Western Newfoundland and Labrador Offshore Area Strategic Environmental Assessment

Prepared by

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environmental research associates

Prepared for

Canada-Newfoundland and Labrador Offshore Petroleum Board
Fifth Floor, TD Place
140 Water Street
St. John’s, NL
A1C 6H6

December 2005
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1.0 Introduction

The purpose of this strategic environmental assessment (SEA) is to provide a broad scale review and assessment of important resources in the Western Newfoundland and Labrador Offshore Area in light of potential oil and gas activities over the next five years. The terms 'offshore' or 'offshore area' refer to the jurisdictional area of the C-NLOPB, as defined in the *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (the *Accord Acts*) to mean "those submarine areas lying seaward of the low water mark of the Province and extending, as any location as far as (a) any prescribed line, or (b) where no line is prescribed at that location, the outer edge of the continental margin or a distance of two hundred nautical miles from the baselines from which the breadth of the territorial sea of Canada is measured, whichever is greater."

Strategic environmental assessment (SEA) is defined as 'The systematic and comprehensive process of evaluating the environmental effects of a policy, plan or program and its alternatives.' (**www.ceaa-acee.gc.ca**). The SEA is in support of the federal government's sustainable development initiatives and is defined in a 1999 Directive from Cabinet.

The SEA is essentially a planning document intended to assist the C-NLOPB in their decision process concerning which areas may or may not be suitable for offshore exploration, and/or which areas may require special mitigations if exploration activity is to proceed. This SEA provided support for the bid process on Parcels 4 to 7 in the Study Area (Figure 1.1). Four Northwest Atlantic Fisheries Organization (NAFO) Unit Areas (4Ra, 4Rb, 4Rc, and 4Rd) occur within the Study Area (Figure 1.1). These Unit Areas are used throughout the SEA in order to reference locations within the Study Area.

Some general potential issues in regard to offshore oil and gas development in Newfoundland and Labrador waters include the following:

- Effects of seismic noise on marine animals
- Accidental oil spills or blowouts
- Benthic habitat disturbance
- Health effects on fish
- Effects on commercial fisheries (contamination and displacement issues)
- Bird attraction to rigs
- Water/sediment quality degradation, especially in regard to cumulative effects

The following specific issues are relevant for the 'Western Newfoundland and Labrador Offshore Area' Study Area:

- Effects of oil and gas activities on the marine ecosystem from the low water mark to the offshore (>500m depth)

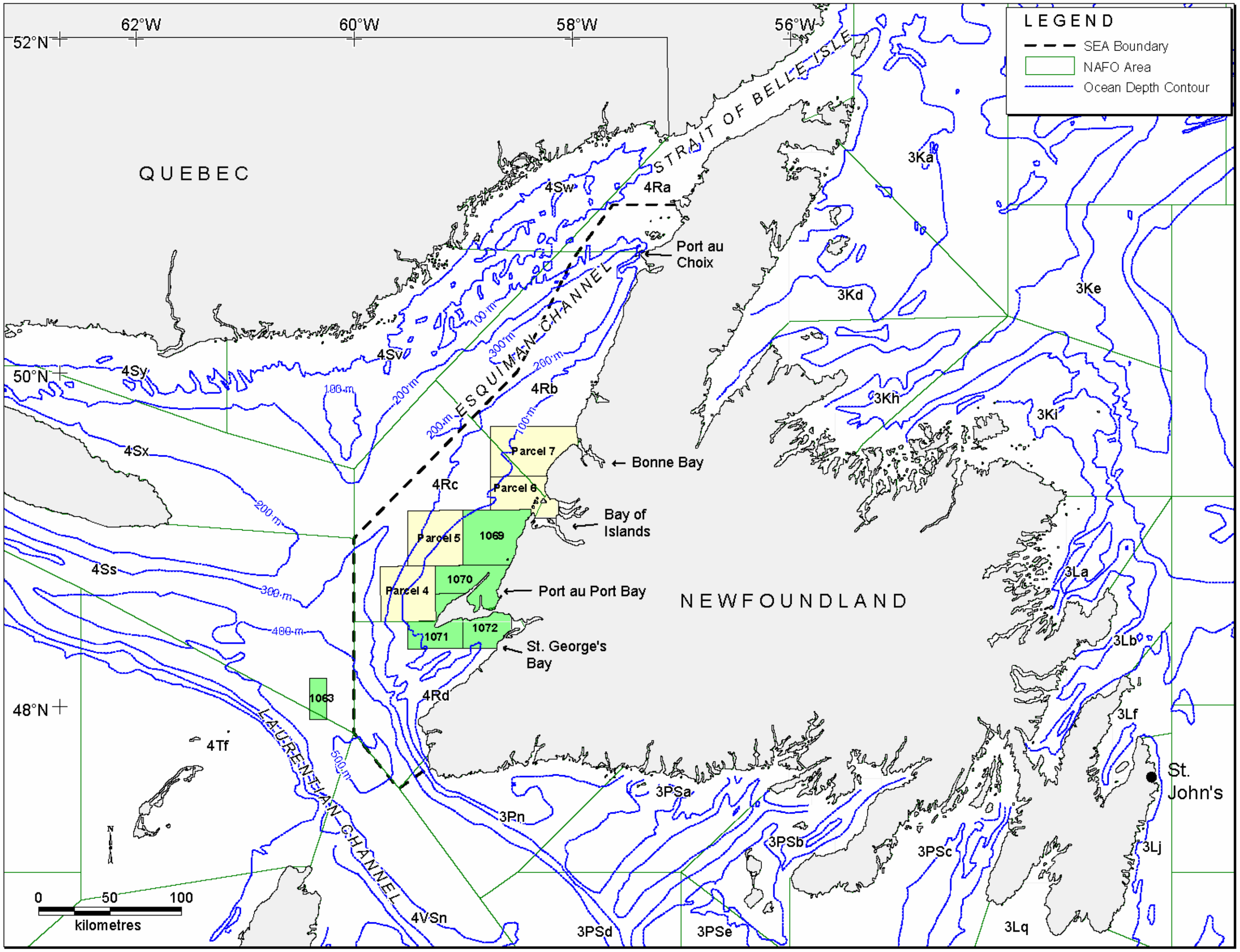

Figure 1.1. SEA Study Area Showing Locations of Parcels Up for Bids and Four Active Exploration Licences.

- Effects of oil and gas activities on finfish and their respective fisheries
- Effects of oil and gas activities on invertebrates (e.g., lobster, snow crab, northern shrimp) and their respective fisheries
- Effects of oil and gas activities on important bird areas
- Effects of oil and gas activities on waterfowl and sea-associated birds
- Effects of oil and gas activities of marine mammals and sea turtles
- Effects of oil and gas activities on species listed under the *Species at Risk Act* (*SARA*)
- Extra sensitive area and times within the Study Area
- Notable data gaps
- Aesthetics associated with oil and gas activities

1.1 Objectives/Purpose

As stated above, this SEA is intended to aid the C-NLOPB in determining whether exploration rights should be offered in whole or in part for an area, and may also identify general restrictive or mitigative measures that should be considered for application to exploration activities. This would be pursuant to the *Accord Acts*. In the following sections, this SEA will:

- Overview the existing environment within the Study Area,
- Discuss potential environmental effects of oil and gas activities in the Study Area,
- Identify knowledge and data gaps within the Study Area,
- Highlight areas and issues of concern within the Study Area, and
- Recommend mitigations and planning relevant to potential oil and gas activities within the Study Area.

1.2 Scoping

Scoping for the SEA was conducted in the following manner.

- Previous SEAs (e.g., Orphan Basin, Laurentian Sub-Basin, Scotian Shelf) were reviewed.
- C-NLOPB invited the public to comment on the Draft Scoping Document in April 2005. With the assistance of a Working Group consisting of representatives from federal and provincial government departments and agencies, local Regional Economic Development (RED) Boards, the fisheries union (FFAW), and non-governmental organizations, the C-NLOPB drafted the Draft Scoping Document.
- A series of scoping consultations were held during June and July 2005 (see Appendix 1).

1.3 History of Oil and Gas Activities in Western Newfoundland and Labrador Offshore Area

An oil seep was discovered in the Parson's Pond area (Unit Area 4Rb) in the early 19th century. An oil exploration program was initiated in this area in 1867, resulting in the confirmation of the existence of crude oil. In 1893, the Newfoundland Oil Company drilled in Parson's Pond area and struck both oil and gas (www.noianet.com/history/timeline.php).

During the 1990s, western Newfoundland received significant attention from the petroleum industry as a result of a new interpretation of the geology, a new regulatory regime, and an oil discovery on the Port au Port Peninsula. In 1994, Hunt Oil and PanCanadian Petroleum Limited spudded an exploration well in the Port au Port area. The next year, these same companies drilled to 3,100 m from an onshore location on the Port au Port Peninsula to an offshore location in Port au Port Bay. This well was eventually abandoned. Five more exploration wells were spudded on Newfoundland's west coast during the 1996-99 period. In 1999, Canadian Imperial Venture Corp. farmed into the Hunt-Pan Canadian Permit covering most of the Port au Port Peninsula, including the exploratory well Port au Port #1 drilled in 1994. In May 2000, oil finally flowed on the Port au Port Peninsula. Later in 2000, a development plan was filed with the Government of Newfoundland and Labrador for the Garden Hill oil and gas development, and an American firm, American Reserve Energy Corporation, drilled near Flat Bay (www.noianet.com/history/timeline.php).

Presently, there are five offshore exploration licences (ELs) in the Study Area, totaling 0.56 million hectares. Past exploration activity in the Study Area has included the drilling of five offshore wells (four drilled from land) and the collection of more than 13,000 line km of 2-D seismic data. The last drilling of a well in the Study Area occurred in 1999.

A recent seismic program proximate to the Study Area occurred in 2002 in the vicinity of EL 1063. In 2005, a 3-D seismic program proposed for an area within the Study Area (EL 1069) underwent a screening level of assessment under the *Canadian Environmental Assessment Act* (*CEA Act*). In July 2005, Vulcan Minerals Inc. announced that drilling had commenced on its Storm #1 location (EL1072; Flat Bay, St. George's Bay) in Unit Area 4Rd.

In March 2005, the C-NLOPB announced a Call for Bids pertaining to four parcels (4 to 7) in the Western Newfoundland and Labrador Offshore Area (Figure 1.1). The Call for Bids closed on December 1, 2005.

1.4 Organization of the SEA

The SEA is organized according to the following major sections:

- Introduction
- Physical Environment
- Biological Environment
- Environmental Effects of Exploration and Production Activities
- Summary and Conclusions
- Literature Cited

2.0 Physical Environment

2.1 Geology

Throughout most of the Precambrian the island of Newfoundland did not exist. Its development began around 620 million years ago with a geologic process known as the "Wilson Cycle" involving rifting, drifting, and ultimate collision of continental and oceanic crust. Extreme compressive forces resulting from colliding crustal plates formed the structurally elevated, folded and faulted landmass of the Appalachians in western Newfoundland, and accumulated onto it three other crustal fragments to the east that now make up the remainder of the island and its continental margin. The Appalachian orogen (mountain building process), as expressed in Newfoundland's geology, is the Paleozoic composite of three separate tectonic compressive events: the Taconic orogeny (during the Middle to Late Ordovician), the Salinic orogeny (Silurian), and the Late Devonian Acadian orogeny. These deformational events have left as their legacy the four distinct geological zones that now make up this island, which from west to east are the Humber, Dunnage, Gander, and Avalon zones (Figure 2.1) (Williams 1995a,b,c,d).

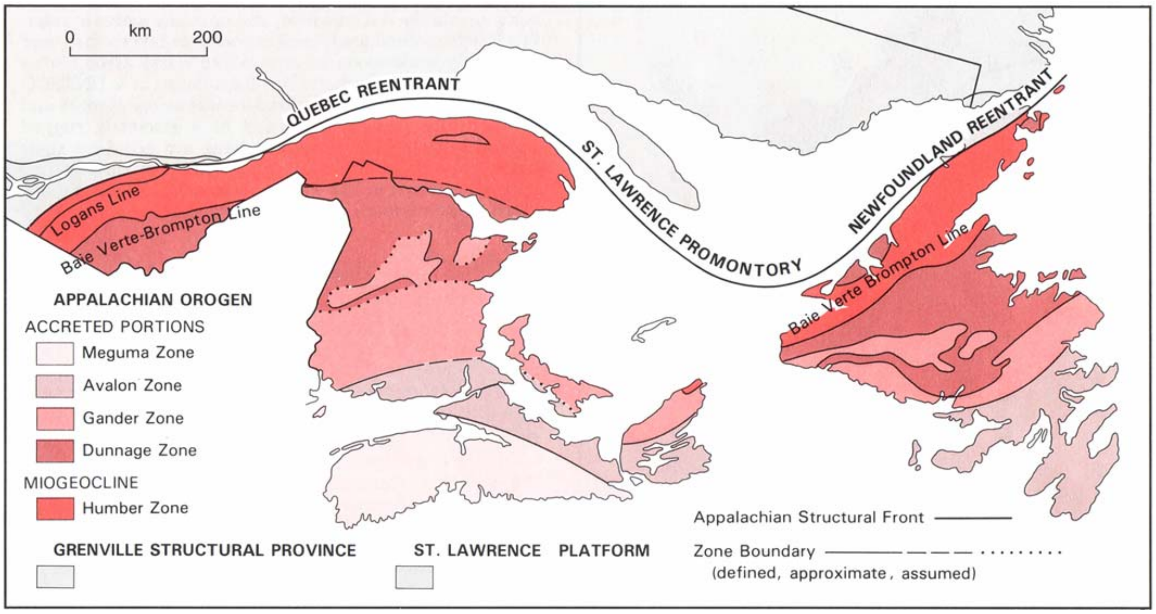

Figure 2.1. Simple Zonation of the Canadian Appalachian Region (adapted from Williams 1995a).

Newfoundland's geology is dynamic, and constantly evolving, with no internal temporal and spatial reference point. Thus, it is useful to view Newfoundland and its offshore areas from the interior, relatively stable, primordial continental crust of North America. It is upon this basement that younger rocks were laid down, reworked, and structurally telescoped by sedimentary processes, tectonic forces, igneous activity, and metamorphism to form what is termed "the Humber zone". And it is to this zone that the three other crustal fragments were added by compressional tectonism, and later reshaped by sedimentary processes, igneous activity, and tensional forces to create the island of Newfoundland and its offshore areas as recognized today (Williams 1995b,c; Sandford 1993a,b).

Despite its complexities, Newfoundland's geology serves as one of the best records of the Appalachians and allows a clearer understanding of the geology of other parts of this mountain system, which can be traced for almost 10,000 km (Williams 1995a). Gros Morne National Park in western Newfoundland was declared a UNESCO World Heritage Site in 1987 mainly because of its rocks and geological relationships.

2.1.1 The Humber Zone – Laurentia's Ancient Continental Margin Affected by Appalachian Tectonism

Starting in the Precambrian with continental crust of the ancient North American continent, Laurentia, subaerial erosion exposed wide areas of this crust within the interior part of northern Canada, which is referred to interchangeably here as the Canadian Shield, continental basement, or craton. It includes the Superior Province underlying a large portion of Ontario and Quebec, and the Grenville Province along the eastern margin (Figure 2.2). This ancient craton developed a series of structural highs (arches) and lows (basins), which greatly influenced sedimentary processes along Laurentia's eastern margin. Being exposed to the effects of weathering and erosion, cratonic arches were the source of sediments that were transported by water and deposited within submerged areas of nearby basins. Along the margin of eastern Quebec and southern Labrador, sediments derived from the Beauge and Laurentian Arches were deposited upon crustal basement in the Anticosti Basin (Figure 2.3) during the Paleozoic, which contributed greatly to the development of the Eastern St Lawrence Platform. It is within sedimentary rocks of this ancient platform that are found hydrocarbon source and reservoir rocks of the Study Area (Sandford 1993a,b).

Early Cambrian to Middle Ordovician sedimentary rocks of the Humber zone of western Newfoundland provide an excellent record of the Eastern St. Lawrence Platform sediments. Phrased differently, the Humber zone comprises the Appalachian miogeocline: the ancient continental margin (platform sediments and underlying Grenvillian basement) that has been affected by Appalachian tectonism. The Appalachian Structural Front marks the western limit of the Humber zone and separates deformed rocks of the ancient margin from those that have been unaffected by orogeny (Figure 2.4). To the east of the Humber zone miogeocline are the accreted portions of the Appalachian orogen, rocks of the Dunnage, Gander, and Avalon zones. Their geographic provenances are not as well understood as that of the Humber zone, but these rocks are thought to represent oceanic crust (i.e., the Dunnage zone) underlying the Paleozoic Iapetus ocean that bordered Laurentia, continental margin (i.e., the Gander zone) on the eastern rim of the Iapetus, and a continental crustal segment (i.e., the Avalon zone) that later remained attached to North America as the Mesozoic Atlantic Ocean developed to the east of Newfoundland's present continental margin (Williams 1995a,b,c,d,e,f; Greenough 1995; Erdmer and Williams 1995).

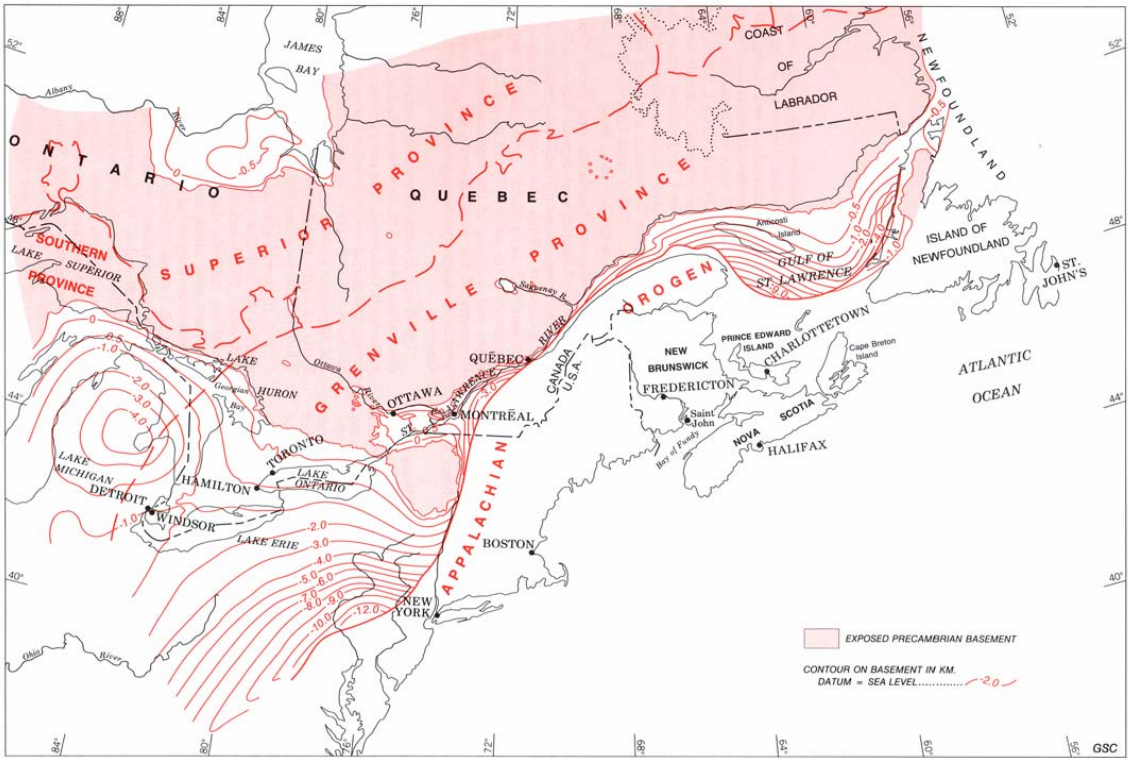

Figure 2.2. **Configuration of Precambrian Basement Rocks Beneath Phanerozoic Cover, St. Lawrence Platform (after Sandford 1993b).**

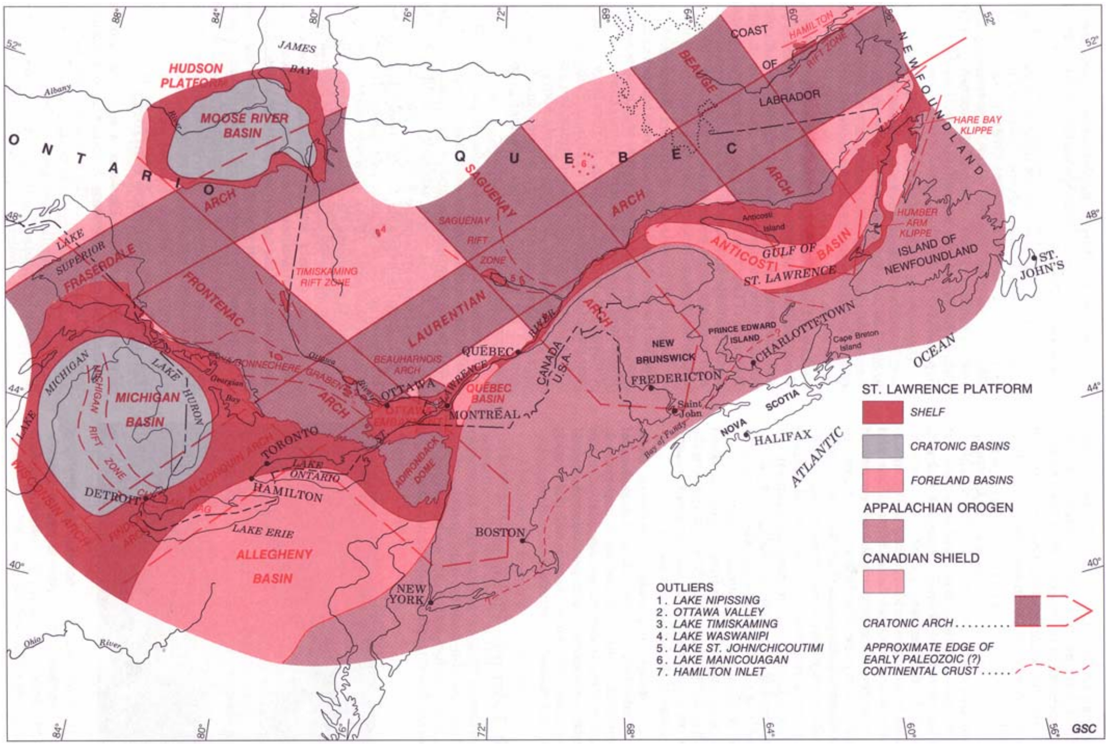

Figure 2.3. **Principle Tectonic Elements of the St Lawrence Platform (after Sandford 1993b).**

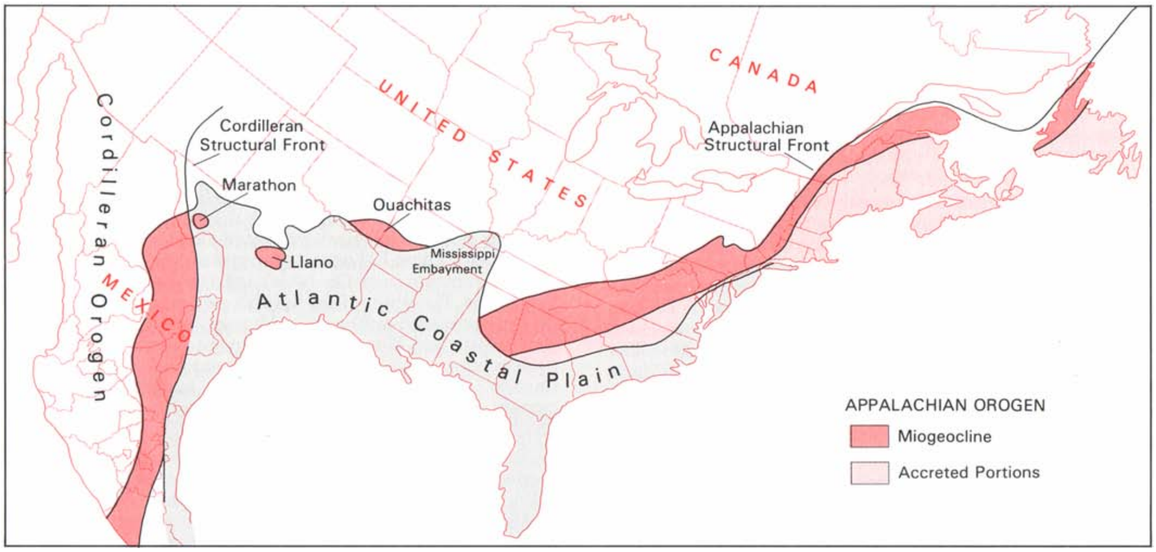

Figure 2.4. Appalachian Orogen, Newfoundland to Mexico (adapted from Williams 1995a).

Cooper et al. (2001) produced a palinspastic cross-section of the Humber zone Paleozoic sediments and described their depositional environments within the context of a tectonically evolving, eastern Laurentian continental margin. They grouped the Paleozoic strata of the Humber zone into six tectono-stratigraphic megasequences, which represent one Wilson Cycle (Figure 2.5). From oldest to youngest, these magasequences are as follows:

1. Synrift Megasequence (SRMS), (Late Proterozoic - Early Cambrian) deposited as eastern Laurentia began to rift apart to form the Iapetus (proto-Atlantic) ocean. These rocks comprise the lower part of the Labrador Group, and they were deposited as arkosic beds of the Bradore Formation and overlying limestones of the Forteau Formation.

2. Passive Margin Megasequence (PMMS), (latest Early Cambrian - Early Ordovician) that records shallow water carbonate sedimentation on the shelf passing eastward into basinal shales. This is analogous to the passive margin of eastern North America, particularly along its southern parts where carbonate sedimentation predominates.[1] In western Newfoundland, the shelf carbonates of this sequence contain the Watt's Bight and the Aquathuna formations, which are recognized reservoir rocks for hydrocarbons which are believed to originate from the hydrogen rich basinal shales of the Green Point formation. At its base this megasequence records progressive upward-deepening sedimentation from shallow marine reefal limestones into deeper marine shales of the Forteau Formation, which reflects thermal subsidence of the platform following cessation of active rifting (Williams and Hiscock 1987). Included in this megasequence are basinal shales of the Cooks Brook and Middle Arm formations, which were later thrust westward at least 100 km from their site of deposition by Taconic compression. These make up part of the Humber Arm allocthon.

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[1] A "passive" margin is one where the transition from continental to oceanic crust is not characterized by the movement of one tectonic plate against another producing seismic activity, as is the case around the Pacific Ocean.

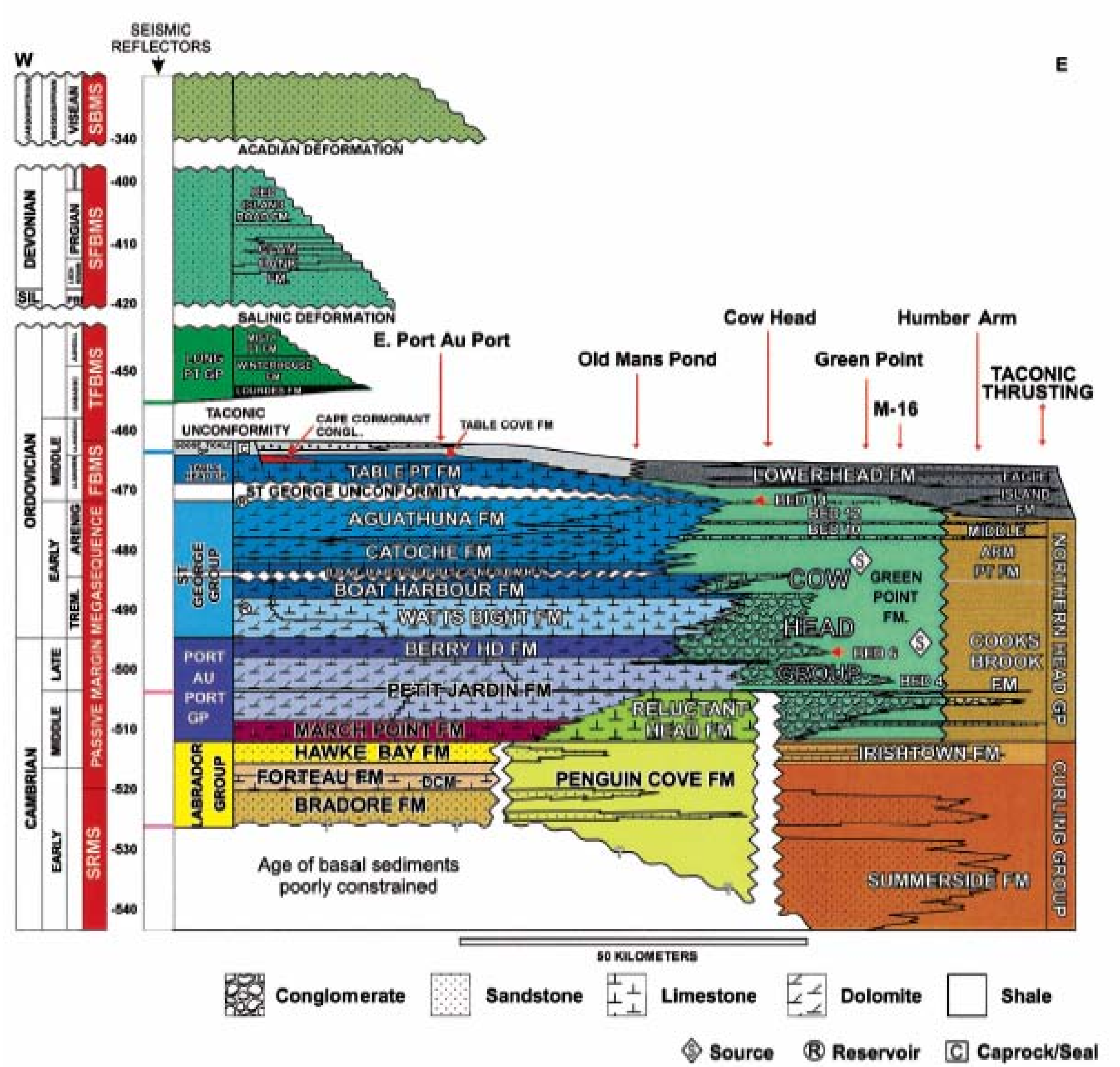

Figure 2.5. Palinspastic Reconstruction of Western Newfoundland Paleozoic Strata (adapted from Cooper et al. 2001)

Lithostratigraphic units are colored, and the ornamentation indicates the dominant lithology. The age ranges of the megasequences defined are shown to the right of the geological stages; SRMS = synrift megasequence; FBMS = flexural bulge megasequence; TFBMS = Taconic foreland basin megasequence; SFBMS = Salinic foreland basin megasequence; SBMS = successor basin megasequence.

3. Flexural Bulge Megasequence (FBMS), (Early to Middle Ordovician). The end of the stable platform and base of this megasequence is marked by the St George unconformity, which represents a depositional hiatus of three to four million years on the Port au Port Peninsula. This unconformity is recognized from Greenland to Quebec. The subsequent collapse of the

platform by extensional faulting is believed to have resulted from westward migration of the Taconic peripheral bulge (Knight et al. 1991). Sediments of the Table Head Group represent progressive deepening from shallow to deep subtidal limestones. The continued westward advance of the Taconic orogenic belt enhanced extensional block fault collapse of the platform. The Table Head Group and its distal correlatives the Cow Head Group are overlain by flysch of the Goose Tickle Group and Lower Head Formation, respectively, which marks a major reversal in sediment provenance from the east (interior carton) to the west (Taconic bulge).

4. Taconic Foreland Basin Megasequence (TFBMS), (Middle Ordovician). Culmination of the Taconic compression resulted in westward thrusting of basinal sediments (e.g., Humber Arm Allochthon) and Bay of Islands ophiolites[2] (likely originating from the Dunnage zone) over autochthonous shelf carbonates. Siliciclastic shallow marine sediments of the Long Point Group were deposited in the quiescent Taconic foreland basin during Late Ordovician to Salinic and onlapped the Taconic Allocthons[3]

5. Salinic Foreland Basin Megasequence (SFBM), (Silurian to Devonian). During the Salinic orogeny, a major unconformity, representing a time gap of 20 million years, was created that separates the TFBMS from this megasequence. Fluvial sands and shales of the Clam Bank Formation and terrestrial red beds of the Red Island Road Formation dominate the SFBM.

6. Successor Basin Megasequence (SBMS), (Carboniferous). This megasequence consists of the youngest preserved sediments in the Humber zone, which include fluvial sandstones, silts, shales, and local evaporites (salts, gypsum, etc) of the Anguille, Codroy, and Barachois Groups. Following the Acadian orogency, these Carboniferous sediments were deposited in the Bay St George and Deer Lake basins along the Cabot Fault, a zone of right lateral strike slip plate movement that developed these pull-apart basins.

2.1.2 Hydrocarbon Occurrence in the Study Area

The Paleozoic rocks of the Humber zone were the first in the Province to be recognized as having petroleum potential. In 1812, Mr. Parsons noticed oil floating on the surface of Parson’s Pond on the Great Northern Peninsula, and in subsequent years numerous oil and gas seeps, bituminous residues, and oil shales were found in other areas. In 1867, Newfoundland’s first oil well was drilled, and during the next 98 years up to sixty shallow wells were advanced in four areas (Parson’s Pond, St. Paul’s Inlet, Deer Lake Basin, and at Shoal Point on the Port au Port Peninsula), more than half of which encountered hydrocarbons. These wells were drilled with little knowledge of the geology, poor quality equipment, insufficient financing, and to depths that typically were less than 500 meters (it is now known that

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[2] An ophiolite is a portion of the upper mantle and overlying oceanic crust that is emplaced onto continental crust during plate collision.

[3] Allocthon refers to a fault block that is transported from its original location by compressive tectonic forces along subhorizontal thrust faults. Autochthon refers to untransported rocks.

sediment thicknesses often exceed 3,000 meters in these areas). In 1965, the NALCO 65-I well was drilled at Parson's Pond to a depth of 1,302 meters. Until that time, this was the deepest well drilled in western Newfoundland, and it was advanced without the benefit of modern geophysical data. Nevertheless, it came very close to penetrating a major thrust slice that is now recognized from modern seismic information. Exploration efforts targeted either rocks in the area of surface oil seeps, or Lower Paleozoic strata of the Anticosti Basin.

A new era of oil exploration began in 1995 in western Newfoundland when Hunt Oil and its partner PanCanadian drilled the first modern well that was based on new seismic mapping and geological theory. This was the *Port au Port #1*, which encountered oil that was flow-tested at 2,000 bopd and 1.3 mmcf/d of gas from a carbonate reservoir at 3,400 metres depth. Data obtained from follow up drilling of four additional deep wells in the Port au Port area coupled with new geophysical data and interpretations have proven the presence of a viable petroleum system in deep Paleozoic rocks of western Newfoundland, as well as the presence of undrilled structures (NLDME 2000). Known hydrocarbon occurrences are shown on Figure 2.6.

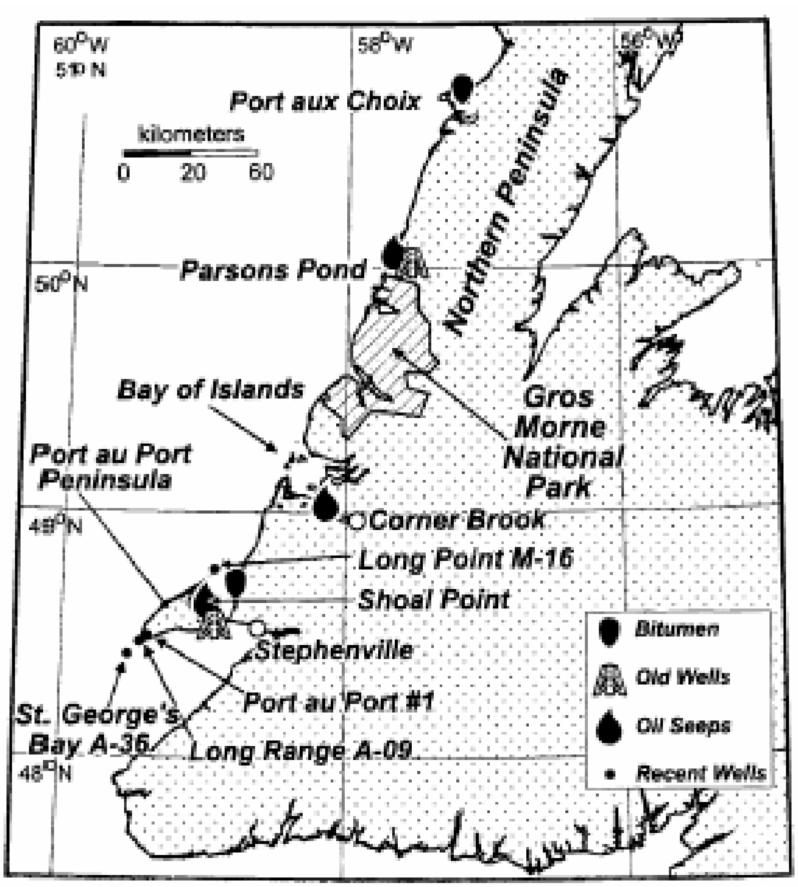


Figure 2.6. Location of Recent Wells, Older Wells, and Hydrocarbon Occurrences in the Humber Zone of Western Newfoundland (adapted from Cooper et al. 2001).

The current thinking on the region's hydrocarbon potential is provided by Cooper et al. (2001), and summarized by the Newfoundland and Labrador Department of Natural Resources (NLDME 2000). Sinclair (1990) provides a slightly dated but comprehensive overview of the hydrocarbon potential within the entire Study Area. The most current structural model of reservoir development associated with *Port au Port #1* in the Humber zone has the oil contained within Paleozoic carbonate rocks that have been subaerially exposed during the Middle Ordovician extensional faulting, followed by westward-directed compressional thrusting of allocthonous blocks during the Taconic orogeny, followed by porosity and permeability enhancement during the Devonian caused by dolomitizing hydrothermal fluids that migrated preferentially along old, reactivated fault zones, and finally by Acadian compression that created anticlinal reservoirs associated with footwall shortcut faults located below reactivated faults such as the Round Head Thrust fault, as shown on Figure 2.7. The model of reservoir formation is shown on Figure 2.8.

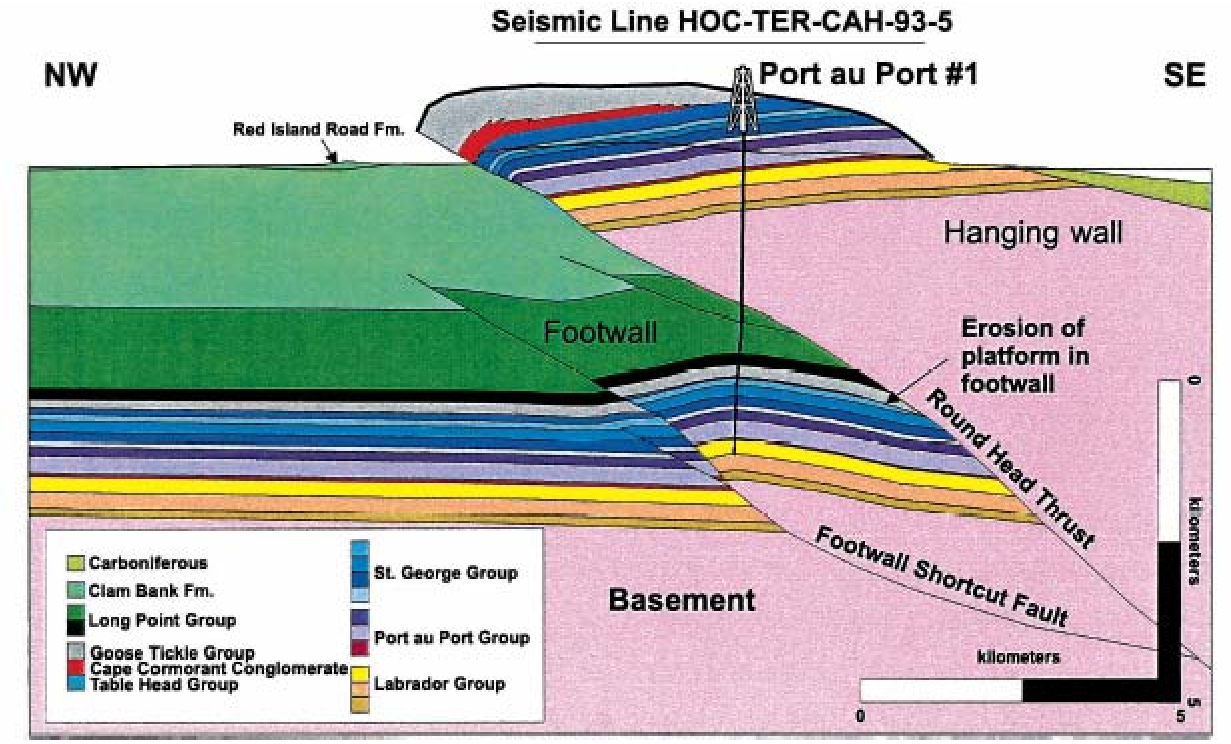


Figure 2.7. Structural Cross Section through *Port au Port #1* Well Based on Surface Geology, Seismic Data, and Dip and Formation Data from the Well (adapted from Cooper et al. 2001).

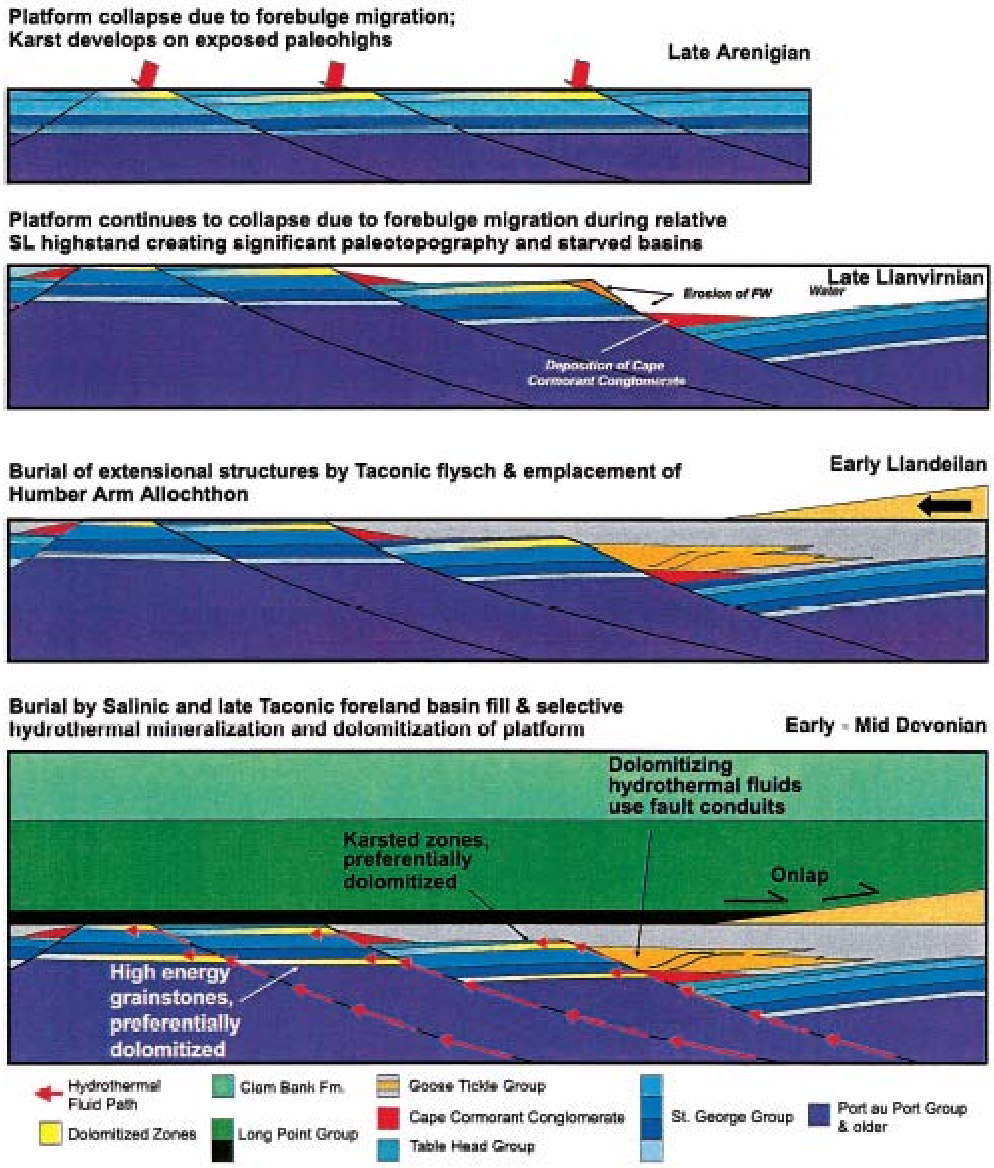


Figure 2.8. Model of Reservoir Development Based on Data from the Wells and Outcrop Studies (adapted from Cooper et al. 2001).

The area to the west of the Appalachian Structural Front within the undeformed Lower Paleozoic East St Lawrence Platform remains an untested area with good hydrocarbon prospects (Sinclair 1990).

2.1.3 Coastal Geomorphology

The coastline of the Study Area stretches from Cape Ray near Newfoundland's southwest corner to Reefs Harbour on the Great Northern Peninsula. The geomorphology of this area has been transformed by events of the past 14,000 years, associated primarily with the advance and retreat of the Laurentide and Newfoundland Ice Sheets and the influence of the sea on the land.

Glaciers scraped off large volumes of bedrock, crushed this into smaller boulders and to clay-sized particles, transported and deposited the resulting debris directly onto the hard surfaces (e.g., bedrock, land, seabed), or deposited it within and left it to be reworked by water. As the glaciers retreated the land rebounded in response to the release of tremendous pressures from the loss of ice and rock. This left areas that were once submerged beneath the sea now subaerially exposed. Evidence (embodied in radiocarbon dates and geomorphological records) has been found of ancient shorelines well above present sea levels throughout the west coast of Newfoundland. In fact, going from south to north along the west coast, historic maximum sea level stands can be found to progress from present sea levels near Cape Ray to about 140 m above sea level at the Strait of Belle Isle (Batterson et al. 2001).

"Type B" relative sea level curves (characterized by sea level falling from a recorded high stand following deglaciation to below the present level, and subsequently rising again) are typical for most of the island. This is the case for much of the southern part of the Study Area, but "Type A" curves (with sea level falling continuously from a high marine limit to present levels) are more representative of the coastline north of Port au Choix (Liverman 1994).

The following description of the coastal geomorphology of the west coast progresses from south to north along the eastern part of the Study Area.

Much of the southern section, from Cape Anguille to Highlands consists of a 50 km linear coastline dominated by cliffs of the Anguille Mountains that rise directly out of the sea. This stretch of coastline has relatively few, small pocket beaches.

Extending from Highlands at the foot of the Anguille Mountains to Romaines, west of Stephenville is the area of St George's Bay. This area has extensive exposures of unconsolidated sediments, deposited during the Late Wisconsinan glaciation and deglaciation. This stretch of shoreline has the thickest and most continuous surficial cover of any region in Newfoundland (Batterson et al. 2001). It is dominated by glacial marine, glaciomarine, marine sediments, and diamicton along elevated coastal bluffs and raised deltas that are up to 75 m above present sea level. In the northern part, around Flat Bay and Port Harmon, coastal sediments derived from erosion of proglacial deposits have accumulated to form large strand plains and beaches.

The area around Port au Port Peninsula starting and ending at its isthmus near Romaines is characterized by raised terraces, paleocliffs, raised marine deltas, and beaches. The southern part of Port au Port Bay is separated (West Bay and East Bay) by a prominent, bedrock cored point of land (Shoal Point). These are relatively flat, saltwater marshes that record a modern rising sea level.

The coastline from Port au Port isthmus to Fox Island River is characterized by a broad coastal plain with well-developed beach systems and barrier bars. The community of Fox Island River is built on a large raised delta at the mouth of Fox Island River. Sea level in this area fell rapidly from its highstand of 45 m above sea level about 13,500 years ago and crossed the modern datum about 12,200 years ago, falling to a lowstand of -25 m above sea level, and has been steadily rising ever since.

To the north, from Fox Island River to Rocky Harbour, the coastline is generally dominated by steep bedrock cliffs of the Long Range Mountains. This stretch includes the Bay of Islands and Bonne Bay. A massive rock slide into Bonne Bay involving about 10 billion m^3 of volcanic and metamorphic rock occurred in post glacial times. The fault scarp can be traced for several kilometres on the west side of Bonne Bay, about 0.5 km north of Woody Point. In general, poor road access for much of this area has restricted geomorphological investigation of most of this area in comparison with other parts of the Study Area coastline. However, the Geological Survey of Canada (Atlantic Region) has recorded much of the coastline with video footage that is available (J. Shaw, pers. comm.).

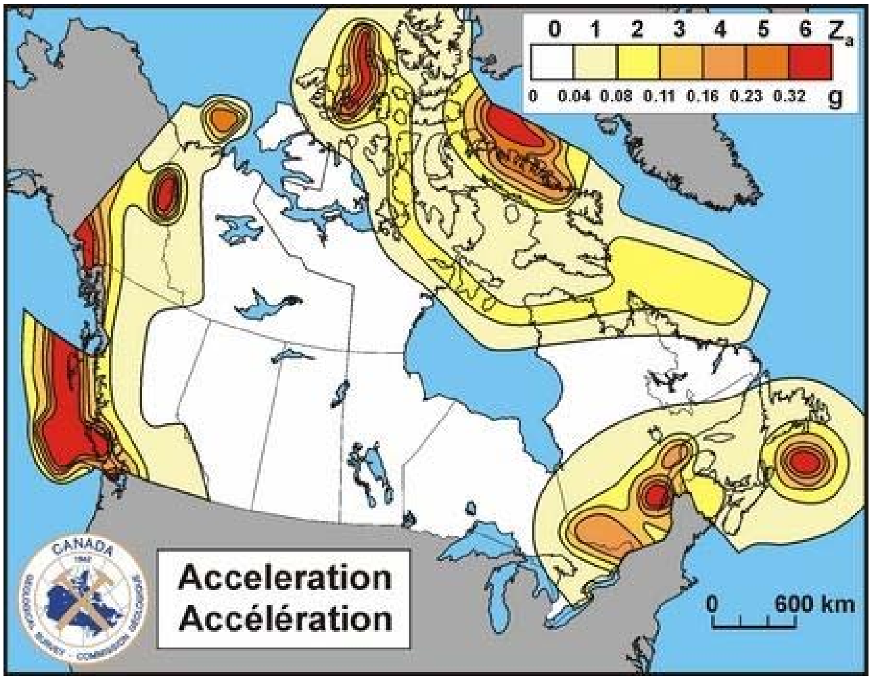
The coastline north from Rocky Harbor to Parsons Pond is marked by a linear shoreline with flat features such as an intertidal rock platform at Green Point, and coastal lowlands and lake basins such at Western Brook Pond, Parsons Pond, St Paul’s Inlet, Bakers Brook Pond, and Ten Mile Pond. These areas are underlain by a thick blanket of soft, stony, sub-stratified shell bearing sediments interpreted to be submarine till laid down beneath floating ice shelves (Grant 1987). Beaches along the shoreline with sand dunes, such as at Western Brook Pond, are common.

The coastline from Parsons Pond to Hawkes Bay is linear, generally with sediment bluffs overlying bedrock typically exposed along long, linear beach systems. The bluffs are typically less thick than those along the Port au Port and St George’s Bay coastline.

The coastline from Hawkes Bay to northern limit of the Study Area is characterized by headlands and deep bays, again with relatively thin sediment layers over bedrock, both of which are exposed along the shoreline in long beach systems.

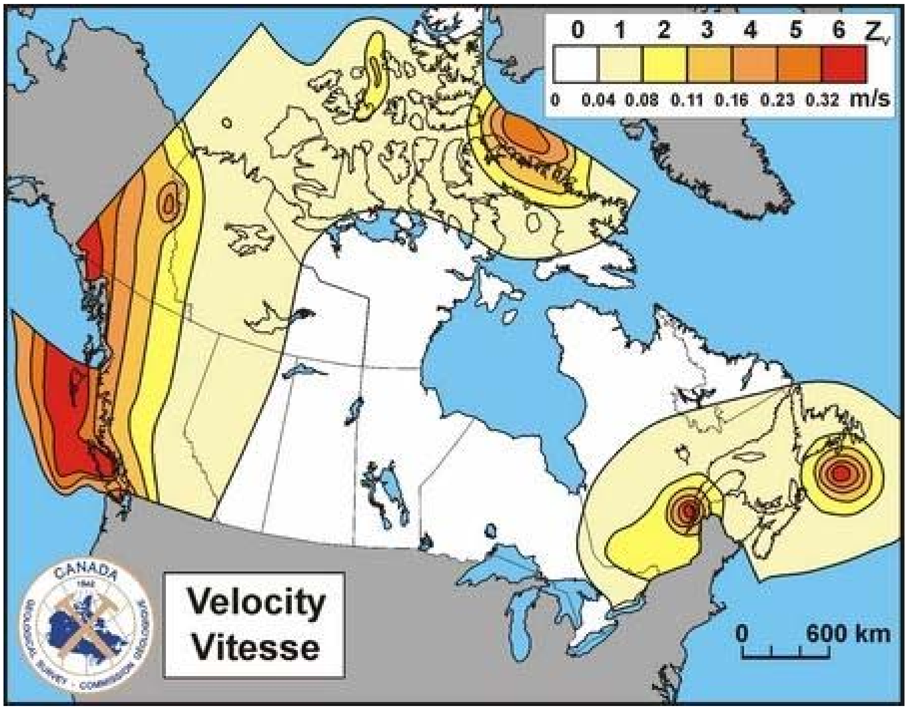
2.1.4 Seismicity of the Offshore Western Newfoundland Study Area

The potential for damage to a structure by an earthquake is primarily determined by two things: the nature of associated ground movements at the site of a structure, and the construction elements of the structure itself. In Canada, expected ground motions (also referred to as “seismic hazard”) are calculated on the basis of probabilistic theory and are represented by seismic zoning maps, as shown in Figures 2.9 and 2.10 (NRCan website 2005)



Source: NRCan Website 2005.

Figure 2.9. Seismic Zoning Map of Canada, 1985: Peak Horizontal Ground Acceleration (g) (Probability of Exceedance: 10% in 50 Years).



Source: NRCan Website 2005.

Figure 2.10. Seismic Zoning Map of Canada, 1985: Peak Horizontal Ground Velocity (m/s) (Probability of Exceedance: 10% in 50 Years).

These maps show peak horizontal ground accelerations and peak horizontal ground velocities, respectively. They have been prepared by the Geological Survey of Canada and are derived from statistical analysis of past earthquakes and from advancing knowledge of Canada's geology. Peak accelerations and velocities define seismic zones throughout Canada, that range from zero (which represent relatively aseismic areas of the Canadian Shield) to six (which represent areas that are the most seismically active within the country).

Although representation of regional seismic hazard has been developed for construction of land-based buildings as part of the National Building Code, the maps also provide an indication of relative seismic hazard for offshore structures, in particular those used for offshore oil exploration and production (Heidebrecht et al. 1983; Adams 1986; Anon. 1992).

The Study Area falls within Zone 1, and is therefore considered to have a relatively low seismic hazard with respect to peak horizontal ground accelerations and velocities.

2.2 Bathymetry

Water depths within the SEA Study Area range from intertidal to >500 m (see Figure 1.1). Approximately 70% of the Study Area is continental shelf (<200 m) and the remainder is slope (200 to >500 m depths). Detailed bathymetry is shown in Figure 1.1.

2.3 Climatology

The weather of the Study Area is governed by the transit of low and high-pressure systems. These circulation systems are embedded in the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes as caused by the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence, it is considerably stronger in the winter months when there is a greater increase in the south to north temperature gradient than during the summer months.

When the upper level long wave trough lies well west of the region, the main storm track lies through the Gulf of St. Lawrence. Under this regime, an east to southeast flow ahead of a warm front associated with a low will give way to winds from the south in the warm sector of the system. Typically, the periods of southerly winds and mild conditions have relatively long durations and, in general, the incidence of extended storm conditions is likely to be relatively infrequent. Strong frictional effects in the stable flow from the south results in a marked shear in the surface boundary layer and relatively lower winds at the sea surface. As a consequence, local wind wave development tends to be inhibited under such conditions. Precipitation types are more likely to be in the form of rain or drizzle, with relatively infrequent periods of continuous snow. Periods of snow showers will prevail in the unstable air in the wake of cold fronts associated with the lows. Visibility will be reduced at times in frontal and advection fogs, in snow, and during snow shower activity.

At times when the upper long wave trough is to the east, the main storm track may lie through or to the east of Newfoundland. With the lows passing to the east of the Gulf of St. Lawrence, and frequent high potential for storm development, the incidence of strong gales is high. During long bouts of cold, west to northwest winds behind cold fronts occur frequently, and because the flow is colder than the surface water temperatures, the surface layer is unstable. The shear in the boundary layer is low, resulting in relatively high wind speeds near the surface and, consequently, relatively high sea state conditions. When very low air and sea surface temperatures are coupled with high winds, the potential for freezing spray occurs quite frequently until the area freezes over. In this synoptic situation, a greater incidence of precipitation in the form of snow is likely to occur. Freezing precipitation, either as rain or drizzle, may occur relatively often over the Port au Port area. Visibility will be reduced in frontal and advection fogs and by snow.

In winter, the Port au Port area is affected by cold arctic air which pours off the Quebec North Shore and crosses the relatively warm waters of the Gulf of St. Lawrence (prior to the formation of ice). The cold air picks up heat and moisture from the waters below resulting in the development of streamers of snow showers that hit the west coast of Newfoundland. For example, Stephenville Airport (48° 32′N; 58° 33′W) receives, on average, more than four metres of snow per year.

Intense low-pressure systems frequently become ‘captured’ and either slow down or stall under an upper air low-pressure centre as they move through the Newfoundland region or across the Labrador Sea. This may result in an extended period of little change in weather conditions that may range, depending on the position, overall intensity and size of the system, from relatively benign to heavy weather conditions.

By summer, the main storm tracks have moved further north than in winter, typically resulting in less frequent and weaker low-pressure systems. With increasing solar radiation during spring, there is a general warming of the atmosphere that is relatively greater at high than low latitudes. This decreases the north-south temperature contrast, lowers the kinetic energy of the westerly flow aloft, and decreases the potential energy available for storm development. Concurrently, there is a northward shift of the main band of westerly winds at upper levels and a marked development of the Bermuda-Azores sub-tropical high-pressure area to the south. This warm-core high-pressure cell extends from the surface through the entire troposphere. The main track of the weaker low-pressure systems typically lies through the Labrador region and tends to be oriented from the west-southwest to the east-northeast.

With low pressure systems normally passing to the north of the region in combination with the northwest shoulder of the sub-tropical high to the south, the prevailing flow across the Gulf of St. Lawrence is from the south to southwest during the summer season. Wind speed is lower during the summer and the incidence of gale or storm force winds relatively low. There is also a corresponding decrease in significant wave height.

The prevailing south to southwesterly flow during the late spring and early summer tends to be moist and relatively warmer than the underlying surface waters of the Gulf of St. Lawrence. Cooling from below coupled with mixing of the air in the near-surface layer frequently results in saturation of the air, the condensation of water vapour, and the development of advection fog, which can persist for days at a time. The incidence of advection fog and the frequency of poor visibility are normally highest during July.

2.3.1 Wind Conditions

This section is based on the AES-40 data set (see Swail et al. 1999; Swail and Cox 2000) that contains 49 years (1954-2003) of climatology data for a number of points in the Gulf of St. Lawrence. Grid point 5817 (48.75°N; 59.17°W) was deemed to be the most representative for this study (Figure 2.11). Winds are 10 m above the surface and considered to be 1-hour mean values.

The percentage of observations of wind speed by direction is shown in Table 2.1. Directions are binned in 45° intervals centred on the directions shown. The table shows that the winds occurred most often from the west to northwest from November to March. In April, winds most often occurred from the southwest to northwest. South to southwest winds dominated from May to August. Southwest to west winds were predominant in September and October.

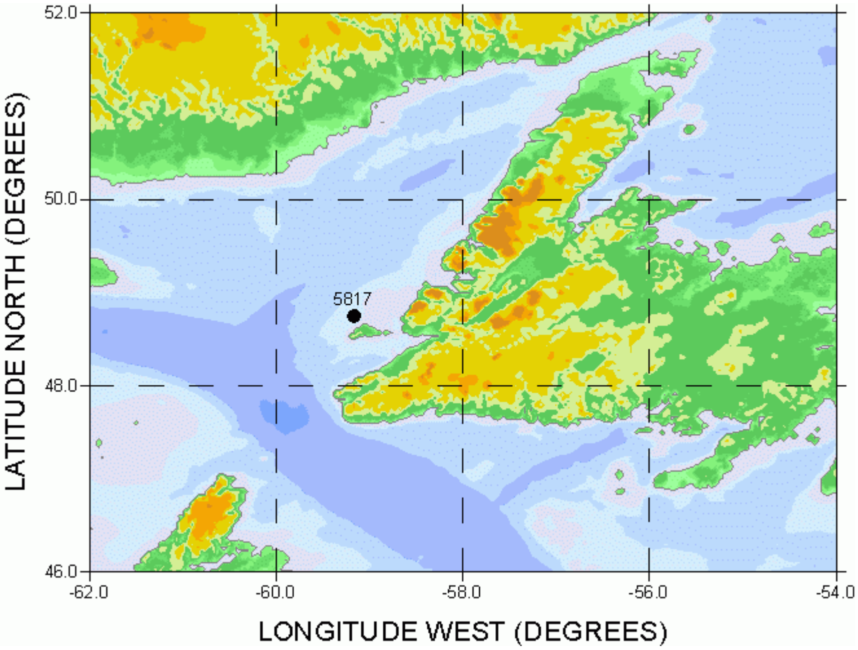


Figure 2.11. Location of Grid Point 5817.

Table 2.1. Percentage of Wind by Direction for AES Grid Point 5817.

Month	Direction								Total
	NE	E	SE	S	SW	W	NW	N	Reports
January	8.1	6.1	5.8	8.4	14.2	25.5	21.9	10.1	6076
February	8.8	6.4	6.2	8.4	14.0	23.3	20.7	12.2	5536
March	12.6	7.5	7.0	10.4	13.9	16.7	17.3	14.6	6076
April	12.4	9.8	10.5	11.4	13.9	13.4	14.0	14.6	5880
May	10.3	9.1	9.4	18.7	18.9	11.9	10.8	10.8	6076
June	6.5	6.4	8.8	22.5	26.6	12.7	8.9	7.5	5880
July	2.8	4.1	7.6	26.3	33.2	15.2	6.6	4.2	6076
August	4.6	4.7	6.0	19.1	32.9	18.2	8.5	5.9	6076
September	5.5	5.0	5.9	15.6	24.9	22.4	12.8	7.9	5880
October	5.7	4.6	7.1	13.0	20.4	21.6	17.1	10.5	6076
November	7.2	6.4	6.9	12.1	16.4	21.9	19.7	9.6	5880
December	6.7	5.7	6.5	9.3	13.5	23.6	22.0	12.6	6076
Years Mean	7.6	6.3	7.3	14.6	20.2	18.9	15.0	10.0	

Source: AES grid point 5817. Lat 48.75°N, Long 59.17 °W, 1954 to 2003.

Table 2.2 shows the highest winds (maximum 1-hour sustained winds) that occur by month in each of eight directions. The highest wind of 25 m/sec occurred in December and January. In January, the highest winds were from the northwest to north whereas in December the highest winds were from the southwest. The lowest maximum winds were in July. [To convert 1-hour means to 1-minute means (gusts), multiply by 1.18—UK Dept. of Energy 1984.]

Table 2.2. Monthly Highest 10 Metre Wind Speed (rounded to the nearest m/s) from each Direction at Grid Point 5817.

Month	Direction								Monthly	
	NE	E	SE	S	SW	W	NW	N	Min	Max
January	23	24	21	23	21	21	25	25	21	25
February	24	20	21	20	20	21	22	20	20	24
March	20	23	19	18	18	24	23	21	18	24
April	19	19	17	16	17	18	18	21	16	21
May	16	19	14	19	19	19	16	15	14	19
June	17	13	13	14	14	14	14	15	13	17
July	14	10	15	15	14	13	13	15	10	15
August	14	14	17	15	14	16	13	16	13	17
September	15	21	15	18	19	18	19	18	15	21
October	21	20	19	20	17	21	19	19	17	21
November	18	20	22	22	20	22	21	21	18	22
December	20	18	22	22	25	22	22	24	18	25
Years Max	24	24	22	23	25	24	25	25		

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.3 gives the monthly mean wind speed, standard deviation and maximum wind speeds. Gale force winds (17.2 to 24.4 m/s) occurred in all months except July and August. Storm force winds (24.5 to 32.6 m/s) occurred in January and December. Hurricane force winds (greater or equal to 32.7 m/s) did not occur at the grid point.

Table 2.3. Monthly Statistics; Mean Wind Speed, Standard Deviation, Maximum Wind Speed (m/s) for Grid Point 5817.

Month	**Mean Speed**	**Standard Deviation**	**Maximum Speed**
January	9.15	3.65	25.01
February	7.5	3.55	23.58
March	7.23	3.52	23.59
April	6.64	3.26	21.42
May	5.44	2.86	19.03
June	5.07	2.6	17.35
July	4.96	2.39	14.76
August	5.49	2.47	16.72
September	6.7	2.97	20.86
October	7.81	3.12	21.47
November	8.63	3.41	22.37
December	9.32	3.7	25.01

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Winter, spring, summer and fall winds roses for the grid point are plotted in Figures 2.12 to 2.15. The data for all months are provided in Tables 2.4 to 2.15. The dominant wind directions are from the northwest, west, southwest and south. There is a strong annual cycle in the wind direction. In winter, the winds are from west to northwest, whereas in summer the winds are from south to southwest. In the transition month of April, winds are distributed throughout all directions.

The bivariate histograms of the wind speeds versus directions in Tables 2.4 to 2.15 show that the wind speeds are much lower in summer than in winter. In general, November, December, and January are the months with the highest occurrence of higher wind speeds. High wind speeds can also occur in late summer and fall due to the passage of tropical systems but the frequency of high winds is lower.

The percentage exceedance of wind speeds at the grid point is shown in Figure 2.16. It should be noted that winds predicted from the AES40 data are representative of an areal average as well as an hourly average and that local winds may exceed these values. Site-specific EAs may examine coastal data from sources such as the Meteorolocal Services of Canada website: http://www.climate.weatheroffice.ec.gc.ca/Welcome_e.html.

Table 2.4. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817.

January

Wind Speed	**Wind Direction (from)**								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	1.05	1.09	1.05	1.20	1.70	1.96	2.39	1.42	11.85
5.00 - 9.99	4.76	2.85	2.81	4.25	7.19	12.21	11.24	5.25	50.56
10.00 - 14.99	1.88	1.71	1.40	2.29	4.59	9.08	6.96	2.80	30.71
15.00 - 19.99	0.39	0.33	0.44	0.64	0.61	1.94	1.32	0.58	6.25
20.00 - 24.99	0.07	0.05	0.05	0.02	0.02	0.12	0.15	0.13	0.59
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.03
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	8.15	6.03	5.75	8.40	14.11	25.31	22.08	10.20	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

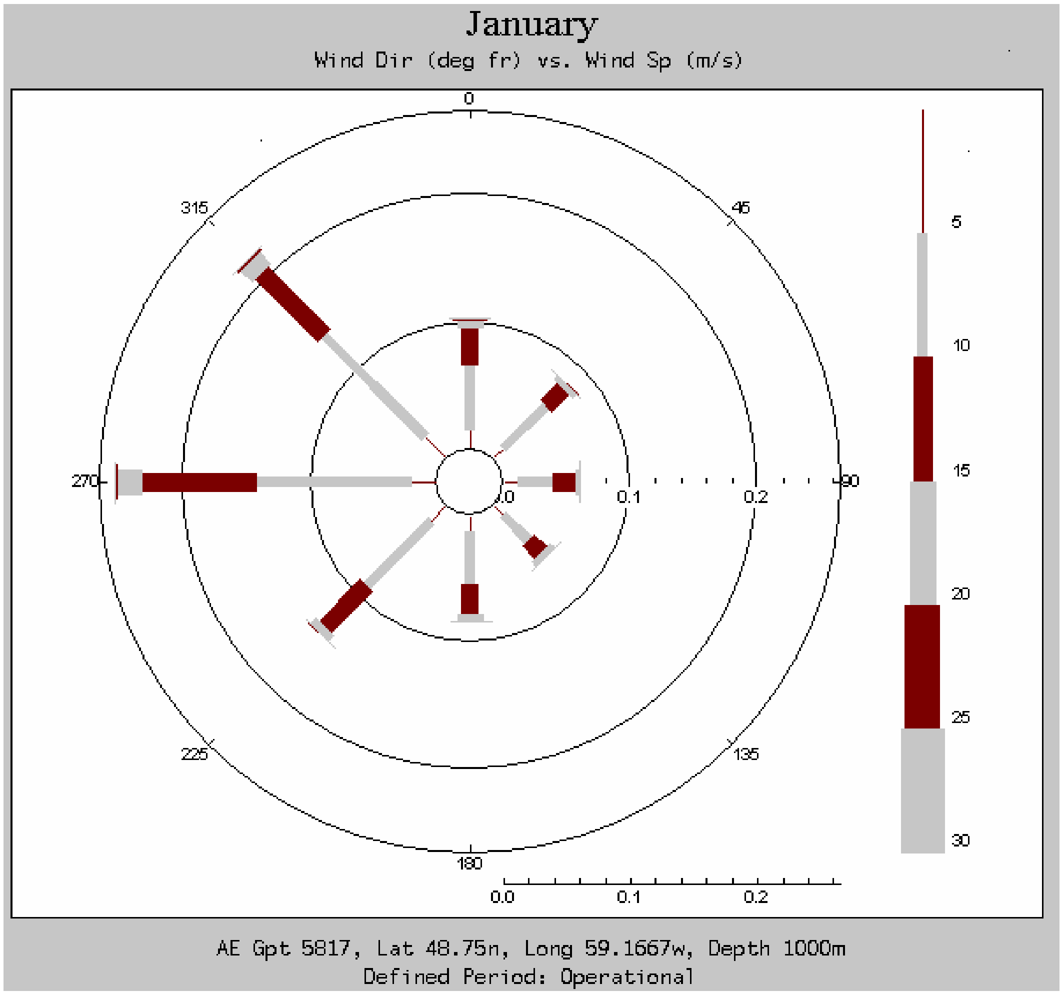


Figure 2.12. Wind Rose for January, Grid Point 5817.

Table 2.5. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. February

Wind Speed	Wind Direction (from)								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	2.78	1.82	1.82	2.51	3.85	4.88	5.33	3.70	26.70
5.00 - 9.99	4.06	3.20	2.75	4.12	7.77	12.68	10.01	5.87	50.45
10.00 - 14.99	1.61	1.23	1.16	1.52	2.08	4.88	4.68	2.47	19.62
15.00 - 19.99	0.22	0.20	0.38	0.23	0.23	0.65	0.69	0.43	3.03
20.00 - 24.99	0.05	0.00	0.04	0.00	0.04	0.02	0.02	0.04	0.20
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	8.72	6.45	6.15	8.38	13.97	23.11	20.73	12.51	100.00
						Total Observations:			5536

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.6. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. March

Wind Speed	Wind Direction (from)								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	3.42	2.45	2.29	3.13	3.80	4.86	5.17	4.08	29.20
5.00 - 9.99	5.43	3.09	3.37	5.48	8.05	8.28	9.04	7.88	50.63
10.00 - 14.99	2.98	1.66	1.23	1.50	1.94	3.00	2.57	2.35	17.23
15.00 - 19.99	0.77	0.23	0.16	0.21	0.13	0.53	0.43	0.30	2.76
20.00 - 24.99	0.00	0.05	0.00	0.00	0.00	0.03	0.08	0.02	0.18
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	12.60	7.48	7.05	10.32	13.92	16.70	17.29	14.63	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.7. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. April

Wind Speed	Wind Direction (from)								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	3.62	3.59	3.49	3.98	5.54	5.29	4.97	4.23	34.71
5.00 - 9.99	5.68	4.51	5.56	5.99	6.87	6.29	6.82	7.93	49.64
10.00 – 14.99	2.59	1.51	1.24	1.41	1.39	1.65	1.94	2.33	14.06
15.00 – 19.99	0.54	0.20	0.14	0.07	0.07	0.19	0.12	0.24	1.56
20.00 – 24.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
25.00 – 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 – 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	12.43	9.81	10.43	11.45	13.87	13.42	13.85	14.74	100.00
						Total Observations:			5880

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

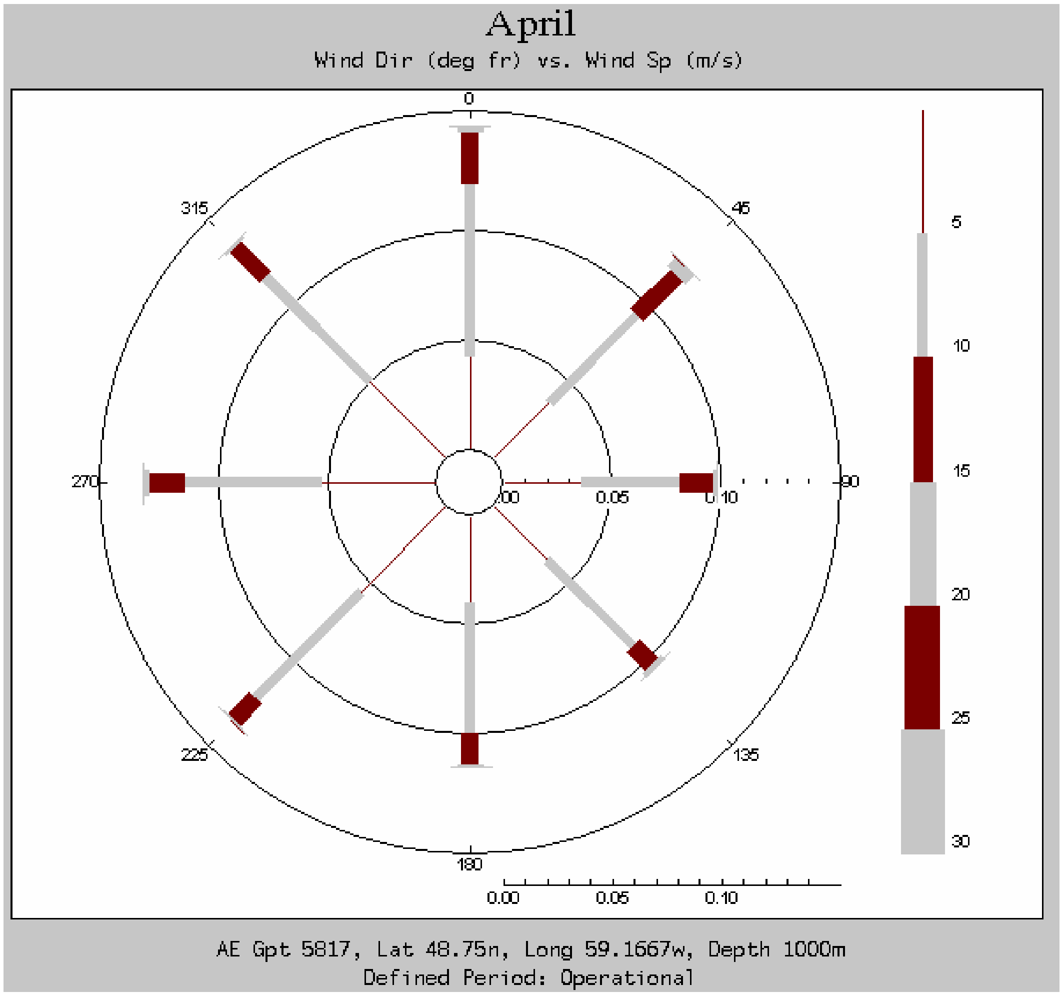


Figure 2.13. Wind Rose for April, Grid Point 5817.

