hazard indices — Relative ranking	A hazard identification/ evaluation technique which can be used to rank different system options and identify the less hazardous options.	Weed risk assessment (WRA) an example of a method to determine the 'invasiveness' of a species based on climate and geographical data.	Indices for a wide range of biological groups which might be introduced are unknown, making the technique of little use outside of few proven applications. Relative ranking is actually an analysis strategy rather than a single, well-defined analysis method.
Human reliability analysis (HRA)	A frequency analysis technique which deals with the impact of people on system performance and evaluates the influence of human errors on reliability.	Usually performed to augment other hazard evaluation techniques, for situations where it is necessary to analyse factors which influence human performance.	No data available on human performance factors which might influence reliability of various barriers to introduction.
Modelling techniques	A means of conducting predictive frequency analysis, using a model of the system which evaluates variations in input conditions and assumptions.	None for the current situation.	Modelling of ecological systems should not be undertaken without a detailed and confident understanding of the behaviour and interactions of biological systems which must be expressed in quantitative, mathematical terms.
Review of historical data — Retrospective analysis	A hazard identification technique that can be used to identify potential problem areas and also provide an input into frequency analysis based on accident and reliability data, etc.	Review of some data is possible to identify situations where cargoes are infected with organisms at some locations (eg Welshpool, Dampier, Barrow Island). Available data could be used to augment other techniques (eg experience of Australian Antarctic Division, AQIS, Defence in East Timor).	Very limited data to predict the behaviour and interactions of the system under study, or to confidently predict frequency of infected cargoes.

The IMEA technique can be applied to the 'carriers' of introduced organisms from the port of origin to Barrow Island (eg materials, equipment, personnel, aircraft, marine vessels). It is unlikely that a direct measure, either quantitative or qualitative, of ecological effects or even survival of introduced species will be achievable in the first instance for many biological groups.[1] The IMEA should be structured to consider 'introduction' (arrival on Barrow Island and surrounding waters) as a measure of the likelihood of exposure, and 'detection' and 'eradication' as a surrogate for potential consequences. In cases where experts can make judgments of the likelihood of survival of an introduced species, survival could also be scored as a surrogate for potential consequences. Estimates of introduction, survival, detection and eradication are made qualitatively using a scoring system, as generally described by Hayes (2002b) in the assessment of the spread of marine organisms by small craft (discussed in Section 5.2 of this document).

The HAZOP analysis can be applied to activities which are intended to be quarantine barriers along the pathways from the port of origin (eg Welshpool, Dampier, overseas ports, private and commercial airports) to Barrow Island. If detailed designs of barriers (eg inspection, testing, treatment) to exclude introduced species from material and personnel movements are provided for each pathway, then the HAZOP technique can be applied to identify and evaluate deviations from the intended performance of these barriers. For this methodology, the HAZOP technique for quarantine threats is given the more intuitive label of 'QHAZ', or quarantine hazard analysis.

The PHA technique is likely to be more useful than a rigorous QHAZ analysis during the early development of quarantine barriers, when only conceptual or preliminary information is available. A PHA can contribute to the analysis and improvement of barriers to meet performance expectations at the early stages of development, as a precursor to QHAZ analysis when detailed designs become available. The PHA technique for quarantine threats is given the more intuitive label of 'PBA', or preliminary barrier analysis.

The combination of IMEA, QHAZ and PBA techniques appear to be the most appropriate methods for assessing the risk of introducing non-indigenous organisms to Barrow Island. To augment the IMEA, QHAZ and PBA techniques, it will be useful to reference any historical data and operating experience from other quarantine efforts (the last hazard evaluation technique listed in Table 4.1).

Details of the risk-based assessment methodology are described in Section 5 of this document.

[1] Collective advice of the Quarantine Expert Panel, 28 November 2003.

5 Risk-based assessment methodology

The framework for a risk-based assessment of the threat of introduced alien species is expressed with regard to AS/NZS 4360 in Figure 5.1.

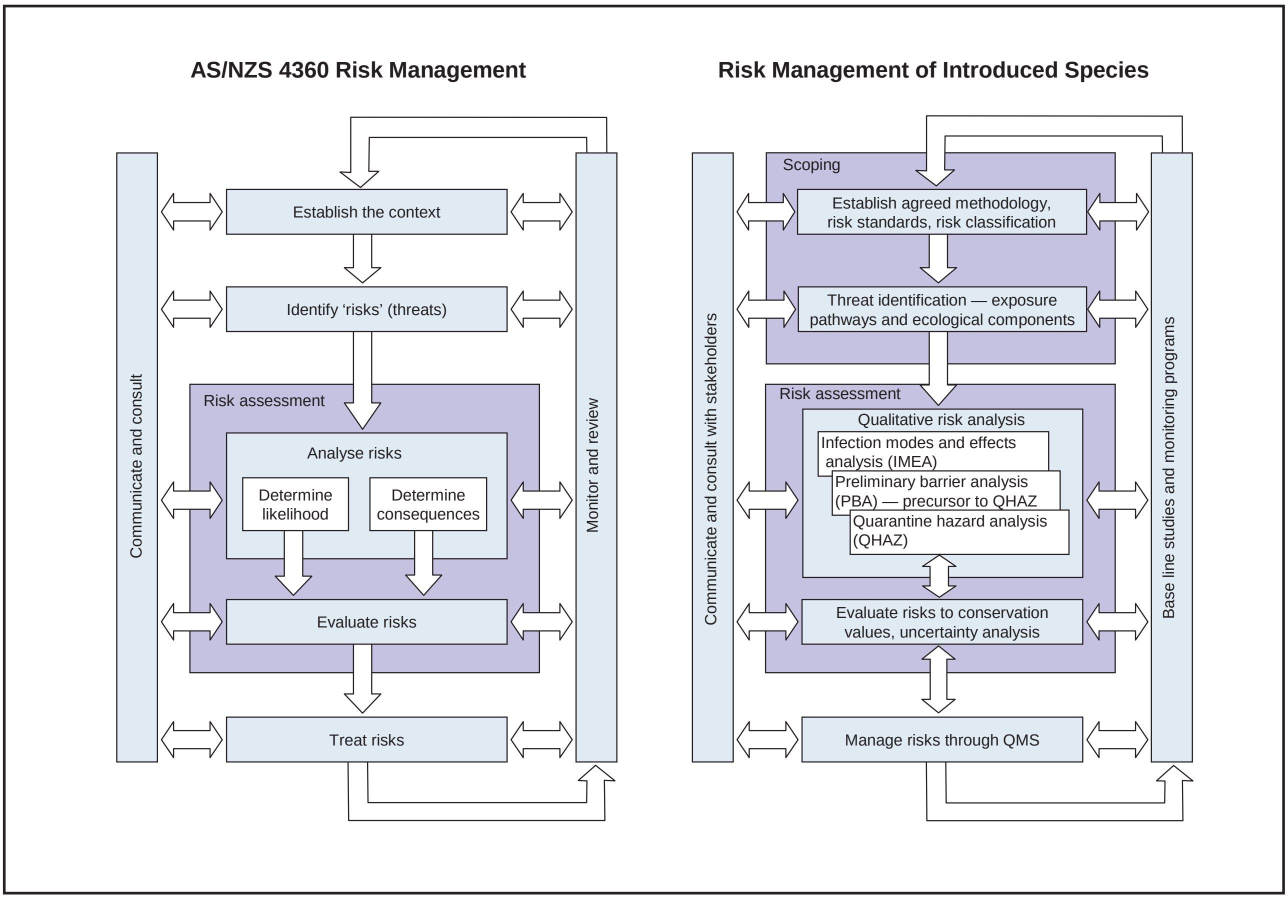

Figure 5.1 Comparison of risk management framework for introduced species to AS/NZS 4360.

To evaluate potential quarantine hazards, the following steps are taken to assist Gorgon to identify and design appropriate quarantine barriers, with clear emphasis given to pre-border prevention of introduced organisms:

1. Describe individual pathways for material and personnel movements from ports of origin to Barrow Island. These will include: types and quantities of materials (or people); layout of facilities used to receive, pack and ship consignments; steps and equipment used in the process of handling materials (or people); and a description of transport vessels (marine vessels, aircraft, trucks). Each pathway is to represent a potential threat of introducing non-indigenous species to Barrow Island, and may encompass different types of materials and equipment which would be subject to common handling and transport activities. Examples of personnel and commodity pathways are listed in Table 5.1. However, this list may grow as construction and operational activities are identified which entail new threats to be managed. In the first instance, these pathways might not include quarantine barriers to introduced species, to allow the workshop participants to identify infection scenarios and consider possible preventive measures.

2. Identify biological groups which may 'infect' materials (or people) handled on the subject pathway. These might include organisms which are present in the materials to be transported, or associated with the equipment and facilities where consignments are handled. An indicative list of biological groups is presented in Table 5.2 for reference.[2] Equally important in the preparation for hazard evaluation is to identify potential pest species (and propagules) which may exist at each port where materials and people are processed for departure. Lists of potential invasive species and biological groups should be sourced from specialists and museums with expertise in terrestrial and marine organisms of interest in Western Australia. These potential pest groups should include, but not be limited to, those listed in Table 5.2.

3. Prepare information for workshops which are to involve environmental specialists (with expertise in the relevant biological groups of concern), material handling and transport specialists familiar with existing operations, and an experienced facilitator. Information should include a description of activities unique to each pathway, and operational experience regarding the performance of quarantine controls for similar types of activities. This operational experience should be sourced from past Barrow Island oil asset activities as well as any broader quarantine experience (eg Australian Antarctic Division, Department of Defence, Australian Quarantine and Inspection Service, and international sources). Individual workshops may address one or more pathways and one or more biological groups.

4. Convene workshops and describe the pathways to all participants (types of materials and types of vessels), and agree on the components of the pathways which may be a source of 'infection' of introduced species. Explain the hazard evaluation procedure for all participants and clarify information on pathways.

5. Perform infection modes and effects analysis (IMEA) on all components of each pathway (refer to Section 5.2.1). Record details of how infections occur, existing safeguards, estimates of risk, and identify possible measures to prevent infections for consideration.

6. Describe conceptual quarantine barriers which could be considered to reduce risk, and undertake preliminary barrier analysis (PBA) of the barrier concept (Section 5.2.2). Re-evaluate risk based on the expected performance of the conceptual barrier.

7. Review and select appropriate barriers for detailed design, based on practicality and effectiveness for reducing risk.

8. Once the design of barriers is advanced to detailed plans, but prior to finalising the design for construction/implementation, undertake quarantine hazard analysis (QHAZ) to evaluate the design intention of selected barriers (Section 5.2.3). Identify improvements which will make barriers more effective. Re-evaluate risk based on expected performance of the barrier.

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[2] Prepared in consultation with the Quarantine Expert Panel, 22 January 2004.

Table 5.1 Conceptual list of potential introduction pathways for consideration in hazard evaluations (persons and cargoes, modes of transport).

▪ Personnel and accompanying luggage	▪ Aggregate, sand
▪ Personal goods consigned for transport	▪ Cement
▪ Skid equipment, accommodation units	▪ Plant, including earthmoving equipment and vehicles
▪ Pre-fabricated modules	▪ Pipe
▪ Food and perishables	▪ Steel
▪ Containerised goods	▪ Marine vessels, aircraft, road transport

Table 5.2 Conceptual list of biological groups for consideration in hazard evaluations.

Terrestrial groups	Marine groups
Vertebrates (eg mammals, birds, reptiles [snakes, geckoes], amphibians, fresh and brackish water fishes)	**Vertebrates** (eg fin fish, sea snakes)
Soil-dwelling invertebrates (eg arthropods [termites, worms]) **Above-ground invertebrates** (eg ants, terrestrial molluscs) **Subterranean fauna** (eg stygofauna [crustaceans, worms], troglofauna [insects, millipedes])	**Invertebrates** (eg molluscs, crustaceans, coelenterates [hydroids, jellyfish, corals], ascidians [sea squirts], worms, echinoderms [sea urchins, starfish], bryozoans)
Plants (vascular plants, non-vascular plants)	**Plants** (eg algae, sea grasses)
Micro-organisms (eg fungi, bacteria, viruses)	**Micro-organisms** (eg zooplankton, phytoplankton, fungi, dinoflagellates, bacteria)

A 'roadmap' of the risk assessment process, based on the approach described here is presented in Figure 5.2. An essential element of the process is the involvement of independent technical specialists to identify threats, recommend appropriate quarantine barriers, and estimate risk.

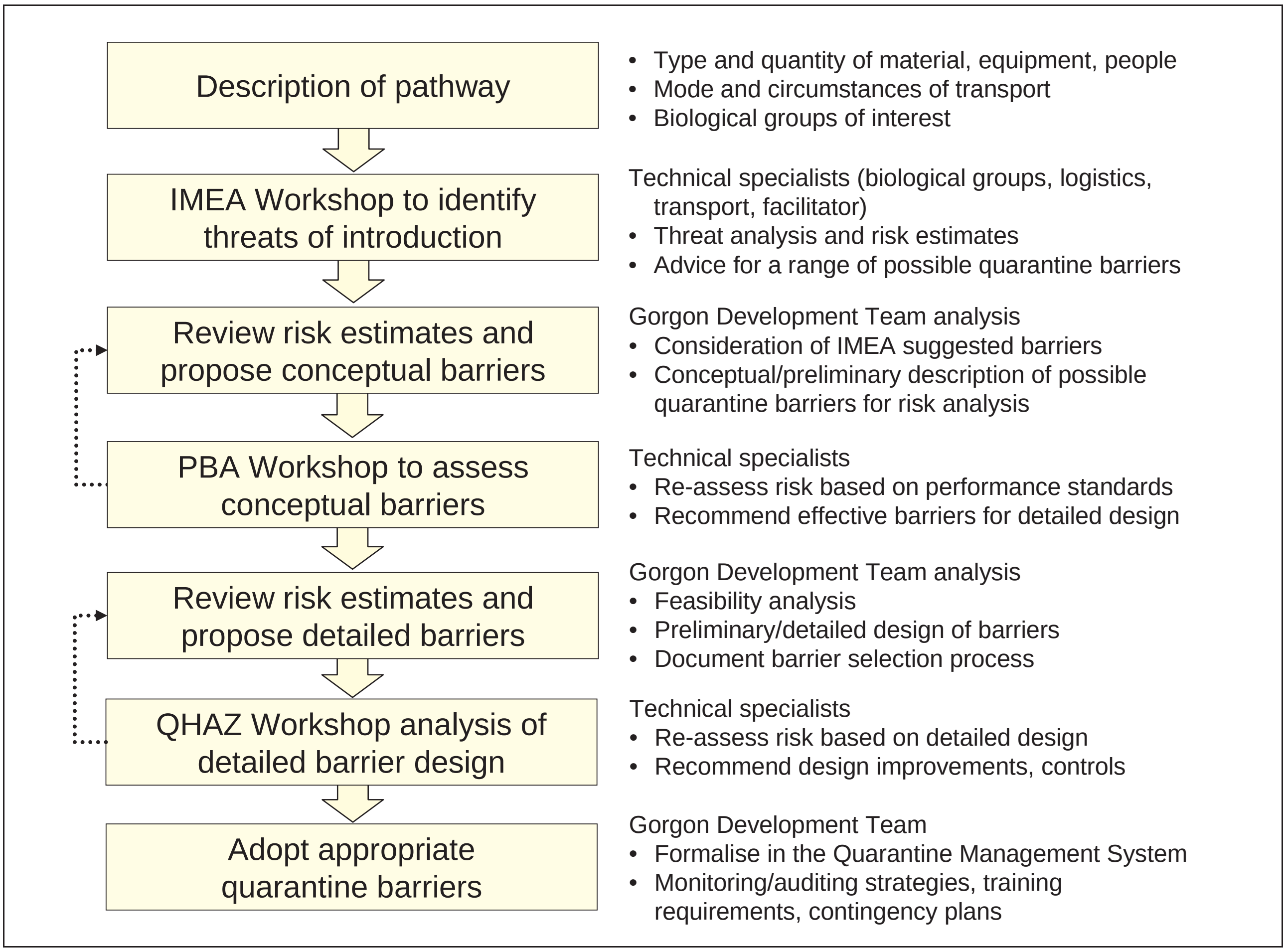


Figure 5.2 Roadmap of the risk assessment process.

5.1 *Establishing the context*

The context of the risk-based assessment is outlined in the guiding principles presented in Section 3 of this document. The selection of appropriate hazard evaluation techniques is discussed in Section 4.

The priority for quarantine management is to first prevent the arrival of infected cargoes, people and vessels at Barrow Island. For purposes of quarantine hazard identification and risk assessment, Barrow Island is considered the 'border' for introductions. The emphasis, then, is 'pre-border' prevention of introductions to the Barrow Island terrestrial and marine environment.

When considering pathways for the potential introduction of organisms, it is important to also acknowledge the potential for the arrival of organisms from natural processes and events (eg seabirds, regional marine currents, wind and cyclones).

5.2 Hazard identification

The IMEA technique has been applied to biological systems as a hazard identification tool for marine pests (Hayes 2002b), and has been selected for evaluating the hazards of introduced species to Barrow Island and the surrounding marine environment. There is also evidence that the QHAZ approach can be effectively applied to biological hazards (after the HAZOP application in RCEP 1991), when the intent of the system which manages those hazards can be fully described—the 'barriers' to introduction. The PBA technique can be used as a precursor to QHAZ analysis, to assist in the selection of effective barriers at the concept selection phase of development.

The methodology described here takes advantage of these three inductive analysis tools. The rationale for selecting these particular hazard evaluation tools is discussed in Section 4 of this document.

5.2.1 Infection modes and effects analysis

Borrowing the methodology from a proven hazard evaluation technique based on failure modes and effects analysis, or FMEA (CCPS 1992; Hayes 2002b), we can estimate the risk of invasion as a function of the likelihood of introduction, the likelihood of survival, the likelihood of detection, and the efficacy of eradication. The analogy to FMEA is an 'infection modes and effects analysis', or IMEA which is used here.

The term 'infection' represents the introduction of a introduced species on people or material any point along the exposure pathway between the port of origin and Barrow Island, analogous to 'contamination' which is more commonly used in the context of chemicals or waste material. IMEA is an inductive technique which allows a group of analysts working together to identify hazards and consequences which may be outside the professional experience of individual participants.

The first step in the IMEA is to identify the 'components' of each pathway which could be infected with alien species (introduced species which originate outside the Barrow Island environment). For coastal vessels (Hayes 2002b), examples of vessel components are the hull skin, propeller surfaces, bilges and anchor wells. Workshop participants should agree on a suitable organisation of components. For example, in the case of marine vessels, it may be more convenient to organise components around dry 'zones' of vessels, splash zones, wet zones, and seabed contact. Infection modes are identified for each of these components, with reference to biological groups. The infection modes for anchor wells, for example, might be retained water and retained sediment which contains live organisms or propagules. The surface of a timber hull component has three infection modes: external fouling, internal fouling, and borers.

The IMEA considers the possible infection modes of the 'components' of material and transport vessels, the survival of biological groups during the journey to the recipient port, the ability to detect an introduction, and the predicted success of response measures to control and eradicate the introduced species or biological group. Each component/infection mode combination is subject to the IMEA hazard evaluation, leading to a potentially large number of specific hazards identified for risk assessment.

Based on the analysis of a team of technical specialists, the potential effects of infections, or introductions, can be estimated qualitatively using a scoring system. The likelihood of introduction at the recipient port, the likelihood of survival, the likelihood of detection, and the likelihood of eradication can be scored, each on a scale of 1-10. An example of such a scoring system used for ballast water risk assessment is suggested by Hayes (2002b), and is adapted for the current objectives in Table 5.3. In some cases, technical experts with knowledge of specific biological groups may be unable to estimate the likelihood of survival due to technical uncertainty associated with the complexity of ecological systems.

Table 5.3 Scoring system for infection modes and effects analysis.

Pre-border quarantine		Post-border quarantine		Score
Infection	**Survival**	**Detection**	**Eradication**	
The infection is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect early enough to consider eradication strategy.	Virtually certain to eradicate without significant impacts to the native environment.	1
The infection is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection early enough to consider eradication strategy.	Very high likelihood of eradication without significant impacts to the native environment.	2
There is a slight chance of infection.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection early enough to consider eradication strategy.	High likelihood of eradication without significant impacts to the native environment.	3
There will be a small number of infections each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection early enough to consider eradication strategy.	Moderate chance of eradication without significant impacts to the native environment.	4
An occasional number of infections are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection early enough to consider eradication strategy	Medium chance of eradication without significant impacts to the native environment.	5
Infections have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection early enough to consider eradication strategy.	Low chance of eradication without significant impacts to the native environment.	6
Infections occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection early enough to consider eradication strategy.	Slight chance of eradication without significant impacts to the native environment.	7
There is a high occurrence of infections each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection early enough to consider eradication strategy.	Very slight chance of eradication without significant impacts to the native environment.	8
There is a very high occurrence of infections each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection early enough to consider eradication strategy.	Remote chance of eradication without significant impacts to the native environment.	9
Infections occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect early enough to consider eradication strategy.	Almost impossible to eradicate without significant impacts to the native environment.	10

Judgments regarding the likelihood of eradication may incorporate the likelihood of isolating and controlling an introduced species if eradication is difficult to achieve. An example is the current situation of buffel grass on Barrow Island, which is considered a pest weed but has been isolated to locations where it is being controlled.

In the first instance, the scoring of infection, survival, detection and eradication may be made without regard to current material handling and quarantine management practices. Existing safeguards, as they relate to individual infection modes, may be discussed in order to suggest preventive measures. However, it is not the intention to adopt all existing safeguards without considering innovative types of quarantine barriers to prevent the introduction of organisms. In cases where performance data from other quarantine operations is available to the workshop participants, it should be used to predict the efficacy of preventive measures which might be considered for Gorgon development activities.

Scoring should be undertaken with regard to the biological groups of interest. It may be convenient to select an 'indicator species' or subgroup for the purpose of scoring, with the intent of choosing one or more known species which represent a more acute invasion hazard. Whenever this approach is taken, the species considered in the scoring is recorded in the workshop record, with the intent of assessing risk in a manner which does not underestimate the hazards of the wider biological group.

The infection scores in Table 5.3 represent a qualitative range of likelihoods that cargoes, people or vessels will be infected with non-indigenous organisms. While there may be the possibility of technical experts interpreting the qualitative infection scores slightly differently among themselves, there is clearly more variability in the scores due to the range of organisms which are the subject of these judgements. Perfectly consistent interpretation of each scoring level is desirable if sufficient data were available to guide judgments of the likelihood of infection. In the more realistic situation of having limited data (typical in the analysis of ecological systems), participants in the IMEA workshop assign maximum and minimum scores for infection, survival, detection and eradication to each of the infection modes, as illustrated in Figure 5.3. The recording of maximum and minimum scores reflects the uncertainty of participants to precisely estimate these likelihoods in the risk analysis.

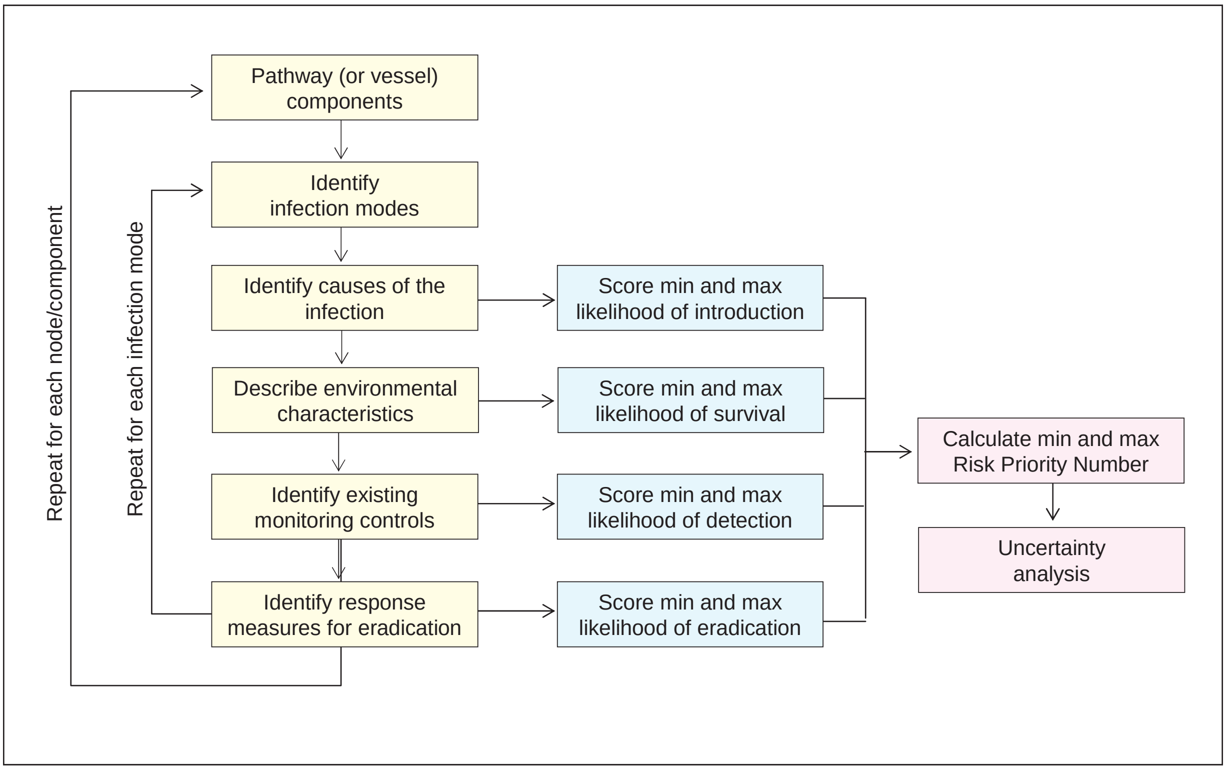


Figure 5.3 IMEA hazard evaluation and scoring process.

Workshop experience has indicated that the range of scores recorded by one group of participants is generally adopted by subsequent workshop participants. Although there are no direct precedents for interpreting scores for quarantine threats, several technical experts have attended multiple workshops (14 specialists have attended more than one workshop through April 2005, and of those 12 have attended three to eight workshops). The repeated involvement of these independent specialists has set a *de facto* standard for applying the scoring system which is recorded and communicated to subsequent workshop participants. Reports of the early workshop records have been made available, and community stakeholders have been invited to attend these workshops as observers. Workshop facilitators have observed that participants have embraced the scoring system shown in Table 5.3, particularly when uncertainty is captured in the recording of maximum and minimum scores.

An IMEA workshop is primarily focused on the infection of cargoes and the survival of organisms prior to arrival on Barrow Island, which is considered the 'border' for quarantine purposes. Unless details of monitoring and eradication strategies are known, estimates of detection and eradication are deferred for later analysis. Thus, the IMEA workshop is primarily interested in the 'pre-border' prevention of infections at the early stages of pathway analysis.

Detection and eradication are 'post-border' activities to prevent invasions, and are taken to be independent of specific terrestrial or marine pathways of introduction. An analysis of post-border monitoring strategies is necessary to estimate risk scores for detection and eradication. It should be noted that eradication may only be an option when detection occurs early enough to contain and control an organism before it is able to establish a wide spatial distribution or monoculture, and when the environmental impacts (eg collateral damage to the native environment) of eradication are acceptably low.

From the IMEA score of infection and survival a Risk Priority Number (RRN) can be calculated to compare the relative magnitude of each hazard (Hayes 2002b). Analysis of risk using the RPN results from the IMEA analysis is discussed in Section 5.3. The RPN is not a risk level, only a relative indication of hazards which may require high priority for preventive measures or corrective action.

Information captured from an IMEA workshop is recorded in a format under the types of headings shown in Table 5.5. Existing safeguards with regard to each infection mode are noted, as are any preventive/corrective measures which are suggested by the IMEA participants. If adoption of any specific preventive/corrective measures clearly reduce the likelihood of the infection or survival of an infection mode, this information can also be recorded in the meeting record.

Table 5.4 Example of information captured in an IMEA analysis.

Pathway: P1. Pre-packaged material received at Welshpool for transport to Barrow Island by container vessel.						
Component: C1. Packed sea container.						
IMEA ref no	**Infection mode**	**Effects**	**Existing safeguards**	**Score (min, max)**		**Preventive/ corrective measures**
				Infection	**Survival**	
1	Internal entrainment	Viable arthropod larvae (ants) released.	None.	3, 4	4,6	Train personnel to recognise larval stages of organisms.
2		Viable weed propagules (kapok) released.	None.	5, 8	7, 9	Detain containers in isolation area for inspection by trained personnel. Infection improved to 3, 4
…						

The IMEA does not attempt to predict the ecological impacts of an introduced species which may have the ability to thrive and reproduce in the Barrow Island terrestrial or marine environment. Such predictions cannot be made with confidence for all biological groups.[3]

5.2.2 Preliminary barrier analysis

The PBA hazard evaluation technique is used early in the concept selection phase, when possible quarantine barriers are being considered for reducing the risk of introductions on specific exposure pathways. The PBA is a means of identifying critical requirements for effective barriers early in the selection process, and is a precursor to a more rigorous QHAZ analysis of design details when they become available.

To conduct the PBA early in the concept selection phase of barrier design, a preliminary description of the proposed barrier must be developed to the extent possible. This may include layout of proposed facilities, examples of comparable equipment and processes used elsewhere, and reference to relevant standards and practices. A workshop of technical specialists is convened to assess the effectiveness of contemplated barriers for specific pathways (referred to as a 'barrier workshop'). Workshop participants are invited on the basis of their experience and ability to explain the technical application of the barriers, logistics aspects of the pathways, and expertise in the biological groups which are targeted by the barriers under consideration.

The purpose of the PBA is to utilise the experience of technical specialists to identify how contemplated quarantine barriers might fail to prevent the infection of cargoes. The causes and effects of potential breaches are evaluated against planned safeguards, and similar to the IMEA technique, qualitative judgments of the likelihood of infection and survival of organisms is recorded.

The results of the PBA are captured in a database, using a reference numbering strategy which identifies contemplated barriers which are applicable to specific steps in an exposure pathway. Information is recorded in a format under the types of headings shown in Table 5.5. The example reflects the early concept selection phase, where the contemplated barrier is described at a conceptual level.

Table 5.5 Example of information captured in a PBA workshop.

Barrier: B1. Kitchen containment facility.					
Pathway steps: S5. Receiving food and perishables from trucks at the loading dock. S6. Unpacking and transfer to food storage locations.					
Ref no	**Potential quarantine breach**	**Causes**	**Consequences**	**Existing safeguards**	**Preventive/ corrective measures**
1	High pressure washing removes chemical treatment of surfaces.	Untreated habitat suitable for invertebrates.	Survival of invertebrates.	None.	Chemical treatment regime.
2	Live invertebrates undetected in transport container.	Incomplete selection of traps, or wrong specification.	Failure to trap invertebrates of concern.	Live trapping and baiting stations on barges.	Obtain expert advice on trap selection.
…					

[3] Collective advice of the Quarantine Expert Panel, 28 November 2003.

5.2.3 Quarantine hazard analysis

A QHAZ technique is used to systematically identify deviations from intended activities which are designed to prevent the infection of materials and personnel arriving at Barrow Island. To conduct a QHAZ, it is first necessary to construct a detailed description of the 'nodes' in the flow of materials and personnel from their port of origin. The analogy to industrial systems, where HAZOP analysis is common practice, is the 'process flow diagram'. It is anticipated that a single port (eg Welshpool, Dampier, commercial airports, outlying islands) will have one or more discrete pathways for the handling of various types of materials and people. Each pathway must be fully described in terms of the processing steps from the arrival of materials and people at the port, to departure for their destination. The description of the flow of materials and personnel used in the pathways for the IMEA is likely to be the starting point, which may be updated as the project develops.

The QHAZ analysis further requires a description of the proposed quarantine barriers (inspection, cleaning, testing, baiting, fumigation, chemical treatment, etc) which are to be applied at various nodes (steps) in the flow of materials and personnel. At the early stages of the project, barriers may be described at a conceptual or preliminary level, where a PBA (Section 5.2.2) is undertaken to assist with evaluating the efficacy of the proposed barrier. As the project develops and more detail becomes available on the design of quarantine barriers, a detailed QHAZ analysis can be undertaken.

Equally important in the preparation for QHAZ analysis is to identify potential pest species (and propagules) which may exist at each port where materials and people are processed for departure. Lists of potential invasive species and biological groups should be sourced from specialists and museums with expertise in terrestrial and marine organisms of interest in Western Australia. These potential pest groups should include, but not be limited to, those listed in Table 5.2.

Once the pathways and barriers are fully described, the QHAZ analysis can be conducted to identify potential hazards arising due to deviations from the intended activities involved at each barrier (eg fumigation of sea containers). The QHAZ analysis relies on having a small group of the 'right people' involved, facilitated by an experienced risk assessor. Workshops should be organised to focus on complete pathways with expertise available for a variety of biological groups, and should include about 4–8 selected technical specialists and operational personnel to be effective.

Guide words are used to trigger the discussion of deviations from the intended activities at each barrier, with regard to the potential infection of materials and personnel by various organisms. The QHAZ facilitator uses guide words to prompt an inductive type of analysis of how planned activities could deviate from their intended actions or results. Suggested guide words which may be used in the QHAZ analysis are listed in Table 5.6, drawing on the experience of the author and other workers (RCEP 1991; CCPS 1992).

Table 5.6 Suggested QHAZ guide words for evaluation of introduction pathways.

▪ More than	▪ Incomplete	▪ Where else
▪ Less than	▪ Reverse	▪ When else
▪ Other than	▪ No verification	▪ Wrong time
▪ As well as	▪ Part of	▪ Wrong place
▪ Not enough	▪ Lack of	

The results of the QHAZ analysis are captured in a database, using a reference numbering strategy which identifies pathways and nodes. Information is recorded in a format under the types of headings shown in Table 5.7. The example reflects an advanced stage of design, where it is possible to analyse the performance of the proposed quarantine barrier in detail.

Table 5.7 Example of information captured in a QHAZ analysis.

<table>
<tr><td colspan="7">Pathway: P1. Pre-packaged material received at Welshpool for transport to Barrow Island by container vessel.</td></tr>
<tr><td colspan="7">Pathway step: S1. Fumigation of packed container at contractor premises, prior to transport to wharf.</td></tr>
<tr><th>Ref no</th><th>Guide word</th><th>Deviation from intended action</th><th>Causes</th><th>Consequences</th><th>Existing safeguards</th><th>Preventive/ corrective measures</th></tr>
<tr><td>1.1</td><td rowspan="3">Not enough</td><td rowspan="3">Insufficient mass of fumigant injected into sea container.</td><td>Failure of gas delivery timer or solenoid delivery valve.</td><td rowspan="3">Arthropod larvae and weed propagules remain viable.
Not immediately evident that fumigation was only partially effective.</td><td>None.</td><td>Test gas delivery timer and valve prior to each fumigation event.</td></tr>
<tr><td>1.2</td><td>Wrong (lower) concentration of fumigant from supplier</td><td>Gas bottles marked with concentration of fumigant.</td><td>Require supplier to perform quality assurance testing.</td></tr>
<tr><td>1.3</td><td>Slow leakage of gas from container</td><td>Visual inspection of containers for damaged seals prior to use.</td><td>Perform monthly integrity testing of container seals.</td></tr>
<tr><td>…</td><td>…</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

It is desirable to estimate the likelihood of infection during the QHAZ analysis of deviations from planned activities. Estimates of likelihood can be supported by incident/near miss data when it is available, performance data from other quarantine operations, or by the judgment of participants in the workshop.

In the case of biological infections of materials or personnel processed at a port, such estimates are likely to be a difficult task. The main purpose of the QHAZ, then, is to identify the circumstances of infection hazards at a donor port with regard to planned barriers, and to utilise the expertise and operating experience of the participants to suggest possible preventive/corrective actions.

Preventive/corrective actions are recorded without prejudice to reduce either the likelihood of the deviation and/or the severity of the consequences. These suggestions for improvement of the barriers are then available in the risk management step (Section 5.5), to identify the appropriate management controls which could be implemented to reduce risk to acceptable levels.

5.3 Risk and uncertainty analysis

Borrowing from the risk of introducing non-indigenous species in ballast water (Hayes & Hewitt 2000), and using the analogy of biological groups which may be represented by an indicator species, the risk of introduction can be estimated on the basis of a combined probability:

$$Risk_{\text{int}\,roduction} = p(\omega) \cdot p(\phi) \cdot p(\psi) \cdot p(\upsilon) \quad [1]$$

where: p(ω) is the probability that the donor port is infected with the organism;

p(ϕ) is the probability that the vessel (or aircraft) becomes infected with this organism;

p(ψ) is the probability that the organism survives the vessel's journey; and

p(υ) is the probability that the organism will survive in the recipient port—Barrow Island.

Note that this combined probability does not attempt to predict the potential establishment and persistence of an introduced alien species in the native environment of Barrow Island. In the first instance, we seek to estimate only the likelihood of introduction.

The first two terms, p(ω) and p(ϕ) can be estimated from information on potential pest organisms found at each port (using existing databases, expert knowledge and stakeholder input), and a rigorous hazard evaluation of activities at each port. These estimates rely on information generated by a QHAZ analysis, conducted with regard to individual pathways where living organisms and viable propagules could be loaded onto vessels for transport to Barrow Island.

The IMEA carries these risk estimates forward, and estimates the last two terms of the risk of introduction, p(ψ) and p(υ). If fully quantitative estimates were possible for all four terms, then a probabilistic risk could be calculated for the introduction of alien species to Barrow Island. In the absence of data to support fully quantitative risk estimates, we can adopt a semi-quantitative approach using the IMEA scoring system (Table 5.4) suggested by Hayes (2002).

Using the IMEA scoring system to allow analysts to estimate the potential effects of infection modes, a Risk Priority Number (RPN) can be calculated when the likelihood of survival can be estimated:

$$RPN = IntroductionScore \cdot SurvivalScore \quad [2]$$

The range of the RPN is therefore 1-100.

It may be useful to capture the maximum and minimum scores among participants for each IMEA workshop, and to average the minimum and maximum scores which might be estimated by separate groups of workshop participants (n>1):

$$RPN_{\min} = \frac{1}{n}\left[\sum_{i=1}^{n}(MinIntroductionScore_i \cdot MinSurvivalScore_i)\right] \quad [3]$$

$$RPN_{\max} = \frac{1}{n}\left[\sum_{i=1}^{n}(MaxIntroductionScore_i \cdot MaxSurvivalScore_i)\right] \quad [4]$$

Such an approach enables the risk assessor to capture a range of scores and to measure variance in the risk estimates of separate groups of participants, or even among individuals in a single workshop (although the data processing task could be significant).

The range of maximum and minimum RPN's indicate the variability in the participants risk estimates, and is therefore an indication of uncertainty in the risk estimates. The variance of individual scores (x_i), compared to the overall average of all minimum and maximum scores ($\bar{x}$), yields a measure of variance (σ):

$$\sigma = \frac{\sum_{i=1}^{2n}\left(x_i - \bar{x}\right)}{2n-1} \quad [5]$$

where: x_i are the maximum and minimum scores, requiring the sum over 2n.

5.4 Risk standards

The EPA in its advice to government on the proposed development of a gas plant on Barrow Island (EPA 2003) stated: "The proponent be required to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island. Such a process should include appropriate technical experts and be structured to ensure a high level of transparency and community involvement."

To fully address the EPA advice to government (EPA 2003), risk reduction strategies (quarantine barriers) should also meet or exceed current best practice. In this regard, risk is reduced to a level 'as low as reasonably practicable', or ALARP, in accordance with AS/NZS 4360 for risk management.

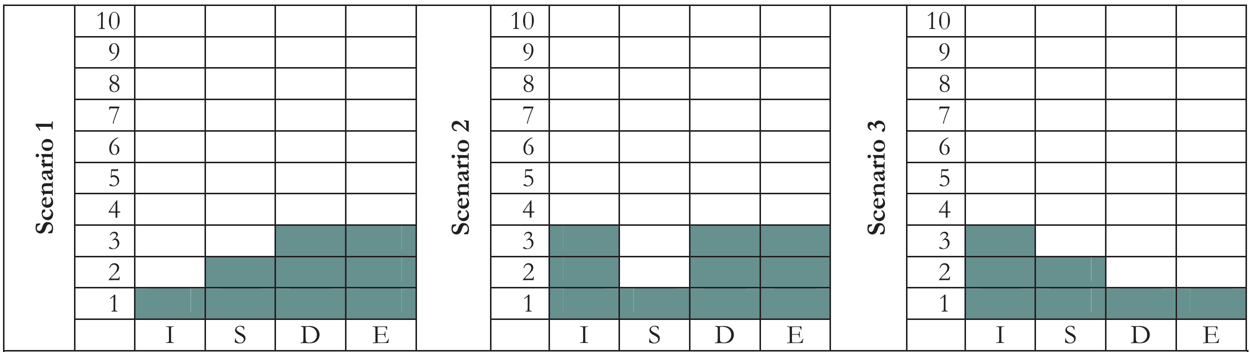
The development of standards for acceptable risk has included the involvement of technical experts and significant community consultation. Community stakeholders on the development of standards for acceptable risk "…proposed that consequences which resulted in the ***establishment*** of an introduced species would be unacceptable" [emphasis added] (Bowen 2004).

While 'establishment' of a species may be an ideal endpoint for risk assessment, the complexity of ecological systems prevents us from making qualitative or quantitative estimates of establishment (refer to Section 3). The prevention of establishment is expressed in terms of the operational endpoints of introduction, survival, detection and eradication. As such, standards for acceptable risk relate to these operational endpoints, as defined by the scoring system in Table 5.3.

Where the IMEA, PBA and QHAZ techniques seek to estimate the likelihood of infection at any pathway step, an overall likelihood of introduction is needed to address risk standards, as a result of qualitatively combining the likelihoods of infection at each step. The analogy in quantitative risk analysis is the calculation of conditional probability (refer to Section 5.3, Equation [1]). It may be possible to use decision rules to combine qualitative estimates of infection, based on the proposition that the residual likelihood of introduction along the overall pathway must be less than the likelihood of infection at any particular step. This would be the case as long as cargo, people and vessels were not threatened with re-infection along the pathway, such that the barriers were only as good as those applied at the very last pathway step prior to arrival at Barrow Island.

5.4.1 Community involvement

Community involvement in the setting of standards for acceptable risk resulted in a proposition that certain combinations of risk estimates could represent risk standards which are acceptable to the community (from the definitions in Table 5.3, where 'introduction' on the overall pathway is substituted for 'infection' at any particular pathway step). While the details are not formally endorsed by all community stakeholders, the proposed scenarios summarised in Figure 5.4 were recognised as the key outcomes of community involvement in this process. Scenarios 1, 2 and 3 are listed in decreasing order of importance to community stakeholders, consistent with the emphasis on the prevention of introductions.



Note: Community expectation of the range of acceptable scores.

Scoring on the vertical axis of each matrix (1-10) is defined in Table 5.3 of this document.
Scenarios 1, 2 and 3 are presented in decreasing order of importance to community stakeholders.

I = Introduction
S = Survival
D = Detection
E = Eradication

Figure 5.4 Community expectations for acceptable risk (Bowen 2004).

The community expectations for acceptable risk were constrained to terrestrial flora and fauna. It was suggested that the scenarios shown in Figure 5.4 were not applicable to micro-organisms or marine introductions.

5.4.2 Consideration of community expectations for acceptable risk

Notwithstanding the primary objective of preventing pre-border infections of cargoes and people, the risk assessment process should address both border and post-border quarantine threats with regard to the introduction of a species to the native environment on Barrow Island. It will be possible to re-assess risk estimates, or to combine risk estimates on each pathway if the overall risk of introduction is conditional on an organism 'slipping through' a number of quarantine barriers.

Analysis of the food and perishables pathway is the most convincing argument for *border* and *post-border* quarantine arrangements when setting standards for acceptable risk. This is because food and perishables obviously consist of plant matter and may harbour invertebrate organisms which are difficult to entirely eliminate. The risk of having food and perishable cargoes infected with invertebrates and plant propagules can only be assessed in the context of a border containment and eradication facility. The detection and eradication of any organisms which might escape the border containment facility (post-border quarantine) should also be considered. Border and post-border quarantine arrangements for organisms arriving at Barrow Island may be quite independent of the pathways through which they were introduced.

A risk analysis which considers pre-border, border and post-border quarantine barriers may meet community expectations for acceptable risk (the 'green' region of the risk scores shown in Figure 5.4). A rationale for accepting risks just outside the community's acceptable risk region of Figure 5.4 would be to acknowledge that, in general, the risk of post-border establishment in the native environment is going to be lower than the risk of pre-border introduction, and to provide for workable detection and monitoring strategies in any case.

For threats of introductions which carry a residual level of risk that exceeds the community expectations, the Quarantine Management System would be required to demonstrate that the barriers adopted for that pathway exceed current best practice, and that there are no other practicable measures suggested by independent technical experts which could be adopted to further reduce risk. In this case, risk would be reduced to a level 'as low as reasonably practicable', or ALARP, as described in AS/NZS 4360 for risk management. In Biosecurity Australia terms, the quarantine threat would be addressed with an 'appropriate level of protection', or ALOP (Biosecurity Australia 2003).