Table 2.8. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. May

Wind Speed	**Wind Direction (from)**								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	4.71	4.25	5.25	8.56	9.41	6.55	5.53	4.87	49.13
5.00 - 9.99	4.26	4.25	3.79	8.69	8.46	4.81	4.51	4.84	43.60
10.00 – 14.99	1.27	0.61	0.43	1.33	1.10	0.54	0.71	1.00	6.99
15.00 – 19.99	0.07	0.02	0.00	0.03	0.05	0.07	0.03	0.02	0.28
20.00 – 24.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.00 – 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 – 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.31	9.13	9.47	18.61	19.02	11.97	10.78	10.73	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.9. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. June

Wind Speed	**Wind Direction (from)**								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	3.69	3.96	5.17	9.88	13.32	8.23	4.90	4.27	53.42
5.00 - 9.99	2.47	2.23	3.33	11.14	12.33	4.15	3.67	2.91	42.23
10.00 - 14.99	0.32	0.19	0.27	1.33	1.04	0.43	0.32	0.39	4.29
15.00 - 19.99	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07
20.00 - 24.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	6.53	6.38	8.77	22.35	26.69	12.81	8.89	7.59	100.00
						Total Observations:			5880

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.10. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. July

Wind Speed	**Wind Direction (from)**								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	1.86	2.45	4.72	12.41	16.77	9.43	4.03	2.34	54.02
5.00 - 9.99	0.79	1.65	2.49	12.51	15.93	5.65	2.34	1.66	43.01
10.00 - 14.99	0.15	0.00	0.18	1.17	0.69	0.30	0.15	0.35	2.98
15.00 - 19.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.00 - 24.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2.80	4.10	7.39	26.09	33.39	15.38	6.52	4.34	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.11. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. August

Wind Speed	**Wind Direction (from)**								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	2.39	2.67	3.52	8.16	13.71	8.28	3.92	2.60	45.24
5.00 - 9.99	1.96	1.96	2.22	9.61	18.07	9.13	4.26	2.91	50.13
10.00 - 14.99	0.23	0.13	0.21	0.92	1.27	0.79	0.53	0.44	4.53
15.00 - 19.99	0.00	0.00	0.02	0.00	0.00	0.05	0.00	0.03	0.10
20.00 - 24.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	4.58	4.76	5.97	18.69	33.05	18.25	8.71	5.99	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

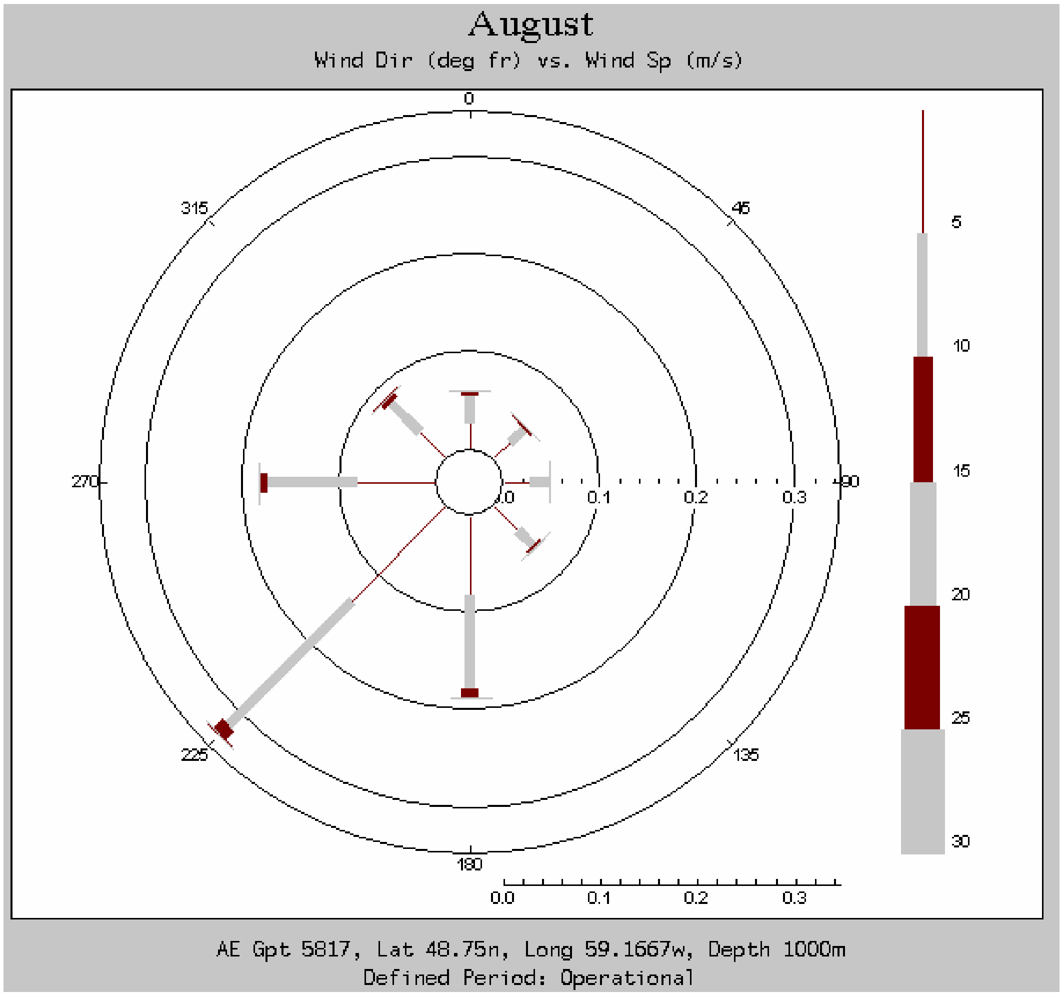


Figure 2.14. Wind Rose for August, Grid Point 5817.

Table 2.12. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. September

Wind Speed	**Wind Direction (from)**								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	1.99	2.13	2.33	4.35	6.79	6.55	3.66	2.79	30.58
5.00 - 9.99	2.99	2.55	2.84	8.76	14.69	12.45	7.28	3.93	55.49
10.00 - 14.99	0.48	0.32	0.73	2.18	3.30	3.21	1.87	1.16	13.25
15.00 - 19.99	0.02	0.00	0.02	0.07	0.14	0.17	0.17	0.09	0.66
20.00 - 24.99	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	5.48	5.02	5.92	15.36	24.92	22.38	12.98	7.96	100.00
						Total Observations:			5880

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.13. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817. October

Wind Speed	Wind Direction (from)								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	1.23	1.12	1.68	2.57	3.69	3.51	3.37	1.94	19.11
5.00 - 9.99	3.19	2.37	3.80	7.29	12.62	12.48	10.35	6.02	58.13
10.00 - 14.99	1.10	0.92	1.38	2.80	3.88	5.13	3.16	2.24	20.62
15.00 - 19.99	0.20	0.20	0.12	0.28	0.12	0.51	0.35	0.33	2.09
20.00 - 24.99	0.02	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.05
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	5.74	4.61	6.98	12.96	20.31	21.65	17.23	10.53	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

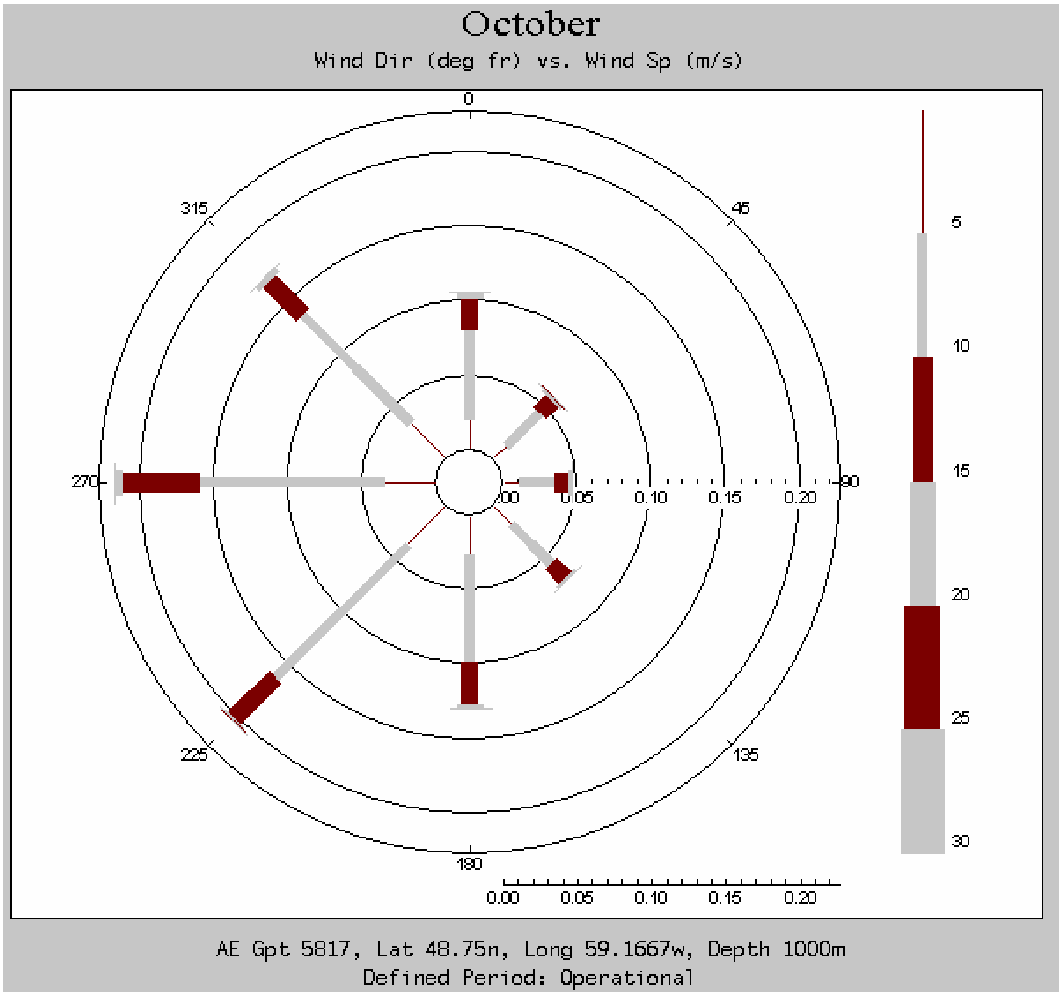


Figure 2.15. Wind Rose for October, Grid Point 5817.

Table 2.14. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817.

November

Wind Speed	Wind Direction (from)							
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	1.09	1.09	1.39	1.87	2.47	2.60	2.60	1.48	14.59
5.00 - 9.99	3.95	3.91	3.30	6.12	9.47	11.34	10.36	5.12	53.57
10.00 - 14.99	1.84	1.28	1.89	3.33	4.08	6.65	5.63	2.41	27.11
15.00 - 19.99	0.24	0.17	0.27	0.61	0.37	1.16	1.11	0.66	4.59
20.00 - 24.99	0.00	0.00	0.02	0.02	0.00	0.05	0.03	0.02	0.14
25.00 - 29.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	7.12	6.45	6.87	11.95	16.39	21.80	19.73	9.69	100.00
						Total Observations:			5880

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.15. Percentages of Observations of Wind Speed by Direction for AES Grid Point 5817.

December

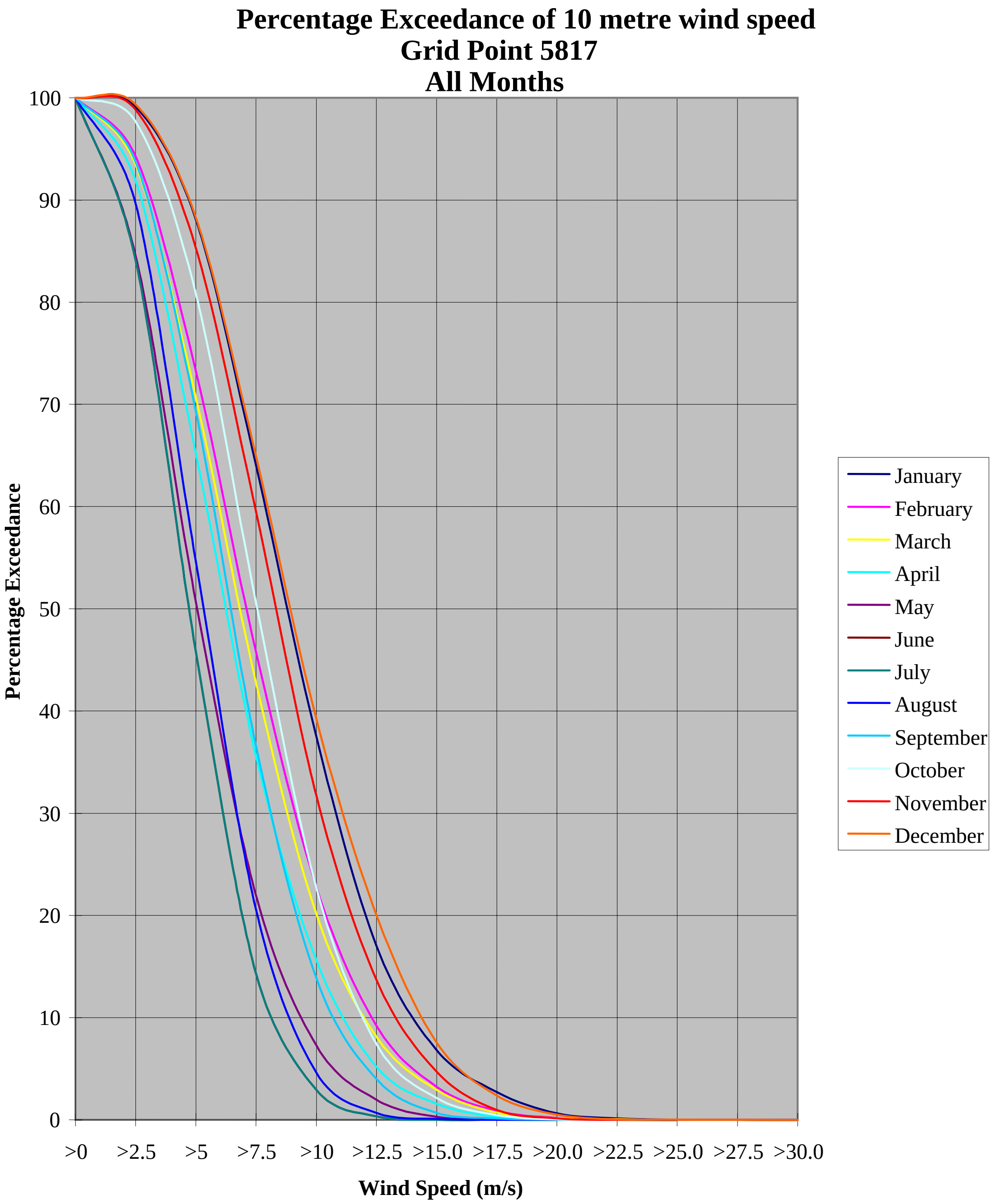
Wind Speed	Wind Direction (from)								
(m/s)	NE	E	SE	S	SW	W	NW	N	Total
0.00 - 4.99	1.28	0.91	0.84	1.40	1.53	1.79	2.17	1.73	11.65
5.00 - 9.99	3.23	2.63	3.04	4.38	7.49	11.21	10.60	6.44	49.01
10.00 - 14.99	1.91	1.79	1.76	3.00	3.79	8.15	7.27	4.08	31.75
15.00 - 19.99	0.28	0.30	0.77	0.61	0.63	2.14	1.84	0.51	7.08
20.00 - 24.99	0.03	0.00	0.02	0.02	0.10	0.12	0.13	0.08	0.49
25.00 - 29.99	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02
30.00 - 34.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	6.73	5.63	6.43	9.41	13.56	23.41	22.01	12.84	100.00
						Total Observations:			6076

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

2.3.2 Weather

In this section, sea surface temperatures (SST) are derived from an analysis performed on NOAA-JPL's AVHRR weekly 18 km MCSST dataset, 1981 to 2000. The multichannel sea surface temperature (MCSST) product from NOAA's polar orbiting satellite is available from January of 1981 through January of 2001. This dataset is distributed at a spatial resolution of 18 km at weekly time periods. Error estimates for this dataset are approximately 0.5-0.7 Celsius degrees.

The air temperatures and visibility data were derived by simple interpolation from the Climatological Charts of the St. Lawrence (Environment Canada 1994). The charts incorporate all available land and ship observations to derive the frequency of visibilities of less than one kilometre. For air temperature, a



Source: AES grid point 5817 Lat 48.75°N, Long 59.17°W , 1954 to 2003.

Figure 2.16. Percentage Exceedance of 10 m Wind Speed at Grid Point 5817.

simple relationship was established between the air temperature at coastal stations and the temperature at sea according to the wind and water temperature. Two years of observations recorded by a weather buoy anchored off the coast of Mont Louis (49° 33′N 65° 45′W) provided these data at sea.

2.3.2.1 Air, Sea and Surface Temperatures

The air temperature follows a normal annual cycle with the minimum mean temperature in February of -6.5°C and the maximum mean temperature in August of 16°C (Figure 2.17).

The mean annual sea surface temperature cycle is also shown in Figure 2.17. The minimum mean temperatures are in February (-0.79 °C) and March (-0.75 °C). The maximum means are in August (15.32 °C) and September (15.52 °C).

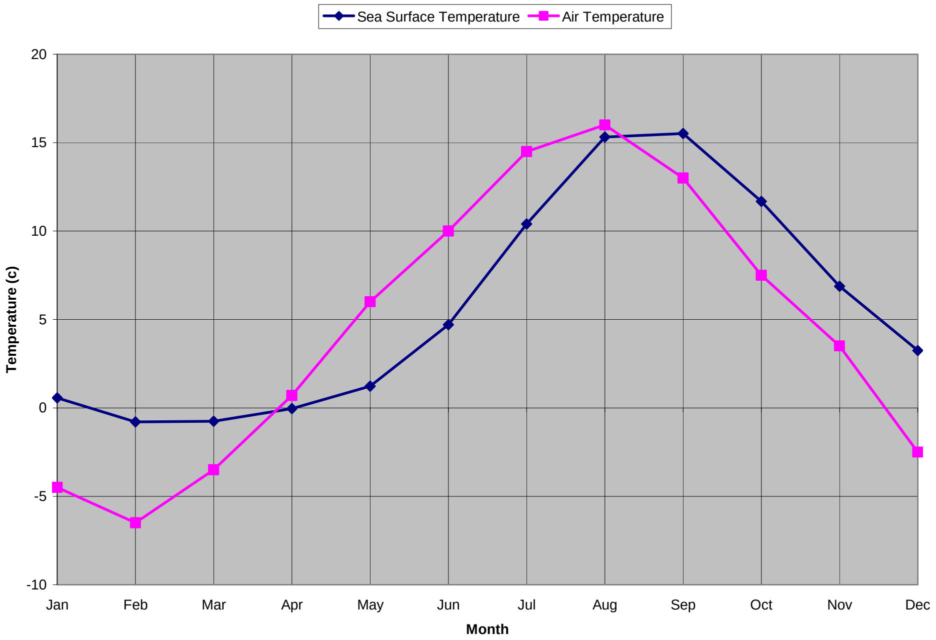
2.3.3 Visibility

Figure 2.18 shows the percentage occurrence of visibilities less than one kilometre near grid point 5817. The relatively high occurrence in January, February and March tend to be due to reduced visibilities in snow. In April, as the snow turns to rain, the reduced visibilities tend to be the result of advection fog. Advection fog forms when warm moist air moves over the cooler waters of the Gulf. The air is cooled from below and becomes saturated, resulting in the formation of fog. Figure 2.17 indicates that the mean air temperature in April rises above the mean sea surface temperature. Advection fog subsequently increases during May, June and July. In August, the temperature difference between the air and the sea lessens and the occurrence of fog decreases. The air temperature falls below the sea surface temperature in September. October has the lowest occurrence of visibilities less than one kilometre because advection fog is minimal and the winter snow has yet to arrive.

2.3.4 Waves

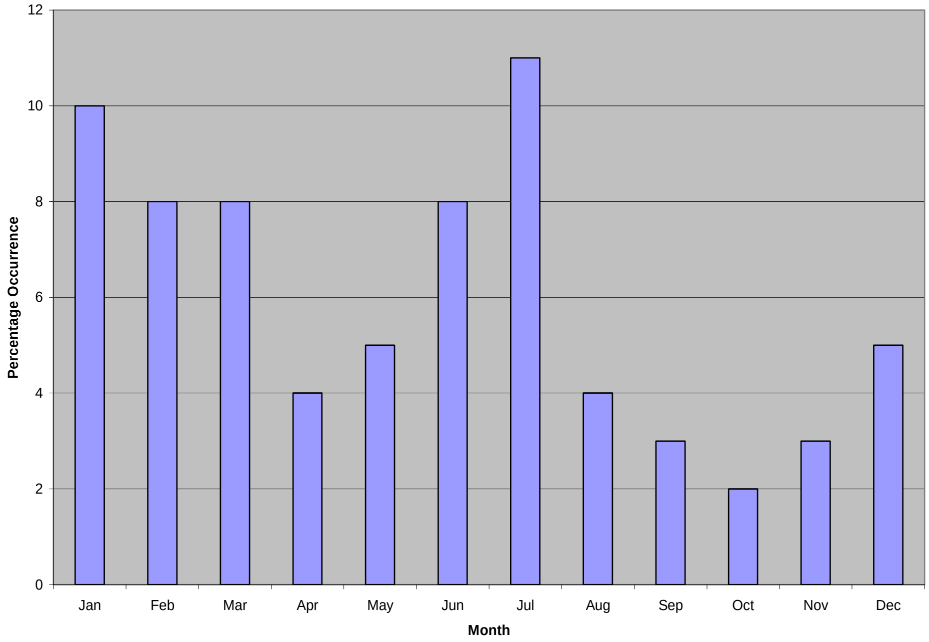
The data source used here was the AES-40 hindcast data set for 49 years (1954-2003) generated by Oceanweather Inc. using their third generation deep-water wave model with input from the wind data previously described. The wave model grid spacing was 0.625º latitude by 0.833º longitude.

The main parameters that describe wave conditions are significant wave height, maximum wave height, spectral peak period, and characteristic period. The significant wave height is the average height of the 1/3 highest waves. Its value approximates the characteristic height observed visually. The maximum height is the greatest vertical distance between a wave crest and adjacent trough. The spectral peak period is the period of the waves with the largest energy levels, and the characteristic period is the period of the group of largest waves in a given sea state. It approximates the period of the 1/3 highest waves. The characteristic period is the wave period reported in ship observations, and the spectral peak period is reported in the AES-40 data set.



Source: SST field was derived from an analysis performed on **NOAA-JPL's AVHRR weekly 18km MCSST** dataset, using data from 1981 to 2000. Air temperatures were interpolated from the Environment Canada, Climatological Charts of the St. Lawrence.

Figure 2.17. Mean Sea Surface Temperature on the First Day of Each Month at Point 48.78°N 59.15°W and Mean Air Temperature for Each Month Near Grid Point 5817.



Source: Data was interpolated from the Environment Canada, Climatological Charts of the St. Lawrence.

Figure 2.18. Percentage Occurrence of Visibility Less Than 1 km for Each Month Near Grid Point 5817.

A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell groups. Swell energy may reach a point from more than two directions at a particular time. Swell wave energy reaching a point may have been generated within the local weather system or from within distant weather systems located elsewhere over the ocean. The former situation typically arises when a front, trough, or ridge crosses the point of concern, resulting in a marked wind shift.

Since the Study Area is a coastal region, swells here can only occur from an offshore direction. In this case, the offshore directions range from southwest to northeast, with reference to a clockwise system.

2.3.5 Wave Climate

The wave climate of the Gulf of St. Lawrence is dominated by extra-tropical storms that occur primarily during October to March period. Severe storms occasionally occur outside this period. Storms of tropical origin may occur during early summer, but most often between late-August and October. Hurricanes are usually reduced to tropical storm strength or evolve into extra tropical storms by the time they reach the Gulf of St. Lawrence. However, occasionally these storms retain hurricane force winds and subsequently produce high waves.

Based on mean values, the highest waves typically occur between October and January (Table 2.16). The maximum significant wave height of 9.43 m was recorded in January. Significant wave heights greater than 5 m occur in every month except for June, July and August. Figure 2.19 shows annual percentage exceedance curves of significant wave heights. Curves starting at less than 100% indicate the presence of ice.

In contrast, on the Grand Banks (grid point 5691) the maximum significant wave height was 13.7 m in February.

The spectral peak period of the waves varies seasonally. The typical peak period during summer is approximately four seconds (Table 2.17). In winter, the typical peak period is approximately six to seven seconds. A scatter diagram of the significant wave height versus spectral peak period is presented in Table 2.18.

It should be noted the wave climate as it relates to transformation from deep to shallow water may have to be examined in detail in site-specific EAs.

Table 2.16. Monthly Maximum, Mean and Standard Deviation of Significant Wave Height at Grid Point 5817.

Month	Maximum Height (m)	Standard Deviation (m)	Mean Height (m)
January	9.43	1.2	1.65
February	6.69	0.94	0.73
March	5.77	0.84	0.58
April	5.88	0.8	0.82
May	6.18	0.63	0.81
June	4.43	0.55	0.76
July	3.48	0.49	0.73
August	4.75	0.54	0.85
September	5.84	0.75	1.16
October	7.78	0.86	1.46
November	8.15	1.04	1.73
December	9.38	1.21	1.98

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.17. Percentage Occurrence of Peak Spectral Wave Period, Grid Point 5817.

	Peak Spectral Period (seconds)																	Total
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Obs
January	0.02	0.23	2.04	13.12	22.63	23.82	19.70	10.27	5.25	2.06	0.70	0.16						5580
February	0.28	2.75	5.37	23.73	27.71	19.46	12.80	4.80	2.02	0.95	0.06	0.06						3165
March	0.84	3.03	7.16	23.64	28.88	18.22	11.97	3.87	1.58	0.67	0.13	0.00						2974
April	0.97	3.74	6.86	28.07	28.35	17.93	9.90	3.04	1.06	0.09								4546
May	2.04	5.59	8.87	32.72	28.36	13.99	6.55	1.53	0.25	0.07	0.03							5941
June	2.16	6.45	9.12	32.27	31.50	13.15	4.08	1.16	0.12									5879
July	1.12	5.23	9.61	37.16	30.02	12.13	4.21	0.48	0.03									6076
August	0.41	3.65	6.90	33.77	33.05	15.24	5.83	0.92	0.15	0.08								6076
September	0.65	1.90	3.69	23.88	31.00	21.04	12.91	3.62	1.17	0.14								5880
October	0.03	0.44	1.97	15.54	27.70	25.53	18.24	7.21	2.53	0.76	0.03	0.02						6076
November		0.17	1.46	12.06	23.08	24.39	21.29	9.91	5.44	1.75	0.43	0.02						5880
December		0.18	0.74	8.71	19.54	23.24	23.62	12.69	7.24	2.52	1.22	0.28	0.03					6076

(Periods are rounded off to the nearest whole number.)

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

Table 2.18. Percent Occurrence of Peak Wave Period against Significant Wave Height for Grid Point 5817.

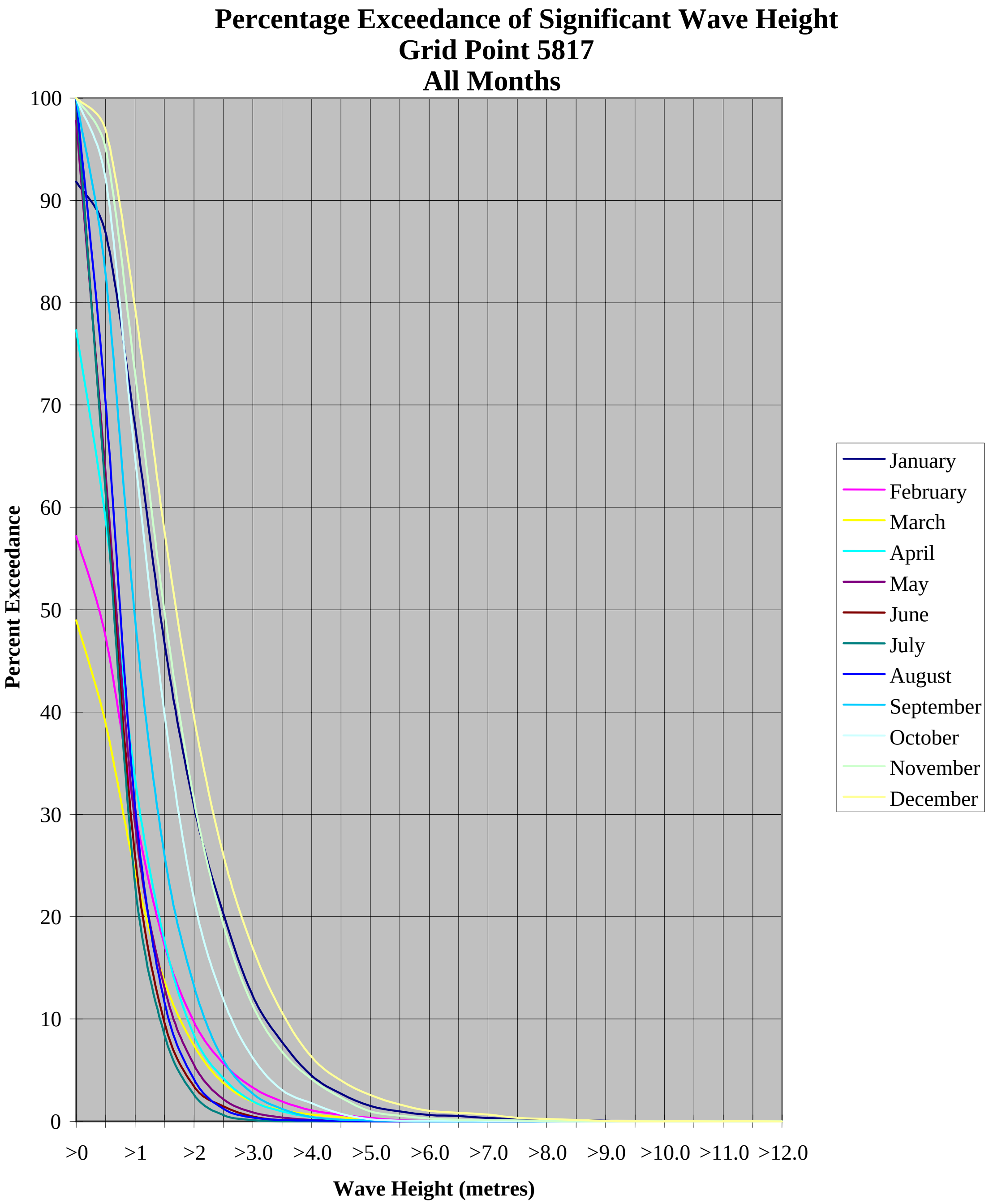
	Wave Height (m)																Total
Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
0	10.394																10.394
1	0.641																0.641
2	2.474																2.474
3	4.170	0.500															4.670
4	8.553	12.666	0.013														21.231
5	2.192	21.678	0.865														24.735
6	0.018	9.059	7.955	0.014													17.046
7		1.510	7.681	2.125	0.003												11.319
8	0.004	0.022	0.961	3.044	0.476												4.508
9	0.003		0.038	0.559	1.260	0.191											2.051
10	0.004			0.014	0.169	0.418	0.073	0.004									0.682
11				0.001	0.003	0.039	0.078	0.067	0.018								0.207
12							0.001	0.007	0.018	0.015							0.042
13										0.003							0.003
14																	
15																	
16																	
17																	
18																	
	28.453	45.435	17.51	5.757	1.911	0.648	0.152	0.078	0.036	0.018							100

Zero period and wave height represents when the grid point is "iced out"
(Wave Heights and Periods are rounded off to the nearest whole number.)

Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W, 1954 to 2003.

2.4 Physical Oceanography

The Gulf of St. Lawrence is a highly stratified semi-enclosed sea with an approximate surface area of 226,000 km^2 (Koitutonsky and Bugden 1991). It exchanges salt with the North Atlantic Ocean and receives considerable input of fresh water from the St. Lawrence River and lesser amounts from other rivers. As a consequence, the Gulf of St. Lawrence acts like a large estuary where Coriolis effects (from force generated by the earth's rotation), geostrophic currents, baroclinic processes, formation of eddies, and wind stress effects are all important. The St. Lawrence River flowing into the Gulf of St. Lawrence drains an extensive watershed which reaches as far west as the Great Lakes.



Source: AES grid point 5817. Lat 48.75°N, Long 59.17°W , 1954 to 2003.

Figure 2.19. Annual Exceedance of Wave height, Grid Point 5817.

2.4.1 Temperature and Salinity

A surface layer of relatively low salinities and seasonally variable thickness is a distinctive element of the water in the Gulf of St. Lawrence. The Study Area falls within North Atlantic Fishery Organization (NAFO) Division 4R and Unit Areas 4Ra, 4Rb, 4Rc and 4Rd. (see Figure 1.1). The seasonal temperature oscillations for this area are wide and increase slightly toward the south from 4Rb to 4Rd. In 4Rb, the range of temperature oscillations is over 15ºC while in 4Rd it is somewhat over 16ºC (Figure 2.20). During the summer, this temperature range decreases significantly with depth in the upper waters due to the presence of a cold intermediate layer between approximately 50 and 200 m. The cold water is due to the influx of Labrador Current water through the Strait of Belle Isle. Below 200 m, the temperature is in the range of 4°C to 6°C. In winter, the upper layer cools to below 0°C and becomes a nearly homogenous mixed layer.

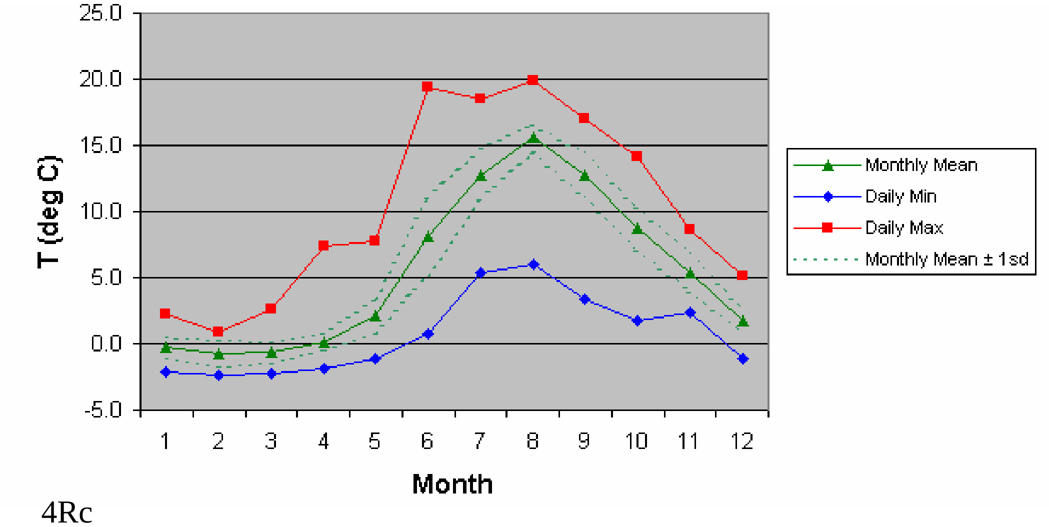
Figure 2.21 shows average vertical distributions of winter and summer temperatures for NAFO Division 4R, taken from B.I.O.'s System Polygons hydrographic database.

2.4.2 Currents

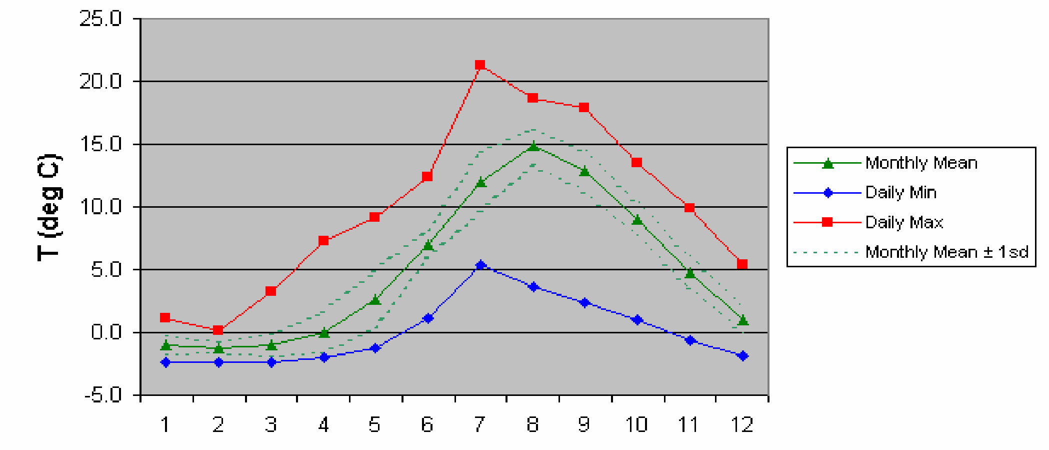
The circulation in the Gulf of St. Lawrence is forced by several factors that include the following: tides, local and regional meteorological events, freshwater runoff, and water exchange through the Strait of Belle Isle and Cabot Strait. In general, the circulation near the surface is cyclonic (i.e., counter-clockwise) (Figure 2.22). The similarities between this cyclonic circulation pattern and the surface salinity distributions in the Gaspé and Magdalen Shallows regions indicate that the surface currents are a result of the geostrophic balance between the horizontal pressure gradient field, and Coriolis effects. (Koutitonsky and Bugden 1991). A feature of the circulation of the Gulf of St. Lawrence is a strong coastal current (Gaspé Current) which originates in the St. Lawrence River Estuary. This current divides into two branches: (1) a branch which crosses the Magdalen Shallows before exiting the Gulf on the southern side of Cabot Strait, and (2) a branch which follows the slope of the Laurentian Channel. The two connections with the Atlantic Ocean (Cabot Strait and Strait of Belle Island) reflect an estuarine-like circulation where fresh water flows to the ocean in the upper waters and more saline waters enter the Gulf in the deeper layers. The mean flushing time of fresh water in the Gulf of St. Lawrence is thought to be around six to eight months (Trites 1972).

The currents in Cabot Strait are the major avenues for water exchange between the Gulf of St. Lawrence and the Atlantic Ocean. In Cabot Strait a two-layer current structure is thought to exist with fresher water leaving the Gulf near the surface and saltier, heavier water entering the Gulf at depth. The surface outflow is shifted toward Cape Breton and the deeper inflow reaches the surface close to the southern shore of Newfoundland (El-Sabh 1976).

4Rb



4Rc



4Rd

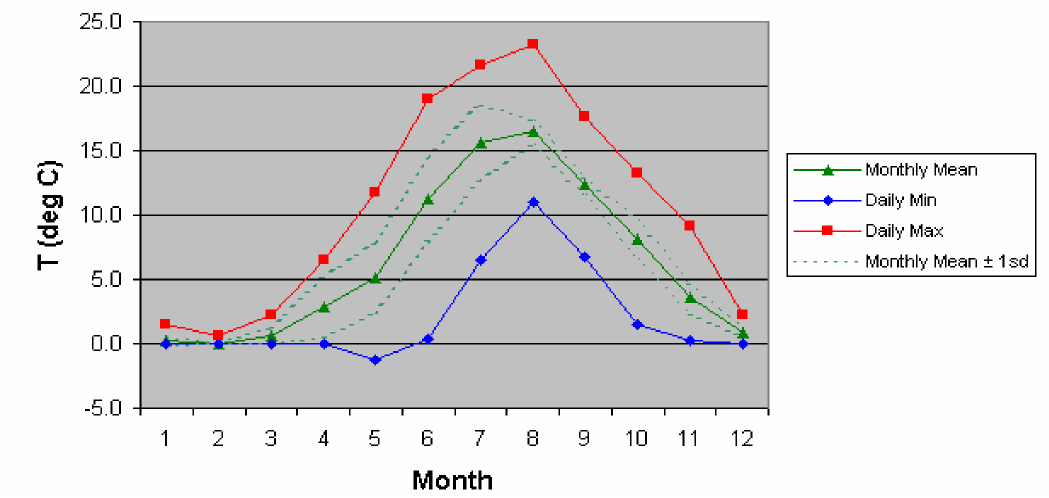


Figure 2.20. Seasonal Temperature Cycle for NAFO Division 4R Unit Areas.

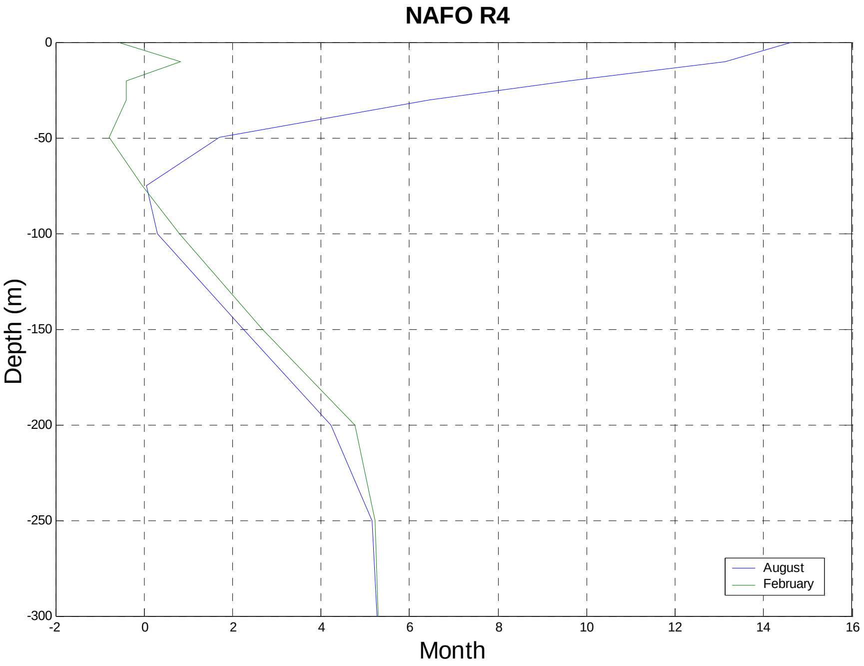
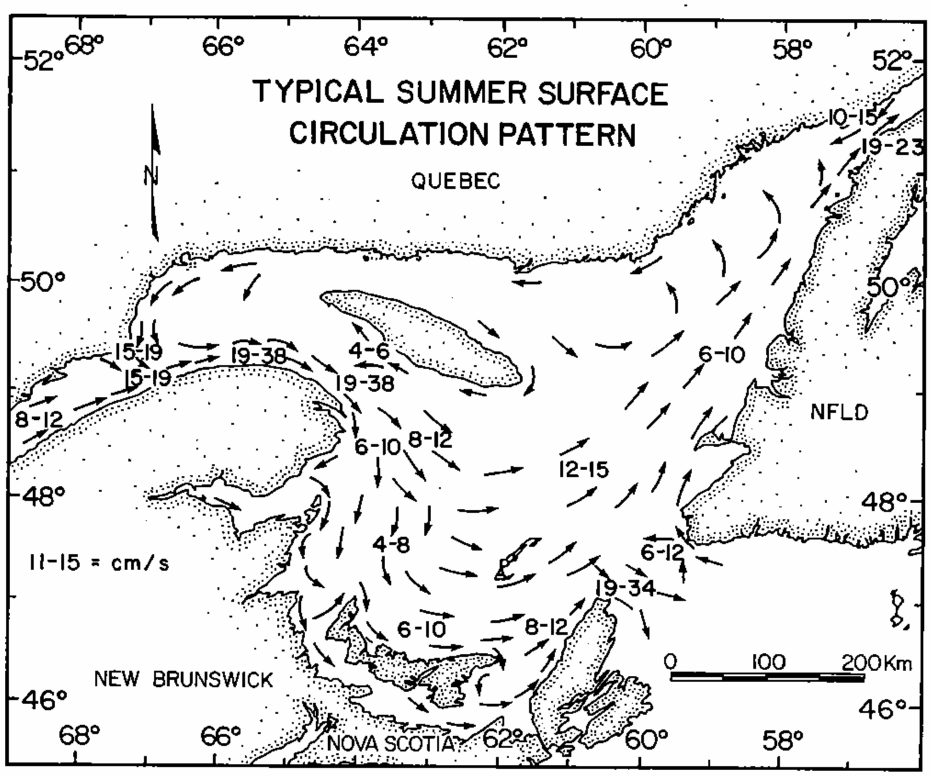


Figure 2.21. Average Vertical Temperature Distribution in NAFO area 4R in February and August. Data from B.I.O. System Polygons, Hydrographic Database.

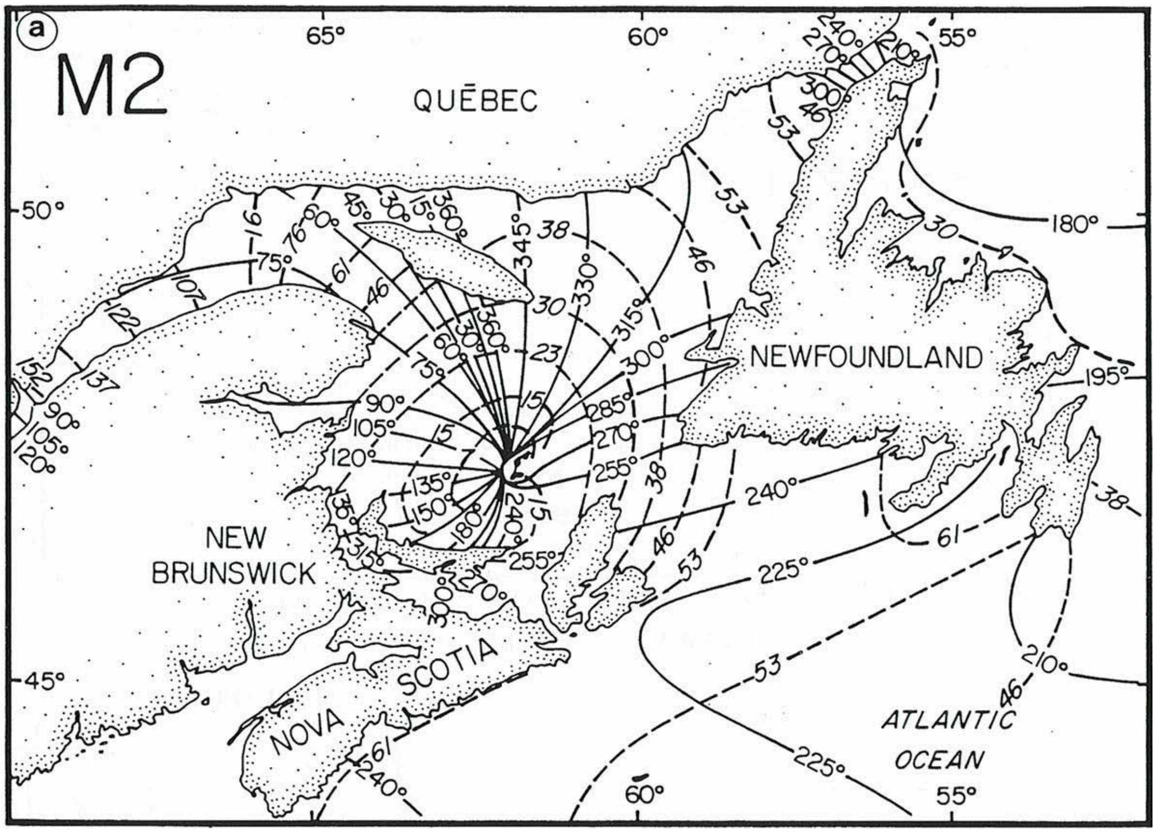


Source: Trites 1972 (Current speed ranges are given in cm/sec).

Figure 2.22. Summer Surface Circulation in the Gulf of St. Lawrence.

The circulation in the Strait of Belle Isle is into the Gulf along the Labrador side of the Strait and out of the Gulf along the Newfoundland side. However, episodic events of massive inflow and outflow though the whole Strait have been observed and are believed to be related to large scale barometric oscillations and the effect of winds.

The tides in the Gulf of St. Lawrence are dominated by the semi-diurnal M_2 constituent of 12.4 hours in the northeast sector of the Gulf of St. Lawrence and mixed in the centre of the Gulf (Godin 1979). The phases and amplitudes of the M_2 component of the tides are shown in Figure 2.23. The amplitudes of the M_2 constituent vary between 0.46 m and 0.53 m in the Study Area. With the exception of the St. Lawrence Estuary, these are the largest tides in the Gulf due to an amphidromic point being located near the Magdelen Islands. Tidal currents seldom exceed 30 cm/sec (Koutitonsky and Bugden 1991).



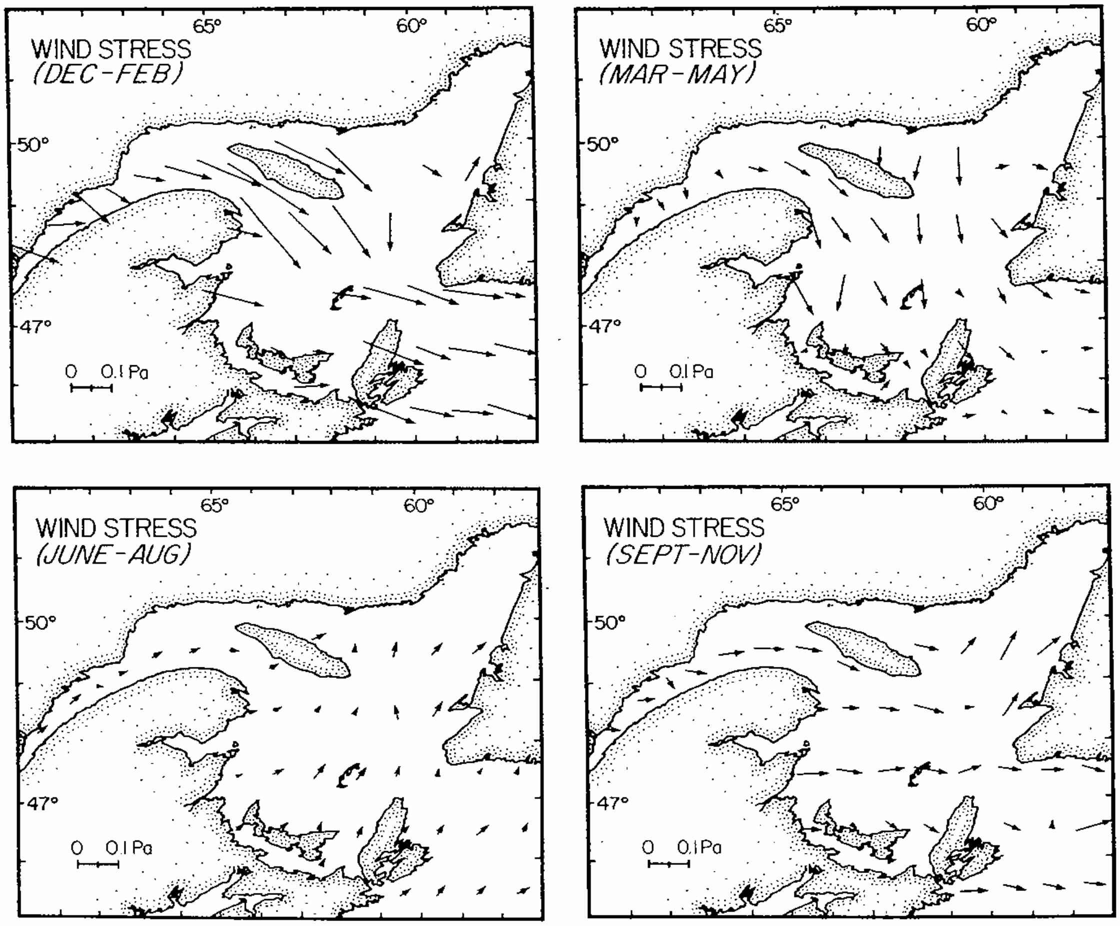
Source: Farquharson 1970. Amplitudes are in cm, and phases are relative to GMT zone.

Figure 2.23. Co-amplitude (dashed) and Co-phase (solid) Lines for the M_2 Tides in the Gulf of St. Lawrence.

Wind stress forcing is a major source of kinetic energy for the Gulf of St. Lawrence. From June to October, the winds are weak. Saunders (1977) estimated the mean seasonal wind stress values over the North Atlantic continental shelf, using wind observations from ships for the period 1941-1972 (Figure 2.24). In this Figure, a predominant westerly direction of the winds is observed during all seasons, with a notable northerly component in spring and a southerly component during the summer.

El-Sabh (1976) and Trites (1972) report northeastward residual currents along the western coast of Newfoundland, corresponding to the cyclonic character of the circulation patterns within the Gulf.

Currents off the southwestern coast of Newfoundland are, in general, the result of interaction between the waters entering the Gulf through Cabot Strait next to the Newfoundland coast, and the eastward flows in the central sector of the Gulf.



Source: Saunders (1977).

Figure 2.24. Mean Seasonal Wind Stress (1941-1972) over the Gulf of St. Lawrence, Averaged from Ship Observations.

According to El-Sabh (1976), the flow in the Study Area is usually directly northeastward along the west coast of Newfoundland. However, clockwise and anticlockwise gyres are part of the permanent features of the circulation pattern in the Gulf. These gyres sometimes move along with the general flow.

The presence of mesoscale and synoptic eddies off the western coast of Newfoundland is frequent and has been documented by means of numerical modeling (Koutitonksy and Bugden 1991), geostrophic calculations derived from oceanographic data (El-Sabh 1976), and direct current measurements (Trites 1972). The presence of these gyres suggests a very complex ocean circulation pattern in the Study Area (Figure 2.25).

Some moored current data exists for the Study Area from which current velocities can be examined. The information on ocean currents is concentrated around Rocky Harbour, St. George's Bay, and Port-aux-Basques. The locations are shown in Figure 2.26.

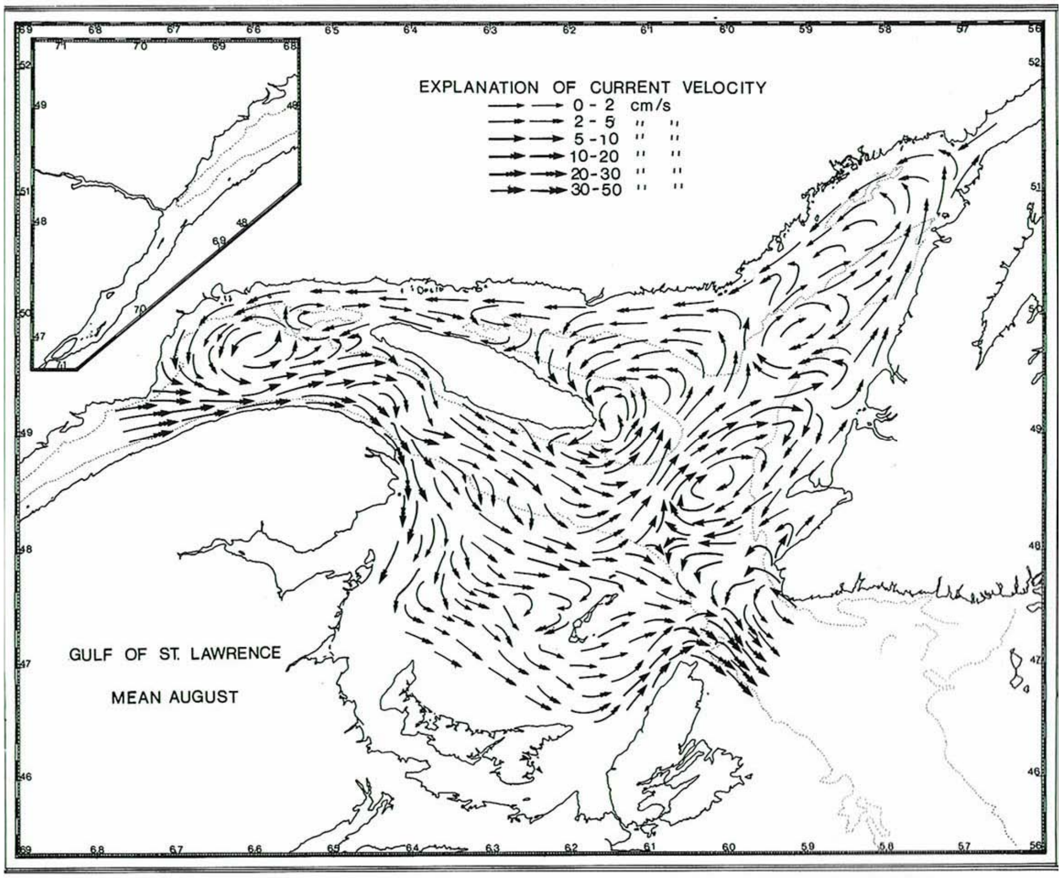


Figure 2.25. Field Surface of the Geostrophic Currents in the Gulf of St. Lawrence during August.

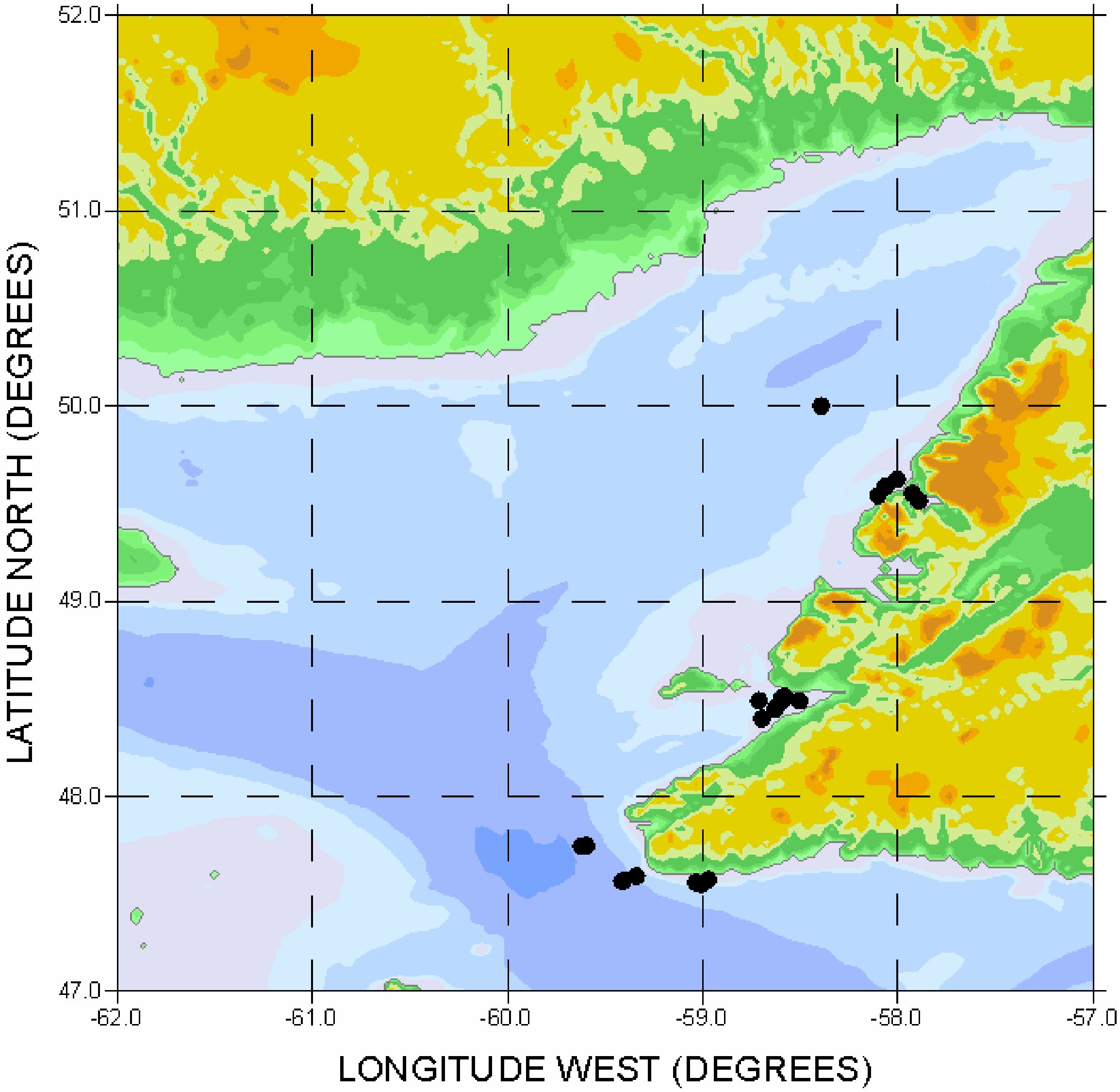


Figure 2.26. Locations of Moored Current Meter Data.

2.5 Ice Conditions

The area off the west coast of Newfoundland is subject to seasonal incursions of ice. There are considerable variabilities in spatial distribution, season length and source of ice between the northern and southern parts of the Study Area. The Study Area is primarily subjected to sea ice as opposed to icebergs but there have been isolated reports of icebergs in the northern and western boundaries of the Study Area.

C-CORE (2005) conducted analyses to determine an ice-free season during which the influence of iceberg and pack ice on ice-sensitive operations may be considered negligible for areas of offshore Newfoundland where exploration activities may potentially occur. The region considered included areas off the west coast of Newfoundland from Cape Anguille to St. Paul's Inlet (southern and central parts of the Study Area).

2.5.1 Data Sources

The primary sources of sea ice data for the Study Area are the Canadian Ice Services (CIS) database and the Sea Ice Climate Atlas, East Coast of Canada 1971-2000. The pack ice data used in C-CORE's analyses covered 36 years.

The primary sources of iceberg data are the International Ice Patrol Database, the CIS iceberg charts, the Provincial Aerospace Iceberg Database, and the PERD (2004) Iceberg Sighting Database. The PERD (2004) data were most extensive and were therefore considered most appropriate for the analysis. The iceberg data used in C-CORE's analyses covered 44 years.

2.5.2 Sea Ice

Sea ice cover in the Study Area comes from two primary sources: (1) sea ice formed off the coast of Labrador which drifts down through the Strait of Belle Isle to the northern part of the Study Area, and (2) ice that forms in the Gulf of St Laurence and affects the central and southern parts of the Study Area. All sea ice in the Study Area is first-year ice, ranging in its un-deformed thickness from 30 to 120 cm. Total ice coverage across the Study Area ranges from 100% in the northern and western sectors to 60% in the inshore areas. Pack ice was most important at Port au Port in establishing the duration of the ice-free season. Based on pack ice, the ice-free season for the Port au Port region was determined to be May to December (C-CORE 2005).

2.5.3 Season Length

There is a large variability in season length between the northern and southern sectors of the Study Area. Sea ice generally drifts across the northern boundary during the first week in January and reaches the southern boundary by the third week of February.

Maximum spatial coverage is typically reached by the second week of March when the entire Study Area is covered with sea ice (Figure 2.27). The sea ice clears the southern boundary by the first week of April and the Study Area is typically ice free by the second week of May. Total season length based on the 30-year median ice coverage is shown in Table 2.19.

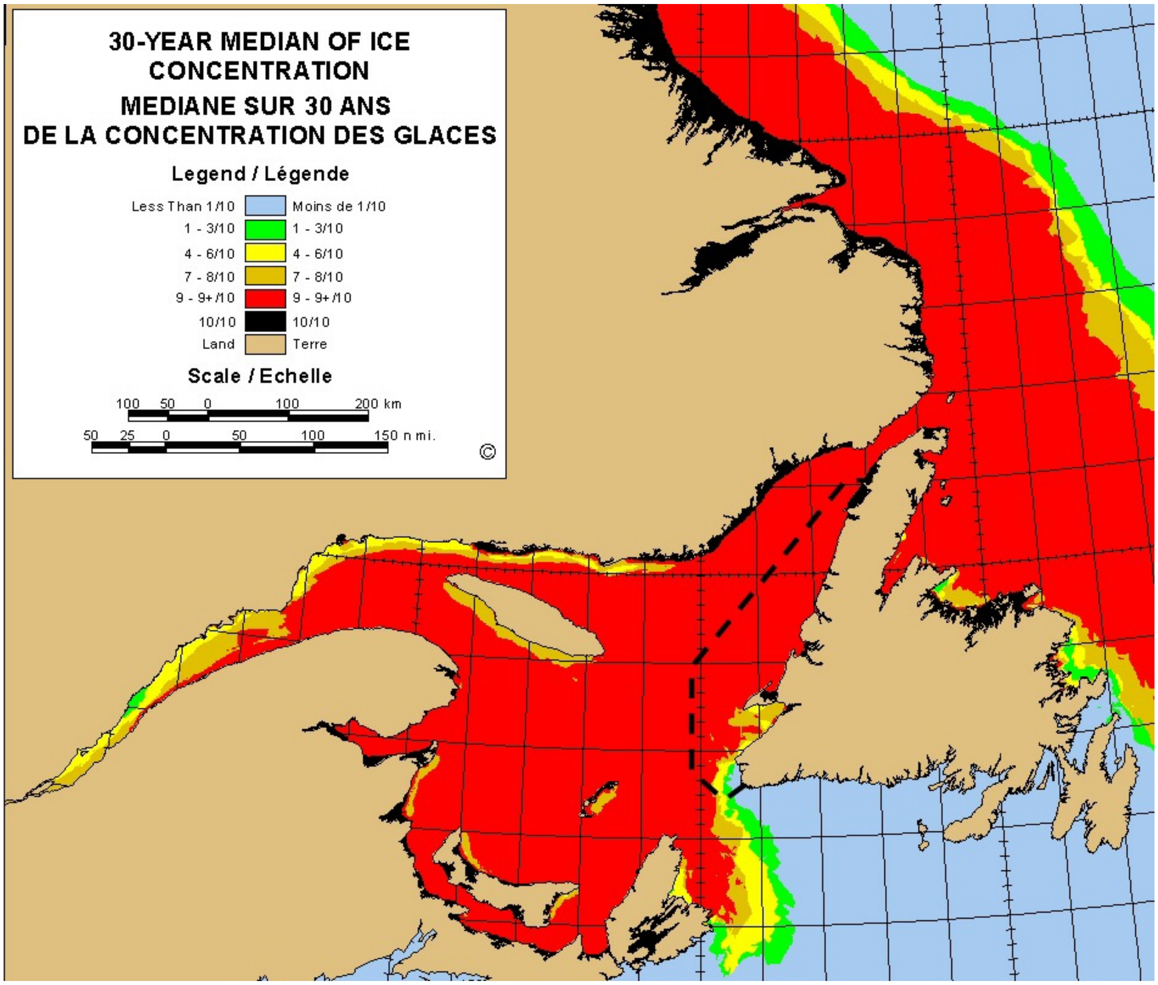


Figure 2.27. Maximum Pack Ice Extent in March (Study Area Delineated by Dashed Line).

Table 2.19. Ice Season Durations.

Sector	Freeze Up	Break Up	Total Days
Northern Sector	Jan-08	May-07	120
Southern Sector	Feb-19	April-02	43
Extreme Cover	Dec-11	July-16	217

2.5.4 Icebergs

The number of iceberg sightings in the Study Area are low. Normalized iceberg drift indicates that bergs travel down the Strait of Belle Isle and then follow the primary current along the Quebec shore of the Gulf.

Isolated iceberg sightings have been reported around the northern and western boundaries of the Study Area. However, there are few quantitative data on iceberg size, shape, or densities in this area.

Based on icebergs, the ice-free season for the Port au Port region was determined to be the entire year (C-CORE 2005). In the <150m waters off Bay of Islands and Gros Morne National Park, icebergs have been infrequently recorded between March and June during the 1960 to 2003 period. Pack ice, on the other hand, occurs in this same area between December and May, based on at least one observation in all years (1969 to 2004) (C-CORE 2005).

2.5.5 Icing of Superstructures

Icing of superstructures can occur throughout the NW Atlantic in winter, including the Gulf of St. Lawrence. Icing caused by freezing spray and freezing precipitation can influence personnel safety and vessel/rig stability. The degree of icing is influenced by a number of factors such superstructure design, air and water temperatures, wind conditions, amount and type of precipitation and other factors.

2.6 Planning Implications

The physical environment has direct implications for oil and gas activities because it may affect operations and safety. It also should be noted that the effects of the environment on a project must be considered pursuant to the requirements for an environmental assessment under the *Canadian Environmental Assessment Act* (*CEAA*).

The physical environment of the west coast is typically less harsh than the Grand Banks at least in terms of iceberg and wave conditions. At the same time, a number of physical factors which likely enhance the biodiversity of the Study Area may also increase the adverse effects of an accidental oil spill (see Section 4.3)

Planning implications related to the physical environment are summarized in the following sections.

2.6.1 Geology

The geology of the Study Area is, of course, of paramount interest to the oil industry as it determines the oil and gas potential. The Study Area is considered to have a relatively low seismic hazard with respect to peak horizontal ground accelerations and velocities and for relatively short term activities such as exploratory drilling. Nonetheless, in the event of a production development application, all potential geohazards, including seismic events, would likely have to be examined in more detail.

2.6.2 Bathymetry

Considering that water depths within the Study Area range from the low water mark of the intertidal zone to >500 m in the offshore, there is considerable diversity of the physical and biological environments, and hence of potential effects of oil and gas activities. This diversity is discussed in greater detail in the next section on the biological environment.

2.6.3 Currents

The currents in the Study Area are certainly of operational concern (e.g., effects of the environment on a project). In general, ocean currents in the somewhat enclosed Gulf of St. Lawrence flow in a counter-clockwise direction. This cyclonic flow could potentially be a factor in the effects of an accidental oil spill in the Study Area (see Section 4.3). Current meter data are typically collected during drilling operations as part of a physical environment monitoring program, thereby enhancing the physical database for the area. Currents play an important role in the distribution of eggs and larvae of fish and invertebrates.

2.6.4 Ice

Ice and icebergs are of paramount interest from an operational and safety point of view. Icebergs are less of an issue in the Study Area compared to areas off eastern Newfoundland and Labrador. In terms of ice, sea ice plays a dominant role in the Study Area. For example, sustained westerly winds have a tendency to pile up ice on the west coast which can hamper coastal operations. [It should be noted that daily ice charts for the Gulf of St. Lawrence are available from the CIS.]

Sea ice is also a factor in the shaping of shallow water plant and animal communities, and it affects oil and gas industry-related issues that include underwater sound transmission, spill behaviour, and spill remediation (see Section 4.3). Icing of superstructures can have implications for the safety of both personnel and offshore vessels and structures.

2.6.5 Climatology, Winds, Waves, Temperature, and Salinity

These physical variables are all of concern to operations and safety. Winds, for example, blow predominantly onshore along western Newfoundland, which would be of concern in the case of an accidental oil spill (see Section 4.3). Data on these variables are typically included in site-specific EAs. These physical factors are also involved in the shaping of shallow water plant and animal communities. Operators will be required to collect meteorological and oceanographic data to support operations.

3.0 Biological Environment

This section presents an overview of the Study Area ecosystem with emphasis on valued ecosystem components (VECs). Typical VECs include fish and fish habitat, fisheries, marine birds, marine mammals, sea turtles, and Species at Risk (SAR) as listed in legislation.

Not only are shallow water areas included in the Study Area (depth range intertidal to >500 m), but three of the four Bid Parcels (4, 6 and 7) and four existing ELs (1069, 1070, 1071 and 1072) impinge on the west coast of Newfoundland. Parcel 4 contacts the western tip of the Port au Port Peninsula (Cape St. George) in Unit Area 4Rc, Parcel 6 contacts the coast within and north of Bay of Islands (Unit Areas 4Rb and 4Rc), and Parcel 7 contacts the section of coast extending from north of Bay of Islands to just north of Bonne Bay (Unit Area 4Rb) (see Figure 1.1). Consequently, it is important in this SEA to consider the biological environment occurring from the intertidal area to the offshore areas where depth exceeds 500 m.

3.1 Coastal Algal Communities

3.1.1 Non-estuarine Areas

Warm summer seawater temperatures, due primarily to the existence of an inshore, northerly flowing water current, characterize the west coast of Newfoundland. The intertidal and shallow subtidal of the open coast is scoured by ice driven ashore by prevailing westerly winds, resulting in these zones being dominated by annual algal species. Luxuriant growth of perennials (e.g., *Fucus*, *Ascophyllum*, *Chondrus*) occurs only locally in more sheltered sites where there is periodic removal by ice (South 1983). Table 3.1 indicates the algal distribution between the high water mark and the shallow subtidal zone at coastline types differentiated by degree of exposure.

3.1.2 Estuarine Areas

There is limited variability in estuarine communities occurring around the island of Newfoundland. Substrate type tends to be the major factor affecting community differences (Table 3.2).

Table 3.1. Generalized Algal Zonation and Associated Invertebrates in Intertidal and Shallow Subtidal Areas in the Western Newfoundland and Labrador Offshore Area.

Wave Exposure	**Typical Algal/Invertebrate Species**		
	HW to 5 m	**5 to 20 m**	**> 20 m[1]**
Low	Maritime lichens Cyanophyta *Bangia atropurpurea* *Fucus vesiculosus* *Balanus balanoides* *Ascophyllum nodosum* *Mytilus edulis* *Bonnemaisonia hamifera*	*Laminaria longicruris* *Phyllophora* sp. *Agarum cribosum* *Laminaria solidungula*	*Phyllophora* sp. *Agarum cribosum* *Lithothamnium tophiforme* *Phymatolithon laevigatum* *Laminaria longicruris* *Laminaria solidungula*
Moderate	Maritime lichens *Pilayella littoralis* *Bangia atropurpurea* *Chordaria flagelliformis* *Chorda filum* *Phyllophora* sp. *Alaria esculenta* *Saccorhiza dermatodea*	*Lithothamnium glaciale* *Desmarestia* sp. *Agarum cribosum* *Laminaria longicruris* *Phyllophora* sp.	*Phyllophora* sp. *Lithothamnium glaciale*
High	Cyanophyta *Porphyra* sp. *Bangia atropurpurea* *Pilayella littoralis* *Chordaria flagelliformis* *Alaria esculenta* *Saccorhiza dermatodea* *Lithothamnium glaciale*	*Clathromorphum circumscriptum* *Lithothamnium glaciale* *Laminaria longicruris* *Agarum cribosum* *Phyllophora* sp.	*Ptilota serrata* *Phyllophora* sp.

[1] 20-40 m for low exposure; 20-25 m for moderate and high exposure; HW denotes high water mark

Source: South (1983).

Table 3.2. Estuarine Algal Communities by Substrate Type.

Substrate Type	**Typical Algal Species**	
	HW to 5 m	**5 to 10 m**
Hard (including pebbles and boulders)	Maritime lichens *Cyanophyta* *Enteropmorpha* sp. *Fucus vesiculosus* *Ascophyllum nodosum* *Ahnfeltia plicata* *Chorda filum* *Phymatolithon laevigatum*	*Laminaria longicruris* *Phymatolithon laevigatum* *Clathromorphum circumscriptum* *Lithothamnium glaciale*
Sand/mud	*Spartina* sp. *Plantago* sp. *Cyanophyta* *Enteropmorpha* sp *Zostera marina* *Ascophyllum nodosum* *Fucus vesiculosus* *Ahnfeltia plicata* Benthic diatoms *Chaetomorpha*	*Zostera marina* *Laminaria longicruris* *Ahnfeltia plicata*

3.1.3 Planning Implications for Marine Algae

Algae associated with some of the more sensitive coastal areas (e.g., saltmarshes, eelgrass beds) are probably of most concern considering the low proportion of these types of habitats along the west coast of Newfoundland. At the same time, algae associated with the more common habitat types (i.e., coarser substrate areas) are also important as primary producers and in their interactions with animal biota. Operators would be required to ensure safe operating practices to minimize the probability of accidental events and to be well prepared to react to an accidental event.

3.1.4 Data Gaps for Marine Algae

More data on oil characteristics, spill trajectories, and oil fate and behaviour is required for the Study Area. Considering the proximity of the Bid Parcels to shore, the primary potential negative effect on marine algae would be accidental spills and blowouts. Continuing collection of physical environment data (e.g., oceanographic, climate) would also help to predict aspects of spills and blowouts.