Once barriers are adopted and documented in design guides or specifications, a risk assessment (PBA or QHAZ) workshop of independent technical specialists, experienced construction and operational specialists and designers is convened to confirm that the proposed barriers can be implemented and will function as intended (Figure 5.2). This step verifies that attention has been given to an effective number of risk reduction strategies identified during the risk assessment process and review of best practice, and that risk is reduced to ALARP. It is also an opportunity to fine tune the design guides or specifications to improve the implementation and performance of adopted barriers.

The test for reducing risk to an acceptable level is to demonstrate that quarantine barriers can be implemented, that the barriers will perform as expected, and that the barriers are sustainable for the duration of the activity they are designed to manage. The involvement of technical experts in various biological disciplines ensures that quarantine barriers will work as intended. The Quarantine Management System ensures that the adopted quarantine barriers are sustainable, and that their performance is regularly reviewed and improved.

5.4.3 Marine organisms

The community expectations for acceptable risk were not considered to be applicable to micro-organisms or marine introductions. In the marine environment, the prevention of introductions from sources independent of the proposed Gorgon Development is an impossible task (eg regional ocean currents, littoral drift, seabirds, cyclonic events). In addition, there are few examples of eradicating marine invasions (URS 2003; McEnnulty *et al* 2001). The distribution of marine organisms in North West Australia typically occurs over hundreds of kilometres, compared to the limited spatial distribution of terrestrial organisms on Barrow Island. Non-indigenous species established in the region can spread to other suitable habitats as a result of planktonic larval reproductive stages common to numerous species. It is also apparent that non-indigenous species establish new populations where they can exploit a suitable ecological niche in a natural or disturbed environment.

Community expectations for acceptable risk, based on terrestrial flora and fauna, are problematic for the waters surrounding Barrow Island when non-indigenous species could arrive quite independently of proposed Gorgon Development activities. Risk standards for marine organisms then, would emphasise prevention of introductions, focussing on risk reduction measures which meet or exceed best practices, and an appropriate range of barriers suggested by technical specialists to demonstrate that risk is reduced to ALARP.

5.4.4 Micro-organisms

In the case of micro-organisms it is not practical to attempt to prevent all introductions, as a very wide range of micro-organisms will be routinely carried by people and cargoes. It is recognised that the taxonomic identification of the vast majority of micro-organism species is not available, however information exists on known pathogens that could be associated with specific cargoes and people.

In the investigation of wildlife mortality events where disease was the suspect causal agent, it is not always possible to identify the infecting micro-organisms with certainty (Anon 2001). It is constructive to engage technical experts to review specific micro-organism threats to Barrow Island, and to suggest strategies for the prevention of known pathogens in cargoes and people.[4] The risk standard for micro-organisms would focus on risk reduction measures for pathways which could be infected with specific pathogens, and specific risk reduction measures to prevent the spread of disease to wildlife suggested by technical specialists. Risk reduction measures would be expected to meet or exceed best practices, incorporating an appropriate range of barriers to demonstrate that risk is reduced to ALARP.

5.5 Risk management

All information generated from the hazard identification and risk assessment process is to be captured in a Risk Register, in accordance with AS/NZS 4360 for risk management. The purpose of the Risk Register is to make the risk profile of various activities visible to the risk manager and stakeholders, and to enable the risk manager to monitor the implementation and efficacy of risk reduction strategies.

High risk pre-border infection modes (those with high combined introduction, survival, detection and eradication scores) should receive first priority for hazard management, followed by medium risk infection modes. In general, the risk management strategy should give attention to (in order of importance):

1. Eliminating the likelihood of introduction;
2. Reducing the likelihood of introduction;
3. Reducing the likelihood of survival;
4. Improving detection methods; and
5. Improving control and eradication responses to introduction.

[4] Collective advice of the Quarantine Expert Panel, 18 March 2004.

The first priority of quarantine management is to prevent the introduction of species from arriving on Barrow Island. As such, risk assessment workshops initially focus on *pre-border* quarantine threats and barriers to assess the likelihood of the arrival of an introduced species on Barrow Island. Pre-border quarantine management and quarantine barriers on pathways of exposure are not likely to prevent the arrival of introduced species in all cases, in spite of a rigorous Quarantine Management System (QMS).

The likelihood of survival at the border, and post-border detection and eradication of an introduced species is given consideration in the risk-based assessment of quarantine management. This addresses the community expectation that consequences which result in the establishment of an introduced species would be unacceptable. Establishment is prevented from the application of pre-border, border and post-border quarantine management practices.

In cases where risks cannot be further reduced to meet the community expectations for acceptable risk (Figure 5.4), the QMS would be designed to ensure that risk is reduced to ALARP and that risk management is consistent with best practice approaches. The QMS would require that monitoring programs and contingency plans are developed to detect introductions of relevant biological groups (and particularly known invasive species) early enough to formulate a response.

Quarantine threats identified from the risk assessment process and the barriers adopted to reduce risk to ALARP are captured in the Risk Register. Design guides and performance specifications for each type of adopted quarantine barrier are to be developed. The QMS is to be used by the Gorgon Joint Venture, its contractors and suppliers to develop specific designs, procedures, processes and programs for managing quarantine threats to Barrow Island.

6 Future direction

With additional data from monitoring activities and specialist studies of potentially invasive species, it may be possible in the future to incorporate estimates of the likelihood of an introduced population persisting, competing for habitat, and becoming predators of native species. Further understanding of detection and control measures may allow better estimates of the likelihood that introduced species can be contained and eradicated. And finally, improved understanding of the ecology of Barrow Island might even allow estimates of the likelihood that native species will recover following eradication of an alien species. As further information becomes available in the longer term, it will be desirable to incorporate these types of factors into the hazard evaluation and risk analysis of introduced species.

Development of a world-class Quarantine Management System for Barrow Island will involve continuing baseline and investigative studies of the ecology of the Island and surrounding waters, development of specific management plans, mitigation strategies, monitoring and auditing programs, and communication with stakeholders. As these aspects of the Quarantine Management System evolve, they will be both guided by the outcomes of a risk-based assessment of quarantine hazards, and will provide new information for revised estimates of risk in a continuous process of re-evaluation and improvement.

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Technical Appendix D3

Report to the Community Consultation Meeting on the Risk Standards Workshops

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

REPORT TO THE COMMUNITY CONSULTATION MEETING ON THE RISK STANDARDS WORKSHOPS

TECHNICAL APPENDIX D3

Prepared for:

ChevronTexaco Australia Pty. Ltd.
250 St Georges Terrace
PERTH WA 6000

Prepared by:

Dr. Bernard Bowen
Chairman,
Barrow Island Quarantine Risk Standards Workshops

August 2004

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Barrow Island Quarantine

Report to the Community Consultation Meeting on the Risk Standards Workshops

By Bernard Bowen

1 PREFACE

The Chairman of the Risk Standards Workshops, Bernard Bowen, provided a report on the outcomes of the Workshops to the Community Consultation Meeting on 16 June 2004. The report was discussed and there was broad agreement that the advice from Workshop #3 represented the views of the Community Consultation Meeting. However, during the course of the discussion some suggested changes to the layout of the report were proposed and agreed upon. Also, some additional information from the Records of the Workshops needed to be included in the report.

During the discussions the point was made, quite properly, that those who attended both the Workshops and the Community Meetings did so as individuals and thus the views expressed should not be read as representing one way or the other the views of the organisation with which they were associated. Also, the discussions should not be interpreted as all participants necessarily being in agreement.

The meeting agreed that the Chairman of the Community Consultation Meeting, Bernard Bowen, would amend his report and distribute it to those attending the Meeting for checking. He would then transmit the amended report to the Gorgon Joint Venture and to the Environmental Protection Authority.

The amended report is set out below.

2 INTRODUCTION

As Chairman of the Risk Standards Workshops I have pleasure in providing this report which brings together the outcomes of the three Workshops held on 10 March, 21 April and 12 May 2004.

The Workshops were held as a result of discussions at the Barrow Island Quarantine Community Consultation Meeting held on 18 February 2004. The purpose of the Workshops was to provide a forum for discussing and progressing advice on a set of standards for acceptable risk to the conservation values of Barrow Island.

This report provides a brief overview of the outcomes of the three Workshops, describes a proposed risk standards framework, sets out the advice flowing from Workshop #3, and provides advice from the Community Consultation Meeting held on 16 June 2004. A copy of the Meeting Record is attached (Appendix 1). Also attached are copies of the Records of the three Workshops (Appendix 2).

3 THE WORKSHOPS

The report of Workshop #1 (10 March 2004) was presented to the Community Consultation Meeting held on 20 April 2004. The reports of Workshop #2 (21 April 2004) and Workshop #3 (12 May 2004) formed part of the documentation attaching to the Agenda for the Community Consultation Meeting held on 16 June 2004. (Note: copies of the Workshop Records are provided in Appendix 2).

Participants are encouraged to read the full text of the reports of the three Workshops to gain a better understanding of the views expressed and the development of the set of standards. However, the main outcomes of the Workshop discussions were:

- Workshop #1:
    - Discussion firstly focussed on the consequences of introductions, noting that in practical terms zero introductions would not be achievable.
    - Consequences which resulted in the establishment of introduced species would be unacceptable.
    - Judgements were needed about acceptable risks in relation to the likelihood of introductions, survival, detection and eradication such that the establishment of a species would not occur.
    - Developed a Risk Standards Framework comprised of three scenarios which form the Framework package.
- Workshop #2:
    - Progressed the discussions of the Risk Standards Framework taking into account the advice provided by the Community Consultation Meeting of 20 April 2004.
    - Requested some additional information and agreed to meet again on 12 May 2004.
- Workshop #3:
    - Clarified the priority use of the draft Risk Standards Framework, noting that the Gorgon Joint Venture has a goal of no introduced species on Barrow Island and in surrounding waters.
    - Agreed, with a small number of participants abstaining, that the risk of establishment of introduced species is acceptably low if it conforms to the Risk Standard Framework, but noting that the risk needs to be considered in the priority order discussed in the Workshop.
    - Established some constraints on the use of the Framework.

4 THE PROPOSED RISK STANDARD FRAMEWORK

The proposed Risk Standard Framework is set out below, followed by a number of constraints on the use of the Framework.

The Environmental Protection Authority set out in its Bulletin 1101 that "The proponent be required to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island". As set out in Workshop #1, the Framework has three scenarios which form a package for the 'set of standards for acceptable risks'.

The risk scoring profiles referred to in the Framework are those used in Table 5.3 of the 'How to Guide for Conducting Risk-based Assessments of Quarantine Hazards on

Barrow Island' presented at the first Community Consultation Meeting held on 18 February 2004.

The highest priority use of the Framework would need to be Scenario 1 followed by Scenarios 2 and 3.

Framework Scenario 1

Introduction has a score of 1, but survival, detection and eradication each have scores of greater than 1, as follows (also refer to Attachment 1, Scenario 1):

- the introduction was extremely remote, highly unlikely (score 1);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- there was a high likelihood of detection, or less (score 3 or less); and
- there was a high likelihood of eradication, or less (score 3 or less).

Framework Scenario 2

Introduction, detection and eradication each have a score greater than 1, but survival has a score of 1, as follows (also refer to Attachment 1, Scenario 2):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was not suitable for survival (score 1);
- there was a high likelihood of detection, or less (score 3 or less); and
- there was a high likelihood of eradication, or less (score 3 or less).

Framework Scenario 3

Introduction and survival each have scores greater than 1, but detection and eradication each have a score of 1, as follows (also refer to Attachment 1, Scenario 3):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- it was virtually certain that detection would occur (score 1); and
- it was virtually certain that eradication would be successful (score 1).

Constraints on the use of the Framework

- Detection would need to be within an acceptable timeframe in the context of the biology of the species concerned.
- Eradication consequences would need to be acceptable.
- The Framework could not be applied to (i) micro-organisms and (ii) marine quarantine.
- The terms used to describe the risk score need to be given meaning in terms of experience elsewhere. This is intended to assist the public in the meaningful interpretation of risk scores.
- To instil confidence in the definitions (descriptions) of risk levels, there is a need to improve the level of rigour of these definitions.

5 ADVICE FROM WORKSHOP #3

- Workshop #3 agreed, with a small number of participants abstaining, that the risk of establishment of introduced species is acceptably low if it conforms to the Risk Standard Framework, but noting that the risk needs to be considered in the priority order set out in Section 4.

- If a risk profile was ALARP (as low as reasonably practicable) but was not within the risk standard, it should not be judged to provide an acceptable risk.

Advice has not been provided on what should happen outside the acceptable risk standard. Judgements would have to be made by those charged with that task (eg EPA, Government).

6 CONSIDERATION BY THE COMMUNITY CONSULTATION MEETING

The Environmental Protection Authority recommended to Government in Bulletin 1101 on the Gorgon proposal that should the Government agree in principle to access to Barrow Island for a gas processing complex "The proponent be required to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island. Such a process should include appropriate technical experts and be structured to ensure a high level of transparency and community involvement".

A process has been implemented which has involved the community and included technical experts. The process has been transparent and the Workshops have been open for attendance by any member of the public. Records of the meetings of the Workshops have been publicly available.

At the Community Consultation Meeting held on 16 June 2004 some suggested changes to the Chairman's report were discussed. Following the adoption of these changes no one present expressed an objection to the proposed Risk Standard Framework. However, the point was made, quite properly, that those who attended both the Workshops and the Community Meetings did so as individuals and thus the views expressed should not be read as representing one way or the other the views of the organisation with which they were associated. Also, the discussions should not be interpreted as all participants necessarily being in agreement.

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Attachment 1

Risk Standards Framework

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Risk Standards Framework - Scenario 1

Introduction	Survival	Detection	Eradication	Score
The introduction is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect.	Virtually certain to eradicate.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection.	Very high likelihood of eradication.	2
There is a slight chance of introduction.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection.	High likelihood of eradication.	3
There will be a small number of introductions each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection.	Moderate chance of eradication.	4
An occasional number of introductions are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection	Medium chance of eradication.	5
Introductions have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection.	Low chance of eradication.	6
Introductions occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection.	Slight chance of eradication.	7
There is a high occurrence of introductions each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection.	Very slight chance of eradication.	8
There is a very high occurrence of introductions each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection.	Remote chance of eradication.	9
Introductions occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect.	Almost impossible to eradicate.	10

Key

Low Risk	Medium Risk	High Risk

Risk Standards Framework - Scenario 2

Introduction	Survival	Detection	Eradication	Score
The introduction is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect.	Virtually certain to eradicate.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection.	Very high likelihood of eradication.	2
There is a slight chance of introduction.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection.	High likelihood of eradication.	3
There will be a small number of introductions each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection.	Moderate chance of eradication.	4
An occasional number of introductions are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection	Medium chance of eradication.	5
Introductions have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection.	Low chance of eradication.	6
Introductions occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection.	Slight chance of eradication.	7
There is a high occurrence of introductions each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection.	Very slight chance of eradication.	8
There is a very high occurrence of introductions each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection.	Remote chance of eradication.	9
Introductions occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect.	Almost impossible to eradicate.	10

Key

Low Risk	Medium Risk	High Risk

Risk Standards Framework - Scenario 3

Introduction	Survival	Detection	Eradication	Score
The introduction is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect.	Virtually certain to eradicate.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection.	Very high likelihood of eradication.	2
There is a slight chance of introduction.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection.	High likelihood of eradication.	3
There will be a small number of introductions each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection.	Moderate chance of eradication.	4
An occasional number of introductions are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection	Medium chance of eradication.	5
Introductions have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection.	Low chance of eradication.	6
Introductions occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection.	Slight chance of eradication.	7
There is a high occurrence of introductions each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection.	Very slight chance of eradication.	8
There is a very high occurrence of introductions each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection.	Remote chance of eradication.	9
Introductions occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect.	Almost impossible to eradicate.	10

Key

Low Risk	Medium Risk	High Risk

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Appendix 1

Barrow Island Quarantine
Community Consultation Meeting Record
Meeting #3 16 June 2004

Editor's note:

This is a record of meeting proceedings only and does not include the 'Invitation and Attendance Record' (Appendix 1).

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Barrow Island Quarantine
Community Consultation Meeting #3

MEETING RECORD
16th June 2004

CONTENTS

1. Particulars of Meeting

Held: 6:15 pm to 8:50 pm
16th June 2004
Perth Zoo Conference Centre - Theatre

Please refer to Appendix 1 for a record of invited persons and attendees.

Material provided: 1) PowerPoint slides presented at meeting
(Above materials are available upon request from Sean Reddan)

2. Welcome and Purpose of Meeting

The Chairman opened the meeting by welcoming those present and outlined the agenda. He then invited Russell Lagdon to address the meeting, and introduce those present from Gorgon.

3. Record of the Community Consultation Meeting of 20th April 2004

The Chairman referred to the Record of the Community Consultation Meeting held on 20th April, and briefly outlined the feedback received in response to the initial draft.

4. Gorgon Status Report

Russell Lagdon addressed the meeting with regard to the following matters:

- Environmental approvals schedule – following advice from the Expert Panel, and concerns noted at prior Community Consultation meetings, the schedule for public release of Environmental Impact Statement / Environmental Review and Management Program (EIS / ERMP) documents has been pushed back from late August to 6th December.

  Points raised in response to the amended schedule were:
  - A question was asked if the public consultation period will be extended to account for the Christmas period. The usual practice of the EPA is to extend the period by two weeks when the Christmas period is included.
  - The schedule still appeared tight
  - There was a need to work on a practical protocol for Gorgon to provide an opportunity for community consultation after the release of the EIS / ERMP document.

- Quarantine resources – an illustration of the personnel and resources being invested in the quarantine effort show that Gorgon currently has 25 people working on the development of quarantine solutions.

- Newspaper advertisements – following publication of 3 newspaper advertisements calling for expressions of interest in the quarantine development process, it was reported there was a total of 18 responses, 3 of which were from members of the general public.

- Quarantine stakeholder site visits – a summary of stakeholder visits to Barrow Island, and the Welshpool and Dampier logistics facilities was presented. It was noted that a further visit to Barrow Island was planned for the following week, and included some people present at the meeting.

- A question & answer facility has been developed on the Gorgon website and is due go live within a matter of days.

5. Report to the Community Consultation Meeting on the Risk Standards Workshops

Bernard Bowen provided an overview of the Report by the Chairman to the Community Consultation Meeting on the Risk Standards Workshops. Those attending Workshop #3 had agreed, with a small number of participants abstaining, that the risk of establishment of introduced species is acceptably low if it conforms with the Risk Standard Framework set out in workshop #1, but there were listed some constraints on the use of the Framework.

Issues raised in response to the report were:

- In response to a question, the Chairman advised that three interests had abstained, one of which was the officer from the Department of Environment because he is part of the Service Unit to the EPA.
- The point was quite properly made that those who attended both the workshops and the community meetings did so as individuals and thus the views expressed should not be read as representing one way or the other the views of the organisation with which they were associated.
- A number of suggested amendments to the Report presented by the Chairman were put to the meeting. As a result, the Chairman proposed that he revise the Report taking into account the suggested amendments and write it in a form suitable for transmittal by the Community Consultation Meeting to the Gorgon Joint Venture and to the Environmental Protection Authority. It was agreed that this revised report would be circulated to all participants for comment and then be finalised by the Chairman for transmission by him.
- Subject to the above amendments, those present at the Community Consultation Meeting expressed no objection to the advice contained in the report of Workshop #3, but again it needs to be noted that this should not be interpreted as all participants necessarily being in agreement.

6. Report on the Technical Risk Assessment Workshops

Richard Stoklosa presented a progress report on the IMEA / HAZOP workshops and the process of assessment of individual pathways.

The point was made that it was important to benchmark the scoring system used so that there was uniformity of judgement between workshops.

7. Quarantine Management System

The Chairman invited Russell Lagdon to introduce Nick Croston and Jane Aberdeen who have been engaged by Gorgon to assist in the development of a Quarantine Management System. An overview of the approach being used in the context of Management Systems (MS) and ISO 14001 International Standards was presented. A distinction between a QMS and a Quarantine Management Plan (QMP) was introduced.

After some discussion with regards to the level of detail, and amount of information currently available the Chairman confirmed that a workshop would be held to involve the community in the development the QMS.

8. Meeting Review and Close

The Chairman thanked the participants and asked if there were any further matters for consideration.

A point was raised that a forum similar to this Community Consultation Meeting is needed to discuss and review the site selection process which led the Gorgon Joint Venture to identifying Barrow Island as the preferred site. This point was acknowledged by the Chairman. Russell Lagdon invited comment on such matters to be taken up with him directly.

The Chairman confirmed that a draft record of the meeting will be distributed to those in attendance for review and comment.

Meeting closed: 8.50 pm.

9. Action Register

Actions arising from this meeting are listed below.

Item #	Action	Who	When
	▪ Convene QMS workshop	Reddan	TBD

10. Appendix 1 – Invitation and Attendance Record

Attachment.

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Appendix 2

Barrow Island Quarantine
Risk Standards Workshop Records

Workshop #1	**10 March 2004**
Workshop #2	**21 April 2004**
Workshop #3	**12 May 2004**

Editor's note:

These records reference workshop proceedings only, and therefore do not include the following:

Workshop #1	**Attachment 1 Risk Standards Framework (provided as an attachment to this Chairman's Report).**
Workshop #2	**Attachment 1 Standards for Acceptable Risk (provided as attachment 2 to Risk Standards Workshop #3 Record).**
Workshop #3	**Attachment 1 Correspondence from Waterbird Conservation Group (provided in full workshop record at www.gorgon.com.au).**

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Barrow Island Quarantine
Risk Standards Workshop #1

WORKSHOP RECORD
10th March 2004

Contents

1. Particulars of Workshop

Held: 4:00 pm to 6:45 pm
10th March 2004
Kings Park and Botanic Gardens – Administration Building Theatre

Attendees:	Bernard Bowen	Chairman
	Eva Crockenberg	Waterbird Conservation Group
	Barry Muir	Environmental Consultant
	Meg Wilson	Waterbird Conservation Group
	Paul Wilson	Waterbird Conservation Group
	John Bailey	Conservation Commission
	Keith Morris	CALM
	Cameron Poustie*	Conservation Council
	Peter Baldwin	Conservation Commission
	Keith Collins	Expert Panel
	Andrew Burbidge	Expert Panel
	Malcolm Nairn	Expert Panel
	Richard Stoklosa	Secretariat (Gorgon)
	Sean Reddan	Secretariat (Gorgon)
	Russell Lagdon	Secretariat (Gorgon)

Apologies: Warren Tacey (Department of Environment), Chris Tallentire (Conservation Council)
*Cameron Poustie was present for part of the Workshop due to other commitments

Attachments: 1) *Development of Risk Standards for Acceptable Quarantine Risk – Status Report*

Supporting document handed out at meeting is available upon request from Sean Reddan - *Barrow Island Quarantine Risk Standards Workshop*

2. Workshop Purpose – (Bernard Bowen)

The Workshop was planned as a result of discussions at the Barrow Island Quarantine Community Consultation Meeting held on 18 February 2004. At that meeting the Chairman proposed that as part of the way forward there be a generic-type Workshop to provide advice on the standards for acceptable risk using the information set out in the "How-to Guide" document which had been distributed.

Accordingly, the purpose of the Workshop could be described as providing a forum for discussing and progressing advice on a set of standards for acceptable risk to the conservation values on Barrow Island.

3. Background Information

The Chairman drew attention to some of the advice provided by the Environmental Protection Authority in its Bulletin 1101 on the Gorgon proposal.

(i) "No accepted risk standards or clear precedents for an acceptable level of risk to conservation values."

(ii) "The proponent be required to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island."

(iii) "If access to Barrow Island is agreed, the prospective developers should be required to engage in a rigorous and public process, involving appropriate technical expertise. to set an acceptable risk limit."

(iv) “If economic, strategic and social values are judged by Government to justify the risks to the environment and conservation values, then substantial steps should be taken to insure that the risks are kept to an absolute minimum..”

(v) “If the project were to proceed, it could only be with a policy of ‘zero tolerance of invasions’ target and an associated quarantine regime of sufficient demonstrated rigor to achieve this.”

Also, Gorgon has set a goal of no introduced species on Barrow Island and surrounding waters.

All participants at the Workshop entered fully into the discussions. However, there were two understandings:

(i) Not all of the participants agreed with a risk assessment approach.

(ii) The Record of the Workshop should not be read to suggest that each participant supported all or any of the matters that were discussed.

4. Outcomes of the Workshop

The discussion firstly focussed on the consequences of introductions, noting that in practical terms zero introductions would not be achievable.

Following a lengthy discussion, and noting the EPA statement of a required policy of ‘zero tolerance of invasions’ target, it was proposed that consequences which resulted in the establishment of an introduced species would be unacceptable.

The Workshop took this as a working statement and discussed the notion of ‘acceptable risks’ that the establishment of a species would not occur. There was a broad understanding that the risks would not be zero but, as set out in the EPA statement (iv) above, the risks would need to be kept to an absolute minimum. This is consistent with reducing risk to a level ‘as low as reasonably practicable’ (ALARP) with regard to Australian Standard 4360 for risk management, and the biosecurity terminology of an ‘appropriate level of protection’ (ALOP).

The Workshop examined the information provided in Table 5.3 of the “How-to Guide” document with a view to making judgements about acceptable risks, in relation to the likelihood of introductions, survival, detection and eradication, such that the establishment of a species would not occur.

As a starting point, if it was judged by people expert in relation to understanding a particular group of animals that:

- the introduction was extremely remote, highly unlikely (score 1);
- the environment was not suitable for survival (score 1);
- it was virtually certain that detection would occur (score 1); and
- it was virtually certain that eradication would be successful (score 1);

the risks would be acceptable.

The discussions then focussed on other frameworks, using Table 5.3, which may provide a set of standards for acceptable risk.

The first framework was based on detection and eradication both having a score of 1 and introduction and survival a score of more than 1, as follows (refer also to attachment 1):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- it was virtually certain that detection would occur (score 1); and
- it was virtually certain that eradication would be successful (score 1).

The second framework was based on detection and eradication both having scores of greater than 1 but survival having a score of 1, as follows (refer also to attachment 1):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was not suitable for survival (score 1);

- there was a high likelihood of detection, or less (score 3 or less);and
- there was a high likelihood of eradication, or less (score 3 or less).

The third framework was based on detection and eradication both having scores of greater than 1, but introduction having a score of 1, as follows (refer also to attachment 1):

- the introduction was extremely remote, highly unlikely (score 1);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- there was a high likelihood of detection, or less (score 3 or less);and
- there was a high likelihood of eradication, or less (score 3 or less).

The three frameworks described above would then form a package for the 'set of standards for acceptable risks.'

There was discussion about whether all areas not coloured green in the draft framework risk standards numbers one to three (attachment 1), should be red (i.e., high risk), or whether some might be coloured yellow (i.e., medium risk). Most of those attending the workshop were of the view that because Barrow Island is a very high value nature reserve, all areas not coloured green, should be considered 'high risk.' However, there was another view that the use of a yellow band (medium risk) may be appropriate in some circumstances and needs further consideration.

5. Summary

The set of standards described in 4 above appear to be consistent with the advice of the EPA about the target of 'zero tolerance of invasions' and the goal of Gorgon of 'no introduced species'.

This set of standards requires testing through the specialist workshops, which are being undertaken as part of the risk assessment process described in the "How-to Guide", and further discussion and consideration through workshops and the wider community.

6. Workshop Review

The Workshop had provided an opportunity for all participants to provide inputs to the discussion on quarantine (biosecurity) standards for acceptable risks to the conservation values of Barrow Island in a relaxed and cooperative atmosphere.

The Chairman thanked the participants for their attendance and valuable input to the Workshop discussions. He suggested that there was likely to be a need for further meetings of the Workshop group as additional technical information became available.

The Workshop concluded at 6:45 pm.

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Barrow Island Quarantine
Risk Standards Workshop #2

WORKSHOP RECORD
21st April 2004

CONTENTS

1. Opening and Particulars of Workshop

Held: 5:00 pm to 7:50 pm
21st April 2004
Perth Zoo Conference Centre – Seminar Room 2

Attendees:	Bernard Bowen	Chairman
	Eva Crockenberg	Waterbird Conservation Group
	Meg Wilson	Waterbird Conservation Group
	Paul Wilson	Waterbird Conservation Group
	John Bailey	Conservation Commission
	Keith Morris	CALM
	Cameron Poustie	Conservation Council
	Peter Baldwin	Conservation Commission
	Keith Collins	Expert Panel
	Andrew Burbidge	Expert Panel
	Malcolm Nairn	Expert Panel
	Richard Stoklosa	Secretariat (Gorgon)
	Sean Reddan	Secretariat (Gorgon)
	Russell Lagdon	Secretariat (Gorgon)
	Warren Tacey	Department of Environment
	Andre Schmitz	Expert Panel
	Diana Jones	Expert Panel
	John Scott	Expert Panel
	Sandra Potter	Expert Panel
	David Carter	Expert Panel

Apologies: None

Attachments: 1) *Standards for Acceptable Risk (2 pages)*

2. Workshop Record

The Chairman opened the workshop and made reference to the record of the Risk Standards Workshop #1 held on 10th March 2004. Correspondence received from the Waterbird Conservation Group was acknowledged at this point and distributed to those present at the workshop. This relates directly to correspondence dated 7th April 2004, and 14th March 2004.

The Chairman invited representatives of the Waterbird Conservation Group to speak to their submission. The Chairman stated that a submission from the Waterbird Conservation Group handed to the Chairman at the Community Consultation Meeting on 20th April 2004 would be attached to the record of that meeting.

The Chairman also verified the point that the Record of the Workshop should not be read to suggest that each participant supported all or any of the matters that were discussed.

3. Community Consultation Meeting of 20th April 2004

The Chairman provided a summary of the main points raised at the Community Consultation Meeting held on 20th April. Specific points were:

(i) Mal Nairn reported on the outcomes of the workshop held on 10th March 2004

(ii) The Scoping Document approved for release by the EPA on 8th April 2004, set out that the proponent would develop a set of proposed standards for acceptable risk.

(iii) The standards set out in the record of the meeting of 10th March 2004 (the 'green' area) may be appropriate but what happens in the likely event that a risk for a pathway or a group of animals would exceed the 'green' risk profiles.

4. Report on Risk Standards

Richard Stoklosa presented a number of hypothetical cases to describe the application of the proposed draft set of risk standards (refer to Attachment #1).

Some present at the workshop sought clarification of what was being demonstrated, and what meaning could be attached to a situation if the risk score could not be reduced to one where it is a requirement of the draft risk standard. The discussion touched upon issues such as consequence, and the application of varying standards for different organisms.

The Chairman proposed that a 'set of acceptable standards' refers to the 'green' area as designated in the draft framework risk standards. The area outside the 'green' area needed more discussion and should form the basis of workshop discussion.

The discussion focussed principally on the nature of advice which could be provided to the EPA if it was found that for any pathway or group of animals independent of pathways Gorgon was unable to deliver on the proposed risk standards.

Points arising from the discussions were:

- A precautionary approach would need to be adopted.
- There was a need to propose a method for better understanding the terms 'the introduction is extremely remote', 'highly unlikely', 'the introduction is remote, unlikely', 'there is a slight chance of introduction' and so on.
- The baseline surveys have not yet been progressed to a level which would allow confidence in detection of introduced plants and animals.
- Consideration of consequences was raised again, as it was in Workshop 1. The question was posed as to whether one risk framework could fit both the terrestrial and marine environments.
- Use of the proposed risk framework may differ if it is being used to consider pathways and if it is being used to consider groups of animals.
- It was noted that Gorgon was looking to the workshop and the community to provide its view on standards for acceptable risk rather than the company presenting a proposed risk profile.
- The discussion would be enhanced if Gorgon could provide some examples of quarantine barriers and procedures using the risk framework such that the establishment of a species would not occur.
- Gorgon should commit to a risk scaling of 3 as an upper limit.
- There would be value in having information on the concept of ALARP ("as low as reasonably practicable).

5. Summary

The Chairman thanked participants for their inputs into the discussion and proposed that the meeting be adjourned until May 2004. He proposed that he arrange to have a brief paper prepared which may assist in the further discussion of the subject.

The proposal was adopted as a way forward and the group agreed to reconvene on Wednesday 12th May 2004 at 4.00 pm. The Workshop adjourned at 7.50 pm.

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Barrow Island Quarantine
Risk Standards Workshop #3

WORKSHOP RECORD
12th May 2004

CONTENTS

1. Particulars of Workshop

Held: 4:00 pm to 6:45 pm
12th May 2004
Subiaco Oval, Subiaco – Outridge Room

Attendees:		
	Bernard Bowen	Chairman
	Meg Wilson	Waterbird Conservation Group
	Paul Wilson	Waterbird Conservation Group
	John Bailey	Conservation Commission
	Norm Caporn	CALM
	Cameron Poustie	Conservation Council
	Peter Baldwin	Conservation Commission
	Keith Collins	Expert Panel
	Andrew Burbidge	Expert Panel
	Malcolm Nairn	Expert Panel
	Richard Stoklosa	Secretariat (Gorgon)
	Sean Reddan	Secretariat (Gorgon)
	Warren Tacey	Department of Environment
	John Scott	Expert Panel
	Barry Muir	Environmental Consultant

Apologies: Russell Lagdon

Attachments: 1) *Waterbird Conservation Group letter dated 7th April 2004*
2). Discussion paper – '*Setting Standards for Acceptable Risk'*

2. Opening

The Chairman thanked participants for attending this reconvened Workshop which will be described as Workshop #3.

The Chairman opened the meeting by providing a review of the background to the purpose for the workshop and referenced relevant aspects of Environmental Protection Authority (EPA) Bulletin 1101, *Environmental Advice on the Principle of Locating a Gas Processing Complex on Barrow Island Nature Reserve*.

In the discussion on the Chairman's opening comments a number of points were made, including :

- The short timeframe for the preparation of the Gorgon environmental impact documents is being driven by the proponent, not by government.
- Although 'in-principle' access to Barrow Island has been approved by the Western Australian Government, consideration of other sites for location of the development is required under the joint Federal/State EIS/ERMP assessment process.
- The set of standards for acceptable risks being discussed relate to the proposal that the Gorgon development proceeds on Barrow Island.

3. Consideration of the letter from the Waterbird Conservation Group

The Chairman referred to the 7th April 2004 letter received from the Waterbird Conservation Group (WCG) and distributed at the 21st April workshop and invited the WCG to address the workshop. The WCG reiterated a number of concerns with regards to the proposed Gorgon development, and was also concerned that the proposed marine conservation reserve (in the vicinity of Barrow Island) and biodiversity conservation legislation may be 'pre-empted' by the proposed development.

The Group was particularly concerned to ensure that:

- The biodiversity of Barrow Island was not reduced in any manner.
- Consideration of risks be within the context of overall or cumulative risk.

Workshop participants were invited to comment on the WGC submission. Points raised included:

- There was support for the tenor of the letter.
- The WCG document was structured around a policy of ‘no risk’ of introductions.
- The Workshop discussions were based on the proposition that while introductions may inadvertently occur, consequences which resulted in the establishment of an introduced species would be unacceptable.

The Chairman confirmed the 7th April 2004 letter would be included with the Workshop Record as an attachment, (Attachment 1).

Further consideration of the WCG letter then focussed on clarifying the priority use of the draft Risk Standards Framework noting that the Gorgon goal is ‘no introductions’. Following discussion, the proposed qualifying text in support of the Framework was proposed by the workshop.

In regard to the draft Risk Standards Framework, the highest priority be 1) below followed by 2)a and 2)b:

1) *Risk of ‘introduction’ of 1 is considered acceptable level of risk*
2) *If the risk of ‘introduction’ is 2 or 3 , the risk is acceptable if and only if either:*
   a. *‘survival’ is 1*
   or
   b. *‘detection and eradication’ are both 1.*

Notes

1) *Detection would need to be within an acceptable timeframe*
2) *Eradication consequences would need to be acceptable.*
3) *The approach to micro-organisms and marine quarantine may need further consideration in the application of the Framework.*

Further discussions addressed the following matters:

- The terms used to describe the risk score need to be given meaning in terms of experiences elsewhere. This is intended to assist the public in the meaningful interpretation of risk scores.
- To instil confidence in the definitions (descriptions) of risk levels, there is a need to improve the level of rigour of these definitions.

The Chairman summarised the discussion that there appeared to be a general consensus that the Framework (described in the Record of Workshop 1), and clarifying statement set out above, represented a reasonable approach to the development of a set of standards of acceptable risks such that the establishment of introduced species would not occur.

The words agreed upon by the Workshop, with a small number of participants abstaining, was that ‘the risk of establishment of introduced species is acceptably low if it conforms with the Risk Standard Framework’, but noting that the Framework needs to be considered in the priority order set out above.

4. Consideration of the record of the Workshop #2

The Chairman identified a number of minor omission and edits in section 4 and section 5.
A number of comments were tabled in relation to the record of the Workshop #2 (21st April 2004). It was agreed that the following three dot points be added to the record in section 4:

- The baseline surveys have not yet been progressed to a level which would allow confidence in detection of introduced plants and animals.

- It was noted that Gorgon was looking to the workshop and the community to provide its view on standards for acceptable risk rather than the company presenting a proposed risk profile.

- There would be value in having information on the concept of ALARP ('as low as reasonably practicable').

- Gorgon should commit to a risk scaling of 3 as an upper limit.

5. Consideration of the paper prepared by Richard Stoklosa

Richard Stoklosa presented the discussion paper *Setting Standards for Acceptable Risk* which highlighted the pre-border, border, and post-border nature of quarantine management which would need to be applied to the management of risk.

A general discussion of the paper addressed the following points:

- While the pre-border barriers would be the prime quarantine activity, participants acknowledged that the prevention of 'introductions' in the proposed risk framework was not limited to pre-border actions.
- A question was raised as to whether detection and eradication could occur pre-border. It was clarified that pre-border 'detection' was considered 'infection' and treated in a different manner from the post-border detection and eradication scenario.
- Participants noted but did not discuss the information provided on ALARP. However, if a risk profile was ALARP but not within the Risk Standard Framework, it should not be judged to provide an acceptable risk.
- Opportunities may exist to test the QMS in environments similar to Barrow Island, and as a principle the QMS should be tested in advance of operation.
- It may be necessary to consider the full raft of options for risk management and consideration should be given to listing such in the EIS /ERMP even if all barriers are not utilised.
- There would be value in having a register of quarantine incidences relating to both pre- and post-border.

The Chairman summarised the discussion with respect to aspects of the Quarantine Management System that whilst pre-border quarantine would be the prime activity, both border and post-border segments of the quarantine (biosecurity) framework (introduction, survival, detection and eradication) are essential elements of the Quarantine Management System. The Chairman confirmed that the discussion paper *Setting Standards for Acceptable Risk* would be attached to the record of the workshop without implying that it had been endorsed or otherwise by those attending. This is Attachment 2.

6. Formulation of advice (or array of advice or report) to be transmitted to the next Community Consultation Meeting.

The Chairman set out that the Workshop had now concluded its work on providing advice to the next Community Consultation Meeting.

The advice is that a Risk Standard Framework had been developed, as reported to the last Community Consultation Meeting, and that the Workshop (with some participants abstaining) has proposed that the risk of establishment of introduced species would be acceptably low if it conformed with the Framework.

The Workshop also advises the Community Consultation Meeting that:

- A qualifying text be included setting out a priority order for operation of the framework as set out in Section 3 of this Workshop #3 report.
- If a risk profile was ALARP (as low as reasonably practicable) but was not within the risk standard, it should not be judged to provide an acceptable risk.
- No advice was offered on what should happen outside the acceptable risk standard. Judgements will have to be made by those charged with that task (eg. EPA, Government).

7. Close

The Chairman thanked all of the participants for their contributions to the discussions at the three Workshops held on risk standards.

The Workshop closed at 6:45 pm.

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Attachment 2

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Setting standards for 'acceptable risk'

Risk-based assessment of quarantine threats to Barrow Island

The EPA policy of a "zero tolerance of invasions target" (stated in EPA Bulletin 1101) has been previously adopted by the Gorgon Development as a 'goal of no introductions'. A risk assessment of 'pre-border' quarantine threats and potential quarantine barriers was considered the most protective approach in view of the advice of the Expert Panel that the 'invasiveness' of species could not be accurately predicted in every situation.

A number of risk assessment workshops have been undertaken and are in progress to identify quarantine threats, using the methodology described in the *How-to guide for conducting risk-based assessments of quarantine hazards on Barrow Island* (E-Systems, 2004). These workshops have, to date, focused on the threat of the arrival of organisms at Barrow Island. Independent experts have made judgments of the likelihood of infections/introductions and survival of terrestrial and marine organisms on several pathways of potential exposure (eg food and perishables, aggregate and people). These judgments have been made without regard to possible protective measures or quarantine barriers to prevent the arrival of introduced species.

Early experience indicates that the scoring system used to estimate the likelihood of introduction and survival of organisms results in 'high' scores (toward the maximum of 10 on a scale of 1 to 10), when undertaking the infection modes and effects analysis (IMEA) workshops without the benefit of possible quarantine barriers. It is also evident from workshop discussions that although these scores will be re-assessed once beyond best practice quarantine barriers are selected by Gorgon, the estimates of introduction and survival are not going to be reduced to the '1' end of the scoring scale in many cases for pre-border quarantine threats and barriers.

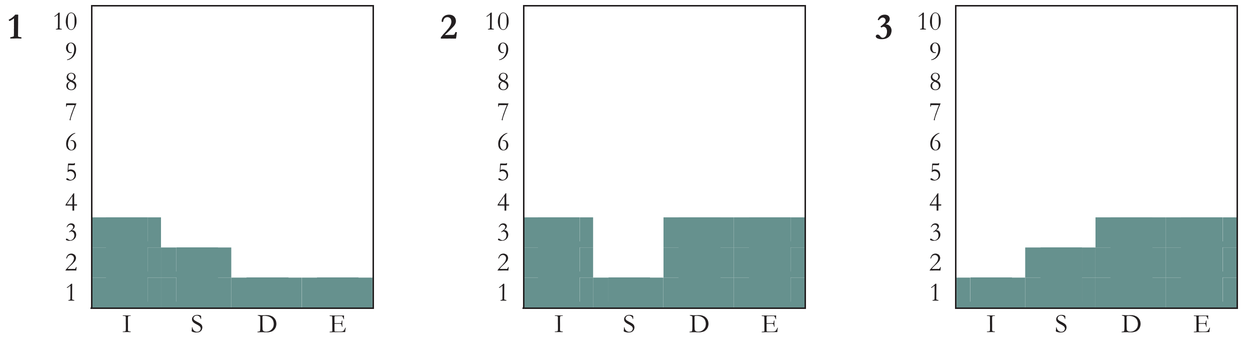
Starting point for acceptable risk

In view of the early results of risk assessment workshops for specific exposure pathways, it was recognised by workshop participants that in practical terms the 'goal of no introductions' would not be achievable. As a result, the first risk standards workshop to seek community consultation on the task of setting standards for acceptable risk (10 March 2004) recorded in the workshop record that "it was proposed that consequences which resulted in the ***establishment*** of an introduced species would be unacceptable" [emphasis added].

Testing of the suggested acceptable risk standards from the quarantine risk assessment workshops (facilitated by E-Systems) indicates that expert judgments about the pre-border likelihood of introductions and survival are not likely to fall into the three types of acceptable risk scenarios ('frameworks') that were put forward for consideration as a starting point in the first risk standards workshop (Figure 1).

Risk standards workshop participants engaged in considerable discussion on the matter of what to do about judgments of risk which do not fall into the 'green' region of acceptable risk, shown in Figure 1. This paper suggests a process for reducing risk to the green region of these matrices, and a process to manage residual risks which cannot be reduced to the green region.

Figure 1. Starting point of community expectations for acceptable risk (10 March Workshop).



Note: Scoring on left side of matrix (1-10) is defined in Table 5.3 of the *How-to Guide*.
Bold numbers 1, 2, 3 on left of matrices designates three acceptable risk scenarios ('frameworks').

I = Infection/introduction
S = Survival
D = Detection
E = Eradication

Pre-border, border and post-border quarantine

Gorgon has stated that the first priority of Quarantine Management is to prevent the introduction of species prior to their arrival on Barrow Island. As such, risk assessment workshops, to date, have focused on *pre-border* quarantine threats and barriers to assess the likelihood of the arrival of an introduced species on Barrow Island. Pre-border quarantine management and quarantine barriers on pathways of exposure are not likely to prevent the arrival of introduced species in all cases, in spite of the best efforts to do so. Gorgon has stated that detection and eradication of any introduced species are also given consideration in the risk-based assessment of quarantine management.

Analysis of the food and perishables pathway is the most convincing argument for *border* and *post-border* quarantine arrangements when setting standards for acceptable risk. The risk of having food and perishable cargoes infected with invertebrates and plant material can only be assessed in the context of a border containment and eradication facility, and the early detection and eradication of any organisms which might escape the border containment facility (post-border quarantine). Border and post-border quarantine arrangements for organisms arriving at Barrow Island may be quite independent of the pathways through which they were introduced.

Risk assessment workshops have only considered border quarantine of introduced organisms on the food and perishable pathway to date, using the HAZOP procedure for a proposed quarantine-designed kitchen facility. There appears to be more scope for proposing other border and post-border protection measures on Barrow Island for all of the other pathways, with a view toward re-assessing the risk of releasing introduced species to the native environment.

This is consistent with the community expectation that consequences which result in the establishment of an introduced species would be unacceptable. Establishment is prevented from the application of pre-border, border and post-border quarantine management practices.

There is an opportunity to specifically consider the types of border facilities and cargo offloading areas which can be designed to contain, detect and eradicate introduced species which may arrive on Barrow Island, before these species can enter the native environment. Post-border monitoring and contingency plans should also be considered when estimating the risk of the establishment of an introduced species. To date, the risk assessment process has only considered pre-border quarantine risks, and should be expanded to take border and post-border risk reduction strategies into account when attempting to meet community expectations for acceptable risk. The suggested relationship of the risk assessment process to the prevention of the establishment of an introduced species is shown in Figure 2. Not all introductions to the native environment necessarily result in establishment.

The risk assessment process shown in Figure 2 would allow Gorgon to re-assess risks of introduction for selected quarantine barriers prior to arrival on Barrow Island (pre-border), at a quarantine containment facility on Barrow Island (border), and as a result of proposed monitoring and contingency plans (post-border). It is a precautionary approach because risk is based on judgments of introduction, survival, detection and eradication of organisms which may arrive on Barrow Island. The community expectation is the prevention of the establishment of an introduced species, which goes beyond the release of an introduced organism to the native environment considered in the risk-based assessment of quarantine threats. The likelihood of establishment of a species is going to be less than or equal to the likelihood of introduction.

Process to be used to meet community standards for acceptable risk

The risk assessment process should be expanded to address both border and post-border quarantine threats with regard to the introduction of a species to the native environment on Barrow Island. It will be possible to re-assess risk estimates, or to combine risk estimates on each pathway if the overall risk of introduction is conditional on an organism 'slipping through' a number of quarantine barriers.

An expanded risk assessment process (pre-border, border and post-border) would allow Gorgon to reduce risk to levels which meet or come very close to the community expectations for acceptable risk discussed in the first risk standards workshop (Figure 1). A possible rationale for accepting risks just outside the 'green' region of Figure 1 would be to acknowledge that, in general, the risk of establishment is going to be lower than the risk of introduction to the native environment, and to provide for workable detection and monitoring strategies in any case.

Management of residual risk which exceeds community expectations for acceptable risk

There may be some threats of introduction on some particular pathways which carry a residual level of risk that exceeds the 'green' region of Figure 1. In such a situation, Gorgon would need to demonstrate that the proposed quarantine management system and barriers adopted for each pathway exceed current best practice, and that there are no other practicable measures suggested by independent technical experts which could be adopted by Gorgon to further reduce risk.

In this case, risk would have to be reduced to a level 'as low as reasonably practicable', or ALARP, as described in AS/NZS 4360 for risk management. In Biosecurity Australia terms, the quarantine threat would have to be addressed with an 'appropriate level of protection', or ALOP. The reduction of risk to a manageable level is a fundamental tenet of risk management practices. In the case of quarantine risk to Barrow Island, all reasonable barriers and management practices would need to be adopted to meet the EPA policy of a 'zero tolerance of invasions target'. It is proposed that risks which have been reduced to ALARP, in consultation with technical experts and community stakeholders, could be regarded as manageable risks which should warrant special attention in the Quarantine Management System (QMS).

In cases where risks cannot be further reduced to meet the community expectations for acceptable risk, the QMS would need to be designed to ensure that specific monitoring programs and contingency plans are developed to detect introductions of the relevant biological groups as early as possible. Specific plans and procedures would need to be detailed in the Quarantine Management Plans (QMP's) to be developed for each pathway activity, and for each type of border facility and post-border quarantine system proposed by Gorgon (refer to Figure 2). As for any introduction detected in the native environment, this would enable Gorgon to rapidly eradicate introduced species to prevent establishment and potential consequences from occurring, and communicate progress to stakeholders.

Figure 2. Relationship of the risk assessment process to the prevention of establishment.

Prevention of the establishment of an introduced species	Risk assessment process (for each exposure pathway)	Quarantine Management System (QMS)	Quarantine Management Plans (QMP's)
Pre-border quarantine (prior to arrival on Barrow Island)	• IMEA, HAZOP workshops to systematically identify threats • Scoring of introduction and survival • Design of barriers to prevent infection of cargoes • Estimates of risk (infection/ introduction and survival)	• Beyond current best practice cargo and people management strategies (pathway-specific) • Auditing of performance • Continual improvement • Competency standards • Communication with stakeholders	• Design of cargo and people handling systems • Procedures for the operation and maintenance of quarantine barriers • Assignment of responsibility, training • Reporting and actions for non-compliance, procedural breach, and incident investigation
	Residual risk — Goal of no introductions		
Border quarantine (arrival at Barrow Island)	• HAZOP workshops to analyse border facilities • Scoring of introduction, survival, detection and eradication • Design of barriers to contain and eradicate arrivals on Barrow Island • Re-assess risk with border quarantine measures	• Beyond current best practice border quarantine measures and facilities (biological group-specific) • Auditing, improvement, competency and communication as above	• Design of containment areas and facilities • Procedures for cargo and people handling • Assignment of responsibility, training • Procedures and actions for non-compliance, procedural breach, and incident investigation
	Residual risk — Prevention of establishment of an introduced species		
Post-border quarantine (Barrow Island native environment)	• Analysis of monitoring programs for early detection • Analysis of contingency plans to eradicate introduced species and limit potential consequences • Scoring of detection and eradication • Re-assess risk with post-border quarantine measures	• Beyond current best practice post-border quarantine measures and systems (biological group-specific) • Demonstrate risk reduction exceeds current best practice, risk reduced to ALARP • Auditing, improvement, competency and communication as above	• Contingency plans and procedures • Resource requirements for monitoring and incident response • Assignment of responsibility, training • Procedures and actions for incident investigation

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Technical Appendix D4

Record of Community Consultation

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

RECORD OF COMMUNITY CONSULTATION

TECHNICAL APPENDIX D4

Prepared by:

ChevronTexaco Australia Pty. Ltd.
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December 2004

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Record of Community Consultation

Chronology of Barrow Island Quarantine Meetings and Workshops

Meeting/Workshop	Venue	Date
Barrow Island Quarantine Community Consultation Meeting #1	Perth Zoo	18/2/04
Barrow Island Quarantine Risk Standards Workshop #1	Kings Park Boardroom	10/3/04
Barrow Island Quarantine Community Consultation Meeting #2	Perth Zoo	20/4/04
Barrow Island Quarantine Risk Standards Workshop #2	Perth Zoo	21/4/04
Barrow Island Quarantine Risk Standards Workshop #3	Subiaco Oval	12/5/04
Barrow Island Quarantine Community Consultation Meeting #3	Perth Zoo	16/6/04
Barrow Island Quarantine – Quarantine Management System / Management Plan Workshop	Subiaco Oval	17/8/04
Barrow Island Quarantine Community Consultation Meeting #4	Perth Zoo	9/9/04

Please note: records of all meetings and workshops are available online at www.gorgon.com.au under the 'Managing Our Environment' tab.

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Technical Appendix D5

Quarantine Procedural Review – Benchmarking Study

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

QUARANTINE PROCEDURAL REVIEW
- BENCHMARKING STUDY

TECHNICAL APPENDIX D5

Prepared for:

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October 2004

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Gorgon Development

Quarantine Procedural Review

Benchmarking Study

October 2004

Consultants

M.P. Bond
A. Catley
K.A. Doyle

Executive Summary

In considering the establishment of a Gas Processing Complex on the Barrow Island Nature Reserve, the Western Australian Environmental Protection Authority advised the WA Government that as a matter of principle, industry should not be located on a nature reserve and specifically not on Barrow Island. However the Authority went on to advise that, if the project were to proceed, it could only be on the basis of a "zero tolerance of invasion" target, and implementation of an associated quarantine regime of sufficient demonstrated rigor to achieve this.

In the broad context of protecting and maintaining the conservation values of an environmentally-sensitive area, the authors were engaged by Chevron Texaco to undertake a Quarantine Procedural Review, to identify quarantine procedures in Australia and elsewhere, that were considered to represent the best current practice. Various 'exposure pathways' for potential incursion of harmful and/or non-indigenous organisms were considered, together with appropriate quarantine procedures used elsewhere to address the associated risks. Wherever possible, specific references have been listed, where 'best practice' can be identified. For other potential pathways for an incursion, the consultants have suggested quarantine procedures that might be applied from experience in similar circumstances.

To complement the desk-top benchmarking study, two of the consultants (MPB and AC) undertook a brief familiarisation visit to Barrow Island and the Toll cargo consolidation depot at Welshpool in June 2004, to gain a first-hand appreciation of present quarantine arrangements, oil-field operations and planning for the proposed gas complex.

It should be noted that most national quarantine strategies aim to prevent the introduction and establishment of specific pests and diseases into areas where they do not occur, and to eradicate, control or limit the spread of such introduced pests and diseases. This is achieved by regulating the movement of people, goods, vessels, aircraft, animals, plants, mail and other things, which provide potential pathways for the passage of pests and diseases. These harmful pests and diseases usually are recognised as such, and the quarantine measures are designed with these specific targets in mind.

The impact of quarantine measures on international trade and commerce is subjected to close scrutiny by the World Trade Organisation. Member countries are now signatories to the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), which aims to eliminate any unfair restriction of trade under the pretext of quarantine requirements. The SPS Agreement requires members to ensure that quarantine measures have a minimal negative effect on trade, and are based on sound scientific principles, including a transparent, objective risk analysis process.

Given the inextricable link between quarantine and trade, it is difficult to make a totally objective judgement as to 'world's best practice', because different procedures are used by various national quarantine services, depending on their perceptions of risk, the prevailing circumstances and operational constraints. In addition to the targeting of specific pests and diseases, it is noteworthy that the protection of the environment and biological diversity is now recognised as an integral element of the quarantine risk assessment process.

This report also makes particular reference to the Australian Antarctic Territory and the Galapagos Islands, where stringent quarantine measures have been implemented, with the aim of protecting unique and threatened ecosystems.

The review has concluded that the quarantine measures implemented thus far on Barrow Island generally appear to have been successful, with relatively few recorded incursions during the past 40 years. Continuing studies of the Island's flora and fauna, particularly of the invertebrates and micro-organisms, should enhance the capacity of the management authorities to meet their environmental objectives, into the future.

Contents

Gorgon Development

Quarantine Procedural Review – Benchmarking Study

The Western Australian Environmental Protection Authority (EPA), in its advice to the WA Government on the Principle of Locating a Gas Processing Complex on Barrow Island Nature Reserve (Bulletin 1101), advised that as a matter of principle, industry should not be located on a nature reserve and specifically not on Barrow Island. However the Authority went on to advise that "if the project were to proceed, it could only be with a policy of a 'zero tolerance of invasion' target, and an associated quarantine regime of sufficient demonstrated rigor to achieve this".

The quarantine target of zero tolerance for the entry and establishment of non-indigenous species on Barrow Island and in the surrounding marine environment is significantly different from the quarantine standards that are generally accepted and applied by national quarantine services.

Development of a quarantine strategy aimed at the preservation or restoration of healthy ecosystems has been addressed by the Institute of Pacific Islands Forestry (USDA Forest Service), as part of the 'Pacific Island Ecosystems at Risk' (PIER) project.[31] The fundamental purpose of the project is to compile and disseminate reference information on exotic plant species of known or potential threat to Pacific islands ecosystems. The *Toolkit of Best Prevention Management Practices* emphasises that exclusion methods based on identified pathways provide the most effective way to concentrate efforts at sites (intervention points) where pests are most likely to enter national boundaries. The *Toolkit* provides a comprehensive account of some useful strategies and case studies dealing with invasive plant and animal species.

National quarantine services

The objectives of a national quarantine strategy are to prevent the introduction and spread of pests and diseases into areas where they do not occur, and to eradicate, control or limit the spread of such introduced pests and diseases. This is done under legislative powers by regulating the movement of people, goods, vessels, animals, plants, mail and other things, which are potential pathways for the introduction or spread of pests and diseases.[52]

Ideally, an effective quarantine service will have three tiers of defence against the introduction of exotic pests and diseases. The first tier (quarantine barrier) consists of well-trained and equipped personnel supported by the necessary legislation to regulate the importation of animals, plants and goods that may pose quarantine risks. The second tier of defence is an ongoing survey and monitoring program to detect exotic pests and diseases before they can become established over large areas, where eradication would be too difficult or costly. The third tier of defence is the capacity to respond to exotic pests, diseases and weeds that have become established, by initiating containment, eradication and control programs.

International trade

In the context of the current trends in global commerce and international trade, the impact of quarantine on these activities has come under close scrutiny by the World Trade Organisation (WTO), which was established in 1995. It is widely recognised that quarantine measures have the potential to unfairly restrict free trade across international borders. To address this issue, members of the WTO are signatories to an associated treaty, the Agreement on the Application of Sanitary and Phytosanitary Measures, commonly referred to as the SPS Agreement.[60] This was designed to address trading regulations for animal and plant products, to ensure that strict health and safety regulations are not used as an excuse for restricting trade to protect domestic producers.

The SPS Agreement sets out the basic rules. It allows countries to set their own quarantine standards but it also stipulates that regulations must be based on sound scientific principles. They should be applied only to the extent necessary to protect human, animal or plant life or health and they should not arbitrarily or unjustifiably discriminate between countries where identical or similar conditions prevail. It includes requirements for transparency of sanitary and phytosanitary regulations, recognition of concepts of pest- or disease-free areas and areas of low pest or disease prevalence and science-based risk analysis.

Member countries are encouraged to use international standards, guidelines and recommendations where these exist. However, members may use measures that result in higher standards, if there is adequate scientific justification. They can also set higher standards based on appropriate assessment of risks provided that the approach is consistent, not arbitrary.

In relation to international standards, guidelines and recommendations, the SPS Agreement recognises the competency of the Office International des Epizooties (OIE), the International Plant Protection Convention (IPPC) and the Codex Alimentarius Commission in developing the standards for measures to protect animal health, plant health and human health (food standards) respectively.

The SPS Agreement provides for measures to address trade disputes between member countries, with provision for sanctions under the WTO Agreement to be applied where trading rules are breached. As a result most countries are committed to incorporating standards, guidelines and recommendations, where they exist, into their quarantine systems.

Sanitary and phytosanitary standards

The development of international standards for sanitary and phytosanitary measures is a very complex process, requiring input and consultation from approximately 200 countries. Furthermore, there are many highly complex scientific issues to consider, and these may be beyond the technical resources of the less well-developed countries. Consequently, as a matter of priority, standards, particularly for plants and plant products, have been developed based on broad principles rather than detailed procedures for quarantine operations such as border activities, inspections and treatments.

The OIE *Terrestrial Animal Health Code*[53] and *Aquatic Animal Health Code*[54] provide detailed standards for the major animal diseases as they relate to trade in animals and animal products. As with the plant standards, these do not cover all animal diseases or all commodities, and are based on the current state of scientific knowledge.

Perhaps the most important standard for plants and plant products that has gained wide acceptance is *International Standard for Phytosanitary Measures No. 2, "Guidelines for Pest Risk Analysis".*[33] A Pest Risk Analysis is the starting point for assessing the quarantine risks associated with particular imports from individual countries. The risk analysis also considers options for managing risks to achieve an appropriate level of protection. Finally a decision is made on the appropriate phytosanitary measures that are required. A similar process developed by the OIE, operates for imports of animals and animal products.

Risk analyses are mainly initiated in response to proposals to import a commodity, material or species that has not been previously imported or not been imported from a particular source, either a country or part of a country. They may also be prompted by perceptions of changed risks with established imports. In some cases an analysis may be conducted on a particular pest or disease rather than a particular commodity; in such cases possible pathways for entry may involve several commodities.[15, 23, 35, 42, 44, 45]

The risk analysis process can be very complex. It is necessary to collate all available information concerning the pests and diseases likely to be associated with the commodity or species in both the importing and exporting countries to ascertain those pest species or organisms that might be provided with a pathway for entry on the commodity. An assessment is then made of all these to determine their potential economic, environmental and social importance, their potential to be introduced and become established and their potential to spread in the importing country.

For plant pests, a pest or disease may be categorised as a "quarantine pest", or a "regulated non-quarantine pest" both of which are defined in the IPPC and may attract phytosanitary measures.[33] The OIE animal codes list diseases according to their harmful potential and their capacity to spread within and between countries.[32, 36, 53, 54]

Management of risk

Options to manage the risks are then considered, so as to achieve the appropriate level of protection as determined by the importing country. These measures must be

a) no more stringent than measures applied to the same pests, if present within the territory of the importing contracting party; and

b) limited to what is necessary to protect plant and animal health and/or safeguard the intended use and can be technically justified by the contracting party concerned.[16, 20, 22]

All the steps in a risk analysis must be fully documented to include sources of information and the rationale for decisions, so that the process is completely transparent. Documented risk analyses are also valuable references for other countries engaged in risk analysis where the same or related pests and diseases are involved.

Whereas in the past, quarantine measures were unlikely to be seriously challenged, the new rules relating to transparency, equivalence and dispute resolution require a structured approach to risk analysis that is detailed in the guidelines.

Pest and disease risk analyses for animals and plants and their products require high levels of economic and scientific resources. Another important issue in pest and disease risk analyses is that completely objective quantitative risk assessments of potential pests, diseases and weeds are rarely possible because of the large number of biological and environmental factors that come into play and the paucity of scientific data. Import risk analyses usually include quantitative, semi-quantitative and qualitative elements. Furthermore, the SPS Agreement allows the "appropriate level of protection" to be determined by individual member countries. As a consequence, it is not unusual for disputes to arise over matters of scientific judgement or opinion, and this may lead to protracted and expensive research programs to seek resolution.[23, 41, 44, 45]

The scope of the IPPC extends beyond pests directly affecting cultivated plants to also cover the protection of wild flora. Some pests may primarily affect other organisms, but thereby cause deleterious effects in plant species, or on plant health in particular habitats or ecosystems. Examples include parasites of beneficial organisms, such as biological control agents. To protect the environment and biological diversity without creating disguised barriers to trade, environmental risks and risks to biological diversity should be assessed as part of a Pest Risk Analysis. International Standard for Phytosanitary Measures No. 11, *Pest risk analysis for quarantine pests, including analysis of environmental risks and living modified organisms –Annex 1*, provides comment on the scope of the IPPC in regard to environmental risk.[35]

World's best practice

Given the inextricable and complex linkages between quarantine and trade, objective assessments of 'world's best practice' are difficult to make, because different procedures are used by quarantine services depending on their perceptions of risk, the prevailing circumstances and operational constraints. Furthermore, the SPS Agreement has a particular clause dealing with the principle of 'equivalence' which requires member countries of the WTO to accept different sanitary or phytosanitary measures of other members as equivalent, if the exporting member objectively demonstrates to the importing country that its measures achieve that importing country's appropriate level of sanitary or phytosanitary protection.

For the purpose of this study, the consultants have drawn largely on their knowledge of quarantine systems in Australia, Canada, Japan, New Zealand, United States of America and the United Kingdom, and experience in other countries to identify procedures which are applied to address quarantine risks in the various 'exposure pathways' that have been identified in the context of protecting the environmentally-sensitive area of Barrow Island. While several national quarantine systems incorporate procedures and features that can be regarded as 'best current practice', no single system provides all these elements.

Protection of conservation values

Taking into account Barrow Island's unique status in Australia as a Class A Nature Reserve, with significant conservation values and a relatively undisturbed terrestrial environment, the consultants sought information on quarantine management systems that have been implemented in other similarly protected areas. Only two comparable situations, the Galapagos Islands and Antarctica were identified, primarily on the basis of their isolation and with limited access by air and sea so that there are opportunities for regulating everything that crosses their 'borders'.

Galapagos Islands

Galapagos is a World Heritage Site with its biodiversity under threat from many invasive alien species. Programs are in place to eliminate the introduced terrestrial species of plants and animals and to prevent further introductions.[57] It should be noted that these programs are primarily aimed at the restoration of ecosystems that have been degraded by earlier incursions.

A dedicated inspection and quarantine system, SICGAL (Sistena de Inspeccion y Cuarentina para Galapagos), was established in 2000 under the control of the Ecuadorian Plant Quarantine Service and with technical support and training provided by the Charles Darwin Research Station on Galapagos.[26, 55]

SICGAL is responsible for inspecting luggage and cargo that arrives on the islands or that is transported between islands. Inspectors check luggage at the airport in Ecuador before check-in and also on arrival in Galapagos. Travellers must declare any kind of organic matter in their possession. Live animals and fresh flowers are prohibited entry to Galapagos. Food, plant and animal products and seeds for sowing are restricted or prohibited. Legislation enacted by the Ecuadorian Government provides for penalties for non-compliance with procedures, including confiscation, fines and imprisonment up to three months.[19]

Restrictions also apply to vessels cruising the islands, with a requirement for inspection by SICGAL officials. [27]

Australian Antarctic Territory

Details of quarantine procedures for protection of the Antarctic environment are summarised in a recent publication of the Australian Antarctic Division (AAD). Under a Memorandum of Understanding, the Tasmanian State Quarantine Service and the AAD are collaborating to strengthen the quarantine integrity of the Australian Antarctic Territory, Macquarie Island and the Territory of Heard and McDonald Islands.

A key component of this quarantine strategy is the implementation of a rigorous inspection procedure for vessels and a wide range of cargo. This is complemented by a comprehensive processing procedure for all personnel and their luggage, and special requirements for fresh fruit and vegetables. Details of quarantine procedures for protection of the Antarctic environment are provided in the recent paper by Sandra Potter, Logistics Section, Australian Antarctic Division (Attachment 1).

Barrow Island

Strict quarantine procedures have been implemented on Barrow Island since the 1960s when oil was first discovered there. These procedures appear to have been effective, based on a review of available information on the quarantine activities to date, and a visit to the Island in June 2004, which provided an opportunity to see the current quarantine procedures. Since oil exploration commenced, there appear to have been only two recorded breaches of quarantine which resulted in recorded vertebrate introductions – two house mice were found in a drilling rig in 1995 and a single mouse was found in a car wreck imported for emergency training purposes in 1998. In both cases the pests were contained and eradicated. Black rats believed to have been introduced to the island by pearlers in the latter part of the 19th century, apparently were eradicated by 1998. [40]

At present, there are no known invasive vertebrate fauna on the island, but there are four designated introduced weed species, which occur in low incidences around the airport and camp facilities. There is a substantial gap in information regarding the status of indigenous and introduced invertebrates on Barrow Island because comprehensive baseline studies have not been undertaken. However, existing quarantine arrangements on Barrow Island appear to compare favourably with contemporary modern quarantine practices.

Chevron Texaco has conducted a series of risk assessment workshops to review potential pathways for entry and risks of introduction and establishment of biological groups in hazard evaluations. The workshops considered the following conceptual list of potential introduction pathways in hazard evaluation of persons and commodities transported to the Island:

- Personnel and accompanying luggage
- Personal goods imported by employees and contractors
- Skid equipment, accommodation units, personnel buildings
- Food and perishables
- General supplies
- Containerised goods
- Aggregate and sand
- Cement
- Pre-fabricated modules for plant construction
- Plant, including earthmoving equipment, vehicles
- Steel
- Pipe
- Marine vessels.

Table 1 provides a summary of procedures that are used by various national quarantine services to address potential risks of spreading pests and diseases along these pathways. These types of quarantine procedures are a benchmark for what is considered current best practice.

Management of quarantine

The objectives of a modern quarantine management system are explicitly stated and realistic, taking account of the environment and circumstances in which it must operate. This helps to instil a sense of common understanding and ownership amongst all stakeholders including regulatory personnel, the general community and in particular individuals and organisations involved in activities such as production, manufacturing, packaging, warehousing, transportation and quarantine activities.

Level of Control

As quarantine operations impact on the free movement of people, goods and vessels, the organisation or authority responsible for managing a quarantine system will have properly constituted powers, preferably under appropriate legislation.[37] There will also be provision for sanctions to be imposed for non-compliance with quarantine requirements. Environmentally-sensitive areas such as the Galapagos are protected by stringent laws designed to protect the threatened ecosystems.[19]

In addition, the legislation should protect the rights of individuals, companies, organisations and special groups who might be inconvenienced or incur additional responsibilities as a result of quarantine requirements.

Quarantine barrier controls

A basic principle of quarantine management is to address the risks before arrival of the commodity, material or animal at the country of destination.[25] The concept of the continuum of quarantine covering all activities from pre-shipment, through border controls to post-border control of waste disposal, monitoring and surveillance is firmly established in the most highly-developed quarantine services in countries such as Australia, USA, New Zealand and Japan.[2, 3, 38, 39] As much as possible, risks are managed before export by sourcing low risk goods, implementing appropriate treatments and conducting thorough inspections. In protecting sensitive environmental areas, this means that as far as possible, quarantine procedures are completed before entry of people or materials into those areas.

As an integral part of modern quarantine systems, many countries have compiled lists of goods that are prohibited or restricted imports.[2, 3, 38, 39] Travellers are required to declare any prohibited or restricted goods; the declaration may be oral or written. This is supported by a regulatory regime to detect any non-compliance, and in that event, imposition of appropriate penalties.

Such a procedure emphasises the importance of quarantine requirements and reduces the probability of ‘accidental’ introductions, especially by short-term visitors or workers, who might not fully understand the significance of quarantine measures.

Personnel

Authorised inspection and other personnel with appropriate training and expertise are located at all intervention points in the quarantine process, including designated airports, seaports, border checkpoints, pre-clearance sites and approved premises. Inspectors play a crucial role in determining the effectiveness of a quarantine system, and their decision-making skills, conscientiousness and integrity are of great importance. A simplified summary of the quarantine processes shows some of the inspectors’ key activities (Diagram 1).

[With reference to Diagram 1, a quarantine protocol is a detailed set of import conditions specified on an import permit issued by the quarantine authority of an importing country. It often involves a formal agreement between quarantine agencies of exporting and importing countries in relation to certification of origin, testing, treatment, packaging or other requirements performed in the country of export.]

All personnel responsible for a modern quarantine system are appropriately trained to perform their duties effectively and efficiently. A useful model is the MAF (New Zealand) *Biosecurity Standard for Appointing Supervisors of Animal Quarantine and Containment* ((July 2000), which lists relevant competency standards.[49, 50] To be effective, the quarantine system should have the support and co-operation of all the people involved. A high profile quarantine awareness program directed at all personnel, suppliers of equipment and provisions and shipping and aircraft transportation should be implemented and regularly reviewed and updated.

Training and Awareness

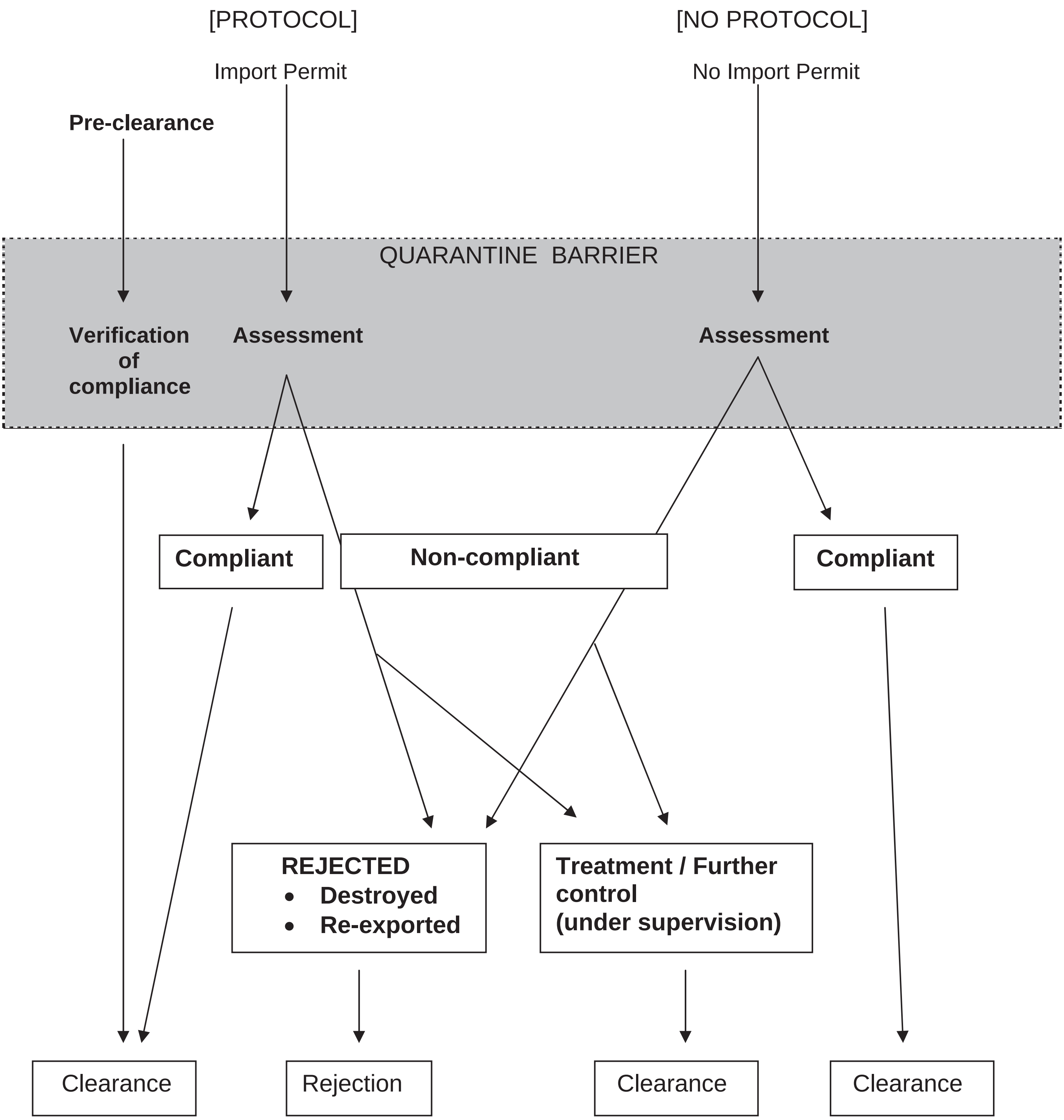
It is widely acknowledged that quarantine services need the cooperation of all sectors of the community to be effective. To achieve this, requires a high level of awareness of the importance and objectives of quarantine. Awareness levels are raised by programs designed to reach particular individuals, groups or organisations by a range of activities including advertising, displays, meetings, special presentations to target audiences etc. Using these methods, it is important to create an organisational culture of awareness and responsibility. The "Quarantine matters!" project devised by AQIS, utilising a range of media and celebrities to promote quarantine awareness, has been very successful. The Northern Australia Quarantine Strategy (NAQS) also has an awareness program aimed specifically at residents and visitors to the Torres Strait region. This has been well received and supported throughout the region.

Another example devised by the AAD, is the *Environmental Code of Conduct for Australian Field Activities in Antarctica*, which is used to remind personnel of their environmental and quarantine responsibilities.[11]

Operational Manuals

Procedural manuals should be available to all personnel to cover quarantine procedures relevant to their responsibilities. A system should be in place to ensure that manuals are regularly reviewed and updated as required. It should be noted that the New Zealand Ministry of Agriculture and Forestry procedures generally are prepared in the ISO Standards format.[43, 45, 46, 48] The USA Animal and Plant Health Inspection Service (APHIS) and Australian Quarantine and Inspection Service (AQIS) manuals also are very good models.[1, 12, 13]

Diagram 1 - Flow chart, showing typical quarantine intervention points for imported goods



NOTE – Procedures in bold-face require decisions by quarantine inspectors.

Databases

To assist in managing quarantine systems, computerised databases which record all quarantine incidents including interceptions, treatments, non-compliance and other events should be maintained and used to identify emerging risks, trends and operational problems, so that they can be addressed in a timely manner. Such databases also provide a valuable historical record, for retrospective analysis and investigation.

Facilities

Appropriate facilities are provided at all sites where quarantine operations are conducted along the pathways for entry of vessels (by air and sea), passengers, luggage and goods. This especially applies to the barrier facilities at border crossings.[41]

In Australia, AQIS approves a range of facilities where post-entry quarantine inspections and treatments may be carried out on a wide range of plants, animals, equipment and machinery, plant and animal products, etc.[17] These Quarantine Approved Premises (QAP) are registered by AQIS and conform to various criteria, to provide an appropriate level of security and control against the introduction of pests and diseases. For example, the requirements for a QAP (Class 1) cover the following components:

- security
- isolation, to prevent any cross-contamination
- hygiene (cleaning facilities, secure disposal, handling of quarantine waste)
- comprehensive and accurate records
- inspection facilities (well-designed, with good lighting, etc.)
- cargo handling facilities and equipment.

Quarantine Procedures for Specific Exposure Pathways

1. Aircraft [1]

Quarantine procedures directly related to aircraft, excluding passengers, baggage and cargo, mainly involve inspection for pests, contaminant materials and compliance with disinsection* requirements and quarantine security while the aircraft are on the ground. External surfaces of aircraft, including undercarriages and wheels are not considered to be significant risks for commercial aircraft operating from hard-sealed surfaces. However rare events such as bee swarms, ant infestations, mud-nest and paper-nest wasps, occasionally occur on and around engines and undercarriages. When detected by airline personnel and brought to the attention of quarantine officials, appropriate quarantine procedures are instituted.

Aircraft transiting airports for short periods and not loading or unloading cargo, may receive cursory inspections after passengers have disembarked.

* 'Disinsection' is a quarantine term, referring to the application of an insecticide to kill insect vectors of human and animal diseases.

Disinsection of passenger cabins and cargo holds may be required to target particular vectors of human and animal diseases and to a lesser extent, some agricultural pests. Depending on the circumstances, disinsection can be done by the crew using aerosol canisters under compliance agreements before departure, in-transit or on-arrival either before or after passengers disembark. Disinsection may also be performed by the application of residual insecticides to aircraft surfaces in passenger cabins and cargo holds at scheduled intervals of time.

Quarantine action may also be required as the result of inspection of cabins, cargo holds and galleys and the detection of prohibited plant or animal material or contamination by such material. Incidents involving live animals escaping and hiding on aircraft are widely reported, and in such cases quarantine officials are required to approve any necessary action to capture the animal.

General quarantine management procedures for aircraft might also include sealing of food stores while the aircraft is on the ground, prohibition on removal of garbage or supervision of its removal in sealed secure containers. Responsibility for these procedures is often given to crew or contractors under compliance agreements which incorporate significant penalties for breaches.

- **Passengers and accompanying luggage** [1]

  Best quarantine practice for passengers and luggage has several aspects, including

  - awareness programs, providing advice to passengers at ticketing, and also signage in departure lounges,
  - inspection of shoes at check-in, and cleaning facilities,
  - in-flight information,
  - passenger declaration, either oral or written,
  - questioning at check-in, regarding animal or plant products,
  - screening of baggage for animal and plant items of quarantine interest, using X-ray equipment or detector dogs,
  - amnesty bins and audio messages encouraging disposal of unacceptable items,
  - facilities for identification, holding and return of any intercepted material.

- **Air Cargo** [27]

  Cargo clearance is a major quarantine activity. It involves close liaison with customs authorities and customs brokers. Manifests are screened to identify any goods of quarantine concern, and requiring subsequent quarantine action. Goods which have been assessed as high quarantine risk require a permit for importation, often under detailed protocol conditions extending back to the source of the goods.

  Air cargo containers are designed to meet airworthiness standards and are mostly of metal construction. They are normally unpacked at approved break-bulk depots at airports, and are accompanied by
  - a declaration by the exporter or consignor regarding absence of timber or straw,
  - an accurate description of the goods,
  - a declaration regarding the cleanliness of the container.

2. Shipping

- **Vessel clearance** [21]

  Quarantine and public health practice includes hygiene inspection of ships. Holds, galleys and crew quarters are inspected for pets, insects, rodents, plants and other material of quarantine concern. If these items are detected, appropriate quarantine measures are applied; these may include treatment, destruction or secure containment while the vessel is in port.

  Ships' effluent is controlled by port authorities, and garbage is held on board, in environmentally-sensitive areas such as the Galapagos and Antarctica. In other situations, garbage must be treated and disposed of in an approved manner; usual methods are sterilisation by boiling, incineration to ash, deep burial or maceration and disposal in an approved sewerage system. At all times, garbage must be covered and secure.

- **Sea Cargo** [12, 47, 48]

  The sea transport of goods in containers is a very common practice that requires particular quarantine attention. In order to streamline the handling of containerised goods, a modern quarantine system makes a clear distinction between the container itself and the cargo.

  Depending on the country of origin and the type of construction, a container will be assessed and treated so as to minimise quarantine risk. In Australia, each container is usually accompanied by a Cleanliness Declaration and a Packing Declaration, which will incorporate a

  - straw packing statement,
  - timber packing statement (dunnage etc.),
  - bark statement (as to whether any timber has bark on it).

  Packing Declarations are not required for hard-frozen containers (held at -18^{o} C for at least seven days) or ISO tank containers; Cleanliness Declarations are required.

  The exporter or consignor is required to provide an accurate description of the goods, which is used to assess the appropriate quarantine treatment. Any goods which are designated as 'subject to quarantine', will be directed to an approved break-bulk depot, for unpacking and inspection. Any restricted or incorrectly-documented cargo will be subject to special inspection, and any prohibited goods ordered into quarantine for destruction or re-export.

- **Rats and mice**

  Rodent control measures are routinely undertaken on vessels in accordance with the World Health Organisation International Health Regulations.[58,59] These procedures include verification of de-ratting and exemption certificates, and placement of rat guards on hawsers.

- **Emergency landings, itinerant yachts**

  Cruising yachts and other pleasure vessels receive particular quarantine attention, mainly due to the likelihood of pets and foodstuffs such as fresh animal and plant products of uncertain origin. Wooden vessels have the potential for insect infestation, such as dry-wood termites and borers. They also pose a particular risk, because of the risk of introduction of hull-fouling invasive species. [51]

  An effective national quarantine strategy will make provision for appropriate inspection and treatment procedures, and rapid response capability, in the event of an emergency landing.

3. Ballast water

The introduction of invasive marine species into new environments in ships' ballast water has been identified as one of the greatest threats to the marine environment. In developing the current best practice, organisations such as Lloyd's Register have been at the forefront in assisting shipowners develop safe, practical and effective strategies for ballast water management.

In February 2004, a new benchmark for dealing with ballast water was established, with the adoption by the International Maritime Organisation (IMO) of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments.*[30] AQIS has recently issued a *Maritime Awareness Kit*, which includes updated Australian requirements for ballast water management, consistent with the IMO Convention.[14] AQIS and CSIRO Marine Research also have compiled a list of 33 potentially harmful invasive marine species.

The US Coast Guard is investigating the efficacy of several ballast water management approaches, including the establishment of a new ballast water discharge standard and procedures for approving ballast water treatment systems. In May 2004, the US Department of Transportation Volpe National Transportation Center was commissioned to conduct an assessment of such existing systems.[56]

4. Hull fouling

There is a wide range of aquatic organisms that may potentially be introduced via shipping, hull fouling and ballast water, and there is limited understanding of their taxonomy, biogeography and potential harmful impacts. In Hawaii, hulls of vessels are inspected, to enable early detection of harmful species.[51]

Following an infestation of the exotic Black Striped Mussel (*Mytilopsis sp.*) in Darwin Harbour in 1999, the Northern Territory Government implemented a successful containment and eradication program. This includes the inspection, treatment (anti-fouling) and clearance of vessels by the NT Department of Primary Industry and Fisheries Aquatic Pest Management Team. [31]

5. Dredge equipment

Dredges and dredging equipment that are moved internationally are subject to the same quarantine requirements as other vessels, ie hygiene, cleanliness, declarations, inspection for verification and penalties/sanctions for non-compliance. Control of dredges within a nation's territorial waters to prevent the spread of marine organisms is not normally the responsibility of quarantine authorities.

6. Foodstuffs [5, 6, 7, 8]

Foodstuffs are always subject to quarantine control. Higher risk materials may require permits under detailed protocol conditions, to contain the risk before arrival at final destination. Other foodstuffs are subject to inspection, for contamination with prohibited material or pests and diseases. Treatments including re-export, disinfestation, sterilisation, etc may be applied as required.

Some commercially-produced canned, bottled, frozen or freeze-dried foodstuffs are considered lower risk, and may have less restrictive import conditions. These are considered by quarantine authorities on a case-by-case basis, taking into account the particular quarantine risks.

7. Plant, earth-moving equipment, and vehicles [9, 13]

These items constitute major quarantine risks, because of the likelihood of contamination with soil and plant material and associated organisms. They are generally difficult to clean due to limited accessibility. Consequently, dismantling before cleaning is necessary, prior to shipment. Cleaning may involve use of high-pressure water or steam, or fumigation.

8. Aggregate, cement and sand

Clean rocks, aggregate, cement and sand (washed) *per se* are not generally considered to be pathways for movement of animal and plant pests, in the context of national quarantine processes. However, as there is a strong likelihood of contamination of aggregate and sand with soil or other organic material, these normally require approval to import after consideration of the potential quarantine risks. For imports into Australia AQIS requires information on identity, origin, freedom from soil and any treatments given to the goods. For bulk materials (containerised or in ships' holds), this includes details as to how the goods are sourced, stockpiled, stored and the measures taken to exclude birds, rodents and other animals from the storage areas. Washing of sand and aggregate before shipment may also be required. For example, AQIS has approved the importation of certain kinds of minimal risk sands, aggregates and minerals from particular sources, subject to washing and other controls to contain the risks and preserve the integrity of the material from the source through the handling and transportation path to the point of importation into Australia.. [16]

If soil or contamination cannot be easily removed, the goods are not permitted importation.

9. Pipe

Pipe represents a particular risk for the introduction of pests and diseases, either as contaminants or harbourage for rodents, reptiles, molluscs, insects, spiders etc. Pre-shipment measures by exporters are warranted, to address the identified risks. These measures might include inspection, cleaning, fumigation with methyl bromide and re-sealing to prevent the reintroduction of pest species.

10. Construction equipment

These items can be contaminated or provide harbourage for pests and diseases, and are routinely inspected by quarantine officers.

11. Portable accommodation units

Portable accommodation units may harbour a range of pests, diseases and unwanted animals. As they are difficult to inspect, it would be appropriate to apply precautionary treatment such as fumigation with methyl bromide.

12. Mail

In most developed countries, quarantine control is exercised over all incoming mail, which is screened for restricted or prohibited material, using consignor declarations, X-ray equipment and detector dogs at international mail centres. Particular attention is given to articles sent as ‘small packets’ and ‘parcel post’.

Surveillance and Monitoring Programs

Some developed countries have implemented monitoring programs for insect vectors of human and animal diseases at airports and seaports, and also early detection of plant pests and disease.[29]

In the US and other developed countries, surveys for early detection of alien species are carefully planned, according to internationally agreed standards, such as the Guidelines for Surveillance, produced by the International Plant Protection Convention. [2]

The Department of Agriculture, Fisheries and Forestry (Australia) has prepared a Disease Watch Awareness Kit, which is due to be released in the near future. This is aimed at protecting the marine environment, by encouraging the reporting of diseases affecting aquatic species.

Contingency Response Planning

A crucial part of early detection is an agreed contingency plan that clearly sets out responsibilities of the stakeholders, channels of communication, etc. The contingency planning components of most national quarantine strategies are aimed at specific high-risk target species or organisms.

Some countries have developed comprehensive plans for responding to incursions of foreign animal and plant diseases.[42, 45] For example, the Australian Veterinary Emergency Plan (AUSVETPLAN) [10] and the Australian aquatic animal health plan (AQUAVETPLAN) [18] are among the most advanced emergency response plans for animal diseases in the world. For incursions of exotic plant pests, the US has developed a series of comprehensive response plans.[2, 4, 8]

Where the environmental, economic or social consequences of an incursion are less well understood, the provisions of a contingency plan have to be broader and more flexible. If the contingency plan cannot be directed at specific targeted species of concern (as is the case with conventional national biosecurity arrangements), the process is more challenging. It is essential to identify any harmful invading species, and strong reliance is placed upon appropriate technical expertise, required for early identification and planning a rapid and effective response.

Conclusions

Since the 1960s, a range of quarantine measures have been implemented for Barrow Island. These procedures generally appear to have been successful, with relatively few recorded incursions of non-indigenous species. However, there are notable gaps in the available information, particularly the lack of adequate baseline studies for invertebrate fauna.

The proposal to establish a Gas Processing Complex on Barrow Island requires a rigorous environmental assessment process, and development of a stringent and effective quarantine management system. This benchmarking study focused on the various identified 'exposure pathways' for potential incursion of harmful and/or non-indigenous organisms. Based on the authors' knowledge and experience, appropriate procedures which are used by advanced national quarantine services to mitigate the chances of such incursions have been identified.