3.2 Plankton

Plankton refers to free-floating organisms that form the basis of the pelagic ecosystem. Members of this group of organisms include bacteria, fungi, phytoplankton (plants), zooplankton (small invertebrates), macro invertebrate eggs and larvae, and ichthyoplankton (eggs and larvae of fish). In simplest terms, the phytoplankton (e.g., diatoms) produces carbon through the utilization of sunlight and nutrients (e.g., nitrogen, phosphorus, silicon). This process is called primary production. Herbaceous zooplankton (e.g., calanoid copepods, the dominant component of Northwest Atlantic zooplankton) feed on phytoplankton. This growth process is called secondary production. The herbivores are eaten by predators (i.e., tertiary production) such as predacious zooplankton (e.g., chaetognaths, jellyfish) which in turn are consumed by higher predators such as fish, seabirds, and marine mammals. This food web also links to the ecosystem on the seabed (the benthos, see below) through bacterial degradation processes, dissolved and particulate carbon, and direct predation.

Plankton production is important because areas of enhanced production and/or biomass tend to be congregation areas for fish, seabirds, marine mammals, and possibly sea turtles. Production is enhanced in areas of bottom upwelling where nutrient-rich bottom water is brought to the surface by a combination of bottom topography, wind and currents. An example of a well-known area of bottom upwelling is the anchovy fishery off the west coast of South America. Frontal areas are where two dissimilar water masses meet to create lines of convergence and often concentrate plankton and predators alike. A well-known example of this phenomenon is the semi-permanent front between waters of Gulf Stream origin and waters of Labrador Current origin. The two physical processes (upwelling and fronts) may be found together in varying degrees, particularly in coastal areas.

3.2.1 Gulf of St. Lawrence

The northeastern Gulf of St. Lawrence has a very low phytoplankton biomass between April and October compared to the other parts of the Gulf (see literature review by de Lafontaine et al. 1991). A decreasing production rate between April and May led the authors to surmise that the phytoplankton bloom in this area might typically occur in late March/early April, immediately following ice melt.

There is evidence that the surface waters overlying the Laurentian and Esquiman Channels (see Figure 1.1) in the northcentral Gulf of St. Lawrence resemble the *Calanus*-*Sebastes*-dominated system occurring in the Northwest Atlantic Ocean. Two *Calanus* species (*C. finmarchicus* and *C. hyperboreus*) dominate the mesoplankton composition in the Laurentian Channel. At the same time (late June), larval redfish (*Sebastes* spp.) appear to dominate the ichthyoplankton, particularly over deeper waters. Interestingly, the phytoplankton regime in this region in late spring/early summer is more typical of a stratified, nutrient-depleted temperate ocean than of a weakly stratified coastal environment supporting high phytoplankton biomass traditionally thought to be essential for spawning of *Calanus*. Therefore, there are suggestions that the strong link between variability in phytoplankton biomass and *Calanus* production does not exist in early summer in the north-central Gulf (Runge and de Lafontaine 1996).

Larvae of cod, herring and American plaice have been encountered primarily in relatively shallow coastal waters of the northeastern Gulf region (de Lafontaine et al. 1991). These authors also indicated redfish larvae as the dominant ichthyoplankton, occurring primarily at deep water areas.

June sampling performed on a transect running perpendicular to the Laurentian Channel and located outside of the Study Area indicated a thermocline at 10-30 m, low nutrient levels in surface waters, and low chlorophyll *a* concentrations that were maximal at 20-25 m depth at the base of the thermocline. Copepods dominated the mesoplankton (90%). Other common zooplankters included medusae, euphausiids (*Meganyctiphanes norvegica*, *Thysanoessa inermis, Thysanoessa raschii*), chaetognaths, larvaceans and ostracods. At stations where depth exceeded 200 m, copepodite stages of *Calanus* (*C. finmarchicus, C. glacialis*, and *C. hyperboreus*) made up about 80% by number of the catch. Icthyoplankton composition was dominated by redfish larvae (>96% of all fish larvae) at the deep stations (>200 m). Most redfish larvae were *Sebastes mentella* and were recently spawned, based on size. At the shallower stations, redfish larvae were less abundant and replaced by two species of shanny. Species richness was greater at shallow stations but the larvae density was about two orders of magnitude lower (Runge and de Lafontaine 1996).

The majority of *Calanus* females and redfish larvae were found in the upper 25 m of the water column (i.e., above the base of the thermocline) during both day and night. Within this surface layer, both the *Calanus* females and the redfish larvae were deeper during the day (10-25 m) than at night (0-10 m). Egg production rates by *Calanus finmarchicus* approached the known maximal level known for the species, indicating no or little food limitation. The principal stomach contents of redfish larvae collected during daylight hours were copepod eggs. Larger redfish larvae also appeared to feed on nauplii and copepodites (Runge and de Lafontaine 1996).

The *Calanus*-larval *Sebastes* interaction in the northern Gulf probably commences in late April/early May and continues throughout the summer. Larval extrusion in this area occurs primarily in May, with a minimal occurrence in early June. Available data indicate that the *Calanus-Sebastes* interaction characterizes large areas of the Laurentian and Esquiman Channels in the north-central Gulf. The authors concluded that *C. finmarchicus* in the area studied were utilizing heterotrophic microplankton (i.e., dinoflagellates, midroflagellates, diatoms) as the primary source of nutrition (Runge and de Lafontaine 1996).

Krill is one of the key species of the food web in the Gulf of St. Lawrence. One of the primary retention areas of krill occurs in the Northeastern Gulf within the Study Area (UAs 4Ra and 4Rb). Sourisseau et al. (2004) indicated upper water column krill concentration “hotspots” during February in the vicinity of Bay of Islands (UA 4Rbc; Parcels 6 and 7) and in the northern part of the Study Area near Port au Choix. Moderate concentrations were indicated along the remaining west coast of Newfoundland. Sourisseau et al. (2004) also indicated deep-dwelling krill concentrations north of Bonne Bay between May and August, and along the shelf edge in UA 4Rc during January and February.

Anecdotal information collected from fishers during SEA consultations in July 2005 (Appendix 1) confirmed this hotspot off Port au Choix indicated by Sourisseau et al. (2004). This area, known locally as “The Hole,” occurs over a steep slope area at the northern end of the Esquiman Channel (more information on the Hole will be provided in later sections) (Figure 3.1). Fishers believe that small invertebrate animals, perhaps zooplankton and ichthyoplankton, are concentrated at this location. Other areas highlighted by fishers which are likely important from an ichthyoplankton perspective include ‘Bad Bay’ area at the mouth of River of Ponds (~ 15 km south of Hawkes Bay; northern 4Rb) where there is substantial spawning (particularly capelin) activity in June and July, Port au Port Bay area (lobster larvae) during the summer (southern 4Rc), and an area west of Port au Port Peninsula (Cape St. George Cod Spawning Area off Port au Port) where 4RS+3Pn cod spawn in the spring (straddles 4Rc and 4Rd boundary; overlaps with Parcel 4). Herring are known to spawn in St. George’s Bay (4Rd) in the spring and in St. John Bay (4Ra) in the fall. More detail on these areas will be provided in later sections.

3.2.2 Planning Implications for Plankton

There are no specific planning issues associated with plankton alone, although there may be areas of enhanced production being utilized by higher trophic levels (e.g., The Hole, the Cape St. George Cod Spawning Area, nearshore area south of Hawkes Bay). This SEA does not consider plankton to be a VEC *per se* but has examined plankton production from the perspective that known or recognizable areas of enhanced production may be indicative of potentially important areas for fish, marine birds, marine mammals and sea turtles. These issues would be discussed in more detail in site-specific EAs.

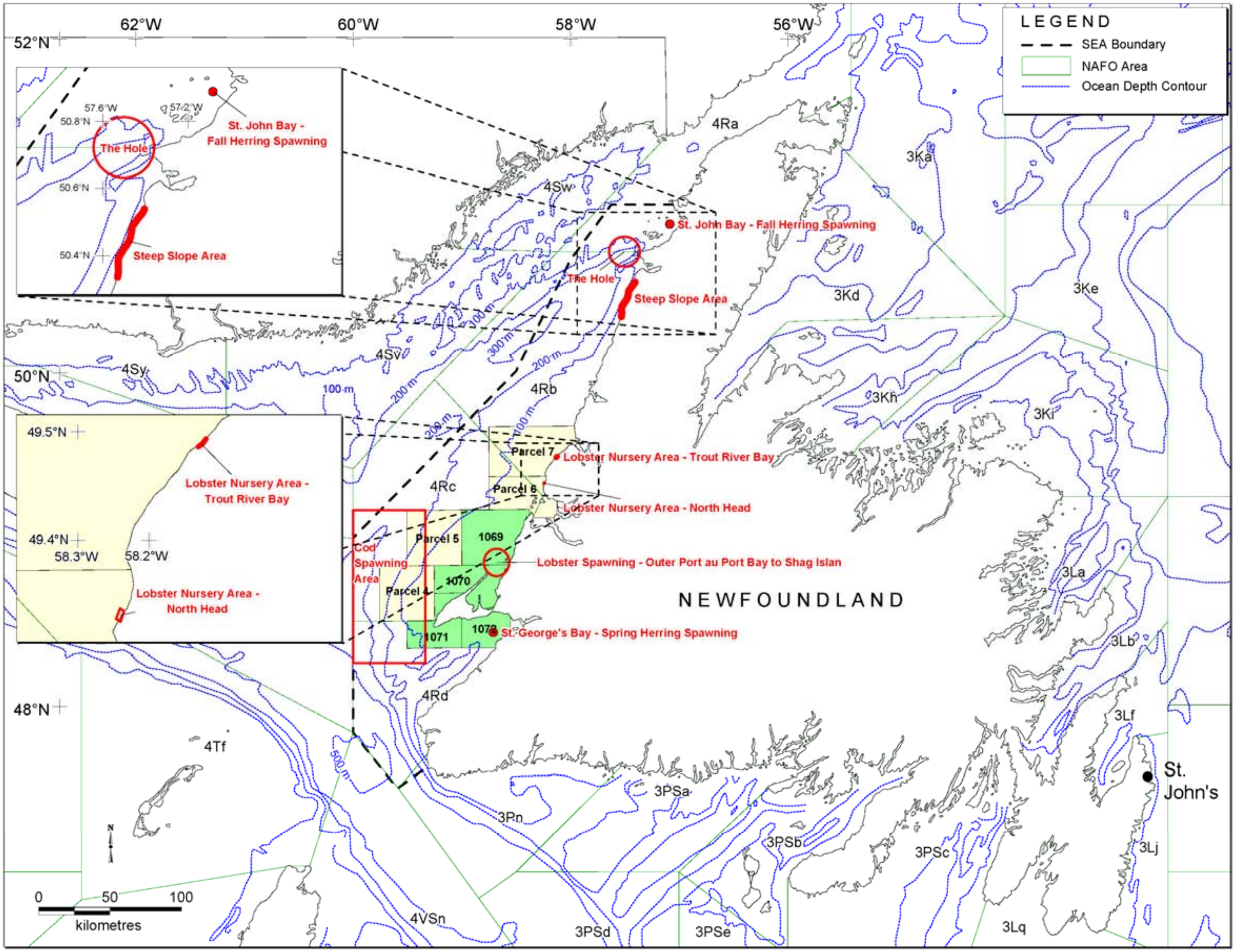


Figure 3.1. Potential Fish/Fisheries Related Sensitive Areas in the Study Area.

3.2.3 Data Gaps for Plankton

The most obvious data gap with respect to plankton concerns the spatial and temporal distributions of ichthyoplankton in the Study Area. Some spawning areas have been identified but little work has been done on the passive movements of planktonic fish and invertebrate eggs and larvae. This type of research would help to identify the plankton drift routes and, subsequently, more fish and invertebrate nursery areas.

Studies of phytoplankton and zooplankton distributions and their associations with ichthyoplankton (e.g., redfish-*Calanus* link) and higher trophic levels should continue.

3.3 Benthic Invertebrates

Benthic invertebrates are an important consideration because they are potentially most affected by disturbances to the seabed. They form an important link to higher trophic levels such as fish, birds and mammals.

Several literature reviews of coastal benthic resources of Newfoundland and Labrador are available (MacLaren 1977; South et al. 1979; Barrie et al. 1980; Campbell and Sutterlin 1981; Thompson and Aggett 1981; LeDrew 1984; Hardy 1985; Gilkinson 1986). In a literature review for marine benthic molluscs in the Newfoundland and Labrador waters, Gilkinson (1986) cites 147 references, noting that while several species have been studied rather intensively, most species have received only very cursory attention. These reviews highlight large gaps in the current knowledge of benthic ecosystems of coastal and offshore waters in the Newfoundland-Labrador region (Coady and Maidment 1984; Gilkinson 1986), with the exception of commercially important species such as the Atlantic sea scallop *Placopecten magellanicus* and the common blue mussel *Mytilus edulis*. A number of zoobenthic inventories have been compiled such as the Offshore Labrador Biological Studies program (OLABS) (Barrie et al. 1980; Barrie and Browne 1980) and others (Denbeste and McCart 1979; Gilbert et al. 1982), with studies targeted at specific coastal areas in Labrador.

For coastal Newfoundland waters, the majority of benthic community composition data exist as a result of EIS-support studies associated with offshore exploration for oil and gas (Barrie et al. 1980; Hutcheson et al. 1981; Hardy 1984) or data associated with research conducted at Memorial University or DFO. While benthic research in many cases has been intensive, the studies tend to be targeted to specific coastal areas or are concentrated in restricted time periods. In general, much of the coastline fauna of Newfoundland and Labrador remains to be inventoried (Gilkinson 1986) and there are considerable data gaps for certain geographic regions and deep-sea environments such as the continental margin and slope environments. Surveys that assess benthic community composition rather than species-specific studies are limited for this region.

Desrosiers et al. (2000) reported on a location in Cabot Strait (47º 40.3’N, 60º 00.0’W) (near offshore limit of UA 4Rd) which was sampled in November/December 1993 and June 1994. The depth of the station was 525 m. The dominant single sediment fraction was silt-clay. The intention was to examine the trophic structure of macrobenthic communities in the Gulf of St. Lawrence in relation to abiotic and biotic characteristics of the sampling sites. Both plankton and sediment were sampled at this station. Levels of both chlorophyll *a* and bacterial levels in sediments were higher in summer than in winter.

Macrofauna appeared to be distributed deeper in the sediment during winter than in summer. Most of the macrofauna individuals were found in the upper 10 cm of sediment during the winter. Approximately half of the macrofauna were surface deposit feeders while another 34% were subsurface deposit feeders. Omnivores and carnivores made up the remainder of individuals found. Summer sampling found a similar scenario. Surface deposit feeders at the Cabot Strait sampling site included Spionidae (*Laonice* sp.), Paraonidae (*Paraonis* sp.), and the Gammaridae (*Harpinia propinqua*). Subsurface deposit feeders at Cabot Strait included scaphopods (*Antalis occidentale*), bivalves (*Nuculana* sp.; *Nucula* sp.), and the mollusc Aplacophora (*Chaetoderma* sp.) (Desrosiers et al. 2000).

Deeper stations had lower macrofaunal biomasses, due mainly to smaller organisms and less food compared to the shallower benthic communities. Deep-water stations also had higher proportions of mobile and semi-mobile small organisms (Desrosiers et al. 2000).

Desrosiers et al. (2000) concluded that geomorphological characteristics (e.g., bathymetry, topography, substratum) influenced the trophic structure and composition of benthic assemblages at the Cabot Strait location. They also suggested that regular albeit relatively low-level inputs of particulate matter favour the development of benthic communities dominated by surface deposit feeders.

3.3.1 Intertidal Communities

Catto et al. (1999) presented intertidal biological shoreline units that were based on a scheme developed for the West Coast Newfoundland Oil Spill Sensitivity Atlas (Dempsey et al. 1995). These shoreline units have been designated on the basis of key biological indicators. They are as follow:

- Saltmarsh (fine substrate)
- Eelgrass (*Zostera*) (fine substrate)
- *Fucus anceps* Surf Zone (coarse substrate)
- Seabird-dominated Shores (coarse substrate)
- *Ascophyllum* Rockweed Shores (coarse substrate)
- Capelin Spawning Beaches (coarse substrate)
- Temporary Intertidal Communities (coarse substrate)
- Barachois Estuaries (fine substrate)

- Vertical Biological Zones (coarse substrate)
- Rockweed Platforms (coarse substrate)
- Periwinkle Shores (coarse substrate)

All of these shore unit types occur within the Study Area but the predominant types are beaches of coarse substrates such as pebble-cobble, sand-gravel, boulders and bedrock. Relatively few areas with finer substrates occur.

3.3.1.1 Periwinkle Shores

Periwinkle shores are similar to the rockweed platform shores except the substrate can include boulders, cobbles and fine gravel. The diversity of both plants and animals is lower. Typical animals on periwinkle shores include periwinkles, green sea urchins, polychaetes, nemerteans, amphipods, oligochaetes, nematodes, and even clams if there are patches of suitable sediment (Catto et al. 1999).

3.3.1.2 *Fucus anceps* Surf Zone

Fucus anceps surf zone shores are typical of extremely exposed bedrock shores subject to essentially continuous surf and pervasive fog (i.e., much of the northern part of the Study Area). Marine plants and animals colonize the rock faces well above the tidal zone. Pack ice can damage these communities by damping wave energy, thereby preventing the raised communities from receiving sea spray. Barnacles are typical animals observed in this type of habitat (Catto et al. 1999).

3.3.1.3 Seabird-dominated Shores

Seabird-dominated shores are typified by green to yellow-orange rock faces, coloured this way by nitrogen loving algae and lichens which thrive in seabird excrement (Catto et al. 1999).

3.3.1.4 Vertical Biological Zones

Vertical biological zones cover sheltered bedrock vertical cliff faces. Horizontal bands of lichens, seaweeds, and invertebrates form well-defined zones, commonly defined as characteristic in the biological literature. These vertical zones are most prominent along glaciated fjord walls (e.g., Bonne Bay in 4Rb). Typical fauna include periwinkles and mussels (Catto et al. 1999).

3.3.1.5 Rockweed Platforms

Rockweed platform exposed shores have an irregular rocky substrate which usually includes frequent tidepools. Some typical fauna include periwinkles, mussels, and barnacles (Catto et al. 1999).

3.3.1.6 Temporary Intertidal Communities

These communities form on rounded boulders that are stable in calm weather but less so under storm conditions. Pocket beaches backed by steep cliffs often develop a biota of rapidly growing, ephemeral seaweeds and invertebrates that are removed by every storm event. Typical animals found in these communities include copepods and amphipods. Species diversity tends to be low with very few species dominating (Catto et al. 1999). Boulder beaches occur throughout the Study Area.

3.3.1.7 Capelin Spawning Beaches

Capelin appear to prefer to spawn on wave-dominated, exposed fine gravel shorelines. Although these beaches might appear to be barren, they are distinguished by microscopic species of algae and invertebrates. In early summer, capelin eggs and dead capelin form the main food supply in this habitat. Numerous animals typically move into this habitat to feed during capelin spawning and incubation season in June/July. Although the biological assemblage of capelin beaches has been poorly studied to date, it is known to include nematodes and burrowing crustaceans (Catto et al. 1999). During SEA consultation meetings in July 2005, fishermen from western Newfoundland indicated that the coastal region immediately south of Port au Choix (4Rb) is a location of substantial capelin spawning activity.

3.3.1.8 *Ascophyllum* Rockweed Shores

These shores are dominated by carpets of yellow-brown fucoid seaweeds growing on bedrock and stable boulder substrata. Since these beds require several years of biological succession to develop, they cannot occur in areas that are regularly scoured by severe storms and sea ice. Common benthic invertebrates on *Ascophyllum* rockweed shores include periwinkles (*Littorina* spp.), polychaetes, hydroids, and bryozoans (Catto et al. 1999).

3.3.1.9 Saltmarsh

Saltmarsh shores are high intertidal areas dominated by vascular vegetation, especially grasses and sedges. Marsh vegetation entraps sediment, thereby stabilizing the shore. Saltmarsh habitats within the Study Area occur at St. Paul’s Bay (4Rb) and in parts of Bonne Bay (4Rb) (A. Laflamme, Environment Canada, pers. comm.). Typical Placentia Bay saltmarsh fauna are described in Catto et al. (1999) and include snails and amphipods.

3.3.1.10 Eelgrass (*Zostera*)

Zostera is normally found in sandy, relatively sheltered lowshore locations such as areas at the head of St. George’s Bay (4Rd; EL 1072). These areas tend to be quite productive and shelter many important commercial species. The sand surrounding the eelgrass roots typically contains a wide range of burrowing invertebrates, including softshell clams (*Mya arenaria*), lugworms (polychaetes), and sand shrimp (*Crangon septemspinosus*). Other fauna typically occurring in eelgrass habitats include hydroids, bryozoans and serpulids which attach themselves to seaweeds (Catto et al. 1999).

Eelgrass beds are generally important areas for salmon, trout and other fish. They not only serve as feeding zones but also as resting areas where fish can acclimatize physiologically between life in freshwater and life at sea. Eelgrass stabilizes sediment, often as much as 30 to 50 cm (Catto et al. 1999).

3.3.1.11 Barachois Estuaries

Barachois estuaries, as is present at the mouth of Grand Codroy River in 4Rd, are characterized by sedimentary bars that isolate lagoon-like water bodies with fresh water at surface and higher salinity waters below. These estuaries are biologically stressful sites, with low biological diversity and low productivity. Many estuaries shelter sea-run trout and/or salmon (Catto et al. 1999).

3.3.2 Subtidal Communities

Characteristic faunal species in the near shore on the shallowest parts of the Newfoundland continental shelf include green sea urchins, horse mussels, sea stars, lobsters and sometimes sea scallops. From the shallow subtidal (~10 m) to about 100 m depth where sand is the predominant substrate type, the dominant faunal species is typically the sand dollar. Snow crab is also abundant at this depth range, particularly if the substrate is coarser than sand (Steele 1983).

The following sections describe macrobenthos found at other subtidal locations on the Newfoundland and Labrador continental shelf at depths comparable to those in the Study Area. It is important to point out that the physical features of the marine environment of the Study Area and the restricted exchange of marine waters with the North Atlantic through the Cabot Strait and Strait of Belle Isle have created a environment different than that of the Atlantic offshore.

3.3.3 Grand Banks Continental Shelf (50 to 185 m)

Benthic data from the Grand Banks are of some relevance to those parts of the Study Area with similar physical conditions (e.g., substrate depth, etc.). In order to provide quantitative baseline data of macrobenthic community composition for the Grand Banks area, specifically the Hibernia region, Mobil Oil conducted a survey in 1980 (Hutcheson et al. 1981). Van Veen samples were collected and analyzed to assess sediment characteristics (grain size, organic content) and benthic community composition. The diversity recorded across all four major sampling stations was high with 343 different taxa in total. Polychaete worms were numerically dominant, however, molluscs and echinoderms accounted for the highest biomass. Small-scale variations in species distributions with changing sediment type were observed. The prevalent sediment types were sand and gravel with wide variations in the proportions of different grain size.

The dominant species and species assemblages in relation to grain size were also identified for the Grand Banks region from the Hibernia surveys. Polychaetes and infaunal bivalves were the dominant species. Sand dollars occurred at almost all stations and were considered to be a characteristic species of the Grand Banks benthos. Interestingly, five assemblages of benthic organisms were identified that varied with changing grain size. Species assemblages that were dominant in sandy habitats included the suspension feeding bivalve *Mesodesma deauratum*, amphipods, polychaetes, and sea cucumbers (notably *Stereoderma unisemita*). Polychaete worms dominated coarse sand habitats and included species such as *Exogone hebes*, *Glycera capitata*, *Parapionosyllis longicirrata* and *Laphania boecki*. A unique species assemblage was identified for habitats comprised of fine silt/clay particles. The crustacean *Harpinia plumosa*, unidentified tanaids, polychaetes *Prionospio steenstrupi* and *Onuphis conchylega*, and the cumacean *Eudorellopsis integra* dominated these sites.

Epibenthic megafauna have been assessed at a higher spatial resolution using photographic transects obtained using sled-mounted cameras (Schneider et al. 1987). Data collected from higher resolutions such as photographic data can provide information of epibenthic communities (benthic animals that live on or just above the sea floor). Photographic transects were taken on the northeastern edge of the Grand Banks in the Hibernia area (Schneider et al. 1987). An investigation of the distribution of megafauna relative to small and large-scale variation in substrate was assessed. Echinoderms (sea cucumbers, sand dollars, asteroids) were the most frequently encountered phylum. The next most abundant phyla were molluscs, annelids, and cnideria. Schneider et al (1987) identified correlations between megafauna and habitat variability (as determined by substrate type). Specifically they found that highly mobile swimming megafauna were less frequently correlated with local variability than non-swimming more sessile megafauna. Large-scale processes influencing the sedimentary cover on the Grand Banks include the hydrodynamic regime and physical forces such as tidal mixing, and reworking of the sediment due to seasonal storms (Barrie et al. 1984).

DFO conducted a 3-year otter trawling experiment on a sandy bottom ecosystem on the Grand Banks of Newfoundland (120 to146 m depths) from 1993 to 1995. The area was selected as it had not experienced trawling for at least 12 years and benthic fauna were sampled before and after trawling as well as in a reference area, hence information of non-disturbed benthic assemblages can be extracted from the before and reference data. Two hundred benthic samples were collected using a new grab-sampling device (0.5 m^2) equipped with a high-resolution video camera system. Samples contained 246 taxa, primarily polychaetes, crustaceans, echinoderms, and molluscs. Bivalves and sand dollars dominated in terms of biomass while abundance was dominated by polychaetes and bivalves (Kenchington et al. 2001). Prena et al. (1999) also report on data collected as part of the same experimental study to assess effects of otter trawling. Dominant species included, in decreasing order of mean biomass, echinoderns, crustaceans, molluscs and soft coral.

Data from all of the above studies conducted on the continental shelf of the Grand Banks suggest the diversity of benthic communities in this area is high. Polychaetes, crustaceans, echinoderms and molluscs were the dominant biota of these communities. Small-scale variations in species distributions with changing sediment type were also observed.

While the results of these studies may not closely reflect the biota comprising the subtidal communities in the Study Area, the community variability as it relates to substrate type and depth is likely similar in the Study Area.

3.3.4 Sensitive Species/Communities

Consistent responses of soft-sediment macrofaunal communities to anthropogenic disturbances in general include structural and functional changes, loss of habitat complexity, reduced diversity and productivity, and changes in the community composition to favour opportunistic species (Ellis et al. 2000). These consistent macrofaunal responses to stress can be used to identify species that are sensitive to anthropogenic disturbances and also investigate subsequent recovery dynamics of species at risk. In this respect, information that has been generated to determine responses of benthic communities in Atlantic coastal waters to fishing impacts can also be used to identify likely species that would be sensitive to other anthropogenic disturbances.

Experimental work conducted by DFO to assess impacts of trawling on benthic communities documented significant immediate declines associated with trawling activities in the abundance and biomass of a number of species (Prena et al. 1999; Kenchington et al. 2001). Benthic biomass of organisms in trawled corridors was on average 24% lower than for reference corridors (Prena et al. 1999). At the species level this biomass difference was significant for snow crabs *Chionoecetes opilio*, sand dollars *Echinarachnius parma*, brittle stars *Ophiura sarsi*, sea urchins *Strongylocentrotus pallidus* and soft corals *Gersemia* sp. The reduced biomass of epibenthic organisms in trawled corridors was hypothesized to be due to several integrating factors including direct removal by the trawl, mortality, damage, predation and migration. This research highlights the potential for detectable changes on both benthic habitat and communities due to otter trawling on sandy bottom ecosystems in the Grand Banks, in particular with significant reduction in the biomass of large epibenthic fauna.

As part of the same experimental trawling impact study, Kenchington et al. (2001) found 12 taxa representing eight families and five orders of the Polychaeta, which appeared to have dynamic population responses to physical disturbance. They included *Chaetozone setosa* and four other sedentary filter- or deposit-feeding spionids, which tend to be small and short-lived (<2 years), with possibility more than one recruitment period per year (Fauchald and Jumars 1979). Four were errant burrowers of the families Opheliidae, Paraonidae, and Phyllodocidae, plus juveniles of the equally motile polynoids and two capitellid deposit feeders, one of which is a tube-building species. Dynamic changes in polychaete populations in response to disturbance are well documented. Their rapid recoveries are attributed to the opportunistic nature of the mobile, scavenging species and the ability of surface tube dwellers to reproduce and in some cases regenerate rapidly. While many polychaetes have the potential for rapid recovery, Kenchington et al. (2001) note that the presence of bioturbators such as sand dollars and some polychaetes, opens the potential for substantial changes in community structure associated with trawling-induced changes in their abundance. The actions of bioturbators provide a habitat complexity that can be critical to the maintenance of species diversity in unconsolidated sediments (Thistle and Eckman 1990). Sand dollars in particular are considered to be critical in structuring sandy-bottom benthic communities. Their movement and burrowing activity particularly affect tube-dwelling polychaetes and the meiofauna (Brenchley 1981). While polychaetes have the potential for rapid recovery following disturbance events, sand dollars have an average life span of eight years and are unable to survive damage to their tests requiring careful consideration of impacts to such key species.

In summary, consistent responses of benthic communities to anthropogenic disturbances such as trawling (and potentially oil production activities such as glory hole excavation or pipeline construction) include reductions in the abundance and biomass of large long-lived epifaunal species and sessile organisms. These types of responses are likely exhibited by benthic communities occurring in the Study Area. The most vulnerable seabed habitats are those with a high degree of structural complexity with an abundance of surface-dwelling flora and fauna such as soft or hard corals and sponges, which could sustain long-term damage through even limited disturbance. Vulnerable species such as sand dollars have key roles in the functioning and structure of benthic communities.

3.3.5 Existing Disturbances in the Western Newfoundland Offshore Area

The main identifiable anthropogenic disturbance presently occurring in Canadian Atlantic waters is due to commercial fishing activities. The effects of these activities range from removal of target and bycatch species to alteration of the proximate benthic habitat and communities. Mobile fishing gear is a widespread cause of physical disturbance to the global continental shelf benthos (Dayton et al. 1995), where large bag or semi-rigid box structures are dragged across the ocean floor. While a number of studies have been conducted on the impacts of fixed gear (gillnets, longlines, traps, etc.) on seabed habitat and communities, the effect of non-mobile gears are expected to be substantially less than those of mobile gears, namely trawls (Kulka and Pitcher 2001). Numerous studies worldwide have documented damage to benthic habitats as a result of trawling (MacDonald et al. 1996; Jennings and Kaiser 1998; Lindeboom and de Groot 1998; Watling and Norse 1998; Hall 1999; Auster and Langton 1999; Collie et al. 2000; WGECO 2000; Thrush et al. 2001). While the results of specific experiments are dependent on the conditions under which they were conducted, it is clear from recent literature that among other conclusions, effects of otter trawling on seabed habitat and communities can be detected and are dependent upon at least three factors: (1) fishing history (intensity and frequency of trawling), (2) type of habitat, and (3) the kinds of organisms present (Kulka and Pitcher 2001).

Trawling occurs in the Study Area where Atlantic cod and redfish are harvested with otter trawls and shrimp trawls are employed to catch northern shrimp. DFO has analysed trawling in Canadian Atlantic and Pacific waters as part of a program to assess the effect of trawling on benthic habitats of the Atlantic and Pacific using a Geographic Information System (GIS) (Kulka and Pitcher 2001). Data from the Fisheries Observer Program for the period 1980-2000 (Atlantic) and 1994-2000 (Pacific) in the form of geo-referenced fishing set locations were used to spatially describe trawl effort location. The primary output are maps depicting the area scoured at varying levels of intensity, hence providing information of bottom disturbance due to trawling. Maps of the extent and intensity of trawling over 21 years for|

Atlantic waters indicate a patchy and complex pattern of trawling for a wide range of groundfish species and shrimp. Although patterns of trawling changed quite dramatically over the time sequence analysed, locations of high intensity trawling were fairly similar from one year to the next. Throughout the 1980s there were numerous persistent core areas of trawling spread mainly along the shelf edge and between the banks. In the early 1990s, fishing patterns changed dramatically in most areas. As the groundfish stocks collapsed and fisheries were closed, the extent of area fished diminished. The only place on the Grand Banks where fishing was sustained over the entire period was along the southwest slope. Trawling was moderately persistent (9 of 21 years) on the central part of the Grand Bank, along the shelf edge centered at Lat 49º and in a few small areas to the north on the outer shelf. Trawling activity was concentrated on the outer shelf and in the trenches between the banks for two reasons: (1) because this is where the fish and invertebrates of commercial size concentrate and (2) because the grounds in these areas are sufficiently smooth (even bottom and free of snags that can damage the gear) (Kulka and Pitcher 2001).

The research on trawling provides an excellent source of knowledge of historical disturbance due to fishing activities as well as information of undisturbed benthic habitats. In order to assess the effects of anthropogenic disturbances such as trawling on benthic habitats one must be able to differentiate gear effects from physical stresses imposed by storm waves, tidal currents, ice scour, sediment transport, as well as biological influences from predation and bioturbation activities. By obtaining information of undisturbed environments, natural variation (both spatial and temporal) can be assessed relative to changes caused by human activities such as fishing and oil exploration and production.

3.3.6 Deep-water Corals

Tropical shallow-water corals have been well studied and are noted for their high diversity. It is less well known, however, that corals (e.g., scleractinians and gorgonians) are widespread in cold temperate waters (Buhl-Mortensen and Mortensen 2003), and have similarly high faunal assemblages associated with coral reefs constituting high biodiversity habitats (Jensen and Frederiksen 1992; Mortensen 2001). Deep-water gorgonian corals are found in oceans around the world most commonly at depths on the order of 200-1,500-m (Genin et al. 1986; Mistri and Ceccherelli 1994) and are considered to be important components of deep-water ecosystems (Rogers 1999; Krieger and Wing 2002). In general, there is limited knowledge of the distribution, habitat, age composition and biological aspects of these deep-water coral habitats (Mortensen et al. 2002). The development of remotely operated vehicles (ROV) or submersibles has provided the ability to sample deep-water habitats although investigations are still limited due to the expense of sampling.

There is growing concern that fishing and oil and gas exploration activities that are moving into deeper waters may damage these coral habitats (Probert et al. 1997; Reed 2002). While there is limited research on the effects of oil exploration activities, evidence of physical damage to coral reefs where sea-fans and coral ‘trees’ are broken or removed due to trawling and longline fishing activities have been documented for Atlantic Canadian waters (Mortensen et al. 2002). Documented anthropogenic impacts include the immediate consequences of physical damage to coral fans with subsequent slow recovery rates, as well as the potential for secondary effects due to alterations in associated benthic and fish communities. Visual surveys can be used to assess areas where coral communities occur at relatively high abundances. For example, in June 2002 DFO established a “Coral Conservation Area” in the Northeast Channel off Nova Scotia after reviewing preliminary results from video records and photographic transects taken using an ROV. Currently finer scale visual information is limited for the Grand Banks and offshore continental slope area. However, it is known that deep-water gorgonians occur off Atlantic Canada on the continental slope, in submarine canyons, and in channels between offshore banks (Verrill 1922; Deichman 1936; Breeze et al. 1997; MacIssac et al. 2001; Mortensen et al. 2002)

Within these habitats they are locally abundant on hard substratum including cobbles and large boulders and in high current areas (Tendal 1992). These environments are therefore the habitats in the Western Newfoundland and Labrador Offshore Area where the highest abundances of these vulnerable coral-assemblage communities may occur.

3.3.7 Planning Implications for Benthic Invertebrates

Benthos is relevant to offshore planning because benthic communities are relatively immobile, are directly affected by drilling discharges and accidental spills (particularly in shallow areas), are an important link to commercial fisheries, and generally exhibit some level of zonation in their distribution. Macrobenthos in the Study Area that are particularly important to fishermen on the west coast of Newfoundland include lobster and snow crab. These are presently the two most valuable commercial species in the Study Area. There is also potential for suitable habitat to support corals. In most coastal and slope areas of North America such as the West Coast, Gulf of Mexico, and U.S. East Coast, there is sufficient information linking specific benthic assemblages to specific depth ranges. It is known that benthic invertebrate community characteristics are directly linked to the physical characteristics of an area. There are a variety of shore types (Sections 2.1.3 and 3.3.1) in the Study Area, indicating a variety of benthic community types. Different shoretypes also have varying levels of sensitivity to the various potential effects of oil and gas activities. Operators may have to collect baseline benthic data in support of exploratory drilling applications.

3.3.8 Data Gaps for Benthic Invertebrates

Because of the commercial importance of macrobenthic invertebrates, more is known about these species compared to non-commercial infauna and epifauna. Overall, however, intertidal and subtidal benthic invertebrate communities in the Study Area are not well understood. Obvious data gaps for benthic invertebrates in the Study Area relate to distributional and biological aspects of corals. The interactions between benthic invertebrates and both lower and higher trophic organisms are also not well understood.

3.4 Fish and Fisheries

3.4.1 Important Commercial Invertebrate Species

3.4.1.1 Lobster

Lobsters (*Homarus americanus*) are distributed nearshore around the island of Newfoundland, including the west coast of Newfoundland. Lobster populations tend to be very localized in nature. The major lobster life history events (i.e., molting, spawning, larval hatching) typically occur between mid-summer and early fall, following the spring fishery (DFO 2003).

Mating between male and female American lobsters usually occurs immediately following the female's shedding of her old shell (molting or ecdysis) during the summer months (Aiken and Waddy 1980). The sperm is stored in a receptacle on the underside of the female's body and carried by the female until she spawns the following year. At that time, the eggs are pushed from the ovaries and fertilized as they pass through the sperm receptacle. The fertilized eggs are extruded and attached to long hairs on the female's pleopods.

The female carries the embryos until the following summer when the pre-larvae hatch and remain attached until they molt into the first larval stage within 24 hours of hatching (Charmantier et al. 1991). Hatching can occur over a wide range of temperatures during the May to July period on the Atlantic coast of North America (Ennis 1995). Hatching generally begins around 10 to 15 ºC and is most intense at 20 ºC (Hughes and Matthiessen 1962). The female then releases the first stage larvae by fanning her pleopods. The larvae may be released over a period of time from a few days to a few weeks. There is normally a two-year period between mating and pre-larval hatch (i.e., a two-year reproductive cycle) (Ennis 1995).

The three distinct larval stages are planktonic, generally found in the upper two to three m of the water column during a two to eight-week period (Hudon et al. 1986). Field studies have suggested that the maximum depth of decapod larval vertical migration is related to the depth of the thermocline (Harding et al. 1987). During this time, lobster larvae are passive drifters so their gross movements are largely controlled by the direction of the wind and water currents. Both are generally onshore during the regular time of larval release. Hudon and Fradette (1993) described the wind-induced advection of larval decapods, including lobster, into a bay of the Magdalen Islands in the southern Gulf of St. Lawrence.

Settling postlarval lobster typically prefer inshore habitat with gravel/cobble substrate (Palma et al. 1999) and kelp cover. During their study in the Gulf of Maine, Palma et al. (1999) observed a conspicuous lack of newly settled lobsters on adjacent finer-sediment substrata. However, lobsters more than 1 year old were found on the finer-sediment substrata. In terms of settlement depth, newly settled lobsters were found on collectors at five and 10 m but not at 20 m.

During SEA consultations with fishermen in July 2005 (Appendix 1), the inshore area between the outer portion of Port au Port Bay and Shag Island to the north (4Rc) was identified as prime lobster spawning area (Figure 3.1). Fishermen indicated that that lobster fishing grounds in the area between Long Point (outer Port au Port Bay) and Shag Island generally yield very large females. Fishers also noted lobster nursery areas near Shoal Point, Outer Bay of Islands located just above North Head (LFA 13B; Parcel 6), and at an area further north known as Trout River Bay (LFA 14A; Parcel 7). These two areas are presently closed to the lobster fishery as a means of conservation. The areas are defined as follow:

Corner coordinates of area in LFA 13B/ Bid Parcel 6

49º 19’ 25’’ N, 58º 14’ 23” W
49º 19’ 35’’ N, 58º 14’ 45” W
49º 20’ 10’’ N, 58º 14’ 25” W
49º 20’ 00’’ N, 58º 14’ 05” W

Headland to headland coordinates of area in LFA 14A/Bid Parcel 7

49º 29’ 30’’ N, 58º 07’ 12” W
49º 28’ 56’’ N, 58º 07’ 24” W

Increases in lobster landings were reported in west coast LFAs 13A (4Rd), 13B (4Rc) and 14A (part of 4Rb) in 2001 and 2002. However, these landings are still low compared to those of the early 1990s. Fishermen consulted in July 2005 identified the Port au Port Bay region as having both male and female lobsters larger than those in other areas along the coast. The lobster is an important commercial species throughout the nearshore area in the Study Area, including the section of coastline in Parcels 6 and 7.

3.4.1.2 Snow Crab

Snow crab (*Chionoecetes opilio*) is a decapod crustacean that occurs over a broad depth range (50 to 1,300 m) in the Northwest Atlantic. The distribution of this decapod in waters off Newfoundland and southern Labrador is widespread but the stock structure remains unclear. Snow crabs have a tendency to prefer water temperatures ranging between –1.0 and 4.0ºC. Large snow crabs (≥95-mm carapace width or CW) occur primarily on soft bottoms (mud or mud-sand) (DFO 2005a), particularly in water depths of 200 to 500 m. Small snow crabs appear to be most common on relatively hard substrates (DFO 2005a). Mating generally occurs during the early spring and the females subsequently carry the fertilized eggs for about two years. Large numbers of sexually paired snow crabs have been observed in relatively shallow water (10 to 40 m) during late April/early May at Bonne Bay, Newfoundland (Taylor et al. 1985; Hooper 1986; Ennis et al. 1990). The pairs were found in algal covered boulder slopes less than one kilometre away from areas of depth >100 m. Level sand or mud substrates supported lower densities of paired snow crab but were the main sites where feeding was observed. The larvae hatch in late spring or early summer, and then remain in the water column for 12 to 15 weeks before settling on the bottom (DFO 2005a).

Comeau et al. (1998) studied a relatively unexploited stock in Bonne Bay, Newfoundland. In that study, relative abundance of early benthic to commercial-size individuals suggested that small immature crabs migrate from shallow rocky areas to deep muddy bottom areas. The patchy spatial distribution observed for the snow crab in Bonne Bay appeared to be determined more by substrate and intraspecific factors than by depth. Seasonal movements to shallow waters by larger crabs were related to density- and temperature-dependent factors associated with the reproductive and growth cycle.

Snow crab typically feed on fish, clams, polychaete worms, brittle stars, shrimp and crustaceans, including smaller snow crab. Hooper (1986) observed the feeding behaviour of sexually paired snow crabs in shallow water at Bonne Bay, Newfoundland during April and May. The most favoured natural prey types of the snow crab were polychaetes, ophiuroids and bivalves although the most frequently eaten food was fish used as lobster bait.

During recent years, most of the snow crab catches have occurred in Unit Area 4Rc, the northern part of 4Rd and southern 4Rb. There has been a pronounced change in the distribution of effort from north to south in recent years (DFO 2005a). In 2004, snow crab catches were made inside all four Bid Parcels.

The snow crab fishery in the area that overlaps with the 4Ra and northern 4Rb portions of the SEA Study Area was placed under moratorium in 2003 (DFO 2004a). Recent trap survey results give no indication that the critical state of the snow crab resource will improve appreciably in the short term (DFO 2005a).

3.4.1.3 Northern shrimp

Northern shrimp (*Pandalus borealis*) mating takes place in the fall and the females carry the fertilized eggs for about eight months (September to April). Larvae are pelagic upon hatching in the spring but eventually settle to the bottom by late summer. Shrimp migrations tend to be associated with breeding (berried females move into shallower waters in winter) and feeding (upward movement in water column at night to get to plankton). Northern shrimp are generally found in areas with water depths ranging between 150 and 350 m (DFO 2004b).

Most of the shrimp catches in the Study Area are made in Unit Area 4Rb, followed by 4Rc. Essentially all of the recent northern shrimp catches have occurred outside of all four Bid Parcels. Division 4R falls within the Gulf of St. Lawrence shrimp fishing area 8, otherwise known as Esquiman. Research survey indices in Esquiman were very high in 2003, well above the 1990-1999 mean.

3.4.2 Important Commercial Fish Species

3.4.2.1 Atlantic Cod

Northern Gulf of St. Lawrence cod (*Gadus morhua*) (NAFO Divisions 3Pn and 4RS) undertake extensive migrations. In winter, they aggregate off southwestern and southern Newfoundland at depths of more than 400 m (4Rd) (Castonguay et al. 1999). In April/May, they move towards the Port au Port Peninsula (UA 4Rcd) near Parcels 4 and 5 where spawning commences (DFO 2005b; Ouellet et al. 1997). In 2002, a new zone was established just off the Cape St. George Cod Spawning Area that is closed to all groundfish fishing between April 1st and June 15th (see Figure 3.1). Cod spawn in the area during this period. The Cape St. George Cod Spawning Area is presently defined by the following corner coordinates:

48º 15’ N	59º 20’ W
49º 10’ N	59º 20’ W
49º 10’ N	60º 00’ W
48º 15’ N	60º 00’ W

During summer, the cod continue their migration and disperse towards the coastal zones along the west coast of Newfoundland (4R) and towards Quebec’s Middle and Lower North Shore (4S). This migration towards the coastal regions appears to be associated with warmer water and the presence of capelin, the primary prey of the cod (DFO 2005b).

According to DFO, the abundance and spawning stock biomass of the northern Gulf stock remain low despite that since 1997, the commercial fishery has been conducted by fixed gears only (longlines, gill nets and handlines) (Fréchet et al. (2003). The spawning stock biomass increased between 1994 and 1999 but subsequently declined between 2000 and 2002. The cod fishery was under moratorium in 2003 and then re-opened under small quotas in 2004. The 2004 cod catches were distributed primarily in the northern part of the Study Area, from nearshore to the extreme offshore. With respect to the Parcels up for bids, Parcel 7 reported the most cod catches, followed by Parcel 6. Catches tended to be in the nearshore areas of these Parcels. Few catches were reported in Parcels 4 and 5.

3.4.2.2 Mackerel

The Atlantic mackerel (*Scomber scombrus*) is a pelagic fish common to temperate waters of the open sea and is one of the most active and migratory of fishes. They winter outside of the Gulf of St. Lawrence but migrate to the Gulf of St. Lawrence in spring to spawn in the Magdalen Shallows (outside of the Study Area). Spawning typically occurs between mid-June and mid-July in open water, resulting in a concentration of fertilized eggs in the upper 10 m of the water column. Larval hatching generally occurs within five to seven days at water temperatures of 11 to 14ºC (Scott and Scott 1988).

The purse seine fishery for mackerel in 4R has grown substantially during recent years. In 2003 and 2004, landings of 4R catches have been 3 to 4 times the 1990 to 2003 average (DFO 2005c). Highest catches of mackerel in the Study Area typically occur in Unit Areas 4Rc and 4Rd during September and October. Mackerel catches commonly occur in the nearshore areas of Parcels 6 and 7.

3.4.2.3 Herring

Atlantic herring (*Clupea harengus harengus*) is primarily pelagic and often schools, particularly just prior to spawning. Along the Canadian coast, Atlantic herring may spawn in any month between April and October, but spawning is concentrated in May (spring spawners) and September (fall spawners) (Ahrens 1993).

Atlantic herring are demersal spawners depositing their adhesive eggs on stable bottom substrates (Scott and Scott 1988; Reid et al. 1999). Spawning may occur in offshore waters (e.g., Georges Bank) at depths of 40 to 80 m; however, most Atlantic herring stocks spawn in shallow (<20 m) coastal waters, and it appears that in the Newfoundland region Atlantic herring spawn in coastal waters only. In the case of coastal spawning, spring spawning generally takes place in shallower waters than fall spawning. For example, in coastal waters in the Gulf of St. Lawrence, Tibbo et al. (1963) suggested that spring spawning largely takes place in waters four to six m deep while fall spawning takes place at depths of 18 to 22 metres. Tibbo (1956) also adds that the main spawning areas are located at the heads of the various bays and deepwater inlets around insular Newfoundland. In their review of Atlantic herring spawning grounds in the Northwest Atlantic Reid et al. (1999) report that spawning on stable substrates in shallow waters close to shore insures that the eggs will be exposed to well-mixed water, and tidal currents averaging .75 to 1.5 m/sec have been recorded in the area of Atlantic herring spawning beds. These high-energy environments provide aeration and reduce siltation and accumulation of metabolites (Reid et al. 1999).

Recently hatched Atlantic herring larvae are pelagic. The duration of the larval stage of fall spawned herring is more extensive (i.e., lasts through the winter months) than spring spawned herring. Some larvae are retained in tidally energetic areas near the spawning site for several months after hatching, while other larvae are dispersed soon after hatching and drift with residual currents.

Important spring (May to June) herring spawning grounds exist in St. George's Bay (4Rd) (see Figure 3.1). There are also indications of spring spawning in 4Ra. Fall spawning occurs mainly in 4Ra from mid-July to mid-September. Important feeding areas for herring occur in St. George's Bay (4Rd) in the spring, in southern 4Ra in the summer, and in north 4Ra in the fall. These Gulf herring overwinter in Esquiman Channel (DFO 2004c).

Large herring catches are made on the west coast of Newfoundland in all of Division 4R, primarily with purse seiners. Gill nets are also used after the seine fishery. Between 1990 and 2002, the highest average annual landings of herring occurred in 4Rc (5,052 mt), 4Rd (4,332 mt), 4Rb (4,127 mt) and finally 4Ra (1,786 mt) (DFO 2004c). Most of the 2004 herring catches in 4Rc and 4Rd occurred in October and November. Herring catches commonly occur in the nearshore areas of Parcels 6 and 7.

3.4.2.4 Capelin

Capelin (*Mallotus villosus*) overwinter in offshore waters, move shoreward in early spring to spawn on beaches throughout the region in the spring-summer, and return to offshore waters in autumn. A combination of factors determine beach suitability as well as when and where beach spawning will occur, these include temperature, substrate type, tidal phase, and light conditions (Templeman 1948). Generally, where substrate conditions are suitable (see below) spawning beaches may be found in exposed, moderately exposed, and sheltered locations throughout the region. Beach spawning is demersal with the eggs being deposited in the intertidal zone. However, occurrence of egg masses indicate that subtidal spawning occurs to depths ranging from approximately one to 37 m and up to approximately 400 m from shore in years and areas where water temperatures on the beaches exceeds the preferred spawning temperatures (Templeman 1948). In the Newfoundland region beach spawning may occur over a wide range of temperatures from 2.5 to 10.8° C (Frank and Leggett 1981). Subtidal spawning is assumed to be variable from year-to-year.

The size of the substrate on the beach will determine the suitability of the beach for spawning with capelin usually preferring gravel five to 15 mm in diameter (Templeman 1948). When the most favoured substrate is occupied, or not available because of tidal conditions beach spawning capelin may spawn on sand less than 2 mm in diameter or on larger gravel up to 25 mm in diameter (Templeman 1948). Capelin do not spawn on larger substrates or mud (Templeman 1948). However, it appears that eggs may incidentally adhere to rocks, large boulders, and macroalgae when they are present among preferred substrates (Templeman 1948). Subtidal spawning inshore appears to be predominantly on sand (Templeman 1948).

Spawning occurs with one or two males accompanying a female as they are carried onto the beach by an incoming wave. They swim up the beach as far as possible, where they are temporarily stranded as the wave recedes. Eggs and sperm are shed on the beach surface, then the fish return to the water on the next series of waves. Fertilized eggs adhere to the substrate while wave and tidal action distributes the eggs over the breadth of the intertidal zone to depths of 15 cm or more below the beach surface. The eggs develop and hatch in the beach substrate. Juvenile capelin are found in bays surrounding insular Newfoundland; however, most larvae are rapidly carried out of the bays and inshore areas by surface currents.

Unit Areas 4abc account for much of the capelin landings in 4RST. Capelin on the west coast of Newfoundland have shown a recent size increase but are still smaller than those observed in 1980s. The capelin fishery is primarily a purse seine fishery (76% in 4R in 2004), along with some catches by trap (24%). The most intensive capelin fishery in 4R occurs in June and July. The purse seine fishery typically occurs near the stretch of coast between Bonne Bay and Port au Port (i.e., 4Rbc, including nearshore areas of Parcels 6 and 7). Between 2000 and 2004, the most highly concentrated capelin catches occurred in Port au Port Bay (4Rd), and between Bay of Islands and Bonne Bay (4Rc; Parcels 6 and 7) (DFO 2005d). SEA consultations in July 2005 noted remarks by fishermen that capelin are particularly plentiful along a section of coast south of Port au Choix. The slope in this area is relatively steep compared to areas further south.

3.4.2.5 Redfish

Redfish typically occur in cool waters (3.0 to 8.0ºC) along the slopes of fishing banks and deep channels in depths of 100 to 700 m. In the western Atlantic, redfish species range from Baffin Island in the north to the waters off New Jersey in the south. The three redfish species that occur in the Northwest Atlantic include *Sebastes mentella*, *S. fasciatus*, and *S. marinus*. The latter species is relatively uncommon except in the area of the Flemish Cap so for the purposes of this assessment, only *S. mentella* and *S. fasciatus* will be considered. *S. mentella* is typically distributed deeper than *S. fasciatus* (Gascon 2003).

Redfish are described as lecithotrophic viviparous with internal fertilization. Mating occurs in the fall months and the larvae subsequently hatch from the eggs inside the female. The larvae feed exclusively on energy stored in the yolk, develop inside the female and eventually are released as young fish sometime between April and July (Gascon 2003; Ollerhead et al. 2004). Based on DFO research vessel survey data collected from 1995 to 2002, Ollerhead et al. (2004) indicated the peak of redfish spawning to be in April. Release of the young occurs in NAFO Subdivisions 3Ps and 4Vn, particularly along the western slope of the St. Pierre Bank, in the deeper waters of the Laurentian Channel, and along the slope region of southern St. Pierre Bank to south of Green Bank (JWEL 2003; Ollerhead et al. 2004). DFO research survey data collected in May between 1998 and 2002 indicated the occurrence of relatively intense redfish spawning along the slope region of southern St. Pierre Bank, southern Halibut Channel and southern Green Bank (Ollerhead et al. 2004). Research survey data collected in July, 1998 to 2002, also indicated spawning activity, albeit at less intense levels. The July spawning was occurring in locations similar to the May spawning (Ollerhead et al. 2004).

The live young aggregate in the surface waters at night but during the day they are found in or below the thermocline at a depth of 10 to 20-m (Fortier and Villeneuve 1996 *in* JWEL 2003). Smaller redfish often inhabit shallower waters while the larger redfish occur at greater depths (McKone and LeGrow 1984 *in* JWEL 2003). Redfish are pelagic predators, feeding primarily on copepods, amphipods, and shrimp (Rodriguez-Marin et al. 1994 *in* JWEL 2003), and sometimes on capelin (Frank et al. 1996 *in* JWEL 2003).

Redfish have large swimbladders and exhibit semi-pelagic shoaling behaviour. Gauthier and Rose (*in* Gascon 2003) reported that redfish perform regular diel vertical migrations. They exhibited consistent patterns of vertical migration in winter, spring and summer that appeared to be limited by hydrostatic pressure. Gauthier and Rose (*in* Gascon 2003) found that the hydrostatic pressure at the upper range of the vertical migration was never less than 67% of the pressure at the bottom. This vertical migration seemed to be a foraging strategy used to follow the movement of their euphausiid prey. The authors reported that redfish were on or near bottom during the day and higher up in the water column at night. Gascon (2003) indicated that the migration and movement patterns of redfish in the Laurentian Channel are poorly understood.

One of the currently identified concentrations of Gulf redfish is located in the Cabot Strait area in 4R (i.e., southern 4Rd) (DFO 2004d).

3.4.2.6 Greenland Halibut

The Greenland halibut (turbot) (*Reinhardtius hippoglossoides*) is a deepwater flatfish species that occurs in water temperatures ranging between –0.5 to 6.0ºC but appears to have a preference for temperatures of 0 to 4.5ºC. In the Northwest Atlantic off northeastern Newfoundland and southern Labrador, these fish are normally caught at depths exceeding 450 m. Reported depths of capture range from 90 to 1,600 m. The larger individuals tend to occur in the deeper parts of its vertical distribution. Unlike many flatfishes, the Greenland halibut spends considerable time in the pelagic zone (Scott and Scott 1988).

These halibut are believed to spawn in Davis Strait during the winter and early spring at depths ranging from 650 to 1,000 m. They are also thought to spawn in the Laurentian Channel and the Gulf of St. Lawrence during the winter. The large fertilized eggs of this species (4.0 to 5.0-mm diameter) are benthic but the hatched young move upwards in the water column and remain at about 30 m below surface until they attain an approximate length of 70 mm. As they grow, the young fish move downward in the water column and are transported by the currents in the Davis Strait southward to the continental shelf and slopes of Labrador and Newfoundland (Scott and Scott 1988).

Greenland halibut are voracious bathypelagic predators that feed on a wide variety of prey. Summer and fall appear to be the seasons of most intense feeding. Prey items include capelin, Atlantic cod, polar cod, young Greenland halibut, grenadier, redfishes, sand lance, barracudinas, crustaceans (e.g., northern shrimp), cephalopods and various benthic invertebrates. Major predators of Greenland halibut include the Greenland shark, various whales, hooded seals, cod, salmon and Greenland halibut (Scott and Scott 1988).

This flatfish is typically found in the channels of the Gulf of St. Lawrence at depths ranging from 130 to 500 m. Based on genetic research, there are indications that the Gulf of St. Lawrence stock of Greenland halibut may complete its entire life cycle within the Gulf (DFO 2005e). Spawning takes place primarily in winter, between January and March.

Newfoundland-landed catch distributions in 2004 indicated that most of the Greenland halibut caught within the Study Area were taken in Unit Area 4Rb beyond the 100 m isobath. Some were also caught in St. George's Bay and along the southwest coast in 4Rd. Catches within the Parcels between 1999 and 2004 have been minimal. Most catches in 2004 were made between May and July.

3.4.2.7 Atlantic Halibut

Atlantic halibut (*Hippoglossus hippoglossus*), the largest of the flatfishes, is typically found along the slopes of the continental shelf. Atlantic halibut move seasonally between deep and shallow waters, apparently avoiding temperatures below 2.5ºC (Scott and Scott 1988). The spawning grounds of the Atlantic halibut are not clearly defined. The fertilized eggs are slightly positively buoyant so that they naturally disperse and only gradually float toward the ocean's surface. Once hatched, the developing larvae live off their yolk for the next six to eight weeks while their digestive system develops so they can begin feeding on natural zooplankton. After a few weeks of feeding, they metamorphose from a bilaterally symmetrical larva to an asymmetrical flatfish, and are ready to assume a bottom-living habit. At this point they are approximately 20-mm long. As juveniles, Atlantic halibut feed mainly on invertebrates, including annelid worms, crabs, shrimps, and euphausiids. Young adults (between 30 to 80-cm in length) consume both invertebrates and fish, while mature adults (greater than 80-cm) feed entirely on fishes (Scott and Scott 1988).

Atlantic halibut in the northern Gulf of St. Lawrence are most abundant in the Esquiman, Laurentian and Anticosti Channels at depths >200 m. Based on observations made during scientific trawl surveys, these halibut are able to spawn in January and May (timing of surveys). Tagging studies have indicated that Atlantic halibut of this stock do not move far from their home range (DFO 2005f).

Most of the Atlantic halibut caught within the Study Area and landed at Newfoundland ports in 2004 were taken in the offshore areas of 4Rb, primarily beyond the 200 m isobath. Scattered catches were reported in all four Parcels as well as in 4Rd. Most Atlantic halibut catches within the Study Area occurred between May and July.

Overall, the 4RST Atlantic halibut stock remains at a very low level. Although recent commercial fishery landings have been increasing, the average of the landings over the last five years remains well below those in the 1960s (DFO 2005f).

3.4.2.8 Witch flounder

Landings of witch flounder (*Glyptocephalus cynoglossus*) in 4R during the mid 1990s were low but they recovered in 1998. Most of the recent 4R witch flounder fishing has occurred in 4Rd between May and October in St. George's Bay. Witch flounder are known to spawn in St. George's Bay. The biomass index for witch flounder in 4R remains below that seen in 1980s (DFO 2004e).

3.4.2.9 American plaice

American plaice (*Hippoglossoides platessoides*) occur primarily in the southern Gulf of St. Lawrence (DFO 2004f) but some are taken as bycatch in the 4R fisheries.

3.4.2.10 White hake

The white hake (*Urophycis tenuis*) Gulf stock occurs primarily in the southern Gulf of St. Lawrence (DFO 2004g) but some are taken in 4R fisheries.

3.4.3 Important Non-commercial Fish Species

3.4.3.1 Atlantic Salmon

Within the SEA Study Area, there are more than 30 scheduled Atlantic salmon (*Salmo salar*) rivers distributed somewhat evenly throughout the area. While the commercial fishery for this species is under moratorium, Atlantic salmon remains an important recreational fishery species in Newfoundland and Labrador. This anadromous fish spends time in both freshwater (spawning) and at sea (feeding, growth), and therefore, could potentially be impacted by oil and gas activities in the Study Area during their migrations between the two systems. Atlantic salmon were raised as an issue during consultations with Parks Canada in June 2005 (Appendix 1).

The two Atlantic salmon management areas (salmon fishing areas or SFAs) in the Study Area are SFA13 (Cape Ray to Cape St. Gregory; 4Rd and small portion of 4Rc) and SFA 14A (Cape St. Gregory to Cape Bauld (remainder of Study Area) (DFO 2003). In these SFAs, there are important large salmon components that contain a mixture of maiden fish (never spawned before) which have spent two or more years at sea, and repeat spawners which are returning to the rivers for a second or subsequent spawning. The large component in most other Newfoundland rivers consists primarily of repeat spawners.

Conservation requirements for Atlantic salmon rivers are considered to be threshold reference points. The status of salmon stocks is assessed on the basis of the proportion of the conservation egg deposition achieved in a given year and trends in abundance of various life stages. These requirements are established for individual rivers in Newfoundland, including the following ones that occur within the Study Area.

- Torrent River (SFA 14A; 4Rb)
- Lomond River (SFA 14A; 4Rb)
- Harrys River (SFA 13; 4Rd)
- Flat Bay Brook (SFA 13; 4Rd)
- Fischells River (SFA 13; 4Rd)
- Robinsons River (SFA 13; 4Rd)
- Middle Barachois River (SFA 13; 4Rd)
- Crabbes River (SFA 13; 4Rd)
- Highlands River (SFA 13; 4Rd)

Improvements were observed in most of the monitored rivers in SFA 13 in 2003 compared to 2002 (DFO 2003) but populations sizes remained low. In SFA 14A in 2003, there was not any increase in adult salmon recruitment. Two of the seven SFA 13 rivers and both SFA 14A rivers exceeded conservation requirements in 2003.

Based on fishway and counting fence data, counts of small and large salmon for the two monitored SAF 14A rivers in 2002 were 3,965 and 397, respectively, for the Torrent River, and 548 and 62, respectively, for the Lomond River. Small and large salmon counts for the Highlands River in 2002 were 169 and 87, respectively.

DFO states that particular concern should be given to the conservation of salmon populations in St. George's Bay (DFO 2003). Rivers that flow into this bay experience dramatic fluctuations in salmon abundance.

The Humber River, a large high profile salmon river, empties into Humber Arm, located off Bay of Islands (i.e., Bid Parcel 6). Based on fishway and counting fence data, 27,000+ small salmon and 4,400+ large salmon were counted in the Humber River in 1999 (O'Connell et al. 2003)

3.4.3.2 Wolffishes

Two wolffish species, spotted (*Anarhichas minor*) and northern (*Anarhichas denticulatus*) are presently listed as *threatened* on Schedule 1 of *SARA*. The Atlantic or striped wolffish (*Anarhichas lupus*) is listed as a species of *special concern* on Schedule 1 of *SARA*.

The northern wolffish typically occurs at intermediate depths of 90 to 200 m but have been found to depths of 600 m. Tagging studies have shown that northern wolffish do not migrate long distances, and do not form large schools. The northern wolffish is a benthic and bathypelagic predator, preying upon jellyfish, comb jellies, crabs, brittle stars, seastars, and sea urchins. Predators of the northern wolffish include redfish and Atlantic cod.

The spotted wolffish typically occurs at depths of 475 m or more. Tagging studies have shown that spotted wolffish only migrate locally, and do not form schools. Spatial analysis of DFO research vessel catch data from the Grand Banks indicated that spotted wolffish abundance declined from the late 1980s to the mid-1990s, with an increase in abundance during both survey seasons since the mid-1990s (Kulka et al. 2003). Its prey includes hard-shelled invertebrates such as crustaceans, molluscs, and echinoderms, and fish, primarily those discarded by trawlers. The species has few predators, although remains have been found in the stomachs of Atlantic cod, pollock and Greenland sharks (Scott and Scott 1988).

Atlantic or striped wolffish is typically found further south than either northern or spotted wolffish. It has been found at depths of up to 350 m (Scott and Scott 1988). There is no evidence that Atlantic wolffish migrates long distances, or form schools in Newfoundland waters (DFO 2004h). In the Northwest Atlantic, Atlantic wolffish feeds primarily on benthic invertebrates such as echinoderms, molluscs and crustaceans, as well as small amounts of fish. No predators of adult Atlantic wolffish have been identified, but juveniles have been found in the stomachs of Atlantic cod (Scott and Scott 1988).

It is not known with certainty if any of these three wolffish species spawn in the Study Area, although it is probable given the limited migration of the species. If spawning does occur in the Study Area, it would most likely take place along the slope region. During the late fall fertilized eggs are deposited on either a hard bottom or underwater ledge (Scott and Scott 1988), producing larvae which are large (2-cm long upon hatching) and semipelagic (DFO 2004h). The spotted wolffish and striped wolffish are regarded as commercial species in Newfoundland waters while the northern wolffish is not (Simpson and Kulka 2002, 2003). While the decline in abundance and biomass estimates of all three species has occurred throughout much of Newfoundland's waters, it seems that the decline has been greater in the more northern areas (Divisions 2J, 3K and northern 3L) than in the southern areas (southern 3L, 3N, 3O) for all three species (Simpson and Kulka 2002, 2003). DFO is presently preparing a 'Wolffish Recovery Plan' but this document has not yet been published (J. Simms, DFO, pers. comm.).

However, fishers consulted for this SEA in July 2005 reported that bycatch for all three wolffish species remains high at certain locations within the Study Area. According to DFO Newfoundland-landed commercial catch statistics, 1,462 wolffish (species breakdown unknown) were caught in NAFO Division 4R between 1999 and 2004. Most wolffish were caught in 4Rb and 4Rd. Little scientific information is available for the wolffish populations inhabiting the waters off western Newfoundland.

3.4.4 Commercial Fisheries

This section provides a description (qualification and quantification) of the commercial fisheries within and adjacent to the SEA Study Area. In particular, it presents a historical overview of past (1985-2004) harvesting activities, a more detailed analysis of harvesting data for the 2002-2004 fishing seasons, and describes expected fish harvesting activities in the Areas in the foreseeable future. Figure 3.2 shows the Study Area in relation to regional fisheries management areas. As this map indicates, the Area falls within North Atlantic Fisheries Organization (NAFO) Division 4R.

3.4.4.1 Information Sources and Data Areas

The fisheries data analyses use Department of Fisheries and Ocean's (DFO) Newfoundland Region (Newfoundland and Labrador), Maritimes Region (New Brunswick and Nova Scotia Atlantic coasts), Gulf Region (Prince Edward Island, and New Brunswick and Nova Scotia Gulf coasts) and Quebec (Gulf and St. Lawrence River) georeferenced catch and effort datasets for 2002 – 2004 (accessed in 2003 for 2002, and 2005 for 2003 and 2004) and other historical DFO datasets for Newfoundland Region (1985-2004). The DFO datasets record domestic harvest and foreign harvest landed in Canada.

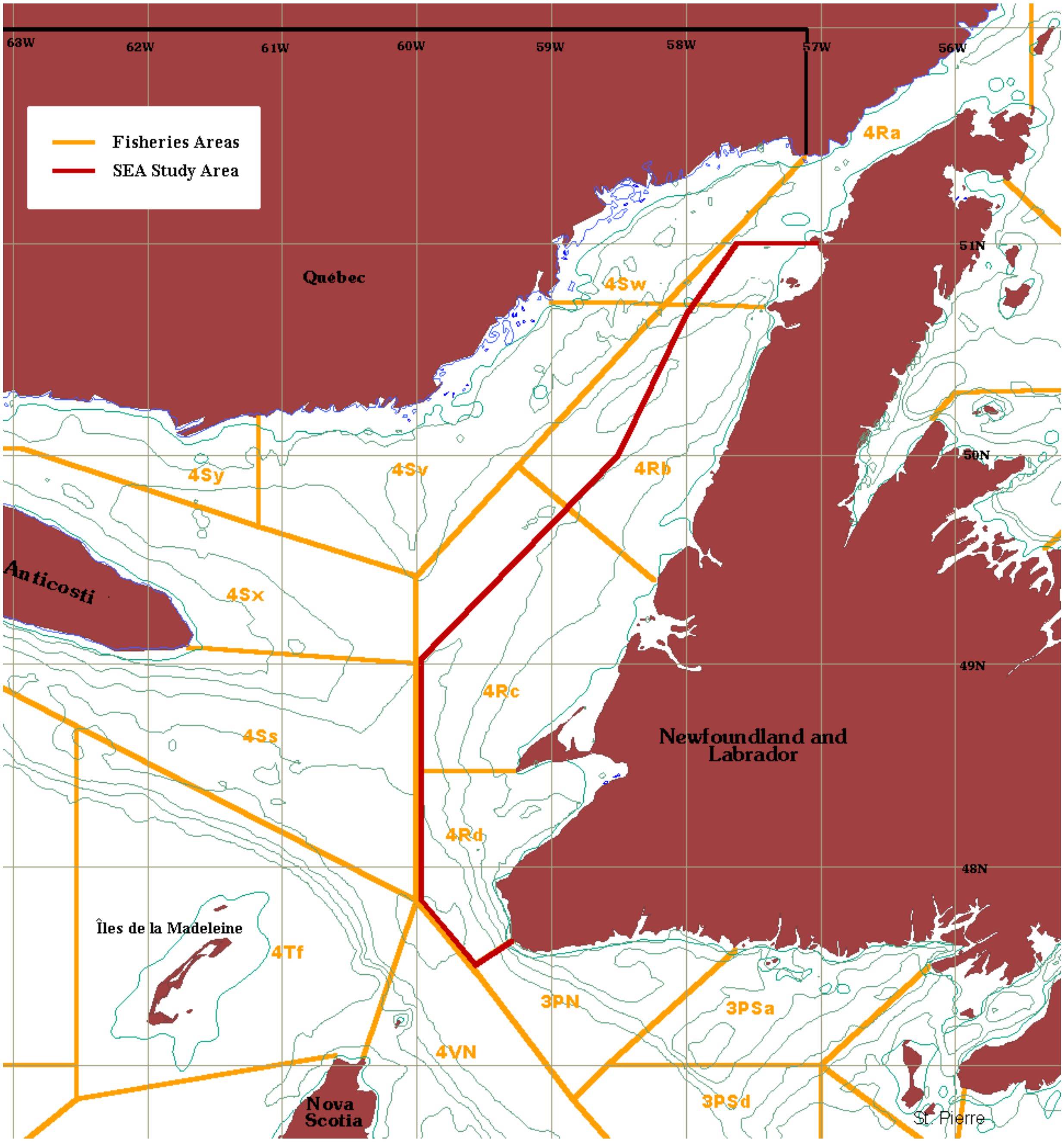


Figure 3.2. SEA Study Area in Relation to Regional Fisheries Management Areas.

The DFO data are georeferenced in two ways: by latitude and longitude (degrees and minutes) of the gear set location, and by the Unit Area in which the catch was harvested. While much of the harvest carries the latitude and longitude information (76% by weight for all of 4R in 2004), virtually all the data carries a Unit Area designation.

Georeferencing by latitude and longitude allows the mapping of specific harvesting locations. Areas farther from shore, fished generally by larger boats, tend to have a greater proportion of their catch georeferenced, while those closer to shore have less. Also, certain inshore species (e.g., lobster) are not thus georeferenced, while the deeper water species (e.g., shrimp) are. For example, in 2004 in 4R, 0% of lobster harvest was so referenced while 44% of groundfish and 84% of the shrimp harvest was (by weight).

The Unit Area designation allows all the harvesting data to be tabulated according to these fisheries management sub-zones. The Unit Areas that most closely approximate the Study Area are Unit Areas 4Rb, 4Rc and 4Rd (see map). These are used in the Study Area Unit Area analysis for this report.[4]

In 2004, approximately 95% of the harvest taken within 4R was landed in Newfoundland and Labrador, and is thus recorded in the Newfoundland Region DFO database.

The maps in the sections that follow show harvesting locations, based on the latitude and longitude (lat/long) data, as dark points. The points are not “weighted” by quantity of harvest, but show where fishing effort was recorded. Such location information data has been groundtruthed with fishers in many consultations and has proven, in past assessments, to be particularly useful for petroleum industry operators in understanding the likely location of gear concentrations and timing of fisheries in order to eliminate or minimize potential mutual interference. Similar maps were also presented to area fishers during the consultations for this SEA and were found to be a good representation of fishing areas and patterns.

In most instances, the information used to characterize the fisheries in this SEA presents quantities of harvest rather than harvest values. Quantities are directly comparable from year to year, while values (for the same quantity of harvest) may vary annually with negotiated prices, changes in exchange rates and fluctuating market conditions. Prices paid may also vary from month to month and from area to area. Although some species vary greatly in price (e.g., snow crab vs. herring), in terms of interference between exploration activities and fisheries, it is the level of fishing effort and gear utilized (better represented by quantities of harvest) that is more important. Values are important in the case of a gear damage incident, and would be carefully evaluated at that time, based on then-current numbers, to calculate compensation (an impact mitigation during an exploration project).

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[4] A small part of southern 4Ra, which extends north to Belle Isle, also occurs within the SEA Study Area, but is not used in the Unit Area analysis.

Fisheries consultations were conducted with representatives of the Fish, Food and Allied Workers Union (FFAWU), DFO and individual fishers living within the SEA Study Area. The consultations were to gather information about area fisheries and to determine any issues or concerns to be considered in the SEA.

Fisheries-related information and issues raised during consultations are presented in Appendix 1.

Other sources consulted for this assessment include DFO species management plans and stock status reports.

3.4.4.2 Commercial Fisheries Overview

This section provides an overview of the commercial fisheries within and/or adjacent to the Study Area (depending on the datasets used). The first part provides the historical context, based on DFO data for NAFO 4R, for the 20-year period 1985-2004. The next section focuses on recent harvests (2002-2004) in 4R Unit Areas b, c and d (the Study Area Unit Areas), and the final part of this fisheries overview section provides similar recent information for the georeferenced (lat/long) data specifically recorded within the SEA Study Area, and maps the locations of these fisheries for that period.

The section following these (Principal Species) provides more detailed information on the important regional fisheries.

Historical Fisheries in NAFO 4R

This section describes the historical fisheries within NAFO Division 4R, which includes the full SEA Study Area (see Figure 3.1), for the 20-year period 1985-2004. Over the past decade and a half, the fisheries in 4R have undergone significant changes, owing largely to the collapse of groundfisheries (mainly cod) after 1991 and consequent fisheries moratoria and reductions within the area (after 1993).

DFO’s most recent cod Science Advisory Report (2005/003) describes the series of steps that have been taken to manage the northern Gulf (4RS,3PN) cod fisheries since the early 1990s: “The fishery was under moratorium from 1994 to 1996. A reduced fishery was authorized in 1997 … . In 2003, the cod fishery faced a second moratorium, so there was no commercial fishery. The 2004 TAC was set at 3,500 t, as recommended by the FRCC. Reported landings in January 2005 were 3,112 t. Sentinel fisheries were introduced in 1994 in order to develop a partnership between the industry and the Department of Fisheries and Oceans (DFO). Sentinel fisheries are carried out within a well-defined framework and provide, among other things, abundance indices of the resource. Three types of fisheries are carried out each year: the gillnet sentinel fishery on the Lower North Shore (Division 4S) and on the west coast of Newfoundland (Division 4R), the longline sentinel fishery and the trawl sentinel fishery on the entire territory (3Pn, 4RS). All catches made by sentinel fisheries are included in the TAC.”