The quarantine measures presently used to protect the sensitive environments of the Australian Antarctic Territory and the Galapagos Islands, are considered to be especially relevant. This is notwithstanding the extremely harsh climatic conditions of Antarctica, and the primarily restorative efforts needed in the Galapagos, to rectify the damage of earlier incursions.

In considering procedures adopted by contemporary national quarantine services, it is important to note the inextricable links between quarantine and trade. This benchmarking study was done in the context of the World Trade Organization Treaty on the Application of Sanitary and Phytosanitary Measures, which requires that such measures are the least restrictive to provide an appropriate level of protection to importing countries.

In the current global trading environment, quarantine measures are designed to facilitate commerce by managing risks with the minimum disruption to trade. While the primary focus for quarantine measures is frequently on pests and diseases of plants and animals, environmental protection against the threats posed by invasive species of plants and animals is also recognised as a legitimate concern of quarantine authorities. Formal arrangements are now well established between quarantine and conservation agencies in many developed countries.

In this study, no attempt has been made to rank the effectiveness of procedures identified, in terms of best current quarantine practice. The primary objective of quarantine is to prevent the spread of pests and diseases, while minimising the adverse effects on trade. The least restrictive measures that manage the risk to an appropriate degree should be used. For example, in considering the management of a particular pest or disease risk, the options available to a quarantine service may range from simple inspection on arrival, through increasingly restrictive treatments involving washing, heating and/or chemical treatments, all of which would provide an appropriate level of protection. The more restrictive and costly measures should not necessarily be applied, if the simpler and less costly measures provide the appropriate level of protection.

Quarantine 'best practice' encompasses science-based risk management, high quality technical resources and well-designed procedures. An effective quarantine service must have clearly defined objectives and these will differ between countries depending on the resources they wish to protect and the relative values attributed to them. The threats and potential impacts posed by imports should then be identified by a rigorous risk analysis covering possible pathways for entry of pests and diseases which are likely to lead to their establishment. Options for managing risks should then be considered, and the least restrictive measures applied, consistent with achieving the appropriate level of protection for the particular circumstances. The view of the consultants is that 'world's best practice' also requires comprehensive surveillance and monitoring programs for early detection of incursions and a capacity to respond quickly and effectively to any incursions that are detected.

In the case of Barrow Island where protection of conservation values is the prime objective of the management authorities, the elements of an effective quarantine system have been implemented over many years. On the basis of interception records provided by Chevron Texaco Australia Pty Ltd and information obtained on a visit to the Island, the authors consider that the quarantine arrangements have been successful in meeting their objective. Ongoing investigations of the flora and fauna, particularly of the invertebrates and micro-organisms, should enhance the capacity of the management authorities and industry operators to continue to achieve their environmental objectives for Barrow Island, into the future.

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Table 1 - Quarantine measures for potential pathways

Pathway	Quarantine Procedure	Reference
Personnel, luggage	Incoming passenger declaration to Customs and/or Quarantine Officers. Both written and oral declarations are used. Random and intuitive inspection of luggage by Customs/Quarantine officers. X-ray examination of luggage. Detector dogs trained to detect odours of plant and animal material.	Australia (AQIS) USA (APHIS) [1]
Passenger baggage (Hawaii to other parts of USA)	Examine carry-on baggage and question passengers re fruits, vegetables and other restricted items they might have in their possession.	USA (APHIS)[8]
Personal goods imported by employees and contractors	Incoming passenger declaration. Detector dogs in Customs arrival hall.	Australia (AQIS) USA (APHIS) [1]
Accommodation units, personnel buildings	Inspection and treatment if necessary. Precautionary fumigation with methyl bromide.	Australia (AQIS) [15] Australia (AQIS)
Food and perishables	Permit to import with conditions prescribed according to assessed risk taking into account, origin, treatment received and end use.	Australia (AQIS) [15] USA (APHIS) [5]
Fresh fruits and vegetables (entering USA)	Except in a few cases, all shipments of approved fresh fruits and vegetables require a permit. Lack of a permit is not grounds to refuse entry to a shipment. If the importer does not have a permit, one may be issued at the port of entry.	USA (APHIS) [5]
Unprocessed seeds (grain and nuts) for human consumption (entering USA)	Sample and inspect to determine if prohibited or infested/infected with pests or disease or contaminated with regulated material. Take appropriate regulatory action	USA (APHIS) [7] Australia (AQIS) [15]

Pathway	Quarantine procedure	Reference
Miscellaneous and processed plant products (entering USA)	Inspection for pests or evidence that a pest is present. Practically, this term also includes the examination of articles to determine compliance with regulations and capability to disseminate pests. Inspection must also include the review and examination of documents to establish compliance with regulations and the acceptance/permissibility of an article.	USA (APHIS) [6]
General supplies	Subject to quarantine. Cargo manifests screened to determine if further quarantine intervention such as verification, inspection or treatment is required.	Australia (AQIS) [13, 15, 16] USA (APHIS)
Containerised goods	Containers and contents assessed separately in relation to quarantine risks. Interior of container must be clean and free from quarantinable material, eg residues of previous cargoes, soil, infested or contaminated dunnage and/or pallets and other packing materials (straw, tyres, hessian etc.) Packers, certification organisations or official government certification may be acceptable evidence to permit delivery to importer. In some cases tailgate inspections might be necessary to verify certification and contents before delivery. Delivery destination might also be regulated if further inspection or verification is required during or after unpacking. Containerised cargo receives the same assessment as for break bulk cargo, however as it is not as accessible for inspection some quarantine services allow delivery to importer if the goods are treated, inspected and/or otherwise conform in respect of packaging materials and are certified by approved authorities.	Australia (AQIS) [12] New Zealand (MAF) [47, 48]
Aggregate and sand	Aggregate *per se* does not present a quarantine risk. However most quarantine services would be concerned about the risk of contamination with soil or organic matter. Therefore a permit to import would usually be required. For imports into Australia AQIS requires information on identity, origin, freedom from soil and any treatments given to the goods. For bulk (containerised or ships' holds) details of how the goods are sourced, stock piled, stored and the measures taken to exclude birds, rodents and other animals from the storage areas. Washing of sand and aggregate before shipment is also required. Inspection on arrival is also required. If soil or contamination is found and cannot be easily removed, the goods are not permitted importation.	Australia (AQIS) ICON [16]

Pathway	Quarantine Procedure	Reference
	As it would be difficult, if not impractical, to satisfactorily inspect large quantities of aggregate, it would not be unreasonable to require precautionary cleaning with water immediately before or during loading.	
Cement	Cement should not constitute a serious quarantine risk either bagged or bulk, provided it is kept free from cross contamination during and after manufacture. The end use of the material would further reduce any associated quarantine risks. As for all imported goods it would be subject to inspection.	
Pre-fabricated modules for plant construction	Timber components would require inspection and treatment if insect infestation or fungi were found. If inspection is impractical, timber components could be immunised against insect and fungal attack and certified by an acceptable authority. Other alternatives would be heat treatment or fumigation but these would provide only temporary protection. Again certification would be required. Non timber components should be inspected for cleanliness and freedom from contaminants and pests. If inspection is impractical, the material could be fumigated with methyl bromide and sealed to prevent reinfestation.	Australia (AQIS) [16]
Plant, including earthmoving equipment, vehicles	Earthmoving equipment is a serious quarantine risk because of the high probability it could be contaminated with soil. It should be inspected and cleaned before shipment. Detailed inspection and cleaning frequently requires dismantling. Cleaning can best be done with high pressure water or steam.	Australia (AQIS) [13]
Pipe	As for plant and machinery. Fumigation with methyl bromide could be used as a precautionary treatment for pests harbouring in pipes. They could then be sealed against re-introduction.	Australia (AQIS) [13]
Mail	All incoming items screened for restricted or prohibited material, using consignor declarations, X-ray equipment and detector dogs at international mail centres.	USA (APHIS) [1]

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Attachment 1

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Information Paper
IP 071
Agenda Item: 4 d
AUSTRALIA
Original: English

AUSTRALIA'S ANTARCTIC QUARANTINE PRACTICES

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AUSTRALIA'S ANTARCTIC QUARANTINE PRACTICES

INTRODUCTION

1. Australia recognises that the introduction of alien species to Antarctica by human agency is an increasingly significant environmental risk associated with the conduct of Antarctic operations. The approach taken to the quarantine management of the Australian Antarctic Program (AAP) activities reflects Australia's commitment to Annex II of the Protocol on Environmental Protection to the Antarctic Treaty.

2. The key protection strategies adopted are outlined in this paper and reflect:

- the desirability of delivering a high level of biosecurity while maintaining operational efficiency in the logistical support of Antarctic science programs;
- the desirability of focussing on the application of measures prior to departure for Antarctica;
- the need to adopt a precautionary approach; and
- the importance of expeditioner participation in, and understanding of, quarantine management initiatives.

INSPECTION MEASURES

3. Inspections of AAP vessels leaving Hobart are conducted by Tasmania's (State government) quarantine body, Quarantine Tasmania, under a Memorandum of Understanding with the Australian Antarctic Division (AAD). The inspections include an examination of the vessels' accommodation, storerooms, galley, waste management areas, helicopters, workboats, cargo holds and machinery spaces for conditions of quarantine concern. Specific checks are undertaken for indicators of the presence of rats, a particular concern with respect to Australia's subantarctic islands. Although 'clean ship status' is ascertained on a voyage-by-voyage rather than seasonal basis, rat baits are placed on all AAD-chartered vessels.

4. Program cargo is consolidated and packed in a dedicated ship-side facility that is accredited to 'Class One Sea and Air Freight Depot' standard by Australia's national quarantine authority, the Australian Quarantine and Inspection Service (AQIS). The cargo facility is regularly audited against prescribed security, hygiene, isolation, staff quarantine training, and administration standards.

5. Cargo containers and their contents are also routinely inspected. Gas bottles, vehicles, machinery, and other items recognised to be particularly prone to contamination, are brushed, steam-cleaned and/or hot washed before loading to dislodge any encrusted soil and organic matter including hitch-hiking invertebrates. In view of the environmental and occupational health and safety issues associated with the use of fumigants and chemical sprays, and the practicalities of protecting large volumes of cargo in the period between treatment and shipment, only the highest risk items are treated using these methods.

6. Fresh fruit and vegetables are inspected in accordance with internationally recognised phytosanitary protocols – 600 units or a 2 per cent sample for each consignment. The inspections address quality and contamination issues, requiring that fruit and vegetables are

intact, clean, and free from abnormal external moisture, foreign smell or taste, disease, insect infestation, soil and other foreign matter.

7. Dressed poultry products are inspected for evidence of disease, in particular, Newcastle's disease, avian tuberculosis, yeast infection, avian encephalomyelitis and salmonella infection under existing arrangements for the inspection of commercial Australian poultry. Poultry meat and eggs are restricted to station use in recognition of the difficulties in the application of complicated food handling protocols in remote field conditions.

8. Expeditioners' hand/cabin luggage is subject to inspection by Quarantine Officers and/or passive quarantine detection dogs that are trained to react to a wide range of organic scents. The dogs also screen mail shipped to the stations. Their presence at ship departures readily attracts the attention of the public and therefore plays an important role in heightening quarantine awareness.

9. Compulsory pre-disembarkation procedures include closely monitored gear cleaning sessions that are repeated at each landing. Seams, pockets, tripods, back-packs, and tool boxes are among areas or items that are targeted.

ADMINISTRATIVE MEASURES

10. The potential for Antarctic operations to introduce alien species and translocate endemic species is among the issues examined in the environmental impact assessment (EIA) process. The conduct of hydroponics, an activity identified as a potentially significant refuge for unintentional introductions, has been assessed at the Initial Environmental Evaluation level. Protection measures in place include the supply of only sterilised seeds and growing media, the incineration of waste plant matter and growing media, and monitoring for invertebrates using a range of trapping methods.

11. Expeditioners are briefed on quarantine issues at nominated stages in their pre-departure preparations and, along with the ship crews, receive additional training during their voyage to Antarctica. Subject matter covered includes the means by which plant material, alien species and disease agents may be inadvertently introduced; measures necessary to prevent transfers between aggregations of wildlife; waste management; and procedures for dealing with any cargo infestations.

12. The AAD sources a wide variety of goods and services from the commercial sector. Guidelines for contractors and purchasing officers specify environmental protection considerations and processes supporting the AAD's environmental management policy. Recent AAD staff and suppliers' innovations that have helped minimise introductions include changes to the design of cage pallets such that they are less susceptible to contamination and are easier to clean, the redesign of clothing to avoid the use of seed-attracting fastenings, such as Velcro, and the deployment of fumigating ozone units in containers of produce being shipped to Antarctica.

ON-SITE MANAGEMENT ACTIVITIES

13. Station leaders, field leaders and voyage leaders are responsible for the on-site management of environmental issues. They are also appointed Inspectors under Australian legislation enacting the Protocol, namely the *Antarctic Treaty (Environment Protection) Act (1980)*.

14. Feeding wildlife is strictly prohibited. Food waste is stored indoors prior to its high temperature incineration. Liquid drained from thawing poultry products is boiled for twenty minutes before its entry into station sewerage systems. The by-products of these systems are returned to Australia for further treatment and disposal.

15. Expeditioners are required to report quarantine issues – discoveries of introduced species, soil contamination of equipment, supplier non-compliance with environmental requirements – via AAD's incident reporting scheme.

16. An unusual mortality event response plan provides instructions to expeditioners on actions to be undertaken if sick or dead animals are discovered in unusually high numbers or with signs that suggest disease. The plan includes procedures to reduce the likelihood of station personnel spreading the infectious agent if disease is involved, information on personal safety precautions, and debriefing procedures. An associated response kit contains equipment necessary to record an event, undertake post-mortem examinations and prepare samples for transport and subsequent analysis.

SUMMARY

17. Australia's Antarctic quarantine protection practices are reviewed regularly as new threats and pathways for introductions are identified, as quarantine management technologies are advanced, as risks analyses are completed, and as the review of incident reports suggest that existing procedures require improvement. While no amount of activity will provide absolute protection against introductions, the measures described in this paper are expected to individually and cumulatively reduce the environmental risks that alien species pose. A vigilant approach to pre-voyage quarantine management measures provides a major line of defence. Inspection and education strategies are primary mitigation tools.

18. For further information on Australia's Antarctic quarantine management activities please contact: Ms Sandra Potter, Environmental Policy Officer at the Australian Antarctic Division, Channel Highway, Kingston Tasmania 7050, Australia, or by email: sandra.potter@aad.gov.au.

Attachment 2 - Consultants

Dr M.P. Bond

Michael Bond has wide-ranging experience in animal health and production, and as a senior veterinary administrator at State and National levels; he held the position of Chief Veterinary Officer for Western Australia for eight years. During this time, in his capacity as Chief Quarantine Officer (Animals), Dr Bond also was responsible for all Commonwealth animal quarantine operations in WA. He also contributed to the Commonwealth/State Task Force which designed and implemented the Northern Australian Quarantine Strategy. Subsequently, he worked as Director of Corporate Services at the WA Department of Environmental Protection. During the past four years, Dr Bond has undertaken consultancies in Australia and overseas, primarily related to intellectual property and patent protection, but also several related to quarantine management and border control.

Mr A. Catley

A. (Mick) Catley is an agricultural entomologist with 24 years experience in Australian plant quarantine and export inspection, including 12 years as Director of the Australian Plant Quarantine Service. Since his retirement from AQIS in 1995 he has maintained his interest in plant quarantine as a consultant. His quarantine and inspection experience covers operations, technical support, training, legislative requirements, policy and market access negotiations. He has wide international experience having represented AQIS on many occasions at multilateral and bilateral forums. He was directly involved in the international activities leading to the concepts of Risk Analysis and International Standards for Phytosanitary Measures and as Vice Chairman of The Asia and Pacific Plant Protection Commission, he played a leading role in acceptance of these concepts by Asian countries. He has advised foreign governments and international agencies on plant quarantine and plant protection matters and has participated in a range of aid projects in the Asia and Pacific region

Dr K.A. Doyle

Kevin Doyle is presently Veterinary Director of the Australian Veterinary Association. Previously, for eight years he was Deputy Chief Veterinary Officer for Australia. For 17 years he was head of Branches responsible for animal quarantine and exports and, for some time, of plant and general quarantine. He was also responsible, for various periods, for endemic and exotic disease control programs and animal and plant health research within the Department of Primary Industries and Energy. He was also an elected member of the International Animal Health Code Commission of the Office International des Epizooties (World Organisation for Animal Health), Paris. Dr Doyle has a special interest in quarantine risk analysis and infectious disease, and has published papers on quarantine and risk analysis.

Technical Appendix D6

Report on Baseline Studies and Data Gaps

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

REPORT ON BASELINE STUDIES AND DATA GAPS

TECHNICAL APPENDIX D6

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November 2003

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GORGON QUARANTINE EXPERT PANEL

REPORT ON BASELINE STUDIES AND DATA GAPS

Andrew A Burbidge and John K Scott, 22 November 2003

OUR BRIEF

Among the key issues that arose from the Expert Panel meeting on 3 and 4 November 2003 were to establish:

- What's there now.
- What may come on to Barrow and surrounds.
- What constitutes "introduced".
- Information to make decisions.

The relevant objective statement developed at the meeting was:

> Objective 2: Identify the major organism groups of concern and the required baseline surveys (designed to incorporate future monitoring).

The strategic action identified for Objective 2 was:

> Establish a Baseline Survey Group eg to:
> - Discuss and identify the species from island knowledge to be a likely threat of introduction (including literature search).
> - Short term planned commencement of baseline studies.
> - Longer term ongoing studies required in future (biological survey expert to be consulted).

WHAT CONSTITUTES INTRODUCED?

Island ecosystems, like any natural area, are not frozen in time and changes may occur due to natural rates of species immigration and loss or extinction. Pathways for natural introduction of new species on Barrow Island include:

- Propagules transported in the wind, e.g., during cyclones.
- Floating debris, e.g., logs.
- Fresh water plumes following major rainfall events on the mainland including wave surge associated with cyclones.
- Birds or bats carrying seeds or diseases.
- Dust or airborne soil carrying micro-organisms.

Considerable work has been done estimating species turnover on islands (Lomolino 2000, Whittaker 1998). A local example, Rottnest Island, has a turnover of about 1% of the vascular flora per year (Rippey *et al*. 2003). This reflects many pathways for the arrival and extinction of introduced species (0.7% per annum) whereas the native species changeover was 0.3% against a background of an overall decline in number during the previous 50-year period. The rate of native species turnover on Barrow Island is unknown, but being a dry climate well removed from the mainland with few introduction pathways, it would be expected to be very low.

Any new species not introduced to the island due to human activity would fall into the following two categories:

- Alien species from neighbouring islands or from the mainland. An example is Kapok bush (*Aerva javanica* Amaranthaceae); a plant with seeds enclosed in a woolly covering that could be dispersed to the island via a cyclone. This species is introduced to Australia (it is widespread in the Pilbara and in the Montebello Islands) and eradication procedures should apply for any population established on the island.
- Native species that arrive naturally from neighbouring islands or the mainland. Here judgement would have to be made on a case by case basis, bearing in mind that native species can also behave as exotics outside their natural range and have the potential to create ecosystem change. As a precaution, eradication would have to be assumed as the first response. It might be necessary to have recourse to an expert group as part of deciding whether or not to eradicate the new arrival. However, the past history of the island indicates that arrival of new native species must be very rare because most species that could disperse to the island would have already done so in the past.

DIMENSIONS OF THE PROBLEM OF ISLAND INTRODUCTIONS

We conducted a brief literature review, including internet searches. We restricted our search to islands smaller than the North and South Islands of New Zealand. There is a large, world-wide body of literature concerning non-indigenous species that have established on islands and the changes they have wrought on local biodiversity. For example, most extinctions of birds world-wide since 1600 have been on islands; most are due to introduced species. Rather than attempt to provide comprehensive lists, we have provided some examples in order to demonstrate the diverse range of organisms involved.

Vertebrates

A wide range of vertebrate species has been introduced to islands. Some of these have been introduced on purpose to support primary production or as pets, or during often misguided attempts at biological control. Many introductions have been ‘accidental’. Table 1 provides examples of vertebrates that have been introduced and established on islands around the world. Some islands and island groups have suffered from large numbers of introduced species, eg, Singapore has more than 100 species of introduced birds, mainly via the enormous cage-bird trade that operates there. There have been many introductions of exotic mammals to Australian islands, mainly rats, mice, cats, sheep, goats and foxes, and there have been at least 41 local mammal extinctions, plus some bird extinctions as a result. Research shows that these extinctions are strongly correlated with exotic mammal introductions. There have been no comprehensive studies of the possible effects of exotic micro-organisms on island mammals in Australia.

Invertebrates

Table 2 lists some invertebrates that have established on islands. Invertebrate introductions are not as well documented as those for vertebrates, nevertheless, the many introductions, mostly ‘accidental’ have led to major biodiversity loss. For example, Hawaii has 85 species of introduced snails. Throughout the Pacific about 100 widespread alien snails introduced through human activities are replacing about 5,000 native and highly endemic land snail species. In an Australian example, honey bees, a centipede species, a cockroach species, two termite species, two fruit fly species, several species of spiders, several species of ants and the giant African snail have been introduced to Christmas Island. The recent development of supercolonies in the yellow crazy ant threatens many endemic species (vertebrates and invertebrates) and control is proving expensive. Even ‘remote’ islands have introduced invertebrates, eg, there are three introduced spiders and an introduced beetle species on subantarctic South Georgia.

Micro-organisms

There appears to be few papers on micro-organisms that have been introduced to islands; however, an expert in this field may be able to find many more examples. The few references we found may also reflect a lack of studies (Table 3). Some micro-organism introductions have been catastrophic; one example is the extinction of several species of endemic honeycreepers (birds) in the Hawaiian islands.

Plants

There is an extensive literature on plant introductions to islands around the world showing that islands are particularly susceptible to invasion. Table 4 shows some Australian examples, ranging from islands with relative few introductions to islands where over half the flora consists of introduced species. Many introduced species are associated with human-related disturbance. Extensive habitat modification has occurred on some islands and these areas are occupied by introduced species. A subset of the introduced species is the cause of change to ecosystems relatively untouched by human related disturbance (transformer species – Richardson *et al*. 2000). Past introductions have been accidental or as contaminants of agricultural practices. The most significant group of recent introductions are associated with garden plants. Considerable time lags of up to 50 years may be involved in the process of establishment of an introduced plant species. The ability to be introduced and colonise is not limited to particular groups of plants and transformer species have included the range of life forms from annual grasses to trees.

Can we predict which species may establish on Barrow Island if introduced?

The process of predicting which species will establish if introduced is well developed in Australia as part of the quarantine barrier. Plant species undergo a “weed risk assessment” to determine if they are a threat to agriculture or the environment in Australia. Proposals for the importation of animals have to be assessed by the Australian Quarantine and Inspection Service and the Department of Environment and Heritage, mainly by a process of public review of submissions assessing the risk of invasiveness and potential to vector diseases. A number of reasons make this type of system unsuitable for Barrow Island, an island with an exceptionally low presence of introduced species.

Organisms generally become pests at a low rate, but the considerable damage that could be caused by a successful coloniser on Barrow Island requires any prediction system to have an extremely high level of accuracy. Smith *et al*. (1999) show that when an event is rare it becomes much harder to forecast reliably because of the “base rate effect”. If the risk assessment is 85% accurate then the probability of making correct pest identification is about 10%, which would be unsatisfactory.

Experience supports the idea that a known pest of agriculture is highly likely to become a pest of agriculture in an area of introduction with similar climate. Even so, the level of predictability is low (Scott and Panetta 1993). For weeds it has not proved possible to predict which species will become invasive in environmental areas (Daehler 1998, Scott and Panetta 1993, Williamson 1999) unless the prediction is between neighbouring areas (Lockwood *et al*. 2001).

Predicting which animals might establish is also fraught with difficulty. While many introduced animals have established only in places with similar climates and habitats, other species once naturally limited to relatively small areas are now widespread and occupy habitats very different from their ‘native’ ones (eg, feral cats on subantarctic Macquarie Island and Marion Island). There are also many examples of species failing to establish on one or several occasions after introduction, and then at a later time establishing and quickly becoming a pest. Thus past experience of introductions failing to establish (eg, house mice on Barrow Island) is not a good prediction of future probability of establishment.

Recommendation: All organisms exotic to the island be treated as potential threats to the ecology of the island.

PATHWAYS

Possible pathways for human-caused introductions to Barrow Island include:

1. Equipment and goods brought to the island by sea.
2. Equipment and goods brought to the island by air.
3. Tankers and other vessels that moor to the proposed jetty.
4. Food brought to the island to feed the work force.
5. Propagules brought to the island by people in personal effects, eg, seeds on clothing, organisms in soil on footwear.
6. Diseases or propagules carried by humans, eg, in blood or other tissues, or in the alimentary tract.
7. Diseases brought to the island in introduced animals or plants.
8. Propagules arriving on the island with flotsam and jetsam from passing boats.

Establishment of many introduced species can be enhanced if new or disturbed habitats are available, eg, soil affected by construction, moist areas around buildings, lawns.

Recommendation: Further assessment of specific pathways be undertaken as part of the risk assessment process.

BASELINE STUDIES

The first step should be to audit surveys already carried out; at this time we have been unable to do so as most ‘grey literature’ reports are not published and have not been provided to us. An initial useful step would be for a specialist librarian to be commissioned to prepare a bibliography of the island, concentrating on publications related to organisms. Such a document will help the expert panel and be very useful for future baseline studies. However, it is clear that there is limited information on what species currently occur on Barrow Island.

Recommendation: A bibliography (with abstracts) of the biology of Barrow Island and nearby areas be commissioned and published as soon as possible.

Recommendation: Critical documents, particularly those that form part of baseline studies, be placed in public libraries (e.g., the Department of Conservation and Land management (CALM)) so that they are publicly available.

The second step might be to review incursions that have happened since the 1960s. The list provided to us includes vertebrates (black rat, house mouse, cat, dog, a tree frog), an invertebrate (honey bee) and several plants (aloe vera, blackberry, kapok, buffel grass, cape weed, double gee, wild passionfruit, nightshade species). (Discussion within the Expert Panel suggests that the list is incomplete.) Some of these clearly have the potential to be highly invasive; with others it is impossible to predict outcomes.

We suggest that it is not useful to depend on the list of past incursions in order to predict future incursions. The list may significantly under-report past incursions because of inadequate reporting systems in the past, as well as the lack of monitoring of invertebrates such as ants and spiders (the WA Museum has two species of introduced spider from Barrow Island in its collection (Dr Mark Harvey, personal communication)). Also, as discussed above, it is not possible to predict with any confidence which species may arrive in future and which of these may establish.

ANIMAL SURVEYS

In recommending which animal groups should be the subject of baseline surveys in the short term on Barrow Island, we have considered the following issues:

- many animal taxa from a wide range of upper level taxonomic groups have established on islands throughout the world;
- there is a broad consensus among invasive species experts that it is not possible to predict which species might establish on islands, once introduced;
- a monitoring program for mammals is in place (although it may require modification to meet Gorgon requirements) and a monitoring program for birds is a low priority;
- information on which species of reptiles and amphibians occur on Barrow is adequate, however, there is no monitoring program in place and the house gecko (*Hemidactylus frenatus*) is a common introduction around the tropics, including the Pilbara coast;
- information on most invertebrate animal groups on Barrow is poor or absent;
- Barrow is an arid island with mainly limestone derived (calcareous) soils; and
- a limited number of invertebrate groups could be surveyed and monitored without extensive and time-consuming taxonomic research.

Recommendation: The following animal groups be surveyed in the short term.

1. Ground-dwelling arthropods: ants, cockroaches, centipedes, millipedes, scorpions and spiders.
2. Web-building spiders and other spider groups that may have been or may be transported in food or equipment.
3. Terrestrial molluscs.
4. Termites.
5. Earthworms.
6. Subterranean fauna.
7. Monitoring for introduced reptiles, particularly the house gecko, should be undertaken.
8. Mammals.

Ground-dwelling arthropods. These groups can be sampled and monitored effectively using 'permanent' pitfall traps that require servicing infrequently (although the design of permanent pitfall traps on Barrow may need modification because of the abundance of bandicoots and some other animals). Expertise in sampling, sorting and identifying these animals has been developed within CALM and the WA Museum during the past surveys of the Southern Carnarvon Basin and Wheatbelt and similar work is currently a part of the Pilbara Region Biological Survey. The distribution of many of these organisms shows strong correlation with surface type and climatic parameters and tight biogeographic patterns are often evident. An important sub-group is ants. Ant taxonomy and distribution in tropical and arid Australia is well documented and ants have proved to be highly invasive on islands elsewhere.

Spiders. Spiders are easily transported in equipment, partly due to their ability to build webs and hide in confined spaces. Spider taxonomy is adequate to allow identification of indigenous and introduced species.

Terrestrial molluscs. Snail taxonomy and distribution in northern Australia is relatively well documented. Snails are particularly well adapted to karsts and often show high levels of diversity and endemism in karstic environments. Snails have proved to be highly invasive on islands elsewhere in the world. While some survey work on snails has occurred (Slack-Smith 2002), it needs extending in time and space.

Termites. Because they can be readily transported in wood, termites are highly invasive and damaging in island environments. A Barrow Island species list (with vouchers in Australian National Insect Collection) is available from the early 1970s (Perry 1972). Termite taxonomy is well advanced.

Earthworms. Earthworms are readily transported in soil. Past introductions include eucalypts planted around the camp, lantana planted near the terminal and exotic indoor plants all of which would have been transported to the island in soil in pots. It would be useful to survey the earthworm fauna of the island to establish which native species occur there and whether there have been any introductions. This would allow future monitoring.

Subterranean fauna. These may not appear to be an obvious candidate for baseline studies and quarantine monitoring. However, Barrow Island supports many species of both troglofauna and stygofauna, many of which are, on current data, endemic (Humphreys 2001) and monitoring of this group is likely to be a requirement for general monitoring of the effects of the Gorgon development (and should already be current because of the possible effects of the oilfield—drilling mud contamination, disposal of produced water at shallow depths, anode wells, surface oil and chemical spills). Past effects, if any, should be quantified as much as possible in order to isolate possible future effects associated with introductions of equipment, etc. for the gas plant and future operation of the gas plant and oil field. Barrow stygofauna inhabit an anchialine system and invasion of exotics from the adjacent sea are not out of the question. There is now evidence that, in at least some anchialine systems, sea water circulates into the system at depth, and returns to the sea at the level of the freshwater/saltwater interface (Beddows *et al*. 2002). If present, this kind of circulation clearly provides some measure of filtration, but the effects of this process in relation to pollution and introduced species are clearly dependent upon rates of transport and substrate types.

Mammals. Barrow has several endemic taxa of mammals and monitoring of them, as well as monitoring to detect introduced mammals, is important. The current mammal monitoring project has been in place for about five years and is due for review (Burbidge *et al.* 2004). It should be continued with any expansion necessary to monitor the effects of the gas plant.

Animal survey methodology

Important considerations in survey design on Barrow Island are:

- sampling efficiency in an arid place like Barrow Island for many groups of organisms is likely to be highly dependent on rainfall—a period of sampling under drought conditions is unlikely to detect many cryptic taxa,
- sampling in different seasons, independent of high rainfall events, will reveal additional taxa,
- baseline studies need to be thorough and sampling must take place over an appropriate length of time in relation to the biological characteristics of the organisms being sampled,

- pitfall trap design needs to take account of the abundant small vertebrate fauna, especially small mammals and reptiles, and should meet Animal Ethics Committee requirements,
- those tendering to undertake baseline studies should be required to demonstrate that they understand the basic principles of sampling theory and are capable of identifying the specimens collected to an appropriate taxonomic level.

The baseline surveys to be carried out on Barrow Island should meet guidelines so that they are comparable in quality and can be used for monitoring (McKenzie and Morris 2002). The following characteristics should be a requirement:

- sampling must be site-based, ie, in fixed, permanently-marked quadrats or transects;
- sampling must be quantitative, using standardised sampling methods such as pit-fall traps;
- sampling must be replicated, ie, there should be additional sample sites in the same habitat type to measure sampling efficiency;
- sampling must be conducted in different seasons and under different climatic conditions, including sampling after heavy summer and winter rainfall, so that taxa that are detectable only at specific times of the year or only in good seasons are sampled;
- sampling must cover enough sites positioned in places where introductions are likely, so as to maximise the probability of early detection of introduced species; and
- monitoring must be frequent enough to maximise the possibility of eradication should introduced species be detected.

Vouchering of biological collections from Barrow Island is vital because

- identifications by field workers may be challenged, and
- continuing taxonomic research, often using DNA technology, will result in biological entities currently considered to be a single species being split into two or more species.

Vouchering should, where appropriate, include the collection of tissue for DNA taxonomic research.

Recommendation: All workers should be required to lodge voucher specimens in appropriate public collections; for most animal groups this should be the Western Australian Museum and for plants the Western Australian Herbarium. It may be necessary to provide funds to collection managers to ensure that the specimens are properly stored and identified.

PLANT SURVEYS

From the quarantine management point of view, the objective of surveys and other monitoring of plants is to detect incursions by exotic plant species so that they can be eradicated. Australian experience in eradicating of exotic plant incursions shows that it is most successful if detected early, if detection is possible at very low densities and where all infestations are known (Mack and Lonsdale 2002). A range of sampling methods will be needed to detect plant incursions:

- A whole island Flora census will be needed regularly (each ten years or so). The plant species identification should be backed by voucher specimens lodged at a recognised herbarium. These specimens would contain the DNA needed for retrospective analyses.
- Lack of correct species identification is a major barrier to detecting the introduction of exotics. Efforts should be made to identify all species on Barrow Island that have not been named or that have been poorly identified. An example of a high priority species group for improved identification would be the figs because they provide resources for animals. A population genetics approach would be required to establish the status of the five taxa. Further taxonomic clarity will be required for many species groups that include weedy species, eg. *Indigofera* spp., *Euphorbia* spp., *Sida* spp. and *Heliotropium* spp. This work

should involve international experts of particular plant groups and should be coordinated through the WA Herbarium.

- Vascular plants are reasonably well known for the island, but there appears to be no information on lower plants such as mosses and lichens. While these groups contain many cosmopolitan species, they do comprise an important element of the ecosystems of dry regions (in particular lichens on the soil) and are easily introduced with soil. A census of these types of plant should be added to the overall census of island flora.
- Monitoring quadrats, replicated in different vegetation types. While these quadrats will mostly serve the purpose of monitoring vegetation changes, they are useful checks for the presence of exotic species and as a check on plant health, which might indicate the arrival of an exotic insect or disease.
- Targeted monitoring following perturbations with a frequency of inspection of each three months:
    - Fire.
    - Significant rainfall events such as cyclones.
    - Significant erosion due to rain or wave action.
    - Soil disturbance following construction.
- Targeted surveys to check for the presence of previous introductions. At least 10 years of monitoring is required following eradication.

Additional surveys to delimit any exotic introduction will be necessary following initial detection. Many species spread, not by progressively expanding distribution, but by establishing "nascent foci" some distance (depending on dispersal mechanism) from the initial source. The degree of sampling required would depend on the dispersal ability of the species. All of these approaches do not resolve the problem that the monitoring and surveys have to detect something of unknown identity that may or may not be present. Innovative approaches to this problem will be needed to determine the effectiveness of the alien species detection process.

Recommendation: That a range of surveys and monitoring activities be undertaken to establish mechanisms for detecting incursions by plant species. These activities would include:

- Surveys to verify the census of the island, particularly following significant rain and targeting disturbance sites.
- Surveys to include lower plants such as mosses and lichens.
- Improved identification of poorly known species groups.
- Establishment of monitoring plots in a range of vegetation types.
- Establish monitoring for exotic species on the perimeter of introduction gateways, including early warning plots that would be artificially disturbed by cultivation or/and water.

DISEASE MICRO-ORGANISM SURVEYS

There has been no survey to identify possible exotic diseases of Barrow Island animals or plants. In the early years of the oilfield development, rubbish disposal was far from ideal and many animals had access to rotting food in open tips. Similar access is known to have led to development of *Salmonella* and other diseases on other islands, including Rottnest. Today, food disposal is much better; however, native mammals such as bandicoots and native birds such as silver gulls and singing honeyeaters are common (and beg for food) around the camp and food disposal areas. Baseline studies of animal (particularly mammal and bird) diseases are necessary so that any changes resulting from the large number of additional people, food and equipment associated with the Gorgon development can be assessed.

Most native plant diseases with airborne spores have probably already been dispersed from the mainland to the island. However, many soilborne plant diseases do not disperse as readily without vectors, but can cause devastation to vegetation communities, leading to a complete change in community structure (eg. *Phytophthora* species).

Recommendation: Gorgon should to seek advice from relevant experts concerning suitable baseline studies for plant and animal diseases.

MARINE INTRODUCED ORGANISM SURVEYS

This report does not cover the issue of the threat of introductions to the marine environment due to ballast water and fouling organisms, the effects of antifouling chemicals, and the creation of novel habitats due to marine substrate disturbance during dredging and construction. It is recommended that a separate analysis by experts in this area be undertaken as soon as possible.

Recommendation: A report on baseline studies and data gaps for the marine environment surrounding Barrow Island be prepared by relevant experts.

BASELINE SURVEYS TO ESTABLISH LIKELY THREATS

Any organism exotic to the island is a potential threat given that it is very difficult to predict what types of organisms would establish on the island. However, the threat would have to be higher if the organism came from any part of the world that has very similar climate and soils to Barrow Island. Secondly, an examination of similar areas would produce an "alert list" of organisms that should be watched for especially, thus improving the quarantine effort. Similar areas can be defined as those with the same type of climate and soils.

Figures 1 and 2 show a preliminary analysis identifying those areas of Australia and the world that have a climate similar to Barrow Island. As would be expected, the nearby coastal mainland, from the Cape Range to Karratha, has the most similar climate. Note information on nearby islands is not available for this analysis. Further away (figure 2), the most similar climates are found in southern Baja California (La Paz), Galapagos Islands (Baltra) and dry coastal Ecuador (Manta), around the Red Sea (Jidda) and coastal regions of Arabia (Masirah Island).

Barrow Island is a limestone island and the closest region with similar geological origins is the Cape Range – North West Cape area. This area already shares a significant number of plant species with Barrow Island (55%, Keighery and Gibson 1993). Combining climate and geomorphology indicates that the North West Cape peninsula would be the most similar region biogeographically to Barrow Island. The next closest region would be the adjacent mainland including the Burrup Peninsula. Both areas could be usefully surveyed to indicate organisms with a high likelihood of establishment on the island, and that should be specifically included in surveys as part of baseline studies on the island. For example, species representing high risk of introduction from the North West Cape peninsula include the exotic species onion weed (*Asphodelus fistulosus*), doublegee (*Emex australis*) and buffel grass, (*Cenchrus ciliaris*). The latter two have already appeared on Barrow Island. Secondly, the repetition of baseline studies on Barrow Island, North West Cape peninsula and the Burrup Peninsula/Dampier area, for groups of organisms without baseline data, would identify organisms to be included in the alert list.

Recommendation: Baseline surveys be extended to nearby islands and nearby mainland regions, in particular, the North West Cape peninsula and Burrup Peninsula/Dampier to determine species with a high risk of introduction.

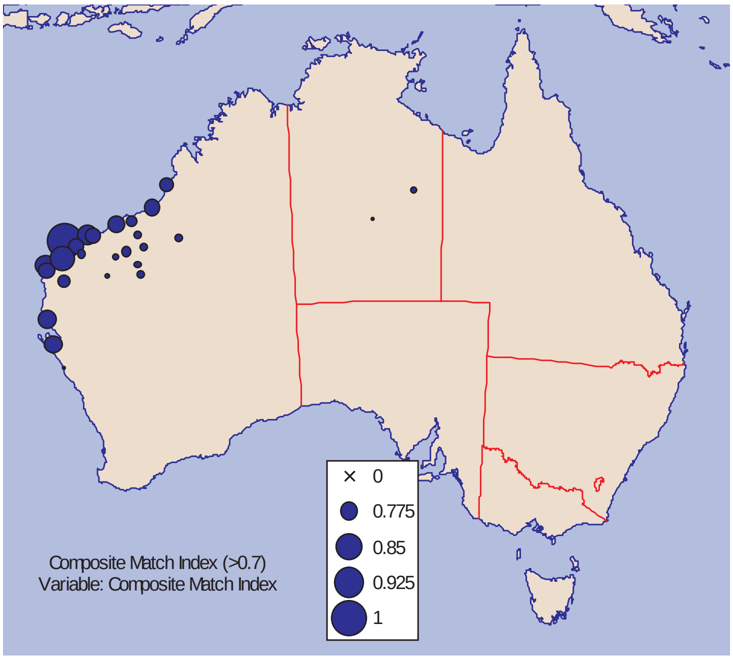

Figure 1. CLIMEX match climates – climate stations similar to Barrow Island in Australia. The larger the dot, the more similar the climate station to that of Barrow Island. Climate attributes used in the analysis include maximum and minimum temperate, total rainfall, rainfall pattern, and relative humidity.

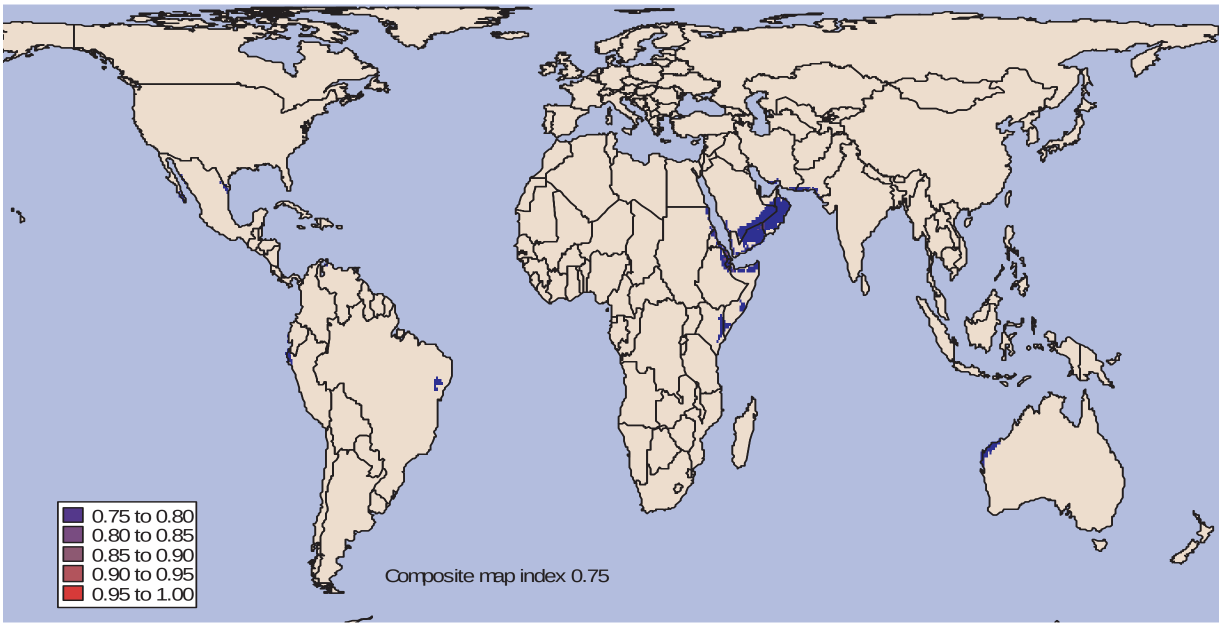

Figure 2. CLIMEX match climates using world climate surface for similarity to Barrow Island. Further analysis will be required to take into account the irregular rainfall pattern for Barrow Island.

Who does the work?

We believe it important that the best people available conduct the baseline studies. There would be considerable benefits in contracting this work to CALM and the WA Museum. Once the groups to be surveyed have been agreed, and the people who are to do the work selected, a workshop should be held where all participants discuss sampling procedures and agree on the location of quadrats and other relevant matters. Coordination with other biological studies commissioned by ChevronTexaco as part of its research/monitoring associated with the Gorgon development is vital. Seeking advice from relevant experts not involved in the studies would also be appropriate.

The presence of a number of scientist teams on the island will in itself create quarantine problems. Procedures will be needed to ensure the highest level of quarantine standards to prevent introduction of organisms and cross contamination of sampling sites (eg. procedures are practiced to prevent movement of subterranean fauna from one site to another during sampling (Biota Environmental Services 2002)).

Recommendation: The coordination of terrestrial animal and plant baseline studies be contracted to CALM and the WA Museum. If these organisations cannot carry out the work, they should be asked to advise on survey design and review ongoing work.

Recommendation: A workshop be organised to coordinate and review sampling procedures, including quarantine during sampling, before the baseline studies start.

Timing

Biological surveys, including baseline studies, need to take place in a variety of seasons over at least three years. Short term surveys usually fail to detect a significant proportion of species.

Significant rainfall events are impossible to plan for in advance. However, sampling in the six months following significant rainfall on the island will be critical for accurately detecting species present on the island. The next period when this rainfall is likely is February to April 2004. Also of critical importance is the date of likely start of construction.

Recommendation: We recommend that animal and plant baseline studies get underway as soon as possible. In the context of such studies, the period available before construction begins is very short.

EXPERTISE IN NATURAL HISTORY SKILLS

One of the most effective ways of monitoring an ecosystem for incursions is the presence of skilled observers with natural history experience and biological training. Such people, with an acquired knowledge of the island, would take part in the monitoring and guarding the island’s ecosystem. The company should ensure that once employed, such people are nurtured and encouraged to remain in the same job for some years. This approach should not be at the expense of the education of the entire workforce who should be encouraged to take an interest in the special conservation nature of the island and the threat posed by introduced species.

Recommendation: That part of the monitoring and quarantine surveillance system include graduate biologist staff with natural history skills and interest, based on the island.

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Table 1. Some vertebrate animals that have been introduced to islands.
Data sources include Charles Darwin Research Station (2003), IUCN/SSC Invasive Species Specialist Group (ISSG) (2003), ISSG Global Invasive Species Database (2003), McKenzie *et al.* (1995) and Sherley (2000).

Species	**Group**	**Island**
Alopex lagopus, Arctic Fox	mammal	Aleutian Islands
Axis sp., Axis Deer	mammal	Maui, Lana'i
beaver, raccoon, rat, squirrel, muskrat, Sitka black-tailed deer, Rocky Mountain elk	mammal	Haida Gwaii, Queen Charlotte Islands, Canada
Bos taurus, cattle	mammal	many
Bubalis bubalis, Water Buffalo	mammal	Moloka'i
Canis lupus familiaris, dog	mammal	many
Canis lupus dingo, Dingo	mammal	several Australian islands
Capra hircus, goat	mammal	many
Cavia porcellus, Guinea Pig	mammal	Laysan
Cervus timoriensis, Rusa Deer	mammal	Mauritius
Felis sylvestris catus, Feral Cat	mammal	many
Herpestes javanicus, Small Indian Mongoose	mammal	many
Lepus nigricollis, Black-naped Hare	mammal	Gunners Quoin
Marmota calagita, Hoary Marmot	mammal	Aleutian Islands
Microtus spp., voles	mammal	Aleutian Islands
Mouflon	mammal	Hawaii
Mus domesticus/*musculus*, House Mouse	mammal	many
Oryctolagus cuniculus, rabbit	mammal	many
Ovis aries, Sheep	mammal	many
Peromyscus sp., deer mice	mammal	Aleutian Islands
Petrogale penicillata, Brush-tailed Rock-wallaby	mammal	Rangitoto and Motutapu Islands
Phalanger orientalis, Common Cuscus	mammal	Bougainville, Moiko, Nissan, Buka
Pronghorn	mammal	Lana’i
Rangifera tarandus, Reindeer, Caribou	mammal	Aleutian Islands
Rattus exulans, Polynesian Rat	mammal	many
Rattus norvegicus, Brown (Norway) Rat	mammal	many
Rattus rattus, Black (Ship) Rat	mammal	many
Spermophilus parryi, ground squirrel	mammal	Aleutian Islands
Suncus maurinus, Indian House Shrew	mammal	many, incl. Guam, Maldives, Mauritius
Suncus murinus, Musk Shrew	mammal	Guam, Palau, Mariana Islands
Sus scrofa, Pig	mammal	many
Thylogale browni, a pademelon	mammal	New Ireland
Trichosurus vulpecula, Common Brushtail Possum	mammal	Kapiti, Rangitoto, Motutapu
Vulpes vuples, Red Fox	mammal	Australian islands, Aleutian Islands
Acridotheres tristis, Common Mynah	bird	many
Anas platyrhynchos, Mallard Duck	bird	many
Cacatua galerita, Sulphur-crested Cockatoo	bird	Palau
California Quail	bird	Hawaii

Species	**Group**	**Island**
Cettia diphone, Thrush	bird	Hawaii
Circus approximans, Harrier	bird	Tetiaroa Island
Columba livia, Rock Dove (Pigeon)	bird	Hawaii, many others
Corvus albus, Indian house crow	bird	Seychelles
Corvus moneduloides, New Caledonian Crow	bird	Mare Island
Gallus gallus, Red Jungle Fowl	bird	many
Java Sparrow	bird	Hawaii
Passer spp., sparrows	bird	Canary Islands, many others
Pycnonotus cafer, Red-vented Bulbul	bird	Fiji, Tonga and possibly Tahiti
Red Avadavit	bird	Hawaii
Sturnus vulgaris, Common Starling	bird	now widespread
Tyto alba affinis, Barn owl	bird	Seychelles
Boiga fusca, Brown Tree Snake	reptile	Guam, Mariana Is
Calotes versicolor, Changeable Lizard	reptile	Singapore
Gehyra mutilata, House Gecko	reptile	Christmas I (Indian Ocean)
Lycodon aulicus capucinus, Wolf Snake	reptile	Christmas I (Indian Ocean)
Lycodon aulicus, Wolf Snake	reptile	Ile aux Aigrettes
Lygosoma bowringii, Grass Skink	reptile	Christmas I (Indian Ocean)
Ramphotyphlops braminus, Black Blind Snake	reptile	Christmas I (Indian Ocean)
Bufo marinus, Cane Toad	amphibian	many, including Sir Edward Pellew Group, NT
Eleutherodactylus coqui, a tree frog	amphibian	Hawaii, Virgin Is
Eleutherodactylus planirostris, a tree frog	amphibian	Hawaii
Litorea aurea,Green and Gold Bellfrog	amphibian	New Caledonia
Litoria fallax, a tree frog	amphibian	Guam
Rana catesbeiana, a bullfrog	amphibian	many
Rana pipiens, American Bullfrog	amphibian	Singapore, others?
Carp, including goldfish	fish	Canary Islands, others
Gambusia affinis/holbrooki, Mosquito Fish	fish	many
Tilapias (Cichlidae), several species	fish	many
various aquarium fish	fish	many

Table 2. Some invertebrate animals that have been introduced to islands.
Data sources as in Table 1.

Species	Group	Island
Anoplecta lateralis, a cockroach	insect	Galapagos Islands
Blattodea sp. German Cockroach	insect	Canary Islands, many others
Periplaneta americana, American Cockroach	insect	Galapagos, many others
Bactrocera species, fruit flies	insect	Nauru
Coptotermes formosanus, Formosam Termite	insect	Hawaii, probably many other islands
Aedes albopictus, Asian Tiger Mosquito	insect	many
Culex pipiens quinquefasciatus	insect	Galapagos, vector for avian malaria
Culex quinquefasciatus, Avian Malaria Mosquito	insect	many, tropical
Icerya purchasi, Cottony cushion scale	insect	Galapagos
mealy bug	insect	Aldabra
Oryctes rhinoceros, Coconut Rhinoceros Beetle	insect	Many
Trechisibus antarcticus, a carabid beetle	insect	South Georgia
Xylosandrus compactus, Black-twig Borer	insect	Many
Polistes versicolor, a wasp	insect	Galapagos Islands
Vespula pensylvanica, Yellowjacket Wasp	insect	Hawaii
Anoplolepis longipes, Yellow Crazy Ant	insect	Christmas I (Indian Ocean), Seychelles, Hawaii, Guam, many others
Monomorium destructor, Singapore Ant	insect	Koolan Island, many other places
Monomorium floricola, ant	insect	Many
Linepithema humile, Argentine Ant	insect	Hawaii, Australia
Pheidole megacephala, Big-headed Ant	insect	Many
Solenopsis geminita, Tropical Fire Ant	insect	many, including Galapagos
Solenopsis invicta, Red Fire Ant	insect	Many
Wasmannia auropunctata, Little Fire Ant	insect	Galapagos, many others
Anyphaenoides octodentata, a spider	spider	Galapagos Islands
Eidmanella pallida, a spider	spider	Galapagos Islands
Tetragnatha maxillosa, a spider	spider	Society Islands
Tetragnatha nitens, a spider	spider	Society Islands
Zoropsis spinimana, a spider	spider	Canary Islands
Scolopenda morsitans, a centipede	chilopoda	Koolan Island, WA
Centruroides gracilis, Bark Scorpion	scorpion	Canary Islands
Dichogaster bolaui, an earthworm	earthworm	Koolan Island, WA
earthworms, several spp.	earthworm	Hawaii, Galapagos
Platydemus manokwari, a flatworm	flatworm	several
Achatina fulica, Giant African snail	mollusc	many
Euglandina rosea, Cannibal Snail, Rosy Wolf Snail	mollusc	many
Pomacea canaliculata, a freshwater snail	mollusc	Hawaii

Species	Group	Island
freshwater snails, many species	mollusc	many
Helix aspersa, Garden Snail	mollusc	many
Laevicaulis alte, a slug	mollusc	Koolan Island, WA

Table 3. Some micro-organisms that have been introduced to islands.
Data sources as in Table 1.

Species	Group	Island
avian pox virus	micro-organism	Galapagos, affects Darwin's finches
coccidiosis	micro-organism	Galapagos
Marek's disease	micro-organism	Galapagos
Plasmodium relictum, Avian Malaria Parasite	micro-organism	Hawaii, has caused the extinction of several bird species
Salmonella, various	micro-organism	Galapagos, Rottnest

Table 4. Some Australian islands in relation to size, number of plant species, total and introduced.

Island	Size	Number of plant species	% introduced (number of spp.)	Reference
Tiwi Islands (Melville and Bathurst)	7,775 km^2	772	12% (95)	Fensham and Cowie 1998
Dirk Hartog Island	620 km^2	294	12% (36)	Burbidge and George 1978
Wessel Islands (35 islands) and English Company Islands (47 islands)	371 km^2 154 km^2	684	Very low, present on 8 islands only	Woinarski 2000
Christmas Island	137 km^2	380	46% (173)	Du Puy 1993
Cocos (Keeling) Islands	30+ islands over an area of 135 km^2	121	47% (57)	Telford 1993
Macquarie Island	118 km^2	41	12% (5)	Hnatiuk 1993
Heard Island	700 km^2	12	8% (1)	Hnatiuk 1993
Norfolk Island	34.6 km^2	445	62% (274)	Green 1994
Lord Howe Island	16.6 km^2	459	48% (218)	Green 1994
Rottnest Island	17 km^2	196	42% (83)	Rippey *et al.* 2003

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Technical Appendix D7

Barrow Island Marine Surveys

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GORGON DEVELOPMENT ON BARROW ISLAND

BARROW ISLAND MARINE SURVEY S

TECHNICAL APPENDIX D7

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Barrow Island Preliminary Survey
for Introduced Marine Pest Species

Preliminary Report

As recommended by Wells & Huisman (2004), a 'short and sharp' survey of the waters off Barrow Island is being conducted for potentially introduced species. The survey will target areas where species are most likely to have been introduced, particularly species on the Commonwealth's list of declared marine pest species (Table 1). In addition, a broader group of species will be surveyed for possible introductions to Barrow Island. For operational reasons the survey was divided into two components:

- An investigation of subtidal habitats off the islands conducted by diving and snorkelling from 11 to 16 August 2004; and

- A subsequent survey of intertidal habitats, which is currently planned for 17 to 21 September.

The present report deals specifically with results of the August diving trip in terms of 'declared marine pest species'. A full report on the presence or absence of 'declared marine pest species' will be submitted shortly after completion of the intertidal survey. This will be followed later by a report on a broader list of possible introduced marine species in the area.

Table 1. Declared marine pest species (NIMPIS 2002).

Group	Species	Notes
Dinoflagellates	*Alexandrium catenella*	Cryptogenic in southeastern Australia
	Alexandrium minutum	Introduced to southern Australia
	Alexandrium tamarense	Cryptogenic in southwestern Australia
	Gymnodinium catenatum	Cryptogenic in southeastern Australia
Macroalgae	*Caulerpa taxifolia*	Native to northwestern Australia, but there is an invasive strain
	Undaria pinnatifida	Introduced to southeastern Australia
Echinoderm	*Asterias amurensis*	Introduced to southern Australia
Ctenophore	*Mnemiopsis leidyi*	Not recorded from Australia
Worm	*Sabella spallanzanii*	Introduced to southern Australia
Molluscs	*Corbula gibba*	Introduced to southeastern Australia
	Crassostrea gigas	Introduced to southern Australia
	Mytilopsis sallei	Introduced Darwin and eradicated
	Potamocorbula amurensis	Not recorded from Australia

Marine benthic algae and phytoplankton, John Huisman

Pest species as included in the NIMPIS 'Declared marine pests' list were absent at all sites visited. Of the species listed, *Undaria pinnatifida* usually occurs in colder waters and is unlikely to survive any introduction to Barrow Island. *Caulerpa taxifolia* was absent from locations visited in the present survey and was not recorded during the intertidal surveys conducted by BBG in the mid 90s. The species is widespread in the region, however, and has been recorded from the Dampier Archipelago, the Montebello Islands and Broome (Huisman & Borowitzka, 2003; Huisman, unpubl. obs.). Its natural presence at Barrow I. is therefore likely. *Caulerpa taxifolia* occurs as two 'strains', one invasive and therefore a pest, the other non-invasive. A PCR-based assay is necessary to establish whether a particular population belongs to the invasive strain (Fama *et al.* 2002). Although previous collections from the region were not tested, it is unlikely they represent the invasive strain, which thus far is known from eastern Australia, the Mediterranean, and California.

Other species of benthic algae and seagrasses collected were typical of the Indo-West Pacific region. Most are widespread.

None of the dinoflagellates species regarded as marine pests were found in the fresh or preserved samples collected in the present survey. Plankton samples contained a mix of the dinoflagellates *Ceratium* (several species) and *Prorocentrum lima* (rarely), plus various diatoms including *Licmophora*, *Rhizosolenia*, *Chaetoceras*, *Pleurosigma*, *Asterionella*, *Leptocylindrus*, *Nitzschia* and *Navicula*. Of these only *Prorocentrum* could be considered potentially harmful, as in bloom proportions it can cause diarrhetic shellfish poisoning if shellfish from affected areas are consumed. This species is worldwide in distribution, however, and its presence at Barrow I. is expected. It was present in only low numbers in the samples. Sediments were course-grained and included no evidence of dinoflagellate cysts. Genera present in sediments included the diatoms *Pleurosigma*, *Campylodiscus*, *Surirella*, and *Amphora*.

Marine invertebrates, Fred Wells

None of the invertebrate 'declared marine pest species' was recorded on the diving trip. As can be seen on Table 1, the comb jelly, or ctenophore, *Mnemiopsis leidyi* has not been recorded in Australia. There are no experts for this group in the country. The expedition did not search directly for this species, but no unusual numbers of comb jellies were found. Similarly, the bivalve *Potamocorbula amurensis* has not been recorded from Australia, and none were found. Most of the remaining species (the starfish *Asterias amurensis,* the tubeworm *Sabella spallanzanii* and the bivalve *Corbula gibba*) are temperate species which are unlikely to be found in the tropical waters off Barrow Island. The oyster *Crassostrea gigas* is also a temperate species, but is intertidal. It was not located at the sites along shore where snorkelling was conducted during the diving survey. Further searches for this species, and the others, will be conducted during the intertidal survey. The mussel *Mytilopsis sallei* was recently introduced to Darwin. It inhabited the protected waters of three marinas where its populations exploded exponentially. Fortunately, the three areas where it occurred could be sealed off and the population was eradicated. As a tropical species, *M. sallei* is the most likely of the declared marine pests to occur at Barrow Island, but it was not recorded during the diving survey.

Appropriate samples were retained for examination for other potentially introduced species.

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Introduced marine species in the waters of Barrow Island, with emphasis on barnacle species.

Report to ChevronTexaco

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February 2005

Introduction

Exotic species introductions are considered one of the major threats to biodiversity worldwide (Padilla *et al.*, 1996). Whilst the introduction of terrestrial plants, animals and freshwater vertebrates in Australia is relatively well documented and their ecological and economic effects recognised, the same cannot be said for the documentation, or the impact, of introduced marine species. The dearth of baseline studies around the Australian coast severely restricts our information regarding exotic marine introductions, especially of marine invertebrates (Jones, 1992a). In Western Australia, the long coastline, the inadequate taxonomic understanding of many species and groups, and the poor biotic lists available for many aquatic habitats, further exacerbate difficulties in recognizing marine introductions (Hass & Jones, 1999).

Three vectors for the introduction of marine exotics have been recognised: via ballast water discharge and hull fouling (considered accidental introductions), and through aquaculture (deliberate introductions) (Carlton, 1985; Jones, 1991). Marine species have been introduced into a number of Australian localities. Accidental introductions have been much more numerous, and have occurred widely over varying time frames. The European mussel, *Mytilus galloprovincialis* (previously considered to be *Mytilus edulis*) is widely distributed in the harbours and bays of southern Australia and may have been introduced by early European ships arriving in Australia. Some recent introductions, such as the Japanese sea star, *Asterias amurensis,* in Tasmania and the European fan worm, *Sabella spallanzanii,* in Victoria, have caused extensive ecological dislocations and damage to fisheries. Most recently, an infestation of the Black striped mussel, *Mytilopsis sallei***,** which has the potential to devastate the pearl industry, foul aquaculture cages and block drains and sewers, was found in a marina at Darwin and successfully eradicated.

Jones (1992a) recorded 113 marine introductions into Australian waters, tabulating 25 exotic marine species from the waters of Western Australia. Most of the Western Australian introductions have been identified from major ports. Over half the species (13) recorded were introduced by shipping, mainly as fouling organisms (11), and eight were introduced via ballast water (Jones 1992a).

Furlani (1996) provided a summary of 72 invertebrate, vertebrate and plant species known or thought to have been introduced into the Australian marine environment Also listed were species not yet recorded from Australia but which have the potential to colonise the waters adjoining the continent. However, although the document provides a good introduction to the problem of marine introductions into Australian waters, it contains various inaccuracies.

Hass & Jones (1999) increased to 30 the number of introduced marine species in Western Australian waters, the majority of which were crustaceans. They recorded 27 introduced species in the Swan River/Cockburn Sound area with the next highest being Bunbury Harbour with four. Only one introduced species, the barnacle *Megabalanus tintinnabulum*, was recorded from the Barrow Island/Dampier region. More recently, Jones (2003, 2004) recorded six fouling barnacle species in the Dampier region. Two of these (*Balanus amphitrite* and *B. trigonus*) are considered cryptogenic and four introduced species (*Balanus reticulatus, Megabalanus ajax, M. rosa* and *M. tintinnabulum*). *Megabalanus ajax, M. rosa, M. tintinnabulum* and *Balanus reticulatus* have all been recorded previously from Australian waters (Jones *et al.,* 1990; Jones, 1991; 1992a; 1992b; 2003; 2004; Jones & Hewitt, 1997) but the record of *Balanus reticulatus* is the first from Western Australian waters. Thus a total of 31 marine organisms (excluding ballast water and ballast sediment species) are now recorded as introductions into Western Australian waters. Most of these introductions are temperate, not tropical, species. The species that can be considered as introductions into the tropical northwestern Australian marine environment are listed in Table 1.

In September 2004 a baseline marine survey was conducted for ChevronTexaco in the waters of Barrow Island, on the northwestern coast of Western Australia, to determine whether any introduced pest species as listed by the National Introduced Marine Pest Information System (NIMPIS) (Hewitt *et al*., 2002) were present. NIMPIS was developed to provide accurate information on the biology, ecology and distribution of introduced marine species and potential control options for those designated as pests. The barnacles collected during the Barrow Island marine survey are reported on in this paper.

Material Collected

Samples were collected by Fred Wells and John Huisman in September 2004 at Barrow Island. The specimens are housed in the Western Australian Museum crustacean collection.

Results

Ten barnacle species were present in the samples (Table 2). This cirripede fauna contains the following elements:

1. **Common northwestern Australian intertidal and shallow water species**

Newmanella vitiata (Darwin, 1854: 340)
Tetraclita squamosa (Bruguière, 1789: 170)
Tetraclitella multicostata (Nilsson-Cantell, 1930: 2)

Chthamalus malayensis Pilsbry, 1916: 310
Armatobalanus quadrivittatus (Darwin, 1854: 284)

These species are typical of the cirripedian fauna of the tropical/warm temperate waters of Australia.

2. Indo-Malayan shallow water species not previously recorded from northern Australian waters

Balanus poecilotheca Krüger, 1911a: 48

This is the first record of this species from Australia waters. It is not, however, considered to be a fouling or a pest species.

3. Fouling species previously collected from Barrow Island (specimens in WA Museum collection)

Megabalanus tintinnabulum (Linnaeus, 1758: 668)

Specimens of this species are housed in the WA Musuem crustacean collection. The species is considered to be an introduction but not as a pest species.

4. Fouling species not previously collected from Barrow Island

Megabalanus ajax (Darwin, 1854: 214 (part))
Megabalanus rosa (Pilsbry, 1916: 61)
Balanus reticulatus Utinomi, 1967: 216

These species are all considered to be introductions but are not included as pest species on the NIMPIS list.

Discussion

The present report documents four barnacle species (*Balanus reticulatus, Megabalanus ajax, M. tintinnabulum* and *M. rosa)* that may be regarded as marine introductions into the waters of Barrow Island. Three of the species, *Balanus reticulatus, Megabalanus tintinnabulum* and *M. rosa*, are well known, widely distributed fouling species.

Balanus reticulatus was originally described from Japan (Utinomi 1967) but now has a widespread, circumtropical distribution - SE USA to W Indies; Mediterranean Sea; Malaysia to SE Africa; Hong Kong, to Gulf of Siam; east Asia from China, Yellow Sea, S China Sea; Australia; Japan and Hawaii to Malay Archipelago. In Australia, the species has been collected from the North Barnard Islands, Queensland (Lewis 1981), and in Western Australia from Yanchep Marina (Jones 1992b), more recently from the Dampier Archipelago (Jones 2003, 2004) and now from Barrow Island. The species has also recently been recorded from Darwin (Northern Territory) as well as from immigrant boats, submarines and shipping visiting various Australian ports (Jones unpublished data). In the Dampier Archipelago, *Balanus reticulatus* appears to be dominant in intertidal areas of Withnell Bay on the western lower Burrup Peninsula. The species is also present, at lower densities, on the eastern side of the Burrup Peninsula, as well as throughout the Dampier Archipelago and along the mainland, from Cape Preston to the west and Point Cleaverville to the east (Jones 2003, 2004). Utinomi (1967) has suggested that ship transport is responsible for the widespread distribution of this Japanese species. The means of *Balanus reticulatus* introduction into the waters of Western Australia are unknown, but the higher densities at Withnell Bay are close to the Woodside LNG jetty facility, supporting Utinomi's suggestion of distribution by ship transport. Shipping may also be assumed to be the vector for the introduction of the species to the waters of Barrow Island.

Megabalanus ajax is an Indo-West Pacific species, attaching mainly to corals (e.g. *Millipora complanata* Lamarck) but also occasionally known as a fouler of ships hulls (Jones, 1992a; 2003; 2004; Jones unpublished data). The species has been recorded from Queensland as well as from Western Australia (Shark Bay, the Muiron Islands, the Dampier Archipelago and now from Barrow Island). The possible vector for the introduction of this species to the waters of Barrow Island is shipping.

The appearance of the Japanese fouler, *M. rosa*, in the waters of Western Australia appears to be recent, the first specimens being collected in 1981 (Jones, 1992a). *Megabalanus rosa* is now established on the central and the north-western coast of Western Australia (Shark Bay, Carnarvon, Barrow Island, the Dampier Archipelago, Port Hedland and Cockatoo Island) as well as on the lower east coast of Australia (Woolongong, Port Botany and Port Kembla in New South Wales) (Jones *et al*., 1990; Jones, unpublished data). These are all areas that receive international shipping and, therefore, ship fouling is the most probable dispersal mechanism for this species. Allen (1953) recorded *M. rosa* with *M. volcano* and *Balanus albicostatus* on aircraft carriers and other vessels returning to Australia after service in Korean and Japanese waters. However, it is not known where these vessels docked and Allen (1953) did not record these species as established on the Australian coastline. It seems unlikely that *M. volcano* has become established in Australia as there are no records of its presence since that time. However, *B. albicostatus* has, more recently, been recorded from Victoria, albeit with few occurrences (Marine Research Group of Victoria, 1984).

Megabalanus tintinnabulum is a well known, cosmopolitan, hull-fouling species, first recorded in Western Australian waters in 1949 (Jones, 1990; 1991; 1992a). Jones (1990) suggested that this was an introduction via shipping since most Western Australian collection localities are in the vicinity of ports or areas that receive international shipping (e.g. Kwinana, Fremantle, Carnarvon, Barrow Island, Thevenard Island, Dampier, Cape Lambert, Cockatoo Island). Although early reports of *M. tintinnabulum* occurring on the eastern Australian coast may be erroneous (Allen 1953; Jones, 1990; 1991), records of the species have been confirmed from Bass Strait and the lower, mid and north-eastern coasts of Australia (Jones *et al*. 1990; Jones, unpublished data).

Although four potentially introduced barnacle species were found during the survey, none of these are considered to be pest species as none are included on the NIMPIS marine pest species list. However, once construction at Barrow Island begins and vessels begin to arrive from various Australian and foreign ports, the possibility of marine introductions and the establishment of potential marine pest species will increase dramatically. This is a situation that requires future long-term monitoring. Such future introductions are most likely to be species already established at Dampier and/or the Fremantle-Cockburn Sound area. No data are available as to whether the presence of introduced species in Western Australia (or Australia) has caused any ecological consequences, or whether they have had any adverse impacts on native species and, thus, any adverse impacts on biodiversity. It must also be noted that many introduced species have been recorded as one or a few individuals on one or a few occasions.

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Table 1: Species considered to be introductions into the NW Australian marine environment.

H = hull fouling

T = ballast tanks

U = unknown

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
ASCIDEACAE (Sea squirts)				
Botrylloides leachi (Savigny, 1816)	1899	**U** **WA** - Dampier Arch.; Rowley Shoals; Geraldton; Cockburn Sound; Bunbury; Albany; **Qld.** - Moreton Bay; Wistari Reef; Heron I.; Green I.; Lizard I.; C. Flattery, Townsville; **NSW** - Port Jackson; Bateman's Bay; Port Hacking; Lord Howe I.; Solitary Is; Norfolk I.; **Vic.** - Portsea Pier; **S Aust.** - Topgallant I.	**U** Distribution: Europe, Atlantic	Herdman, 1899 Kott, 1985 Furlani, 1996
Botryllus schlosseri (Pallas, 1766)		**H?** **WA** - Rowley Shoals; Shark Bay; Cockburn Sound; Swan R.; Albany; **Qld.** - Moreton Bay; Wistari Reef; Heron I.; Lizard I.; **Vic.** - Port Phillip Bay; Tas. - Bruny I.; **S Aust.** - E Great Australian Bight;	**U** Distribution: NE Atlantic to Mediterranean	Hartmeyer & Michaelsen, 1928 Kott, 1985 Sabbadin & Graziani, 1967 Furlani, 1996

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
		St Vincent Gulf; Yorke Pen.		
Styela plicata (Lesueur, 1823)	?1878	**H** **WA** - Monte Bello Is; Cockburn Sound; **Qld.** - Moreton Bay; Hervey Bay; Ross R.; **NSW** - Botany Bay; Port Jackson; Port Hacking; Port Kembla; Port Stephens; **Vic.** - Port Phillip Bay; Geelong; **S Aust.** - St Vincent Gulf; Spencer Gulf	**?H** Distribution: Philippines	Hartmeyer & Michaelsen, 1928 Kott, 1952 Kott, 1985 Kott & Goodbody, 1982 Hutchings *et al.*, 1987 Furlani, 1996
CRUSTACEA Cirripedia (Barnacles)				
Balanus amphitrite Darwin, 1854		**?H** Common fouler throughout **WA, S Aust., Vic., NSW, Qld, NT**	**U** Distribution: cosmopolitan in tropical, subtropical and temperate waters	Jones, 1992a
Balanus cirratus (Darwin, 1854)		**?H** Common fouler throughout **NWA, Qld**	**U** Distribution: Indo-west Pacific	Jones, 1992a
Balanus reticulatus Utinomi, 1967	1981 1992	**?H** **Qld** **WA** Yanchep Marina; Barrow I.; Dampier Archipelago	**?H** Distribution: Japan	Utinomi, 1967; Lewis 1981; Jones, 1992a; 2003; 2004
Balanus trigonus Darwin, 1854		**?H** Common fouler throughout **WA, NT, S Aust., Vic., Tas., NSW, Qld**	**U** Distribution: cosmopolitan in tropical and warm temperate seas.	Jones, 1992a
Megabalanus ajax (Darwin, 1854)		**?H** Occasional fouler throughout tropical and warm temperate seas in **WA** and **Qld**	**U** Distribution: Indo-west Pacific	Jones, 1992a; 2003; 2004
Megabalanus rosa (Pilsbry, 1916)	1981	**?H** **WA** - records	**?H** Distribution: Japan,	Allen, 1953; Jones, *in* Hutchings *et*

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
		from near ports (e.g. Port Hedland, Dampier, Barrow I., Carnarvon) **NSW –** off Wollongong	China, Taiwan	*al.*, 1987; Jones *et al.*, 1990; Furlani, 1996; Jones, 2003; 2004
Megabalanus tintinnabulum (Linnaeus, 1758)	1949	**H** **WA** - most records from near ports (Kimberley to Albany); **NSW** – Botany Bay, Port Kembla **Vic.** - Bass Str.; **NT** - Port Essington, Darwin	**U** **Distribution:** **c**osmopolitan	Allen 1953; Jones *in* Hutchings *et al.*, 1987 Jones, 1990; 1991; 1992a; Jones *et al.*, 1990; Furlani,, 1996
CRUSTACEA Isopoda				
Paracerceis sculpta (Holmes, 1904)	1996 1975	**H** **WA** - Bunbury, Mandurah, Fremantle, Port Denison; **Qld** - Townsville	**U** Distribution: California, USA, Brazil, Mexico, Italy, Spain	Harrison & Holdich, 1982b; Hutchings *et al.*, 1987; Furlani, 1996; Hass & Jones, 1999
Paradella dianae (Menzies, 1962)	1980 1971	**H** **WA** - Swan River; **Qld.** -Townsville, N Stradbroke I.	**U** Distribution: California, USA, Brazil, Puerto Rico or Marshall Islands	Harrison & Holdich, 1982a Hutchings *et al.*, 1987 Furlani, 1996
Sphaeroma serratum Fabricius, 1787	1980	**H** **WA** -	**U** Distribution: Widespread	Holdich & Harrison, 1983 Hutchings *et al.*, 1987 Furlani, 1996
BALLAST WATER				
22 zooplankton species, 45 other planktonic taxa including: crustaceans, molluscs, polychaete worms, arrow worms, coelenterates, sea squirts	1976-78	**T** **WA** -Dampier, C Lambert; **NSW** - Eden; **Tas**. - Triabunna	13 Japanese ports natural distribution uncertain	Williams *et al.* 1988
DINOPHYTA Toxic dinoflagellate cysts				

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
Alexandrium catenella (Whedon et Kofoid) Balech, 1985 **(**causes paralytic shellfish poisoning, PSP)	1989	**T** **WA** - Port Hedland; **Vic.**, **-** Port Philip Bay	Distribution: Japan	Jones, 1991 Hallegraeff *et al.* 1988 Hallegraeff & Bolch 1991 Hallegraeff *et al.* 1990
BALLAST SEDIMENT				
16 invertebrate species, 21 invertebrate taxa including: crustaceans, polychaete worms	1977-78	**T** **WA** - Cape Lambert, **NSW** - Sydney, Eden; **Tas. -** Triabunna	7 Japanese ports Natural distribution Japan/N Pacific/ uncertain	Williams *et al.* 1988

Table 2: Barnacle species collected from Barrow Island in September 2005

Label	Collection date	Identification	Nos individuals	Comments
BR1-7 Crus		*Newmanella vitiata*	12	
BW1-8C	17/09/04	*Newmanella vitiata*	6	
BW1-9	18/09/04	*Newmanella vitiata*	4	
BW1-10 Crus	18/09/04	*Newmanella vitiata*	12	
		Tetraclita squamosa	3	
		Tetraclitella multicostata	6	
		Chthamalus malayensis	3	
BW1-14 Crus	20/09/04	*Megabalanus ajax*	8	**Introduced species**
		Tetraclita squamosa	1	
		Chthamalus malayensis	4	
		Newmanella vitiata	9	
BW1-9 Crus		*Megabalanus tintinnabulum*	7	**Introduced species**
		Tetraclita squamosa	1	
BW1-2 Crus		*Megabalanus tintinnabulum*	9	**Introduced species**
BR1-2		*Megabalanus tintinnabulum*	20	**Introduced species**
		Megabalanus rosa	8	**Introduced species**
		Balanus reticulatus	26	**Introduced species**
		Balanus poecilotheca	4	
		Armatobalanus quadrivittatus	2	
BW1-15	20/09/04	*Tetraclita squamosa*	2	

Label	Collection date	Identification	Nos individuals	Comments
		Chthamalus malayensis	3	
BR1-12		*Tetraclita squamosa*	many	
BR1-4		*Tetraclita squamosa*	many	
BR1-2		*Megabalanus tintinnabulum*	19	**Introduced species**
		Megabalanus rosa	2	**Introduced species**

Technical Appendix D8

Pathogenic Micro-organism Threats to the Terrestrial Vertebrate Fauna of Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

PATHOGENIC MICRO-ORGANISM THREATS TO THE TERRESTRIAL VERTEBRATE FAUNA OF BARROW ISLAND

TECHNICAL APPENDIX D8

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August 2004

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Pathogenic Micro-organism Threats to the Terrestrial Vertebrate Fauna of Barrow Island

A Quarantine Assessment Report to the Gorgon Joint Venture

August 2004

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Table of Contents

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1. Background

1.1 Barrow Island

Barrow Island covers an area of 23,567 hectares and is situated 56 km off the Pilbara coast of Western Australia. It has been isolated from the mainland for approximately 6000 - 8000 years (Buckley, 1983; Sharrad and King, 1981), and as such forms an important sanctuary for its flora and fauna. In recognition of its pristine and unique nature, Barrow Island was declared a permanent reserve Class A for the protection of flora and fauna in 1910 (Cox, 1977), and is internationally recognised as a unique biodiversity repository. Introduced stock or feral animals have not grazed its vegetation and introduced predators have not affected its animal assemblages. Barrow Island Nature Reserve is probably the largest island in Australia, and one of the largest land masses in the world that has no introduced animals, making it one of the oldest and most valuable biodiversity conservation reserves in the world (CCWA, 2003; EPA, 2003).

1.2 Oil production and Barrow Island

In addition to Barrow Island's unique conservation and biodiversity values, it has been an actively producing oilfield since 1964 (Butler, 1970). West Australian Petroleum Pty. Ltd. (WAPET) operated the oilfield until 1999, when it was taken over by ChevronTexaco Australia Pty. Ltd. Since 1964 approximately 1000 wells have been drilled on the island, and these along with their attendant roads, gravel pits, campsites and other ancillary activities have only disturbed approximately 3% of the island's total area (Anon., 2003). With the proposed development of the gas processing facility on Barrow Island, this figure is expected to increase to 5% of the total area (Anon., 2003). Surveys of the vertebrate fauna commenced in 1964 to obtain information regarding the impact, if any, of this industry on the island fauna. Monitoring of the island wildlife has continued to the present, with very little indication of any adverse impact on vertebrate populations (Burbidge *et al.*, 2000a; Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Butler, 1970; Butler, 1975; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999; Serventy and Marshall, 1964; Smith, 1976).

The continued integrity of the Barrow Island wildlife can be attributed, at least in part, to the stringent quarantine policies put in place by ChevronTexaco with regard to anything coming onto Barrow Island (Anon., 2002b). These procedures have helped to ensure that introductions of invasive species (both animals and plants) do not occur. However, with the recent proposal to expand operations on Barrow Island, the issue of preventing microbial introductions has been identified as an important issue. Therefore this report is intended to assess the potential risk that introduced micro-organisms may pose to the terrestrial vertebrate fauna of Barrow Island.

1.3 Definitions

The terms micro-organism and parasite are used to describe the range of infectious agents, including viruses, bacteria, fungi, protozoa and helminths in this report. The terms pathogen and pathogenic are used to describe those infectious agents that are capable of causing disease. The term infectious is used to describe the capability of the micro-organisms to be transmitted to or between individual animals but is not in itself an indication of pathogenicity. External parasites (ticks, fleas, lice, flies etc.) may contribute a pathogenic effect to their host species (eg. anaemia), however they are deemed to be outside the scope of this report. Nevertheless, their role as vectors of infectious diseases will be discussed in the appropriate section(s). For the purpose of this report vectors are defined as invertebrate species capable of maintaining and introducing micro-organisms (eg. mosquitoes, ticks, fleas).

2. Importance of Micro-organisms in Wildlife

2.1 Importance of disease-causing micro-organisms

Disease-causing micro-organisms of wildlife occur in many different forms in a wide range of species which, when expressed in free-ranging populations, can have a significant effect on wildlife ecologies (Morner *et al.*, 2002). Whilst some micro-organism infections may occur as symptomless, subclinical disease with no obvious impact and/or consequence, occasionally there are dramatic epizootic outbreaks characterised by high morbidity and mortality (Morner *et al.*, 2002). As such, under certain conditions, micro-organisms can be considered a major evolutionary force and an important threat to biodiversity (Gulland, 1995; May, 1988; Scott, 1988).

The impact of micro-organisms on the survival, reproduction or dispersal of host individuals will depend upon the virulence of the pathogen, the infective dose and the resistance of the host to infection (Anderson and May, 1978; Gulland, 1995). These parameters can be modified by a number of factors such as malnutrition, overcrowding, stress and multiple parasitism that complicate the dynamics of the host-pathogen interaction (Gulland, 1995). Micro-organisms may also indirectly affect the survival of the host by increasing their susceptibility to predation or by reducing their competitive fitness (Berdoy *et al.*, 1995; Scott, 1988; Webster, 2001). Therefore, the consequences of these disease-causing agents may well be as important at the population level as at the immediate level of the individual (Lyles and Dobson, 1993).

2.2 Genetic Fitness and Infectious Diseases

Conservation biologists hypothesize that endangered species are especially vulnerable to infectious disease due to their small population sizes, leading to reduced genetic diversity and a reduced ability of the host to respond to pathogens in an evolutionary sense (Lyles and Dobson, 1993; O'Brien and Evermann, 1988). A lack of genetic variability in a population significantly improves the odds of an infectious disease-causing devastating effects, because when it overcomes one individual defence system it more likely than not will overcome the others in a genetically uniform population (O'Brien and Evermann, 1988; Ralls *et al.*, 1979). The same is true of island populations that have been isolated for long periods of time, such as on Barrow Island. Indeed, the reduced genetic diversity observed in some Barrow Island species (CCWA, 2003; King, 1998), could very well increase the effects of any debilitating disease should one be introduced to the island.

2.3 Population Size and Threshold Density

Host population size has a profound effect on the dynamics of a pathogen as every parasite requires a minimum density of hosts (threshold population) whereby it can maintain itself (Bartlett, 1960; Dobson and May, 1986; Lyles and Dobson, 1993). Ironically, the presence of a threshold for establishment suggests that small populations of species are relatively protected from virulent pathogens as there may be too few individuals present to continuously support an infection (Lyles and Dobson, 1993). However, this perceived level of protection actually increases the susceptibility of these animals to catastrophic disease outbreaks, as small populations of species are at a greater risk from non-host-specific pathogens than host-specific pathogens.

The susceptibility of small populations to pathogens may also be enhanced by the loss of endemic diseases once the population size falls below the critical levels required for the maintenance of such diseases (Cunningham, 1996). These populations risk becoming immunologically naïve, resulting in low levels of acquired immunity (Cunningham, 1996; Viggers *et al.*, 1993). Without this level of exposure, these populations are at an increased risk of being adversely affected by epidemics of what were previously endemic diseases, as well as new and emerging diseases (McCallum and Dobson, 1995).

2.4 Human Involvement in Disease Outbreaks

A common factor driving the emergence of wildlife disease is the anthropogenic movement of pathogens into new geographic locations – a phenomenon termed ‘pathogen pollution’ (Cunningham, 1996; Daszak *et al.*, 2000). Pathogen pollution is rooted in the unprecedented globalisation of agriculture, commerce, human travel and the transport of domestic animals and their products (Daszak *et al.*, 2001). Human landscape changes that remove portions of host populations, alter host migration patterns or increase host density are also likely to increase the risk of pathogen emergence (Dobson and May, 1986). Pathogen introductions have a particularly high impact when naïve host populations are involved and introduced pathogens may contribute to the competitive success of the invading carrier hosts (Hudson and Greenman, 1998).

2.5 Disease and Biodiversity

Wildlife populations have long been considered a link in the chain of pathogen emergence, by forming the reservoirs from which pathogens may emerge (Daszak *et al.*, 2001). However, wildlife populations are seldom the guilty party in the event of a disease outbreak, though more often than not they bear the brunt of its effects. Emerging infectious wildlife diseases have been responsible for mass mortalities as well as local (population) extinctions and global (species) extinctions (Cunningham and Daszak, 1998; Daszak and Cunningham, 1999). This direct loss of biodiversity due to infectious disease may lead to further impacts on ecosystems via 'knock-on' effects. These knock-on effects may lead to the extinction of species further up the food chain that remain uninfected by the pathogen. Hence, apart from the immediate direct and indirect effects on individual animal species, the introduction of disease may also have broad, long-term, and unforeseeable effects on ecosystems (Cunningham, 1996).

3. Vertebrate Species on Barrow Island

3.1 Mammal Species Present on Barrow Island

Barrow Island Nature Reserve is best known for its abundant mammal species. Oil exploration on Barrow Island commenced in 1954 (Cox, 1977), and since then, although a complete census has not been performed, numerous studies of the vertebrate fauna have been undertaken, focussing primarily upon the mammal fauna (Burbidge *et al.*, 2000a; Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Butler, 1970; Butler, 1975; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999; Serventy and Marshall, 1964; Smith, 1976). Presently there are 14 resident species and 1 vagrant species of mammal (Table 1) recognised as occurring on Barrow Island (Anon., 2002a).

Despite the relatively low number of mammal species present on Barrow Island, its mammal fauna is highly significant, as six of its species are listed as threatened pursuant to the *Wildlife Conservation Act 1950* (CCWA, 2003; EPA, 2003). Additionally, the Black-flanked Rock-wallaby (*Petrogale lateralis*) has declined across much of its former range due to habitat disturbance and introduced predators (Anon., 2002a; CCWA, 2003), whilst five of the mammal taxa (*Bettongia lesueur*, *Isoodon auratus barrowensis*, *Lagorchestes conspicillatus conspicillatus*, *Macropus robustus isabellinus* and *Pseudomys nanus ferculinus*) are regarded as being endemic subspecies or races (Anon., 2002a; CCWA, 2003; EPA, 2003).

Table 1. Terrestrial mammal species resident on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM mammal monitoring reports.

Family	Species	Common Name
Dasyuridae	*Planigale* sp. *Pseudantechinus* sp.	- -
Macropodidae	*Lagorchestes c. conspicillatus* *Macropus robustus isabellinus* *Petrogale lateralis*	Barrow Island Spectacled Hare-wallaby Barrow Island Euro Black-flanked Rock-wallaby
Peramelidae	*Isoodon auratus barrowensis*	Barrow Island Golden Bandicoot
Phalangeridae	*Trichosurus vulpecula arnhemensis*	Northern Brush-tailed Possum
Potoroidae	*Bettongia lesueur*	Barrow Island Boodie
Emballonuridae	*Taphozous gergianus*	Common Sheathtail Bat
Mollosidae	*Tadarida (Nyctinomus) australis*	White-striped Bat
Vespertilionidae	*Vespadelus (Eptesicus) finlaysoni*	Inland Cave Bat
Pteropodidae	*Pteropus alecto*	Black Flying-fox (vagrant)
Muridae	*Hydromys chrysogaster* *Pseudomys nanus ferculinus* *Zyzomys argurus*	Water-rat Barrow Island Chestnut Mouse Common Rock-rat

3.2 Reptile Species Present on Barrow Island

Barrow Island has an abundant terrestrial reptile fauna, comprising 35 species of lizard and 8 species of snake (Table 2). The assemblage of reptile species present on Barrow Island is somewhat more diverse than would typically be expected due

Table 2. Terrestrial reptile species present on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM fauna monitoring reports.