The following graphs (based on DFO Maritimes and Newfoundland Region data) show the overall (all species) harvest for the last 20 years (Figure 3.3), the same for groundfish species (Figure 3.4), and then for shrimp and snow crab (Figure 3.5), the two species which increased the most during this period. These two high-value fisheries now make up a substantial proportion of the commercial fisheries in the Gulf of St. Lawrence, and have largely replaced the groundfisheries for many participants in the region.

The most recent scientific advice does not indicate that the groundfisheries are likely to increase in the foreseeable future.

Additional historical information on principal fisheries is provided in following sections.

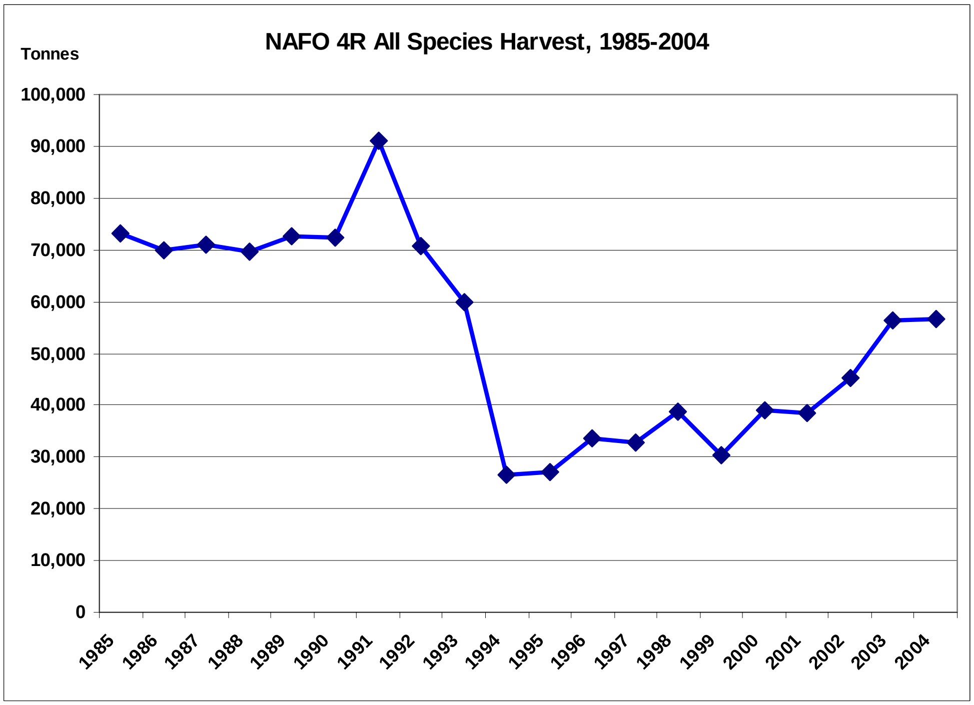


Figure 3.3. 1985-2004 Commercial Harvest from 4R, All Species.

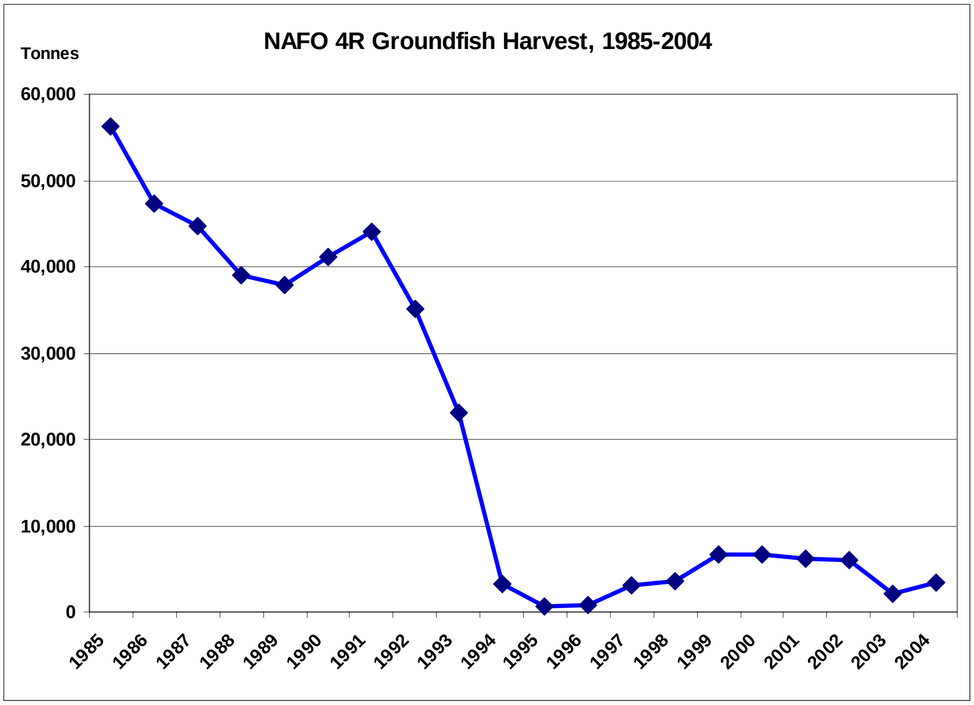


Figure 3.4. 1985-2004 Commercial Harvest from 4R, All Groundfish Species.

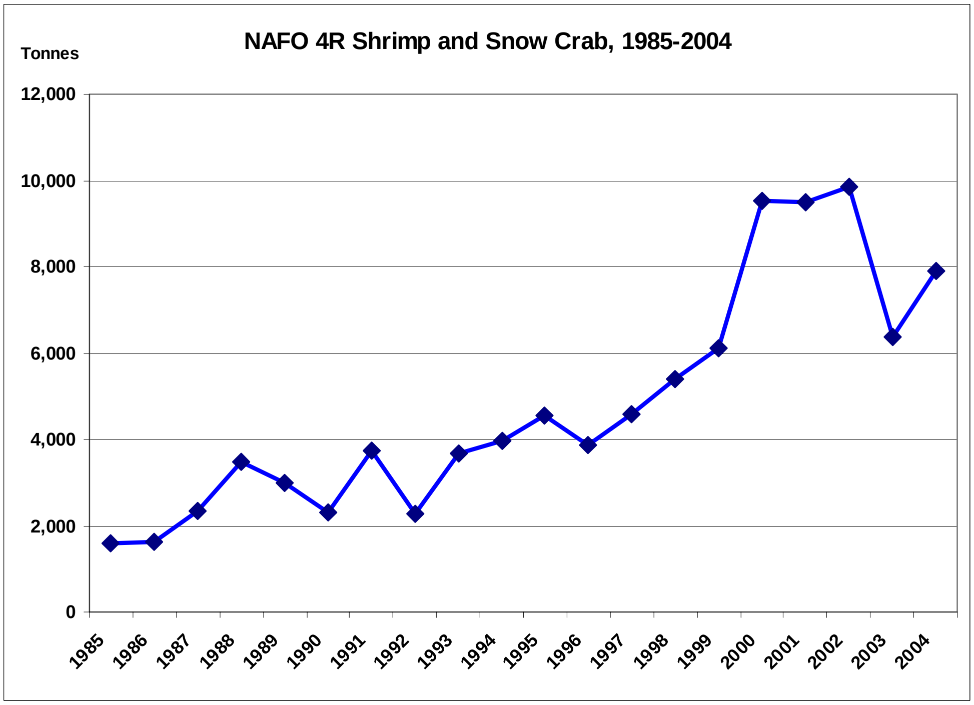


Figure 3.5. 1985-2004 Commercial Harvest from 4R, Shrimp and Snow Crab.

The following graph shows the composition of the harvest in 1985 and in 2004, indicating the changes in the make-up of the 4R harvest (Figure 3.6).

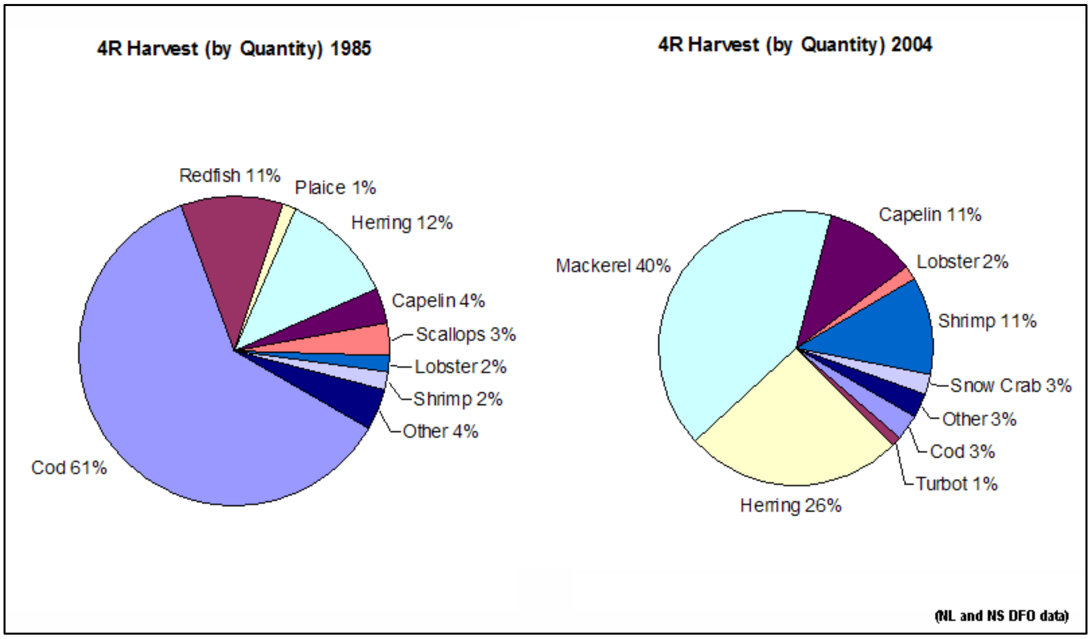


Figure 3.6. **Composition of the Harvest (4R), 1985 *vs.* 2004**

Study Area Unit Areas (4Rb,c,d) Harvest, 2002-2004

Table 3.3 shows the quantity of the domestic harvest recorded within 4R Unit Areas b, c and d during 2002, 2003 and 2004 (all DFO regions data). As Table 3.3 indicates, the harvest was primarily composed of two pelagic species, herring and mackerel, during 2002 - 2004. Overall, in these years, these two species made up nearly 72% of the harvest by quantity. Other principal species during these years have been northern shrimp, capelin, cod and snow crab. The lobster fisheries – though comparatively low in quantity – are of high economic and social value, and are particularly important to local Study Area-based fishers who typically harvest this species in waters near their home ports.

Table 3.3. **2002-2004 Harvest in Study Area Unit Areas (4Rb,c,d).**

Species	Tonnes	% of Total
2002		
Atlantic Cod	2,751.1	6.9%
Redfish (Sp.)	689.3	1.7%
Halibut	84.3	0.2%
Plaice	123.7	0.3%
Greysole/witch flounder	440.0	1.1%
Winter flounder	11.9	0.0%
Turbot/Greenland halibut	510.0	1.3%
Skate (sp.)	70.3	0.2%

Table 3.3 Continued.

White hake	9.6	0.0%
Wolffish/catfish	74.8	0.2%
Monkfish	7.2	0.0%
Herring	11,499.1	28.7%
Mackerel	11,027.9	27.5%
Eels	16.1	0.0%
Capelin	3,187.9	8.0%
Mako shark	1.3	0.0%
Icelandic scallops	3.4	0.0%
American lobster	763.7	1.9%
Spider/toad crab	11.4	0.0%
Northern shrimp	7,004.7	17.5%
Rock crab	20.9	0.1%
Snow crab	1,725.2	4.3%
All other	3.5	0.0%
Total	40,036.9	100.0%
2003		
Atlantic Cod	146.8	0.3%
Redfish (Sp.)	482.9	0.9%
Halibut	132.4	0.2%
Plaice	146.1	0.3%
Greysole/witch flounder	274.1	0.5%
Turbot/Greenland halibut	947.9	1.7%
Skate (sp.)	61.0	0.1%
Pollock	2.8	0.0%
White hake	11.8	0.0%
Wolffish/catfish	7.6	0.0%
Monkfish	15.5	0.0%
Herring	13,887.9	25.3%
Mackerel	25,209.9	45.8%
Eels	26.2	0.0%
Capelin	4,520.0	8.2%
American lobster	987.4	1.8%
Spider/toad crab	18.9	0.0%
Northern shrimp	6,481.2	11.8%
Snow crab	1,556.1	2.8%
Seal parts	49.3	0.1%
Lumpfish roe	25.5	0.0%
All other	6.4	0.0%
Total	54,997.5	100.0%
2004		
Atlantic Cod	1,230.1	2.3%
Haddock	2.8	0.0%
Redfish (Sp.)	484.8	0.9%
Halibut	123.9	0.2%
Plaice	74.9	0.1%
Greysole/witch flounder	407.0	0.8%

Table 3.3 Concluded.

Turbot/Greenland halibut	834.0	1.5%
Skate (sp.)	14.4	0.0%
White hake	28.3	0.1%
Wolffish/catfish	6.3	0.0%
Herring	14,258.3	26.4%
Mackerel	23,300.7	43.2%
Capelin	2,873.9	5.3%
Mako shark	2.4	0.0%
American lobster	756.8	1.4%
Northern shrimp	7,993.1	14.8%
Snow crab	1,427.2	2.6%
Seal parts	62.8	0.1%
Lumpfish roe	26.7	0.0%
All other	3.3	0.0%
Total	53,911.6	100.0%

Seasonality. The timing of the harvest is dictated by weather and ice conditions, the availability of the resource, fisheries management plans and other resource conservation considerations (e.g., the closure of the cod spawning area from 1 April to mid June), as well as individual fishers' harvesting plans (e.g., harvesting lobster before turning to snow crab. The following graph (Figure 3.7) shows the 2002-2004 4Rb,c,d harvest by month. As the graph shows, little or no harvesting occurs before May. This is primarily due to ice in the Gulf, and in some years this can delay the start of particular fisheries. Figures 3.13 to 3.24 show the location of the Study Area harvest by month for 2004, based on the georeferenced (lat/long) data. More information on the timing and other aspects of principal fisheries is provided in following sections.

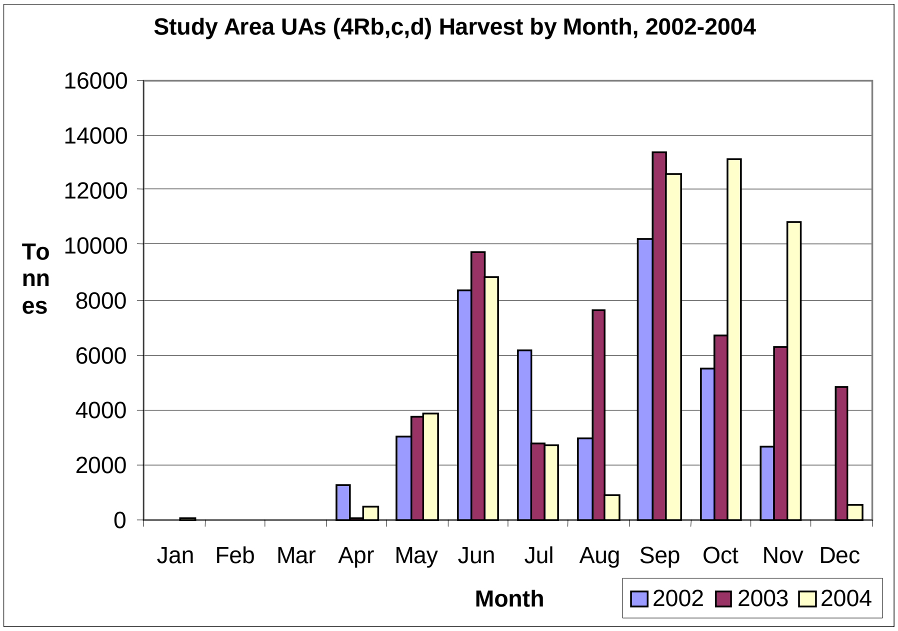


Figure 3.7. 4Rb, c, d Harvest by Month, 2002, 2003 and 2004.

Fishing Gear. The area's fisheries use both fixed (e.g., crab and lobster pots) and mobile (e.g., seines and shrimp trawls) fishing gears. The following table shows the breakdown of the harvest (quantities) by gear type (Table 3.4). Figures 3.8 and 3.9 show the location of the Study Area harvest by principal gear type for 2004, based on the georeferenced (lat/long) data.

In general, fixed gear poses a much greater potential for conflicts with exploration activities (particularly seismic surveys) since it is often hard to detect when there is no fishing vessel near by, and it may be set out over long distances in the water. Because mobile gears are towed behind a vessel, they pose less risk of conflict because the activity can be more easily observed and located on the water. For example, a survey ship and fishing vessels should be able to communicate with each other and exchange information about their operating areas and activities.

Table 3.4. 4Rb,c,d Harvest by Gear Type, All Months, 2004.

Gear Type	Tonnes	% of Total
Stern otter trawl (bottom)	413.2	0.8%
Stern trawl (midwater)	61.1	0.1%
Shrimp trawl	7,993.3	14.8%
Danish seine	509.4	0.9%
Purse seine	39,845.1	73.9%
Gill net*	1,823.9	3.4%
Longline*	616.5	1.1%
Baited handline*	184.6	0.3%
Trap*	217.4	0.4%
Pot*	2,183.9	4.1%
Seal hunting	62.8	0.1%
Total	53,911.3	100.0%

*fixed gear

3.4.4.3 Study Area Unit Areas (4Rb,c,d) Landed Value

Table 3.5 shows the landed value of the domestic harvest recorded within 4R Unit Areas b, c and d during 2004 (all DFO regions data). This includes all recorded harvest from these waters whether or not it was landed by fishers based in Study Area ports.

These values are based on Newfoundland Region average prices for 2004 derived from DFO statistical reports (see http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/ Land_All_2004.htm). They are thus an approximation of the landed value, since prices for some species may vary slightly from area to area within Newfoundland Region, and from province to province, depending on where the harvest was actually landed and sold. Prices for some species vary throughout the fishing season, as well, so that the value of the same quantity of a species landed at the being of its harvesting season may be higher or lower than that landed at the end.

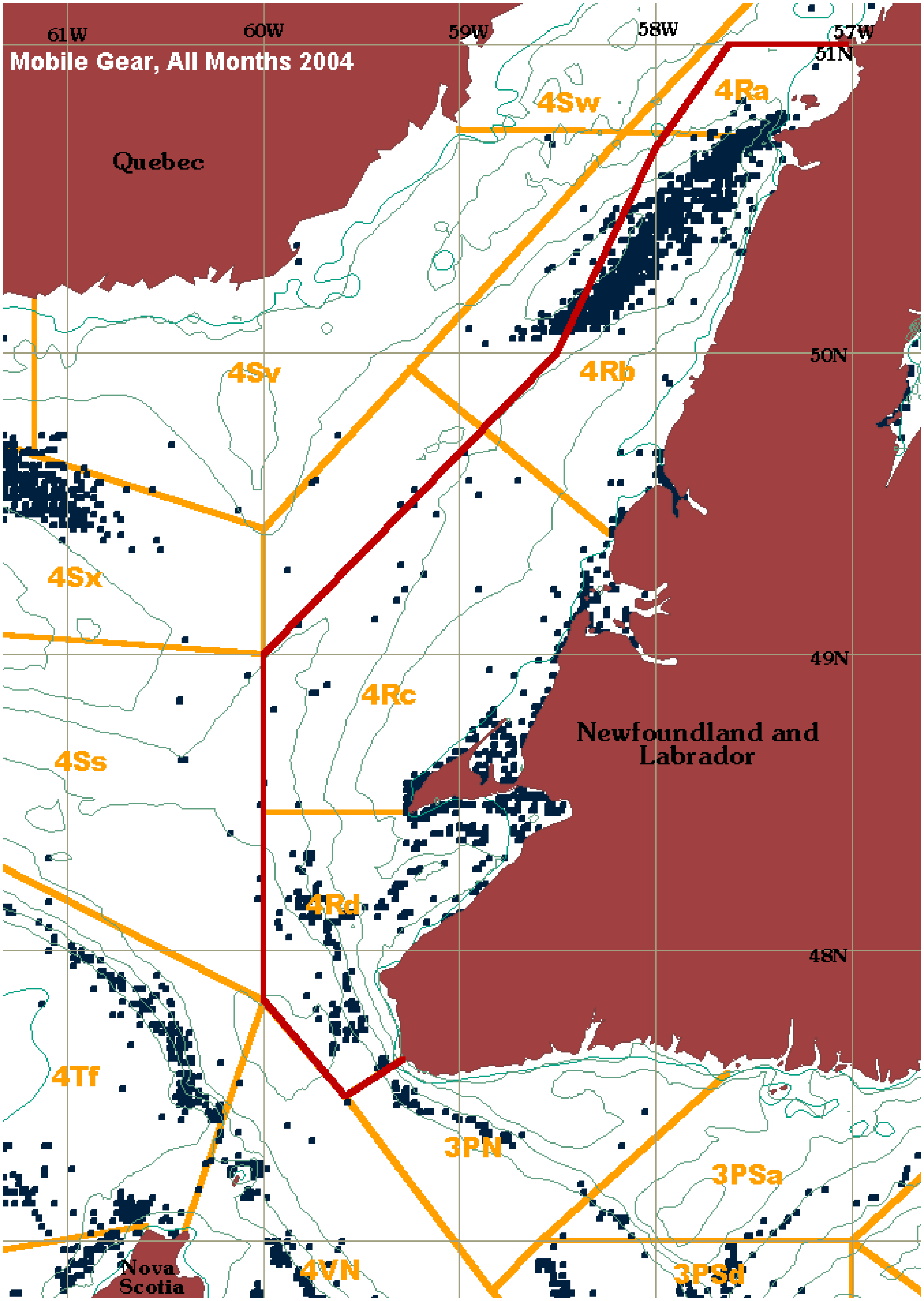


Figure 3.8 . **Mobile Gear Harvesting Locations, Study Area and Adjacent Waters, All Species, All Months, 2004.**

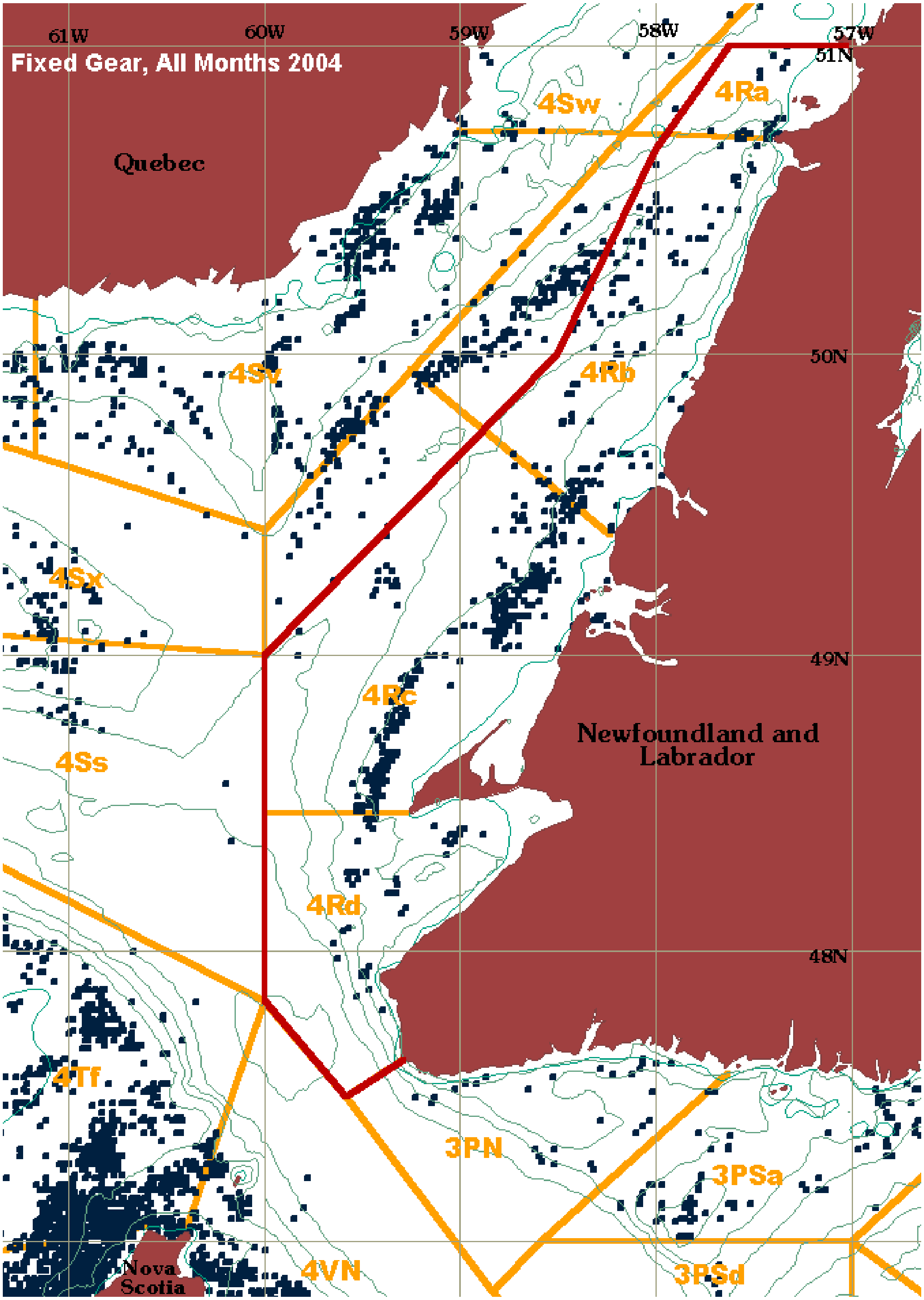


Figure 3.9 . Fixed Gear Harvesting Locations, Study Area and Adjacent Waters, All Species, All Months, 2004.

Table 3.5. Landed Value, Study Area Unit Areas (4Rb,c,d) 2004.

Species	Kgs	$/Kg	Landed Value
Atlantic Cod	1,230,100	$1.25	$1,532,211
Haddock	2,800	$1.01	$2,827
Redfish (Sp.)	484,800	$0.49	$236,203
Halibut	123,900	$6.61	$818,904
Plaice	74,900	$0.77	$57,628
Greysole/witch flounder	407,000	$0.87	$354,423
Turbot/Greenland halibut	834,000	$1.32	$1,097,666
Skate (sp.)	14,400	$0.24	$3,429
White hake	28,300	$0.53	$14,974
Wolffish (sp.)/catfish	6,300	$0.28	$1,736
Herring	14,258,300	$0.16	$2,263,237
Mackerel	23,300,700	$0.27	$6,215,616
Capelin	2,873,900	$0.27	$779,303
Mako shark	2,400	$1.03	$2,471
American lobster	756,800	$11.03	$8,347,212
Northern shrimp	7,993,100	$1.39	$11,083,979
Snow crab	1,427,200	$5.40	$7,708,693
Seal parts (1)	62,800	$0.26	$16,328
Lumpfish roe	26,700	$5.36	$143,112
All other (2)	3,300	$1.80	$5,940
Total	53,911,700		$40,685,890

Notes:

1. The value for seal parts is based on parts reported by weight (meat, fat);
2. The value for “all other” species is based on the average 2004 price for all Newfoundland region species reported by weight.

The landed value is the value of the catch “at the wharf”, generally the price paid to the harvesting sector. It does not show, for instance, the “downstream” indirect or induced economic benefits of the harvest, during or after processing or value-added manufacturing of fish-based products.

As discussed previously, total values (and the amount paid per Kg) for many species vary annually with negotiated prices, changes in exchange rates and fluctuating market conditions. For instance, the average Newfoundland Region price per Kg of snow crab, as of the beginning of September 2005, was $3.19 (vs. $5.40 in 2004) (http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Land_All_2005.htm accessed 1 September 2005).

3.4.4.4 Fishing Enterprises and Licences (4R)

Table 3.6 shows the numbers of Core and non-Core / Recreational fishing licences by species for NAFO 4R for 2003, the most recent year for which these data are published. However, DFO notes (D. Ball pers. comm. September 2005) that the 2004 Report (available late September 2005) will be very similar.

Table 3.6. Licences held by 4R Fishers, Vessels < 65', NAFO Division 4R.

Species	Core	Non-Core and Recreational	Total
Bait	619	139	758
Capelin (Fixed Gear)	203	44	247
Capelin (Mobile Gear)	12	1	13
Capelin (Mobile Gear) - Exploratory	8	0	8
Eels	36	15	51
Groundfish (Fixed Gear)	638	171	809
Groundfish (Mobile Gear)	61	1	62
Herring (Fixed Gear)	554	77	631
Herring (Mobile Gear)	15	1	16
Lobster	622	140	762
Mackerel (Fixed Gear)	414	21	435
Mackerel (Mobile Gear)	12	0	12
Mackerel (Mobile Gear) - Exploratory	8	1	9
Scallop	115	17	132
Scallop - Recreational	17	170	187
Seal - Assistant	65	1,070	1,135
Seal - Personal Use	1	105	106
Seal - Professional	598	869	1,467
Shark	0	3	3
Shrimp - Gulf	45	0	45
Shrimp SFA 06 - Temporary	63	0	63
Shrimp SFA 08/Gulf - Temporary	10	0	10
Snow Crab - Commercial	17	0	17
Snow Crab - Inshore	17	0	17
Snow Crab - Inshore	44	0	44
Snow Crab - Inshore Commercial	322	0	322
Squid	80	9	89
Tuna, bluefin	1	0	1
Whelk	110	0	110
Total	4,707	2,854	7,561

Source: DFO 2003, Tables 1a,b,c.

Table 3.7 shows fishing enterprises by category for 2003.

Table 3.7. Enterprises, 4R, by Category, Vessels <65'.

Category	< 25'	25' – 34'	35' – 44'	45' – 54'	55' – 64'	Total
Core	293	356	45	25	62	781
Non-Core	183	50	4			237
Total	476	406	49	25	62	1,018

Source: DFO 2003, Tables 12a,b,c.

Study Area Georeferenced Harvest, 2002-2004

This section provides data and maps for the components of the 2002-2004 DFO datasets that are georeferenced by latitude and longitude (as described above). As noted, more than 75% (by weight) of the 4R harvest was so referenced in 2002 - 2004. However, some species harvested in 4R (e.g., lobster and scallops) are not included, or have only a small proportion of the actual harvest represented (e.g., cod and halibut).

The georeferenced data for the SEA Study Area similar to the data for 4R as a whole indicate that herring and mackerel make up the greatest part of the Study Area harvest by quantity, representing between 60% and 76% of the harvest in recent years (Table 3.8). Various groundfish, capelin, northern shrimp and snow crab account for nearly all the remainder.

Of the groundfish species, cod, redfish and greysole (witch flounder) make up the great majority of the georeferenced harvest, though, as noted, other groundfish species not georeferenced, are harvested in greater quantities than indicated, most notably halibut and turbot.

Table 3.8. Georeferenced Harvest Within the Study Area, 2002-2004.

Species	Tonnes	% of Total
2002		
Atlantic Cod	575.7	2.4%
Redfish (Sp.)	626.8	2.7%
Halibut	22.4	0.1%
Plaice	37.3	0.2%
Greysole flounder	403.3	1.7%
Turbot/Greenland halibut	53.2	0.2%
Skate (sp.)	5.4	0.0%
White hake	5.3	0.0%
Wolffish/catfish	21.0	0.1%
Herring	6,435.0	27.3%
Mackerel	7,809.0	33.2%
Capelin	2,500.5	10.6%
Northern shrimp	4,365.6	18.5%

Table 3.8 Concluded.

Snow crab	676.6	2.9%
All other	1.77	0.0%
Total	23,537.2	100.0%
2003		
Atlantic Cod	32.2	0.1%
Haddock	1.6	0.0%
Redfish (Sp.)	395.8	1.1%
Halibut	39.5	0.1%
Plaice	31.1	0.1%
Greysole flounder	253.7	0.7%
Turbot/Greenland halibut	133.2	0.4%
Skate (sp.)	1.4	0.0%
Pollock	2.3	0.0%
White hake	4.2	0.0%
Wolffish/catfish	1.3	0.0%
Herring	11,162.8	32.4%
Mackerel	15,278.7	44.3%
Capelin	3,298.4	9.6%
Northern shrimp	3,369.1	9.8%
Snow crab	498.1	1.4%
All other	6.34	0.0%
Total	34,503.5	100.0%
2004		
Atlantic Cod	148.2	0.4%
Haddock	2.8	0.0%
Redfish (Sp.)	478.5	1.3%
Halibut	28.7	0.1%
Plaice	32.7	0.1%
Greysole flounder	372.7	1.0%
Turbot/Greenland halibut	72.9	0.2%
White hake	18.4	0.1%
Herring	10,688.2	29.6%
Mackerel	16,285.1	45.1%
Capelin	1,103.9	3.1%
Northern shrimp	6,394.4	17.7%
Snow crab	500.0	1.4%
All other	2.0	0.0%
Total	36,128.5	100.0%

The following maps (Figures 3.10 to 3.12) show the location of the georeferenced harvest within the Study Area and adjacent waters for the years 2002 to 2004, summarized for all months and species.

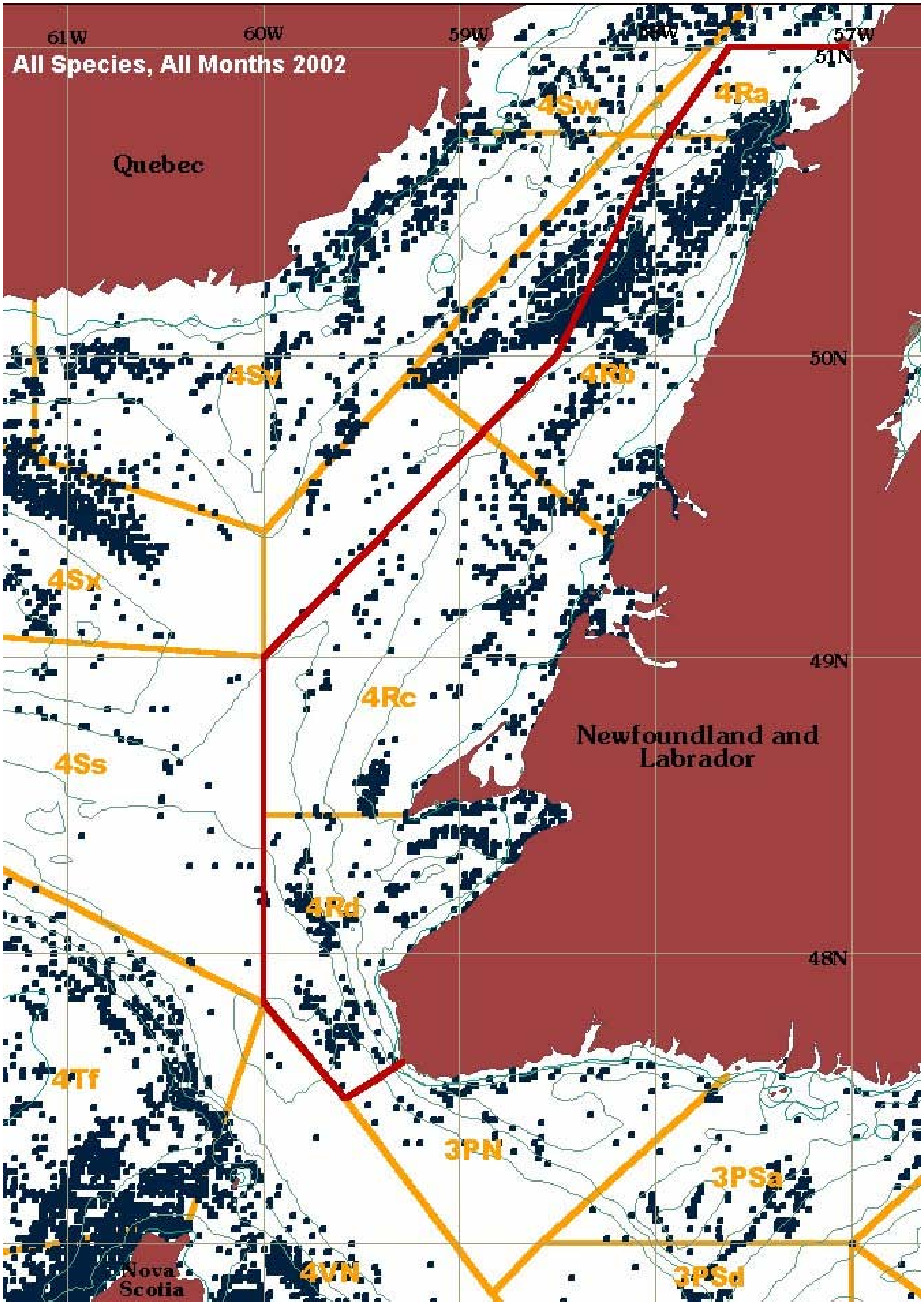


Figure 3.10. Harvesting Locations, Study Area and Adjacent Waters, All Species, All Months, 2002.

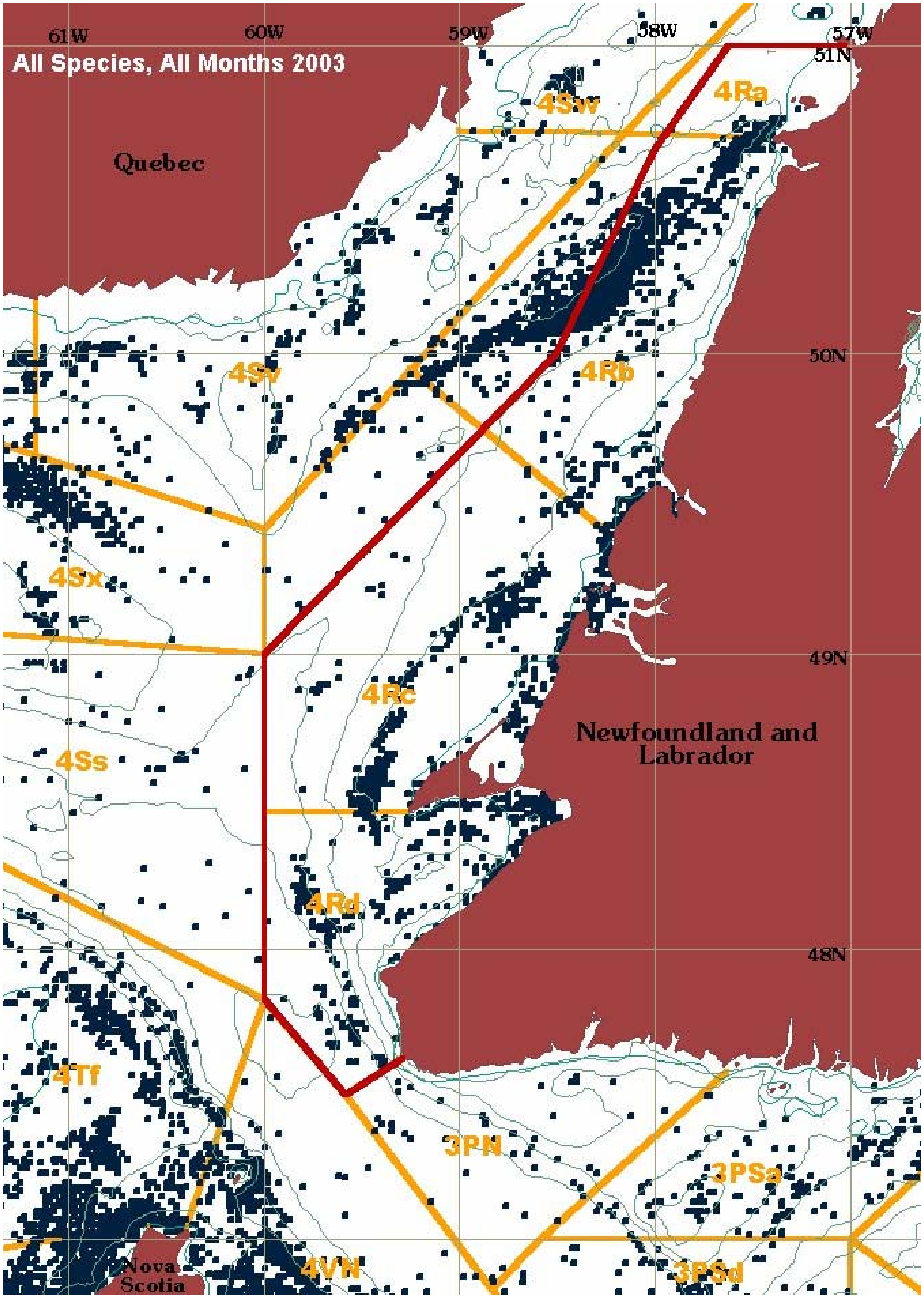


Figure 3.11. Harvesting Locations, Study Area and Adjacent Waters, All Species, All Months, 2003.

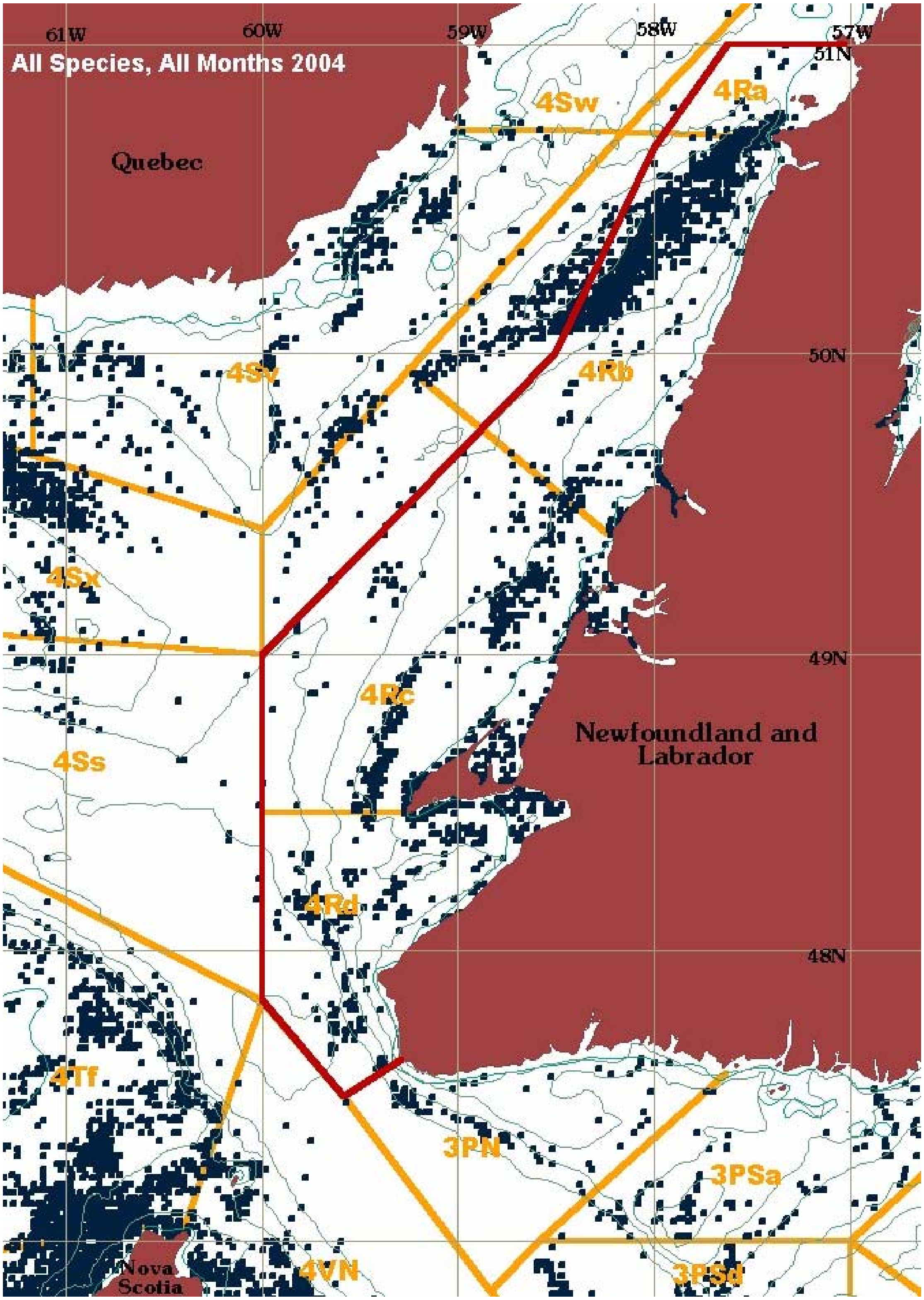


Figure 3.12 . **Harvesting Locations, Study Area and Adjacent Waters, All Species, All Months, 2004.**

The following maps (Figures 3-13 to 3.24) show the annual harvest in the region by month for 2004 using these data.

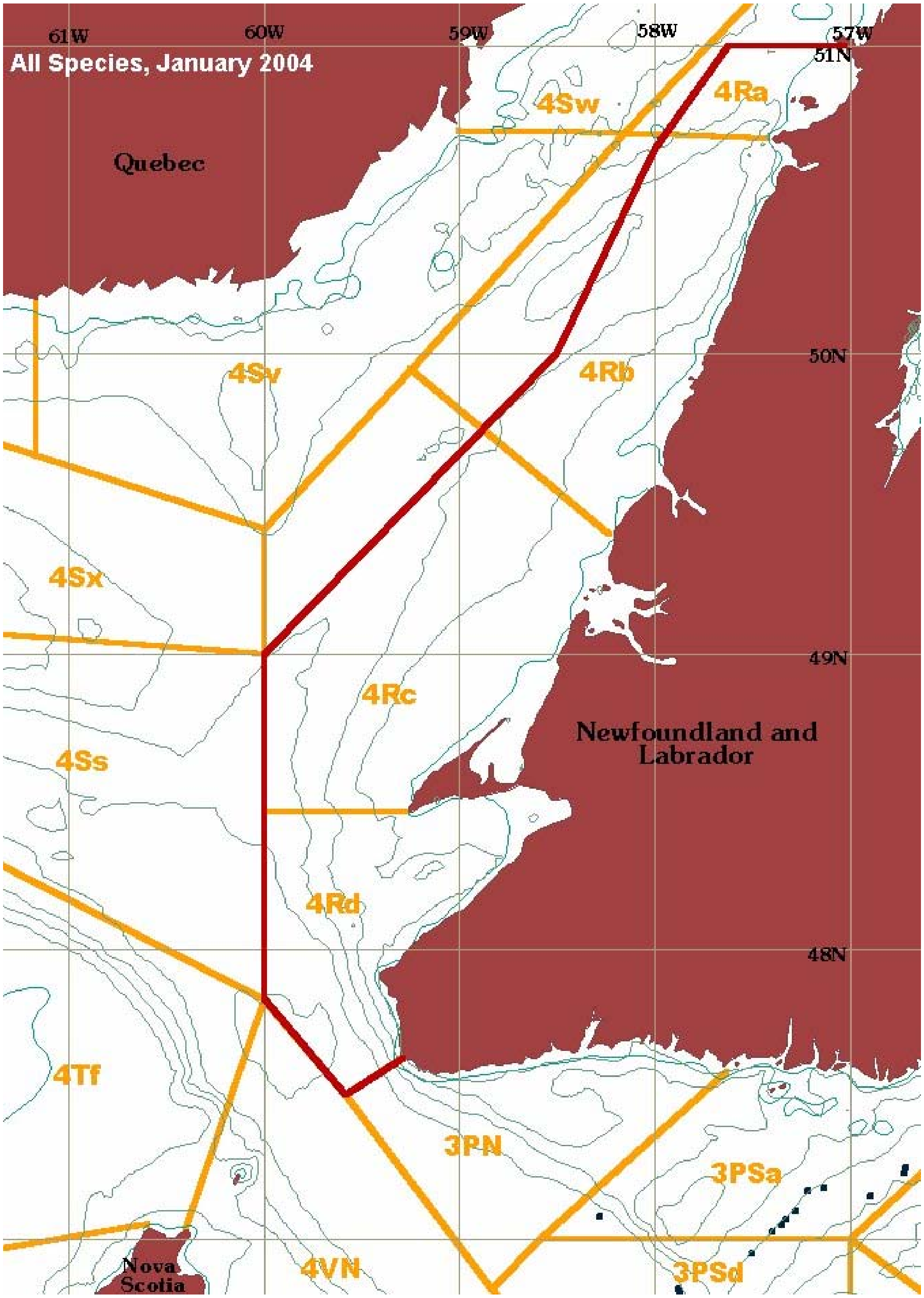


Figure 3.13. Harvesting Locations, Study Area and Adjacent Waters, All Species, January 2004.

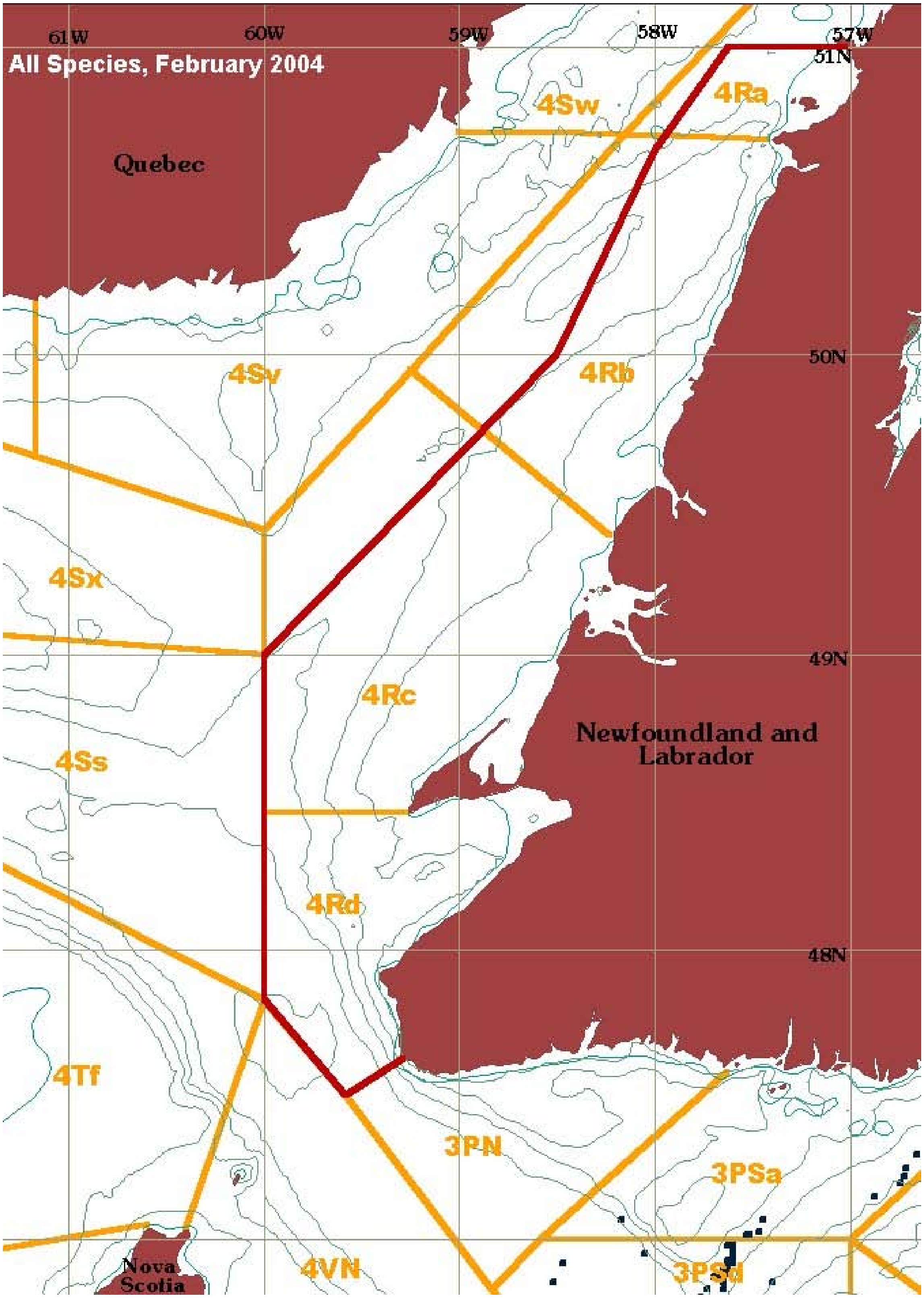


Figure 3.14. Harvesting Locations, Study Area and Adjacent Waters, All Species, February 2004.

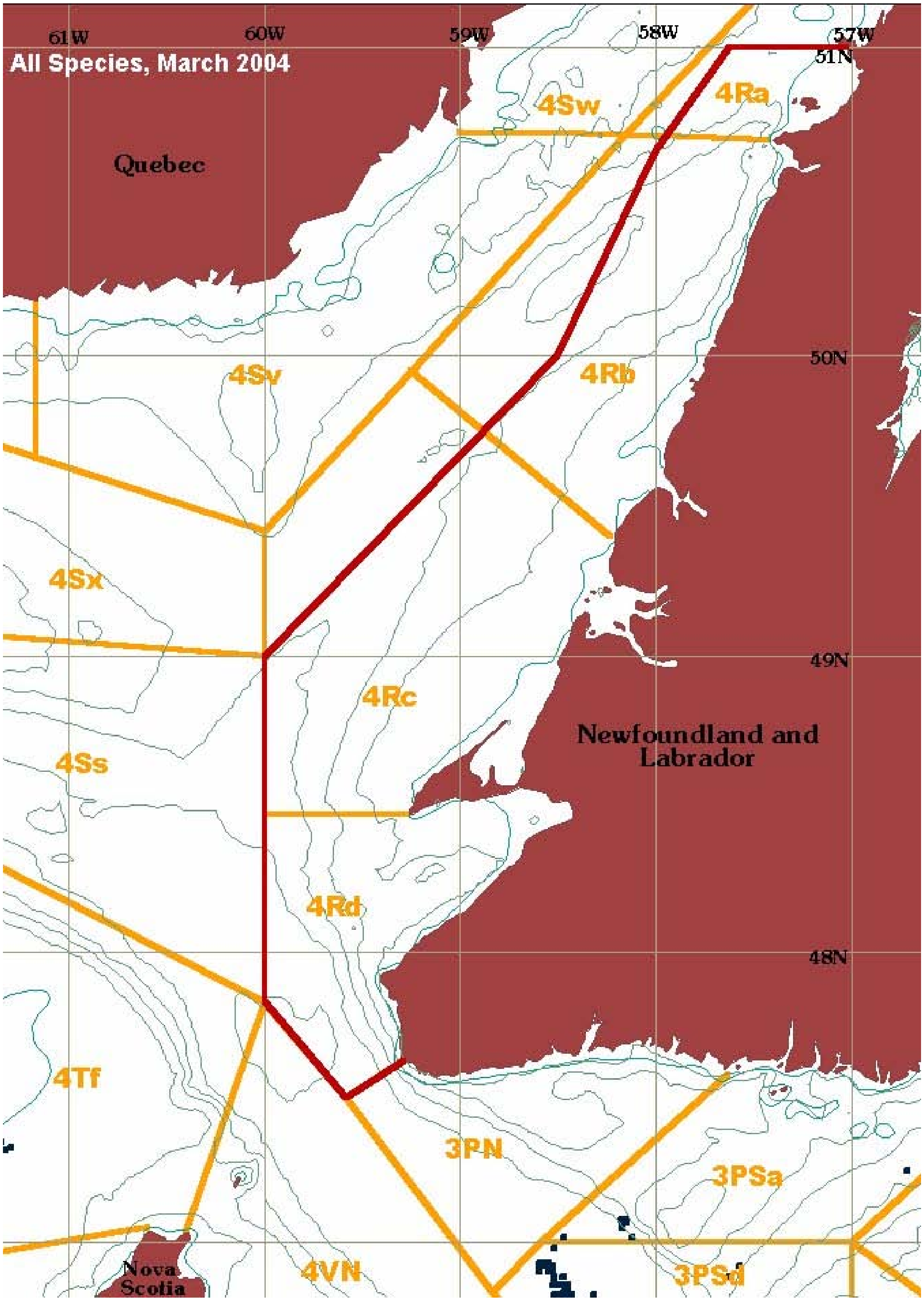


Figure 3.15. Harvesting Locations, Study Area and Adjacent Waters, All Species, March 2004.

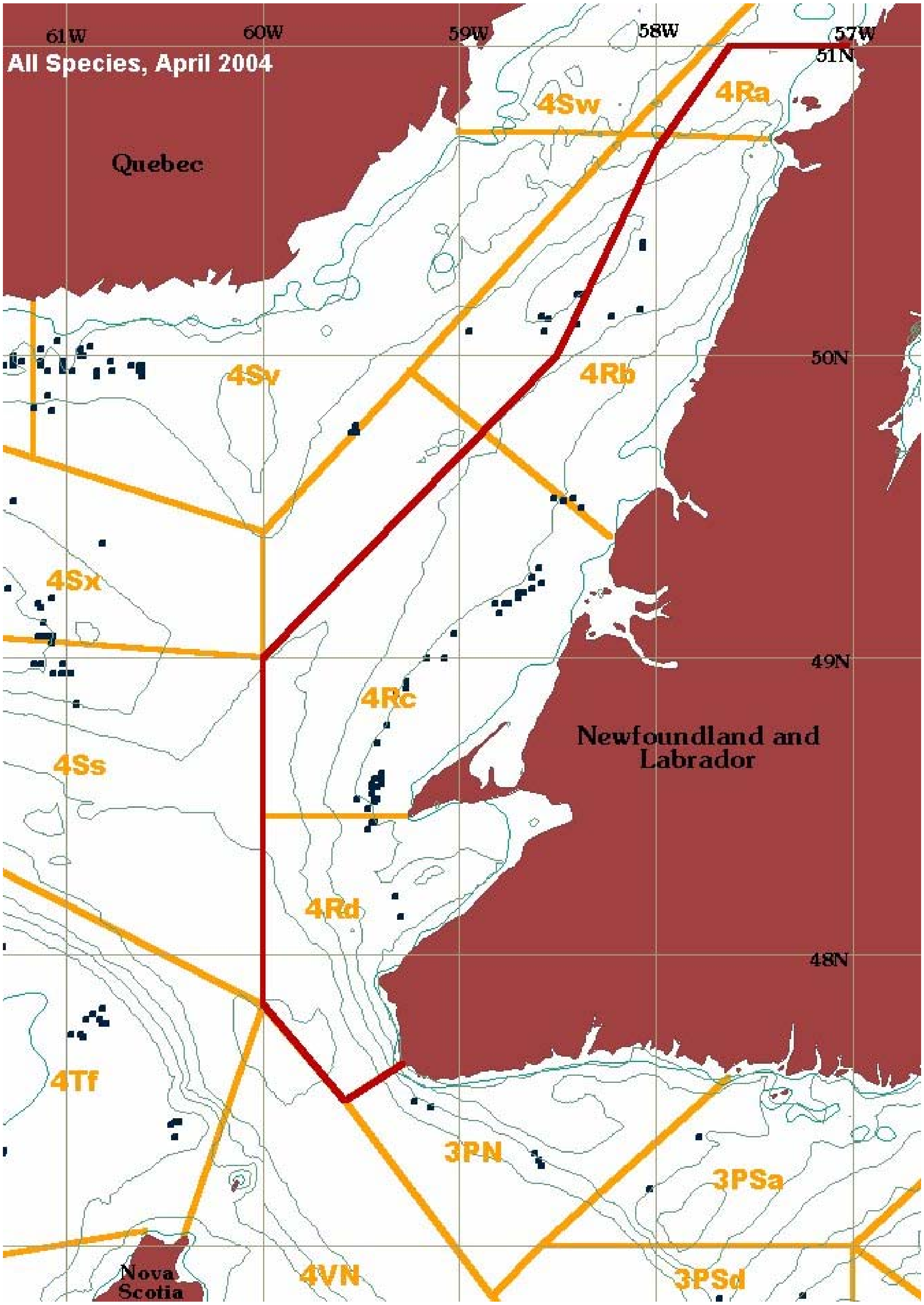


Figure 3.16. Harvesting Locations, Study Area and Adjacent Waters, All Species, April 2004.

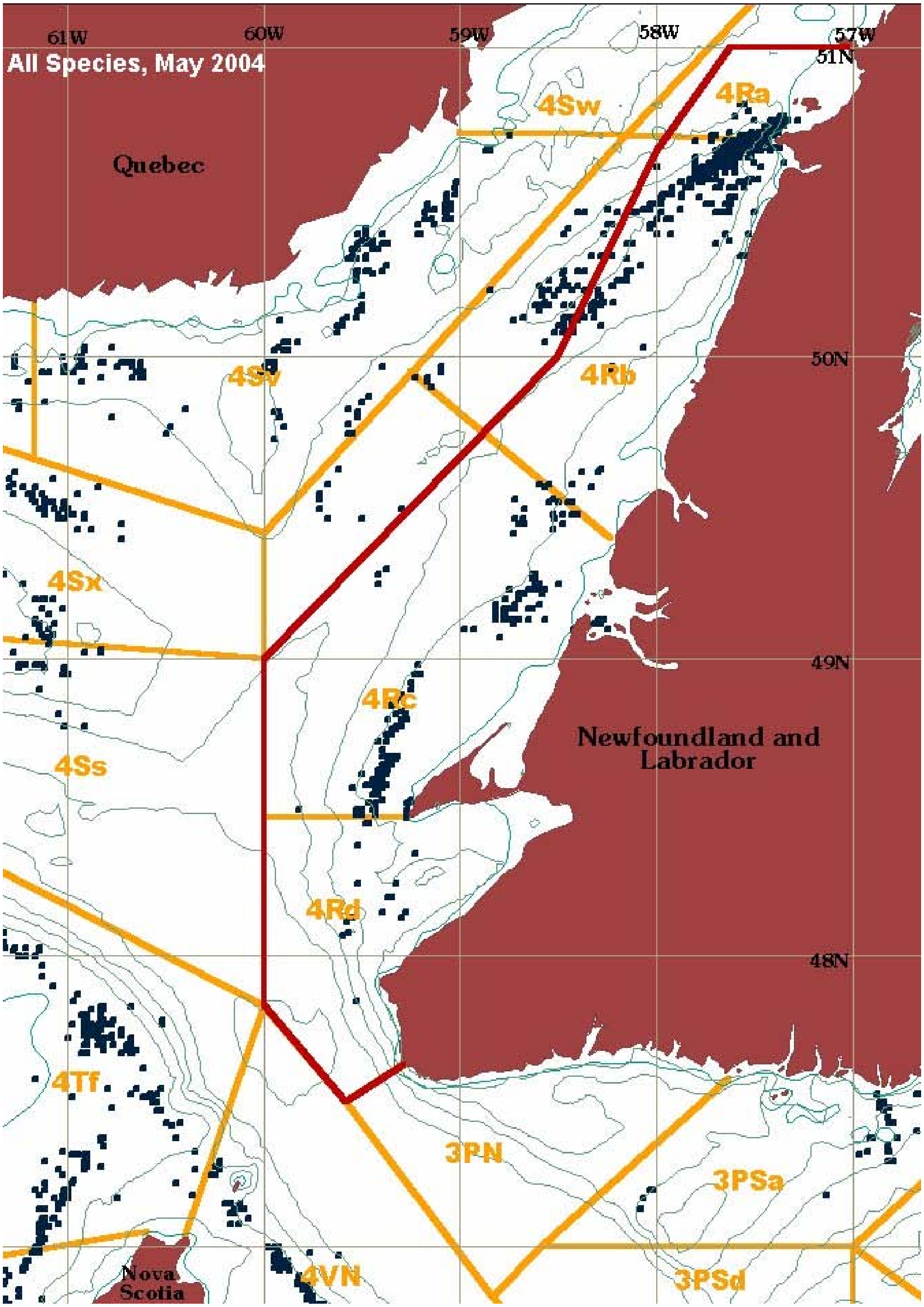


Figure 3.17. Harvesting Locations, Study Area and Adjacent Waters, All Species, May 2004.

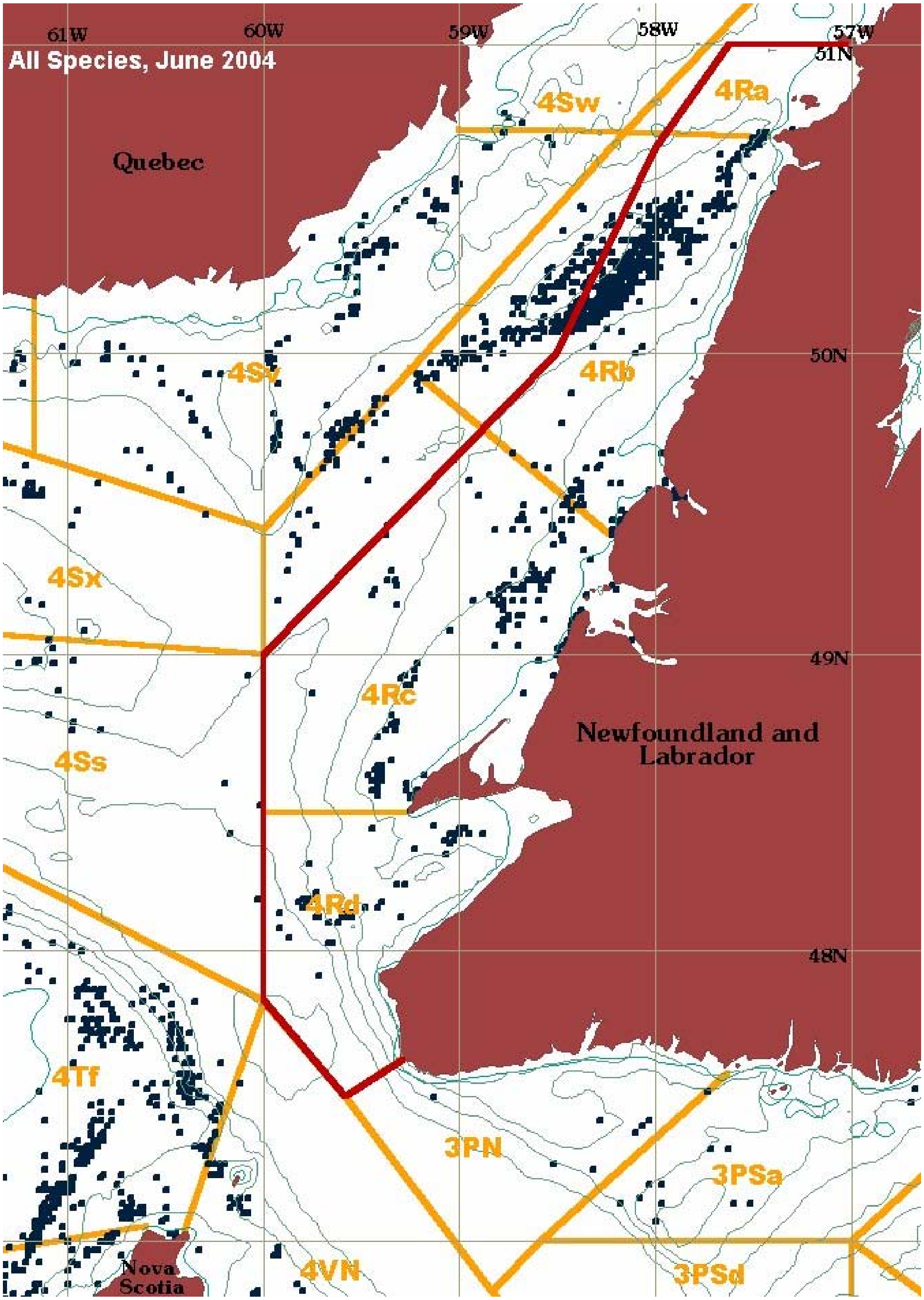


Figure 3.18. Harvesting Locations, Study Area and Adjacent Waters, All Species, June 2004.

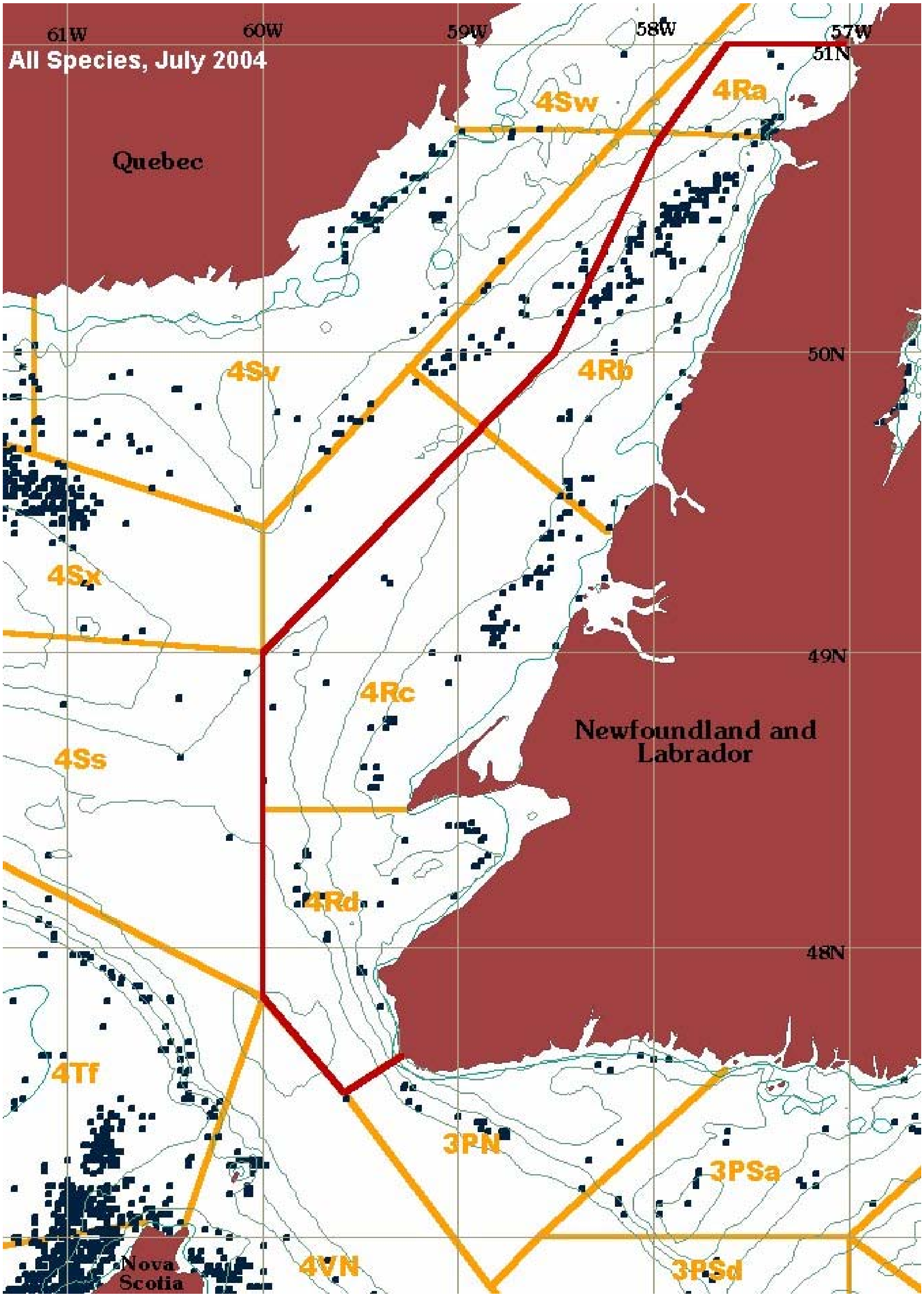


Figure 3.19. Harvesting Locations, Study Area and Adjacent Waters, All Species, July 2004.

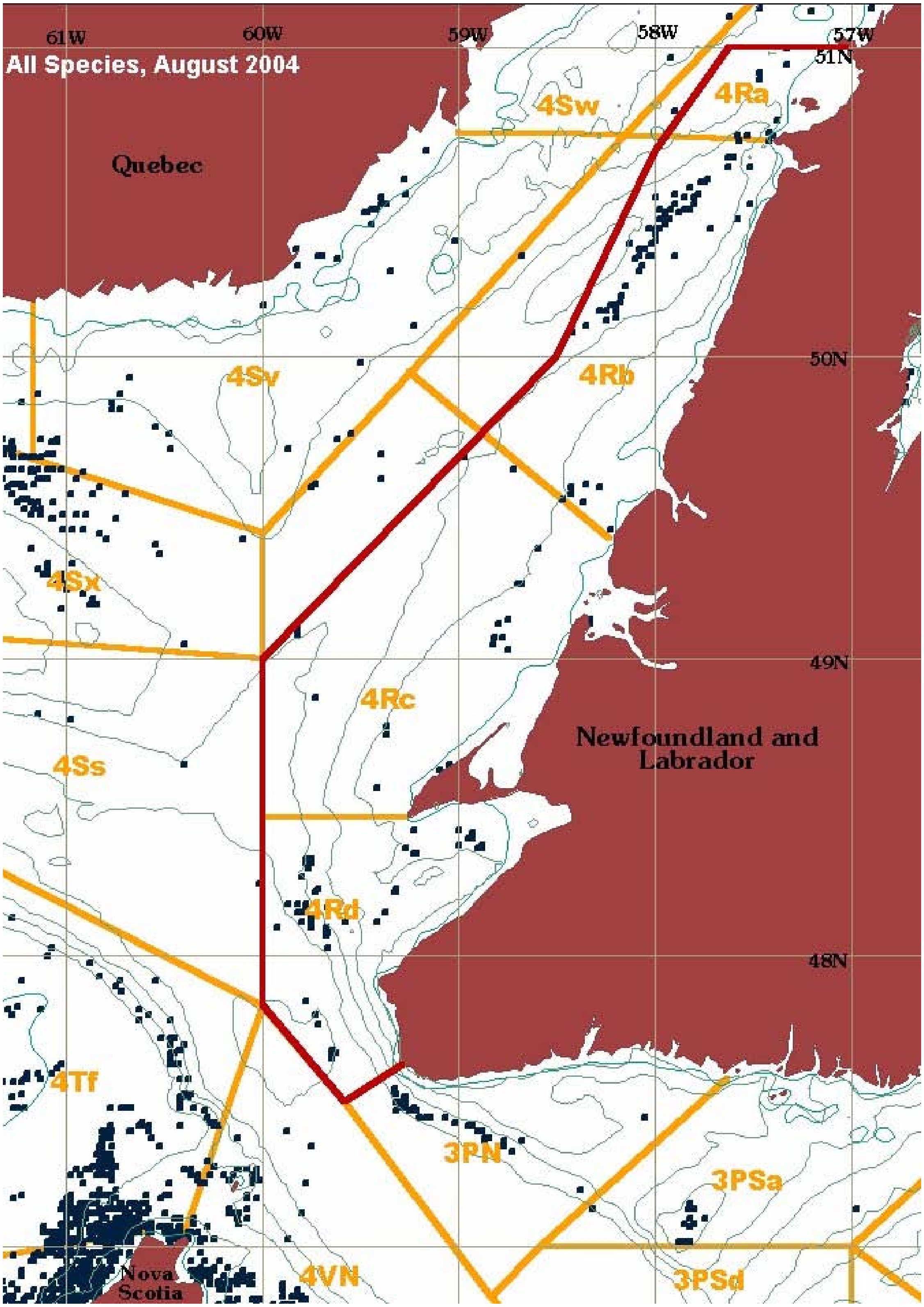


Figure 3.20. Harvesting Locations, Study Area and Adjacent Waters, All Species, August 2004.

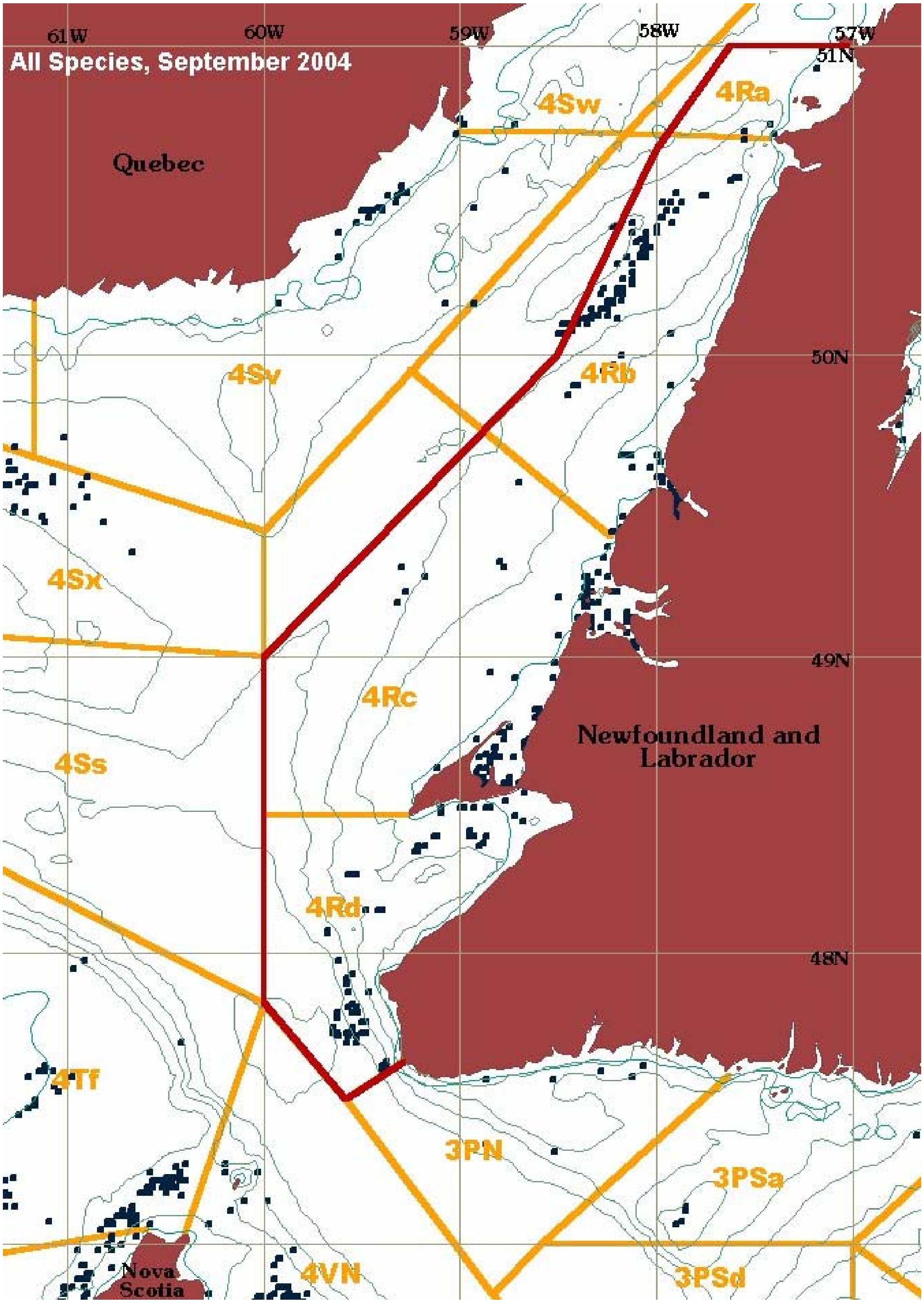


Figure 3.21. **Harvesting Locations, Study Area and Adjacent Waters, All Species, September 2004.**

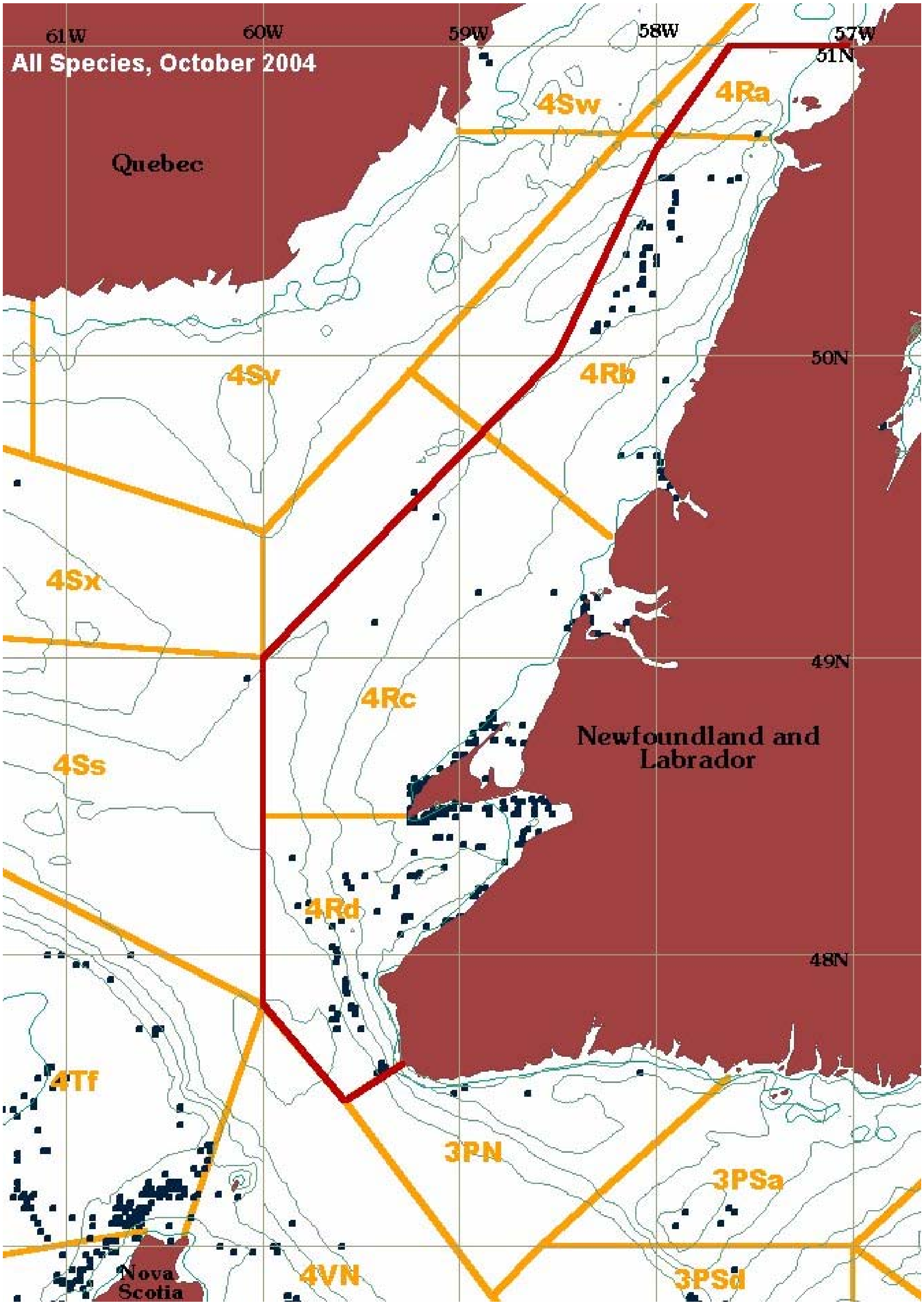


Figure 3.22. Harvesting Locations, Study Area and Adjacent Waters, All Species, October 2004.

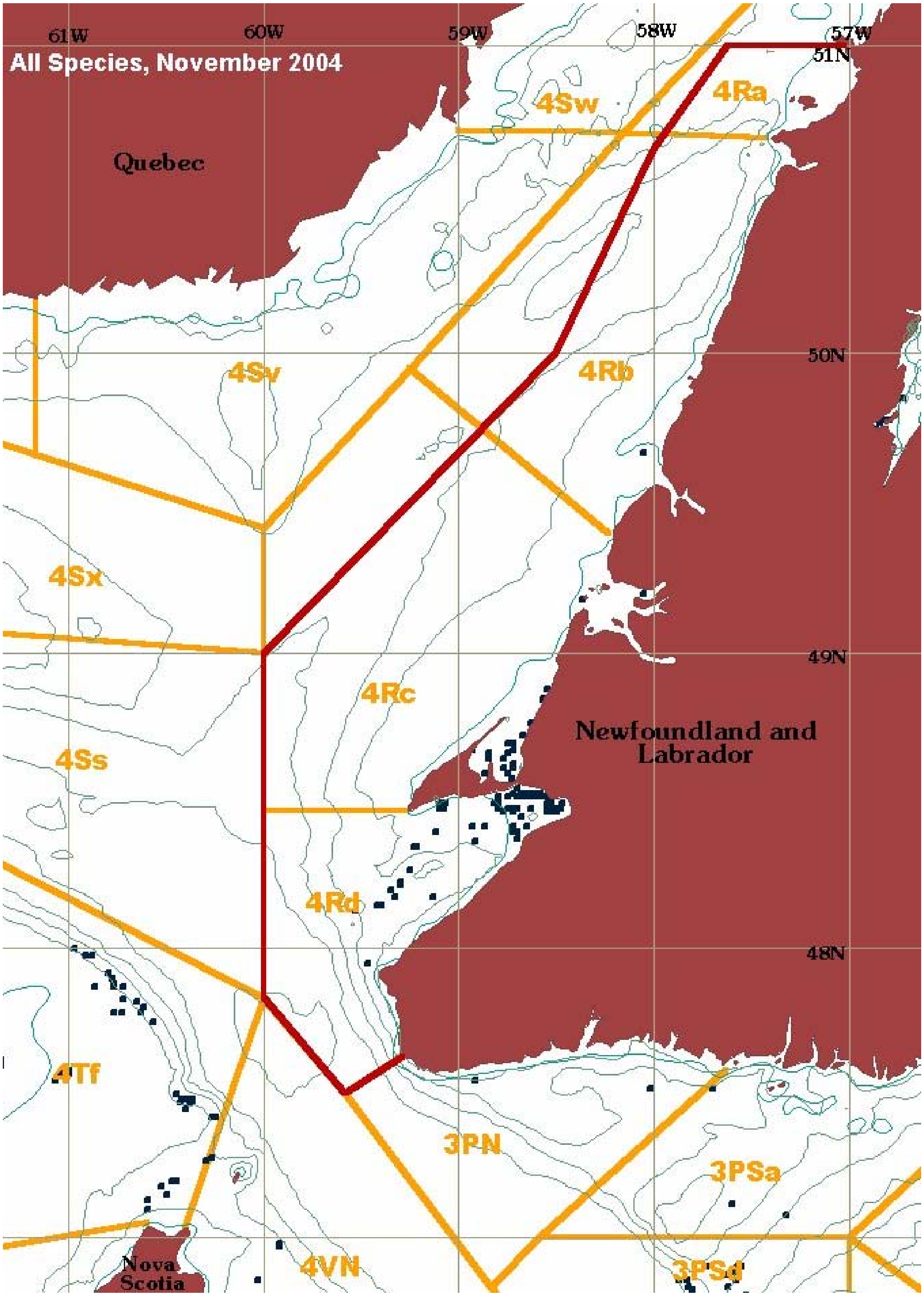


Figure 3.23. Harvesting Locations, Study Area and Adjacent Waters, All species, November 2004.

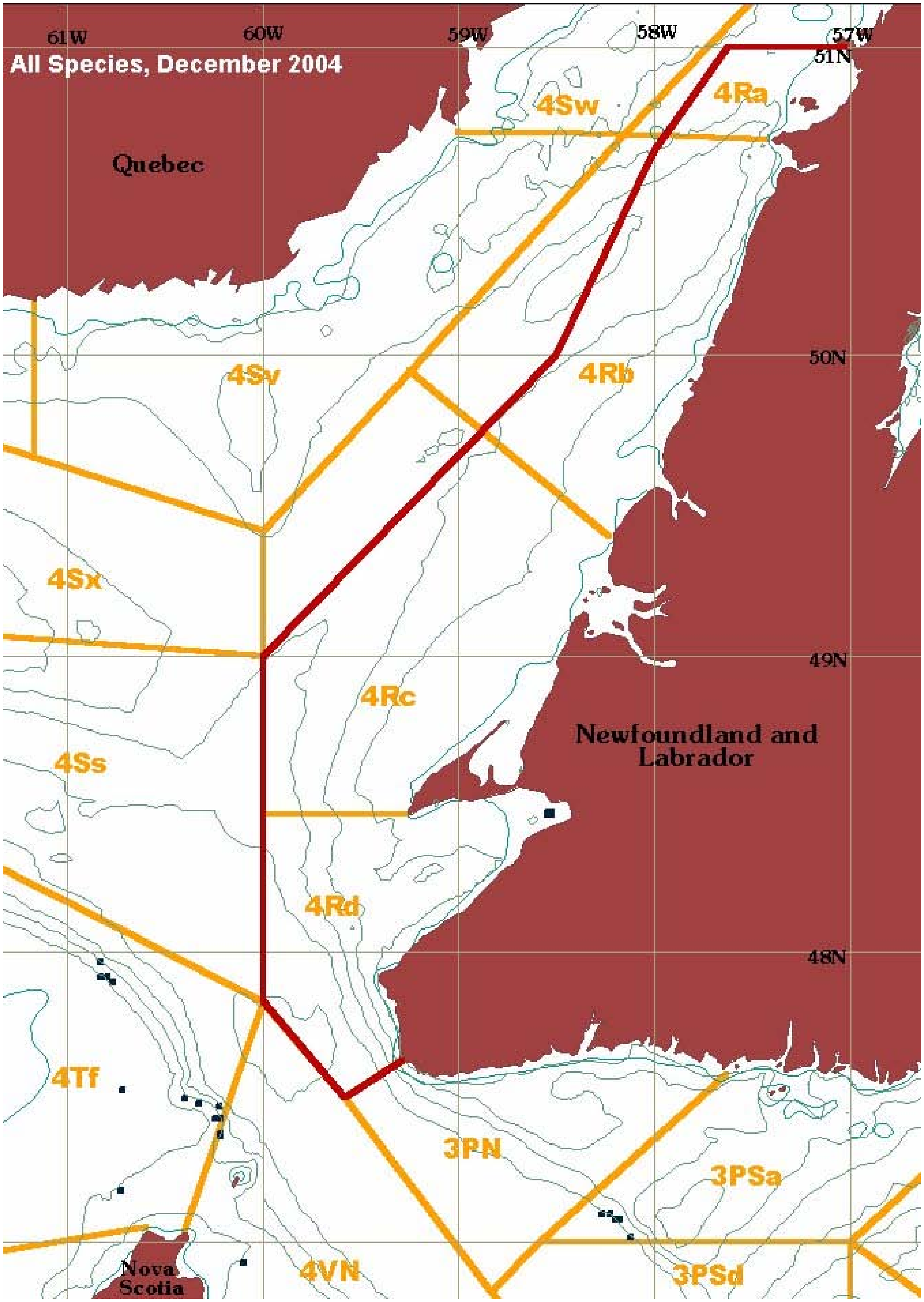


Figure 3.24. Harvesting Locations, Study Area and Adjacent Waters, All Species, December 2004.

3.4.4.5 Principal Species Fisheries

As discussed, groundfish (primarily cod, redfish and greysole flounder), herring, mackerel, capelin, lobster, shrimp and snow crab make up more than 99% of the 4Rb,c,d harvest in recent years. This section provides more detailed information on these fisheries. Maps presented are based on the georeferenced (lat/long) data for 2002 - 2004.

Groundfish

As discussed previously, the groundfish harvest has been drastically reduced in Division 4R (NL and NS data) over the last two decades, owing largely to changes in the cod fisheries (Figure 3.25). Although still important socially and economically, in 2004 the groundfisheries were only about 5% of what they had been two decades earlier (Figures 3.25 to 3.28). Rather similar declines occurred in some other groundfish harvests, such as redfish, while halibut and greysole (witch) flounder harvests have not followed these same trends, as indicated in the following graphs of key groundfish harvests.

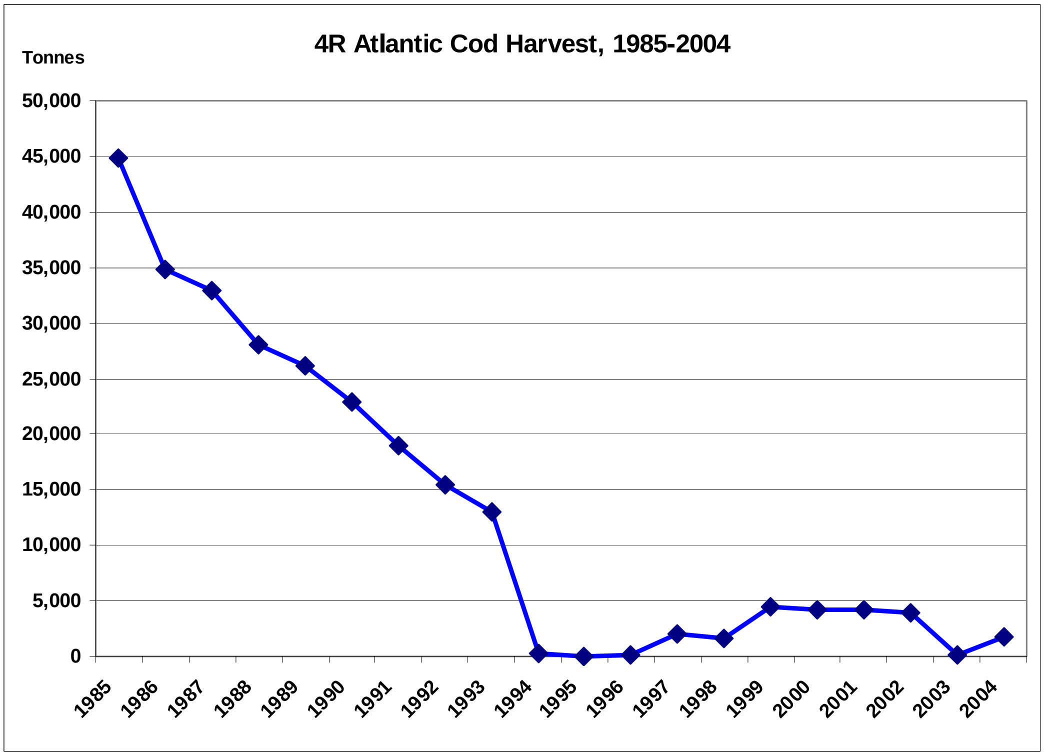


Figure 3.25. Cod Harvest in 4R, 1985-2004.

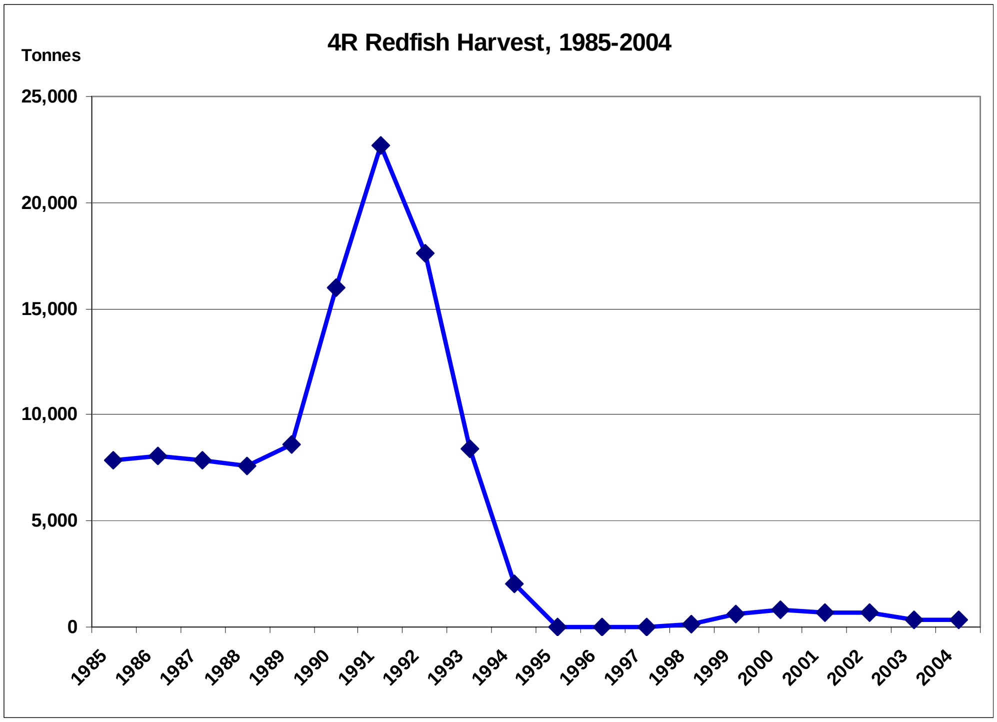


Figure 3.26. Redfish harvest in 4R, 1985-2004

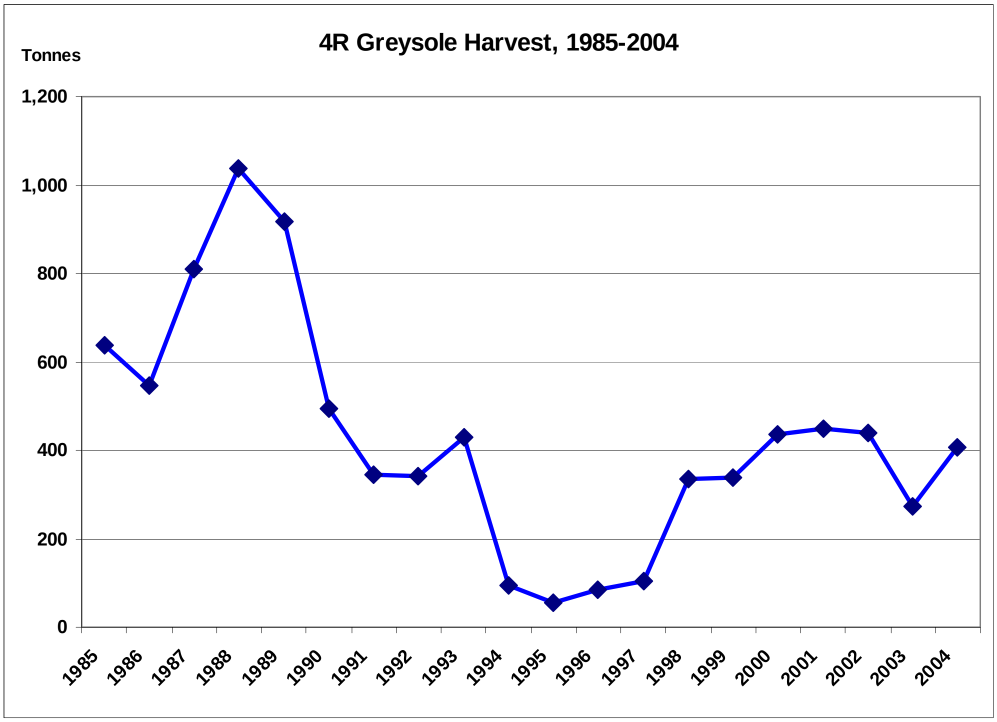


Figure 3.27. Greysole Flounder Harvest in 4R, 1985-2004

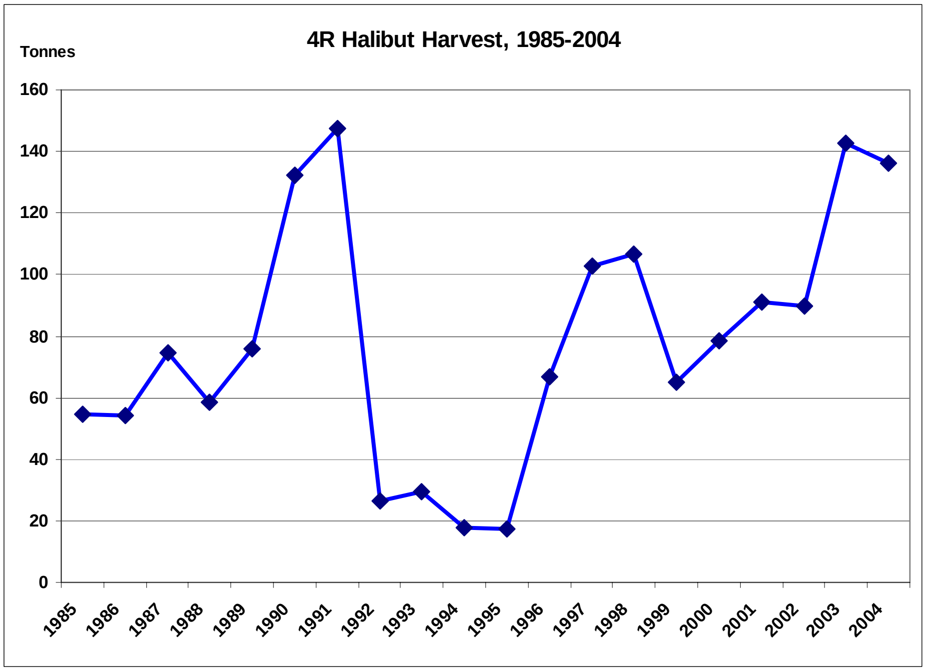


Figure 3.28. Atlantic Halibut Harvest in 4R, 1985-2004

Cod are harvested in the area mainly with gillnets, longlines and handlines. Redfish are taken almost entirely with stern otter trawls. Greysole are caught using midwater trawls. Halibut are harvested primarily using longlines, though small quantities are also harvested using gillnets and otter trawls.

Figures 3.29 to 3.35 show the timing of the groundfish harvest in 4Rb,c,d during 2002 – 2004, and - show the locations of the georeferenced harvest for groundfish (2002-2004), and then for key groundfish species during 2004.

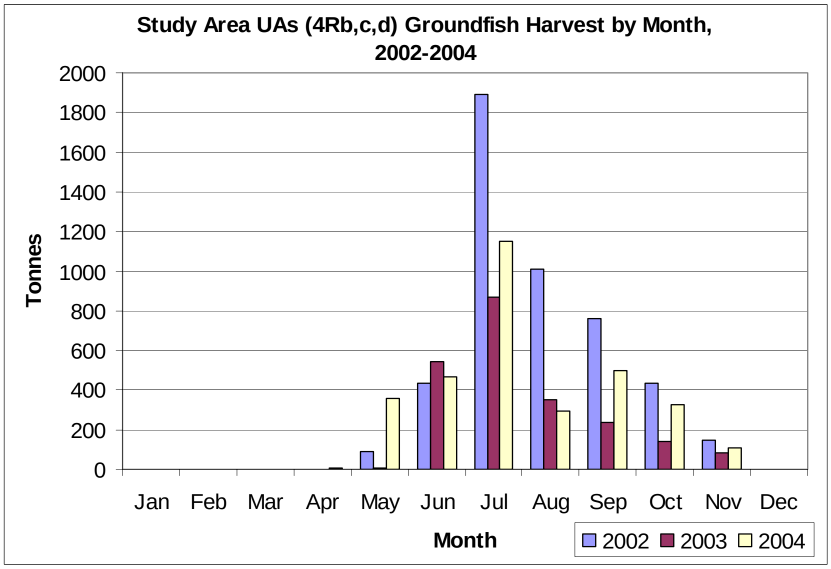


Figure 3.29. 4Rb,c,d Groundfish Harvest by Month, 2002, 2003 and 2004.

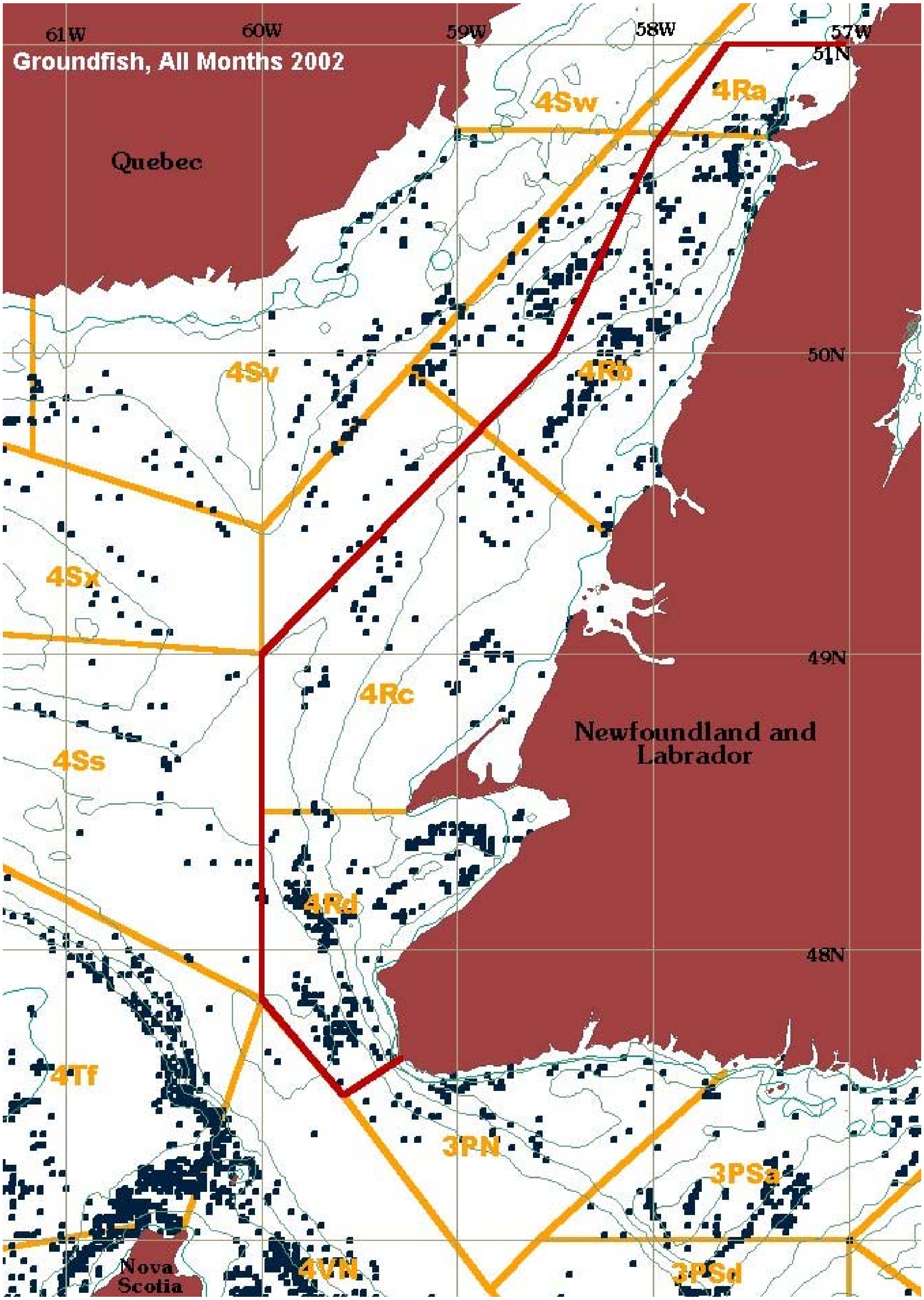


Figure 3.30. Harvesting Locations, Groundfish Species, All Months 2002.

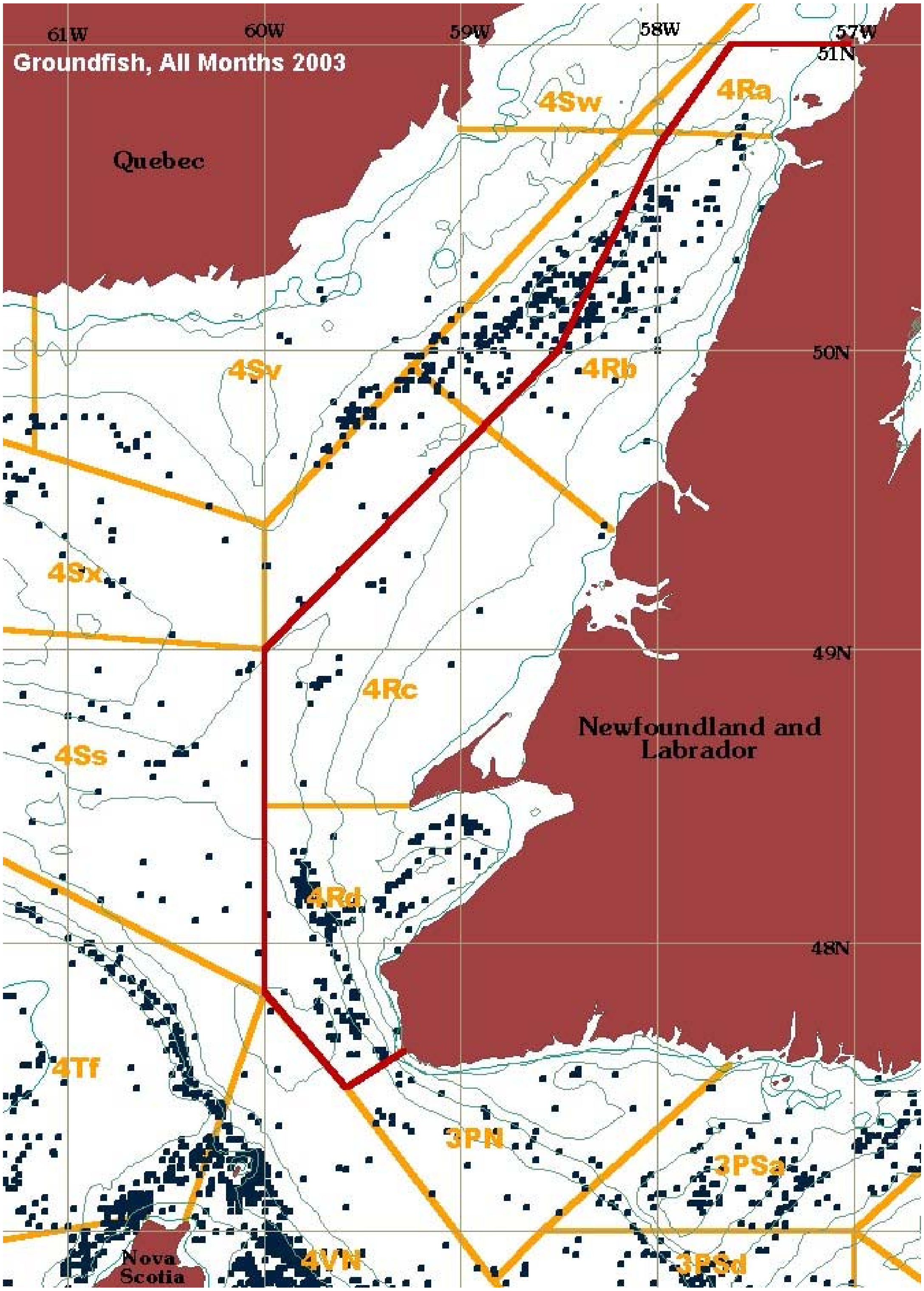


Figure 3.31. Harvesting Locations, Groundfish Species, All Months 2003.

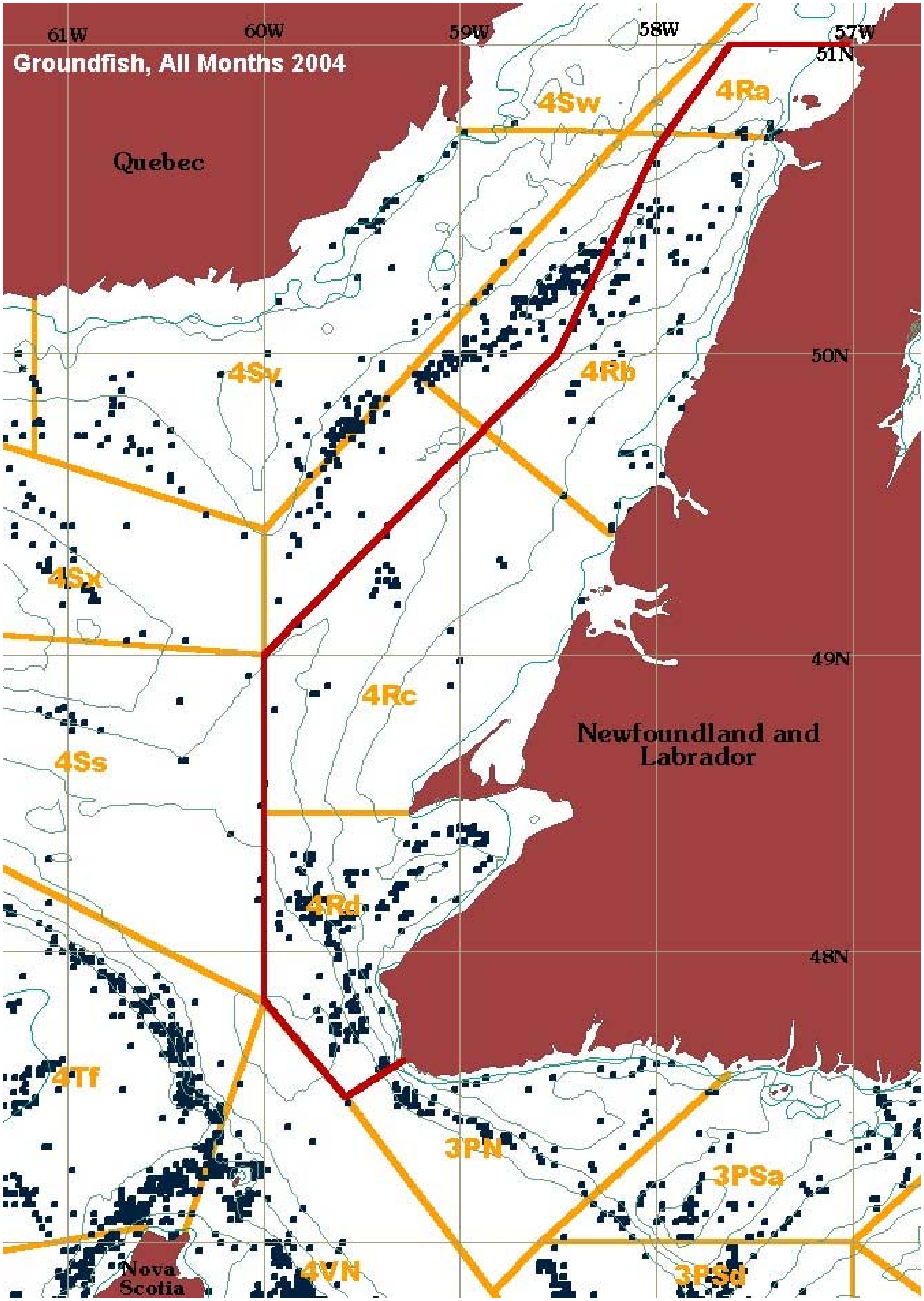


Figure 3.32. Harvesting Locations, Groundfish Species, All Months 2004.

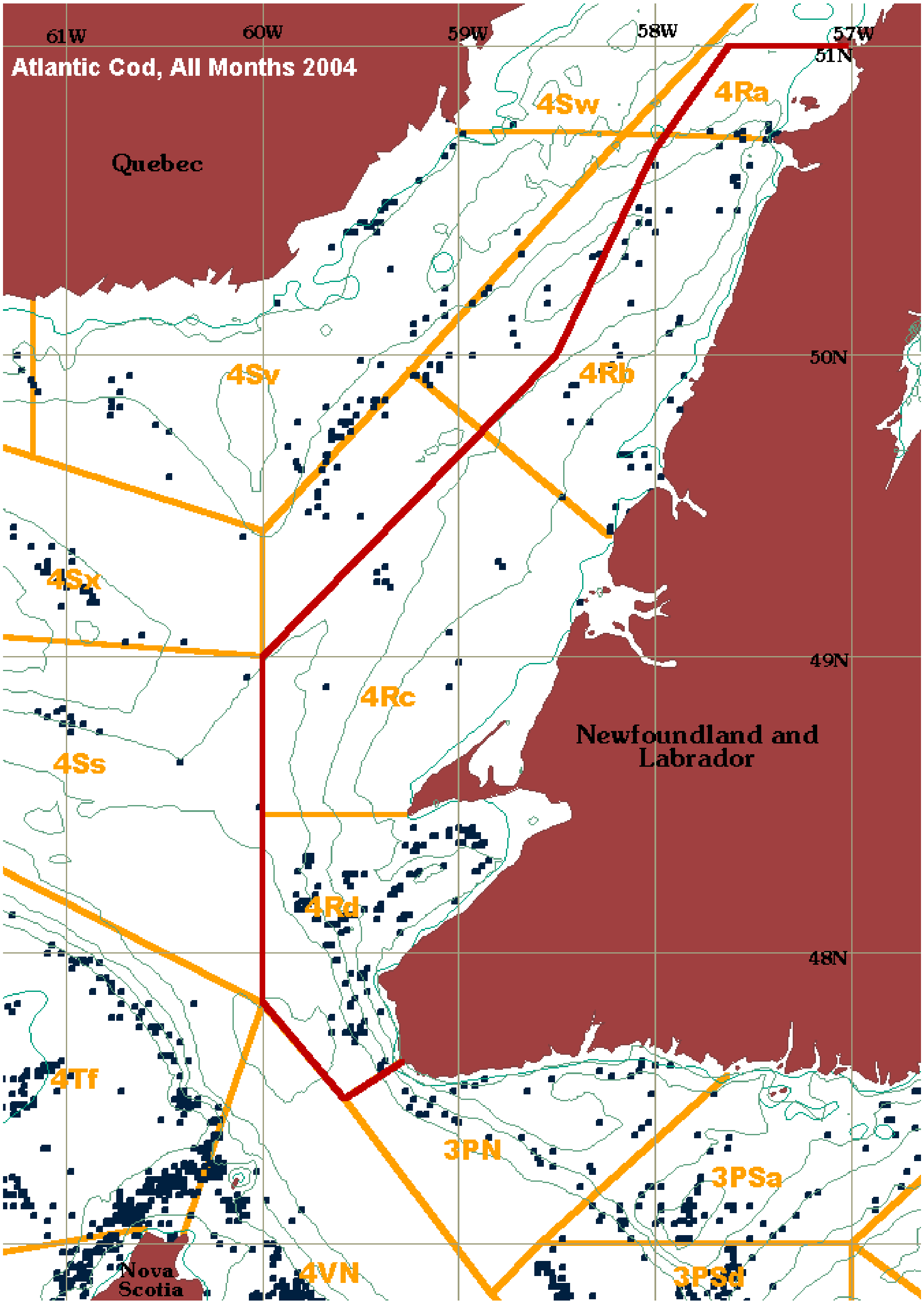


Figure 3.33. Harvesting Locations, Atlantic Cod, All Months 2004.

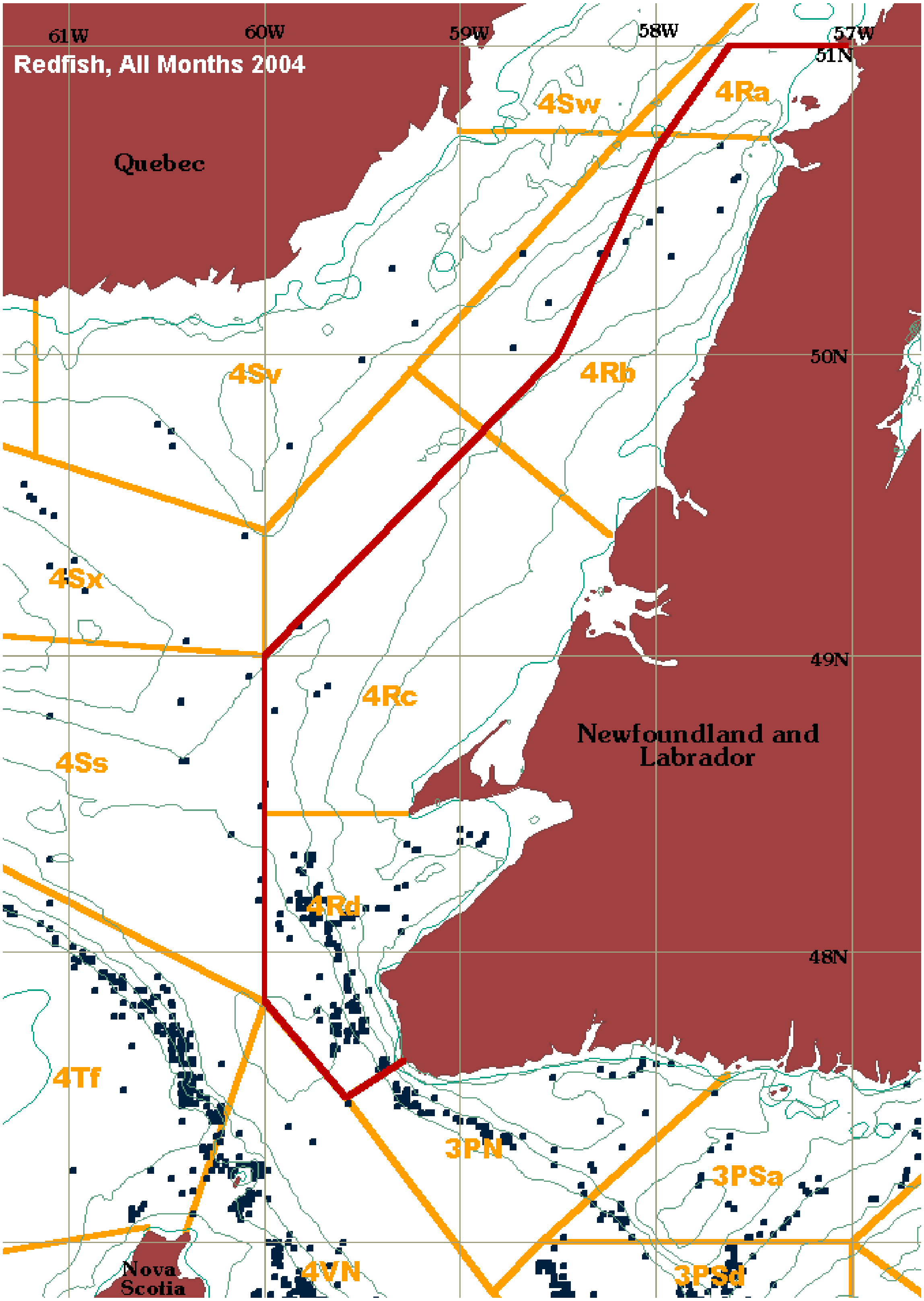


Figure 3.34. Harvesting Locations, Redfish, All Months 2004.

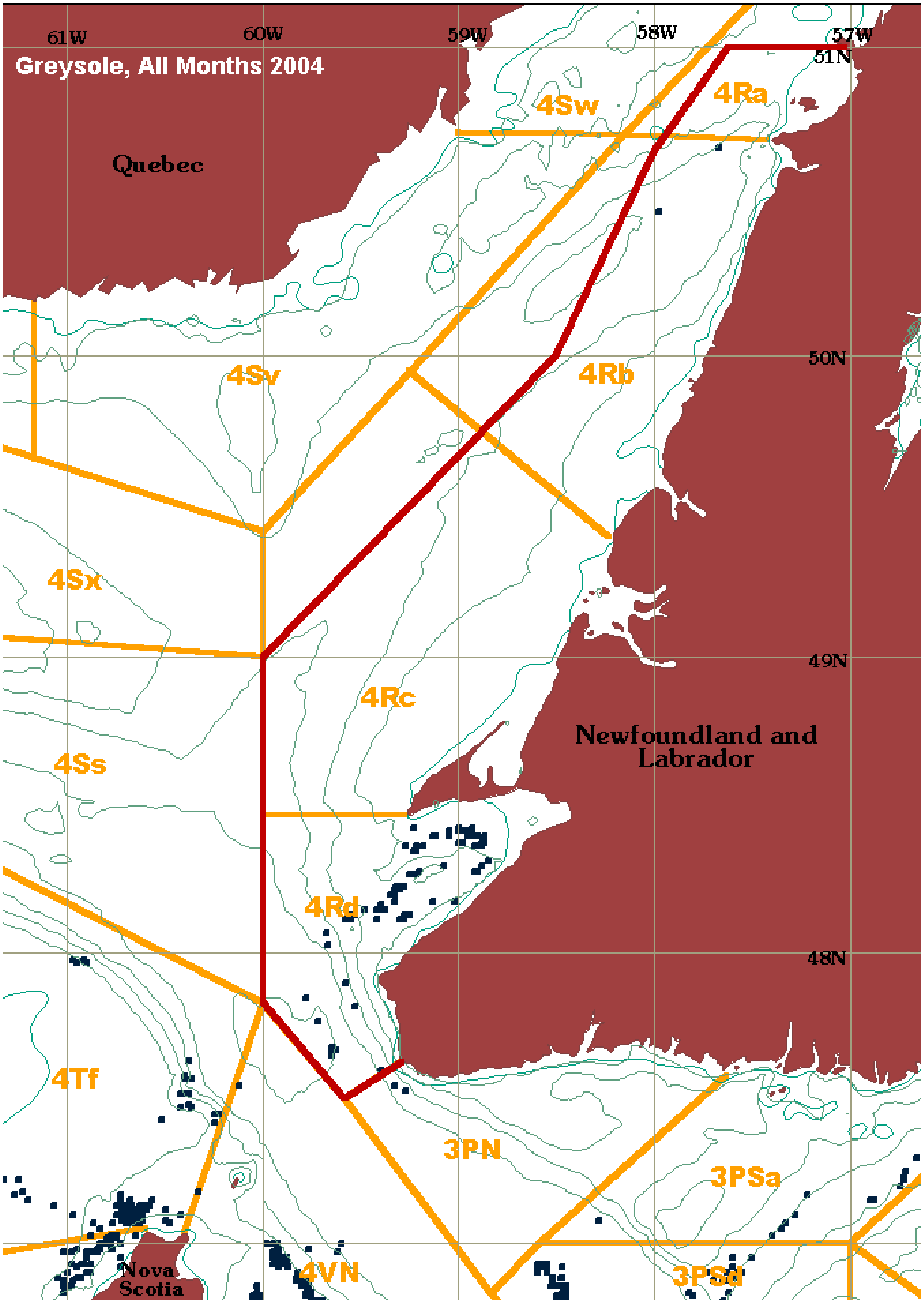


Figure 3.35. Harvesting Locations, Greysole Flounder Species, All Months 2004.

Herring

The herring fishery in the area now accounts for the second largest part of the harvest, by quantity, after mackerel. Figure 3.36 shows commercial landings for 1985 to 2004. As the data indicate, the herring harvest over the past decade or so has been fairly stable in the area, accounting for about 15,000 tonnes of the harvest annually. However, in addition to the landings recorded in the DFO datasets, there is also a substantial bait fishery for herring which is not recorded. As DFO notes, “These catches are not accounted for and could be substantial, especially since the crab (*Chionoecetes opilio*) and lobster (*Homarus americanus*) fisheries have recently shown record highs” (DFO 2005g).

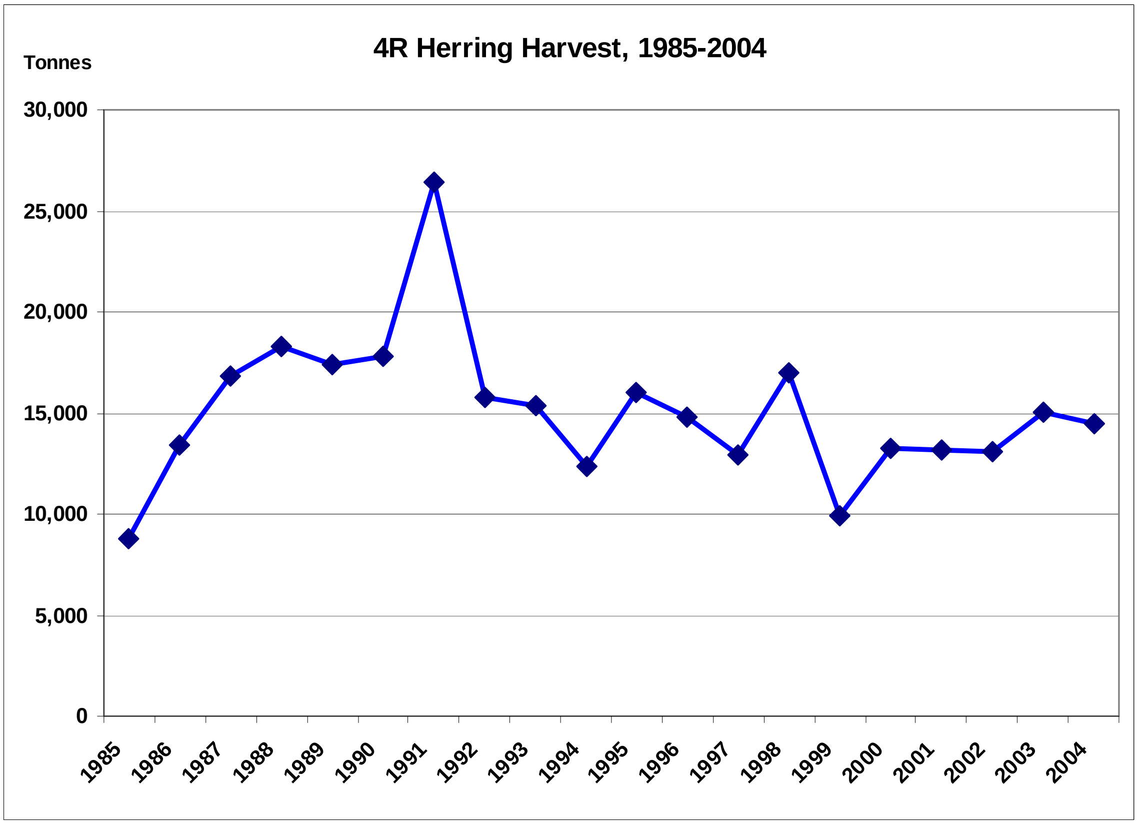


Figure 3.36. 4R Herring Harvest, 1985-2004.

The herring are harvested primarily with purse seines, though there is also a smaller gillnet fishery. DFO notes, “The two herring stocks of the west coast of Newfoundland are harvested separately during spawning gatherings or collectively when the stocks are mixed between April and December. These stocks are mainly harvested by a fleet of large (>65’) and small (<65’) seiners, and by many gillnet fishermen. From 1990 to 2003, landings made using the three types of gear averaged 15,285 t per year. The average annual landings were 10,859 t for large seiners, 2,915 t for small seiners, and 1,368 t for gillnetters.”

The following graph (Figure 3.37) shows the timing of the harvest in 4Rb,c,d during 2002 – 2004, and the following maps (Figures 3.38 to 3.40) show the locations of the georeferenced harvest for herring (2002-2004). As the graph indicates, the herring fishery is conducted in two phases during the year: a spring fishery (May-July) and a more substantial fall harvest (October-December).

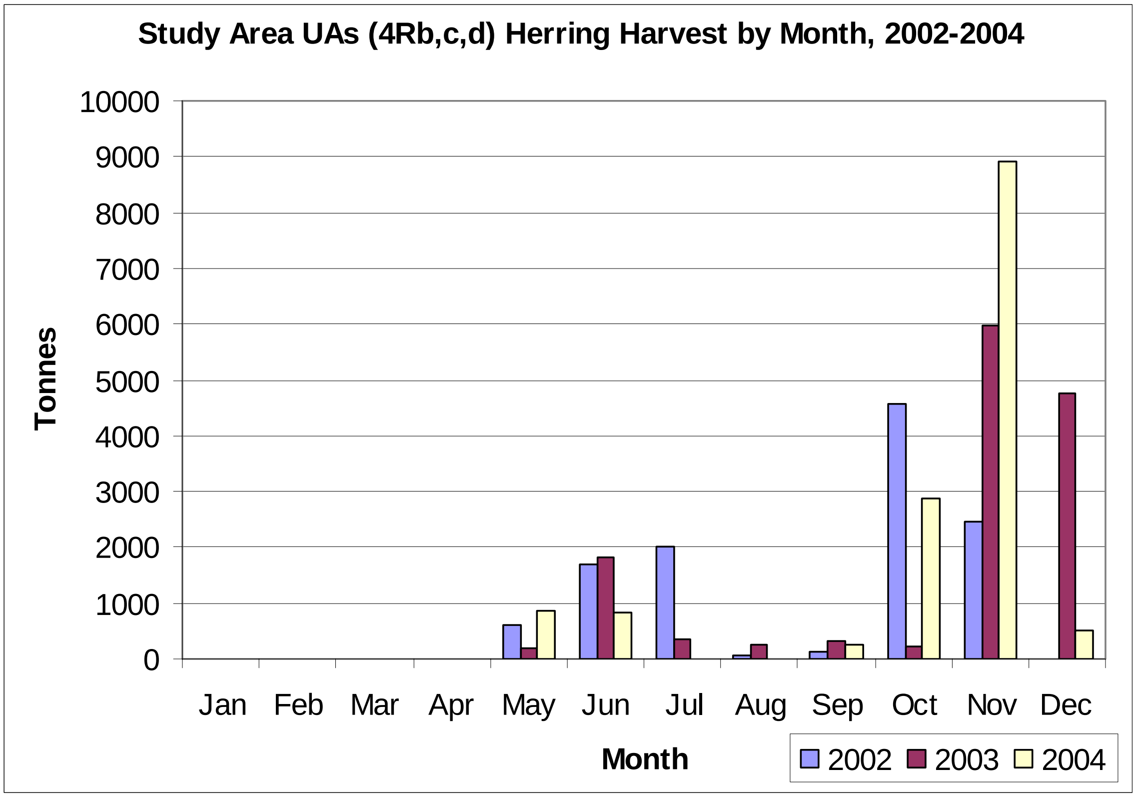


Figure 3.37. 4Rb,c,d Herring Harvest by Month, 2002, 2003 and 2004.

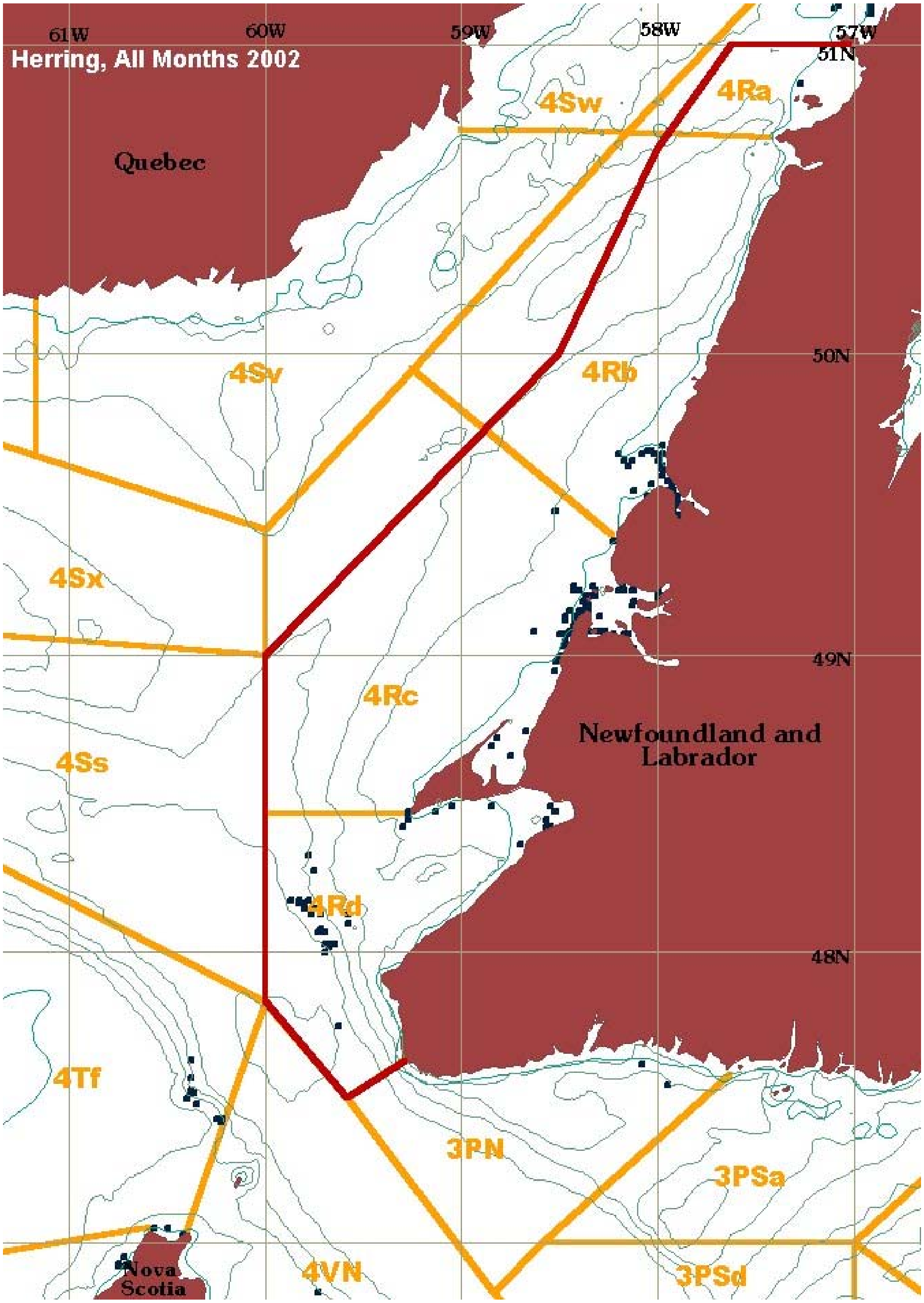


Figure 3.38. Harvesting Locations, Herring, All Months 2002.

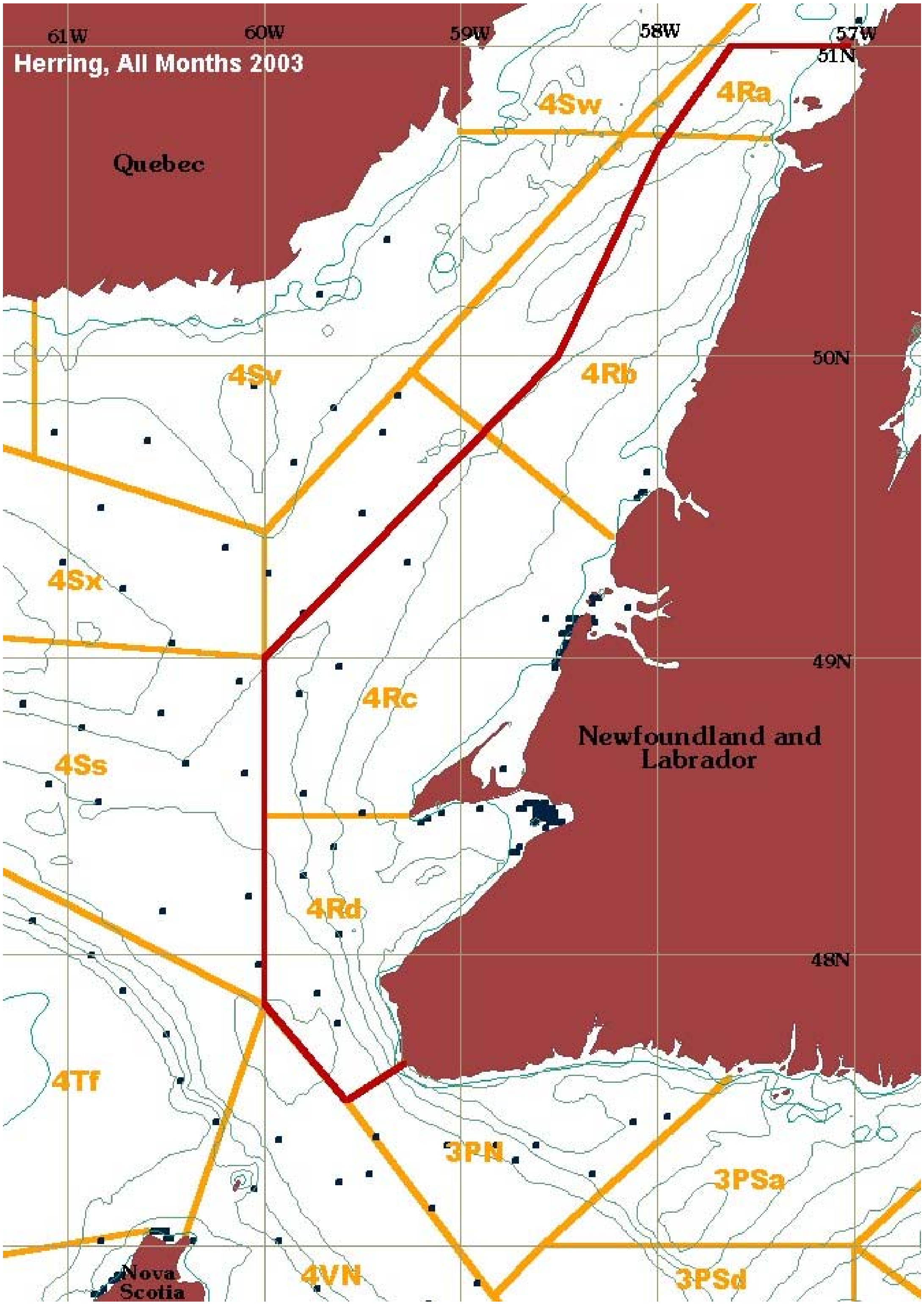


Figure 3.39. Harvesting Locations, Herring, All Months 2003.

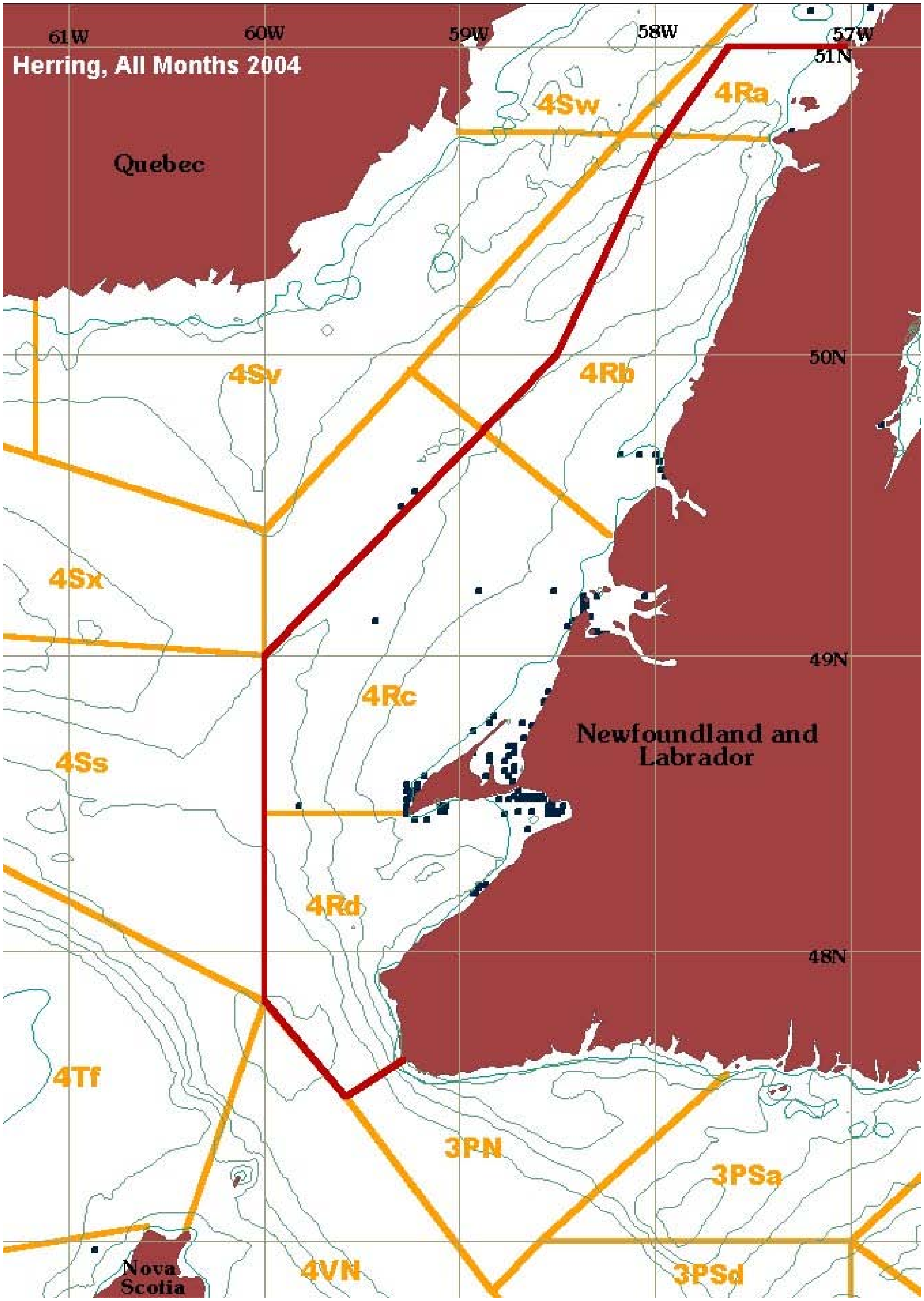


Figure 3.40. Harvesting Locations, Herring, All Months 2004.

Mackerel

The mackerel fisheries typically accounts for the most significant harvest, by quantity in the area, though its low price (relative to shellfish species, for example) means that it is less significant economically. Figure 3.41 shows commercial landings for mackerel for 1985 to 2004. As it indicates, since 2000 the harvests have risen dramatically, though they declined slightly in 2004. However, as DFO notes, of the eastern Canadian/U.S. mackerel fishery, “The mackerel that are caught and then used for bait do not appear in the Department’s official statistics, which are based on purchase slips from sales to processing plants. Recreational fishing is very popular in summer, and these statistics aren’t recorded either. Since these activities are carried out throughout Eastern Canada, the actual total number of mackerel caught is largely underestimated” (DFO 2005c).

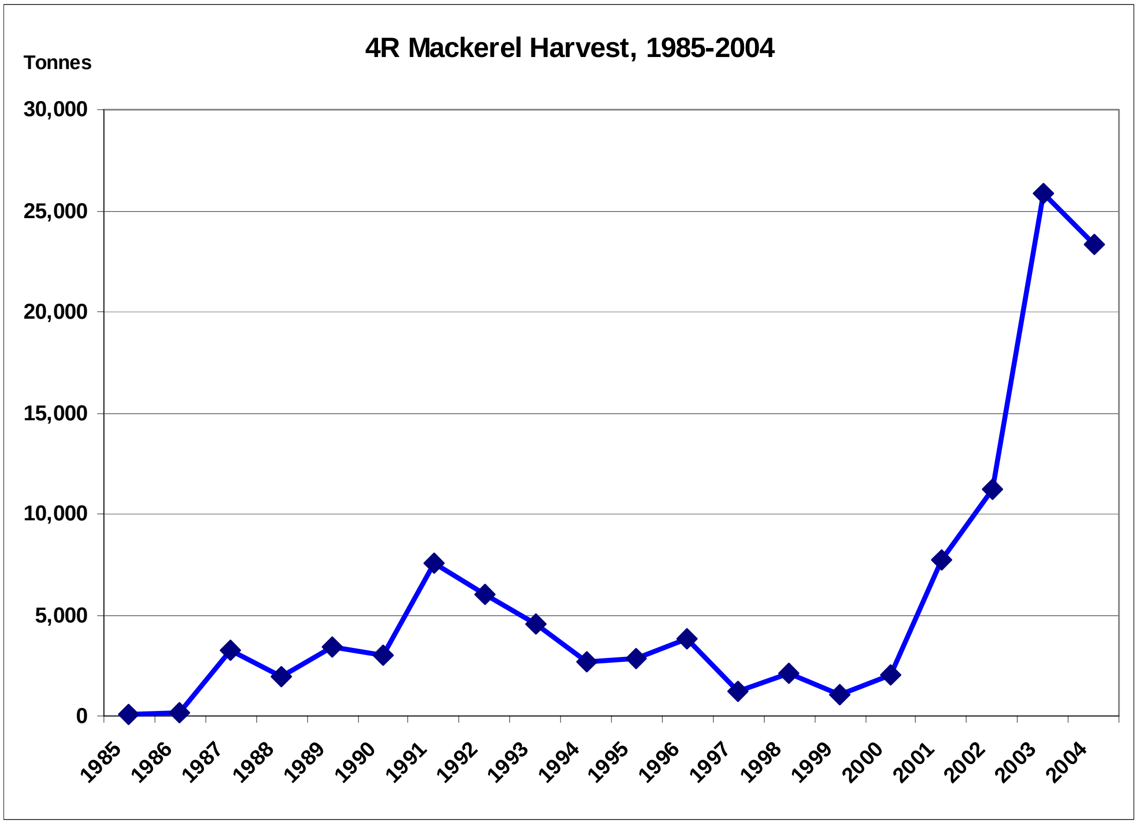


Figure 3.41. 4R Mackerel Harvest, 1985-2004.

The mackerel fishery, like herring, is mainly pursued using purse seines in this area. However, DFO reports, “For several years, 40% of the TAC has been allocated to mobile gear over 65’ (19.8 m), and 60% to mobile gear under 65’ and to coastal fixed gear such as traps, gillnets, lines and weirs. In the first case, nearly 50% and 35% of the quota was reached in 2003 and 2004 respectively. These values were the highest of all historical landing series. In the second case, 66% and 55% of the quota was reached over the last two years.”

The following graph of the timing of the mackerel harvest in the area indicates that it is primarily a late summer – early fall fishery (Figure 3.42).

The maps that follow show georeferenced harvesting locations for 2002 – 2004 (Figures 3.43 to 3.45).

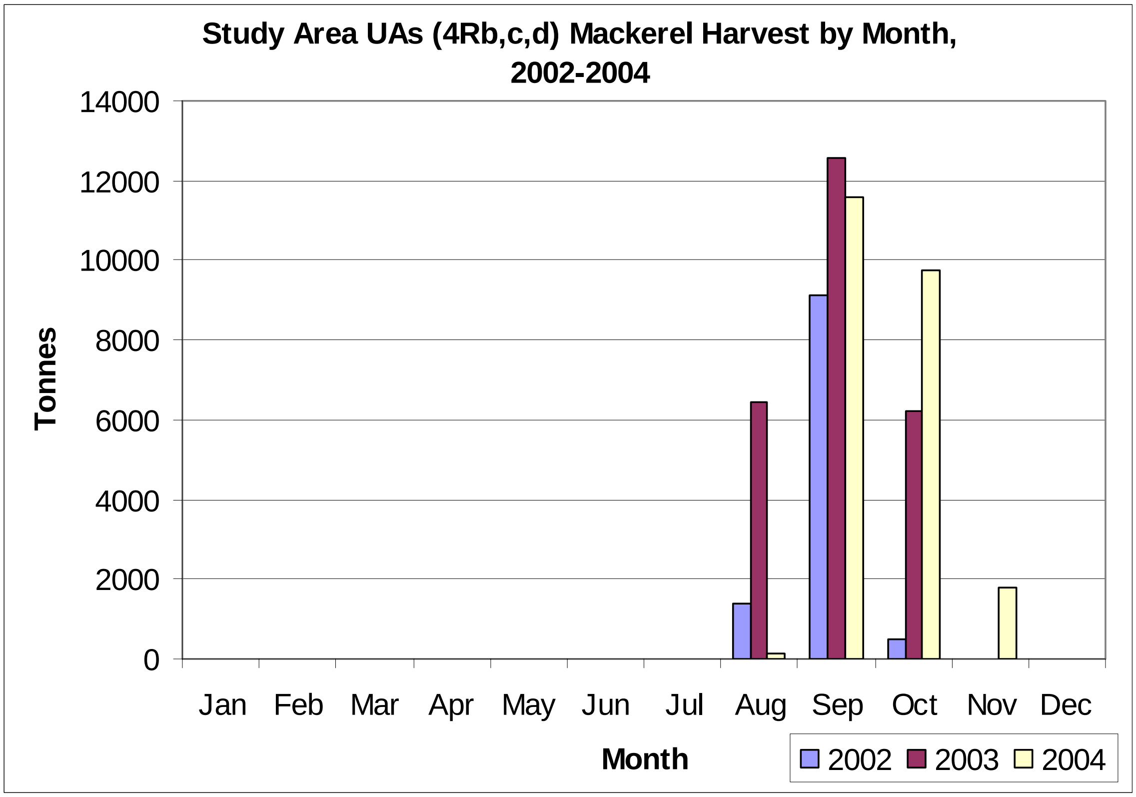


Figure 3.42. 4Rb,c,d Mackerel Harvest by Month, 2002, 2003 and 2004.