Family	Species	Common Name
Lizards		
Agamidae	*Ctenophorus caudicintus*	Ring-tailed Dragon
	Gemmatophora longirostris	Long-nosed Water-dragon
	Pogona minor	Bearded Dragon
Gekkonidae	*Diplodactylus jeanae*	
	Diplodactylus stenodactylus	Crowned Gecko
	Gehydra variegata	Tree Dtella
	Gehydra pilbara	Pilbara Dtella
	Heteronotia binoei	Bynoe's Gecko
Pygopodidae	*Delma borea*	
	Delma nasuta	
	Delma tincta	
	Lialis burtonis	Burton's Legless-lizard
	Pygopus nigriceps	Hooded Scalyfoot
Scincidae	*Carlia triacantha*	
	Cryptoblepharus carnabyi	
	Ctenotus duricola	
	Ctenotus grandis	
	Ctenotus hanloni	
	Ctenotus pantherinus acripes	
	Ctenotus saxatilis	
	Ctenotus serventyi	
	Cyclodomorphus melanops	
	Eremiascincus richardsonii	
	Glaphyromorphus isolepis	
	Lerista bipes	
	Lerista elegans	
	Lerista muelleri	
	Menetia greyii	Dwarf Skink
	Morethia lineoocellata	
	Morethia ruficauda	
	Notoscincus ornatus	
	Proablepharus reginae	
Varanidae	*Varanus acanthurus*	Spiny-tailed Goanna
	Varanus brevicauda	Short-tailed Goanna
	Varanus giganteus	Perentie

Snakes Boidae	*Antaresia stimsoni*	Stimson's Python
Elapidae	*Brachyurophis (Vermicella) approximans* *Demansia rufescens* *Furina ornate* *Pseudechis australis* *Suta (Rhinoplocephalus) monachus*	 Rufous Whip-snake Moon Snake Mulga Snake Monk Snake
Typhlopidae	*Ramphotyphlops ammodytes* *Ramphotyphlops longissimus*	

primarily to its geographic location, which encompasses species from both northern and southern regions (Smith, 1976). Whilst the majority of Barrow Island's reptile species are represented on the Australian mainland, the skink *Ctenotus pantherinus acripes* is an endemic subspecies, and the blind snake *Ramphotphlops longissimus* is the only endemic vertebrate species exclusive to Barrow Island (Anon., 2002a).

3.3 Amphibians Present on Barrow Island

The Western Australian Museum database suggests that three species of frog may occur on Barrow Island; *Cyclorana maini*, *C. platycephala* (Water-holding Frog), and *Litoria rubella* (Inland Tree Frog) (Anon., 2002a). However, there are no records of the Water-holding Frog and the Inland Tree Frog is believed to be an introduced specimen from the mainland in 1965 (Anon., 2002a). At present the only frog species recognised as being present on Barrow Island is *Cyclorana maini* (Table 3), which is also widespread throughout the adjacent Pilbara region (Anon., 2002a).

Table 3. Amphibian species present on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM fauna monitoring reports.

Family	Species	Common Name
Hylidae	*Cyclorana maini*	-

3.4 Bird Species Present on Barrow

Barrow Island is recognised as providing major and significant habitat for migratory wading birds which are protected by international treaty and by Commonwealth and State law (CCWA, 2003). As such, 110 species of birds have been recorded on Barrow Island, of which only 32 species are known to breed there (CCWA, 2003), making the island a major stopover/feeding ground for both locally and internationally migratory birds. Whilst some bird pathogens may potentially be brought on to Barrow Island via food and/or materials, the greatest potential for micro-organism introductions would be through migratory birds which is thus outside the control of Gorgon. Therefore it has been decided that the inclusion of birds in the present study under the aspect of controlling micro-organism introductions is outside the scope of this report as it would not be feasible to attempt to prevent birds from bringing micro-organisms onto Barrow Island.

3.5 Population Sizes and Dynamics

The mammal fauna on Barrow Island is currently subject to an annual monitoring programme run by the Department of Conservation and Land Management (DCLM) (Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999). Several attempts have been made to obtain estimates of population size for the larger mammal species on Barrow Island prior to the establishment of a mammal monitoring programme by DCLM (Butler, 1970; Short and Turner, 1991; Short and Turner, 1993; Short *et al.*, 1988). However, obtaining accurate population size estimates agreeable to all parties has proven difficult due to the variety of techniques used (eg. spotlight transects, monitoring grids, quadrat surveys, track count surveys) and the sampling errors associated with each technique. Data collected via spotlighting surveys has generally been considered inaccurate due to variation between different operators as well as the visibility of particular mammal species. However, it is still a common and widespread method used to estimate species population size.

The spotlight monitoring transects set up and run by DCLM on Barrow Island since 1998 using the same techniques and transects (detailed in their mammal monitoring reports) have provided data collected by a common means over a number of years, providing an estimation of population size for the larger mammal species (Table 4). However, there is no similar data available for the smaller mammal species present on Barrow Island. Likewise, there is a dearth of information regarding population size and distribution of reptile species on Barrow Island with data on their patterns of distribution limited to reports of them being closely related to the soil type, areas of accumulation of leaf litter and to distinctive vegetation types present across the island (Anon., 2002a).

Table 4. Estimates of minimum total population size of commonly sighted mammals on Barrow Island, sourced from Burbidge *et al.* (2003).

	Barrow Island Euro	Boodie	Brushtail Possum	Golden Bandicoot	Spectacled Hare-wallaby
Butler (1970)	200+	400+	-	1000+	600+/800+*
Short *et al.* (1988)	1500	2500	-	3200	8600
Burbidge *et al.* (1998)	914 (554-1526)	2884 (1883-4589)	1360 (1149-1945)	3679 (2867-4235)	1661 (1389-1988)
Burbidge *et al.* (2000)	761 (462-1268)	564 (444-716)	650 (491-861)	1753 (855-1333)	1016 (749-1067)
Morris *et al.* (2001)	935 (497-1714)	2223 (1583-3125)	1366 (951-1973)	1971 (1515-2597)	888 (720-1098)
Morris *et al.* (2002)	528 (305-924)	1718 (1368-2176)	910 (683-1213)	1679 (1327-2133)	828 (650-1053)
Burbidge *et al.* (2003)	851 (462-1607)	1896 (1454-2472)	1468 (1033-2110)	2528 (2031-3145)	1137 (908-1423)

*600+ estimated in 1966, 800+ estimated in 1969 (Butler, 1970).

4. Micro-organisms Infecting Barrow Island Terrestrial Vertebrates or Related Mainland Species

4.1 Micro-organisms present on Barrow and surrounding islands

Despite the extremely high biodiversity conservation values of Barrow Island, there is relatively little published data on the biology and ecology of its terrestrial vertebrate species and even less is known of its invertebrate fauna. Very little information exists regarding micro-organisms present on Barrow Island. Therefore, in assessing and compiling a list of potential micro-organisms that may pose a risk to the vertebrate fauna on Barrow Island, we have had to extrapolate our results from studies on similar vertebrate species which have been conducted elsewhere in Australia, and in some instances overseas.

The only known research conducted on Barrow Island related to micro-organisms involved the isolation of *Salmonella* species from seagulls in 1986 and several observed cases of "Lumpy Jaw" in euros (presumably *Fusobacterium necrophorum*) (Butler, W. H. pers. comm., 2004). Recent studies carried out by a PhD student on Barrow Island have detected ticks and fleas on mammals however their identification is still ongoing. In addition, analysis of ticks from mammalian hosts has identified two novel *Rickettsia* species within the Spotted Fever Group and these are still being characterised. Spotted Fever Group rickettsiae are zoonotic organisms that are well documented as disease agents in many parts of the world including Australia. The pathogenicity of these rickettsiae for humans and animals on the island is as yet unknown.

4.2 Micro-organisms infecting Barrow Island vertebrates and related species in Australia

Due to the dearth of information regarding micro-organisms present in the terrestrial vertebrate species of Barrow Island it was necessary to refer to the literature detailing the occurrence of micro-organisms in similar and related host species elsewhere in

Australia. However, in comparison to the amount of information available regarding pathogens of humans and domestic livestock, there is still very little information available with regard to disease/infection risks for Australian native mammals, and even less for reptiles.

The typically destructive techniques involved with collecting and identifying internal parasites has lead most investigations to focus on the study of parasites in the more common native species (O'Donoghue and Adlard, 2000; Spratt *et al.*, 1990), however systematic surveys of native species are still rare. As such, comprehensive records of parasitic infections and disease infections are known for very few of our native species. Similarly, the less invasive methods required for surveying gastro-intestinal parasites of wildlife species has resulted in a more thorough understanding of them as opposed to the more cryptic species of pathogen. In addition, much of the available information relates to surveys of fauna for infectious micro-organisms rather than to actual disease occurrence.

Diseases in wild populations should be investigated from the perspective that multiple aetiological agents and predisposing factors are involved (Fowler, 1982), as they are an aspect of wildlife death-rate that must be understood in order to gain an accurate view of population dynamics (Speare *et al.*, 1989). The occurrence and localisation of disease in wildlife is determined by a variety of factors, including those that relate to the host, the causative agent and the environment (Morner *et al.*, 2002). Indeed many parasites have well-established commensal relationships with their host species and outbreaks of disease only occur following a shift in the hosts' ecology caused by environmental or physical stress. The vast majority of parasitic species recorded from host animals have no obvious pathological effects upon their host under normal conditions. Therefore, the presence of a parasitic agent in a host species does not necessarily indicate the occurrence of disease.

For the purpose of this review of the species of micro-organism that may potentially pose a risk to the terrestrial vertebrate species present on Barrow Island, we have grouped the mammalian species into their family assemblages (except for the bats which have been grouped into their order Chiroptera), the reptile species into lizards and snakes, and the single frog species is dealt with as a whole.

Additionally, the micro-organisms known to occur in these vertebrate hosts are presented in three sections. The first list of micro-organisms describes those genera that have been reported as occurring in the above host groups throughout Australia, encompassing both disease-causing as well as commensal micro-organisms. These are presented in Appendices 1-3 for the mammals, reptiles and amphibians respectively. Secondly, an abbreviated list, including only those pathogens reported as causing disease in host species representative of the Barrow Island vertebrate fauna, is presented for the mammals (section 4.2.1; Table 5), reptiles (section 4.2.2; Table 6) and amphibians (section 4.2.3; Table 7). Thirdly, a shortened list is presented concerning only those micro-organisms considered to pose a significant risk to the Barrow Island vertebrate fauna. This list is based on pathogenicity, transmission risk to Barrow Island and occurrence in Western Australia fauna (section 4.2.4).

4.2.1 Mammalian hosts

The abbreviated list of pathogens reported as potentially causing disease in mammalian host species representative of the Barrow Island fauna is presented in Table 5. Below is a brief synopsis of the disease syndromes for each pathogen listed.

4.2.1.1 Viruses

Wart Disease in bandicoots – newly discovered unidentified viral disease-causing debilitating wart-like lesions in Western Barred bandicoots from Bernier Island off Western Australian coast, cross species infectivity unknown (Swan *et al.*, in prep.).

Macropod Herpesvirus – cause of conjunctivitis, muco-cutaneous blisters and ulcerations and may progress to death; reported as a cause of disease in numerous species of captive macropods, clinical disease not reported from free-ranging macropods (Speare *et al.*, 1989).

Macropod Poxvirus – causes two types of lesions including wart-like lesions in several species of wild macropods; its natural history in free-ranging populations is unknown (Speare *et al.*, 1989).

Table 5. List of mammalian groups present on Barrow Island and pathogens reported as causing disease in these species elsewhere in Australia.

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Dasyuridae	Bacteria	*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
Antechinus sp.		*Leptospira*	soil; water	Yes	E Aust	(Arundel *et al.*, 1977)
Planigale sp.	Protozoa	*Babesia*	vector	Yes?	E Aust	(Arundel *et al.*, 1977)
		Cryptosporidium	faecal; water	Yes	SE Aust	(Barker *et al.*, 1978)
		Giardia	faecal; water	Yes	Tas	(Milstein and Goldsmid, 1997)
		Toxoplasma	food; water	Yes	WA	(Haigh, 1994)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)
		Pelecitus	vector	Yes	Aust	(Spratt, 1979)
		Marsupostrongylus	vector	Yes	E Aust	(Spratt, 1979; Spratt, 1984)
		Ophidascaris	faecal	Yes	Aust	(Speare *et al.*, 1984)
		Spirometra	vector	Yes	Aust	(McMillan and Walker, 1969)
Peramelidae	Viruses	Wart disease	animal	Yes	WA	(Swan *et al.*, in prep.)
Barrow Island Golden Bandicoot	Bacteria	*Chlamydia*	animal	Yes	WA	(Warren *et al.*, in prep.)
		Salmonella	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	WA	(Adams, 2003)
		Giardia	faecal; water	Yes*	WA	(Adams *et al.*, in press)
		Toxoplasma	food; water	Yes	WA	(Adams, 2003)
		Trypanosoma	exprmtl; vector	Yes	Qld?	(Bettiol *et al.*, 1998)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Phalangeridae	Bacteria	*Bacillus*	faecal	No	Aust	(Speare *et al.*, 1984)
Northern Brushtail Possum		*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
		Leptospira	soil; water	Yes?	SE Aust	(Durfee and Presidente, 1979)
		Mycobacterium	soil	No	SE Aust	(Corner and Presidente, 1980)
		Pseudomonas	animal	Yes	SE Aust	(Speare *et al.*, 1984)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	SE Aust	(Power *et al.*, 2003)
		Giardia	faecal; water	Yes*	Tas	(Milstein and Goldsmid, 1997)
		Leishmania	exprmtl; (vector)	Yes	Qld?	(Backhouse and Bolliger, 1951)
		Toxoplasma	food; water	Yes	NSW	(Canfield *et al.*, 1990; Cook and Pope, 1959)
		Trypanosoma	exprmtl; (vector)	Yes	Qld?	(Backhouse and Bolliger, 1951)
		Hepatazoon	?	Yes	SE Aust	(Speare *et al.*, 1984)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)
		Marsupostrongylus	vector	Yes*	Qld	(Speare *et al.*, 1984)
		Ophidascaris	faecal	Yes	Qld	(Presidente, 1978)
Potoroidae	Bacteria	*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
Barrow Island Boodie		*Salmonella*	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	Aust	No record
		Giardia	faecal; water	Yes*	Aust	No record
		Toxoplasma	food; water	Yes	Aust	(Patton *et al.*, 1986)
	Helminths	*Angiostrongylus*	vector	Yes?	Qld, NSW	(Prociv and Carlisle, 2001)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Macropodidae	Viruses	Macropod herpesvirus	animal	Yes	WA	(Britt *et al.*, 1994)
Barrow Island Euro		Macropod poxvirus	animal	Yes	WA	(Speare *et al.*, 1989)
Spectacled Hare-wallaby		Wallal & Warrego viruses	vector	Yes	WA	(Hooper *et al.*, 1999)
Black-flanked Rock Wallaby	Bacteria	*Fusobacterium*	soil	Yes	WA	(Speare *et al.*, 1989)
		Leptospira	soil; water	Yes?	SE Aust	(Durfee and Presidente, 1979)
		Salmonella	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	NSW	(Power *et al.*, 2004)
		Giardia	faecal; water	Yes*	Tas	(Milstein and Goldsmid, 1997)
		Leishmania	vector	Yes	NT	(Rose *et al.*, 2004)
		Toxoplasma	food; water	Yes	WA	(Jakob-Hoff and Dunsmore, 1983)
		Trypanosoma	exprmtl; vector	Yes	Aust?	(Noyes *et al.*, 1999)
	Fungi	*Microsporum*	soil	Yes	Aust	(McAleer, 1980; Speare *et al.*, 1989)
		Trichophyton	soil	Yes	Aust	(McAleer, 1980; Speare *et al.*, 1989)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(McKenzie *et al.*, 1978)
		Filaroids	vector	Yes	Aust	(Speare *et al.*, 1989)
		Pelecitus	vector	Yes*	Aust	(Speare *et al.*, 1989; Spratt, 1972)
		Globocephaloides	soil	Yes*	Aust	(Arundel *et al.*, 1977)
		Hypodontus	soil	Yes*	Aust	(Beveridge, 1979; Speare *et al.*, 1989)
		Marsupostrongylus	vector	Yes	Aust	(Speare *et al.*, 1989)
		Strongyloides	soil	Yes	Aust	(Arundel *et al.*, 1977; Speare *et al.*, 1983)
		Echinococcus	soil	Yes*	WA	(Lymbery *et al.*, 1990)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Chiroptera	Viruses	Australian Bat Lyssavirus	animal	Yes	Qld	(Warrilow *et al.*, 2003)
Common Sheathtail Bat	Bacteria	*Leptospira*	soil; water	Yes?	Aust	(McCoy, 1974)
White-striped Bat		*Salmonella*	faecal; food; water	Yes*	Aust	(McCoy, 1974)
Inland Cave Bat		*Mycobacterium*	soil	Yes*	Aust	(McCoy, 1974)
Black Flying-fox (vagrant)	Protozoa	*Toxoplasma*	food; water	Yes	Aust	(Hoar *et al.*, 1998)
		Trypanosoma	exprmtl; vector	Yes	Aust	(Hoar *et al.*, 1998; Molyneux, 1991)
	Fungi	*Histoplasma*	soil	Yes*	Aust	(Hoar *et al.*, 1998)
		Blastomyces	soil	Yes*	Aust	(Hoar *et al.*, 1998)
		Cryptococcus	soil	Yes*	Aust	(Hoar *et al.*, 1998)
	Helminths	*Angiostrongylus*	vector	Yes	NSW, Qld	(Barrett *et al.*, 2002)
Muridae	Viruses	Mossman Virus (MoV)	?	No	Qld	(Miller *et al.*, 2003)
Barrow Island Chestnut Mouse		Murine Cytomegalovirus	animal	Yes	WA	(Moro *et al.*, 1999)
Common Rock-rat		Murine corona virus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
Water-rat		Murine rotavirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Mouse adenovirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Parvovirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Reovirus type 3	animal	Yes	SE Aust	(Smith *et al.*, 1993)
	Bacteria	*Leptospira*	soil; water	No	Qld	(Glazebrook *et al.*, 1978)
		Pseudomonas	soil; water	Yes	Qld	(Glazebrook *et al.*, 1978)
		Salmonella	faecal; food; water	Yes*	Qld	(Glazebrook *et al.*, 1978)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	WA	(Swan *et al.*, in prep.)
		Toxoplasma	food; water	Yes	WA	(Smales and Obendorf, 1996)
	Helminths	*Angiostrongylus*	vector	No	WA	(Prociv and Carlisle, 2001)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

Wallal and Warrego virus – orbiviruses responsible for kangaroo blindness throughout Australia; outbreaks have been observed in both kangaroos and euros in Western Australia (Hooper *et al.*, 1999).

Australian Bat Lyssavirus – closely related to rabies; present in numerous species of Australian bat; Black Flying-foxes (*Pteropus alecto*) are known to be infected with Australian Bat Lyssavirus (Warrilow *et al.*, 2003).

Mossman virus – a novel paramyxovirus and respiratory pathogen of both introduced and native rodents in Queensland; disease-causing potential is unclear (Miller *et al.*, 2003).

Murine Cytomegalovirus – has been detected in domestic mice in WA on Thevenard Island; no evidence of transmission to native mice and experimental infections did not produce infections (Moro *et al.*, 1999).

Murine corona virus, Murine rotavirus, Mouse adenovirus, Mouse parvovirus and Mouse reovirus type 3 – these viruses are a widespread cause of disease in domestic mice throughout south-eastern Australia; none of these viruses have been detected in surveys of domestic mice in WA (Moro *et al.*, 1999; Smith *et al.*, 1993).

4.2.1.2 Bacteria

***Bacillus* –** enteric infection often spreading to the liver (Tyzzer's disease), spores shed in faeces are environmentally resistant for at least 12 months (Speare *et al.*, 1984).

***Chlamydia* –** obligate intracellular pathogen causing a wide range of diseases including enteritis, respiratory disease, polyarthritis, conjunctivitis urogenital tract disease and abortion, symptoms range from inapparent through to severe in its many different host species; currently a disease of concern in reintroduced and translocated bandicoots in Western Australia (Bodetti *et al.*, 2003).

***Fusobacterium* –** soil-borne micro-organism; causative agent of "Lumpy Jaw" in macropods, associated with various stress factors, often degenerates to terminal septicaemia in affected animals; widespread occurrence in Australia (Speare *et al.*, 1989).

***Leptospira* –** bacterial pathogen passed in the urine of many rodents; infective to a wide range of hosts; associated with abortion in infected hosts (Speare *et al.*, 1989).

Mycobacterium **–** causative organism of tuberculosis, infections are generally atypical (Corner and Presidente, 1980).

Pseudomonas **–** associated with pouch infections leading to death of pouch young due to peritonitis and/or septicaemia (Speare *et al.*, 1984).

Salmonella **–** can cause gastroenteritis and septicaemia in mammals, infections appear to be related to nutritional and environmental stressors; zoonotic infections reported from marsupials in Western Australia (Iveson and Bradshaw, 1973; Speare *et al.*, 1989).

4.2.1.3 Protozoa

Babesia **–** blood-borne parasite associated with anaemia and post-mating mortalities in male dasyurids, may potentially facilitate other infections (Arundel *et al.*, 1977).

Cryptosporidium **–** can cause gastroenteritis in both young and adult animals, environmental and stress factors may influence infections, known to cause deaths in young and juvenile animals, prevalent in water sources throughout Australia (Hallier-Soulier and Guillot, 2000; Power *et al.*, 2004).

Giardia **–** disease symptoms range from asymptomatic to severe diarrhoea; responsible for malabsorption; common water source contaminant; human strains shown to be readily infective to bandicoots (Bettiol *et al.*, 1997).

Hepatozoon **–** blood borne haemogregarine, associated with decreases in body condition and anaemia in animals (Speare *et al.*, 1989).

Leishmania **–** causative agent of cutaneous inflammation and skin lesions in kangaroos; transmitted between hosts by sandflies, potential zoonotic pathogen (Rose *et al.*, 2004).

Toxoplasma **–** ubiquitous obligate intracellular parasite infective to virtually all species of warm-blooded animals, common cause of death in captive and wild Australian marsupials (Obendorf and Munday, 1990; Reddacliff *et al.*, 1993).

Trypanosoma **–** blood-borne parasites causing anaemia, ulcerative gastritis, enteritis and death in its hosts; prevalent throughout southeast Asia; shown to be infective to native marsupials (Bettiol *et al.*, 1998; Reid *et al.*, 2001).

4.2.1.4 Fungi

Blastomyces, ***Cryptococcus*** – fungal genera causing granulomatous disease of mucous membranes; typically acquired from direct contact with soil enriched with bat faeces (Hoar *et al.*, 1998).

Histoplasma – soil saprophyte, thrives in warm, moist environments especially if enriched with organic material; infection occurs predominantly through aerosols and direct contact with contaminated soils (Hoar *et al.*, 1998).

Microsporum, ***Trichophyton*** – soil-borne and animal associated fungi; causative agents of Ringworm; common in captive mammal species throughout Australia, though can cause infections in stressed populations (Speare *et al.*, 1989).

4.2.1.5 Helminths

Angiostrongylus – nematode parasite cycled through slugs/snails with a rodent definitive host; causes neurological disorders and mortalities in non-specific hosts such as macropods and bandicoots (Prociv and Carlisle, 2001).

Echinococcus – cestode parasite cycled between dogs and macropods; intermediate stages form large fluid filled cysts in lungs, liver and other internal organs (Lymbery *et al.*, 1990).

Globocephaloides, ***Hypodontus*** **–** common nematode parasites of macropods capable of causing anaemia and hypoproteinaemia; known to cause death in wild macropods (Speare *et al.*, 1989).

Marsupostrongylus – mosquito-borne lungworms often associated with a mild to severe interstitial pneumonia; severity usually determined by the number of parasites infecting the lung (Spratt, 1984).

Ophidascaris **–** nematode found in numerous marsupial species; pythons as definitive host; mortalities have been reported in intermediate hosts such as possums and small dasyurids due to migration of larvae within host (Speare *et al.*, 1984).

Pelecitus **–** blood-borne nematode; transmitted by biting tabanid flies; infection in macropod hosts ranges from asymptomatic to severe disease (Speare *et al.*, 1989).

Strongyloides – nematode parasite commonly occurring in macropods, may cause focal hyperaemia, responsible for deaths of captive macropods though usually well tolerated by host (Speare *et al.*, 1989).

4.2.2 Reptilian hosts

The abbreviated list of pathogens reported as causing disease in reptilian host species representative of the Barrow Island reptile fauna is presented in Table 6. A brief synopsis of the disease associated with each pathogen is presented below. Diseases occurring in reptile species outside of Australia may have the potential to infect Australian reptiles given their common evolutionary ancestry, however this was deemed to be outside the scope of this report as at this point in time the ports of origin of vessels supplying Barrow Island have not been confirmed. Nevertheless, it must be noted that reptiles can be brought to Barrow Island from outside Australia via equipment and vessels and may therefore act as a source of exotic reptilian disease.

4.2.2.1 Viruses

Ophidian paramyxovirus – recently reported virus affecting numerous snake species; cause of "die-offs" in viperid, elapid, boid and colubrid snakes; produces intranuclear inclusion bodies in lung and brain, respiratory disease associated with wasting and death; reported in snakes from several collections in New South Wales (Ross, 2004).

Inclusion body disease – primarily a boid-specific disease; cause of regurgitation and central nervous system signs; no available treatment and infection is invariably fatal in pythons; present in snakes in Western Australia (Bush, 2000).

Wamena virus – reported to have caused disease in a python in Queensland (Daszak *et al.*, 1999).

4.2.2.2 Bacteria

Chlamydia - obligate intracellular pathogen causing a wide range of diseases in numerous host species; symptoms range from inapparent to severe; present in reptiles in Australia (Bodetti *et al.*, 2002; Jacobson and Telford, 1990).

***Dermatophilus* –** cause of skin disease and debilitation of crocodiles in the Northern Territory (Fenwick, pers. comm., 2004).

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Table 6. List of reptilian groups present on Barrow Island and pathogens reported as causing disease in these species elsewhere in Australia.

Group	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Lizards	Viruses	Ophidian Paramyxovirus	vector?	?	?	No reports
		Inclusion Body Disease	vector?	?	?	No reports
	Bacteria	*Salmonella*	faecal; food; water	Yes*	Aust	(Iveson *et al.*, 1969)
		Leptospira	soil; water	Yes*		No reports
		Rickettsia	vector	Yes*	Aust	(Stenos *et al.*, 2003)
		Dermatophilus	soil; animal	Yes	NT	(Fenwick pers. comm.., 2004)
	Protozoa	*Cryptosporidium*	faecal; water	Yes	Aust	(Oros *et al.*, 1998; Xiao *et al.*, 2004)
	Helminths	*Angiostrongylus*	vector	Yes	Thailand	(Radomyos *et al.*, 1994)
Snakes	Viruses	Ophidian Paramyxovirus	vector(?)	Yes	NSW	(Ross, 2004)
		Inclusion Body Disease	vector	Yes	WA	(Bush, 2000; Carlisle-Nowak *et al.*, 1998)
		Wamena virus	?	?	Qld	(Daszak *et al.*, 1999)
	Protozoa	*Cryptosporidium*	faecal; water	Yes	NSW	(Boylan *et al.*, 1985)
	Fungi	*Chrysosporium*	animal; faecal	Yes*	Qld	(Vissiennon *et al.*, 1999)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

***Salmonella* –** cause of gastroenteritis; known to occur in reptiles in Western Australia (Iveson *et al.*, 1969).

4.2.2.3 Protozoa

***Cryptosporidium* –** cause of chronic gastro-intestinal disease in snakes with protracted clinical disease eventually resulting in death; generally results in only subclinical infections in lizards; most reports originating from captive reptiles however survey of free-ranging reptiles in South Australia reported infections occurring in snakes (O'Donoghue, 1992; O'Donoghue, 1995).

4.2.2.4 Fungi

***Chrysosporium* –** ubiquitous mould commonly occurring in soil, rarely disease-causing in humans and animals (Vissiennon *et al.*, 1999).

4.2.2.5 Helminths

Angiostrongylus - nematode parasite cycled through slugs/snails with a rodent definitive host, infective stages recently reported in varanid lizards from Thailand (Radomyos *et al.*, 1994).

4.2.3 Amphibian hosts

The abbreviated list of pathogens reported as causing disease in amphibian host species belonging to the family Hylidae is presented in Table 7. A brief synopsis of the disease associated with each pathogen is presented below.

4.2.3.1 Viruses

Bohle virus – highly virulent ranavirus causing systemic infections in frogs from eastern Australia; tadpoles appear to be most susceptible (Daszak *et al.*, 1999).

Table 7. List of pathogens reported as causing disease in amphibian species elsewhere in Australia that may infect *Cyclorana maini*.

Family and Species	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Hylidae	Viruses	Bohle virus	?	?	Aust	(Hengstberger *et al.*, 1993)
Cyclorana maini	Bacteria	*Chlamydia*	animal	Yes	Qld	(Berger *et al.*, 1999)
		Leptospira	soil; water	Yes*	Aust	(Charon *et al.*, 1975)
	Fungi	*Batrachochytrium*	animal	Yes	WA	(Berger *et al.*, 2000; Morell, 1999)
		Mucor	animal; faecal	Yes	Aust	(Berger *et al.*, 1997)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

4.2.3.2 Bacteria

Chlamydia **–** cause of a wide range of diseases in mammalian hosts; recently reported in amphibians (Berger *et al.*, 1999).

4.2.3.3 Fungi

Batrachochytrium **–** ubiquitous fungi found in aquatic habitats and moist soil; cause of chytridiomycosis and responsible for mass deaths in amphibans in Australia and worldwide (Daszak *et al.*, 1999).

Mucor **–** report of disease occurring in frogs belonging to the family Hylidae in Australia (Berger *et al.*, 1997).

4.2.4 Pathogens posing disease risks to Barrow Island fauna

Tables 5-7 are extensive lists of those micro-organisms recognised as infecting native animals but not necessarily causing disease. It is therefore important to look more closely at those that are potentially pathogenic for the vertebrate fauna on Barrow Island. In consideration of this Table 8 lists those micro-organisms that pose the greatest threat to the fauna and their potential routes of transmission. The list has been compiled based on available information from the literature. In all cases these organisms have been associated with disease on more than one occasion and most have been described in Western Australia or are suspected to be present. Details of disease syndromes and related references have already been supplied (section 4.2.1, 4.2.2 and 4.2.3). Although some of these micro-organisms do not cause severe disease the potential effects of debilitation on isolated populations are unclear. However, it must be stressed that without any background information a number of these micro-organisms may already be present on the island. Similarly, micro-organisms not on this list may also be capable of causing disease in the Barrow Island fauna.

Table 8. Pathogenic micro-organisms that pose the highest risk to the Barrow Island terrestrial vertebrate fauna.

Pathogen	Species Affected	Infection Route
Chlamydia	all	animal
Cryptosporidium	all	faecal; water
Toxoplasma	all	food; water
Salmonella	all	faecal; food; water
Wart Disease	bandicoots	animal
Wallal & Warrego virus	macropods	vector
Globocephaloides/Hypodontus	macropods	soil
Australian Bat Lyssavirus	bats	animal
Ophidian Paramyxovirus	reptiles	animal; vector(?)
Inclusion Body Disease	reptiles	animal; vector(?)
Batrachochytrium	frogs	animal
Trichophyton, Microsporum	all	animal; soil

4.2.5 Zoonotic diseases of concern on Barrow Island

Zoonoses are those infections carried by animals capable of causing disease in humans. As stated previously little is currently known of the micro-organisms on Barrow Island or their zoonotic capability (apart from the presence of Spotted Fever Group rickettsiae and *Salmonella* strains), however a number of those that could potentially establish in the wildlife and thus pose a risk are outlined in Table 9.

Previous reports of zoonotic disease on Barrow Island are limited to the possible presence of Q fever (*Coxiella burnetii*), however this caused considerable concern among the workforce in 2002 (Fenwick pers. comm., 2004). With the presence of an expanded workforce on Barrow Island a brief discussion of potential zoonotic diseases, either present or at risk of introduction, was deemed important.

Table 9. Micro-organisms that pose a zoonotic risk to the Barrow Island workforce should they be transmitted to the Barrow Island fauna.

Pathogen	Disease in Animal	Reservoir Host	Infection Route	Reference
Cryptosporidium sp.	Yes	all	faecal; water	(O'Donoghue, 1992)
Salmonella sp.	Yes	all	faecal; water	(Iveson and Bradshaw, 1973)
Coxiella	No	mammals	vector	(Fenwick pers. comm., 2004)
Spotted Group Rickettsiae	No	mammals	vector	(Fenwick pers. comm., 2004)
Ross River virus	No	macropods	vector	(Mackenzie *et al.*, 2001)
Barmah Forest virus	No	marsupials	vector	(Mackenzie *et al.*, 2001)
Murray Valley encephalitis	No	macropods	vector	(Cordova *et al.*, 2000)
Australian Bat Lyssavirus	Yes	bats	animal	(Warrilow *et al.*, 2003)

Cryptosporidium **–** readily transmissible between host species; highly resistant stages able to persist in environment for long periods of time; commonly found to be contaminating water sources; contact with animals is a known risk factor (Hallier-Soulier and Guillot, 2000; O'Donoghue, 1992).

Salmonella **–** common cause of gastroenteritis in both animals and humans; readily transmitted via food and faecal contamination; contact with marsupials has been reported as causing infection in humans in Western Australia (Iveson and Bradshaw, 1973).

Coxiella **–** cause of Q fever; maintained in animal and arthropod reservoirs; transmission via aerosols, dust and ticks; cause of concern on Barrow Island however organism has not been isolated; studies are ongoing as to its presence on the island (McDiarmid *et al.*, 2000; Storer *et al.*, 2003).

Spotted Fever Group Rickettsiae – tick-borne organisms causing disease in people in Australia; maintained in animal and arthropod reservoirs; transmission via tick bites; two new species recently isolated from ticks on Barrow Island, significance uncertain, further studies ongoing (Fenwick pers. comm., 2004).

Ross River virus – mosquito-borne virus causing an epidemic polyarthritis, macropods considered to be reservoir hosts, most prevalent in coastal areas and salt marshes; considered to be an emerging disease; increased awareness has lead to improved diagnosis and higher incidence of disease detection (Mackenzie *et al.*, 2001).

Barmah Forest virus – mosquito borne virus causing epidemic polyarthritis-like disease; similar to but distinct from Ross River virus; circulates between mosquitos and terrestrial animals, particularly marsupials; considered an emerging disease; increasing incidence due to greater awareness of symptoms (Mackenzie *et al.*, 2001).

Murray Valley encephalitis – mosquito-borne virus typically more prevalent throughout the Kimberley though reported as far south as the northern Goldfields in Western Australia following excessive rainfall in 2000 (Broom *et al.*, 2002; Cordova *et al.*, 2000).

Australian Bat Lyssavirus – closely related to the rabies virus; cause of illness and neurological disorders in bats; two cases of infection in humans, both resulting in fatal encephalitis; research has shown that two genetically distinguishable strains occur, one in frugivorous bats and the other in insectivorous bats; insectivorous bat colonies are present on Barrow Island and frugivorous bats have also been recorded on the island (Mackenzie, 1999; Mackenzie *et al.*, 2001).

5. Pathogen Pathways

Major transmission pathways for exotic organisms onto Barrow Island have been identified in relation to the movement of building and related materials, personnel and their belongings, and food. These pathways are common for movements between the Australian mainland, other countries and Barrow Island. In addition to higher organisms, these pathways are also potential routes for micro-organism incursions onto the island. For the purpose of this report the high risk pathogens for Barrow Island identified in Table 8 have been used as examples of how transmission onto the island might occur. Table 10 details the micro-organisms associated with each pathway and possible steps to prevent introductions. Many of the major pathways listed below are linked to each other and will be discussed in further detail.

Table 10. Potential pathways for high risk micro-organisms onto Barrow Island and recommended procedures for minimising pathogen entry.

Pathway	Pathogen	Steps to Avoid Introduction
Soil	*Globocephaloides* *Hypodontus*	Sterilisation (eg. steam or chemical) Containment of soil within development site, and isolation from island fauna
Equipment	Wart Disease Wallal & Warrego virus *Globocephaloides* *Hypodontus*	Disinfection (eg. spraying) Cleaning to remove soil Inspection for vector species prior to shipping Futher monitoring on island or at materials off-loading facility
Food	*Cryptosporidium* *Salmonella* *Toxoplasma*	Inspection of fresh produce Appropriate protocols to dispose of food scraps around camp and in the field HACCP plans at food supply areas to include steps to avoid introduction
People	*Cryptosporidium* *Salmonella* Ophidian Paramyxovirus Inclusion Body Disease Wart Disease Ringworm	Reporting of disease symptoms eg. diarrhoea Appropriate protocols for disposal of human waste, both around camp and in the field Education for workforce on risk factors involved with introductions eg. pet ownership
Personal Goods	Ophidian Paramyxovirus Inclusion Body Disease Chytridiomycosis	Disinfection protocols on arrival eg. footbaths, change of clothes Quarantine inspection Education
Transport Vessels	Wallal & Warrego virus Ophidian Paramyxovirus Inclusion Body Disease	Control of onboard vermin eg. baiting, spraying Only essential vessel landings to occur Thorough inspection of all materials carried Regular inspection of transport vessels

5.1 Soil

Soil is primarily involved in the transport of dormant or environmental stages of pathogens (eg. *Globocephaloides* and *Hypodontus* larvae, *Toxoplasma* oocysts). This can occur when soil/aggregate destined for Barrow Island is contaminated prior to its arrival on the island (eg. soil associated organisms, animal faeces). Soil can also transfer pathogens via infected vector species (both vertebrate and invertebrate). For example, the mechanical transmission of *Toxoplasma gondii* has been demonstrated with earthworms and cockroaches (Bettiol *et al.*, 2000; Wallace, 1972).

5.2 Equipment

The movement of equipment onto Barrow Island can facilitate the transport of micro-organisms via soil, animals or insect vectors. Strategies to prevent animal incursions and soil contamination are currently under review. Insect vectors such as mosquitoes can be trapped inside vehicles and their larvae can be present in puddles of water present inside vehicle tyres or other equipment. Additionally, vertebrate animals including mammals and reptiles can also be introduced via equipment, particularly in large prefabricated modules stored for long periods of time prior to shipping to Barrow Island. Invertebrate vectors such as mosquitoes, ticks and fleas can potentially introduce a number of infections identified in the high risk and zoonotic lists (Table 8 and 9).

5.3 Food

Micro-organisms capable of causing disease in wildlife are commonly found in unprocessed foodstuffs such as meat and fresh produce (eg. *Toxoplasma*, *Salmonella*), and this may pose a significant risk to the Barrow Island fauna. While food brought onto the island for the workforce should be strictly controlled, it may still be contaminated with micro-organisms. Therefore, food scraps fed to animals in the camp or transported outside the camp by birds or people may also transmit these micro-organisms to animals. Uncontrolled routes also exist whereby food can be brought onto the island (eg. inadvertent or smuggled introductions by workforce or disposal from nearby vessels), and these may pose an even greater risk to the Barrow Island wildlife. Finally, invertebrate vectors capable of transmitting disease (eg. cockroaches, flies), may be brought onto the island inside shipments of food.

5.4 People and personal goods

People are capable of transmitting micro-organisms either directly (eg. *Salmonella*, *Cryptosporidium*) or indirectly via vectors (eg. ticks fleas) or contaminated clothing and/or personal goods (eg. viruses, ringworm fungi). These introductions would for the most part be inadvertent and can be controlled by appropriate education and inspection protocols. It must be noted that people are also capable of introducing micro-organisms via smuggled goods such as food, soil contaminated personal goods or (rarely) animals, although similar procedures to those mentioned above should prevent this from occurring.

5.5 Transport vessels

As with the previous pathways, transport vessels may introduce micro-organisms via soil contaminated equipment, invertebrate vectors or vertebrate hosts. Appropriate quarantine strategies should significantly reduce the risk, however monitoring procedures as discussed in the recommendations (section 7) should be put in place. Of particular concern is the issue of privately owned watercraft landing on Barrow Island without being subject to any of the above mentioned quarantine procedures or restrictions. The current development of the Montebello and Barrow Islands Marine Conservation Reserves will result in an increased number of privately owned watercraft visiting the region. With this will come a significant increase in the number of watercraft wishing to make landfall on Barrow Island. If these are not subject to the same quarantine restrictions and procedures as the transport barges ferrying goods and equipment to the island, then these watercraft greatly increase the chance of a quarantine breach and foreign organism introduction(s). The potential for these events to occur puts the Barrow Island wildlife at risk.

5.6 Other pathways

Other pathways with the potential to introduce pathogens onto Barrow Island include: strandings of cetaceans (eg. whales, dolphins) and the “hauling out” of pinnipeds (eg. seals, sea-lions) on the beaches; transmission of disease by wild/migratory birds; and the washing ashore of storm debris (either from the mainland or other islands).

Although these are not deemed to pose a major risk for micro-organism introductions to Barrow Island, they still warrant consideration.

6. Conclusions

6.1 Predisposition of Barrow Island vertebrate fauna to disease

Being an island population, the Barrow Island fauna is isolated from other wildlife populations therefore the opportunities for the introduction of infections from outside are severely limited. In some respects this can be seen as beneficial, as island populations generally only have to deal with a subset of the diseases that their mainland counterpart populations have to. However, this reduced level of challenge can often lead to immunologically naïve populations that, when faced with new or even endemic infections, may suffer much higher levels of mortality and morbidity than do their mainland counterparts that are frequently challenged.

6.2 Genetic bottle neck experienced after separation of Barrow Island from Australian mainland has resulted in a genetically depauperate terrestrial vertebrate fauna

Small island populations isolated for long periods of time, such as those on Barrow Island, typically experience a reduction in genetic diversity due to a lack of "fresh" genetic material in the form of individuals moving between populations. This inbreeding can manifest in numerous ways, such as the reported anaemic status of the island's larger mammal species. The probable genetic homogeneity of the Barrow Island fauna means that if a disease has a debilitating effect on one individual, there is a much greater chance that it will have the same effect on the rest of the population. Thus, the risk of a catastrophic depopulation of a species on the island, following the introduction of what may well be deemed a benign disease, is increased.

6.3 Insufficient data available regarding micro-organisms associated with the vertebrate fauna on Barrow Island

Clearly this report is principally literature-based and relies on the supposition that many of the micro-organisms reported from mainland fauna are transmissible to the Barrow Island fauna. However, the almost complete lack of information regarding micro-organisms present in the vertebrate fauna on Barrow Island (coupled with the dearth of information regarding pathogens and native fauna in general) severely limits the effectiveness of any assumptions made in this regard. As a consequence, the limited data available regarding those species of micro-organism already present on Barrow Island means that in the event of a disease outbreak in the vertebrate fauna, Gorgon would have difficulty in determining whether it was due to an introduced or an endemic pathogen.

6.4 Zoonotic diseases and occupational safety

This report has identified a number of zoonotic diseases that are either present in the wildlife or that could potentially be introduced to Barrow Island. Many of these that are currently of little significance may be of greater concern given the much larger workforce that will be required to construct the gas processing facility. Additionally, the potential for people infected with zoonotic infections arriving for work on the island should not be overlooked, as many of these diseases have incubation periods during which infection is not noticeable or detectable. Given the presence of ticks and mosquitos on Barrow Island, there is significant potential for the fauna to act as a reservoir for many of these diseases, some of which may also cause disease in the vertebrate fauna, particularly those populations under stress. As with other micro-organisms, there is little data available on the presence of zoonotic pathogens on the island however studies are underway to investigate the status of tick-borne infections and their potential to cause occupational diseases.

6.5 Risk of introduction of exotic micro-organisms to Barrow Island

While it is impossible to completely exclude the introduction of ‘exotic’ micro-organisms onto the island, the risks of introducing micro-organisms potentially pathogenic for the terrestrial vertebrate fauna is considered to be low. However, this is reliant upon appropriate quarantine strategies and effective surveillance and monitoring systems being installed. Although a number of pathways by which micro-organisms might gain access to Barrow Island have been identified, the most likely pathways for micro-organism incursions onto the island are considered to be people (including personal goods) and foodstuffs. This view is based on three factors: i) the relative ease with which all other materials can be exposed to high levels of inspection, cleansing and disinfection; ii) the reduced ability of other materials to support viable stages of pathogenic micro-organisms and iii) the documented role of animals and foodstuffs in the frequent transmission of pathogens.

7. Recommendations

The importance of disease in wildlife populations, particularly in pristine environments such as Barrow Island, is of growing concern and must be approached in a methodical and thorough manner. Two examples are the recent reports on the risk assessments for introducing non-indigenous species to Heard and McDonald Islands (Chown, 2003) and diseases of Antarctic wildlife (Australia, 2001). The recommendations arising from the current report deal primarily with the biosecurity of Barrow Island, the health of the native terrestrial fauna and the health and safety of the future Gorgon workforce.

7.1 Biosecurity

7.1.1 Background information on the terrestrial fauna and their endemic micro-organisms

At present there is practically no information available regarding micro-organisms present in the vertebrate fauna or the environment on Barrow Island. As such, a disease outbreak would have to be considered to be associated with an introduced infection. To combat this, it is vital that baseline data is acquired on potentially pathogenic micro-organisms already present in the wildlife. In addition, as a complete census of the Barrow Island fauna has not been performed, it would be advisable to discuss ways of getting accurate population figures in order to monitor the ongoing status of the endemic populations. Such information would be extremely valuable in the unlikely event of a disease occurrence on the island and would help to provide the company with information to refute claims of negligence.

7.1.2 Monitoring of mainland quarantine sites for infections in potential vector species

Whilst a baseline survey of micro-organisms in the Barrow Island vertebrate fauna is considered important for the management of biosecurity on the island, this only addresses post-border quarantine issues. To properly manage the quarantine and biosecurity of Barrow Island an understanding of the micro-organisms occurring in potential vector species present at pre-border quarantine sites is also of high importance. Knowledge of the presence/absence of micro-organisms in potential vector species (rats, mice, mosquitoes, tabanid flies etc) at and around pre-border quarantine sites (i.e. Welshpool, Onslow, Dampier) allows risk assessments to be made regarding current practices, and supports the implementation of pro-active quarantine control measures. Whilst it is recognised that the level of quarantine management is such that the possibility of invasive species landing on Barrow Island is extremely low, the risk of micro-organisms being transported to Barrow Island in goods containing vector species still exists. Therefore, an assessment and ongoing monitoring of the micro-organisms present at these quarantine sites should be an important part of the biosecurity programme.

7.1.3 Disease surveillance system

It is well recognised that countries which conduct disease surveillance of their wild animal populations are more likely to detect the presence of infectious and zoonotic diseases and to swiftly adopt counter measures (Morner *et al.*, 2002). However, it is intrinsically more difficult to monitor diseases in wildlife than in domestic animals, as sampling opportunities may only occur at selected times or locations. In addition, the occurrence of disease in wildlife populations is not static, and the Barrow Island fauna experiences a seasonal exposure to biting arthropods as well as nutritional and environmental stresses. Thus, the development of surveillance and monitoring programmes is a vital first step towards providing an appropriate level of understanding of the health status of wildlife populations. Aspects of a surveillance system for disease on Barrow Island would include the collection and analysis of opportunistic wildlife samples from road kill and other animal mortalities, which, provided relevant information relating to the findings is collected and stored for future reference, will help to create a comprehensive database over time. Additionally, regular health monitoring, as outlined below, should also be established for the terrestrial vertebrate fauna on Barrow Island. The development of both passive and active surveillance systems for disease on the island will assist in the long term protection of the Barrow Island fauna.

7.1.4 Health monitoring of Barrow Island vertebrate fauna

Monitoring of the vertebrate fauna for a range of micro-organisms should be performed twice a year if possible (during spring and autumn to compensate for any seasonal fluctuations in pathogen prevalence). This would entail trapping and the collection of faecal, blood and ectoparasite (ticks and fleas) samples from the vertebrate fauna to allow the detection of micro-organisms of potential concern. As regular population monitoring is performed by DCLM, health monitoring should be integrated with this and other animal-associated activities as far as possible to reduce the stresses on the animals. Analysis of information gained through monitoring would assist in the anticipation of mortality events or adverse health problems.

7.1.5 Laboratory development

While the analysis of samples from the monitoring would usually be performed in mainland laboratories, improvements to the laboratory facility present at the current camp on Barrow Island is highly recommended. This facility could become a designated area on the island for disease/quarantine matters to be investigated, and would include offices for quarantine staff, repositories for storage of opportunistic samples (e.g. roadkills, suspicious deaths) and laboratory space for visiting researchers and monitoring personnel.

7.1.6 Contingency plans in the event of a suspected wildlife mortality event

In a setting such as Barrow Island it is highly likely that non-specialist personnel will discover an unusual morbidity, mortality or disease event in the wildlife. In such an event it is necessary to be able to contact and relay information and instructions to specialists with regard to the correct sampling and storage of specimens (Morner *et al.*, 2002). The drafting of policies and regulations to be followed in the event of an incident or disease epidemic occurring on the island (e.g. contacts of relevant scientists/institutes, types of samples and information to be collected, informing and liaising with island personnel, overseeing occupational safety issues etc.) will improve the capability of researchers to respond to such incidents. Therefore, it is recommended that dedicated quarantine officers should be employed and be present on the island at all times. These employees will undergo training in the correct procedures to follow should an incident occur (eg. potential vector species brought onto island, unexplained mortalities observed), will have the ability to liaise with visiting scientists in regard to quarantine and disease issues on the island and will ensure that as much relevant data relating to the incident is collected as possible including GIS data. The quarantine officers will liaise with the medical staff on the island to ensure that potential infections in the workforce related to animal contact are also investigated and prevented and will be involved in the ongoing education of the workforce on biosecurity issues.

7.1.7 Education of the workforce

Increasing the understanding of the workforce as to the importance of Barrow Island biosecurity with regard to micro-organisms in addition to the plant and vertebrate pest species is vital, as they are potentially the "eyes and ears" of the quarantine management strategies. Information regarding not only the key species of concern and the company's quarantine strategies, but also the correct procedure(s) to follow in the event of an incident or observation should be an integral component of the induction process. Examples of this would be the discussion of contact details for quarantine officer(s) and the procedures for dealing with road-kill incidents and observed mortality events. As discussed later, health protection strategies for those in contact with animals should also be stressed.

Regular on-site meetings or seminars to discuss wildlife and quarantine issues would be important to get the support of the workforce. For example, these could identify risk factors for bringing disease onto the island or the possibility of diseases associated with handling animals, both on and off the island. Such information sessions could be used to alert workers who have visited Queensland within the last two weeks to the potential for presenting with symptoms of tick typhus or Q fever, those from the southwest of Western Australia to the possible exposure to Ross River virus, and even workers from Southeast Asia to the potential risk of tropical zoonoses. Other information could include the risks associated with handling pets at home and the potential for bringing disease or disease vectors (reptile viruses, cat fleas) onto the island on themselves or on personal equipment. This type of education should not be alarmist but should help the workforce to be aware of disease issues and of their role in keeping the island's biosecurity intact.

7.1.8 Footbaths at airport

Use of disinfectant footbaths at the airport would play an important part in decreasing the risk of soil-borne pathogens coming onto Barrow Island, and would serve as a physical reminder to the workforce of the importance Gorgon places on quarantine.

This would supplement the use of educational media (posters, leaflets etc.) on the island highlighting the importance of quarantine and informing the workforce of the correct steps to take in the event of a perceived quarantine breach.

7.1.9 Foodstuffs

Alcohol is not permitted to be brought onto Barrow Island and the same should apply to food regardless of whether it was sourced from the local shop in Perth or the back yard garden. Food (fresh or packaged) can act as an ideal transport medium for agents potentially infectious for both wildlife and people, and all food brought onto the island should be subject to the same quarantine procedures. Bringing home grown foodstuffs onto Barrow Island circumvents existing quarantine procedures and would greatly increase the risk of micro-organisms coming onto the island. Therefore, food should only be brought onto Barrow Island via supplies for the mess, with any alternate or unusual food wanted on the island by the workforce to be requested via the kitchen staff.

One area of concern is the removal of food from the mess and its discard in areas where it might be scavenged by wildlife. This includes both the camp area and the field. While it is not intended to prevent food removal from the mess for future consumption, education of the workforce as to the consequences of discarded food scraps should be a priority. Specialised containers for disposal of such scraps could also be included around the camp and in vehicles.

Provisions for the disposal of kitchen scraps are already in place on the island, with incineration being the method of choice, however, with the expanded workforce consideration should be given to the significant increase in waste that will occur.

7.1.10 Reducing contact between wildlife and the workforce

Isolation of the work camp from the Barrow Island environment and fauna will reduce the potential for pathogens being transmitted to the wildlife and will create a designated border/post-border quarantine area. Vermin-proof fencing around the processing, equipment and camp areas, coupled with electrified pads at entry points, would provide a physical barrier that would prevent the escape of any potential vertebrate vectors onto the island and aid in keeping the workforce and native fauna separated. While it is pleasant for the workforce to be surrounded by animals such as bandicoots in the camp area, their presence and their scavenging habits could compromise the quarantine strategies being developed. As foodstuffs are considered to be one of the most important pathways for potential pathogens onto the island, stores should be vermin and wildlife-proof.

7.1.11 Sewage disposal

In addition to physical separation of people and animals, consideration must also be given to the separation of human waste from the environment. Current procedures incorporate a closed effluent disposal and treatment system however, as discussed previously the expansion of the workforce necessitates careful planning to ensure that biosecurity is not compromised. Regular monitoring of the effluent for potential pathogens (e.g. *Salmonella*, *Cryptosporidium*) following treatment should be included in the island's disease surveillance strategy.

7.1.12 Provision for other potential breaches of biosecurity

A number of potential pathways for micro-organisms to enter the island exist that are difficult to control. These include migratory birds, bats and aquatic mammals. In addition, unlawful landing of tourist boats onto the island could compromise the island's biosecurity. Provision should be made for the monitoring of migratory bird and bat populations for micro-organisms if possible, and stranded aquatic mammals should be removed immediately, or if dead, be subject to inspection and sampling by the quarantine officer. To prevent unlawful landings, material could be developed for dispersal via tour operators, local marinas and the media.

7.2 Health and Safety

7.2.1 Health monitoring of Barrow Island workforce

Workers on Barrow Island suffering diarrhoeal illness should be encouraged to report this to the medical personnel on site and to have samples taken for analysis if possible. This would assist in the monitoring for infectious organisms such as *Salmonella* and *Cryptosporidium* on the island, and is a standard practice within the meat and food industries.

7.2.2 Potential zoonotic infections in the Barrow Island workforce

Potential zoonotic infections have been listed in Table 9. While these are not likely to be a major cause for concern, education programs regarding their presence, methods of transmission and control would be useful. Additionally, in the light of previous concerns over Q fever in the workforce on Barrow Island and the presence of Spotted Fever Group rickettsiae in ticks it would be useful for all new long term or high risk workers (those working in tick infested areas) to undergo pre-employment blood tests with serum stored for future reference. Whether this was made a mandatory requirement is up to the company to decide.

Due to the morbidity currently associated with tick bites in employees on the island it is considered important to investigate the ecology of ticks and the incidence of tick bites, particularly if infections are likely to be present in these ticks. Some data has been gathered on tick bites in conjunction with the company medical staff however more comprehensive studies are required. This can be done in association with the current study of ticks on the mammalian fauna.

7.2.3 Portable toilets for "off-site" work groups

Faecal contamination of the environment has been identified as an important pathway of infection for the vertebrate fauna of Barrow Island. Pathogens such as *Cryptosporidium* and *Salmonella* species are capable of being transmitted directly from the workforce to the fauna should employees openly defecate in the environment. With the current workforce on Barrow Island of approximately 100 employees, this is not a common occurrence. However, with an increase to potentially 3000 employees on the island and “off-site” work groups (i.e. construction crews building the overland pipeline), this becomes a potentially significant pathway for micro-organisms to be transmitted to the native fauna. Portable chemical toilets should accompany groups of workers who will be working away from toilet facilities.

7.2.4 Contact between workforce and wildlife

Preventing the potential transmission of micro-organisms or vectors from the workforce to the Barrow Island wildlife requires limiting the interface between the two. This would mean that situations such as the presence of golden bandicoots in the wet mess area and around the entrance to the mess/kitchen need to be controlled. Although the close proximity and interaction of this novel and enjoyable experience does much to foster an appreciation for the wildlife amongst the workforce, it is also potentially an avenue for the transmission of disease from people to the wildlife and vice versa.

Personal clothing brought onto the island has the potential to transmit micro-organisms, particularly where it belongs to workers who have pets or regular contact with animals at home. If possible casual clothing should be either freshly laundered or left off the island and be provided by the company.

8. Contacts and Acknowledgements

The following institutions and organizations were contacted over the course of this review for the purpose of obtaining information over the course of this report. These institutions are not listed in any particular order.

Australian Wildlife Health Network
Department of Conservation and Land Management
Agricultural Department of Western Australia
Perth Zoo
Taronga Park Zoo
Armadale Reptile and Wildlife Centre
ChevronTexaco Australia Pty. Ltd.

The following people need to be acknowledged for their assistance in providing information pertaining to this report. These people are acknowledged in no particular order.

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Dr Kristin Warren
Professor Mal Nairn
Dr Rupert Woods
Ms Jenny Mills
Ms Joanne Smith
Mr Russell Hobbs
Ms Felicity Donaldson
Dr David Obendorf

9. Feedback

Over the course of this report we have received feedback and comment from numerous people with various backgrounds. Of particular note was an email received, following a request for information on the Australian Wildlife Health Network, from Dr David Obendorf who has been involved in wildlife disease research in Australia since the early 1970's and has published numerous papers in this field. In his email, Dr David Obendorf made some valuable suggestions and raised several important issues, and as such we feel that the inclusion of his email in this report is both pertinent and warranted.

Date: Thu, 1 Jul 2004 23:13:39 + 1000
From: David Obendorf <davidobendorf@tassie.net.au>
To: padams@central.murdoch.edu.au
Cc: rwoods@zoo.nsw.gov.au
Subject: Response to the posting with AWHN

Dear Peter,

I was interested to read your request for assistance in relation to monitoring of wildlife diseases and pathogens on Barrow Island WA.

I congratulate you on contemplating doing such a study!

I'm guessing that this might be a baseline study for any pre-existing disease-causing agents and pathogens of native fauna – focussing on the significant ones.

I have had a long-standing interest in wildlife disease monitoring, and I sense that islands with unique ecologies and high biodiversities are really great places to strategically test biosecurity theory about quarantine and containment capabilities.

One of the potential difficulties in any such study aiming to assess the microbiological biodiversity of a diverse population of terrestrial vertebrates (mammals, reptiles, amphibians and ?birds) is the need for a range of specialist diagnostic capabilities you might use to test.

In a remote area you almost need a mini-diagnostic lab or the ability to get samples to existing labs.

Yes, you might focus on significant pathogens already identified and/or isolated from related species or in animals interacting with human & synanthropic hosts (like introduced rodents, feral cats, dogs and livestock species).

I would commend you to a paper I co-authored a few years ago for the OIE. ['Surveillance & monitoring of wildlife disease' 2002 by Torsen Morner, David Obendorf, Marc Artios and Michael Woodford, Rev. Sci. Tech. Off. Int. Epiz. **21(1)**]. In it we try to explain the need to take advantage of opportunistic mortality & morbidity events involving wildlife – either in multiple-animal events or from a series of point incidents over time. We also highlight the value of retrospective databases and historical searches for case pathologies or investigations which assist with the direction of prospective research studies.

Cutting to the chase, you might need to initially focus [on] one or two indicator host species as *case species studies*. They could be chosen on the basis of population size, sheer biomass impact on the island ecology, possible interface potential between the humans & their synanthropes (if there are any) or maybe just because they are a threatened species.

As we explain in our paper overt disease expression causing morbidity or mortality is usually the first indication that a new pathogen might have arrived or that epizootiological factors in the population are favouring the expression of a pre-existing endemic pathogen.

It is always easier to work from a clinical malady involving wildlife to defining the pathological diagnosis, then the aetiological diagnosis (i.e. possible exogenous pathogen) and finally the pathogenesis of infection and epidemiology. You need to be also lucky to have access to good samples and that isn't that easy with wildlife investigation in hot climates!

Just screening for a range of microbes can be done but it takes up lots of resources and usually can only focus on the easily recoverable (parasites), culturable (fungi & clinical bacteria and possibly some viruses).

Your access to animals for bleeding, necropsy examination or parasite sampling will be critical to how much you can realistically achieve in any short-term study.

Maybe serum & tissue can [be] collected and banked for retrospective screening when you do have a mass mortality or morbidity event.

You can almost guarantee that the microbial biodiversity of Barrow Island vertebrates will be quite large indeed.

Microbes that might be useful to assess include *Salmonella* (by faecal culture)…I understand that Quokkas on Rottnest Island have a high prevalence of this gut bug. But this type of survey might only be an incidental finding. It would need to be linked to something epidemiological.

The questions I would first ask is:

1. Are there any known disease-causing pathogens associated with mortality or morbidity in any Barrow Island animals?

2. On mainland WA are there any disease-associated *threatening processes* that have caused the decline of similar species that also exist on Barrow Island? If so, do these organisms *per se*, or their vectors, pose a biosecurity entry/establishment & spread risk to the island?

By adopting this approach you might focus on highly significant pathogens in any initial screening efforts. It is likely to appeal to WA Conservation Authorities as well!

Or you might decide to look for a novel (& high profile) virus such as Bat Lyssavirus, or arboviruses by serology through collaboration with a reference laboratory.

Any pathogen screening of a wide range of terrestrial fauna, in my opinion, needs to be strategic and focussed on potential biodiversity risks of pathogen introductions with new animals, insect vectors or breakdowns in island quarantine protocols.

Keep me posted on your work.

Best of luck with your studies,

Regards

David Obendorf

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Appendix 1

Extended list of micro-organism genera reported as occurring in those mammalian hosts belonging to the taxonomic groups outlined below in Australia.

		Mammals	
	Dasyuridae (Dasyurids)		
Viruses	No Records		
Bacteria	*Chlamydia*	*Leptospira*	*Salmonella*
Protozoa	*Babesia*	*Hepatozoon*	*Toxoplasma*
	Cryptosporidium	*Klossiella*	
	Giardia	*Sarcocystis*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Fibricola (T)*	*Pelecitus (N)*
	Anatrichosoma (N)	*Filaria (N)*	*Peramelistrongylus (N)*
	Angiostrongylus (N)	*Filaroides (N)*	*Pharyngostomoides (T)*
	Anoplotaenia (C)	*Gigantorhynchus (A)*	*Physaloptera (N)*
	Antechiniella (N)	*Gnathostoma (N)*	*Plagiorchis (T)*
	Antechinostrongylus (N)	*Gongylonema (N)*	*Pseudoleucochloridium (T)*
	Australiformis (A)	*Hymenolepis (C)*	*Pseudorictularia (N)*
	Baylisascaris (N)	*Inglechina (N)*	*Psilorchis (T)*
	Brachylaima (T)	*Linstowia (C)*	*Seurechina (N)*
	Brachylecithum (T)	*Mackerrastrongylus (N)*	*Spirometra (C)*
	Breinlia (N)	*Maritrema (T)*	*Spirura (N)*
	Capillaria (N)	*Marsupostrongylus (N)*	*Sprattellus (N)*
	Cercopithifilaria (N)	*Mehlisia (T)*	*Sprattia (N)*
	Choanotaenia (C)	Metacestode (C)	*Strongyloides (N)*
	Coelomotrema (T)	*Metaplagiorchis (T)*	*Synhimantus (N)*
	Copemania (N)	*Metathelazia (N)*	*Taenia (C)*
	Cyathospirura (N)	*Mirandula (C)*	*Tetrabothriostrongylus (N)*
	Cylicospirura (N)	*Nasistrongylus (N)*	*Trichinella (N)*
	Dasyurotaenia (C)	*Neodiplostomum (T)*	*Trichuris (N)*
	Denticulospirura (N)	*Oochoristica (C)*	*Woolleya (N)*
	Dessetostrongylus (N)	*Ophidascaris (N)*	*Zonorchis (T)*
	Dipetalonema (N)	*Parastrongyloides (N)*	
	Echinonema (N)	*Patricialina (N)*	
	Peramelidae (Bandicoots)		
Viruses	Arbovirus (Ross River virus)	Wart disease - Papilloma-like virus	
Bacteria	*Chlamydia*	*Salmonella*	*Serpulina*
Protozoa	*Babesia*	*Entamoeba*	*Theileria*
	Cryptosporidium	*Hepatozoon*	*Toxoplasma*
	Giardia	*Klossiella*	*Trypanosoma*
	Eimeria	*Sarcocystis*	

Fungi	No Records		
Helminths	*Abbreviata (N)*	*Fibricola (T)*	*Ophidascaris (N)*
	Angiostrongylus (N)	*Filostrongylus (N)*	*Parastrongyloides (N)*
	Asymmetracantha (N)	*Heterakis (N)*	*Peramelistrongylus (N)*
	Australiformis (A)	*Hymenolepis (C)*	*Physaloptera (N)*
	Bashkirovitrema (T)	*Labiobulura (N)*	*Plagiorhynchus (A)*
	Beveridgiella (N)	*Linstowia (C)*	*Platynosomum (T)*
	Brachylaima (T)	*Mackerrastrongylus (N)*	*Spirometra (C)*
	Breinlia (N)	*Marsupostrongylus (N)*	*Sprattia (N)*
	Capillaria (N)	*Mehlisia (T)*	*Strongyloides (N)*
	Cercopithifilaria (N)	*Metathelazia (N)*	*Tetrabothriostrongylus (N)*
	Cylicospirura (N)	*Mirandula (C)*	*Trichuris (N)*
	Dipetalonema (N)	*Nicollina (N)*	*Woolleya (N)*
	Echinonema (N)	*Oochoristica (C)*	
	Phalangeridae (Possums)		
Viruses	No Records		
Bacteria	*Bacillus*	*Leptospira*	*Pseudomonas*
	Chlamydia	*Mycobacterium*	
Protozoa	*Cryptosporidium*	*Hepatozoon*	*Toxoplasma*
	Eimeria	*Leshmania*	*Trypanosoma*
	Giardia	*Sarcocystis*	
Fungi	No Records		
Helminths	*Adelonema (N)*	*Echinococcus (C)*	*Parastrongyloides (N)*
	Amplicaecum (N)	*Fasciola (T)*	*Paraustrostrongylus (N)*
	Angiostrongylus (N)	*Filarinema (N)*	*Patricialina (C)*
	Anoplotaenia (C)	*Filostrongylus (N)*	*Profilarinema (N)*
	Bertiella (C)	*Gongylonema (N)*	*Protospirura (N)*
	Breinlia (N)	*Marsupostrongylus (N)*	*Sprattia (N)*
	Capillaria (N)	*Nematodirus (N)*	*Strongyloides (N)*
	Cooperia (N)	*Odilia (N)*	*Toxocara (N)*
	Dipetalonema (N)	*Ophidascaris (N)*	*Trichostrongylus (N)*
	Potoroidae (Bettongs)		
Viruses	No Records		
Bacteria	*Chlamydia*	*Salmonella*	
Protozoa	*Cryptosporidium*	*Klossiella*	*Toxoplasma*
	Eimeria	*Sarcocystis*	
	Giardia	*Theileria*	
Fungi	No Records		

Helminths	*Anoplotaenia (C)* *Angiostrongylus (N)* *Australiformis (A)* *Breinlia (N)* *Calostaurus (C)* *Capillaria (N)* *Cloacina (N)* *Corollostrongylus (N)*	*Dasyurotaenia (C)* *Filarinema (N)* *Globocephaloides (N)* *Gongylonema (N)* *Hymenolepis (C)* *Labiostrongylus (N)* *Mastophorous (N)* *Ophidascaris (N)*	*Paraustrostrongylus (N)* *Peramelistrongylus (N)* *Potorostrongylus (N)* *Potoxyuris (N)* *Progamotaenia (C)* *Raillietina (C)* *Strongyloides (N)* *Trichuris (N)*
	Macropodidae (Macropods)		
Viruses	Ross River virus Macropod Herpesvirus Macropod Pox Virus	Foot and Mouth Disease Murray Valley encephalitis Wallal and Warrego virus	Mucosal Disease Virus Encephalomyocarditis virus (EMCV)
Bacteria	*Chlamydiales* *Coxiella* *Fusobacterium*	*Leptospira* *Mycobacteria* *Rickettsia*	*Salmonellae* *Tetanus*
Protozoa	*Acanthamoeba* *Babesia* *Cryptosporidium* *Cycloposthium* *Dasytricha* *Eimeria* *Entamoeba* *Entodinium* *Giardia*	*Globidium* *Hammondia* *Heterotricha* *Ileocystis* *Isotricha* *Klossiella* *Leishmania* *Lymphocystis* *Macropodinium*	*Monocercomonas* *Pfeifferinella* *Pneumocystis* *Retortomonas* *Sarcocystis* *Toxoplasma* *Trichomonas* *Trypanosoma*
Fungi	*Microsporum*	*Trichophyton*	

Helminths	*Alocostoma (N)*	*Fasciola (T)*	*Pelecitus (N)*
	Amphicephaloides (N)	*Filarinema (N)*	*Pharyngostrongylus (N)*
	Angiostrongylus (N)	*Filaroides (N)*	*Physaloptera (N)*
	Anoplotaenia (C)	*Foliostoma (N)*	*Physocephalus (N)*
	Antechinostrongylus (N)	*Gemellicotyle (T)*	*Polydelphis (N)*
	Arundelia (N)	*Globocephaloides (N)*	*Popovastrongylus (N)*
	Austrostrongylus (N)	*Gongylonema (N)*	*Progamotaenia (C)*
	Bancroftiella (C)	*Hypodontus (N)*	*Rugopharynx (N)*
	Baylisascaris (N)	*Labiostrongylus (N)*	*Rugostrongylus (N)*
	Beveridgea (N)	*Macropicola (N)*	*Spirostrongylus (N)*
	Breinlia (N)	*Macroponema (N)*	*Strongyloides (N)*
	Calostaurus (C)	*Macropostrongyloides (N)*	*Sutarostrongylus (N)*
	Capillaria (N)	*Macropostrongylus (N)*	*Taenia (C)*
	Cassunema (N)	*Macropotrema (T)*	*Tethystrongylus (N)*
	Cloacina (N)	*Macropoxyuris (N)*	*Thallostonema (N)*
	Coronostrongylus (N)	*Maplestonema (N)*	*Thylonema (N)*
	Cosmostrongylus (N)	*Marsupostrongylus (N)*	*Thylostrongylus (N)*
	Cyclostrongylus (N)	*Monilonema (N)*	*Thysanotaenia (C)*
	Cylicospirura (N)	*Ophidascaris (N)*	*Trigonostonema (N)*
	Dasyurotaenia (C)	*Papillostrongylus (N)*	*Triplotaenia (C)*
	Dipetalonema (N)	*Paralabiostrongylus (N)*	*Wallabinema (N)*
	Dorcopsinema (N)	*Paramacropostrongylus (N)*	*Woodwardostrongylus (N)*
	Dorcopsistrongylus (N)	*Parapharyngostrongylus (N)*	*Zoniolaimus (N)*
	Durikainema (N)	*Pararugopharynx (N)*	
	Echinococcus (C)	*Parazoniolaimus (N)*	
	Chiroptera (Bats)		
Viruses	Australian Bat Lyssavirus	Hendra virus	
	Menangle virus	Nipah virus	
Bacteria	*Borrelia*	*Leptospira*	*Shigella*
	Coxiella	*Mycobacterium*	
	Escherichia	*Salmonella*	
Protozoa	*Eimeria*	*Polychromophilus*	*Trypanosoma*
	Haemosporidia	*Toxoplasma*	
Fungi	*Blastomyces*	*Cryptococcus*	*Scopulariopsis*
	Candida	*Histoplasma*	*Sporotrichum*
Helminths	*Angiostrongylus*		

	Muridae (Rodents)		
Viruses	Minute virus of mice (MVM) Mouse adenovirus (MAdV)	Mouse hepatitis virus (MHV) Murine cytomegalovirus (MCMV)	Murine reovirus (reo3) Murine rotavirus
Bacteria	*Leptospira*	*Pseudomonas*	*Salmonella*
Protozoa	*Acanthamoeba* *Babesia* *Bartonella* *Besnoitia*	*Eperythrozoon* *Giardia* *Hammondia* *Hepatozoon*	*Plasmodium* *Sarcocystis* *Spironucleus* *Toxoplasma*
	Cryptosporidium *Eimeria* *Entamoeba*	*Hexamita* *Klossiella* *Naegleria*	*Trichomonas* *Trypanosoma*
Fungi	No Records		
Helminths	*Abbreviata (N)* *Amplicaecum (N)* *Angiostrongylus (N)* *Ascaris (N)* *Ascarops (N)* *Aspiculuris (N)* *Capillaria (N)* *Choanotaenia (C)* *Cosmocephalus (N)* *Echinococcus (C)* *Eucoleus (N)* *Fibricola (T)* *Ganguleterakis (N)* *Gongylonema (N)*	*Hepatojarakus (N)* *Hymenolepis (C)* *Mastophorus (N)* *Microphallus (T)* *Moniliformis (A)* *Monopylidium (C)* *Neoascaris (N)* *Neodiplostomum (T)* *Nippostrongylus (N)* *Odilia (N)* *Oligorchis (C)* *Physaloptera (N)* *Plagiorchis (T)* *Protospirura (N)*	*Pseudoporrorchis (A)* *Raillietina (C)* *Rictularia (N)* *Spirometra (C)* *Spirura (N)* *Strongyloides (N)* *Syphacia (N)* *Taenia (C)* *Toxocara (N)* *Trichostrongylidae (N)* *Trichosomoides (N)* *Trichuris (N)*

Letters in parentheses indicate major taxonomic groups for helminth parasites.

A = Acanthacephala

C = Cestoda

N = Nematoda

T = Trematoda

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Appendix 2

Extended list of micro-organism genera reported as occurring in both lizards and snakes in Australia.

		Reptiles	
	Lizards		
Viruses	Adenoviridae	Iridoviridae	Polyomaviridae
	Herpesviridae	Ophidian Paramyxovirus	Poxviridae
	Inclusion Body Disease	Parvoviridae	
Bacteria	*Dermatophilus*	*Rickettsia*	
	Leptospira	*Salmonella*	
Protozoa	*Babesia*	*Globidia*	*Pirhemocyton*
	Billbraya	*Haemocystidium*	*Plasmodium*
	Bodo	*Haemogregarina*	*Sarcocystis*
	Copromonas	*Haemoproteus*	*Schellackia*
	Cryptosporidium	*Hemolivia*	*Trichomonas*
	Eimeria	*Hepatozoon*	*Trypanosoma*
	Endamoeba	*Isospora*	
	Fallisia	*Nyctotherus*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Mesocoelium (T)*	*Pneumonema (N)*
	Acanthocephala (A)	microfilaria (N)	*Porrorchis (A)*
	Acanthotaenia (C)	*Microphallus (T)*	*Pseudorictularia (N)*
	Angiostrongylus (N)	*Moaciria (N)*	*Pseudothamugadia (N)*
	Ascaridoidea (N)	*Oochoristica (C)*	*Raillietascaris (N)*
	Ascaris (N)	*Ophidascaris (N)*	*Skrjabinelazia (N)*
	Bothridium (C)	*Ophiotaenia (C)*	*Skrjabinodon (N)*
	Brachylecithum (T)	*Oswaldofilaria (N)*	*Skrjabinoptera (N)*
	Cardianema (N)	Oxyuridae (N)	*Sphaerechinorhynchus (A)*
	Cylindrotaenia (C)	*Oxyuris (N)*	*Spinicauda (N)*
	Dioctowittus (N)	*Paradistomum (T)*	*Spirometra* (C)
	Filarioidea (N)	*Parapharyngodon (N)*	*Strongyluris (N)*
	Hastospiculum (N)	*Pharyngodon (N)*	*Tanqua (N)*
	Hedruris (N)	Pharyngodonidae (N)	*Terranova (N)*
	Herpetostrongylus (N)	*Physaloptera (N)*	*Tetracotyle (T)*
	Johnpearsonia (N)	*Physaloptera (N)*	*Thelandros (N)*
	Kapsulotaenia (C)	Physalopteridae (N)	Trichostrongyloidea (N)
	Kreisiella (N)	*Physalopteroides (N)*	*Veversia (N)*
	Maxvachonia (N)	*Piestocystis (C)*	*Wanaristrongylus (N)*
	Mermithidae (N)	*Piratuboides (N)*	

	Snakes		
Viruses	Adenoviridae	Iridoviridae	Wamena virus
	Herpesviridae	Ophidian paramyxovirus	
	Inclusion Body Disease	Parvoviridae	
Bacteria	No Records		
Protozoa	*Babesia*	*Entamoeba*	*Schellackia*
	Caryospora	*Haemogregarina*	*Trichomonas*
	Cryptosporidium	*Pirhemocyton*	*Trypanosoma*
	Eimeria	*Sarcocystis*	
Fungi	*Chrysosporium*		
Helminths	*Abbreviata (N)*	*Hastospiculum (N)*	*Piestocystis (C)*
	Acanthotaenia (C)	*Herpetostrongylus (N)*	*Polydelphis (N)*
	Ascarididae (N)	*Hydrophitrema (T)*	*Proteocephalus (C)*
	Ascaris (N)	*Kalicephalus (N)*	*Simhatrema (T)*
	Atrophecaecum (T)	*Maxvachonia (N)*	*Sphaerechinorhynchus (A)*
	Bothridium (C)	*Moaciria (N)*	*Spinicauda (N)*
	Capillaria (N)	*Ophidascaris (N)*	*Spirometra (C)*
	Dioctowittus (N)	*Ophiotaenia (C)*	Spiruroidea (N)
	Dolichopera (T)	*Paraheterotyphlum (N)*	*Sterrhurus (T)*
	Goezia (N)	*Physaloptera (N)*	
	Harmotrema (T)	Physalopteridae (N)	

Letters in parentheses indicate major taxonomic groups for helminth parasites.

A = Acanthacephala

C = Cestoda

N = Nematoda

T = Trematoda

Appendix 3

Extended list of micro-organism genera reported as occurring in amphibians in Australia.

		Amphibians	
	Frogs		
Viruses	Adenoviridae	Herpesviridae	Polyomaviridae
	Bohle virus	Iridoviridae	Poxviridae
Bacteria	*Chlamydia*	*Leptospira*	
Protozoa	*Amoeba*	*Karotomorpha*	*Retortamonas*
	Balantidium	*Monocercomonas*	*Spironucleus*
	Chilomastix	*Myxidium*	*Trichomastix*
	Copromonas	*Myxobolus*	*Trichomitus*
	Entamoeba	*Myxosporidium*	*Trichomonas*
	Giardia	*Nyctotherus*	*Trypanosoma*
	Haemogregarina	*Opalina*	*Zelleriella*
	Hoarella	*Protoopalina*	
Fungi	*Batrachochytrium*	*Mucor*	
Helminths	No Records		

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Technical Appendix D9

Plant Pathogen Threats to Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

PLANT PATHOGEN THREATS TO BARROW ISLAND

TECHNICAL APPENDIX D9

Prepared for:

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PLANT PATHOGEN THREATS TO BARROW ISLAND

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Summary

An examination of specimen-based plant pathology herbarium databases and the scientific literature revealed that only two plant pathogens have been recorded from Barrow Island or neighbouring islands. These pathogens, *Aecidium* sp. and *Uredo* sp., both occur on *Acanthocarpus verticillata* and certainly represent different stages of the same undescribed rust fungus.

Records of plant pathogens from mainland Australia indicated that 126 plant pathogens have been reported from the approximately 350 species of host plant that occur on Barrow Island. One of these, the soil-borne pathogen *Phytophthora cinnamomi*, was assessed as having the greatest potential to threaten the resident flora through the movement of soil, although it is unlikely that the arid, tropical environmental conditions on Barrow Island are conducive to its establishment. It is estimated that there could be over 4,000 indigenous plant pathogens on Barrow Island.

Background

Barrow Island is situated in the arid tropics directly between the Gorgon area gas fields which are approximately 130 km off the north-west coast of Western Australia and the Australian mainland. As well as sustaining one of Australia's most important oilfields, Barrow Island is a declared Class A Nature Reserve of international importance with unique conservation values for the protection of its flora and flora (Gorgon Australian Gas, 2003). Strict quarantine policies imposed by the operator of the oilfields have ensured that very few invasive plant species have established on Barrow Island. The aim of this report is to identify the plant pathogens that occur on Barrow Island and to assess the risk that all plant pathogens from the mainland pose to the resident flora.

Methodology

Vegetation and flora surveys list the resident flora of Barrow Island at about 350 species (Astron Environmental, 2002). Three specimen-based databases, Australian Plant Pest Database (APPD), Australian Plant Disease Database (APDD) and Queensland Department of Primary Industries Plant Pathology Herbarium Database (BRIP) were interrogated for the presence of records of plant pathogens on these host plants from Barrow Island and neighbouring islands as well as from mainland Australia. The scientific literature was also examined to determine reports of plant pathogens on these hosts. The identified pathogens were assessed to determine the level of risk that they posed to the resident flora of Barrow Island.

Results

Only two records of plant pathogens on Barrow Island and neighbouring islands were found (Table 1). Records of plant pathogens from mainland Australia indicated that 126 plant pathogens have been reported from the approximately 350 species of host plant that occur on Barrow Island (Appendix I). The table contains only plant pathogenic fungi as there were no reliable records of bacteria, viruses and nematodes. Only those pathogenic fungi that had been identified to species level were listed. The soil-borne fungus, *Phytophthora cinnamomi*, was considered to pose a potential risk to the resident flora of Barrow Island.

Table 1. Plant pathogens recorded from Barrow Island and neighbouring islands.

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	LOCATION	REFERENCES
Aecidium sp.	Rust	*Acanthocarpus verticillata*	Varanas Island, Lowendal group, 10 km E Barrow Island	APDD, Shivas (1989)
Uredo sp.	Rust	*Acanthocarpus verticillata*	Varanas Island, Lowendal group, 10 km E Barrow Island	APDD, Shivas (1989)

Discussion

The analysis in this report has been done against a background that very little is known about plant pathogens on native plants in Australia. Most of the records of plant pathogens in Australia are from agriculturally important or cultivated plants as the published Australian State plant diseases lists indicate, for example, see Shivas (1989) for Western Australia. There is some specialised knowledge for particular groups of fungi on native plants, for example, smut fungi (Ustilaginomycetes) on grasses and sedges (Shivas & Vánky, 2003), powdery mildews (Erysiphales) (Pascoe, unpublished) and rusts (Uredinales) (Walker, unpublished).

There are about 165 genera of plants on Barrow Island (Astron Environmental, 2002). Shivas & Hyde (2002) estimated that the number of fungal plant pathogens specific to vascular plant genera in the tropics was about 25. It follows that there may be up to 4,000 indigenous genera-specific fungal plant pathogens on Barrow Island. This number reflects the potential biodiversity of fungi on Barrow Island rather than an indication of the amount of disease, as most, if not all of these fungi will cause diseases of minor significance and be a normal part of the ecosystem.

Despite the potential diversity of fungi on Barrow Island, the only records of pant pathogens from Barrow Island and neighbouring islands are the two rusts, *Aecidium* sp. and *Uredo* sp., reported on fruits of *Acanthocarpus verticillata* A.S. George collected at Varanas Island, which is 10 km of Barrow Island (Shivas, 1989). These two rusts are certainly the aecidial and uredinial stages of the same rust as APDD records show that both were collected by V. Long and C. Nicholson on 15 Oct 1986. This rust is apparently undescribed, and possibly even endemic to islands in the region, as there are no species of rust described from the host plant family Xanthorrhoeaceae in Australia.

There are at least 126 plant pathogenic fungi (Appendix I) that have been reported from the mainland on hosts that occur on Barrow Island. This number is an underestimate in that only pathogens that had been identified to species level were considered. Many records of microfungi that had been identified only to generic level were excluded, for example *Alternaria*, *Colletotrichum*, *Phoma*, *Phomopsis* and *Oidium*. Exclusion of microfungi not identified to species level is justified on grounds that many of these are probably weak pathogens or secondary invaders. Identification to species level is necessary to fully determine the threat that the micro-organisms pose, especially for the purpose of quarantine pest risk assessments.

There are several potential pathways by which plant pathogens might enter Barrow Island (Table 2). Of these pathways, the movement of soil provides the greatest risk of introducing harmful plant pathogens, particularly soil-borne fungi such as *Phytophthora* spp. and nematodes, which may have wide host ranges. Soil (topsoil, plant nursery mixes) includes any material on the surface of the earth in which plants can grow. Sand is not a risk unless it has had plants growing in it, which would mean it was collected from within a metre of the earth's surface.

Two soil-borne plant pathogens warrant mention. *Verticillium dahliae* is a plurivorous pathogen that causes severe diseases in the tropics and sub-tropics. It forms sclerotia and survives for long periods in the soil. It invades the vascular system of host plants and causes a characteristic wilt syndrome. In Australia it has been isolated from native and introduced plants in several host plant families and is widespread (APDD, 2004). It is most likely to be found on herbaceous weeds and cultivated plants, for example ornamentals and vegetables. It is not considered to pose a significant threat to the native plants populations.

In Western Australia, the destruction of large areas of natural plant communities by *Phytophthora cinnamomi* Rands is unique (Weste, 1994). The disease is known as jarrah dieback but more than 1,000 plant species are susceptible. *P. cinnamomi* is a serious root rot pathogen and has demonstrated ability to cause explosive pandemics in Australia. However the arid tropical climate on Barrow Island is not conducive to the establishment *P. cinnamomi*. Furthermore *P. cinnamomi* may already be present on Barrow Island and surveys are needed to determine this. There are no other plant diseases on the adjacent mainland that were identified as presenting a threat to the flora of Barrow Island.

Table 2. Potential pathways for plant pathogens to enter Barrow Island and neighbouring islands.

PATHWAY	PATHOGENS	RECOMMENDED QUARANTINE PRECAUTIONS
Soil and sand (including as contaminated equipment, machinery, personal goods etc.)	Soil-borne fungi Nematodes	Sterilisation Disinfection Cleaning Containment
Wind	Many foliar fungi produce wind-borne spores	Surveillance

PATHWAY	PATHOGENS	RECOMMENDED QUARANTINE PRECAUTIONS
Propagating material (incl. cuttings, seed)	Most pathogens	Restrictions and controls Use material certified as disease free
Fresh food	Seed-borne fungi Post-harvest fungi Viruses	Inspection Education
Insects (incl. as infested food, in cargo and baggage)	Some plant viruses are insect transmitted.	Inspection Surveillance

Recommendations

1. Determine the common plant pathogens on Barrow and surrounding islands through targeted surveys. This knowledge will provide baseline information about (i) the health status of the resident flora and (ii) the biodiversity of plant pathogens on the islands. Virtually nothing is known about the indigenous plant pathogens on Barrow Island. Interestingly the only plant pathogen collected from the region is an undescribed rust fungus.

   Targeted surveys are essential, as specialised skills are required to identify and classify microfungi, bacteria, viruses and nematodes. As 95% of plant diseases are caused by microfungi (Shivas & Hyde, 1996) these should receive the highest priority. A field survey should be done during or at the end of the wet season when plant growth is most vigorous and plant pathogens most active. This survey should also target diseases of introduced plants (particularly weeds), garden and amenity plants as well as the native plants. A short survey (7 days) by plant pathologist(s) experienced in tropical diseases would certainly identify any current or emerging plant health issues.

2. That on-going surveillance and identification of plant pathogens on Barrow Island be facilitated through linkages with plant disease diagnostic laboratories and/or plant disease herbaria in Australia. These linkages will allow the rapid determination of the cause of plant diseases in incidental samples not obtained through a targeted survey. This will only be successful if those who may encounter diseased plants are trained in plant disease identification and how to prepare specimens for submission to a diagnostic laboratory or herbarium. There are numerous methods used to collect and submit different types of pathogens, that is fungi, bacteria, viruses and nematodes.

3. Ensure that adequate safeguards are in place to prevent the movement of soil-borne pathogens, for example *Phytophthora cinnamomi*, to Barrow Island. The ability of *P. cinnamomi* to cause devastating disease in natural plant communities in Western Australia is of concern although it is unlikely to establish in an arid tropical environment. Despite the unlikelihood that *P. cinnamomi* is present on Barrow Island,

it is recommended that a survey be undertaken to verify its presence or otherwise on Barrow Island.

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Appendix I. Pathogens recorded in Australia on hosts present on Barrow Island.

Abbreviations –APDD = Australian Plant Disease database; BRIP = plant pathology herbarium records held by the Queensland Department of Primary Industries and Fisheries.