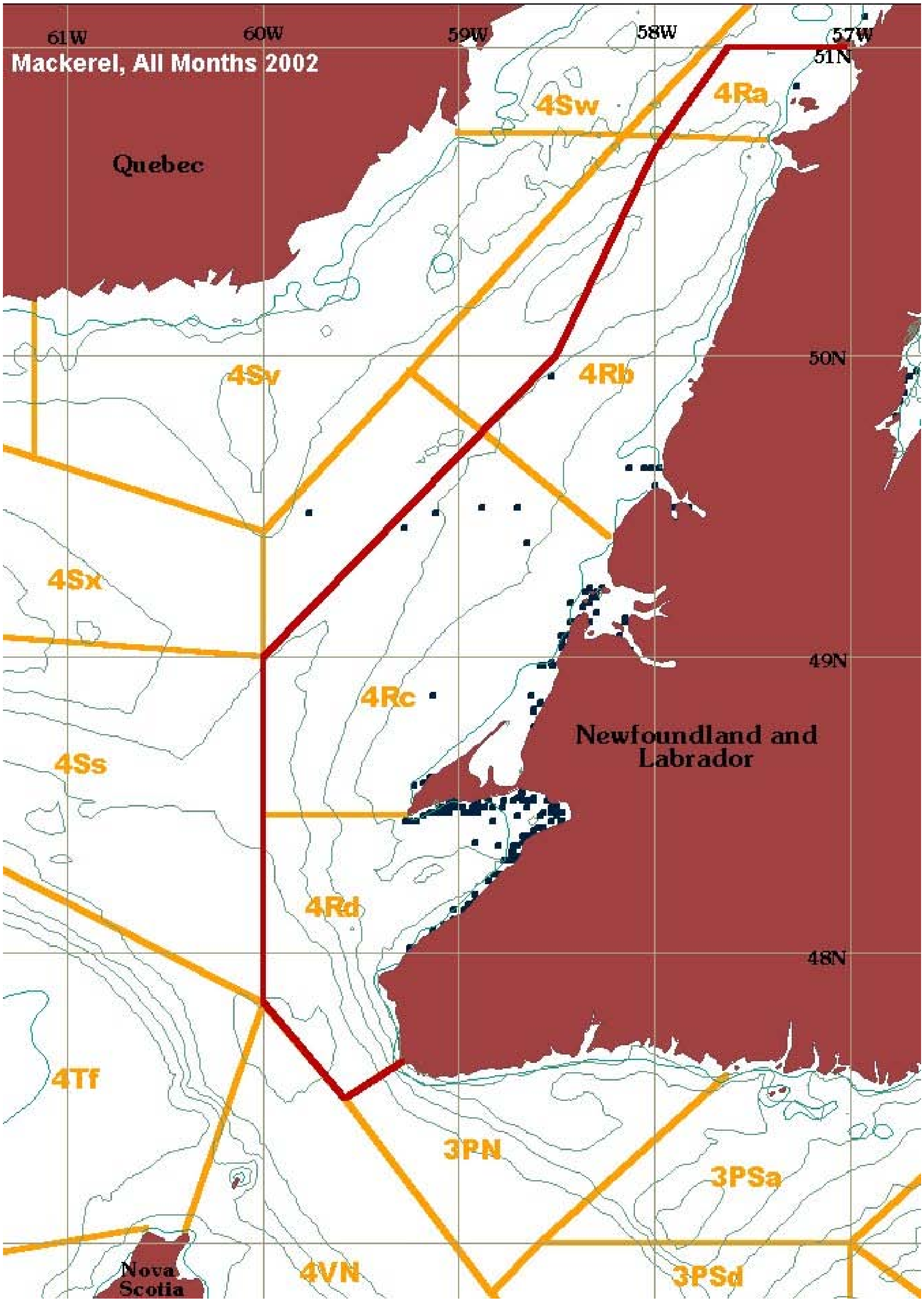


Figure 3.43. Harvesting Locations, Mackerel, All Months 2002.

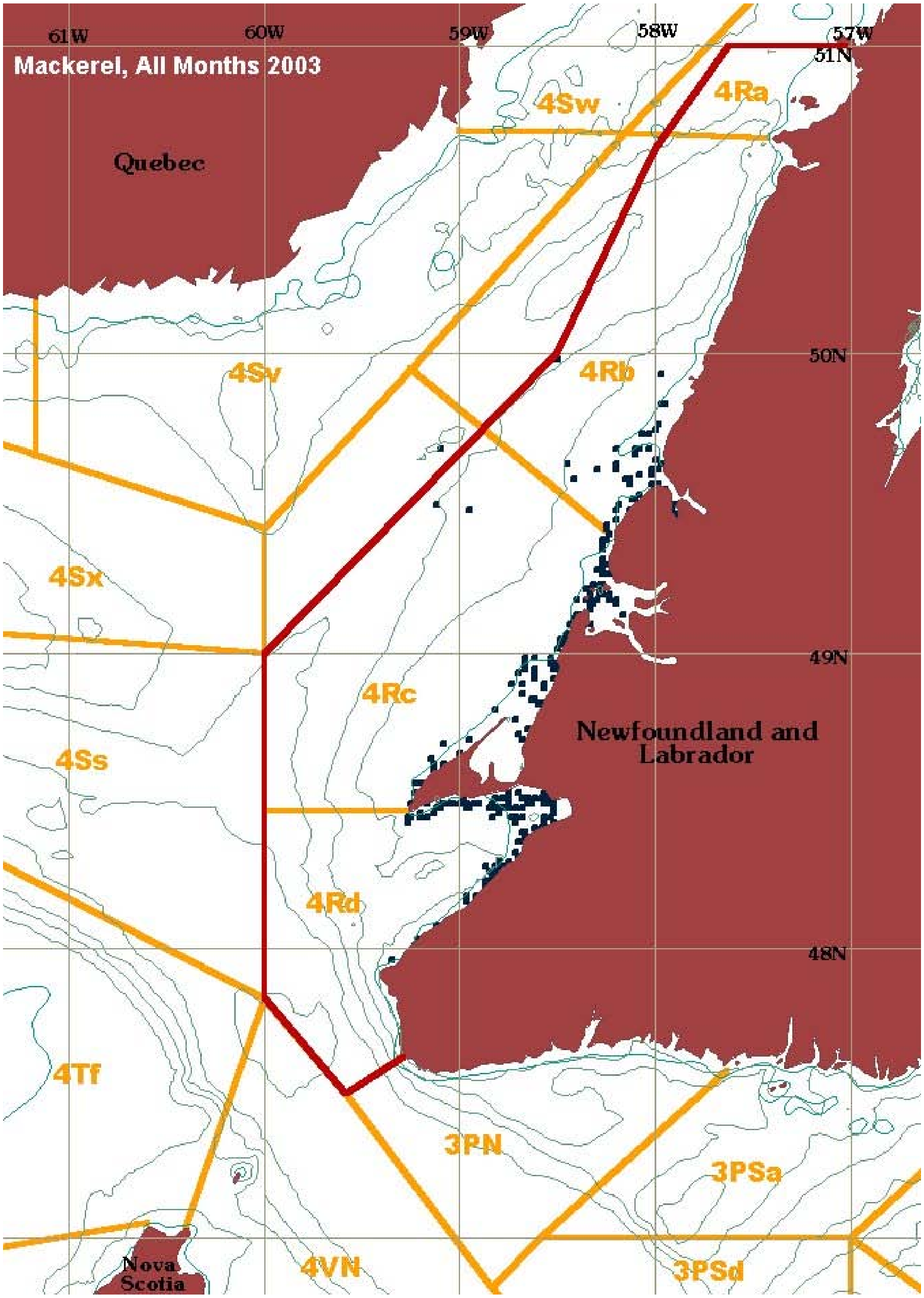


Figure 3.44. Harvesting Locations, Mackerel, All Months 2003.

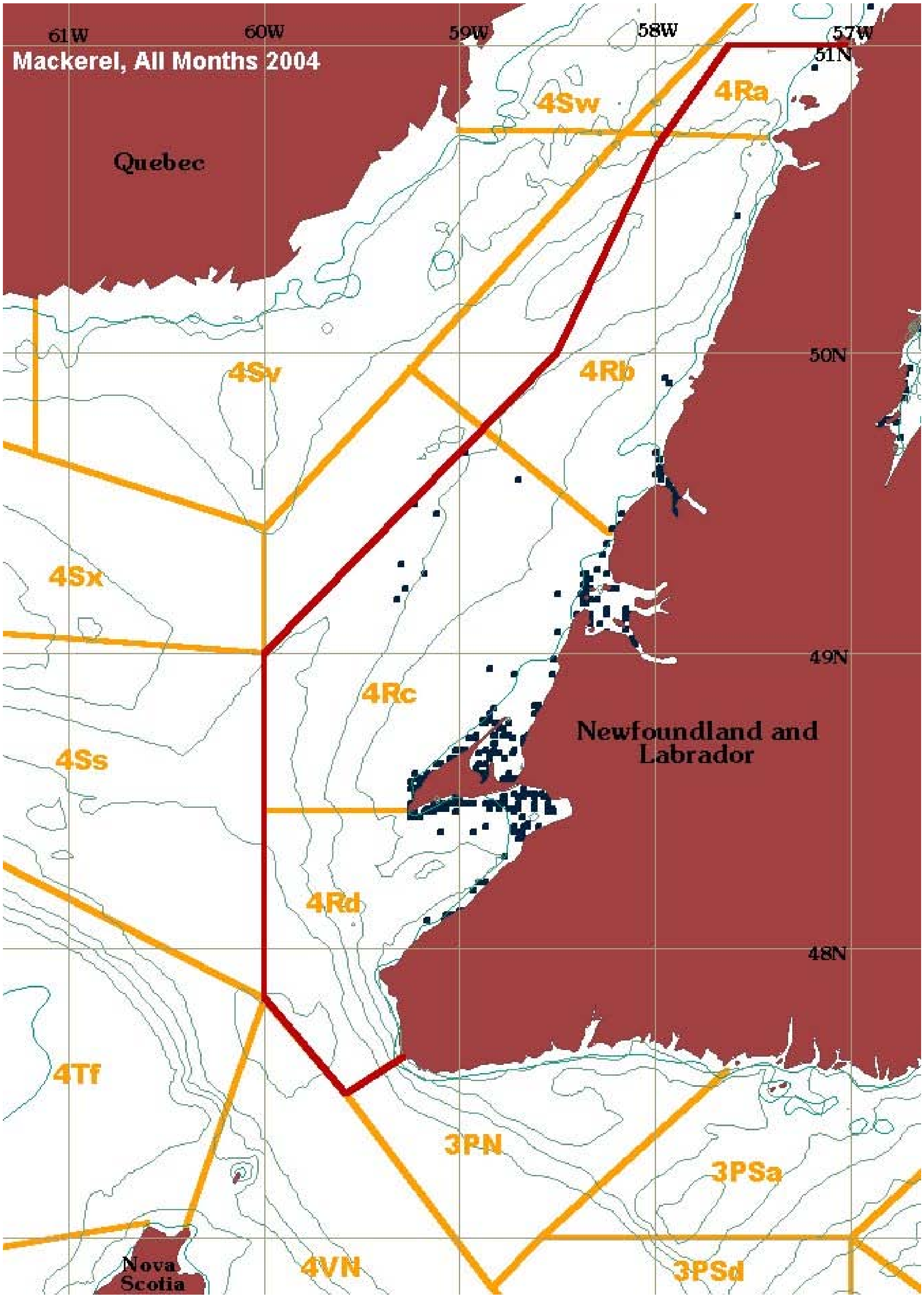


Figure 3.45. Harvesting Locations, Mackerel, All Months 2004.

Capelin

The capelin fishery in the area is quite important to some fishers, though, as the following graph indicates, the fishery has fluctuated markedly over the past several years (Figure 3.46). The fishery is primarily pursued using purse seines in this area.

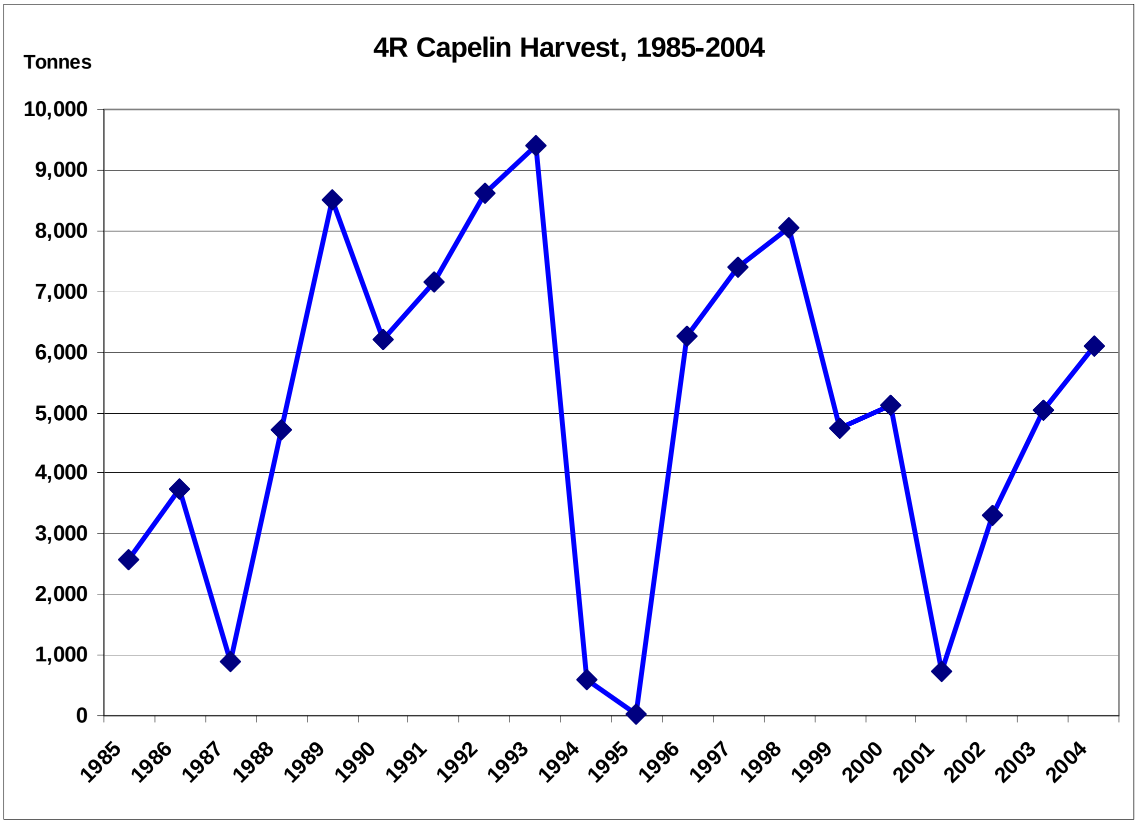


Figure 3.46. 4R Capelin Harvest, 1985-2004.

As the following graph showing the capelin harvest by month for 2002 to 2004 shows, the fishery is quite focused in June and the beginning of July, when the fish aggregate to spawn (Figure 3.47). The purse seine fishery focuses on pre-spawning aggregations and a trap fishery occurs during the spawning period. Both target mature females fish for the Japanese roe market. DFO observes, “Compared to the 1980s, capelin fishing and spawning seasons began later in the 1990s. A relative stability in fishing periods has been observed since 2001. However, median fishing dates are still later than those observed during the 1980s” (DFO 2005d).

Georeferenced harvesting locations are mapped on Figures 3.48 to 3.50. DFO notes that “The largest landings for the entire Gulf of St. Lawrence are made on the west coast of Newfoundland”.

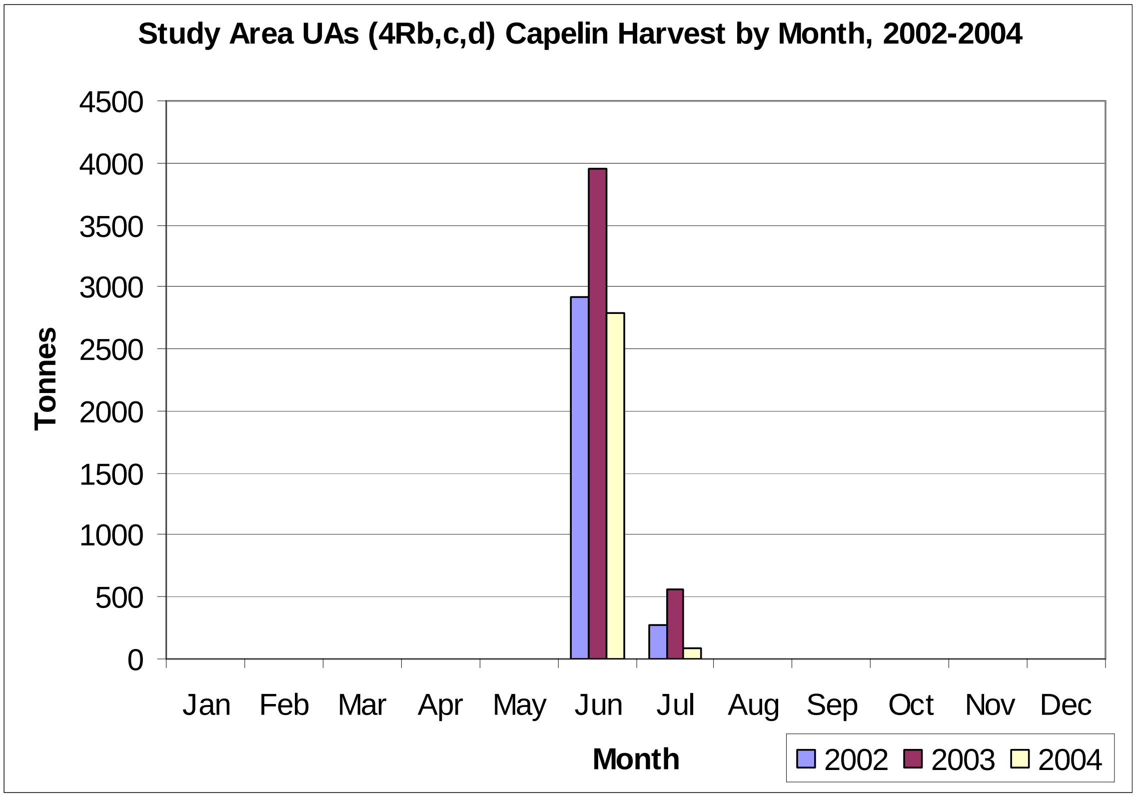


Figure 3.47. 4Rb,c,d Capelin Harvest by Month, 2002, 2003 and 2004.

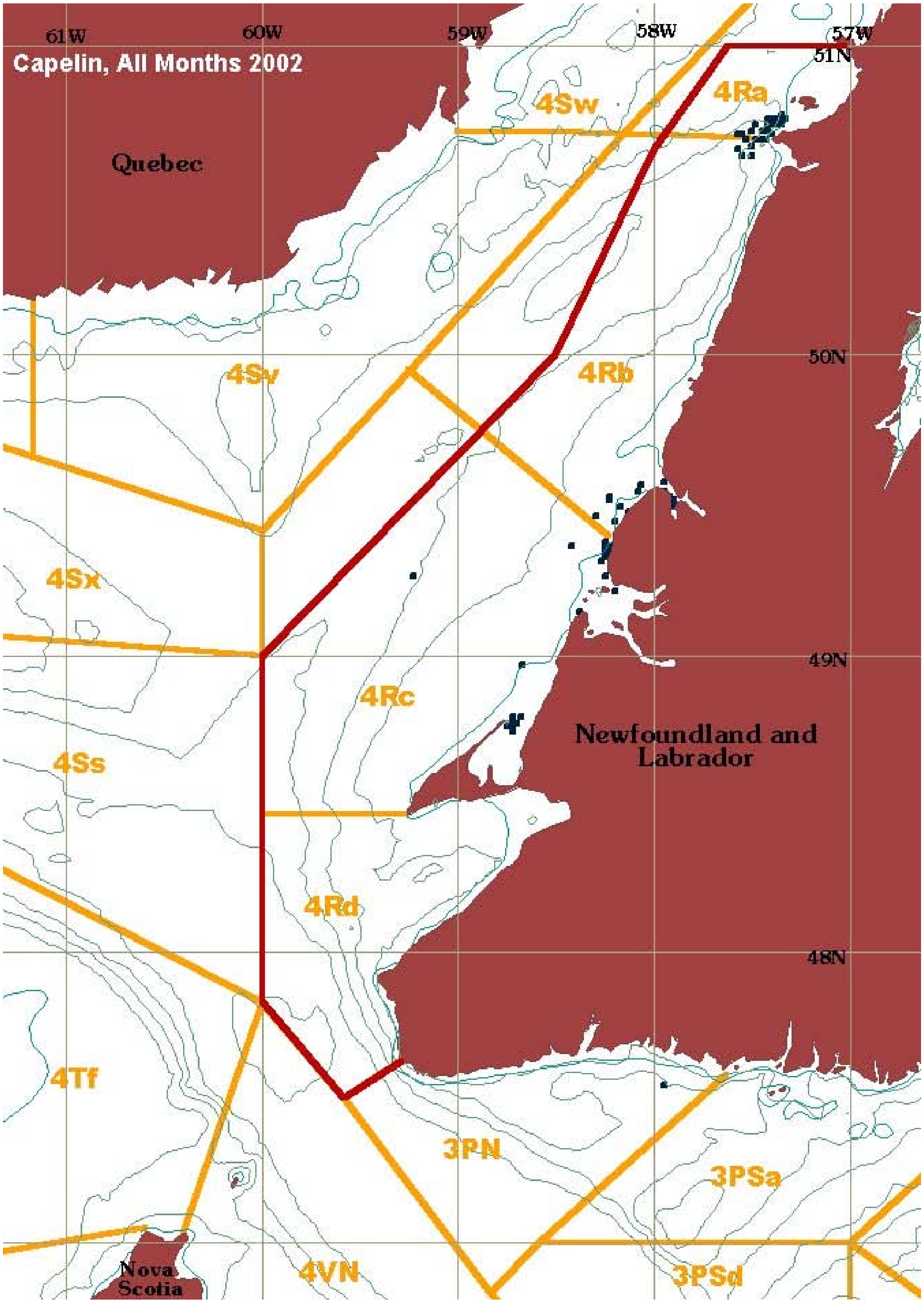


Figure 3.48. Harvesting Locations, Capelin, All Months 2002.

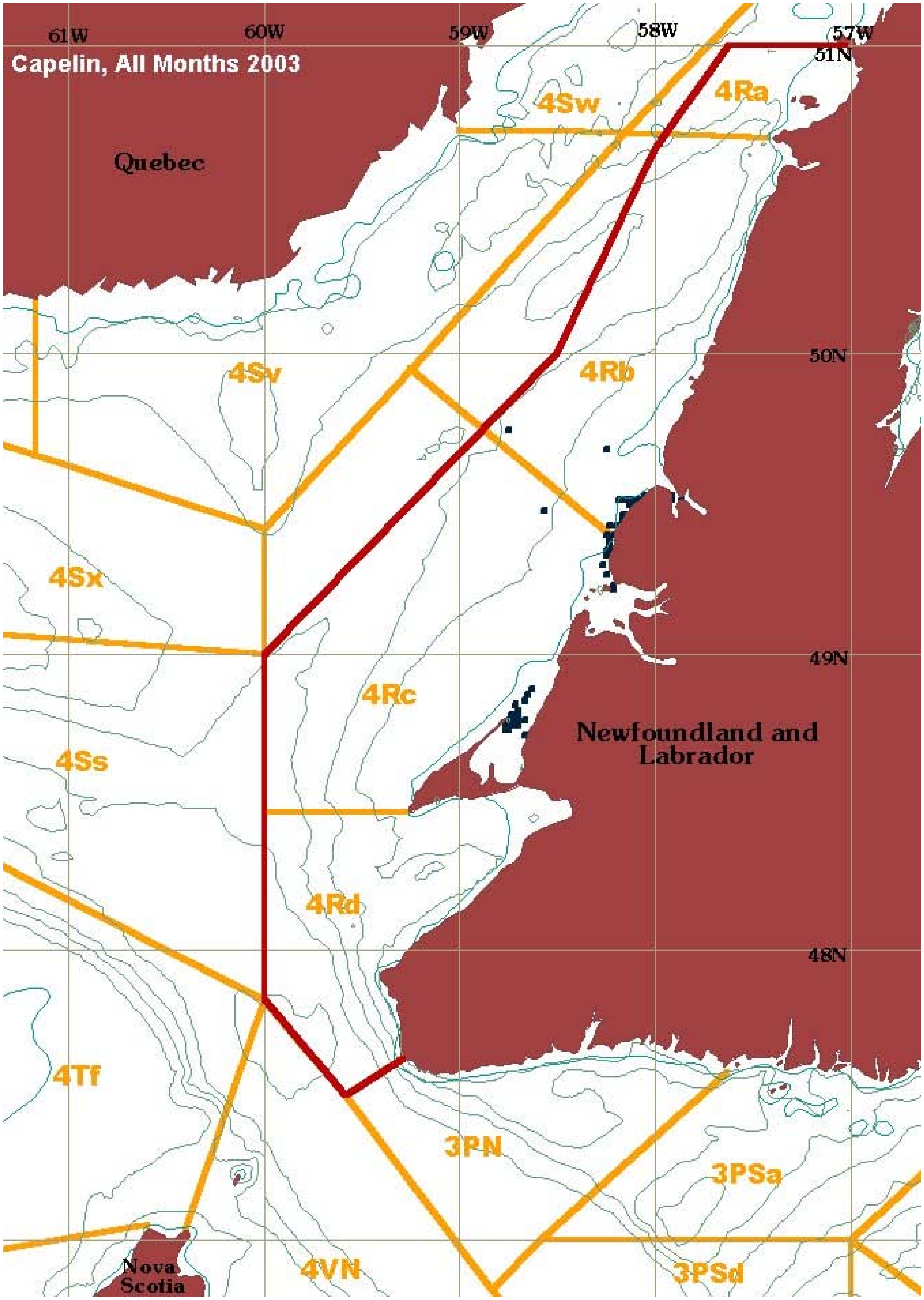


Figure 3.49. Harvesting Locations, Capelin, All Months 2003.

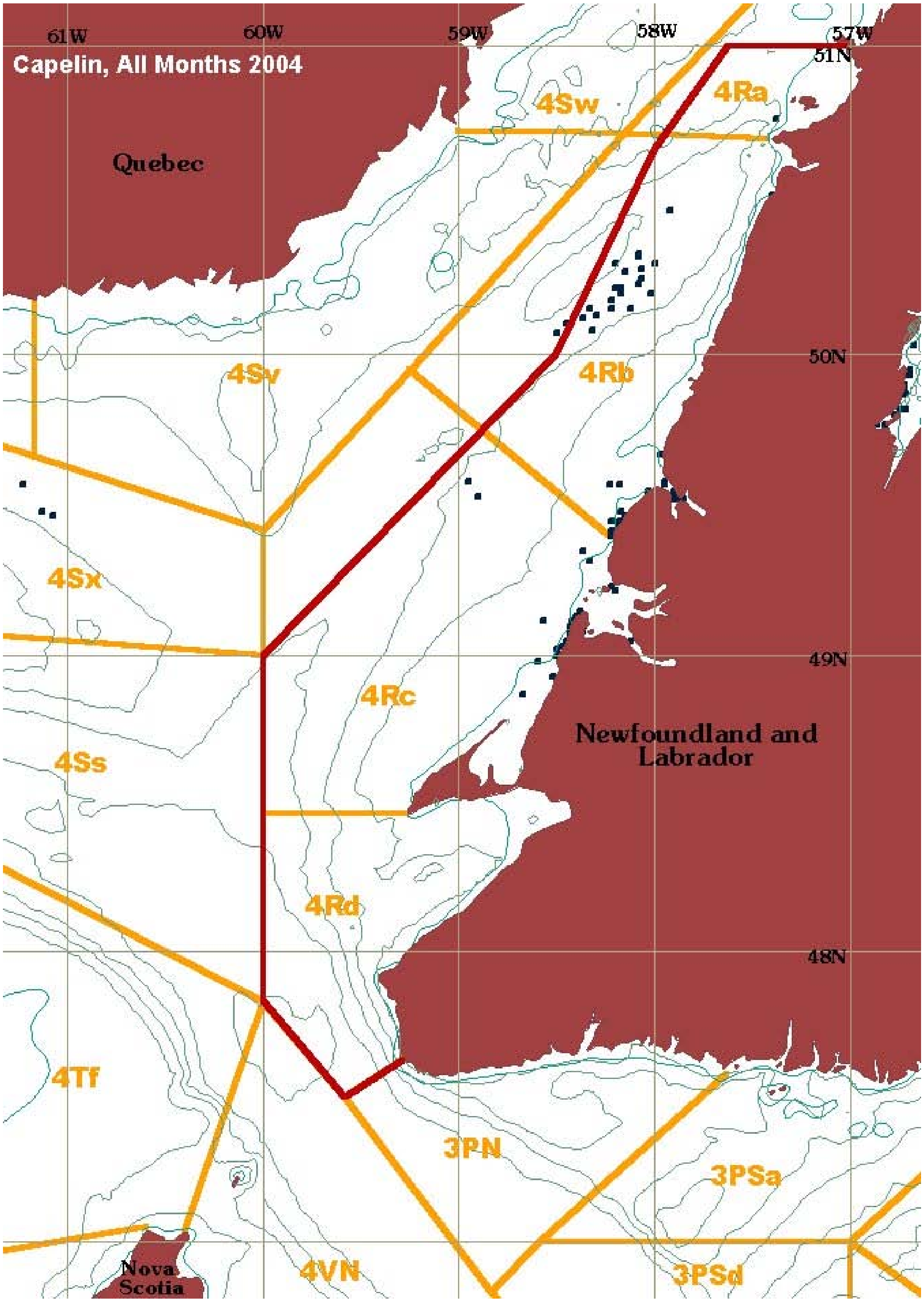


Figure 3.50. Harvesting Locations, Capelin, All Months 2004.

Lobster

The lobster fishery, although it typically makes up under 2% of the harvest by quantity, is a high-value fishery and are very important to many local Study Area-based fishers who typically harvest this species in waters near their home ports. As Figure 3.51 illustrates, the lobster fishery has been relatively stable, compared to the fluctuations in other fisheries, it experienced a decline in the late 1990s and early years of this decade, though the harvest has been closer to historical levels in the past two years.

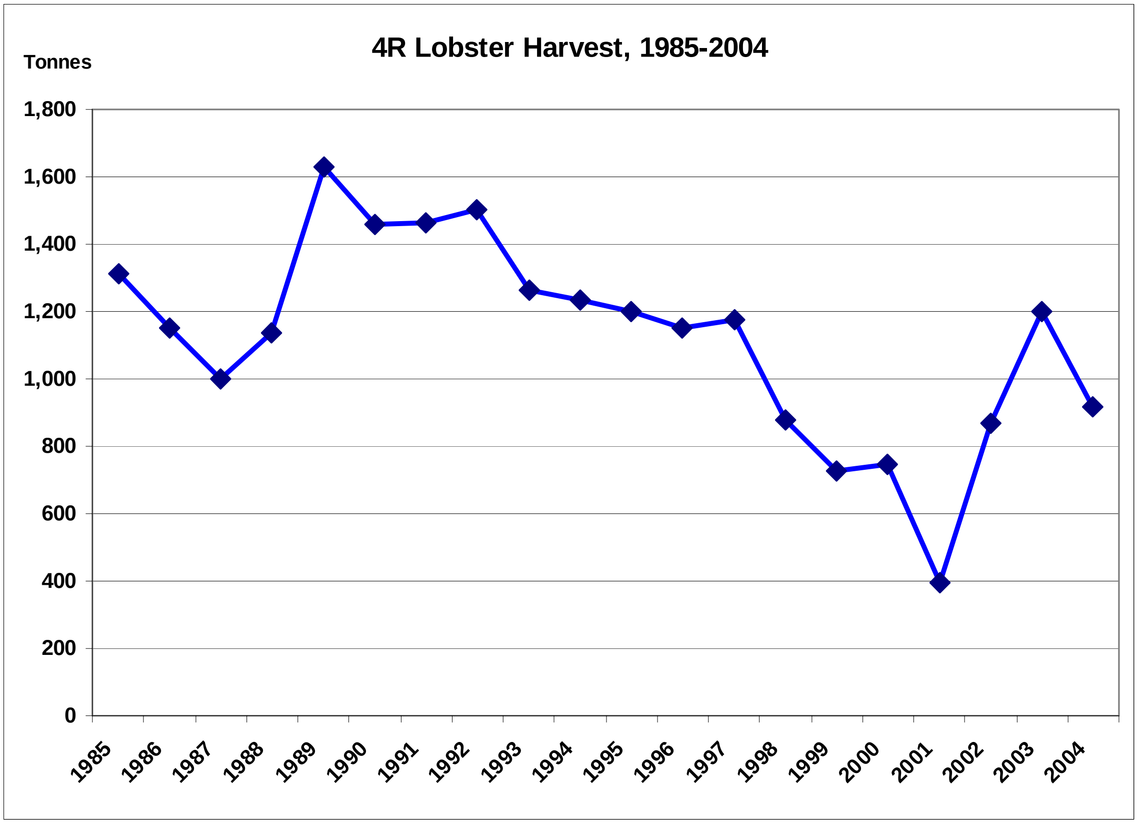


Figure 3.51. 4R Lobster Harvest, 1985-2004.

The lobster season in this area is focused in the spring, from ice out (April) to June–early July (Figure 3.52).

The lobster fishery uses lobster traps (or “pots”) weighted to the bottom typically in rocky areas near to shore or around offshore islands, in depths generally less than 20 m. In Newfoundland, trap limits vary between lobster fishing areas (LFAs) from 100 to 425 traps. The Study Area includes LFAs 13A, 13B and 14A.

Although no maps of these locations are available, the gear is typically set in waters adjacent to or near the fisher’s home port.

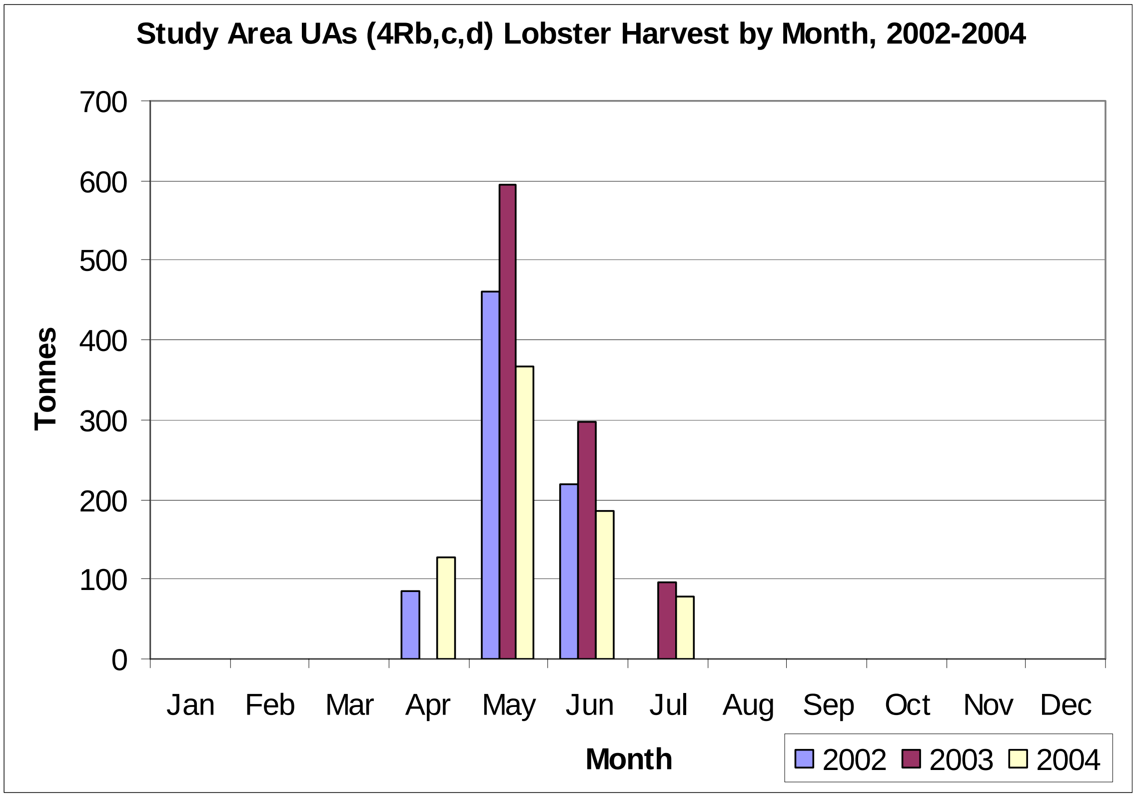


Figure 3.52. 4Rbcd Lobster Harvest by Month, 2002, 2003 and 2004.

Northern Shrimp

In terms of quantity and value, the northern shrimp fishery is very important to the region. In many respects it has come to replace much of the value of the fishery lost through the declines in most groundfisheries. A high value (price per quantity) fishery, it has had a fairly steady increase since the early 1980s, though in recent years the resource has shown some measure of variability, and quotas and catches have fluctuated (Figure 3.53). For example, in 2003 the 4R shrimp quota was reduced by about 14%, to 6,674 tonnes, but was increased to 8,520 tonnes the following year (2004). For 2005, it was again reduced to 6,909 tonnes.

Within the Gulf of St. Lawrence, three fleets of trawlers based in Quebec, New Brunswick and Newfoundland harvest shrimp in four areas: Sept-Îles (Area 10), Anticosti (Area 9), Esquiman (Area 8) – which includes 4R - and the Estuary (Area 12). DFO notes, "Shrimp fishing is controlled by a number of management measures, including total allowable catches (TAC) in the four areas. In 2002, there were 112 permanent shrimp licences. In addition, since 1997, temporary allocations have been granted to shrimpers without permanent licences" (DFO 2004b)

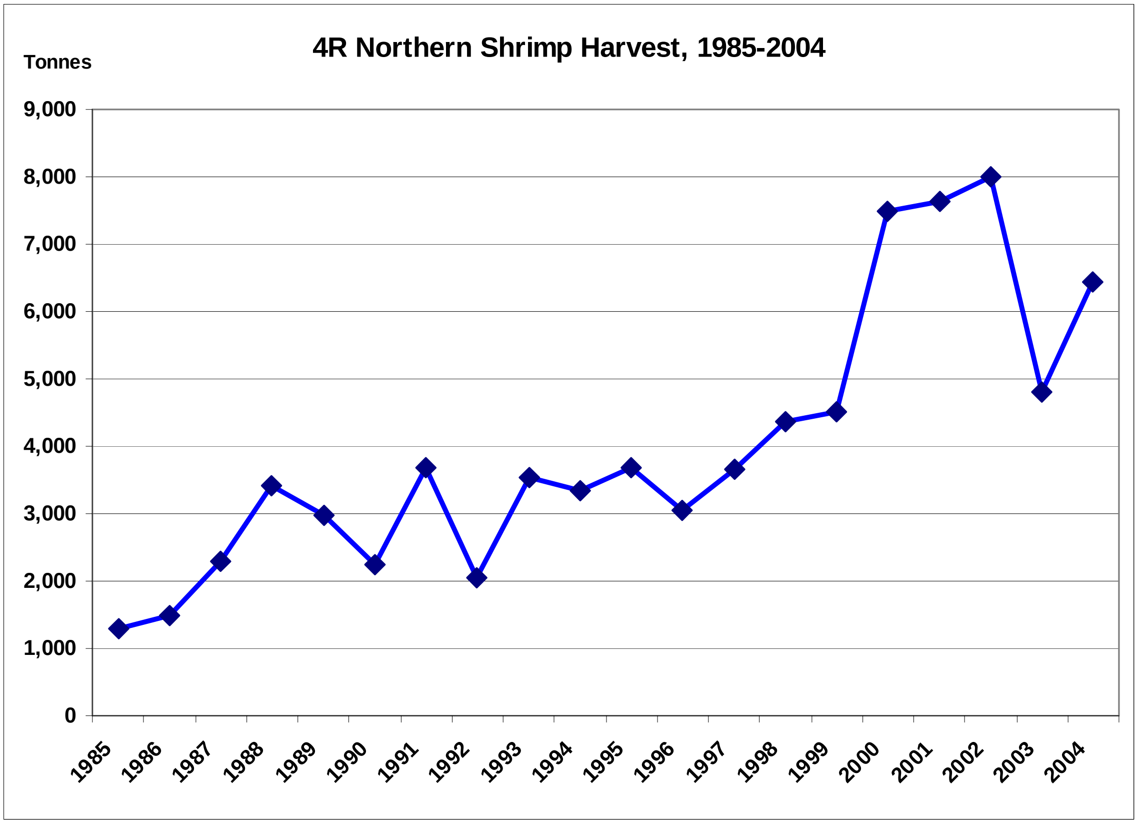


Figure 3.53. 4R Northern Shrimp Harvest, 1985-2004.

As Figure 3.54 illustrates, the great majority of the catch is typically taken between May and July, though the fishery is open from April 1 to December 31.

The gear used to harvest the shrimp is a specially designed shrimp trawl.

As Figures 3.55 to 3.57 indicate, the location of the shrimp fishery is highly consistent from year to year. Effort is focused on the deeper waters (and “holes”) of the Gulf, typically in depths greater than 200 m.

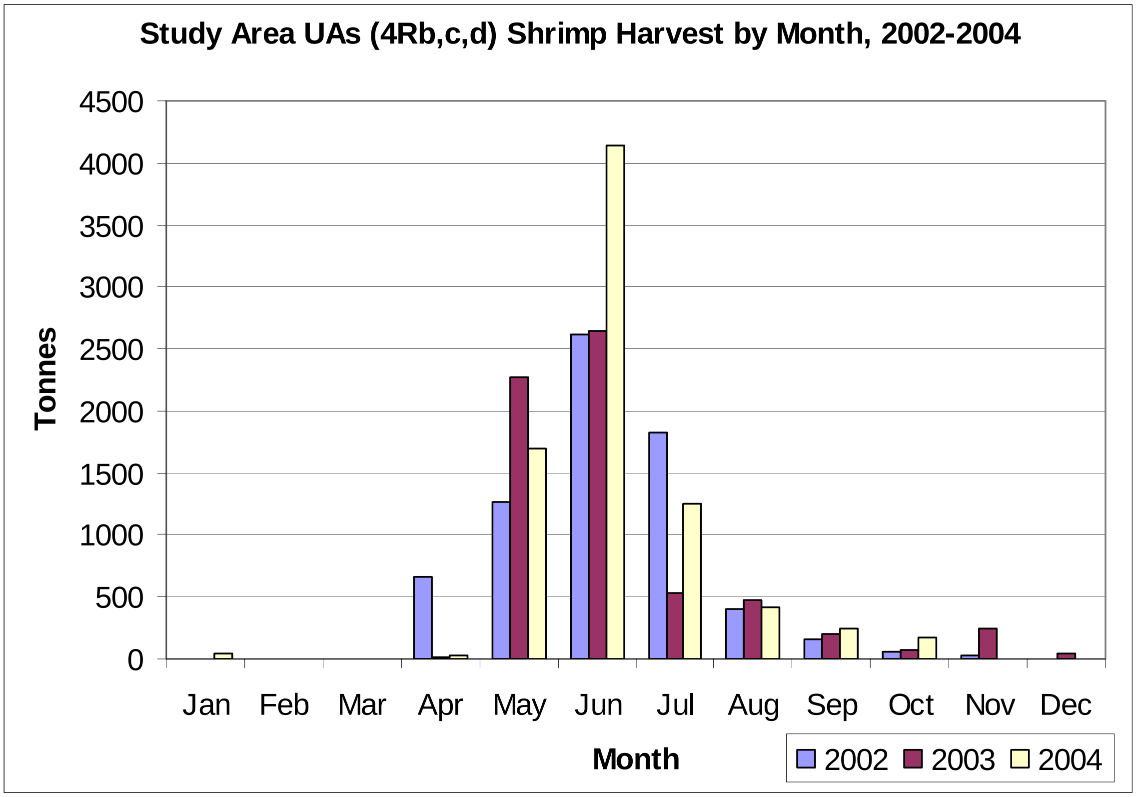


Figure 3.54. The 4Rbcd Northern Shrimp Harvest by Month, 2002, 2003 and 2004.

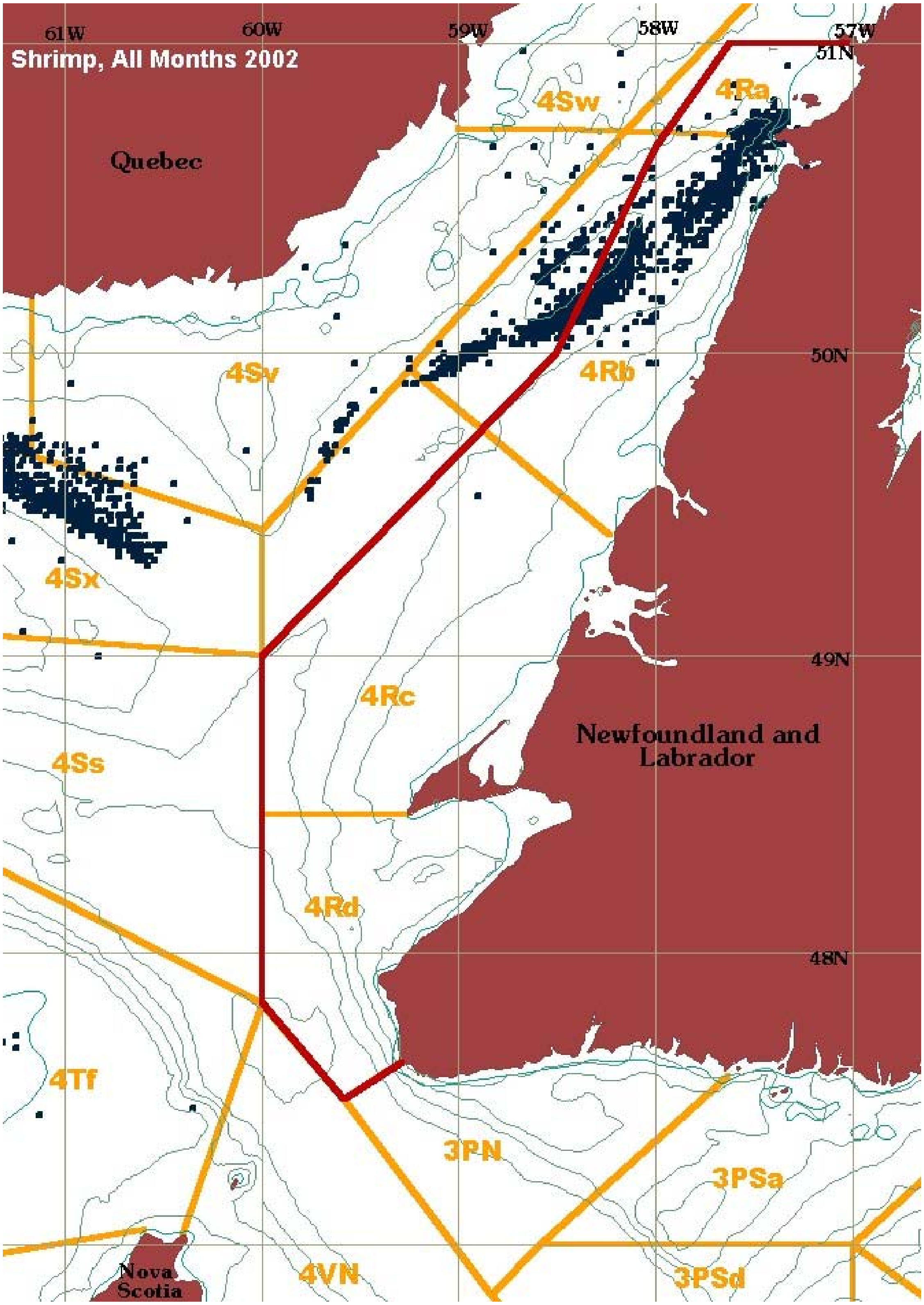


Figure 3.55. Harvesting Locations of Northern Shrimp, All Months 2002.

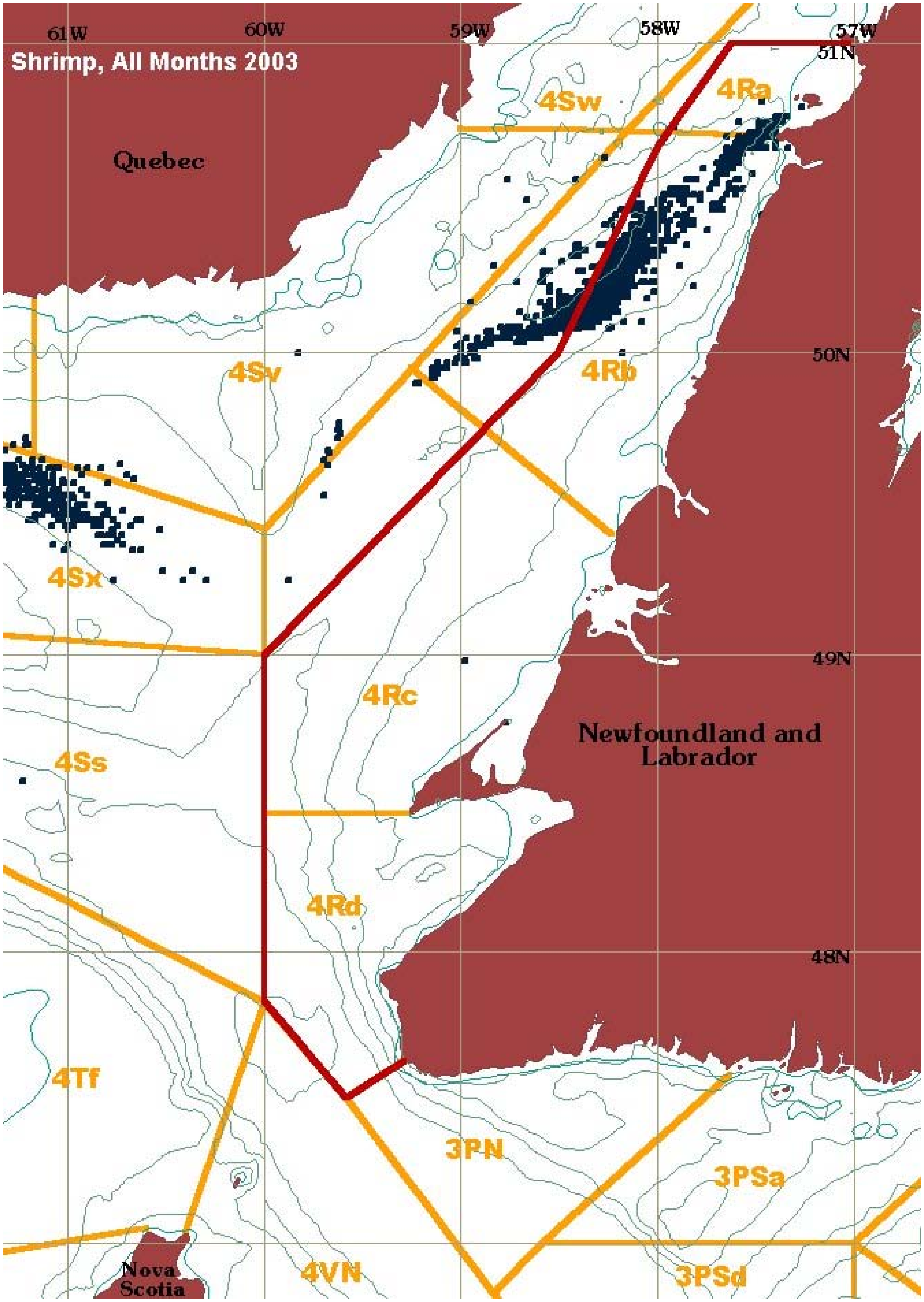


Figure 3.56. Harvesting Locations of Northern Shrimp, All Months 2003.

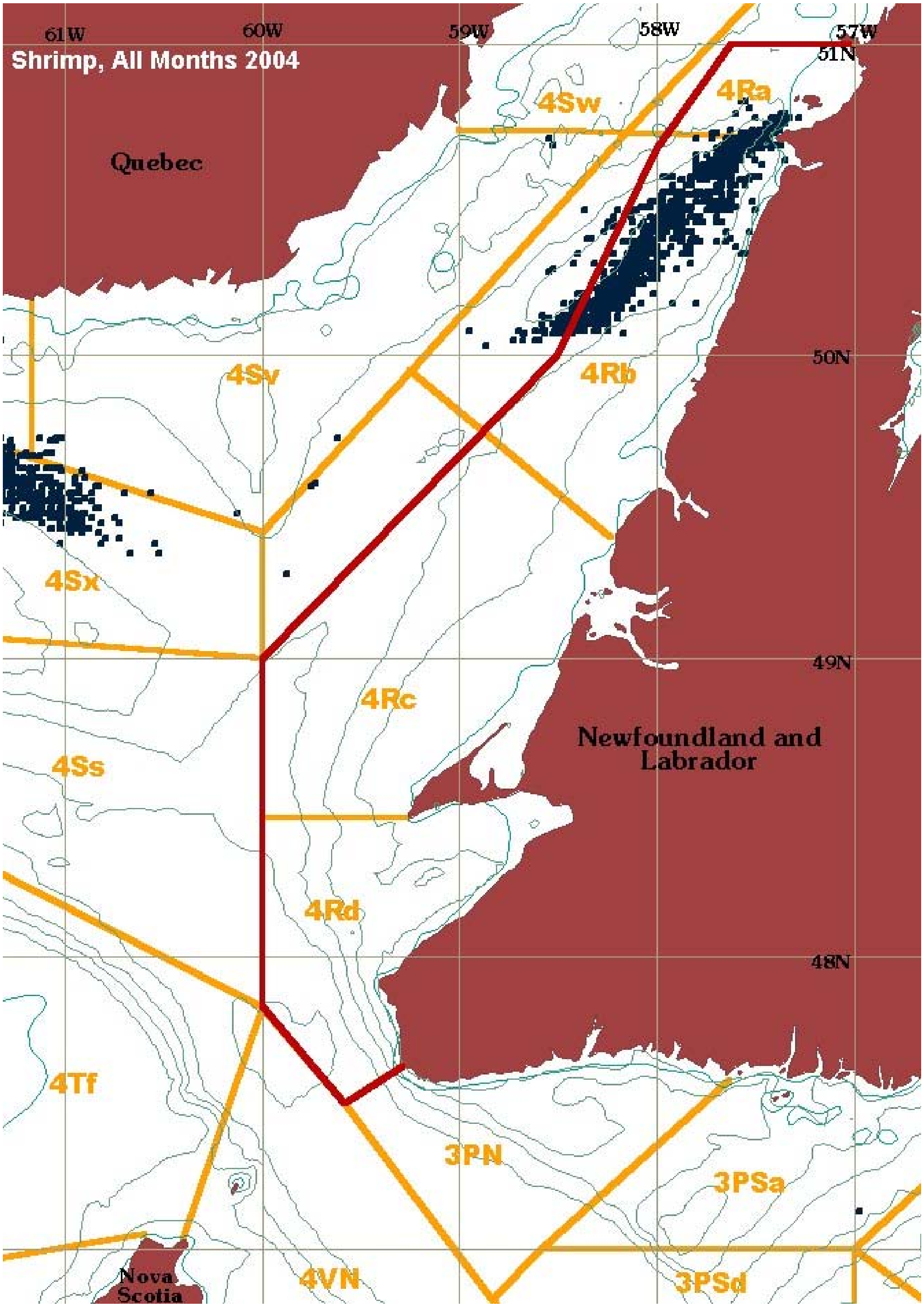


Figure 3.57. Harvesting Locations of Northern Shrimp, All Months 2004.

Snow Crab

Similar to the shrimp fishery, snow crab has increased dramatically in the area over the past two decades, and has become a very important high-value fishery, taking the place of groundfish for many local fishers (Figure 3.58). As has been the case for shrimp, the snow crab fishery has experienced a decline in recent years (since 2000), following a very rapid rise after the groundfish closures. Between 2002 and 2003 there was a significant reduction in the Area 12 (Figure 3.59) quotas, and smaller reductions since then.

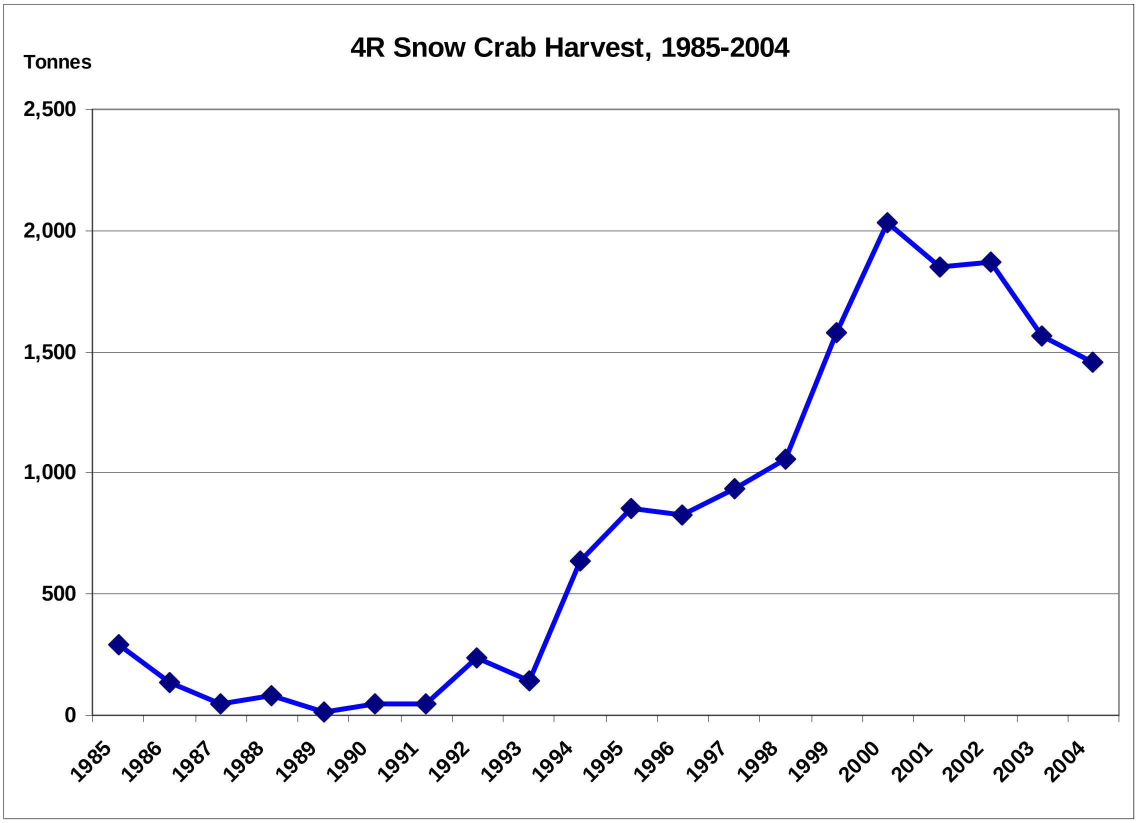


Figure 3.58. The 4R Snow Crab Harvest, 1985-2004.

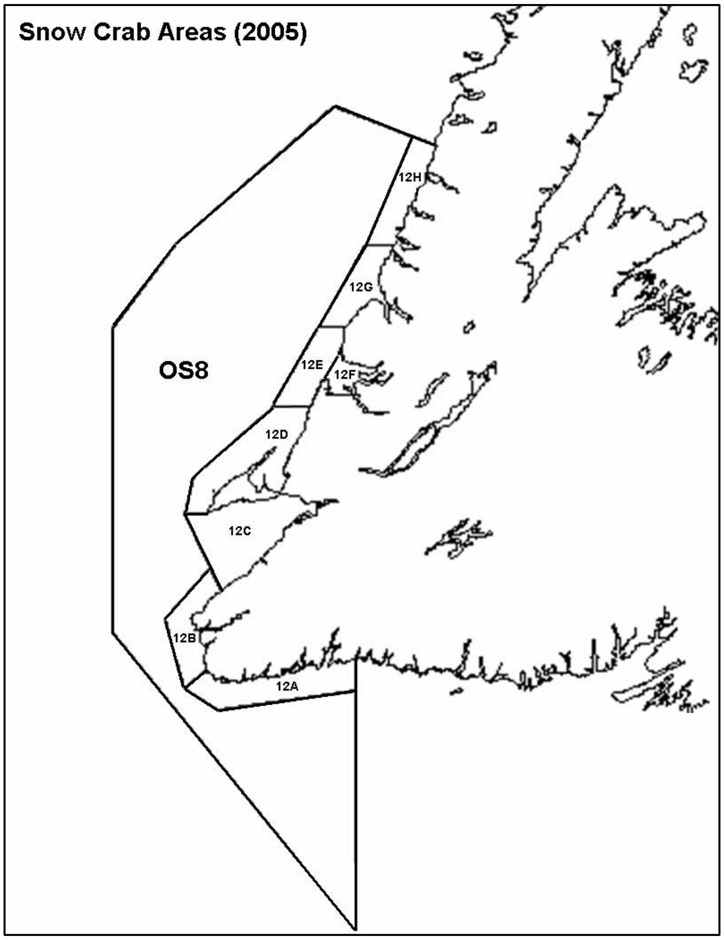


Figure 3.59. West Coast Crab Fishing Areas (Zone 12/Offshore 8).

Figure 3.60 shows the timing of the snow crab harvest in the area. It occurs throughout the spring and summer, though is most focused in the spring months. Closing dates can vary, depending on resource conditions (e.g., occurrence of "soft shell", and quotas). In 2004 the Area 12 fishery continued until mid-August, but closed mid-July in 2005.

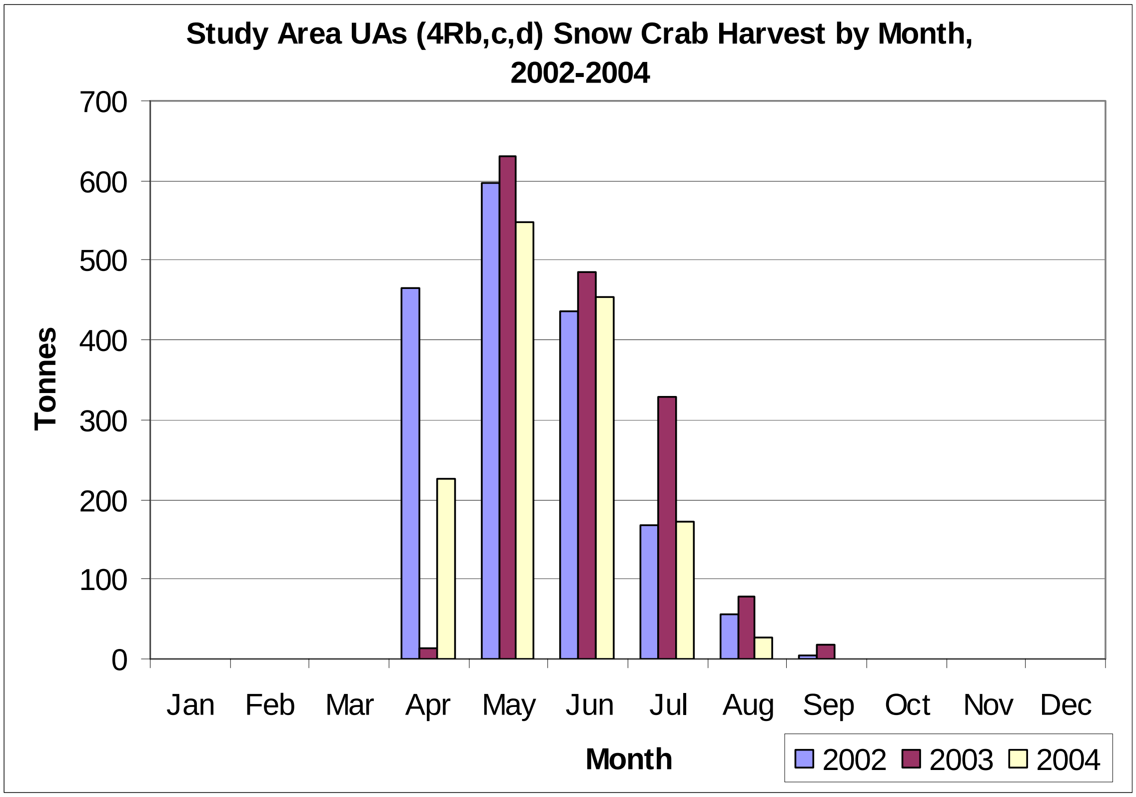


Figure 3.60. The 4Rbcd Snow Crab Harvest by Month, 2002, 2003 and 2004.

The following maps (Figures 3.61 to 3.63) show the recorded harvesting locations of the georeferenced portion of the snow crab harvest for 2002, 2003 and 2004. As with shrimp, snow crab harvest locations were relatively consistent between 2002 and 2004. However, if one considers the distribution of harvesting locations since 1999, there has been a progressively increasing concentration of effort in the southern and inshore regions of the Study Area, particularly in the vicinities of Bay of Islands and Bonne Bay.

Snow crab is harvested using bottom set crab pots, marked at the surface with buoys and often highflyers.

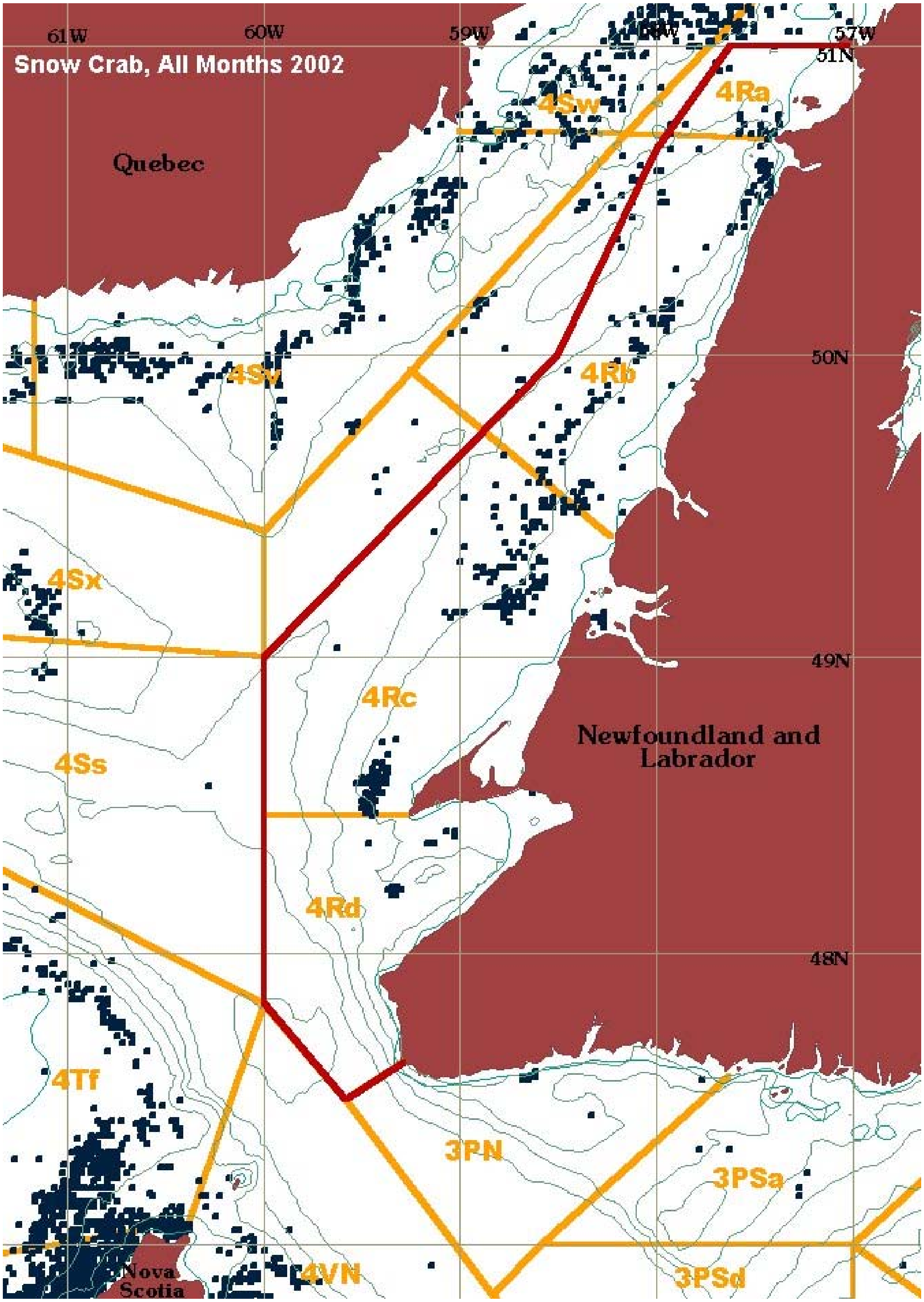


Figure 3.61. Harvesting Locations of Snow Crab, All Months 2002.

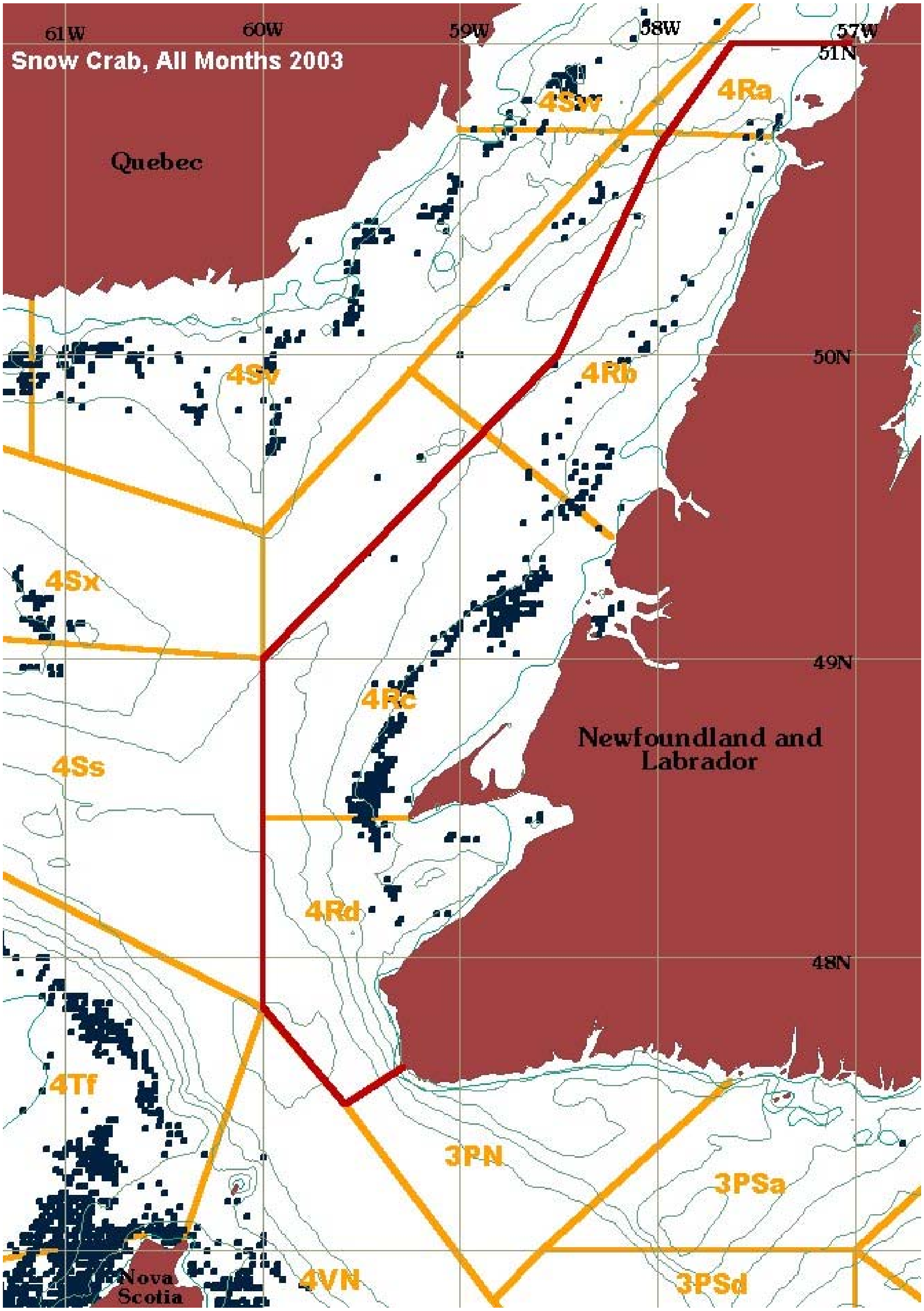


Figure 3.62. Harvesting Locations of Snow Crab , All Months 2003.

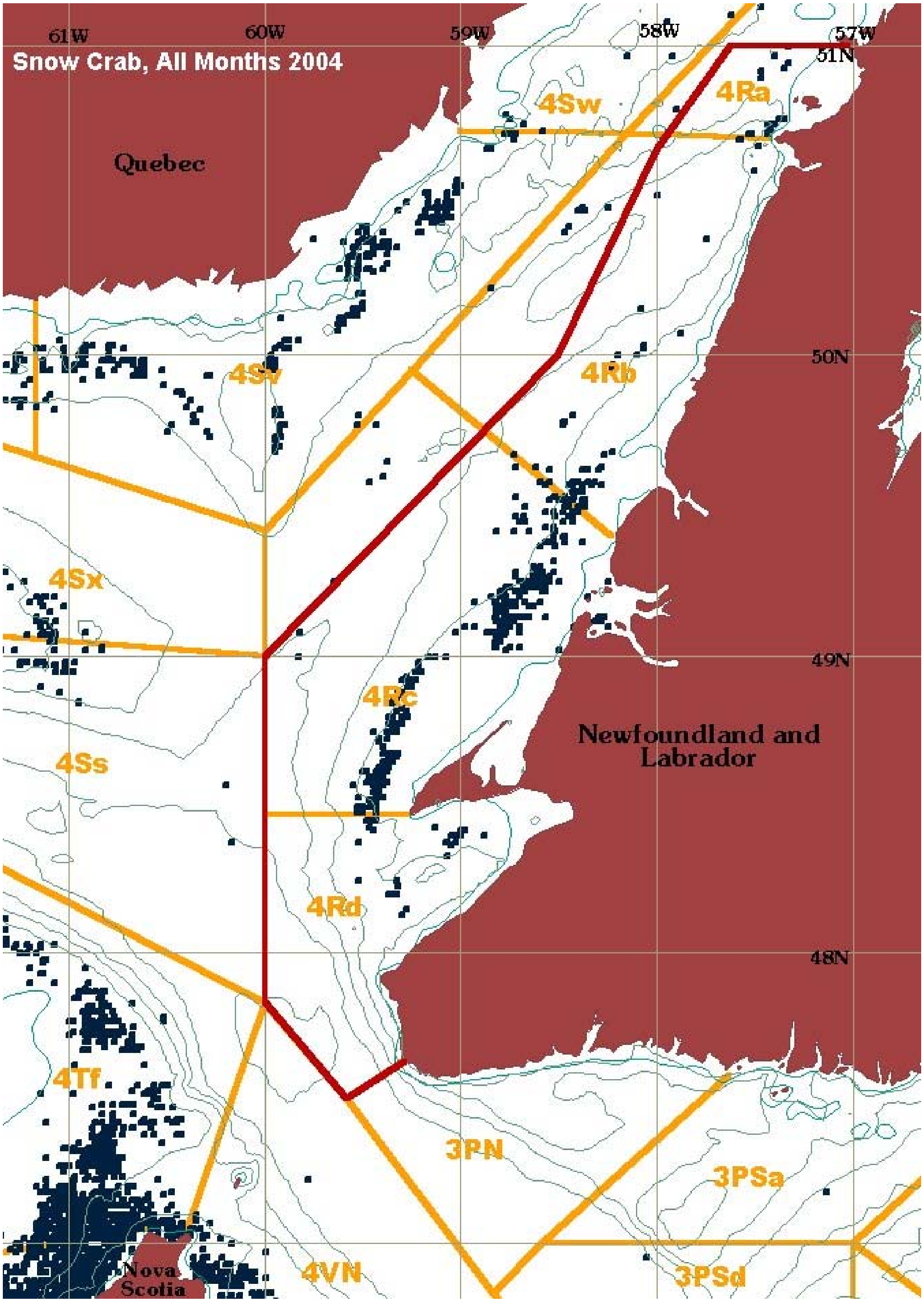


Figure 3.63. Harvesting Locations of Snow crab, All Months 2004.