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Albugo blytii	White rust	*Alternanthera nodiflora*	A minor disease.	APDD
Albugo centaurii	White rust	*Centaurium erythraea*	A minor disease.	APDD
Albugo platensis	White rust	*Boerhavia coccinea* *Boerhavia schomburgkiana*	A minor disease.	APDD
Albugo quadrata	White rust	*Portulaca oleracea*	A minor disease.	APDD
Alternaria sonchi	Early blight	*Sonchus oleraceus*	Widespread.	APDD
Alternaria solani	Early blight	*Solanum nigrum*	A minor disease.	APDD
Arkoola nigra	Leaf spot	*Crotalaria medicaginea* *Rhynchosia minima*	A minor disease.	APDD
Armillaria luteobubalina	Root rot	*Eucalyptus gomphocephala*	A primary pathogen causing decline and death that is widely distributed in eucalypt communities in Australia.	APDD
Aulographina eucalypti	Leaf spot	*Eucalyptus camaldulensis* *Eucalyptus torquata*	A widespread pathogen causing minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Bipolaris papendorfii	Leaf spot	*Bothriochloa bladhii*	A widespread pathogen causing minor disease.	Sivanesan (1987)
Bipolaris perotidis	Leaf spot	*Aristida holathera var. holathera (syn. Aristida browniana)*	Native fungus that has been reported on several grass species. Occurs in WA and Qld.	BRIP
Bipolaris zeae	Leaf spot	*Cenchrus ciliaris*	A widespread pathogen causing minor disease.	Sivanesan (1987)
Botrytis cinerea	Stem wilt	*Senna artemisioides*	A minor disease.	APDD
Cercospora apii s. lat.	Leaf spot	*Ipomoea pes-caprae*	Widespread on many hosts.	APDD
Cercosporella dioscoreophylli	Leaf spot	*Tinospora smilacina*	A minor disease.	APDD
Cerotelium fici	Smut	*Ficus opposita*	A widespread pathogen on *Ficus*.	APDD
Cintractia axicola	Smut	*Fimbristylis dichotoma*	A widespread pathogen.	APDD
Cintractia bulbostylidis	Smut	*Bulbostylis barbata*	Known only from the type location in NT.	APDD
Cintractia limitata	Smut	*Cyperus iria*	Widespread pathogen but rarely collected on this host.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Cintractia lipocarphae	Smut	*Bulbostylis barbata*	Known only from the type location in central Australia.	APDD
Claviceps annulata	Ergot	*Eulalia annulata*	A minor disease.	APDD
Claviceps cynodontis	Ergot	*Cynodon dactylon*	A widespread pathogen causing a minor disease.	APDD
Claviceps hirtella	Ergot	*Cenchrus ciliaris*	A native fungus only occurring in Qld.	APDD
Claviceps pusilla	Ergot	*Bothriochloa bladhii* *Dichanthium sericeum* *Themeda australis*	Reported from many grass species in Australia.	APDD
Cochliobolus cymbopogonis (anamorph Curvularia cymbopogonis)	Leaf spot	*Bothriochloa bladhii* *Sarga plumosum*	Minor disease on several grasses.	Sivanesan (1987)
Cochliobolus cynodontis (anamorph Bipolaris cynodontis)	Leaf spot	*Cynodon dactylon*	Widespread and often severe on this host.	Sivanesan (1987)
Cochliobolus dactyloctenii (anamorph Bipolaris dactyloctenii)	Leaf spot	*Dactyloctenium radulans*	Minor disease.	Sivanesan (1987)

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Cochliobolus hawaiiensis (anamorph Bipolaris hawaiiensis)	Leaf spot	*Dichantium sericeum*	A minor disease.	APDD
Cochliobolus heterostrophus (anamorph Bipolaris maydis)	Leaf spot	*Bothriochloa bladhii*	Reported as a minor disease on this host in WA.	APDD
Cochliobolus peregianensis (anamorph Bipolaris peregianensis)	Leaf spot	*Cynodon dactylon*	Only recorded from Qld.	Sivanesan (1987)
Cochliobolus spicifer (anamorph Bipolaris spicifera)	Leaf spot, root rot	*Bothriochloa bladhii* *Dactyloctenium radulans*	Spring dead spot of *Cynodon dactylon* and foot rot of winter wheat are the main diseases caused by this pathogen. Occurs throughout Australia on grasses.	Sivanesan (1987)
Colletotrichum caudatum	Leaf spot	*Bothriochloa bladhii*	Minor disease on this host in Qld.	APDD
Colletotrichum truncatum	Leaf spot	*Tribulus terrestris*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Curvularia andropogonis	Leaf spot	*Eulalia aurea*	Minor disease.	APDD
Curvularia bothriochloae	Leaf spot	*Bothriochloa bladhii*	A native fungus causing a minor disease on this host in Qld.	Sivanesan, Alcorn & Shivas (2003)
Curvularia uncinata	Leaf spot	*Aristida contorta*	A minor disease reported from NSW.	APDD
Erysiphe trifolii	Powdery mildew	*Sesbania cannabina*	Common on some genera of legumes.	APDD
Glomerella cingulata (anamorph Colletotrichum gloeosporioides)	Anthracnose	*Cleome viscose* *Portulaca oleracea*	Widespread on many host plants.	APDD
Gonotophragmium mori	Leaf spot	*Ficus opposita var. micrantha*	A minor disease.	APDD
Kordyana celebensis	Leaf spot	*Commelina ensifolia*	A minor disease.	APDD
Laetisaria fuciformis	Red thread	*Aristida contorta*	A widespread disease of turf grasses that occurs in cool and humid areas.	APDD
Leptosphaeria korrae	Root rot	*Cynodon dactylon*	A widespread disease of grasses.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Leptosphaeria narmari	Spring dead spot	*Cynodon dactylon*	A widespread disease of grasses.	APDD
Macalpinomyces eriachnes	Smut	*Eriachne mucronata*	Minor disease.	APDD
Macalpinomyces ewartii	Smut	*Sarga plumosum*	Minor disease.	APDD
Macalpinomyces tubiformis	Smut	*Chrysopogon fallax*	Only known from the type collection in Qld.	Shivas & Vánky (2004)
Masseeëlla capparidis	Leaf rust	*Flueggea virosa* subsp. *Melanthesoides*	Only known from Qld.	APDD
Meliola clerodendricola	Black mildew	*Clerodendron tomentosum*	Minor disease.	APDD
Miyagia pseudosphaeria	Black mildew	*Sonchus oleraceus*	Widespread in Australia.	APDD
Moreaua fimbristylidis	Smut	*Fimbristylis dichotoma*	Only known from central Australia.	APDD
Mycosphearella cryptica	Leaf spot	*Eucalyptus camaldulensis* *Eucalyptus gomphocephala*	Widespread on eucalypts in Australia.	APDD
Nigrocornus scleroticus	Stem gall	*Chrysopogon fallax* *Eriachne mucronata* *Sarga plumosum* *Themeda australis*	Widespread on tropical grasses.	APDD
Passalora fusimaculans	Leaf blight	*Bothriochloa bladhii*	Worldwide on many grass species.	Crous & Braun (2003)
Peronospora farinose	Downy mildew	*Chenopodium melanocarpum* *Chenopodium pumilio*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Peronosclerospora maydis	Downy mildew	*Sarga plumosum*	Minor disease.	APDD
Peronosclerospora noblei	Downy mildew	*Sarga plumosum*	Minor disease.	APDD
Phaeophleospora epicoccoides (synonyms *Kirramyces epicoccoides, Phaeoseptoria eucalypti*)	Leaf spot	*Eucalyptus camaldulensis*	Widespread in Australia.	APDD
Phaeophleospora eucalypti (synonyms *Kirramyces eucalypti, Pseudocercospora eucalypti*)	Leaf spot	*Eucalyptus camaldulensis*	Widespread in Australia.	APDD
Phleospora myopori	Leaf spot	*Myoporum acuminatum*	Minor disease.	APDD
Phyllachora cynodontis	Tar spot	*Cynodon dactylon*	Minor disease.	APDD
Phyllachora hakeicola	Tar spot	*Hakea lorea*	Minor disease.	APDD
Phyllachora infectoria	Tar spot	*Ficus virens*	A minor disease.	APDD
Phyllachora ischaemi	Tar spot	*Chrysopogon fallax* *Dichantium sericeum* *Themeda australis*	Widespread on many grasses causing minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Phyllachora platyelliptica	Tar spot	*Themeda australis*	A minor disease.	APDD
Phyllachora rhytismoides	Tar spot	*Ficus opposita*	Widespread on *Ficus*.	APDD
Phytophthora nicotianae var. *parasitica*	Root rot	*Swainsona formosa*	Widespread and with a wide host range.	APDD
Plasmopara halstedii	Downy mildew	*Arctotheca calendula*	Rarely collected.	APDD
Pseudocercospora atromarginalis	Leaf spot	*Solanum nigrum*	A minor disease.	APDD
Pseudocercospora conspicua	Leaf spot	*Cleome viscosa*	Known only from Qld.	APDD
Pseudocercospora dolichandrones	Leaf spot	*Dolichandrone heterophylla*	Only known in Australia from one collection.	APDD
Pseudocercospora sabbatiae	Leaf spot	*Centaurium erythraea*	A minor disease.	APDD
Pseudocercospora stahlii	Leaf spot	*Passiflora foetida*	Widespread on this host.	APDD
Puccinia arthrocnemi	Leaf rust	*Halosarcia halocnemoides*	Known only from SA.	APDD
Puccinia bassiae	Leaf rust	*Sclerolaena convexula*	Minor disease.	APDD
Puccinia canaliculata	Leaf rust	*Cyperus iria*	Widespread in Australia but rarely collected on this host.	APDD
Puccinia cynodontis	Leaf rust	*Brachyachne* sp. *Cynodon dactylon*	Widespread in Australia.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Puccinia cyperi-tegetiformis	Leaf rust	*Cyperus bifax*	Known only from NSW.	APDD
Puccinia dielsiana	Leaf rust	*Threlkeldia diffusa*	A minor disease.	APDD
Puccinia duthiae	Leaf rust	*Bothriochloa bladhii* *Dichantium sericeum*	Widespread in tropical Australia.	APDD
Puccinia heterospora	Leaf rust	*Abutilon leucopetalum*	Widespread in Australia.	APDD
Puccinia kochiae	Leaf rust	*Enchylaena tomentosa*	Minor disease.	APDD
Puccinia levis	Leaf rust	*Sarga plumosum*	Widespread in Australia.	APDD
Puccinia versicolor	Leaf rust	*Themeda australis*	A minor disease.	APDD
Puccinia xanthii	Leaf rust	*Flaveria australasica*	Widespread in Australia on several hosts.	APDD
Pyricularia grisea	Eye spot	*Cenchrus ciliaris*	Widespread in Australia.	APDD
Sclerotinia homeocarpa	Dollar spot	*Cynodon dactylon*	Widespread particularly as a disease of golf greens.	APDD
Sclerotinia sclerotiorum	Root and stem rot	*Arctotheca calendula*	Widespread and with a wide host range.	APDD
Septoria perforans	Leaf spot	*Arctotheca calendula*	Rarely collected.	APDD
Septoria sonchi	Leaf spot	*Sonchus oleraceus*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Setosphaeria holmii (anamorph Exserohilum holmii)	Leaf blight	*Dactyloctenium radulans*	Rarely collected.	APDD
Setosphaeria rostrata (anamorph Exserohilum rostratum)	Leaf spot	*Cynodon dactylon* *Dactyloctenium radulans*	Widespread on many grasses in Australia.	APDD
Sphaerotheca fuligenea	Powdery mildew	*Erythrina vespertilio*	Widespread in Australia causing the important cucurbit powdery mildew.	APDD
Sporisorium andropogonis	Smut	*Dichantium sericeum*	Widespread in Australia.	APDD
Sporisorium benguetense	Smut	*Themeda australis*	Only known from one location in northern Qld.	APDD
Sporisorium bothriochloae	Smut	*Dichantium sericeum*	A minor disease.	APDD
Sporisorium centrale	Smut	*Themeda australis*	Only know from one location in central Australia.	APDD
Sporisorium confusum	Smut	*Aristida holathera var. holathera*	This smut is widespread in Australia on several *Aristida* spp.	Vánky (2001)
Sporisorium doidgeae	Smut	*Bothriochloa bladhii* *Dichantium sericeum*	Widespread in Australia.	Vánky & Shivas (unpublished)

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Sporisorium exsertum	Smut	*Themeda australis*	Widespread in Australia.	APDD
Sporisorium fallax	Smut	*Chrysopogon fallax*	Widespread but rarely collected.	Shivas & Vánky (2004)
Sporisorium langdonii	Smut	*Themeda australis*	Rarely collected.	APDD
Sporisorium lanigeri	Smut	*Cymbopogon ambiguus* *Cymbopogon bombycinus*	Widespread.	APDD
Sporisorium mutabile	Smut	*Cymbopogon bombycinus*	Widespread.	APDD
Sporisorium normanensis	Smut	*Cynodon dactylon*	Known only from one location in Qld.	Vánky & Shivas (2003)
Sporisorium ryleyi	Smut	*Sarga plumosum*	Minor disease.	Vánky & Shivas (2003)
Sporisorium sorghi	Smut	*Sarga plumosum*	Minor disease.	Vánky & Shivas (2003)
Sporisorium tenue	Smut	*Bothriochloa bladhii*	Widespread in Australia.	Vánky & Shivas (unpublished)
Sporisorium themedae	Smut	*Themeda australis*	Rarely collected.	APDD
Sporisorium tumefaciens	Smut	*Chrysopogon fallax*	Widespread but rarely collected.	Vánky & Shivas (unpublished)
Sporisorium tumeforme	Smut	*Chrysopogon fallax*	Rarely collected.	Vánky & Shivas (2004)
Sporisorium walkeri	Smut	*Themeda australis*	Widespread.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Thanatephorus cucumeris (anamorph Rhizoctonia solani)	Root rot	*Cynodon dactylon*	Widespread in Australia on many plants.	APDD
Tilletia cape-yorkensis	Smut	*Whiteochloa airoides*	Known only from the type location in northern Qld.	APDD
Tilletia opaca	Smut	*Spinifex longifolius*	Rarely collected.	APDD
Uromyces orientalis	Smut	*Indigofera linifolia*	A minor disease.	APDD
Uromyces salsolae	Smut	*Salsola tragus*	Rarely collected.	APDD
Uromyces scaevolae	Rust	*Scaevola spinescens*	A minor disease.	APDD
Uromycladium tepperianum	Gall rust	*Acacia bivenosa*	Widespread on *Acacia* in Australia.	APDD
Ustilago altilis	Smut	*Triodia pungens*	Widespread in tropical Australia.	APDD
Ustilago cynodontis	Smut	*Cynodon dactylon*	Very common wherever couch grass is grown.	APDD
Ustilago latzii	Smut	*Triraphis mollis*	Known only from the type location in central Australia.	APDD
Ustilago porosa	Smut	*Sarga plumosum*	Minor disease.	APDD
Ustilago radulans	Smut	*Dactyloctenium radulans*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Ustilago schmidtiae	Smut	*Enneapogon polyphyllus*	Minor disease.	APDD
Ustilago spermophora	Smut	*Sporobolus australasicus*	Minor disease on several grasses.	APDD
Verticillium dahliae	Vascular wilt	*Euphorbia drummondii* *Portulaca oleracea* *Salsola tragus* *Solanum nigrum* *Sonchus oleracuea*	An important pathogen of many introduced herbaceous plants.	APDD

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Technical Appendix D10

Conceptual Quarantine Barriers – Subject to Feasibility Analysis and Design

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GORGON DEVELOPMENT ON BARROW ISLAND

CONCEPTUAL QUARANTINE BARRIERS
Subject to Feasibility Analysis and Detailed Design

TECHNICAL APPENDIX D10

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June 2005

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CONTENTS

1 Introduction

Three high-risk exposure pathways identified by the Quarantine Expert Panel were selected for priority assessment to demonstrate confidence in the ability to manage quarantine threats. The three pathways represent what are considered the greatest threats of introducing non-indigenous species to Barrow Island. The three priority pathways are:

1. 'Sand and aggregate';
2. 'Food and perishables'; and
3. 'Personnel and accompanying luggage'.

This document details the full list of quarantine barriers which have been suggested by technical experts at the *conceptual* level to meet the Joint Venturers' standards for acceptable risk on the three priority pathways. These conceptual quarantine barriers have been recorded through Infection Modes and Effects Analysis (IMEA) workshops, have been subject to assessment in Preliminary Barrier Analysis (PBA) workshops, and have been classified as either 'key barriers' or 'non-key' barriers. Key barriers are those which are expected to be highly effective in mitigating the risk of introducing a non-indigenous species, while non-key barriers may offer additional options to further reduce risk.

All of the conceptual quarantine barriers suggested by workshop participants will undergo feasibility analysis. Upon completion of the feasibility analysis and engagement of front-end engineering design contractors, specific quarantine barriers will be selected for detailed specifications and design, and will be subject to further risk assessment by technical experts to confirm that the barriers will perform as expected, using a Hazard and Operability (HAZOP) analysis technique. The application of the HAZOP process to this quarantine assessment is known as a 'QHAZ' analysis and is described in the *How to Guide for Conducting Risk-based Assessments of Quarantine Hazards on Barrow Island* (E-Systems 2005).

All of the pathways which result in the arrival of materials, supplies and personnel to Barrow Island will be subject to exactly the same process of threat identification and development of quarantine barriers, utilising the expertise of technical specialists and communication of quarantine barriers to government and stakeholders.

Seventeen risk assessment workshops have been completed through April 2005, involving 26 ecologists and conservation specialists attending multiple workshops (plus 15 construction, logistics and environmental specialists, and ten government observers). Information on pathway-specific quarantine threats and suggested barriers has been captured in quarantine risk assessment workshop reports (available on the Gorgon Development website, www.gorgon.com.au).

The quarantine barriers for the three priority pathways are presented in subsequent sections of this document, followed by an explanation of how quarantine barriers will be implemented. All information presented in this document is sourced from the records of quarantine risk assessment workshops.

2 'Sand and Aggregate' Pathway

Conceptual quarantine barriers which are subject to feasibility analysis for the procurement, handling and transport of sand and aggregate are described in this section of the document. Sand and aggregate is to be used for the construction of proposed facilities at Barrow Island.

Conceptual quarantine barriers for the sand and aggregate pathway have been identified to reduce the risk of introducing non-indigenous species at each step of the pathway. The pathway steps start at the quarry and include all activities for handling cargoes through their arrival at the Barrow Island Materials Offloading Facility (marine wharf), as shown in Figure 2.1.

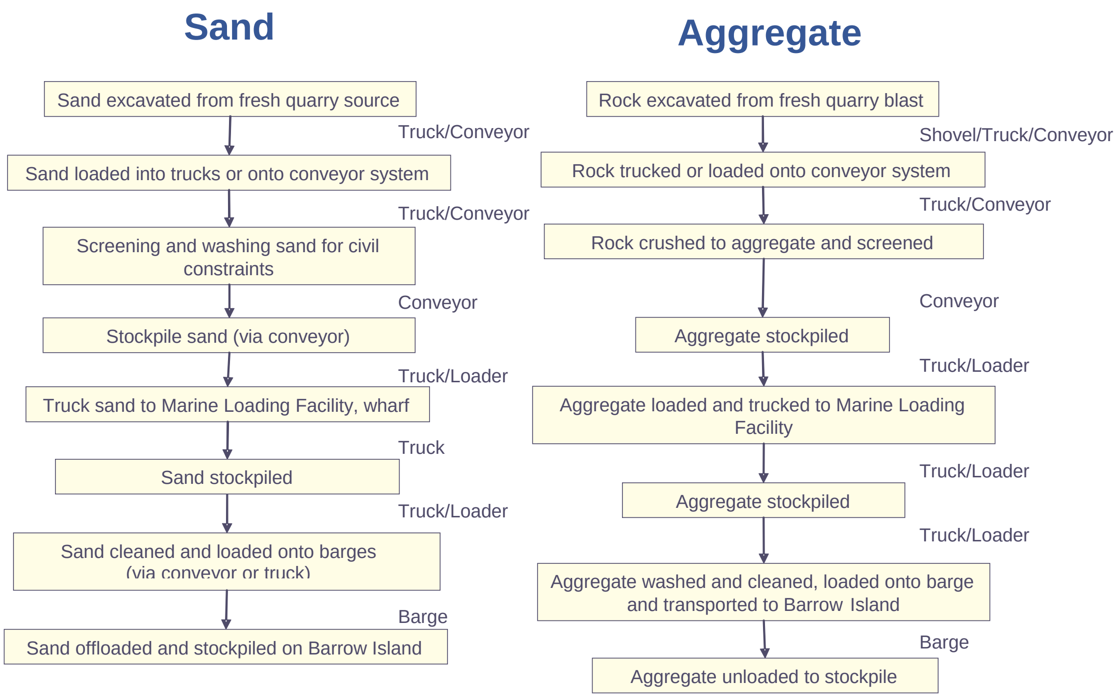

Figure 2.1: 'Sand and Aggregate' Pathway Steps

Of the quarantine barriers identified by technical experts, several barriers were singled out as key barriers. Quarantine barriers are listed in Table 2-1 by pathway step for reference, and numbered as per the relevant PBA workshop report for sand and aggregate (4 November 2004). Key barriers are designated with the 🔑 symbol beside the workshop barrier number. Some of the quarantine barriers apply to more than one pathway step, and these are listed at the top of Table 2-1.

Table 2-1: Conceptual Quarantine Barriers Identified for the 'Sand and Aggregate' Pathway

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
All pathway steps	B9 🔑	Induct all personnel in quarantine management expectations before commencing work. Conduct ongoing inductions and training in quarantine management. Ensure that all footwear and clothing is free of seeds, plant and animal matter. Prohibit cuffs on trousers.
	B44 🔑	Ensure compliance with quarantine requirements through a regular schedule of audits and checks (specifically noted in the mainland marine loading facility pathway step).
Quarry activities	B1 🔑	Implement a site selection process for quarry or pit (and possibly transport corridors), including a baseline flora and fauna survey. Conduct on-going flora and fauna surveys.
	B2 🔑	Establish a site-specific environmental management plan (throughout operations).
	B3	Obtain all necessary environmental approvals for quarry operations.
	B4	Implement weed management practices at the quarry or pit site.
	B5	Manage stormwater, including diverting stormwater off-site to minimise the formation of surface water ponds in the quarry or pit.
	B6	Control personnel access and movement through fencing, gates and a site office.
	B7	Establish a dedicated quarry or pit, or fenced area to segregate Gorgon operations from other users.
	B8	Implement a dust management strategy.
	B10	Minimise night-time operations. Operate under lighting that minimises potential for invertebrate infestation (particularly insects).
	B11	Erect fencing at crushing and screening areas to minimise fauna incursions.
	B12	Strategically locate overburden and stockpiles to minimise blow-back of into the quarry or pit. Ensure sufficient distance between locations and the blast line. Remove vegetation and topsoil (including seed bank) prior to blasting.
	B13 🔑	Wash-down and decontaminate all vehicles prior to commencing quarry operations. Minimise use of all non-essential vehicles. Consider drive-through wash area with high pressure jets, possible chemical treatment (eg sodium hypochlorite) to decontaminate tyres.
	B14	Decontaminate the crushing and screening equipment prior to processing raw materials. Alternatively, use a dedicated crusher and screen.
	B15	Manage operations to minimise the length of time that sand and aggregate are stockpiled before transport to the mainland marine loading facility.
	B16	Undertake vehicle maintenance outside main quarry area.
	B17	Develop requirements for appropriate packaging of supplies brought into the quarry, such that they are free from contamination. Remove packaging material from the quarry in a timely manner.
	B18	Maintain quarry floor and operating areas such that saltation, vegetation, waste materials and food scraps are minimised.

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B19	Monitor tailings for invertebrates (and other biological groups). In the event that invertebrates or other biological groups are discovered, quarantine the infested area and decontaminate.
	B20	Ensure that aggregate dries completely before stockpiling or loading onto trucks.
	B21	Consider chemical disinfection of water, or using high temperature water for washing.
	B22	Monitor stockpiles for invertebrates. In the event that invertebrates or other biological groups are discovered, quarantine the infested area and decontaminate.
	B23	Minimise stockpiling of material during peak cyclone season.
	B24	Establish a buffer area around stockpile to exclude terrestrial species.
	B25	Start-up the sand or aggregate loading conveyor for a sufficient period to shake-off invertebrates between uses.
	B26	Treat conveyor system with a chemical residual herbicide/insecticide.
	B27	Re-wash and re-process any sand or aggregate which is spilt from a conveyor system to the ground.
	B28	Design the stockpile area to be on the order of 60 m x 20 m x 9 m (height).
Road transport	B29 🔑	Wash-down and decontaminate all vehicles. Consider drive-through wash area with high pressure jets, possible chemical treatment (eg sodium hypochlorite) to decontaminate tyres.
	B30 🔑	Comprehensively inspect and clean trucks put into transport service from other jobs. Inspect and clean trucks before each loading.
	B31 🔑	Ensure that trucks do not make any stops along the roadway between the quarry and the mainland marine loading facility.
	B32 🔑	Establish a dedicated truck fleet and pre-qualify road transport contractors.
	B33	Develop contingency plans for spilt loads.
	B34	Minimise invertebrate (particularly spider) infestation of tarps used to cover cargoes when not in use.
Mainland marine loading facility	B35 🔑	Construct a hard-stand (cement) area for the loading dock.
	B36	Establish secure fencing around the loading zones.
	B37	Minimise stockpile time on the wharf (limit of four weeks). Cover and monitor stockpile for infestation. In the event that invertebrates or other biological groups are discovered, quarantine the infested area and decontaminate.
	B38	Plan for the full turnover of stockpiles to ensure that material does not remain at the wharf for more than four weeks (e.g. to avoid infestation of 'tramp ants').
	B39	Eliminate or manage lighting in stockpile area to minimise invertebrate (insect) attraction, especially within 2–3 days of loading barge.
	B40	Minimise barge loading activities in non-daylight hours.
	B41	Establish a dedicated wharf area/loading area.
	B42	Establish dedicated handling equipment.
	B43	Ensure that storage and handling of aggregate on the wharf does not compromise previous efforts to reduce infections.

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B45	Maintain good 'housekeeping' and facility hygiene practices at all times.
	B46	Chemically treat mooring lines and gangways. Establish a quarantine area on the wharf.
	B47	Install mooring dolphins to keep vessels separated from the wharf.
	B48	Use gangways with rollers to enable constant movement of vessel and gangway when moored.
	B49 🔑	Wash-down and decontaminate all vehicles prior to entering the mainland marine loading facility. Minimise use of non-essential vehicles.
	B50	Develop a contingency plan for unauthorised visitors, or vessels mooring alongside barge.
	B51 🔑	Consider heat sterilisation, chemical treatment and washing of sand and aggregate as it is being loaded into barges.
	B52	Establish dedicated barges for Gorgon Development cargoes.
	B53 🔑	Clean barge hulls and decks to not less than Australian Quarantine Inspection Service (AQIS) requirements.
	B54	Wash cargo bays (with sea water under high pressure) and treat with insecticide before loading.
	B55 🔑	Cover cargo with tarp or enclose cargo in hold or cover. Store tarps such that infestation between uses is minimised.
	B56 🔑	Sample sand and aggregate during loading for quarantine compliance. If contamination is detected after a barge sails, the infected cargo is not landed on Barrow Island. Infected cargoes to be quarantined and decontaminated.
	B72 🔑	Covered conveyors for loading cargo.
Sea transport	B57 🔑	Inspect and clean barge prior to loading. Low-dosage insecticide treatment in cabin areas, including treatment of soft furnishings. Bait for cockroaches and rodents.
	B58 🔑	Wash cargo bay (eg high pressure seawater), and treat with insecticide prior to loading.
	B59 🔑	Enclose living quarters to exclude flying insects. Control insects in living quarters with electric 'fly zappers', sticky traps, baits, etc during voyages.
	B60	Inspect and conduct regular maintenance of baits and insect control mechanisms.
	B61 🔑	Train and induct barge operations personnel in quarantine management procedures (also applies to sea transport pathway step).
	B62 🔑	Store food in living quarters in compliance with quarantine standards for food and perishables (refer to Section 3.0). Alternatively, source food from kitchen facilities on Barrow Island.
	B63 🔑	Maintain good hygiene standards on barge deck and in cabin areas.
	B64	Cover cargo with tarps throughout the voyage.
	B65 🔑	Maintain good housekeeping practices. Minimise lighting after daylight hours, including sources of light which are away from cargo bays.
	B66	Discourage birds from landing on vessels.
	B67	Enable mooring and handling lines to be immersed in seawater on voyage.
	B68	Prohibit fishing on commercial barges during voyages.

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B69	Develop a contingency plan for supporting any (other) vessels in distress.
	B70	Inspect cargo to ensure integrity and quarantine compliance before barge landing on Barrow Island.
Arrival and unloading on Barrow Island	B71 🔑	Establish a chain of custody for transport cargo, to ensure quarantine requirements have been undertaken.
	B73 🔑	Take weather conditions into account in barge landing procedures.

3 'Food and Perishables' Pathway

Conceptual quarantine barriers which are subject to feasibility analysis for the procurement, handling and transport of food and perishables are described in this section of the document. This pathway specifically represents the level of effort required to service the construction camp for the proposed development, however the same quarantine barriers would also apply to a much smaller operational workforce.

All food and perishable items included in this pathway (for consumption at the Barrow Island construction camp) are transported by road and barge. Quarantine barriers for food and perishables stored, handled and consumed on aircraft are considered in the 'Personnel and accompanying luggage pathway' (refer to Section 4).

Conceptual quarantine barriers for the food and perishables pathway have been identified to reduce the risk of introducing non-indigenous species at each step of the pathway. The pathway steps start at the food growers and suppliers, and include all activities for handling cargoes through their arrival at a Barrow Island kitchen facility, as shown in Figure 3.1.

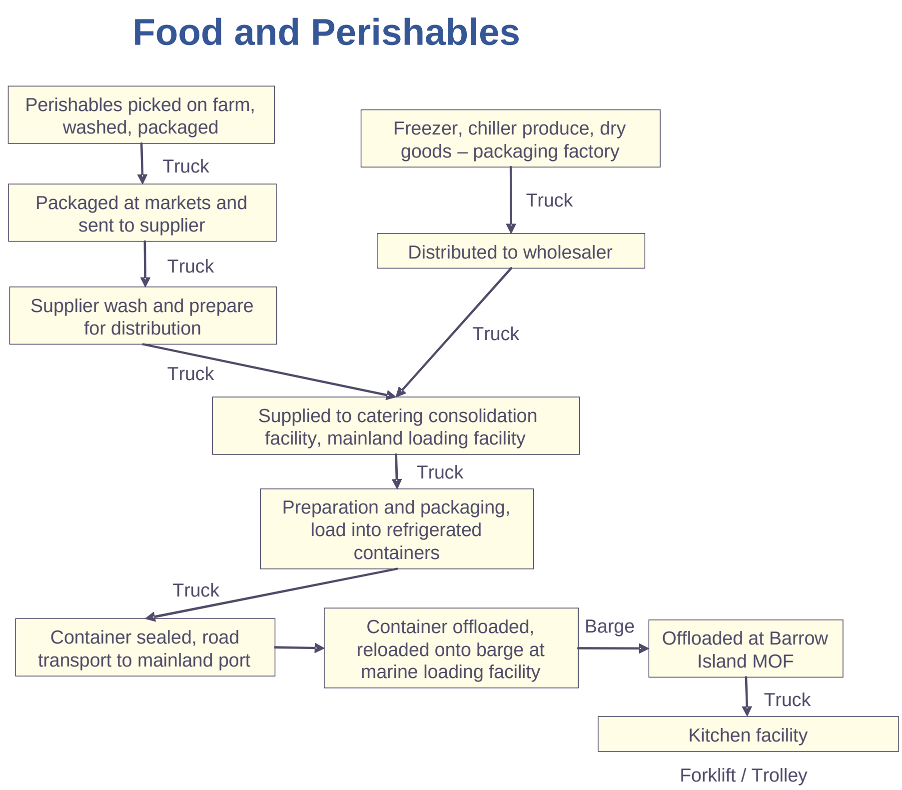

Figure 3.1: 'Food and Perishables' Pathway Steps

Most of the quarantine barriers identified by technical experts are considered to be key barriers. Quarantine barriers are listed in Table 3-1 by pathway step for reference, and numbered as per the relevant PBA workshop report for food and perishables (5 November 2004). Key barriers are designated with the 🔑 symbol beside the workshop barrier number.

Table 3-1: Conceptual Quarantine Barriers Identified for the 'Food and Perishables' Pathway

Food and perishables pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
All pathway steps	B9 🔑	Induct all personnel in quarantine management expectations before commencing work. Conduct ongoing inductions and training in quarantine management, and include conservation values of Barrow Island. Ensure that all footwear and clothing is free of seeds, plant and animal matter. Prohibit cuffs on trousers. Note: Barrier number B48 is identical to B9, and is not repeated here.
	B24 🔑	Regularly audit and check to ensure quarantine compliance (specifically noted in the mainland marine loading facility pathway step).
Growers and suppliers	B1 🔑	Prequalification and auditing of all food suppliers to ensure food safety compliance under Australian guidelines and regulations. Quarantine requirements to include food and packaging free from soils, visible invertebrates, etc.
	B4 🔑	Education of all supplier personnel in quarantine awareness and Barrow Island conservation values (also applies to mainland loading facility step).
Centralised mainland loading facility	B2. 🔑	Establish a central facility in Perth for receiving, packaging and dispatch of all chilled, fresh and dry foods. This will also include additional washing and processing of food and perishables identified as high risk by technical specialists. Prepared food to be vacuum-packed.
	B3	Prohibit high risk foods and perishables where risk cannot be reduced by processing.
	B5 🔑	Limit external packaging where possible by supplying food in pre-approved plastic containers, or on plastic pallets. Minimise packaging with organic materials such as wood. Packaging to be selected to facilitate manual handling and inspection.
	B6 🔑	All food and perishables from suppliers received into warehouse within the loading facility, and distributed for cleaning, processing and/or packaging.
	B7 🔑	Food to be packaged into consignments, inspected and checked, and loaded into chilled containers.
	B8 🔑	All equipment regularly cleaned and disinfected to maintain good hygiene and housekeeping practices.
	B9 🔑	Induct all personnel in quarantine management expectations before commencing work. Conduct ongoing inductions and training in quarantine management, and include conservation values of Barrow Island. Ensure that all footwear and clothing is free of seeds, plant and animal matter. Prohibit cuffs on trousers.
	B10 🔑	Food and perishables warehouses will operate under the Australian health regulations and guidelines.
Road transport	B11	Install air curtains on building entries and exits to minimise incursions of invertebrates into food processing and packaging areas.
	B12	Clean and treat internal spaces of all containers before packing. Seal containers upon completion of loading.
	B13	Place flour trays or other means of detection in containers for 12 hours prior to the container leaving the loading facility.
	B14 🔑	Wash-down and decontamination of all vehicles. Consider drive-through wash area with high pressure jets, possible chemical treatment (eg sodium hypochlorite) to decontaminate tyres.

Food and perishables pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B15 🔑	Comprehensive inspection and cleaning for trucks put into transport service from other jobs. Inspect and clean trucks before each loading.
	B16 🔑	Ensure that trucks do not make any stops along the roadway between the mainland loading facility and the mainland marine loading facility.
	B17 🔑	Establish a dedicated truck fleet and pre-qualify road transport contractors.
Mainland marine loading facility	B18 🔑	Inspect all six sides of containers.
	B19 🔑	Construct a hard-stand (cement) area for the loading dock.
	B20 🔑	Establish secure fencing around the loading zones.
	B21	Minimise barge loading activities in non-daylight hours.
	B22 🔑	Establish a dedicated wharf area/loading area.
	B23 🔑	Establish dedicated handling equipment.
	B25 🔑	Maintain good 'housekeeping' and facility hygiene practices at all times.
	B26 🔑	Chemically treat mooring lines and gangways. Establish a quarantine area on the wharf.
	B27 🔑	Install mooring dolphins to keep vessels separated from the wharf.
	B28 🔑	Use gangways with rollers to enable constant movement of vessel and gangway when moored.
	B29 🔑	Wash-down and decontamination of all vehicles prior to entering the mainland marine loading facility. Minimise use of non-essential vehicles.
Sea transport	B30 🔑	Develop a contingency plan for unauthorised visitors, or vessels mooring alongside barge.
	B31 🔑	Dedicated barges for Gorgon Development cargoes.
	B32 🔑	Clean barge hulls and decks to not less than AQIS requirements.
	B33 🔑	Wash cargo bay (with sea water under high pressure) and treat with insecticide before loading.
	B34 🔑	Inspect barge prior to loading for quarantine compliance. If contamination is detected after a barge sails, the infected cargo is not landed on Barrow Island. Infected cargoes to be quarantined and decontaminated.
Arrival and unloading on Barrow Island (kitchen facility and waste management)	B35 🔑	Establish a purpose-built kitchen facility on Barrow Island to receive food and perishable containers. The kitchen facility is to function as an effectively sealed building and truck loading area. Install dark-coloured doors.
	B36 🔑	Implement a barrier between the food preparation and serving areas to retard the movement of invertebrates and seeds. Barrier may include environmental, chemical and/or physical controls.
	B37 🔑	Waste treatment to minimise contamination of the Barrow Island environment.
	B38 🔑	Process all food before it leaves the kitchen facility.
	B39 🔑	Establish effective sewage treatment system.
	B40 🔑	Implement a barrier between the food serving area and the Barrow Island environment to retard the movement of invertebrates and seeds. Barrier may include environmental, chemical and/or physical controls.
	B41 🔑	Filter air prior to discharge from the kitchen facility.

Food and perishables pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B42 🔑	Perform chemical treatment inside and outside of the kitchen facility.
	B43 🔑	Install 'insect zappers' in all loading and food preparation areas.
	B44 🔑	Establish a chilled area in the kitchen facility for receiving food and perishables on Barrow Island, where food containers are to be unloaded. Maintain a temperature of 12°C to reduce activity of flying insects.
	B45 🔑	High pressure water hosing of the facility at the end of each shift.
	B46 🔑	Include traps in the design specifications of the kitchen facility to facilitate ongoing monitoring.
	B47 🔑	Regularly clean and disinfect all equipment to maintain good hygiene and housekeeping practices.
	B49 🔑	Establish higher risk and lower risk quarantine zones in the kitchen facility, with restricted personnel movement between the two areas. Require food and perishables to undergo processing (eg cleaning, washing, blanching, chopping) to reduce risk before it crosses a barrier into a lower risk zone.
	B50 🔑	Wash all fresh vegetables in a saline solution and potable water during processing.
	B51 🔑	Install air handling exhaust hoods in higher risk quarantine zones of the kitchen facility. Exhaust hoods to contain air filtration systems.
	B52 🔑	Double-bag all waste produced within the kitchen facility, prior to removal to a central waste processing area.

In addition to the conceptual quarantine barriers described above, additional barriers primarily related to reducing threats of introducing non-indigenous species as a result of waste management activities will undergo feasibility analysis and detailed design. These additional barriers include:

- Installation of an incinerator for waste management;
- Incineration of cardboard and plastics used for packaging;
- Fencing of the incinerator unit to exclude intrusion by native fauna;
- Processing waste in the incinerator following each meal period to minimise storage;
- Separation of waste water to grey water and sewage water;
- Excluding kitchen waste water from re-use as grey water for dust suppression, due to potential entrainment of seed material;
- Consideration of subsurface fauna in feasibility studies for reinjection of waste water (from waste systems or reverse osmosis separation plant);
- Return of waste material (eg waste oil, sewage sludge) to the mainland for processing or disposal; and
- Consideration of the design of above ground waste water storage tanks to exclude intrusion by native fauna.

4 'Personnel and Accompanying Luggage' Pathway

Conceptual quarantine barriers which are subject to feasibility analysis for the movement of 'personnel and accompanying luggage' by aircraft are described in this section of the document. This pathway includes only those activities associated with moving the large construction work force to and from Barrow Island from mainland airports. Any contemplated use of the Barrow Island airfield for inter-island aircraft flights will be the subject of a different pathway, and will undergo the same type of assessment.

The quarantine barriers for the personnel and accompanying luggage pathway have been identified to reduce the risk of introducing non-indigenous species at each step of the pathway. The pathway steps start at the point where personnel pack their personal belongings, and include all activities for processing luggage and personnel through their arrival at the Barrow Island airport, as shown in Figure 4.1.

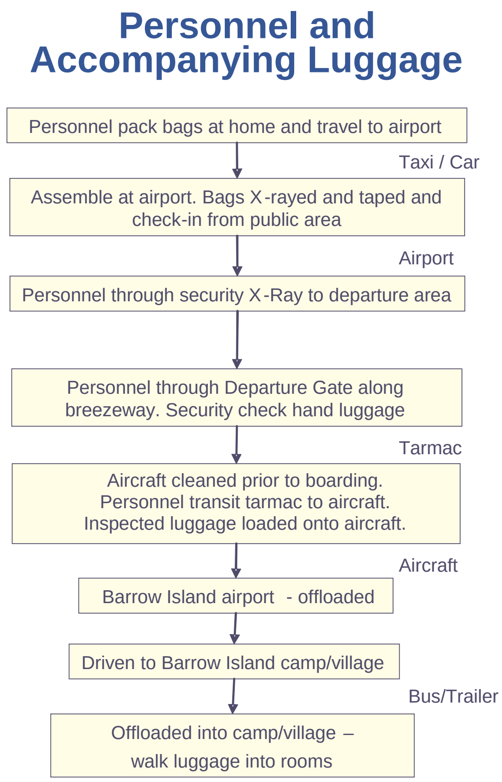

Figure 4.1: 'Personnel and Accompanying Luggage' Pathway Steps

The storage and handling of cargo which is shipped through a mainland logistics facility is being more comprehensively assessed on the 'containerised goods' pathway (separately from people and luggage), which is subject to the same type of assessment. Cargo is checked in at a mainland airport for transport with personnel and luggage. Quarantine barriers were considered with an emphasis on prevention of introductions at the point where cargo arrives at an airport for loading.

Of the conceptual quarantine barriers identified by technical experts, four barriers were singled out as key barriers. Quarantine barriers are listed in Table 4-1 by pathway step for reference, and numbered as per the relevant PBA workshop report for people and luggage

(29 October 2004). Key barriers are designated with the 🔑 symbol beside the workshop barrier number.

Table 4-1: Conceptual Quarantine Barriers Identified for the 'Personnel and Luggage' Pathway

People and luggage pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
Packing of luggage for work or visit Recruitment, selection and training of personnel	B1 🔑	Develop pre-employment agreements, including personal awareness training and inductions to appreciate quarantine risks and management. Provide list of prohibited items and require a statutory declaration by travellers.
	B2	Issue standard work clothing, boots, for use only on Barrow Island. Provide laundry services.
	B3	Consider issuing personal clothing and providing cleaning/laundry services.
	B4	Issue standard luggage to facilitate inspection and manual handling.
	B5	Ship personal items (eg specialised tools and equipment) through mainland logistics facility. Provide electronics (eg televisions, music players) and recreational facilities and equipment within the construction camp.
	B6	Establish a list of prohibited items as part of quarantine induction training. Reasons for prohibited items to be explained.
Check-in at mainland airports People, hand luggage, air crews, in-flight catering transported in the passenger cabin of aircraft	B7 🔑	Inspect every bag of personal luggage (x-ray and visual), by trained inspectors. Opportunities to further reduce risk if small organisms can be detected and eliminated during inspections.
	B9	Establish the same inspection processes (x-ray, visual) for air crew.
	B10	Establish procedures for personal inspection, subject to checklist provided at induction (cuffs, pockets, socks, etc). Allow additional check-in time to process people.
	B11	Require x-ray equipment to be capable of detection of invertebrates and vertebrates (pending further analysis of technology and alternatives).
	B12	Tag and seal carry-on luggage after passing quarantine inspection.
	B13	Self-check personnel clothing to verify compliance. Provide awareness training and reinforcement (eg posters at airport).
	B20	Establish a dedicated passenger assembly and waiting lounge which is segregated from other airport passengers. Establish dedicated transfer bus and air curtain where people board aircraft.
Loading of aircraft Checked personal luggage, and mainland logistics cargo, transported in the cargo hold of aircraft	B8 🔑	Establish a dedicated luggage handling circuit at the airport, segregated from other airport check-in activities. Dedicated equipment subject to chemical treatment. Establish a chain of custody and chemical treatment to reduce the risk of infections and cross-contamination on the outside surfaces of luggage. Establish air curtain where luggage and cargo is transferred to aircraft. Manage lighting to avoid attraction of invertebrates.
	B11	Require x-ray equipment to be capable of detection of invertebrates and vertebrates (pending further analysis of technology and alternatives).
	B12	Tag and seal checked luggage after passing quarantine inspection.
	B21	Containerise luggage for loading onto aircraft.

People and luggage pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
Flight to Barrow Island Airport facilities and aircraft	B14	Provide quarantine awareness training to air crew and airport personnel. Establish a list of prohibited items to in-flight catering contractors. Establish a contingency plan for managing quarantine during evacuation flights (eg cyclone evacuation of Barrow Island).
	B15	Establish dedicated aircraft and air crews. Restrict aircraft to Perth — Barrow Island flights (or flights between other mainland airport and Barrow Island). Establish procedures for quarantine clearance of standby or replacement aircraft. Consider steam cleaning of all candidate aircraft (fleet of BAe146) on a regular maintenance schedule.
	B16 🔑	Clean aircraft to meet prescribed quarantine standards, including disinfection of cargo hold prior to departure. Treat cabin with insecticide, establish vertebrate controls. Clean and inspect in-flight food catering trolleys prior to food being loaded into aircraft. Consider removing carpet from passenger cabin.
	B17	Apply residual chemical treatment to aircraft using insecticide and herbicide (pending further analysis of compatibility with airframe components, safety and human health considerations). Noted that cleaning of aircraft to remove dirt and seeds may be more effective than herbicide application.
	B18	Include quarantine compliance checks in the pre-flight checks conducted by the Air Captain (pending further investigation, may be the role of a trained quarantine inspector authorised to access aircraft).
	B19	Inspect internal aircraft spaces (passenger cabin, luggage compartments, cargo holds) for quarantine compliance prior to loading aircraft. Develop inspection program to allow random re-checking with additional staff, and establish response procedures for breaches. Establish 'no-go' criteria for grounding aircraft on quarantine grounds, to be decided by a Joint Venture representative or major contractor representative.
	B22	Establish procedures for allowing only dedicated personnel who have undertaken quarantine awareness training to have access to aircraft.

References

E-Systems, 2005. *"How to Guide" for Conducting Risk-based Assessments of Quarantine Hazards on Barrow Island.* Prepared for ChevronTexaco Australia Pty. Ltd., Perth, Western Australia.

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