3.4.4.6 Planning Implications Regarding the Commercial Fishery

The Study Area fisheries are conducted primarily in the May – November period, owing in large part to ice and weather conditions. This is also when offshore exploration is likely to be active for the same reasons. As a consequence, there is very likely to be temporal overlap between exploration activities and commercial fisheries. Depending on locations chosen by the petroleum industry, there may also be spatial overlap.

While exploration drilling activities would be site-specific and thus affect a very small geographical area (except in the event of an accident), seismic surveys (particularly 2-D surveys) typically range over a relatively broad area, and thus have the greater potential for interference with concurrent fisheries. The project-specific EAs will need to consider this potential depending on the locations of specific project activities.

Physical impacts on eggs, larvae and juveniles, potential scaring of fish (preventing them from being harvested, diverting migrations, interrupting spawning behaviour) and physical interference with harvesting (gear conflicts, particularly with fixed gear, which might become entangled with seismic streamers) are of concern to fish harvesters, as they might affect their fisheries in both the short and longer term.

The implications of potential impacts of exploration and production activities on the commercial fishery as well as the mitigations typically employed in Atlantic Canada and elsewhere to avoid or mitigate interference with active fishing are discussed in the relevant sub-sections of Section 4.0.

3.4.5 Aquaculture

Aquaculture activity in the Western Newfoundland and Labrador Offshore Area Study Area is limited compared to the rest of the Gulf of St. Lawrence. Less than 1% of Newfoundland and Labrador’s aquaculture production occurs in the Gulf of St. Lawrence. According to Alexander et al. (2005), there were seven shellfish and ten finfish aquaculture operations along the west coast of Newfoundland in 2003, located between Robinsons on the southwest coast and Pistolet Bay on the Northern Peninsula (Table 3.9; Figure 3.64). Of these seventeen sites, four occur outside of the Study Area. Of the thirteen aquaculture sites that occur within the Study Area, five shellfish (six blue mussel and one sea scallop) and five Atlantic cod grow-out sites are located in the marine system. The remaining three finfish sites (two Atlantic salmon/rainbow trout and one eel) are land-based. All thirteen aquaculture sites occur in either Unit Area 4Rb or 4Rc.

Table 3.9. Marine-based Aquaculture Sites Occurring within the Study Area.

Location	Species	Number of Sites
Port Saunders (Keppel Harbour)	Atlantic cod	1
Port Saunders (Northeast side of Keppel Island)	Atlantic cod	1
Bonne Bay (Stores Cove)	Atlantic cod	1
Bonne Bay (Gadd's Harbour)	Atlantic cod	1
Bonne Bay (Rocky Harbour)	Atlantic cod	1
Bay of Islands (Outer Goose Arm)	Blue mussels	1
Bay of Islands (Goose Arm)	Blue mussels	1
Port au Port Peninsula (Piccadilly Bay)	Blue mussels	2
Port au Port Peninsula (Piccadilly Bay)	Sea scallop	1

Source: Alexander et al. 2005.

Following a four-year Atlantic cod moratorium (1993-1996) in the Gulf of St. Lawrence, commercial fishers were permitted to fish cod on a limited basis. Fishers on the west coast of Newfoundland began to hold and feed cod in grow-out traps for a period of a few months, and subsequently harvest them during the fall and early winter when prices tend to be higher. Blue mussels and sea scallops are grown in suspension in Newfoundland and Labrador as opposed to being grown on the ocean bottom (Alexander et al. 2005)

Location and type of licensed aquaculture activity in the Study Area, as well as production and value data, are available at the following address for AquaGIS on the Government of Newfoundland and Labrador website: www.aquagis.com (Alexander et al. 2005).

3.4.6 Planning Implications for Fish and Fisheries

Several sensitive areas directly associated with fish and invertebrates occur within the Study Area. These include The Hole (off Port au Choix, straddling boundary between 4Ra and 4Rb) which appears to be a steep slope area of high productivity. Some fishers who were consulted claimed that high biological activity continued year-round at The Hole. The nearshore area (relatively steep slope) immediately south of Port au Choix was also identified as an area of high biological activity. Other areas highlighted by fishers included Bonne Bay, the Bay of Islands area (lobster nursery), Port au Port Bay (lobster spawning), cod spawning area (Cape St. George Spawning Area) off Cape St. George, Port au Port Peninsula, and herring spawning within St. George's Bay. These examples represent essentially the whole of the nearshore within the Study Area. Specific mitigative measures would likely be established during site-specific EAs.

3.4.7 Data Gaps for Fish and Fisheries

The distribution of invertebrate and fish eggs and larvae is poorly understood in the Study Area. Specific areas have been identified as spawning areas for various species but little information related to the passive movements of these ichthyoplankton exists.

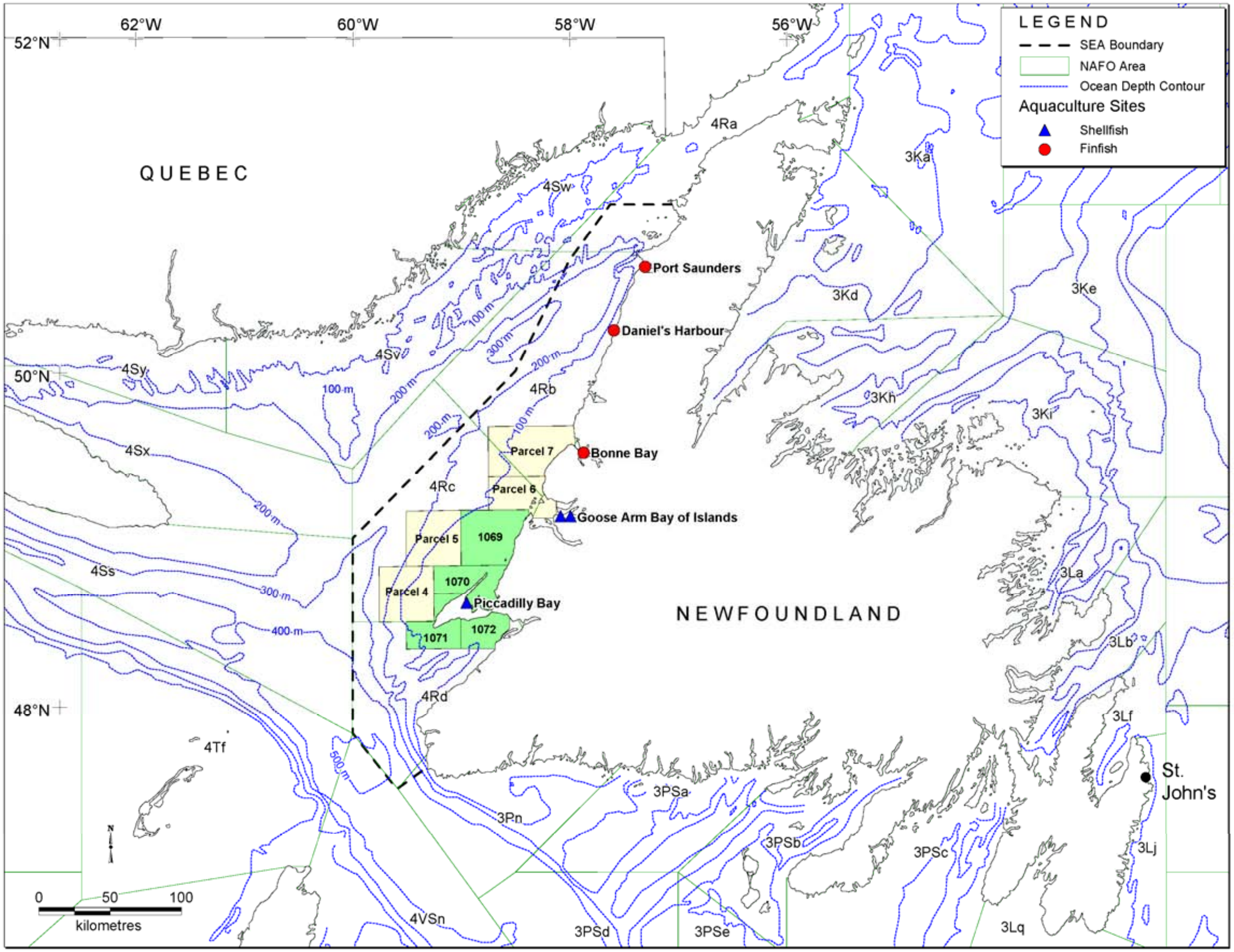


Figure 3.64. Locations of Recent Aquaculture Activity within the Study Area.

There are still considerable data gaps related to the movements of fish within the Study Area. Most of what is known comes from commercial fishery data. A telemetry study is presently being conducted off the southwest coast of Newfoundland (J. Spingle, FFAW, pers. comm.). The study will provide information on the movement of cod across the 4Rd-3Pn boundary, and the 3Pn-3Ps boundary.

3.5 Marine-associated Birds

Marine-associated birds are considered in three categories: (1) seabirds, (2) coastal waterfowl, and (3) shorebirds.

3.5.1 Seabirds

The marine coast and waters of western Newfoundland have lower abundances of seabirds than other coastal areas of Newfoundland (Lock et al. 1994) likely because they are less influenced by the major oceanic currents. This also may be due to a lack of breeding habitat along the west coast and the lower productivity of the adjacent waters compared to the east coast (Lock et al. 1994). Nevertheless the general area has received relatively little survey coverage and numerous oversights are apparent, such as the awareness of unique migratory bird concentrations at Flat Bay Islands (UA 4Rd). Seabirds in the area include shearwaters, fulmars, petrels, jaegars, skuas, phalaropes, gannets, cormorants, alcids, kittiwakes and gulls. Some relatively large seabird colonies occur along the Quebec North Shore, for example Bonaventure Island (Rail and Chapdelaine 2002), and notably, Northern Gannets, Razorbills, Common Murres, and lesser numbers of Atlantic Puffins that breed along the Quebec North Shore occur pelagically in the Study Area. Only the large gulls and terns and gannets are reported common in the Study Area. Foraging strategies of these seabird groups vary from plunge diving (gannets) and pursuit diving (alcids), through surface feeding (phalaropes) to kleptoparasitism (jaegars and skuas) (Table 3.10).

The period of peak vulnerability to perturbations (in terms of concentrations) of seabirds in the Study Area is between January and March. The highest abundance of seabirds during this period occurs at the southern part of the Study Area (i.e., UA 4Rcd), particularly in the vicinity of Parcels 5 and 6. Seabirds are least abundant in the Study Area during the October to December. Greater than 10 birds per km are vulnerable to perturbations in coastal areas adjacent to the southwest coast of Newfoundland from January to September and less than 10 birds per km are vulnerable from October to December (Lock et al. 1994).

3.5.1.1 Nesting Populations and Breeding Biology

Common Terns, Arctic Terns, Great Black-backed Gulls, Herring Gulls, Ring-billed Gulls and Black-legged Kittiwakes nest in small colonies scattered along the coast (Table 3.10; Figure 3.65). Black-headed Gulls nest at Stephenville Crossing (discovered in 1977, Lock et al. 1994) and intermittently at Sandy Point (UA 4Rd). There are a few pairs also nesting in the area of Plum Point (UA 4Ra). The largest colony in Newfoundland is located at Ladle Cove Island off the Northeast Coast.

Table 3.10. General Distributions, Seasonal Abundances, and Foraging Strategies of Seabirds that Occur in the Study Area.

Common Name	Scientific Name	General Area of Distribution	Abundance				Foraging Strategy
			Summer (June-Sept)	Autumn (Oct-Dec)	Winter (Jan-Mar)	Spring (Apr-May)	
Fulmars and Shearwaters							
Northern Fulmar	*Fulmarus glacialis*	Offshore, coastal	Uncommon	Uncommon	Rare	Uncommon	SF
Greater Shearwater	*Puffinus gravis*	Offshore, coastal	Uncommon	Uncommon	Absent	Scarce	PP
Sooty Shearwater	*Puffinus griseus*	Offshore, coastal	Scarce	Scarce	Absent	Rare	PP
Manx Shearwater	*Puffinus puffinus*	Offshore, coastal	Rare	Rare	Absent	Rare	PP
Jaegers and Skuas							
Pomarine Jaeger	*Stercorarius pomarinus*	Offshore	Scarce	Scarce	Absent	Scarce	K
Parasitic Jaeger	*Stercorarius parasiticus*	Offshore	Scarce	Scarce	Absent	Scarce	K
Long-tailed Jaeger	*Stercorarius longicaudus*	Offshore	Rare	Rare	Absent	Rare	K
Great Skua	*Catharacta skua*	Offshore	Rare	Rare	Absent	Absent	K
Gannets and Cormorants							
Northern Gannet	*Sula bassanus*	Offshore, coastal	Common	Uncommon	Absent	Uncommon	DP
Double-crested Cormorant	*Phalacrocorax auritus**	Coastal	Common	Common	Absent	Common	PD
Great Cormorant	*Phalacrocorax carbo**	Coastal	Common	Common	Uncommon	Common	PD
Storm Petrels							
Wilson's Storm-Petrel	*Oceanites oceanicus*	Offshore	Scarce	Absent	Absent	Absent	SF
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Offshore	Uncommon	Uncommon	Absent	Uncommon	SF
Red Pharalope	*Phalaropus fulicaria*	Offshore	Scarce	Scarce	Absent	Scarce	SF
Red-necked Pharalope	*Phalaropus lobatus*	Offshore	Scarce	Scarce	Absent	Scarce	SF
Gulls and Kittiwakes							
Herring Gull	*Larus argentatus**	Coastal, offshore	Common	Common	Uncommon	Common	SF
Iceland Gull	*Larus glaucoides*	Coastal, offshore	Absent	Common	Common	Common	SF
Glaucous Gull	*Larus hyperboreus*	Coastal, offshore	Absent	Uncommon	Uncommon	Uncommon	SF
Great Black-backed Gull	*Larus marinus**	Coastal, offshore	Common	Common	Common	Common	SF
Sabine's Gull	*Xema sabini*	Offshore	Absent	Rare	Absent	Absent	SF
Ivory Gull	*Pagophila eburnea*	Offshore	Absent	Rare	Rare	Rare	SF
Black-legged Kittiwake	*Rissa tridactyla **	Offshore, coastal	Uncommon	Uncommon	Scarce	Uncommon	SF
Common Tern	*Sterna hirundo**	Coastal, offshore	Common	Scarce	Absent	Common	SF, PP
Arctic Tern	*Sterna paradisaea**	Coastal, offshore	Common	Scarce	Absent	Common	SF, PP
Alcids (Auks)							
Dovekie	*Alle alle*	Offshore, coastal	Absent	Uncommon	Uncommon	Uncommon	PD
Common Murre	*Uria aalge*	Offshore, coastal	Uncommon	Uncommon	Rare	Uncommon	PD
Thick-billed Murre	*Uria lomvia*	Offshore, coastal	Scarce	Uncommon	Uncommon	Uncommon	PD
Razorbill	*Alca torda*	Offshore, coastal	Scarce	Scarce	Rare	Scarce	PD
Black Guillemot	*Cepphus grille **	Coastal	Uncommon	Uncommon	Scarce	Scarce	PD
Atlantic Puffin	*Fratercula arctica **	Offshore, coastal	Scarce	Scarce	Absent	Scarce	PD

Source: Modified from Husky (2000). *'*' indicates species that are known to nest along the western coast of Newfoundland*

'SF' : surface feeding; 'PP' : pursuit plunging; 'DP' : deep plunging; 'K' : kleptoparasitism; 'PD' : pursuit diving

In cases with two 'general area of distribution' designations, the species occurs primarily in the first area and secondarily in the second.

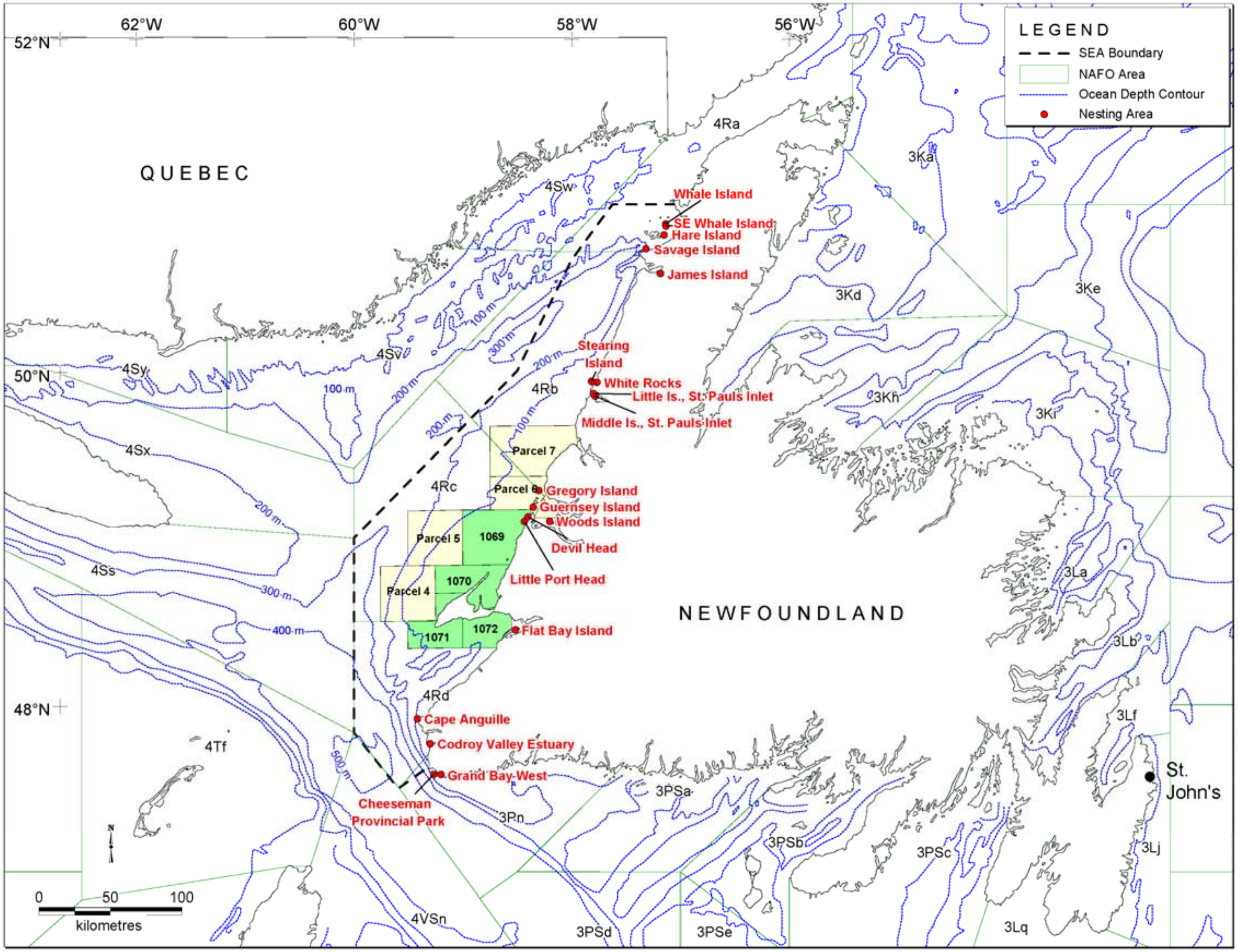


Figure 3.65. Areas used by Nesting Seabirds within the Study Area.

Caspian Terns, currently listed as *species of concern* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), have been observed in the Study Area and nest in incidental numbers, e.g., Plum Point and likely Stephenville Crossing and Robinsons-Jeffreys area. This species frequently nests in single pairs and therefore it can be difficult to confirm nesting. At Stephenville Crossing, groups of 20 or more are regularly observed during migration (P. Linegar, pers. comm.).

Aerial surveys in mid June 2001 and 2002 conducted by the Canadian Wildlife Service (CWS) indicated relatively larger concentrations of terns (total individuals) at Bay of Islands in UA 4Rc (off McIvers - 425), St. John Bay in UA 4Ra (Horn Bay – 1,000) and St. Paul's Inlet in UA 4Rb (mostly Little Island, also Middle Island and Western Island – 2,300). Black-legged Kittiwakes nest on the Port au Port Peninsula in UA 4Rd (Cape St. George –1 to 2,000) (Appendix 2). Lock et al. 1994 did not identify any colonies in the Study Area that were vulnerable to oil pollution but this reflects the lack of information for this geographic area. There are high reported frequencies of oil spills in the Stephenville – Stephenville Crossing area, i.e., >100 and, the unique concentrations of migratory birds in that area, for example Flat Bay Islands and Port au Port Peninsula would be vulnerable to toxic spills.

There are small colonies of Double-crested Cormorant and Great Cormorant near Cape Anguille, Bay of Islands (UA 4Rc) and the northern portion of Gros Morne National Park (UA 4Rb). Other seabird species nesting along this coast include a few small colonies of Black Guillemots (Lock et al. 1994) and Atlantic Puffins (Cairns et al. 1989). Several islands in the Bay of Islands are used from April to October for egg laying and brood rearing by these species. Nesting colonies in Bay of Islands are distributed across NAFO Unit Areas 4Rabcd (Table 3.11, Figure 3.65).

Seabirds nesting near the Study Area are long-lived with low rates of population growth (Table 3.12). Egg-laying commences in mid to late May and into June, and most species are fledged by July – August with Northern Gannets fledging into October and November (Table 3.13). Most nesting is on coastal islands, and Terns and gulls also nest at many of the sandy beaches, and peninsulas in the Study Area (e.g., Flat Bay - Sandy Point).

3.5.1.2 Prey and Foraging Habits

Seabirds in the Study Area feed on a variety of prey species including capelin, sandlance, copepods, amphipods and short-finned squid. Some species such as terns and phalaropes specialize in foraging in shallow depths at the surface, while species such as alcids and loons may dive to great depths (20 to 50m). Fish, crustaceans, cephalopods, and offal comprise the main prey, and foraging strategies of seabirds vary by species (Table 3.14).

Table 3.11. Estimated Numbers of Pairs of Colonial, Marine-associated Birds and Bird Species of Conservation Concern Nesting in Coastal Western Newfoundland in the Study Area.

	Sites in or near Study Area		**Nesting Areas and Important Bird Areas**																
Species	# of Nesting Sites	# of Nesting Pairs	Grand Bay West to Cheese-man Prov. Pk.[1]	Codroy Valley Estuary[1]	Cape Anguille	Flat Bay Island	Little Port Head	Devil Head	Woods Is. & unnamed is.	Guernsey Is.	Gregory Is.	Middle Is., St. Paul's Inlet	Little Is., St. Paul's Inlet	White Rocks & Stear-ing Is.[2]	James Is.	Savage Is.	Hare Is.	SE Whale Is.	Whale Is.
Cormorants																			
Great Cormorant	2	39			20					19									
Double-crested Cormorant	2	2			1				1										
Shorebirds																			
Piping Plover[3]	3	12	8	1		3													
Gulls, Kittiwakes and Terns																			
Black-headed Gull[4]	1	3				3[7]													
Ring-billed Gull	3	181				100								6					75
Herring Gull	5	650				10	250		200	165					25				
Great Black-backed Gull	3	235				100			60						75				
Black-legged Kittiwake	2	800						300			500								
Arctic Tern[5]	4	435				100[6]						15[6]	20[6]					300	
Common Tern[5]	7	795		25		200			30[6]			135[6]	180[6]			25			
Unidentified Tern[5]	1	200												200[6]	200[6]				
Alcids (Auks)																			
Black Guillemot	2	20							10					10					
Atlantic Puffin	1	10															10		
TOTALS	33	3380	8	26	20	516	250	300	300	184	500	150	200	216	300	25	10	300	75

Source: Cairns et al. 1989, Lock et al. 1994, except where noted.

[1] Important Bird Area.

[2] Gros Morne National Park Important Bird Area.

[3] Endangered, *Species at Risk Act*, Schedule 1.

[4] Rare.

[5] Provincially Sensitive.

[6] P. Thomas, Canadian Wildlife Service, unpublished.

[7] Currently relocated to Stephenville Crossing

Table 3.12. Marine-associated Birds Nesting in or near the Study Area and Demographic Parameters Reported for Other Sites.

Species	Mean Adult Survival Rate	Age of First Breeding (yr)	Clutch Size	Breeding Success [1]	Sources
Seabirds					
Northern Gannet	0.95	4-7	1	0.81	Nelson (1966), Montevecchi and Porter (1980)
Herring Gull	0.80-0.85	3-7	2-3	1.03-1.58	Pierotti and Good (1994), Haycock and Threlfall (1975), Kadlec (1976)
Great Black-backed Gull	-	4-5	3	0.50-2.11	Good (1998), Butler and Trivelpiece (1981)
Black-legged Kittiwake	0.81-0.86	3-7	2	0.54-0.58	Baird (1994), Maunder and Threlfall (1972
Common and Arctic Terns	0.86	2-4	1-3	0.59-0.77	Cullen (1956), Kirkham (1980)
Black Guillemot	0.77-0.89	2	1-2	0.12-0.78	Asbirk (1979), Cairns (1981)
Coastal Waterfowl					
Common Eider	0.90	2-5	3-5	0.5-0.93	Goudie et al. (2000)

[1] Numbers of chicks fledged per breeding pair of adults.

Table 3.13. Marine-associated Birds Nesting, Hatching and Fledging in or near the Study Area, and Demographic Parameters Reported for Other Sites.

Species	Egg Laying	Incubation	Hatching	Nesting	Fledging	Comments
Seabirds						
Northern Gannet[1]	mid - late May(1,2)	42 days (1,2)	late June to early July	91 days(1,2)	Late Sept. to early Oct.(1,3)	NF breeding population represents 17% of the eastern Canadian population. NF's population is stable and increasing
Herring Gull[2]; Great Black-backed Gull[3]	mid - late May(4,5,6)	26-29days 4,5,6)	mid-late June	45 days(12) 50-55 days (4,6)	late July - early August	Nest singly or in colonies at many locations along NF East Coast(7). Study area breeding population is only a small proportion of total Canadian(8) population.
Black-legged Kittiwake[4]	late May - early June(9)	27 days(9)	late June(9)	42 days(9)	early Aug.(9)	Three major colonies along Avalon Peninsula(10). NF group represents approx. 33% total Canadian breeding population.
Common Tern[5]; Arctic Tern[6]	first half June(11)	22 days (11)	mid July	21 - 26 days(11)	late July-early Aug.(11)	Occur singly or in small colonies along the Avalon Peninsula(10)
Black Guillemot[7]	Mid May - early June(12)	28 - 33 days(12)	mid June - mid July(12)	34 -39 days(12)	early - late August(12)	No estimate of the number of breeding birds in the Study Area, but considered to be low(8,13).
Coastal Waterfowl						
Common Eider[8]	Early May -mid June	26 days	mid June - mid July	35 - 40 days	mid August – late September	Nest in high densities, sometimes in large colonies
[1]Mowbray (2002) [2]Pierotti and Good (1994) [3]Good (1998) [4]Baird (1994) [5]Nisbet (2002) [6]Hatch (2002) [7]Butler and Buckley (2002) (8)Goudie et al. (2000)	(1) Kirkham (1980) (2) Montevecchi and Porter (1980) (3) Pitocchelli. et al. (1981) (4) Haycock and Threlfall (1975)		(5) Pierotti (1982) (6) Butler and Trivelpiece (1981) (7) Erwin (1971) (8) Nettleship (1980) (10) Brown et al. (1975)		(9) Maunder and Threlfall (1972) (11) Hawksley (1950) (12) Cairns (1981) (13) Nettleship (1972)	

Table 3.14. Foraging Strategy and Types of Prey for Seabirds that Frequent the Study Area.

Species (Group)	Foraging Strategy	Prey	Source
Procellaridae			
Northern Fulmar	Surface feeding	Fish, cephalopods, crustaceans, offal	Brown (1970)
Greater Shearwater	Pursuit plunging	Capelin, squid, crustaceans, offal	Brown.et al. (1981)
Sooty Shearwater	Pursuit plunging	Capelin, squid, crustaceans, offal	Brown et al. (1981)
Storm-Petrels	Surface feeding	Myctophid fish, amphipods	Linton (1978)
Pelecaniformes			
Northern Gannet	Deep plunging	Mackerel, capelin, squid	Kirkham (1980)
Cormorants	Pursuit Diving	Mackerel, capelin, squid	Brown et al. (1981)
Charadriformes			
Phalaropes	Surface feeding	Copepods	Brown (1980)
Jaegers and skuas	Kleptoparasitism	Fish	Hoffman et al. (1981)
Herring Gull [1]	Surface feeding	Fish, crustaceans, cephalopods, offal	Threlfall (1968)
Iceland Gull	Surface feeding	Fish, crustaceans, cephalopods, offal	Cramp and Simmons (1977)
Glaucous Gull	Surface feeding	Fish, crustaceans, cephalopods, offal	Cramp and Simmons (1977)
Great Black-backed Gull [1]	Surface feeding	Fish, crustaceans, cephalopods, offal	Threlfall (1968)
Black-legged Kittiwake	Surface feeding	Fish, crustaceans, cephalopods, offal	Threlfall (1968)
Terns	Surface and pursuit plunging	Fish, crustaceans	Braune and Gaskin (1982)
Alcidae			
Dovekie	Pursuit diving	Amphipods, copepods	Bradstreet (1982a)
Common Murre	Pursuit diving	Fish, invertebrates	Bradstreet (1982b)
Thick-billed Murre	Pursuit diving	Fish, invertebrates	Tuck (1961)
Black Guillemot	Pursuit diving	Fish, invertebrates	Cairns (1981)
Razorbill	Pursuit diving	Fish, invertebrates	Bradstreet (1982b)
Atlantic Puffin	Pursuit diving	Fish, invertebrates	Bradstreet (1982b)

[1] These species feed on eggs and chicks of seabirds, and occasionally adults (Rodway et al. 1996; Stenhouse and Montevecchi 1999a).

Foraging strategies of seabirds affects their breeding success during periods of limited food availability (Bryant et al. 1999; Regehr and Rodway 1999). In 1992 and 1993, Black-legged Kittiwakes, Herring and Great Black-backed Gulls, had lower hatching, fledging and breeding success than in previous years, and this was attributed to reductions in food availability for seabirds in the Study Area because the inshore spawning migration of capelin (a major prey species) was delayed by one month in the Northwest Atlantic. As well, the ground fisheries moratorium eliminated the production of fish offal, an important alternative food source for large gulls and kittiwakes. Other species, such as Atlantic Puffins and Common Murres were not negatively affected, and offshore surface feeders such as the Leach's Storm Petrel had high breeding success (Regehr and Rodway 1999). Depredation by large gull species on seabird adults, chicks and eggs increased in 1992 and 1993 (Rodway et al. 1996; Stenhouse and Montevecchi 1999b), and seabirds shifted their diets coinciding with changes in sea surface temperature on the Newfoundland Shelf (Montevecchi and Myers 1997). The significance of gull depredation on other seabirds and sea ducks is a matter of considerable debate as some researchers have demonstrated such mortality to be compensatory to starvation or mediated by human disturbance Swennen 1989, Goudie 1991a)

3.5.1.3 Geographic and Seasonal Distribution

During the nesting season, numbers of seabirds in the Study Area are greatest in the immediate vicinity of the larger nesting colonies (Lock et al. 1994). Most seabird species mature slowly and some do not begin breeding until four to five years of age (e.g. alcids), and the immature cohorts are present offshore and in adjacent waters. Sub-populations may mix at these times (e.g., individuals from colonies in Newfoundland with individuals from the Québec north shore), and species such as the large auks may aggregate in very large numbers. Some relatively large seabird colonies occur along the Québec North Shore (Rail and Chapdelaine 2002), and notably, Northern Gannets, Razorbills, Common Murres, and lesser numbers of Atlantic Puffins that breed in this political unit, occur in the Study Area.

Species such as Greater Shearwater, Sooty Shearwater and Wilson's Storm Petrel nest in the South Atlantic during the northern hemisphere winter and are present in waters of Newfoundland and Labrador during the summer (June to October). It is only a small proportion of the millions of these birds (especially Greater Shearwaters) that occur off the west coast of Newfoundland.

During the winter, Northern Fulmars, Glaucous Gulls, Black-legged Kittiwakes, Thick-billed Murres and Dovekies from breeding colonies in the Arctic spend the winter in offshore waters south of the ice edge (Lock et al.1994). The geographic and seasonal numbers of these seabirds varies (Figure 3.66). Further north, the Strait of Belle Isle (not in the Study Area) is an important migration route for some marine-associated birds, alcids and sea ducks in particular (Tuck 1967; B. Mactavish, LGL Limited, pers. comm.).

3.5.2 Coastal Waterfowl

The west coast of Newfoundland has not been systematically surveyed for coastal waterfowl. Lock et al. (1994) reported a small wintering population of Common Eiders, and these and scoters (notably Black Scoter) aggregate off the Port au Port Peninsula and possibly Cape Ray (UA 4Rd). Cairns et al. (1989) did not report any sites in the Study Area for nesting Common Eiders, and significant sites such as St. John Bay were also omitted in Lock et al. (1994). The Strait of Belle Isle was historically reported to be an important migration route for Common and King Eiders (Tuck 1967; B. Mactavish, pers. comm.). Some component of eiders migrating during fall-winter from breeding colonies in coastal Labrador and the eastern Canadian Arctic are thought to migrate through the Strait of Belle Isle, with some over-wintering along the Quebec North Shore and southwest coast of Newfoundland (Gillespie and Learning 1974; Goudie et al. 2000).

The islands of St. John Bay (immediately north of Port aux Choix in UA 4Ra) have hundreds of nesting Common Eiders; the archipelago is one of the larger sites in coastal Newfoundland (Goudie 1986) where current estimates are between 500 and 1000 nesting pairs (CWS, unpublished). Smaller numbers of eiders nest in St. Margaret's Bay in UA 4Ra (~200 pairs), on Stearin Island in UA 4Rb (<100 pairs), and in Bay of Islands (<50 pairs) (CWS, unpublished). Eider broods frequent the coastline of the Strait Shore from Eddies Cove West south to Hawkes Bay (UAs 4Rab) during late summer (Figure 3.67). Tables 3.12 and 3.13 present some nesting, hatching and fledging data relevant to the Common Eider.

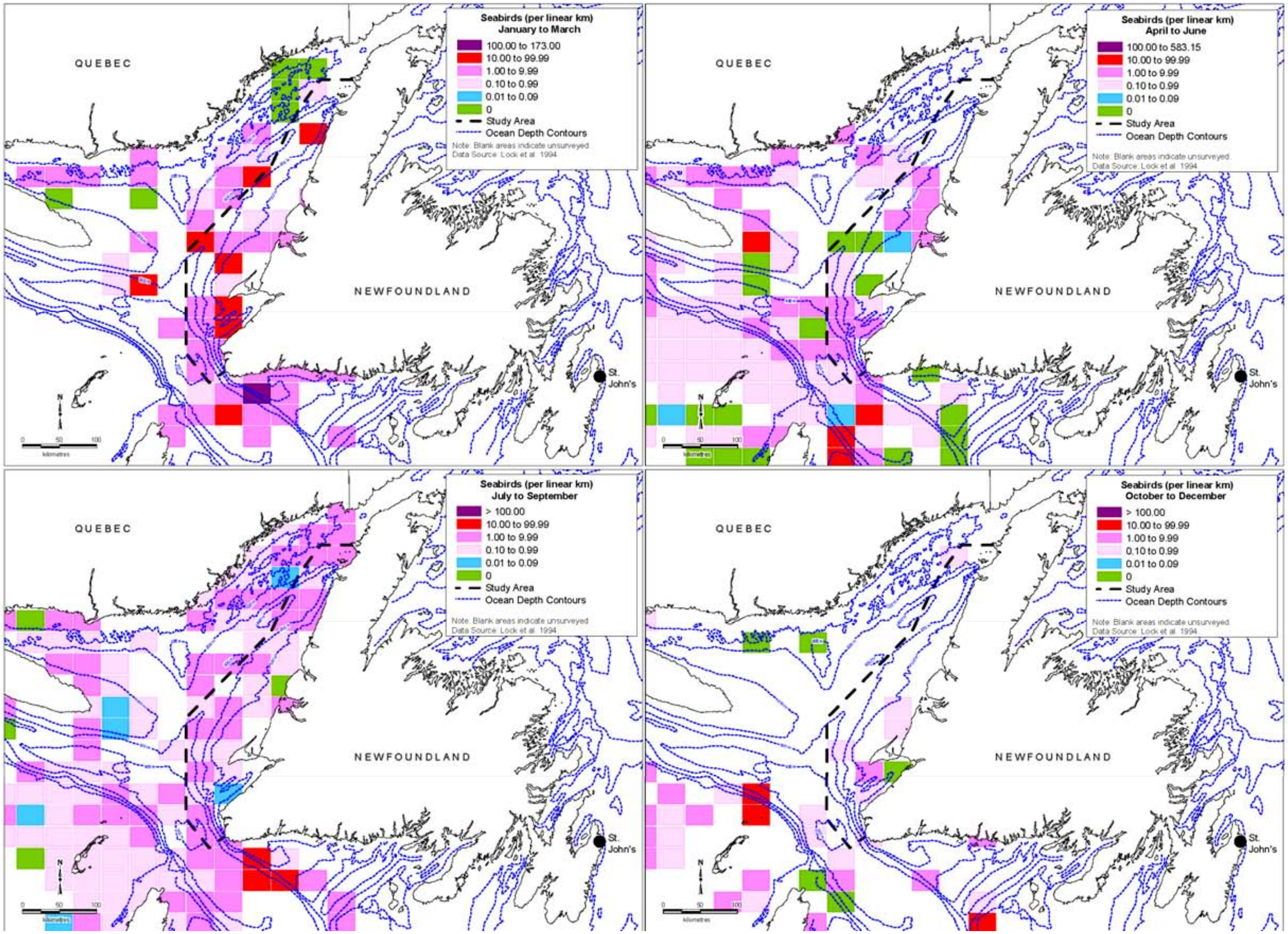
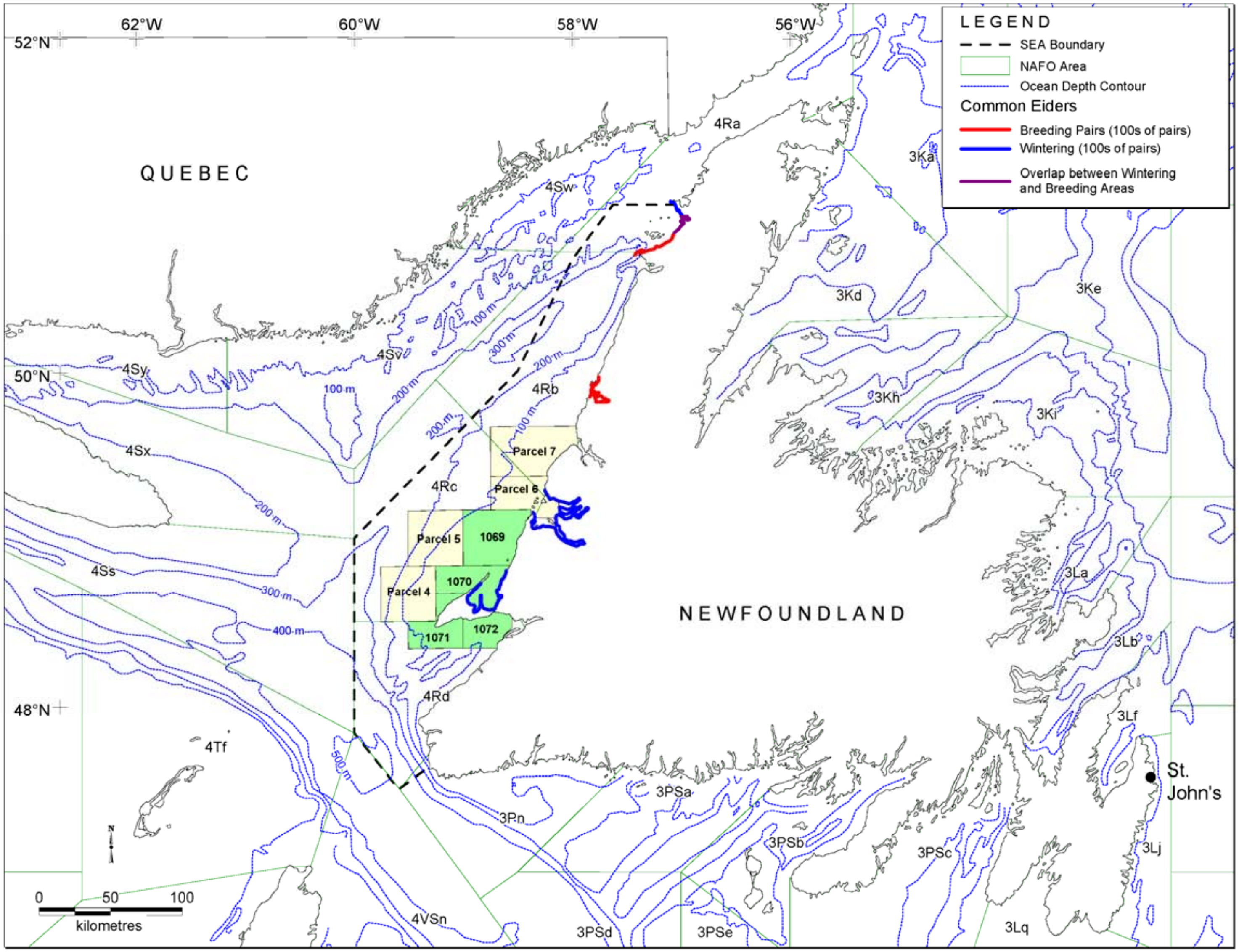


Figure 3.66. Geographic and Seasonal Distributions and Abundances of Vulnerable Seabirds within the Study Area.



Source: Conservation Data Centre.

Figure 3.67. Breeding and Wintering Locations of Common Eiders within the Study Area.

The eastern population of Harlequin Duck was listed as *endangered* in 1990 (Goudie 1991b), and are currently listed by *SARA* as a *species of concern*. Rivers and streams used for breeding (Robertson and Goudie 1999) occur in watersheds draining the Long Range Mountains in UAs 4Rabc (Thomas and Robert 2001). The only coastal aggregation identified in the Study Area is a small concentration of Harlequin Ducks (<100) that moults in late summer-early fall at Stearin Island off Cow Head (Figure 3.68). Few moulting areas have been identified for the eastern population and the current status of this site is unknown, and information on temporal distribution and male-female composition is lacking. Some broods of Harlequin Ducks are known to descend the natal rivers to coastal marine habitats in the Study Area (e.g., Doctors Brook near Eddies Cove West). The extent to which this occurs for other watersheds is unknown although likely for rivers such as Western Brook where breeding occurs relatively close to the estuary. For other watershed such as Torrent River it is clear that broods fledge inland and fly to marine habitats in late summer-early fall (Goudie and Gilliland 2005, in press).

Some relatively large concentrations of breeding and staging waterfowl occur in the Codroy River estuary (UA 4Rd) that has been designated a wetland of international importance under the international Ramsar Convention. Some of the largest provincial and regional aggregations of Canada Geese occur there in spring, late summer and early fall. The rich estuarine marshes support wetland species that are rare on insular Newfoundland, such as breeding American Wigeon and likely Great Blue Herons, and the only provincial breeding records for Pie-billed Grebes. Other notable sites include nesting records for Sora in Stephenville south to Codroy (P. Linegar, pers. comm.). Coastal concentrations of staging waterfowl, especially Canada Geese and Black Ducks occur in migration at Flat Bay Island/Sandy Point, and Stephenville Crossing in UA 4Rd, St. Pauls Inlet in UA 4Rb and Parsons Pond in UA 4Rb. These sites may support diving ducks (family Athyini) such as Greater Scaup that are uncommon in Newfoundland. Common Goldeneye and Mergansers of the sea duck group are common throughout.

Common Loons occur in the Study Area and winter in coastal areas that remain ice-free. Species such as Red-throated Loon and grebes are relatively uncommon. American Coots are rare and occur in the Codroy estuary.

3.5.3 Shorebirds

Migrant shorebirds that occur within the SEA Study Area include multiple species of Sandpipers, Yellowlegs, Plovers, and Phalaropes also based on Lock et al. (1994), Cairns et al. (1989), Brown (1986), and recent surveys from Gros Morne National Park and CWS (Conservation Data Centre). The most abundant shorebird species in the Study Area are White-rumped Sandpipers, Semipalmated Sandpipers, Greater Yellowlegs, Semipalmated Plovers, Black-bellied Plovers with lesser numbers of Least Sandpipers, Ruddy Turnstones and Sanderlings. Maximum abundance and diversity occurs in the mid-late August to early September period, and 10 to 14 species have regularly been recorded at Sandy Point, Flat Bay Spit, Stephenville Crossing, St. Paul's Inlet, and Eddies Cove East. Flat Bay Island/Sandy Point supports the highest recorded abundance and diversity of migrating shorebirds, and abundance and diversity is highest in the July-September period (Appendix 3).

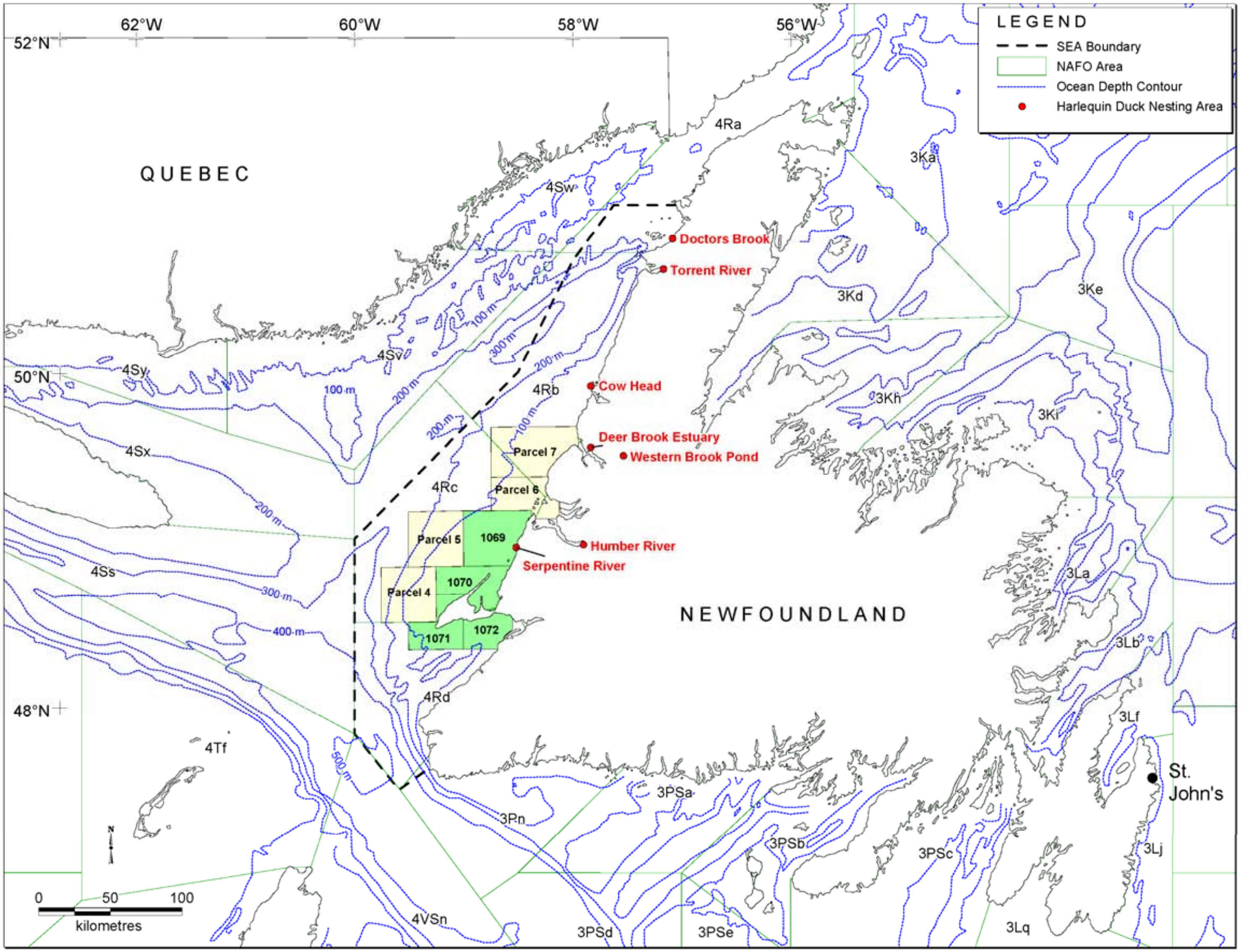


Figure 3.68. Some Locations of Harlequin Duck Nesting Areas within the Study Area.

Migrating shorebirds (sandpipers and plovers) concentrate at various beaches and tidal flats in the SEA Study Area. There is limited published information on shorebirds in western Newfoundland (B. Mactavish, LGL, pers. comm.). The largest concentrations of shorebirds in the Study Area identified by Lock et al. (1994) occur in UA 4Rb (Bonne Bay and immediately to the north notably St. Pauls Inlet and Parsons Pond), followed by UAs 4Rd (Cape Anguille, St. George's Bay) and 4Rc (Port au Port Bay) (Figure 3.69) (Lock et al. 1994).

Important shorebird areas for western Newfoundland identified by P. Thomas of CWS (pers. comm.), P. Linegar (pers. comm.) and B. Mactavish (pers. comm.) include the following:

- Eddies Cove East (north of Study Area),
- Parson's Pond (UA 4Rb),
- St. Paul's Inlet (UA 4Rb),
- Point au Mal (Port au Port Bay, UA 4Rc),
- Piccadilly Lagoon (Port au Port Bay, UA 4Rc),
- West Bay (Port au Port Bay, UA 4Rc),
- Black Duck Brook (Port au Port Bay, UA 4Rc),
- Stephenville Crossing (St. George's Bay, UA 4Rd),
- Sandy Point (St. George's Bay, UA 4Rd),
- Flat Bay (St. George's Bay, UA 4Rd),
- J.T. Cheeseman Park (just outside southern limit of the Study Area)
- Grand Bay West area (just outside southern limit of the Study Area).

3.5.4 Important Bird Areas

The Important Bird Area (IBA) program identifies habitat important to the survival of bird species. The program is coordinated by BirdLife International and administered in Canada by the Canadian Nature Federation and Bird Studies Canada (www.ibacanada.com). The criteria used to identify important habitat are internationally standardized and are based on the presence of *threatened* and *endangered* species, endemic species, species representative of a biome (keystone species), or a significant proportion of a species' population. These criteria focus on sites of national and international importance and it is important to recognize that areas of regional and provincial significance can be over-looked if assessment of important habitat is limited to this approach.

Three coastal sites in the west-southwest Newfoundland have been afforded the IBA designation. They are as follows:

1) Codroy Valley Estuary (NF041) (UA 4Rd) that is a wetland of international importance under the RAMSAR convention.
2) Grand Bay West to Cheeseman Provincial Park (NF038) (UA 4Rd).
3) Gros Morne National Park (NF045) (UA 4Rb; Parcel 7).

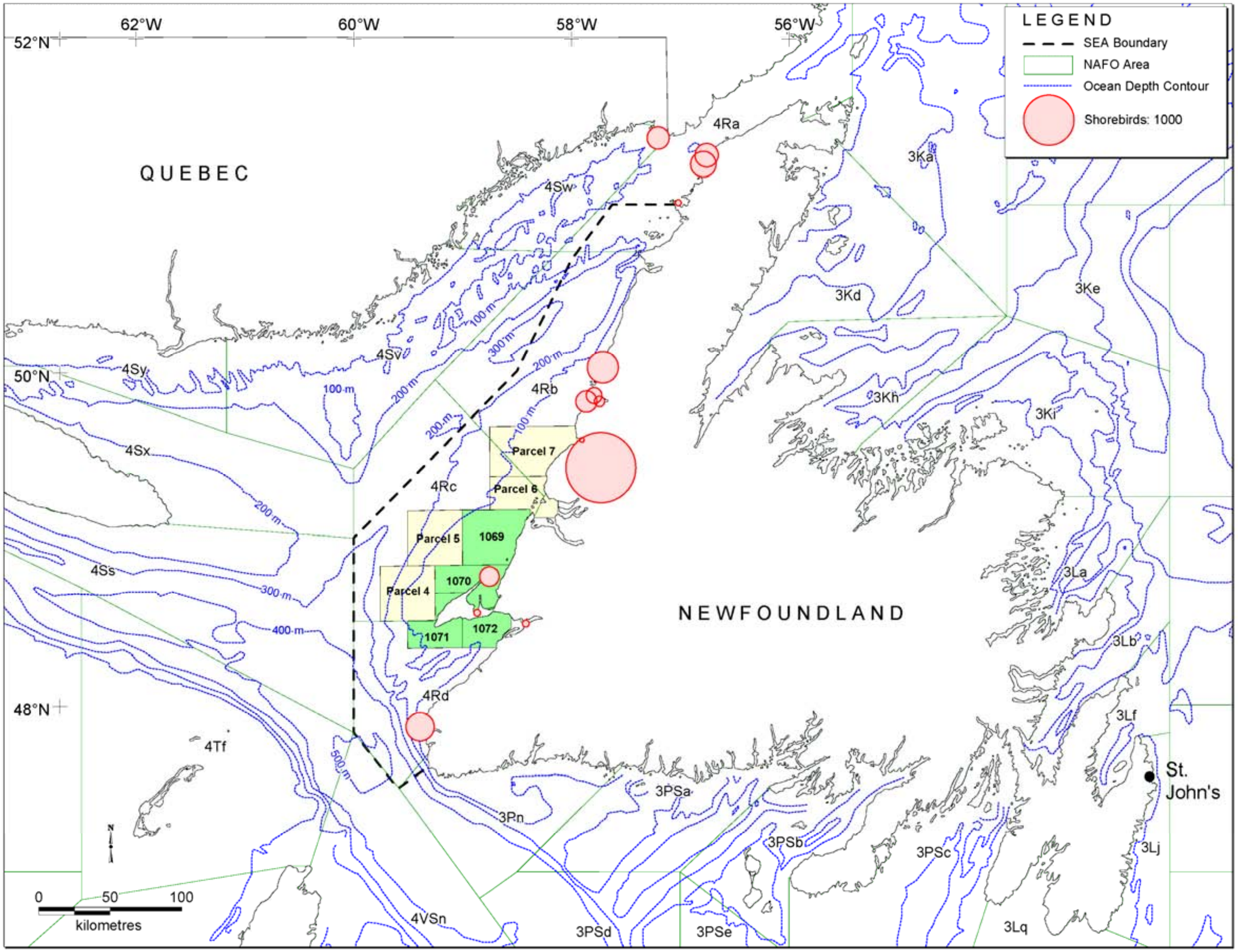


Figure 3.69. Locations of Important Migrant Shorebird Areas within the Study Area.

These three IBAs rank low in ‘IBA Population Threshold’ score compared with other Newfoundland IBAs (www.ibacanada.com) such as alcid colonies that support massive numbers of birds.

3.5.4.1 Codroy Valley Estuary

Located at the mouth of the Grand Codroy River, this IBA site supports a high diversity of breeding and staging site waterfowl species, and is a wetland of international importance (Ramsar Convention 1971). At least 20 waterfowl species have been identified in the estuary including Wood Duck, Green-winged Teal, American Black Duck, Northern Pintail, American Wigeon, Gadwall, Lesser and Greater Scaup, and Common and Red-breasted Mergansers. Rare ducks such as Eurasian Wigeon and Tufted Duck have also been seen at this IBA. In addition, thousands of Canada Geese staging during migration has been recorded here in continentally significant numbers. This IBA also has the first Newfoundland breeding record for Northern Shoveler, American Wigeon and Blue-winged Teal. The adjacent upland habitats support an array of provincially-rare breeding passerine birds (e.g., Boblink) and Ruby-throated Hummingbird.

The Piping Plover nests on Grand Codroy beach (Searston Beach and historically north beach). This species is globally vulnerable and is listed as *endangered* on Schedule 1 of *SARA*. A pair successfully bred on the beach at the mouth of the estuary from 1992 to 1998.

3.5.4.2 Grand Bay West to Cheeseman Provincial Park

This area consists an extensive eight kilometres of sand beach and small sections of rocky coastline stretching east from J.T. Cheeseman Provincial Park near Port aux Basques. The site is important nesting habitat for the Piping Plover, and supported an average of 17 adults during the period 1995 to 1998. The 18 individuals counted in 1996 comprised 4.2% of the Atlantic Canada population of the species.

3.5.4.3 Gros Morne National Park

At least 207 bird species have been recorded in the park, of which Common Tern and Arctic Tern occur along the coast (Lamberton 1976). Terns nest on two offshore islands in Gros Morne National Park, namely, Stearin Island and the White Rocks (Lock et al. 1994). Both species are designated *sensitive* by the provincial government. The eastern Canadian population of the Harlequin Duck is listed as a *species of concern* on Schedule 1 of *SARA*, and occurs here on turbulent rivers and streams in the park. Before and after the nesting season some broods congregate where the breeding streams drain into coastal waters and a small concentration (<100) moults at Stearin Island (Thomas and Robert 2001; Lock et al. 1994). Relatively large aggregations of shorebirds and waterfowl occur during migration in St. Paul’s Inlet, and Piping Plover likely breed there up to recent times.

3.5.4.4 Other Significant Habitat Areas

Sandy Point/Flat Bay Islands (UA 4Rd) is under consideration for special protection due to its unique migratory bird fauna, notably breeding Willets and Piping Plovers (CWS files). The greatest average abundance and diversity of shorebirds has been recorded there (Appendix 3). The nesting concentration of Common Eiders in St. John Bay is one of the largest in coastal Newfoundland. Stephenville Crossing supports a relatively rich intertidal flats and marshes that are little studied and likely unique for insular Newfoundland. The area supports some of the largest concentrations of migrating shorebirds (Appendix 3). Breeding Piping Plovers, Black-headed Gulls and likely Caspian Terns attest to its significance. Rare birds are frequently observed there and the recent presence of a Western Reef Heron (natural range being West Africa) has raised a lot of international interest in the bird watching community.

3.5.5 Bird Species at Risk

Bird species in the Study Area considered *at risk* include the Piping Plover and Harlequin Duck. The Piping Plover is listed as *endangered* on Schedule 1 of *SARA* and designated *endangered* by the Government of Newfoundland and Labrador. It currently nests on an array of beaches along the southern and southwestern part of the Study Area (Table 3.11; Figure 3.65). A Proposed Recovery Strategy for the Piping Plover is outlined in Goossen (2002). Recommendations for protection of critical habitat under the Endangered Species Act of Newfoundland Labrador have been forwarded to the responsible provincial minister by the Newfoundland Piping Plover Working Group (J. Brazil, pers. comm.) (see Section 3.8).

Piping Plovers are listed as *endangered* (COSEWIC and *Endangered Species Act of Newfoundland and Labrador, 2001*), and are present on sandy beaches from April to September. Ten to 12 pairs breed on 14 km of sand-beach habitat from Cheeseman Provincial Park (Cape Ray Beach) to Grand Bay West in Unit Area 3Pn. Sandy beach habitat is extensive in this area of the province and beaches known to support breeding pairs include Osmond Beach (1 to 2 pairs), Short Sand Beach (1 to 2 pairs), Big Barasway Beach and Sand Banks Park Beach (2 to 6 pairs), Bottles Beach (Rocky Barasway Beach) (1 to 2 pairs), and Second Beach (Rocky Barasway Bight) (1 to 2 pairs).

Further north, breeding pairs have been recorded at Little Codroy (1 to 2 pairs), Grand Codroy (1 pair) and Flat Bay Spit/Sandy Point (3 pairs) and, Stephenville Crossing (1 pair). There was a recent sighting at Piccadilly Beach on Port au Port Peninsula (2005), and there were regular sightings and suspected breeding at St. Paul's Inlet through the 1980's although there have been no recent observations (Area UA 4Rd, Table 3.11; Figure 3.65) (Lock et al. 1994).

Critical habitat is defined as habitat that is critical to survival of a species (*Endangered Species Act of Newfoundland and Labrador, 2001*). The act also defines 'recovery habitat' as habitat that is necessary for the recovery of a species. A person may not destroy or disturb the residence of an individual of a designated species where residence is defined as a specific dwelling place habitually occupied by one or individuals during all or part of their life cycles. Critical habitat for Piping Plovers has been delineated by the Newfoundland Piping Plover Working Group, comprised of Government and non-government interest representatives, that has made recommendations to the national Piping Plover Recovery Team and the provincial responsible Minister for the Government of Newfoundland and Labrador. Options for conservation and management of identified critical habitat areas are presented to the responsible minister by the Newfoundland Piping Plover Working Group. These options can include things such as the Provincial Park Act, Wildlife Reserves, Ecological Reserves and others (J. Brazil, pers. comm.). Most beach areas known to support breeding habitat for Piping Plovers are likely to be identified as critical habitat. Approaches to conservation and/or protection are dependent on area-specific management plans that can vary. The responsible minister may issue permits to permit economic related activities in areas of critical habitat if the actions are considered sustainable. The Accord between the Governments of Canada and Newfoundland and Labrador generally favour the responsible protection of critical habitat by the provincial jurisdiction. The federal Minister of Environment may in special circumstances invoke additional protection of critical habitat.

The Strait of Belle Isle is also thought to be an important migration route for shorebirds such as Whimbrels (B. Mactavish, pers. comm.) and may have been the migration route of the Eskimo Curlew (listed by COSEWIC as *endangered* but likely extinct) (Todd 1967). Other breeding shorebirds in the Study Area that are rare include the only provincial breeding records of Willet at Sandy Point.

The eastern population of the Harlequin Duck is presently listed as a *species of concern* on Schedule 1 of *SARA* and designated *vulnerable* by the Government of Newfoundland and Labrador. It breeds along streams and rivers draining the Long Range Mountains (Figure 3.66). It may be found in coastal waters during both spring and fall staging at the mouths of nesting streams occurring in UAs 4Rabc. A small late summer – fall moulting concentration occurs at Stearin Island. Terns are regarded as *sensitive* in the province. Arctic and Common Terns nest at nine coastal locations scattered throughout the Study Area (Table 3.11; Figure 3.65). The Caspian Tern is designated as vulnerable by COSEWIC and breeds infrequently as single pairs in sections of the Study Area (see above).

3.5.6 Rare Species

There are only a few sites for breeding Black-headed Gull in North America as this European species has expanded its range to North America in recent decades. A few pairs of this species have nested at Flat Bay Island/Sandy Point and maybe relocating from the original site at Stephenville Crossing. The movement between Sandy Point and Stephenville Crossing may reflect more frequent disturbance at Sandy Point (P. Linegar, pers. comm.).

The breeding range of Willets is south of Newfoundland, and this large shorebird species is only known to nest at Flat Island/Sandy Point, and more recently Stephenville Crossing. Rare birds infrequently occur at these enriched coastal locations, such as the Western Reef Heron (from West Africa) recently observed at the latter site that created a lot of international bird watching interest and tourism. Other species, such as the Sora and Great Blue Heron may breed in the province only in these enriched marshes of southwestern coast.

3.5.7 Planning Implications for Migratory Birds

Marine-associated bird abundance is low in the Study Area compared to other parts of Newfoundland and Labrador. Their peak vulnerability occurs between January and March. Common Eiders, Harlequin Ducks, Black Ducks and Canada Geese are the highest profile coastal waterfowl occurring in the Study Area. Common Eiders are most abundant in St. John Bay (4Ra, north of Port au Choix) and Harlequin Ducks occur at various locations in Unit Areas 4Ra, 4Rb, and 4Rc, and notably a moulting concentration at Stearin Island in Gros Morne National Park. Harlequin Ducks are listed on Schedule 1 of *SARA* as a *species of concern* and are considered vulnerable by the Government of Newfoundland and Labrador.

Nationally significant concentrations of Canada Geese occur at Codroy estuary, and the wetlands that also support an abundance of breeding and staging Black Ducks, Pintail, Wigeon and other waterfowl are designated as internationally significant (RAMSAR Convention).

Shorebirds are common at various locations within the Study Area. They are most abundant at Sandy Point-Flat Bay in St. George's Bay (4Rb) and in the Port au Port area in UA 4Rc, Stephenville Crossing and St. Paul's Inlet,. The Piping Plover is the highest profile shorebird. This species is listed as *endangered* on both Schedule 1 of *SARA* and by the Government of Newfoundland and Labrador. It occurs at different locations in Unit Area 4Rd between April and September.

Nearshore shallow water areas are obviously very important to most marine birds at some time of the year. Appropriate mitigations will have to be developed to minimize any impact of oil and gas activities on the shore area.

For most exploration, delineation and production drilling programs in recent years, the C-NLOPB has required that the operator undertake seabird monitoring from drilling rigs during the drilling program. For seismic programs, mitigation includes seabird monitoring a stranded bird release program in the Newfoundland and Labrador offshore area. Therefore, it is anticipated that the Board will require similar monitoring programs during this exploration, seismic and drilling programs in the Western Newfoundland and Labrador Offshore Area. A recent Environmental studies Research Fund (ESRF) study developed protocols for seabird monitoring programs for the offshore (Moulton and Mactavish 2004).

3.5.8 Data Gaps for Marine-associated Birds

There is relatively little information on seabirds for this area of coastal Newfoundland. Data on seabirds off coastal Newfoundland rely mainly on Brown et al. (1975) and Brown (1986), and are therefore historical in context. These ship-based data are now two to three decades old, and may not be representative of current abundance and distribution (Lock et al. 1994). Additional temporal and spatial data on marine-associated birds on the West coast of Newfoundland are desirable as they are the most sensitive group to oil spills. Operators will be encouraged to utilize suitable qualified personnel to collect marine-associated bird data during exploratory and production activity.

3.6 Marine Mammals and Sea Turtles

Thirteen species of cetacean, including dolphins, small and large toothed whales, and baleen whales occur in the western Newfoundland offshore region. These are presented in Table 3.15. Some of the cetacean species outlined in Table 3.15 have been afforded special status under *SARA*. The North Atlantic right whale and the blue whale are listed under Schedule 1 of *SARA* as *endangered*. The fin whale and the Scotian Shelf population of the northern bottlenose whale are listed under Schedule 3 of *SARA* as species of *special concern*. Further, the northern bottlenose whale is currently under consideration for listing under Schedule 1. The St. Lawrence Estuary population of beluga whales is currently listed under Schedule 1 of *SARA* as *threatened*. The harbour porpoise is currently listed under Schedule 2 of *SARA* as *threatened* and is under consideration for listing under Schedule 1.

Four species of pinniped are known to occur regularly in the western Newfoundland offshore region (Table 3.15). None of these species is listed under *SARA*. Hooded seals and grey seals are considered by COSEWIC to be *not at risk*, and the harbour seal is considered as *data deficient*. Two other species of pinniped could potentially occur in the western Newfoundland offshore region. These are the ringed seal (*Phoca hispida*) and the bearded seal (*Erignathus barbatus*). However, although they are known to occur in the Gulf of St. Lawrence, including the western Newfoundland offshore region (Environment Canada, n.d.), they are likely to be rare visitors to the area, as their usual distributions are thought to be much further north.

The other species of “marine mammal” that could occur in the western Newfoundland offshore region is the North American river otter (*Lontra canadensis*). North American river otters occur in rivers and streams throughout much of North America; in the northern portion of their range, they occur in coastal marine areas as well (Estes and Bodkin 2002). The breeding season of this species is from December to April and pups are born between February and April (Larivière and Walton 1998). The abundance of this species along the Atlantic coast of North America is unknown (Estes and Bodkin 2002), but they are thought to be relatively common in most of Canada where suitable habitat exists (Melquist et al. 2003). Preferred habitat consists of rugged coastal areas with irregular shorelines that have short intertidal lengths (Melquist et al. 2003). Otters in Newfoundland belong to a distinct subspecies, *L. canadensis degener* (Parks Canada n.d.). Their abundance is unknown. The status of the North American river otter has not been assessed by COSEWIC.

Table 3.15. The Habitat, Occurrence, and Conservation Status of Marine Mammals Occurring in the Study Area.

Species	**Habitat**	**Occurrence in area**	***SARA* status***
Mysticetes			
North Atlantic right whale (*Eubalaena glacialis*)	Coastal and shelf waters	Rare	Schedule 1: *Endangered*
Humpback whale (*Megaptera novaeangliae*)	Mainly nearshore waters and banks	Common	*Not at Risk*
Blue whale (*Balaenoptera musculus*)	Coastal and pelagic	Uncommon	Schedule 1: *Endangered*
Fin whale (*Balaenoptera physalus*)	Continental slope, pelagic	Common	Schedule 3: *Special Concern*
Minke whale (*Balaenoptera acutorostrata*)	Continental shelf, coastal	Common	Not Assessed
Odontocetes			
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	Common	Not Assessed
Northern bottlenose whale (*Hyperoodon ampullatus*)	Pelagic	Uncommon	Schedule 3: *Special Concern*[1]
Killer whale (*Orcinus orca*)	Widely distributed	Uncommon	Not Assessed
Long-finned pilot whale (*Globicephala melas*)	Mostly pelagic	Common	Not Assessed
Beluga whale (*Delphinapterus leucas*)	Estuarine	Rare	Schedule 1: *Threatened*[2]
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Continental shelf and slope	Common	Not Assessed
White-beaked dolphin (*Lagenorhynchus albirostris*)	Continental shelf	Uncommon	Not Assessed
Harbour porpoise (*Phocoena phocoena*)	Continental shelf	Common	Schedule 2: *Threatened*[3]
Pinnipeds			
Harbour seal (*Phoca vitulina*)	Coastal	Common	Not Assessed
Harp seal (*Phoca groenlandica*)	Ice	Common	Not Assessed
Hooded seal (*Cystophora cristata*)	Ice	Common	Not Assessed
Grey seal (*Halichoerus grypus*)	Coastal	Common	Not Assessed

*Species designation under *SARA* (Government of Canada 2005).

[1] Scotian Shelf population; currently under consideration for listing under Schedule 1.

[2] St. Lawrence Estuary population.

[3] Currently under consideration for listing under Schedule 1.

3.6.1 Mysticetes

3.6.1.1 North Atlantic right whale (*Eubalaena glacialis*)

The North Atlantic right whale is the most *endangered* large whale in the world. In spite of being the first whale to receive total protection from hunting over 60 years ago, its population size remains low. The western North Atlantic population is estimated to be on the order of about 300 individuals (IWC 2001a; Kraus et al. 2001) and appears to be declining (Caswell et al. 1999). The North Atlantic right whale is listed under Schedule 1 of *SARA* as *endangered* (Government of Canada 2005).

Right whales are generally found in waters with surface temperatures ranging from 8-15°C in areas that are 100-200 m deep (Winn et al. 1986). In the lower Bay of Fundy, they are generally distributed in areas where the bottom topography is relatively flat and the water column is stratified (Woodley and Gaskin 1996). In the Great South Channel, the average right whale dive depth was found to be only 7.3 m and few dives were deeper than 30 m (Winn et al. 1994). The primary prey item of the North Atlantic right whale is the copepod *C. finmarchicus*, and shifts in the distribution and abundance of this species can dramatically affect right whale distribution (Kenney 2001). North Atlantic right whales produce low-frequency moans of <400 Hz that are used in communication (reviewed by Thomson and Richardson 1995).

Right whales are known to aggregate in five seasonal habitat areas along the east coast of North America (IWC 2001b). In Canada, they can be found in the Bay of Fundy from June-November, with a peak of abundance in August to early October, and in the Roseway basin, south of Nova Scotia, from July-November, with a peak in abundance in August-September, although their use of this area seems to be declining in recent years (IWC 2001b). Although there has been a great deal of effort put into identifying their distribution, on average, only about 25% of the known right whale population can be accounted for in any month except August (IWC 2001b). Right whales are only occasionally sighted in the Gulf of St. Lawrence (Lien et al. 1989), and sightings are likely to be rare in the western Newfoundland offshore region.

3.6.1.2 Humpback whale (*Megaptera novaeangliae*)

The humpback whale has a cosmopolitan distribution. Although considered to be mainly a coastal species, it often traverses deep pelagic areas while migrating. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). In the North Atlantic, there are five areas where humpback whales aggregate in the summer to feed—Iceland–Denmark Strait, western Greenland, Newfoundland (including Labrador), the Gulf of St. Lawrence, and the Gulf of Maine–Scotian Shelf (Katona and Beard 1990). Genetic studies have revealed matrilineally determined distinctiveness between feeding aggregations of humpback whales in the western North Atlantic and off Iceland, but no genetic differences among humpback whales of the four western North Atlantic feeding areas (Palsbøll et al. 1995). The North Atlantic population of humpback whales likely numbers >11,500 individuals, approaching pre-exploitation levels, and although an abundance estimate is not available for Canadian waters, COSEWIC considers this species to be *not at risk* (COSEWIC 2003).

Humpback whales are often sighted singly or in groups of two or three; however, while in their breeding and feeding ranges, they may occur in groups of up to 15 individuals (Leatherwood and Reeves 1983). Whitehead et al. (1998) reported a mean group size of 1.47 for humpback whales seen off Nova Scotia.

Humpback whales produce sounds in the frequency range of 20 Hz to 8.2 kHz, although the songs sung by males on the wintering grounds have dominant frequencies of 120-4000 Hz (reviewed by Thomson and Richardson 1995).

Humpback whales aggregate in the Gulf of St. Lawrence in the summer to feed (Katona and Beard 1990). Although there were too few sightings to provide a reliable estimate, sightings data collected during aerial surveys in the Gulf from late August to early September of 1995 and from late July to early August of 1996 suggest that there were about 100 humpback whales in Gulf during those times (Kingsley and Reeves 1998). Most humpback whale sightings occurred in the northeast portion of the Gulf, north of the western Newfoundland offshore region. Humpbacks are occasionally observed in the St. Lawrence Estuary (Edds and Macfarlane 1987).

Humpback whales are much less common off the west and southwest coasts of Newfoundland than elsewhere off Newfoundland. Lynch (1987) provided summer (June-September) sighting frequencies that ranged from zero to 0.29 humpback whale sightings per week of land-based observations in survey blocks encompassing the western Newfoundland offshore region in 1979-1982. All sightings occurred in the northern portion of this region. She also reported no sightings of humpback whales during 865 nautical miles of shipboard survey effort in the western Newfoundland offshore region between 48°N and 50°N in 1976-1983. However, these data should be viewed with caution, given the often limited visibility in the area. Similar to the Kingsley and Reeves (1998) study, humpback sightings in the shipboard portion of her survey in the Gulf of St. Lawrence occurred off the northwest coast of Newfoundland.

3.6.1.3 Blue whale (*Balaenoptera musculus*)

The blue whale is widely distributed throughout the world's oceans and occurs in coastal, shelf, and oceanic waters. All populations of blue whales have been exploited commercially, and many have been severely depleted as a result. Recent estimates suggest a mere 400-1,400 blue whales remain in the Southern Hemisphere (IWC 2005). The North Atlantic population has been estimated to be 1,400 (NMFS 1998), while that of the western North Atlantic is probably on the order of a few hundred individuals (Sears and Calambokidis 2002). The blue whale is listed as *endangered* by COSEWIC (Sears and Calambokidis 2002) and by *SARA*.

The distribution of blue whales during the times of year when feeding is a major activity is specific to areas that provide large seasonal concentrations of euphausiids, which are the whale's main prey (Yochem and Leatherwood 1985). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). In the western North Atlantic, blue whales occur in the Gulf of St. Lawrence and east of Nova Scotia in spring, summer, and fall, in the Davis Strait in summer, and off southern Newfoundland in winter; movement between the Gulf of St. Lawrence and western Greenland has been demonstrated (summarized by Waring et al. 2002). Blue whales usually occur alone or in small groups (Leatherwood and Reeves 1983). Whitehead et al. (1998) noted an average group size of 1.38 for blue whales sighted off the coast of Nova Scotia. The best-known sounds of blue whales consist of low-frequency moans and long pulses that range from 12.5 Hz to 200 Hz and can have source levels up to 188 dB re 1 µPa (Cummings and Thompson 1971).

Blue whales can be found in the Gulf of St. Lawrence from January through November, but are most abundant from August to October (Sears et al. 1990). Sightings of this species in the Gulf occur predominantly along the north shore between the Saguenay River and the Strait of Belle Isle (Sears et al. 1990). Three hundred seventy-two blue whales were photographically identified during 21 years of research, primarily in the Gulf of St. Lawrence, but these data could not be used to produce an abundance estimate for this region (COSEWIC 2002a). There were only five sightings of blue whales during aerial surveys in the Gulf from late August to early September of 1995 and from late July to early August of 1996 (Kingsley and Reeves 1998). The western North Atlantic population of blue whales was severely depleted by whaling, and sightings of this species anywhere within its range, including the western Newfoundland offshore region, are uncommon.

3.6.1.4 Fin whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world's oceans (Gambell 1985), but typically occur in temperate and polar regions. They appear to have complex seasonal movements and are likely seasonal migrants (Gambell 1985). Fin whales mate and calve in temperate waters during the winter, but migrate to northern latitudes during the summer to feed (Mackintosh 1965). Genetic analyses suggest several different populations of fin whales in the North Atlantic (Berubé et al. 1998). In that study, fin whales from the western North Atlantic (Gulf of St. Lawrence and Gulf of Maine) were found to be genetically different from fin whales off Iceland and from those in the eastern North Atlantic. The entire North Atlantic population of fin whales is estimated at 47,300 (IWC 2005). Fin whales are considered as a species of *special concern* by COSEWIC (Table 3.15).

Fin whales occur in coastal and shelf waters, as well as in oceanic waters. Sergeant (1977) proposed that fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours due to tidal mixing and perhaps current mixing. Fin whales in the Bay of Fundy, Canada, were distributed in shallow areas with high topographic variation (Woodley and Gaskin 1996). Fin whales are sometimes observed alone or in pairs, but on feeding grounds, groups of up to 20 individuals are more common (Gambell 1985). Whitehead et al. (1998)

reported a mean group size of 1.31 for fin whales sighted off the Nova Scotian shelf. Fin whales are seen in the St. Lawrence Estuary in groups of two to six; adult–calf pairs are observed occasionally (Edds and Macfarlane 1987). The distinctive 20-Hz pulses of fin whales, with source levels as high as 180 dB re 1 µPa, can be heard reliably to distances of several tens of kilometres (Watkins 1981; Watkins et al. 1987). These sounds are presumably used for communication while swimming slowly near the surface or traveling rapidly (Watkins 1981).

Aerial surveys of the Gulf of St. Lawrence from late August to early September of 1995 and from late July to early August of 1996 found fin whales located predominantly along the margins of the Laurentian channel (Kingsley and Reeves 1998). Although there were too few sightings to provide a reliable estimate, sightings data from those surveys suggest that there were a few hundred fin whales in the Gulf during those times (Kingsley and Reeves 1998). Fin whales from the Gulf of St. Lawrence migrate to the Laurentian Channel and probably to northern Nova Scotia in the winter (Sergeant 1977).

Finback whales are less common off the west and southwest coasts of Newfoundland than elsewhere off Newfoundland. Lynch (1987) provided summer (June-September) sighting frequencies that ranged from zero to 0.18 finback whale sightings per week of land-based observations in survey blocks encompassing the western Newfoundland offshore region in 1979-1982. All sightings occurred in the northern portion of this region. She also reported no sightings of finback whales during 865 nautical miles of shipboard survey effort in the western Newfoundland offshore region between 48°N and 50°N in 1976-1983. Finback sightings in the shipboard portion of her survey occurred off the northwest coast of Newfoundland in the Gulf of St. Lawrence.

3.6.1.5 Minke whale (*Balaenoptera acutorostrata*)

Minke whales have a cosmopolitan distribution that spans ice-free latitudes (Stewart and Leatherwood 1985). In the Northern Hemisphere, they migrate northward during spring and summer and can be seen in pelagic waters at that time. Genetic analyses have revealed evidence of four distinct subpopulations in the North Atlantic: west Greenland, central North Atlantic–east Greenland–Jan Mayen, northeast Atlantic, and North Sea (Andersen et al. 2003). Minke whales off the east coast of North America are considered to belong to a separate stock, but their relationship to the other North Atlantic stocks in unknown (Waring et al. 2004). The status of the minke whale has not been evaluated by COSEWIC, but their populations are generally considered to be much healthier than those of the other baleen whales.

Minke whales are generally sighted in waters <200 m deep (Hooker et al. 1999; Hamazaki 2002), and this species is believed, in general, to prefer shallow water. In fact, Whitehead et al. (1998) found the minke whale to be the only cetacean species sighted less often in the waters around a deep biologically significant submarine canyon on the Scotian Shelf than in the other Shelf waters. In the northern Gulf of St. Lawrence, although minke whales were most often found in areas with steep bottom topography and depths between 20 m and 40 m, their distribution was most closely linked to the presence of underwater sand dunes, which are thought to be important habitats for sand lance and capelin, their preferred prey in the area (Naud et al. 2003).

Minke whales are relatively solitary, usually seen individually or in groups of two or three, but they can occur in large aggregations of up to 100 animals at high latitudes where food resources are concentrated (Perrin and Brownell 2002). Minke whales are most often sighted alone in the Gulf of St. Lawrence Estuary and are occasionally sighted in pairs (Edds and Macfarlane 1987). A large variety of sounds, ranging in frequency from 60 Hz to 12 kHz, have been attributed to minke whales (Stewart and Leatherwood 1985; Mellinger et al. 2000). The minke whale call recorded most often in the St. Lawrence estuary consisted of a 0.4-second downsweep in frequency that began at 100-200 Hz and ended below 90 Hz; this call may function to maintain spacing in this feeding area (Edds-Walton 2000).

Minke whales are widespread throughout the Gulf of St. Lawrence, but are encountered more frequently in northern portions of the Gulf (Kingsley and Reeves 1998). Using sighting information collected during aerial surveys in the Gulf from late August to early September of 1995, one thousand minke whales were estimated to be present in the entire Gulf; aerial surveys in late July to early August of 1996 provided an abundance estimate of 600 minke whales for the northern portion of the Gulf alone (Kingsley and Reeves 1998).

As with the other baleen whale species, minke whales are less common off the west and southwest coasts of Newfoundland than elsewhere off Newfoundland. Lynch (1987) provided summer (June-September) sighting frequencies that ranged from zero to 0.64 minke whale sightings per week of land-based observations in survey blocks encompassing the western Newfoundland offshore region in 1979-1982. The highest reported frequency (0.64 sightings per week) in this region was for St. George's Bay in the southern portion of the region. A sighting rate of 0.35 per week was reported for a survey block that included the northern portion of the Newfoundland offshore region, while no minkes were sighted in the central portion of the region. Lynch (1987) also reported sightings rates of zero and 0.01 minke whale sightings per track line surveyed during 470 nautical miles of shipboard survey effort in the 1° × 1° square from 48°N to 49°N and 60°W to 59°W and during 395 nautical miles of shipboard survey effort in the 1° × 1° square from 49°N to 50°N and 59°W to 58°W, respectively, in 1976-1983.

3.6.2 Odontocetes

3.6.2.1 Sperm whale (*Physeter macrocephalus*)

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). They range as far north and south as the edges of the polar pack ice, although they are most abundant in tropical and temperate waters where temperatures are higher than 59ºF or 15ºC (Rice 1989). Sperm whale distribution is linked to their social structure; adult females and juveniles generally occur in tropical and subtropical waters, whereas adult males are commonly alone or in same-sex aggregations, often occurring in higher latitudes outside of the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). In the North Atlantic, female sperm whales range only as far as about 45-50°N (Rice 1989), so most sperm whales encountered in the western Newfoundland offshore region are likely to be solitary, older males. There currently are no valid estimates for the size of any sperm whale population (Whitehead 2002); however, COSEWIC considers sperm whales to be *not at risk*.

Sperm whales are generally distributed over large areas that have high secondary productivity and steep underwater topography (Jaquet and Whitehead 1996); their distribution and relative abundance can vary in response to prey availability (Jaquet and Gendron 2002). Sperm whales routinely dive to depths of hundreds of meters and may occasionally dive as deep as 3000 m (Rice 1989). Presumed feeding events have been shown to occur at depths >1200 m (Wahlberg 2002). Sperm whales are capable of remaining submerged for longer than two hours, but most dives probably last a half hour or less (Rice 1989).

Whitehead et al. (1998) reported an average group size of 1.09 for 92 sightings of sperm whales off Nova Scotia.

Sperm whales produce acoustic clicks that are used for both echolocation and communication (Backus and Schevill 1966; Møhl et al 2000; Madsen et al. 2002b, 2002c; Wahlberg 2002; Whitehead 2003). During foraging dives sperm whales produce "usual clicks" in the frequency range of 5-24 kHz (Madsen et al. 2002b). Patterns of clicks, known as "codas" are used by socializing groups of female sperm whales (Weilgart and Whitehead 1992; Rendell and Whitehead 2003; Whitehead 2003). On their breeding grounds in the Galápagos Islands, mature males produce "slow clicks" that are likely related to mating (Whitehead 1993, 2003).

Sperm whales are known to occur in the Gulf of St. Lawrence, including the western Newfoundland offshore region (Environment Canada, n.d.). This species is generally seen only sporadically in the Gulf of St. Lawrence; however, a few individuals can be seen there on a regular basis (Reeves and Whitehead 1997). Sperm whale sightings are common in the western Newfoundland offshore region.

3.6.2.2 Northern bottlenose whale (*Hyperoodon ampullatus*)

Northern bottlenose whales live in deep water areas of the North Atlantic and are rarely found in waters less than 500 m deep (Gowans 2002). They range as far south as Nova Scotia and as far north and east as Spitzbergen, at about 80°N, 20°E; their range extends to 70°N in the Davis Strait (Mead 1989). In the western North Atlantic, there are two areas of abundance of northern bottlenose whales, one off northern Labrador and the other in a submarine canyon known as "the Gully" on the Scotian Shelf. The northern bottlenose whale is listed as *endangered* by COSEWIC (COSEWIC 2002b) and as a species of *special concern* under Schedule 3 of *SARA*; it is currently under review for listing under Schedule 1 as *endangered*.

Northern bottlenose whales routinely dive to depths greater than 800 m and are capable of remaining submerged for over an hour. Their primary prey is deep water squid (Gowans 2002). Northern bottlenose whales can be found in groups ranging in size from one to 20 individuals (Gowans 2002). Whitehead et al. (1998) reported a mean group size of 3.29 in the Gully. There is evidence that males form long-term bonds with other males that last for years, while females have a loose network of associates (Gowans 2002). Northern bottlenose whales produce whistles with a frequency range of 3-16 kHz and clicks that range in frequency from 0.5 kHz to >26 kHz (reviewed by Thomson and Richardson 1995).

Northern bottlenose whales are known to occur in the Gulf of St. Lawrence, including the western Newfoundland offshore region (Environment Canada, n.d.). However, they are likely to be uncommon in the western Newfoundland offshore region as it is not within the known areas of concentration of this species. Reeves et al. (1993) reported that there were only two known occurrences of this species in the Gulf of St. Lawrence and Wimmer and Whitehead (2004) show four stranding records from the region.

3.6.2.3 Killer whale (*Orcinus orca*)

Killer whales are cosmopolitan and globally fairly abundant; they have been observed in all oceans of the world (Ford 2002). Although they prefer cold waters, they have been reported from tropical waters as well (Heyning and Dahlheim 1988). High densities of this species occur at high latitudes, especially in areas where prey is abundant. Killer whales prey on a diverse variety of items, including marine mammals, fish, and squid. They are known to have preyed upon 20 different species of cetacean, including sperm whales and the large baleen whales, and 14 different species of pinniped (Jefferson et al. 1991). The greatest abundance of killer whales is found within 800 km of major continents (Mitchell 1975), although they also have been reported in offshore waters (Heyning and Dahlheim 1988).

Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Killer whales are capable of hearing high-frequency sounds, which is related to their use of these sound frequencies for echolocation (Richardson 1995). They produce whistles and calls in the frequency range of 0.5-25 kHz (reviewed by Thomson and Richardson 1995), and their hearing ranges from below 500 Hz to 120 kHz (Hall and Johnson 1972; Bain et al. 1993; Szymanski et al. 1999). The displacement of killer whales from one location to another as a result of the introduction of noise (in the form of acoustic harassment devices intended to deter harbour seal predation on fish pens) into their environment has been documented (Morton and Symonds 2002). Killer whale occurrence was re-established beginning six months after the noise source was removed.

Killer whales are known to occur throughout the Gulf of St. Lawrence, including the western Newfoundland offshore region (Environment Canada, n.d.). Their occurrence is somewhat regular near the Mingan Islands and at the western end of the Strait of Belle Isle (Baird 2001). Lien et al. (1988) reported occasional sightings of this species over a 12-year period off western Newfoundland and suggest that the population of this species in all Newfoundland waters is quite small. Based on the available information, this species is likely to be uncommon in the western Newfoundland offshore region.

3.6.2.4 Long-finned pilot whale (*Globicephala melas*)

Pilot whales are widely distributed throughout the world's oceans. There are two species of pilot whales, long-finned pilot whales and short-finned pilot whales (*Globicephala macrorhynchus*), distinguished most easily by their disparate distributions, with short-finned pilot whales being primarily tropical while long-finned pilot whales are mostly distributed antitropically (Olson and Reilly 2002). Long-finned pilot whales are abundant throughout the North Atlantic ocean to as far north as 70°N (Bernard and Reilly 1999), with some evidence of segregation between the western and eastern North Atlantic (Bloch and Lastein 1993).

Pilot whales exhibit great sexual dimorphism; males are longer than females and have more pronounced melons and larger dorsal fins (Olson and Reilly 2002). Molecular evidence suggests that pilot whale pods are composed of related individuals with little or no dispersal of either males or females from their natal group (Amos et al. 1993). Pilot whales pods are known to strand frequently en masse. Whitehead et al. (1998) reported an average group size of 11.44 for 54 sightings of long-finned pilot whales off Nova Scotia. Long-finned pilot whales produce whistles with dominant frequencies in the range of 1-8 kHz and echolocate using clicks with frequencies ranging from 6-11 kHz (reviewed by Thomson and Richardson 1995).

During an aerial survey from late August to early September of 1995, long-finned pilot whales were seen in the southeastern portion of the Gulf of St. Lawrence, near Cape Breton Island and southwestern Newfoundland (Kingsley and Reeves 1998). This species occurs regularly in that region and can be considered common in the western Newfoundland offshore region. Sightings in the region occurred in deep water with steep bottom topography (Kingsley and Reeves 1998).

Lynch (1987) provided summer (June-September) sighting frequencies that ranged from zero to 1.07 pilot whale sightings per week of land-based observations in survey blocks encompassing the western Newfoundland offshore region in 1979-1982. The highest rate (1.07 sightings per week) was reported for the central portion of the region, while no pilot whales were sighted in the St. George's Bay area. An intermediate rate of 0.35 sightings per week was reported for the northern portion of the western Newfoundland offshore region. Lynch (1987) also reported sighting rates of 0.08 and 0.15 pilot whale sightings per track line surveyed during 470 nautical miles of shipboard survey effort in the 1° × 1° square from 48°N to 49°N and 60°W to 59°W and 395 nautical miles of shipboard survey effort in the 1° × 1° square from 49°N to 50°N and 59°W to 58°W, respectively, in 1976-1983.

3.6.2.5 Beluga whale (*Delphinapterus leucas*)

The beluga whale, or white whale, is generally limited to seasonally ice-covered Arctic and sub-Arctic waters (Lesage and Kingsley 1998). The St. Lawrence population of beluga whales is at the southern limit of distribution of this species worldwide and seems to be isolated from its more northern conspecifics (Lesage and Kingsley 1998). This population has been estimated at 900-1,000 individuals and is considered *threatened* by COSEWIC (COSEWIC 2004) and *SARA*.

Beluga whales (*Delphinapterus leucas*) could potentially occur in the western Newfoundland and Labrador offshore region, but their presence is likely to be rare. They are thought to be confined, for the most part, to the St. Lawrence Estuary and Saguenay Fjord within the St. Lawrence region (Environment Canada n.d.); however, they occasionally range much further (e.g., Brown Gladden et al. 1999). Curren and Lien (1998) report only three sightings of live beluga whales, including one mother and calf pair, and two beluga whale strandings off western Newfoundland from 1979-1992.

3.6.2.6 Atlantic white-sided dolphin (*Lagenorhynchus acutus*)

Atlantic white-sided dolphins occur in temperate and sub-Arctic portions of the North Atlantic, where they are quite abundant (Reeves et al. 1999a). The total population of Atlantic white-sided dolphins in the North Atlantic may be as high as a few hundred thousand (Reeves et al 1999a). Evidence suggests that there may be three distinct populations of Atlantic white-sided dolphins in the western North Atlantic—Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea (Palka et al. 1997).

Atlantic white-sided dolphins are fairly gregarious, commonly seen in groups of 50-60 and occasionally seen in groups numbering hundreds of individuals (Reeves et al. 1999a). Whitehead et al. (1998) reported a mean group size of 8.8 for this species off Nova Scotia. Atlantic white-sided dolphins produce whistles with dominant frequencies between 6 and 15 kHz (reviewed by Thomson and Richardson 1995).

Atlantic white-sided dolphins can be seen throughout the Gulf of St. Lawrence; however, most sightings of this species occur in areas with steep bottom topography along the margins of the Gulf (Kingsley and Reeves 1998). This species was seen frequently during aerial surveys from late August to early September of 1995, which provided an abundance estimate of 12,000 animals for the entire Gulf; however, surveys from the following year suggest that the number of these animals that visits the Gulf varies greatly from year to year (Kingsley and Reeves 1998). Atlantic white-sided dolphins were sighted often off southwest Newfoundland during those surveys, and this species is likely to be common in the western Newfoundland offshore region.

3.6.2.7 White-beaked dolphin (*Lagenorhynchus albirostris*)

White-beaked dolphins are found in cold temperate and sub-Arctic waters in the North Atlantic (Reeves et al. 1999b). Populations in the eastern and western North Atlantic appear to be distinct (Kinze 2002). White-beaked dolphins are less abundant in the western North Atlantic than in the eastern portion of their range, with the greatest abundances occurring in this region off Labrador and southwest Greenland (Kinze 2002). White-beaked dolphins occur in schools up to several hundreds or thousands in number, although groups of 30 animals or so are most common (Kinze 2002). White-beaked dolphins produce squeals with a dominant frequency range of 8-12 kHz and echolocate at frequencies up to 325 kHz (reviewed by Thomson and Richardson 1995).

Within the Gulf of St. Lawrence, white-beaked dolphins are seen almost exclusively in shallow waters (<100 m deep) in the northeast corner of the Gulf near the Strait of Belle Isle (Kingsley and Reeves 1998). Aerial surveys from late August to early September of 1995 and from late July to early August of 1996 provided an abundance estimate of approximately 2500 of these animals for the entire Gulf (Kingsley and Reeves 1998). However, white-beaked dolphins are likely to be uncommon in the western Newfoundland offshore region. Hai et al. (1996) reported one stranding of three white-beaked dolphins in St. George's Bay during 1979-1990.

3.6.2.8 Harbour porpoise (*Phocoena phocoena*)

The harbour porpoise is found in shelf waters throughout the northern hemisphere, usually in waters colder than 17°C (Read 1999). The northernmost limit of their range is 70°N, but they are present in northern coastal waters only during the summer months (IWC 1996). Harbour porpoises in the western North Atlantic have been divided into three different subpopulations—Bay of Fundy–Gulf of Maine, Gulf of St. Lawrence, and Newfoundland—on the basis of mtDNA genetic differences (Wang et al. 1996) and pollutant burden (Westgate and Tolley 1999). The boundaries between these populations are not well defined as there is some genetic overlap. The Northwest Atlantic harbour porpoise is listed under Schedule 2 of *SARA* as *threatened* and is currently under consideration for listing under Schedule 1.

Harbour porpoises are usually seen in small groups of one to three animals, often including at least one calf; occasionally they form much larger groups (Bjørge and Tolley 2002). Harbour porpoises feed independently on small schooling fishes (Read 1999) and echolocate using frequencies in the range of 110-150 kHz (reviewed by Thomson and Richardson 1995). The range of their most sensitive hearing is from 8-32 kHz (Read 1999).

Harbour porpoises were seen throughout the Gulf of St. Lawrence during aerial surveys from late August to early September of 1995 and from late July to early August of 1996 (Kingsley and Reeves 1998). They were most numerous in the northern portion of the Gulf but were also widely distributed in the southern and central Gulf. Sightings data collected during those surveys provided estimates of 12,000 and 21,000 harbour porpoises, respectively, for the entire Gulf during those two years (Kingsley and Reeves 1998). This species was seen frequently during those surveys in waters off central and southwestern Newfoundland and is likely to be common in the western Newfoundland offshore region.

3.6.3 Pinnipeds

3.6.3.1 Harbour seal (*Phoca vitulina*)

Harbour seals have one of the largest distributions of any pinniped. They can be found in most coastal waters of the North Atlantic and North Pacific to as far north as about 80°N off Spitzbergen (Bigg 1981). This species has been divided into five different subspecies (Burns 2002). Western North Atlantic harbour seals belong to the subspecies *P. vitulina concolor*. The population of harbour seals in eastern Canadian waters was estimated at 30,000-40,000 in 1993 (Burns 2002). Harbour seals are present throughout the Gulf of St. Lawrence and are the only year-round residents of the St. Lawrence Estuary (MLI 1999). Harbour seal distribution is continuous throughout the Gulf of St. Lawrence (Burns 2002), and this species is likely to be common in the western Newfoundland offshore region. The harbour seal is considered *data deficient* by COSEWIC (Table 3.15).

3.6.3.2 Harp seal (*Phoca groenlandica*)

Harp seals range throughout the North Atlantic and Arctic Oceans from the Gulf of St. Lawrence to Russia (Lavigne 2002). They are one of the most abundant pinniped species, with an estimated population size in 2000 of 5.2 million (95% C.I. = 4.0-6.4 million) in the Northwest Atlantic (Healey and Stenson 2000). This population size appears to have been stable since 1996. Harp seals that whelp in the Northwest Atlantic (in the Gulf of St. Lawrence and off southern Labrador/northern Newfoundland) are genetically distinct from those that whelp in the northeast Atlantic (Perry et al. 2000).

The Northwest Atlantic harp seal population summers in the Canadian Arctic and Greenland, migrating south to the Gulf of St. Lawrence or off southern Labrador and northern Newfoundland where pups are born on the ice in late February or March (DFO 2000). Females nurse their pups for about 12 days, then mate and disperse. Older seals aggregate to moult off northeastern Newfoundland and in the northern Gulf of St. Lawrence in April and May. After that time, they disperse and migrate northward (DFO 2000). Harp seals dive to a maximum of about 370 m, and dives can last for up to 16 minutes (reviewed by Schreer and Kovacs 1997). Harp seals produce sounds in the frequency range of <0.1 to >10 kHz (reviewed by Thomson and Richardson 1995).

Pupping in the Gulf of St. Lawrence occurs in the southern portion of the Gulf, north of Prince Edward Island, in late February or March, and moulting occurs in northern portions of the Gulf in April and May (DFO 2000; Lavigne 2002). Harp seals are likely to be common in the western Newfoundland offshore region in the late fall to early spring and rare during other times of the year.

3.6.3.3 Hooded seal (*Cystophora cristata*)

The range of the hooded seal encompasses a large portion of the North Atlantic from as far south as Nova Scotia to as far north as north of Svalbard in the Barents Sea (Kovacs 2002). It is not uncommon for hooded seals, particularly young animals, to be found outside their normal range. Hooded seals are migratory, congregating to breed in spring in the Gulf of St. Lawrence, north of Newfoundland, in the Davis Strait, and east of Greenland (Kovacs 2002). After breeding, hooded seals move to moulting areas on the southeast and northeast coasts of Greenland. Hooded seals disperse widely in the summer and fall (Kovacs 2002). There are no good estimates of the hooded seal population size because this species is difficult to survey, but the total population probably numbers on the order of half a million (Kovacs 2002).

The hooded seal breeding season lasts only 2-3 weeks in each area. Females give birth in loose pack ice areas and nurse their pups for a mere four days, during which time the pups consume up to 10 litres of milk per day (Kovacs 2002). Mating occurs in the water after weaning. Hooded seals are quite solitary outside the breeding season and, as a result, their vocal repertoire is quite simple (Kovacs 2002). They produce sounds in the frequency range of 0.1-1.2 kHz (reviewed by Thomson and Richardson 1995).

Hooded seals gather in the Gulf of St. Lawrence in the spring to breed, then migrate toward Greenland to moult several weeks later and are dispersed widely during the rest of the year (Kovacs 2002). Whelping occurs in the southern portion of the Gulf near the Magdalen Islands, Prince Edward Island, and Cape Breton Island (Hammill 1993). Only a small proportion of the hooded seal population visits the Gulf, with the bulk of the population whelping off northeast Newfoundland and in the Davis Strait (Hammill 1993). Hooded seals are likely to be common in the Newfoundland offshore region in the spring and rare during other times of the year.

3.6.3.4 Grey seal (*Halichoerus grypus*)

Grey seals are distributed in coastal areas of the North Atlantic, off eastern Canada, Iceland, the United Kingdom, and Norway during the breeding season from September to December (Bonner 1981). Outside the breeding season, they range farther. Large-scale movements up to 2,100 km have been demonstrated (NAMMCO 1997). The Northwest Atlantic stock of grey seals occurs in the Gulf of St. Lawrence and around Nova Scotia and Newfoundland and Labrador. The largest breeding colony in the North Atlantic is on Sable Island, east of Nova Scotia, with about 85,000 individuals (Hall 2002). Stocks of grey seals in the northeastern and Northwestern Atlantic are thought to be genetically distinct (NAMMCO 1997).

Female grey seals give birth between September and March (Hall 2002). In Canada, the peak pupping season occurs in January (Hall 2002). Pups are nursed for approximately 18 days and the female mates again near the end of the lactation period either on land or in the water (Hall 2002). Grey seals from Sable Island disperse after the breeding period, moult during May-June, and move northward during July-September, returning to Sable Island to breed in October-December (Stobo and Zwanenburg 1990). Most grey seals likely return to breed in the same area where they were born (Bonner 1981). Grey seal dives last, on average, from 4-10 minutes, with a maximum duration of 30 minutes (Hall 2002). Grey seals produce sounds in the frequency range of 0.1-16 kHz (reviewed by Thomson and Richardson 1995).

Grey seals gather in breeding colonies from October to December; in the Gulf of St. Lawrence, these are located between the eastern end of Prince Edward Island and Cape Breton Island, mainly on Amet Island, and on the ice in St. George's Bay (Stobo and Zwanenburg 1990). They disperse following the breeding season, from January to April, but during the moulting season in May and throughout the summer, grey seals are also seen on Anticosti Island (Stobo and Zwanenburg 1990). The Gulf of St. Lawrence population of grey seals has been estimated at 69,000 animals (Hall 2002). This species is likely to be common in the Newfoundland offshore region.

3.6.4 Sea Turtles

Three species of sea turtle could potentially occur in the Western Newfoundland and Labrador Offshore Area (Table 3.16). In order of decreasing abundance in North American waters, these are as follow: (1) the loggerhead turtle (*Caretta caretta*), (2) the leatherback turtle (*Dermochelys coriacea*), and (3) the Kemp's ridley turtle (*Lepidochelys kempii*). Both loggerheads and leatherbacks are common in the waters off Newfoundland during the summer and fall (Goff and Lien 1988; Marquez 1990; Witzell 1999). Less is known about the distribution of Kemp's ridley turtles in eastern Canada, although they are thought to be rare (Breeze et al. 2002). Adults of this species are rarely found beyond the Gulf of Mexico; however, juvenile animals range as far north as Newfoundland (Ernst et al. 1994).

Table 3.16. The Habitat, Abundance, and Conservation Status of Sea Turtles Found in the Western Newfoundland and Labrador Offshore Area.

Species	**Occurrence in Study Area**	***SARA* status***
Leatherback turtle (*Dermochelys coriacea*)	Seasonally common	Schedule 1: *Endangered*
Loggerhead turtle (*Caretta caretta*)	Uncommon	Not Listed
Kemp's ridley turtle (*Lepidochelys kempii*)	Very rare, only juveniles	Not Listed

*Species designation under *SARA* (Government of Canada 2005).

3.6.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the largest living turtle, attaining up to 219 cm in length and over 900 kg. It also may be the most widely distributed reptile, ranging throughout the Atlantic, Pacific, and Indian Oceans and into the Mediterranean Sea (Ernst et al. 1994). Leatherbacks are predominantly pelagic and are highly carnivorous, consuming mostly invertebrates. Although they occasionally ingest algae or vertebrates, their preferred prey is jellyfish.

The worldwide population of leatherbacks was recently censused at between 26,000 and 43,000 (Dutton et al. 1999). This number, not far from the evolutionary effective population size, is estimated to be between 45,700 and 60,000 calculated from observed genetic diversity (Dutton et al. 1999). The current population is thought to be declining, as major nesting colonies have declined in the last 20 years, although Dutton et al. (1999) report an increase in leatherbacks nesting in Florida over the last few years. There are no estimates of the population size in Canada; however, adult leatherbacks are thought to be a regular part of the Newfoundland marine fauna in the summer and fall (Goff and Lien 1988; Witzell 1999). The leatherback turtle is listed under Schedule 1 of *SARA* as *endangered*.

Data from the U.S. Pelagic longline fishery observer program have added to the knowledge of leatherback distribution off Newfoundland (Witzell 1999). Nearly half of the leatherbacks (593 captures) caught incidentally by this fishery between 1992 and 1995 from the Caribbean to Labrador were captured in waters on and east of the 200-m isobath off the Grand Banks (Witzell 1999). Animals were caught in this region during all months from June to November, with the bulk of captures from July to September. Not surprisingly, leatherback captures within these waters corresponded closely with fishing effort, both clustered near the 200-m isobath. Two leatherback turtles were sighted during a shipboard survey east of the Scotian Shelf out to the Laurentian Channel in 2002 (Clapham and Wenzel 2002). Breeze et al. (2002) state that adult leatherback turtles are regularly observed on the Scotian Shelf from June to October. Goff and Lien (1988) report three captures of leatherback turtles off west and southwest Newfoundland from 1976-1985. This species is occasionally sighted off Quebec in the Gulf of St. Lawrence (James 2001). Although there are no estimates available for the number of leatherback turtles in the western Newfoundland offshore region, they are likely a regular part of the marine fauna in the area.

3.6.4.2 Loggerhead Turtle (*Caretta caretta*)

The loggerhead is the largest hard-shelled turtle in the world (typically 85–100 cm) and also the most abundant sea turtle in North American waters (Ernst et al. 1994). They wander widely throughout their range, found in coastal areas or sometimes more than 200 km out to sea. Loggerheads are omnivorous, predominantly consuming many types of invertebrates but also algae and vascular plants (Ernst et al. 1994). The North American population, which is thought to be declining, has been estimated to number between 9,000 and 50,000 adults (Ernst et al. 1994). This species is classified as *threatened* under the U.S. ESA.

Loggerheads found in Canadian waters tend to be smaller than their counterparts in coastal U.S. waters (Witzell 1999), so are likely younger animals. Ninety percent of females nesting in the Atlantic do so in the southeastern U.S. in what appear to be demographically independent groups based on mitochondrial DNA haplotype distributions (Encalada et al. 1998). How genetic distinctions in nesting areas may relate to genetic structure elsewhere in their range has not been investigated.

Data from the U.S. Pelagic longline fishery observer program have added to the knowledge of loggerhead distribution off Newfoundland (Witzell 1999). Seventy percent of loggerheads (936 captures) caught incidentally by this fishery between 1992 and 1995 from the Caribbean to Labrador were captured in waters on and east of the 200-m isobath off the Grand Banks. Animals were caught in this region during all months from June to November with a peak in captures during September. Within these waters, loggerhead captures corresponded closely with fishing effort, both being clustered near the 200-m isobath where oceanographic features lead to the concentration of prey species for both the turtles and the swordfish and tuna that are the targets of the longline fishers.

Loggerheads are not observed as frequently as leatherbacks on the Scotian Shelf (Breeze et al. 2002). Although there are no estimates available for the density of loggerhead turtles in the western Newfoundland offshore region, they are likely to be rare.

3.6.4.3 Kemp's Ridley Turtle (*Lepidochelys kempii*)

Adult Kemp's ridley turtles rarely range beyond the Gulf of Mexico, but juveniles can be found as far north as Newfoundland on the east coast of North America (Ernst et al. 1994). There are no estimates on the number of Kemp's ridley turtles occurring in Canadian waters. Breeze et al. (2002) list them as accidental visitors to eastern Canada and state that the Scotian Shelf is not believed to an important habitat for them. Almost all nesting of Kemp's ridleys occurs along a single beach in Rancho Nuevo, Mexico. The number of females nesting there dropped from as many as 40,000 over 50 years ago to a low of around 700 in the late 1980s, but saw a steady increase in the 1990s as a result of conservation measures (Marquez et al. 1999). The number of Kemp's ridleys that visit the western Newfoundland offshore region is unknown, but this species is likely to be extremely rare. Kemp's ridley turtles are considered *endangered* under the U.S. ESA.

3.6.5 Planning Implications for Marine Mammals and Sea Turtles

For most exploration, delineation and production drilling operations, the C-NLOPB has required that the operator undertake whale monitoring from drilling rigs during the drilling program. For seismic programs, it has been a standard mitigative measure in recent years to conduct marine mammal monitoring for all seismic programs in the Newfoundland and Labrador offshore area. Observational data on sea turtles in conjunction with any marine mammal monitoring will be required.

Marine mammal and sea turtle species with special consideration under *SARA* are the blue whale, North Atlantic right whale, fin whale, northern bottlenose whale, beluga whale and harbor porpoise. Of greatest concern are the blue whale, the North Atlantic right whale, the St. Lawrence Estuary population of the beluga whale, and the leatherback sea turtle, which are all listed under Schedule 1 of *SARA*. Blue whales, North Atlantic right whales and leatherback sea turtles are all listed as *endangered*. The St. Lawrence Estuary population of the beluga is listed as *threatened*.

3.7 Species at Risk

All of the following *SARA*, COSEWIC, and Government of Newfoundland and Labrador “species at risk” designations are current as of 30 August 2005.

3.7.1 *SARA*

Schedule 1 of *SARA* is the official list of wildlife species in Canada that have legal protection and conservation requirements. Once a species is listed, measures to protect it and help its recovery are implemented.

Species that are legally protected under *SARA* (i.e., Schedule 1 *threatened* or *endangered*) and that may occur in the Study Area include the following:

- Blue whale (*Balaenoptera musculus*) (Atlantic population) – *endangered*
- North Atlantic right whale (*Eubalaena glacialis*) – *endangered*
- Piping Plover (*Charadrius melodus melodus*) – *endangered*
- Leatherback sea turtle (*Dermochelys coriacea*) – *endangered*
- Northern wolffish (*Anarhichas denticulatus*) – *threatened*
- Spotted wolffish (*Anarhichas minor*) – *threatened*
- Beluga whale (*Delphinapterus leucas*) (St. Lawrence Estuary population) – *threatened*

Atlantic wolffish (*Anarhichas lupus*) and the Ivory gull (*Pagophila eburnea*) are presently listed as *special concern* on Schedule 1 of *SARA*. Schedules 2 and 3 of *SARA* identify species that were designated 'at risk' by COSEWIC prior to October 1999 and must be reassessed using revised criteria before they can be considered for addition to Schedule 1.

Under *SARA* Schedule 1, a 'recovery strategy' and corresponding 'action plan' must be prepared for *endangered*, *threatened* and extirpated species, and a management plan must be prepared for species listed as *special concern*. Currently, there are no recovery strategies, action plans, or management plans in place for species listed under Schedule 1 and are known to occur in the Study Area. It is possible that a Recovery Strategy will soon be in place for blue whales (J. Lawson, DFO, pers. comm.).

3.7.2 COSEWIC

COSEWIC have also designated some species as either *endangered* or *threatened* that do not occur on the *SARA* listing as either *endangered* or *threatened*. These COSEWIC-listed species that may occur in the Study Area include the following:

- Porbeagle shark (*Lamna nasus*) – *endangered*
- Winter skate (*Leucoraja ocellata*) (Southern Gulf of St. Lawrence population) – *endangered*
- Striped bass (*Morone saxitilis*) (Southern Gulf of St. Lawrence population) – *threatened*
- Atlantic cod (*Gadus morhua*) – *threatened*
- Cusk (*Brosme brosme*) – *threatened*

3.7.3 Government of Newfoundland and Labrador

Species that are listed as "at risk" by the Government of Newfoundland and Labrador and that may occur in the Study Area include the following:

- Banded killifish (*Fundulus diaphanus*) – vulnerable
- Ivory Gull (*Pagophila eburnea*) – vulnerable
- Harlequin Duck (*Histrionucus histrionucus*) – vulnerable
- Piping Plover (*Charadrius melodus melodus*) – *endangered*

The Newfoundland and Labrador population of the banded killifish is presently listed as a species of *special concern* on Schedule 1 of *SARA*. It is found in seven locations in Newfoundland and Labrador, including the west coast of the island. This small fish mostly occurs in freshwater, rarely in estuarine or marine areas.

3.7.4 Planning Implications for Species at Risk

Operators are required to be *SARA*-compliant over the lifespan of a project. Mitigations currently being employed include delayed ramp-up of seismic arrays when a marine mammal or sea turtle designated as either *endangered* or *threatened* under *SARA* Schedule 1 is within either 500 or 1,000 m of the seismic array, and shutdown of operating seismic arrays when a marine mammal or sea turtle designated as either *endangered* or *threatened* under *SARA* Schedule 1 is within either 500 or 1,000 m of the seismic array. The radius of the monitoring safety zone is project-specific. Any marine mammals or sea turtles that become listed on *SARA* Schedule 1 as *endangered* or *threatened* during an ongoing project immediately qualify as species requiring the above mitigations.

It is also important that operators use spatial and temporal scheduling mitigations to avoid critical life stages of Species at Risk. This mitigation applies to invertebrate, fish and bird species as well as to marine mammals and sea turtles.

Critical habitat of Species at Risk is also protected under *SARA*. The protection of critical habitats is a major aspect of *SARA* Recovery Strategies (e.g., identified Piping Plover critical habitat sites in the southern part of the Study Area). Mitigations to protect critical habitat in such areas will have to be employed and monitored.

3.7.5 Data Gaps for Species at Risk

As is the case with most marine biota, much of the basic biological information related to species identified as being at risk is lacking (e.g., critical habitat, movement patterns, inter-relationships with other species, critical life stage behaviours). More scientific research is required to address knowledge gaps which deter the effective implementation of recovery strategies. Collaborative efforts involving industry and government could potentially fill some of the data gaps for Species at Risk and introduce GIS or web-based information tools, thereby providing more of an ecosystem perspective rather than data for individual species only.

3.8 Potentially Sensitive Areas

Key areas of highest potential sensitivity have been identified within the Study Area. The locations of the potentially sensitive areas discussed in the following sections are indicated in Figure 3.70.

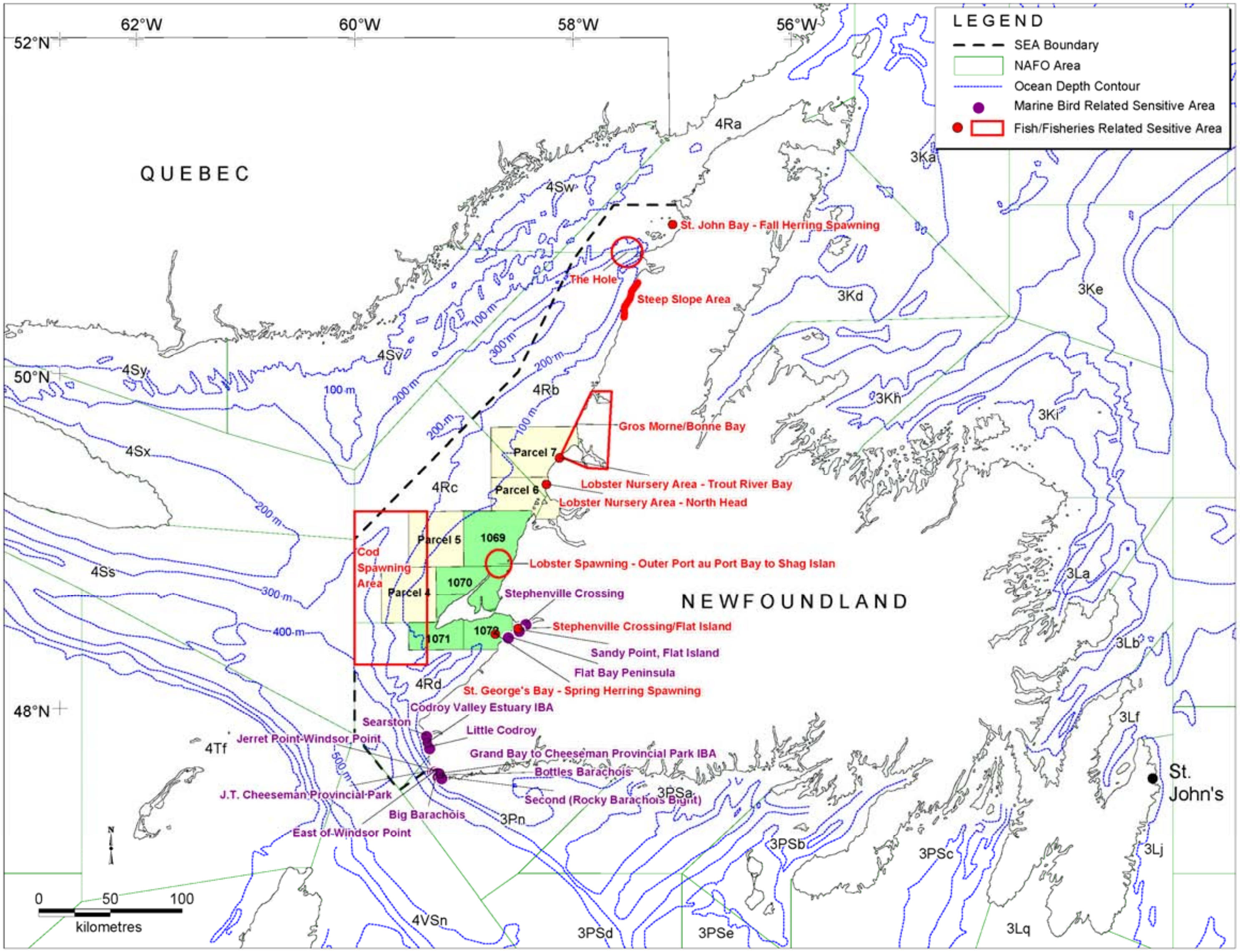


Figure 3.70. Potentially Sensitive Areas within the Study Area.

3.8.1 Fish and Invertebrates

3.8.1.1 Slope Region (4Ra/4Rb)

A steep slope area at the northern end of the Esquiman Channel and just offshore from Port au Choix (4Rab) is known locally as 'The Hole'. This area is considered by local fishers to be quite productive and, therefore, a very sensitive fisheries resource zone throughout the year. Various life stages of numerous species (e.g., cod, capelin, shrimp) occur at The Hole, including juveniles, adults, and likely eggs and larvae. According to fishers, DFO has been considering this area as a candidate for a Marine Protected Area.

Another relatively steep slope area which occurs close to shore between Bellburns and River of Ponds (~ 15 km south of Port au Choix) is also considered special by local fishers. As with The Hole, there is likely upwelling in the area, resulting in the occurrence of various life stages of numerous species.

Another steep slope area within the Study Area occurs in the southern portion of 4Rd.

3.8.1.2 4Rc/4Rd Cod Spawning Area off Cape St. George

The region defined by the following corner coordinates is closed to groundfish fishing between 1 April and 23 June because of the occurrence of spawning by 4RS/3Pn cod. The area was established in 2002 and has been resized since that time. Corner coordinates of the Cape St. George Spawning Area are as follow:

48º 00' N,	59º 20' W
49º 10' N,	59º 20' W
49º 10' N,	60º 00' W
48º 00' N,	60º 00' W

Depths within the area range from just under 100 m to more than 300 m. The Cape St. George Spawning Area overlaps with portions of Bid Parcels 4 and 5 and EL 1071.

St. George's Bay (4Rd)

Spring spawning by herring typically occurs in this bay in May/June

St. John Bay (4Ra)

Fall spawning by herring typically occurs in this bay between mid-July and mid-September.

Lobster Spawning/Nursery Areas (4Rbc)

Although lobster essentially spawn along the entire west coast of Newfoundland, particular areas have been designated as special spawning and nursery locations. The area between outer Port au Port Bay and Shag Island was identified as a location with very large female lobsters carrying sizeable egg clutches. Two other areas along the coast north of Bay of Islands are now closed to fishing because of their roles as lobster nursery areas.

3.8.2 Marine-associated Birds

3.8.2.1 Critical Habitat of Piping Plover (UA 4Rd)

In the proposed draft recovery strategy for Piping Plover, Amirault (2005) identified numerous sites within or proximate to the Study Area that meet Piping Plover critical habitat criteria. All are located in Unit Area 4Rd. They are as follow:

- Stephenville Crossing (48.50ºN, 58.43ºW)
- Sandy Point, Flat Island (48.46ºN, 58.49ºW)
- Flat Bay Peninsula (48.42ºN, 58.59ºW)
- Searston (47.83ºN, 59.34ºW)
- Little Codroy (47.76ºN, 59.31ºW)
- East of Windsor Point (47.62ºN, 59.25ºW)
- J.T. Cheeseman Provincial Park (47.62ºN, 59.28ºW)
- Jerret Point-Windsor Point (47.62ºN, 59.26ºW)
- Big Barachois (47.61ºN, 59.24ºW)
- Bottles Barachois (47.59ºN, 59.23ºW)
- Second (Rocky Barachois Bight) (47.58ºN, 59.20ºW)

Amirault (2005) also describes Action Plans that include the identification of sites presently not occupied by Piping Plover but which may eventually be identified as Piping Plover critical habitat.

3.8.2.2 Sandy Point, St. George's Bay (UA 4Rd)

Four hectares (10 acres) of property on Sandy Point were acquired by the Nature Conservancy of Canada in 2005. Sandy Point has tidal sand flats, sand beaches, and dunes, habitats that are relatively uncommon in Newfoundland and Labrador. One of eastern North America's largest and most northerly *Spartina* salt marshes also occurs on this property. Approximately 30% of the nationally *endangered* Piping Plover population in Newfoundland occurs in this area. Sandy Point is also important habitat for migrating birds, including American Widgeon, American Black Duck, Green-winged Teal, Red-breasted Merganser, Northern Pintail, Greater Scaup, White-winged Scoter and Common Goldeneye. Until July

2005, Sandy Point was the only known nesting location of the Willet (*Catoptrophorus semipalmatus*) in Newfoundland. Twelve rare species of plants also occur in this area, including seabeach sedge and saltwater cordgrass (Georgian, 12-18 July 2005).

3.8.2.3 Grand Codroy Estuary (UA 4Rd)

The Grand Codroy Estuary is on the Ramsar List which acknowledges wetlands of international importance. It is the only Newfoundland and Labrador wetland among the 37 Canadian wetlands listed by Ramsar (http://www.ramsar.org/index_list.htm).

Grand Codroy is one of the most productive of Newfoundland's few estuarine wetland sites. Portions of the intertidal area are heavily vegetated with eelgrass (*Zostera marina*), an important food source for up to 3,000 Canada Geese (*Branta canadensis*) during fall and early winter, and for up to 1,000 American Black Ducks (*Anas rubripes*) in late September. Small concentrations of shorebirds use the intertidal bars and flats in late summer.

On either side of the Grand Codroy River lies shallow brackish wetland with mudflats and sandbars exposed at low tide. The mouth of the estuary is separated from the open ocean (Searston Bay) by a one kilometre long sand spit which is vegetated by dune grass (*Ammophila* sp.). Other notable bird species occurring here include Northern Pintails (*Anas acuta*), Green-winged Teal (*A. crecca*), American Widgeon (*A. americanus*), and Greater Scaup (*Aythya marila*). Piping plover (*Charadrius melodus*) were reported to be nesting on the sandbar at the mouth of the estuary in 1992 but none have been sighted since.

3.8.2.4 Stephenville Crossing (UA 4Rd)

Stephenville Crossing is the most significant North American breeding location of the Black-headed Gull (5 to 15 breeding pairs as of July). Nineteen juveniles were sighted on 13 July 2005 (B. Mactavish, pers. comm.). It was determined in July 2005 that the tidal marsh at Stephenville Crossing is now a nesting location for Willets. Two breeding pairs, one with four downy young, were sighted (B. Mactavish, pers. comm.).

Other significant bird sightings at the Stephenville Crossing tidal marsh in June/July 2005 include the Western Reef Heron (first Canadian and second North American sighting of this African/Middle Eastern bird), the Little Egret (fifth Newfoundland sighting of this European bird) which is rare in North America, and the Bar-tailed Godwit (second Newfoundland sighting of this primarily Eurasian bird) which is rare in Canada and breeds in Alaska (B. Mactavish, pers. comm.).

According to the Natural History Society of Newfoundland and Labrador Inc., 195 bird species are listed for Stephenville Crossing, not all directly associated with the estuarine and marine environment.

3.8.2.4 IBAs

Three coastal sites in the west-southwest Newfoundland have been designated IBAs: (1) Codroy Valley Estuary (NF041) (Unit Area 4Rd), (2) Grand Bay West to Cheeseman Provincial Park (NF038) (Unit Area 4Rd), and (3) NF045 – Gros Morne National Park (Unit Area 4Rb; Parcel 7). These three IBAs on the west-southwest coast of Newfoundland rank low in 'IBA Population Threshold' score compared with other Newfoundland IBAs (see www.ibacanada.com). See Section 3.5.4 for more details.

3.8.3 Gros Morne National Park (UA 4Rb)

Gros Morne National Park was declared a UNESCO World Heritage Site in 1987 (http://whc.unesco.org/). Some of the unique areas within and adjacent to Gros Morne include Bonne Bay, Western Brook Pond and St. Paul's Bay (http://www.grosmorne.ca/). Bonne Bay and the area immediately north of it are considered 'hotspots' for various shorebirds.

3.8.4 Planning Implications for Potentially Sensitive Areas

Operators should be aware of the potentially sensitive areas within the Study Area. The Bid Parcels overlap with only some of the identified sensitive areas (i.e., Cod Spawning Area, the lobster spawning/nursery areas and Gros Morne/Bonne Bay. However, future Parcels out for bids may be located at or near other sensitive areas, particularly those identified for marine-associated birds. Depending on the sensitive area, various mitigations would be employed to minimize impact on the area. These mitigations have been discussed in the relevant sections.

3.8.5 Data Gaps for Potentially Sensitive Areas

As discussed in the previous sections, data gaps relating to both the physical and biological environment are numerous. Later sections of the SEA discuss the knowledge gaps relating to the potential effects of oil and gas exploratory and production activities on the environment. All of these data gaps apply to the potentially sensitive areas.

4.0 Environmental Effects of Exploration and Production Activities

Offshore oil and gas activity has been ongoing at least since the 1940s and therefore most environmental effects are reasonably well known. The SEA has focused on such sources as sound, drilling fluids and cuttings, attraction of animals, discharges, and accidental events.

Important potential interactions have been identified in the following sections. The potential effects of underwater sound (particularly seismic surveying) and non-sound aspects of exploration/production drilling are discussed in detail. Mitigations for the potential effects are also considered.

4.1 Sound

4.1.1 Underwater Acoustics

The audibility or apparent loudness of a sound source is determined by (1) the radiated acoustic power (source level), (2) the propagation efficiency, (3) the ambient sound, and (4) the hearing sensitivity of the subject species at relevant frequencies.

Most analyses of the effects of underwater sound are based on the *Source → Path → Receiver* concept. In this case, the acoustic energy originates with a "source" that generates underwater sound. Sound from the source radiates outward and travels through the water ("path") as pressure waves. Water is an efficient medium through which sounds can travel long distances. The received level decreases with increasing distance from the source. The "receiver" of these sounds is a marine animal. Whether or not the sounds are received depends upon how much propagation loss occurs between the source and the receiver, the hearing abilities of the receiving animal, and the amount of natural ambient or background sound in the sea around the receiver.

Underwater ambient sound, if it is sufficiently strong, may prevent an animal from detecting another sound through a process known as masking. Masking can occur as a result of either natural sounds (e.g., periods of strong winds or heavy rainfall) or anthropogenic sounds (e.g., ship propeller sound). The sea is a naturally noisy environment and even in the absence of anthropogenic sounds, this natural sound can "drown out" or mask weak signals from distant sources.

4.1.1.1 Source Levels

Animals, including humans, hear sounds with a complicated non-linear type of response. The ear responds logarithmically rather than linearly to received sound. Therefore, acousticians use a logarithmic scale for sound intensity and denote the scale in decibels (dB). In underwater acoustics, sound is usually expressed as a Sound Pressure Level (SPL):

$$\text{Sound Pressure Level} = 20 \log (P/P_o),$$

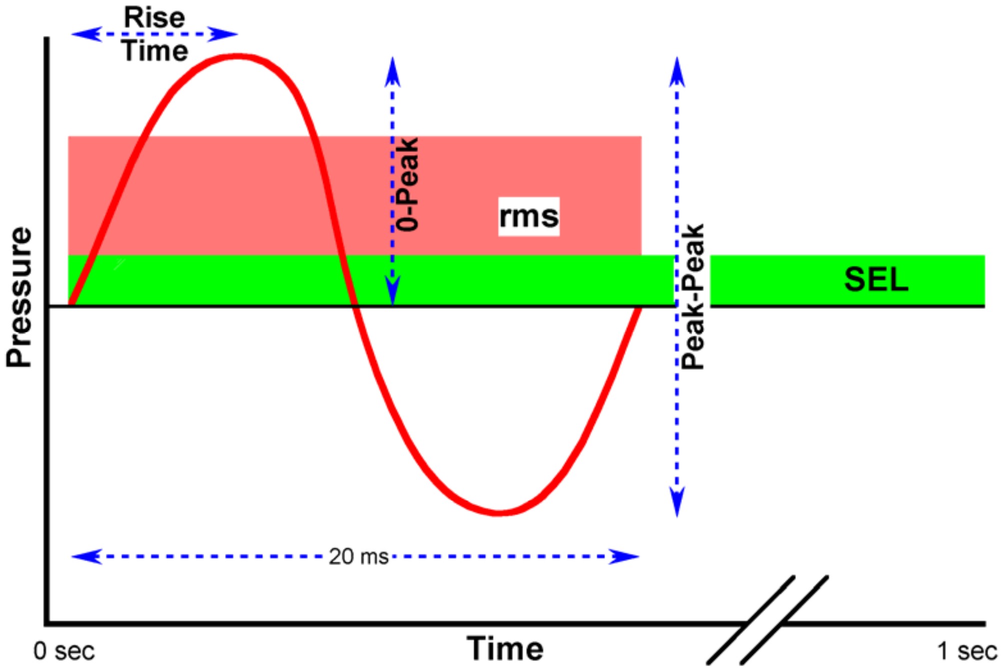
where P_o is a reference level, usually 1 μPa (micro-pascal). The reference level should always be shown as part of the SPL unit. A sound pressure (P) of 1,000 Pascals (Pa) has an SPL of 180 dB re 1 μPa and a pressure of 500 Pa has an SPL of 174 dB. On this scale, a doubling of the sound pressure means an increase of 6 dB. In order to interpret quoted sound pressure levels one must also have some indication of where the measurement applies. SPLs are usually expressed either as a received sound level at the receiver location or the sound level "at the source." A source level is usually expressed as the SPL at one meter (1 m) from the source. If the source is large (i.e., not a point source), as is true for many industrial sources, then the source level of the large source is usually considered to be the received level 1 m from a point source emitting the same total energy as the actual large or "distributed" source.

Sound impulses, such as those often created by the offshore oil and gas industry (e.g., seismic airgun or pile-driving pulses), are composed of a positive pressure pulse followed by a negative pressure pulse. The difference in pressure between the highest positive pressure and the lowest negative pressure is the peak-to-peak pressure (p–p; Figure 4.1). The peak positive pressure, usually called the peak or zero to peak pressure (0–p), is approximately half the peak-to-peak pressure. Thus, the difference between the two is approximately 6 dB. The average pressure over the duration of the pressure pulse can be expressed as the root mean square (rms) or average pressure. The rms pressure is usually about 10 to 12 dB lower than the peak pressure and 16 to 18 dB lower than the peak-to-peak pressure for airgun arrays (Greene 1997). To compare pulses of various types, sound pressure can be integrated over a standard unit of time, usually one second (1 s), to obtain the Sound Exposure Level (SEL). The SEL is typically 20 to 25 dB lower than the zero to peak pressure and 10 to 15 dB lower than the rms pressure.

Sound measurements are often expressed on a broadband basis, meaning the overall level of the sound over a wide range or band of frequencies. When the sound includes components at a variety of frequencies, the level at a specific frequency will be lower than the broadband sound level for some band containing that frequency. Sound signatures from underwater sources consist of measurements of the sound level at each frequency (i.e., a sound spectrum). The sound level can also be measured at specific frequencies and then summed (integrated) over groups or bands of frequencies, such as octaves or third octaves (Richardson et al. 1995).

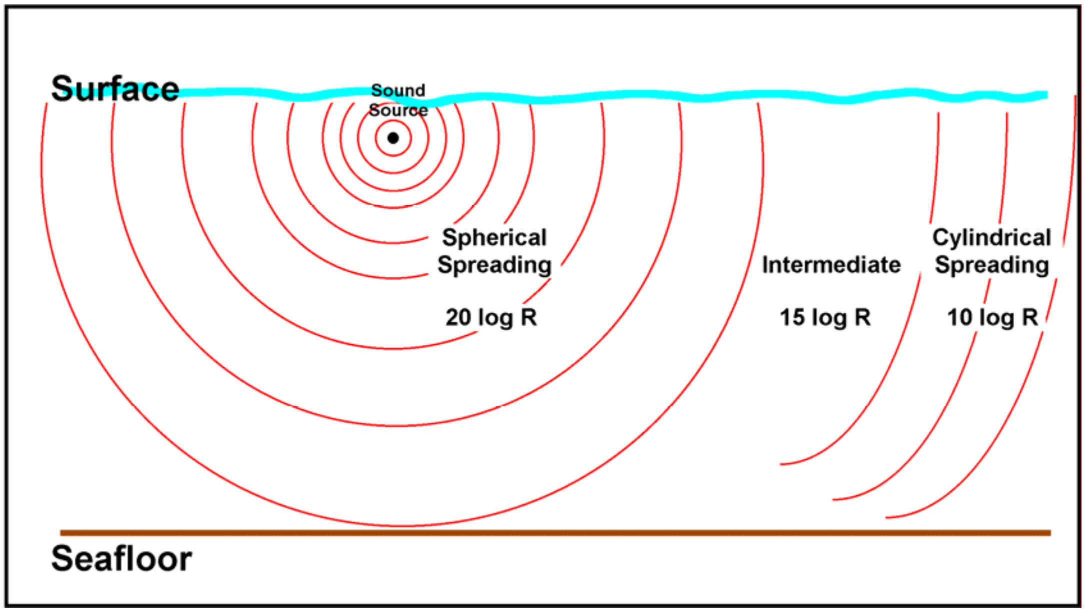
4.1.1.2 Path

The pressure of a sound pulse diminishes with increasing distance from the source. Most of the loss in pressure is due to spreading. The diminishing of pressure with increasing distance from the source is spherical to a distance that is approximately equivalent to the water depth (Figure 4.2). In shallow water at horizontal distances much greater than bottom depth, sound propagates through a channel bounded by the bottom and the surface. For hard-bottom regions spreading is approximately cylindrical.



Source: Lawson et al. (2000).

Figure 4.1. Terminology Used to Describe Sound Pressure Levels in an Acoustic Impulse (horizontal axis not drawn to scale).



Source: Lawson et al. (2000).

Figure 4.2. Schematic Representation of Acoustic Spreading Loss from a Sound Source as a Function of Distance and Interaction with the Seafloor.

A simple model of acoustic spreading would use spherical spreading to distances equal to that of the bottom and then cylindrical spreading. However, for typical shallow water propagation the effect of bottom absorption results in a spreading loss of intermediate between spherical and cylindrical spreading. Which model of spreading to choose is not a simple matter of knowing the water depth, the receiver and source depth, and receiver distance, as other factors such as bottom absorption and sound speed gradients (with depth) are important.

Sound speed varies with water temperature, salinity, and pressure, and thus there can be reflection and/or refraction at water mass discontinuities such as the seasonal thermocline. In deep (and in arctic) water, sound speed often varies with depth in a way that causes sound waves to be channeled within the water mass, resulting in low propagation loss and thus propagation over long distances. Sound propagation characteristics may change as sound travels from a source in shallow water (such as the Mississippi Delta) to a receiver in deeper water (e.g., deepwater Gulf of Mexico). Received levels are generally lower just below the surface than deeper in the water column, especially for the lower frequency components. This is a result of "pressure release at the surface" and interference effects associated with reflections of sound from the surface (Richardson et al. 1995). These and other factors complicate the estimation of transmission loss and necessitate the use of sophisticated models.

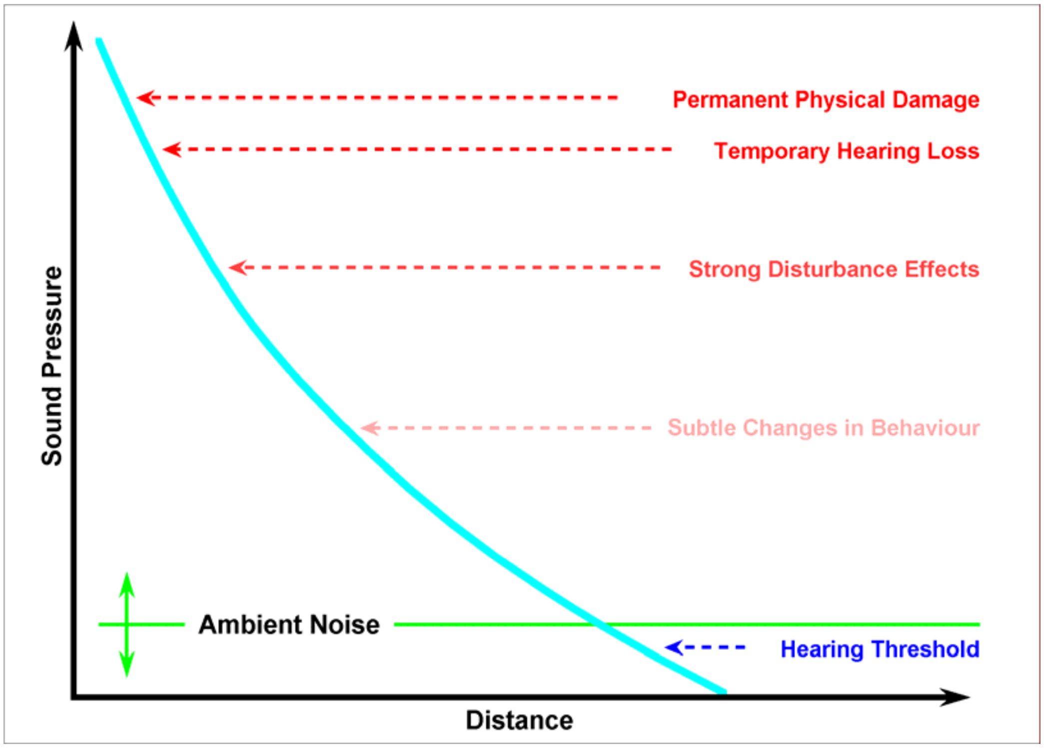
4.1.1.3 Receiver

The receiver component is the most complicated and least understood component of the *Source → Path → Receiver* concept. For a fish, marine mammal or sea turtle to hear an underwater sound, the received level of the sound within a particular bandwidth relevant to the animal's hearing processes must be greater than the absolute hearing threshold of that animal at that frequency (Davis et al. 1998). A sound with a received level below this threshold is not detectable by the animal. The hearing threshold varies with frequency and the frequencies of greatest hearing sensitivity vary among different species. Hearing thresholds, usually presented as audiograms that plot sensitivity versus sound frequency, are known for some species of fish, marine mammals and sea turtles.

A marine animal's ability to detect sounds produced by anthropogenic activities also depends on the amount of natural ambient or background sound in the waters in which it occurs. If background sound is high, then a source of anthropogenic sound will not be detectable as far away as would be possible under quieter conditions. Wind, thermal sound, precipitation, ship traffic and biological sources are all major contributors to ambient sound. However, ambient sound is highly variable on oceanic continental shelves and this probably results in significant variability in the range at which marine animals can detect anthropogenic sounds.

A hierarchy of criteria for establishing zones of influence can be derived based on ambient sound levels, absolute hearing thresholds of the species of interest, slight changes in behavior of the species of interest (including habituation), stronger disturbance effects (e.g., avoidance), temporary hearing impairment, and permanent hearing or other physical damage (Figure 4.3).

Underwater anthropogenic sound above a particular received level often disturbs some marine animals. However, the levels of such sound that elicit specific disturbance or other effects have not been studied in detail for many species. Generally, for man-made sounds, the levels, frequencies and types of sound that cause disturbance vary from species to species, and perhaps with area and season for a given species. Habituation (diminishing sensitivity during repeated exposures) and possibly sensitization (increasing sensitivity during repeated exposures) are additional sources of variability in responsiveness.



Source: Lawson et al. (2000).

Figure 4.3. Schematic Representation of the Zones of Potential Influence of Anthropogenic Sounds on Marine Animals (vertical distances among the different effects are not drawn to scale).

Disturbance is sometimes evident from changes in the behavioral patterns of the species in question. Behavioral changes can be subtle, such as a slight change in respiration rate, or conspicuous, such as movement out of an area to reduce exposure to sound. As compared with continued and undisturbed occupancy of a preferred area, displacement from a preferred area due to sound-related or visual disturbance can be considered potentially negative. However, displacement could be considered beneficial if the animal left the disturbed area before injury occurred but detrimental if it prevented the animal from performing an important life function.

Temporary threshold shift (TTS) is the lowest level of hearing effect. Brief exposures to loud sounds can temporarily increase the hearing threshold of an animal. This effect is temporary and reversible.

4.1.2 In-Air Sound

In-air anthropogenic sound propagation has implications for marine mammals both underwater and, in the case of pinnipeds (e.g., seals), with their ears above the water surface, and in some cases, invertebrates, fish and sea turtles. The source frequencies and intensities of sounds from various oil and gas-related activities interact with the propagation characteristics between the source and receiver to cause variation in the quality and quantity of sound reaching a receiver. Sound traveling from a source in air to a marine animal receiver underwater propagates in four ways: (1) via a direct refracted path; (2) via direct refracted paths that are reflected by the bottom; (3) via a "lateral" (surface-traveling) wave; and (4) via scattering from a rough sea surface (Urick 1972). The types of propagation vary in importance depending on local conditions, water depth, and the depth of receiver. Under calm sea conditions, airborne sound is totally reflected at larger angles and does not enter the water. However, some airborne sound may penetrate water at angles >13° from the vertical when rough seas provide water surfaces at suitable angles (Lubard and Hurdle 1976).

4.1.3 Ambient Sound

The ocean is noisy and there are varying levels of background ambient sound from physical sources such as wind, rain, sleet, ice and icebergs, thermal sources, thunderstorms, surf, tidal currents, earthquakes, volcanoes, and distant shipping. Airborne sources such as aircraft may also add to ambient sound levels. Transient sound from biological sources can also be significant. For example, blue whale calls have been recorded as far distant as 600 km (Stafford et al. 1998). Source levels as high as 232 dB re 1 µPa at 1 m (rms) have been recorded for male sperm whale (*Physeter catodon*) (Møhl et al. 2000). Some invertebrates and fish are also capable of producing sound energy, and peak source levels of 185-188 dB re 1 µPa at 1 m have been recorded for snapping shrimp (Au and Banks 1998).

4.1.4 Offshore Oil and Gas Industrial Sounds

Sounds are generated by exploration, construction, production, and decommissioning phases of offshore oil and gas development.

4.1.4.1 Exploration Activities

Geophysical Surveys

Typical seismic surveys on the East Cost consist of 2-D or 3-D seismic where a sound source array composed of a tuned series of compressed air cylinders and strings of hydrophones (streamers) are towed behind a vessel. The streamers may cover an area of 900 m by 8,000 m behind the vessel. The sound is produced by the rapid release of air and is focused down into the seabed; the characteristics of the returned sound signals allow a map of geological structure below the seabed. Resolution for 3-D surveys is greater than for 2-D. The vertical seismic profile (VSP) is used to assist the drilling process and is similar to 3-D except that is usually conducted with a smaller sound source, and over a much smaller geographic area and much shorter time span (typically one or two days). Shallow geohazard or well site surveys may consist of multi-beam sonar, side scan sonar, bottom sampling and/or video and a small seismic array.

Airguns

Most marine seismic surveys use airguns, singly or strung in array. Airguns create a sound wave through the rapid release of compressed high pressure air (typically 2,000 psi). Airgun arrays produce some of the strongest man-made sounds (typically short sharp pulses about 10 to 15 seconds apart) in the ocean; they produce a range of frequencies but for the most part frequencies emitted are low (below 120 Hz). One of the purposes of the array is to focus the sound energy toward the sea bed and thus sound energy below the array is greater than that measured horizontal to the array. Energy is often, but not always, less near the surface than at deeper depths (e.g., 3 m vs. 9 to 18 m) and less to the bow and stern of the seismic vessel (Richardson et al. 1995). Airgun arrays produce very high peak levels of sound but the energy often attenuates quickly subject to influences of bottom depth and slope, substrate characteristics, water density and other factors.

Water Guns

Water gun arrays may occasionally be used to conduct high resolution surveys. The guns create sound energy by inducing cavitation through shooting water from a cylinder. Compared to airguns of similar size, water guns produce more energy above 200 Hz (Richardson et al. 1995).

Boomers

Boomers are used to profile the seafloor to depths below the floor of up to about 50 m and a resolution of about 0.5 to 1.0 m. Boomers are broadband energy sources operating between about 300 Hz and 10 kHz. Sound is produced by the cavitation resulting from the sudden repelling of electrically charged metal plates. A source level of 212 dB re 1 µPa at 1 m (peak) has been reported (Richardson et al. 1995).

Sparkers

Sparkers penetrate deeper into the substrate than boomers (about 200 m vs. 50 m) but at a lower resolution. Sparkers are broadband energy sources operating between 50 Hz and 4 kHz. Sparkers generate sound energy by vaporizing water using electrical power; the collapsing bubble produce omni-directional sound pulses. A source level of 221 dB re 1 µPa at 1 m peak has been reported (Richardson et al. 1995).

Vibrators

Vibrators are heavy, hydraulically-operated devices that have been used for many years for seismic surveys on land and for a few years on ice. Adaptations are now being developed to allow their use in the marine environment.

Sonars

Bottom-profiling and side-scan sonar surveys conducted by the offshore industry are designed to identify hazards on the seafloor. Echo sounders in use by the oil and gas industry include depth sounders, similar to those used by the fishing industry, which operate at high frequencies (12 or more kHz) and source levels of 180 dB re 1 µPa at 1 m (rms) or more (Richardson et al. 1995). Bottom profilers may operate at 0.4 to 30 kHz (source level of 200-230 dB re 1 µPa at 1 m, rms). Side-scan sonar pingers are mounted on "fish" that are towed behind the survey vessel. Side scans typically operate at 50-500 kHz with source levels around 220-230 dB re 1 µPa at 1 m (rms) (Richardson et al. 1995). Peak power levels for sonars can be quite high but pulse durations are usually very short (0.01 to 0.1 ms for side scan sonar) (Richardson et al. 1995). Military sonars are much more powerful and of longer pulse duration than the side scan sonars used by the oil and gas industry.

Transponders

Transponders may be used by the oil and gas industry to position drill rigs and other equipment although they are probably used less now than previously because of the availability of very precise global positioning systems (GPS). Navigation transponders generally have frequencies about 7 to 60 kHz, source levels of 180-200 dB re 1 µPa at 1 m (rms) and durations of 3 to 40 ms (Richardson et al. 1995).

Explosives

Explosives provided the sound source for seismic surveys until the 1960s when they were replaced by the less environmentally intrusive airgun. Explosives have a much more rapid rise time than airguns and are the only underwater sound sources that have been clearly demonstrated to harm marine animals, particularly fish and marine mammals. At present, the use of survey explosives are very rare and may only be used in highly localized and/or specialized situations. They are discussed further under construction and decommissioning activities.

Vessel Traffic

Vessels are major contributors to background sound in the ocean. Sound levels generated by boats and ships are highly variable but generally related to type, age, size, power, load, and speed. The primary sources of sound are propeller cavitation and singing, and propulsion, pumping, compressor and generating systems, and so forth. A ship breaking ice creates additional sound from the ice but most of the increase in sound level is due to the increased load on the vessel and increased cavitation. It should be noted that vehicles such as snowmobiles and hovercraft traveling on ice may also transmit sound into the water but there are few data on these sources.

Aircraft

The offshore industry uses helicopters for crew changes and support and fixed wing aircraft for various surveys including ice reconnaissance. Propeller-driven aircraft produce sounds audible in water with most energy at frequencies below 500 Hz (Richardson et al. 1995). Sound does not transmit well from air to water and the level and characteristics received depend on the aircraft type, speed, altitude, angle, environmental conditions, and other factors. Most sound is greatest when the aircraft is directly overhead and therefore of short duration. Helicopters are noisier than fixed wing aircraft (Richardson et al. 1995).

Offshore Drilling

Drilling of underwater wells may be conducted from a variety of platforms including land (using directional drilling), artificial islands, concrete or steel caissons, barges, semi-submersibles, drill ships, or bottom-founded jack-ups. In addition, some production platforms, floating or gravity-based also have drilling capabilities. All of these rig types likely emit different sound levels and frequencies with drillships with hull mounted machinery potentially being the noisiest type (Richardson et al. 1995). Data on drilling sound are not extensive given the different types of rigs but in general the strongest tones appear to be at low frequencies.

4.1.4.2 Offshore Construction Activities

Construction activities may include the following:

Dredging. Dredging can produce significant sound in nearshore regions especially in the low frequencies but rapid attenuation occurs in the shallow water and dredging may not be detectable beyond about 25 km (Richardson et al. 1995).

Pile-Driving. Individual pile-driving pulses have been measured in the Arctic during June and July. Underwater mean levels were 157 (flat-weighted peak) and 151 re 1 µPa at 1 m (rms) (Blackwell et al. 2003).

Construction on Ice. Construction activity in Alaskan waters may occur on or through the ice. Underwater and ice vibration sound levels have been recorded for truck traffic, ice road construction, ice cutting, trenching, driving of sheet piles and drilling (Moulton et al. 2003). On-ice activities would not be likely to occur in the SEA Study Area.

Note that these offshore construction activities are not exploration activities, although seismic surveys can be conducted from the ice under certain conditions..

4.1.4.3 Offshore Production Activities

In general, the amount of underwater sound a production platform creates is related to the area of hull or structure that contacts the water. Production systems may be mounted on artificial islands, caissons, barges, semi-submersibles or other floating configurations, concrete gravity-based structures, steel pillar mounted jack-ups, or mounted on the sea floor (subsea). A typical floating, production, storage and offloading platform (FPSO) constructed from a ship's hull is expected to be noisier than a semi-submersible or jack-up. Artificial islands are probably the quietest.

4.1.4.4 Offshore Decommissioning Activities

Decommissioning of offshore infrastructure such as pipelines, caissons, wellheads, conductors and platforms, etc. entails a number of activities that generate sound. The removal of structures in the Gulf of Mexico has become an environmental issue because of the use of explosives and the large number that will have to be decommissioned in the near future. It has been estimated by API that 5,500 structures will have to be removed over the next 35 years (DOC 2002).

Of the various types of sound energy produced by offshore oil and gas activities, explosions are the only source for which damage to marine animals has been conclusively demonstrated. This is of concern for fish which are know to congregate around structures in the Gulf of Mexico, turtles (particularly loggerheads) which may at times use the structures for feeding and resting, and for marine mammals which are potentially sensitive to sound and whose ranks include *endangered* and *threatened* species (e.g., blue whale).

4.1.5 Effects of Industrial Sounds on Marine Animals

Once source levels and propagation loss have been evaluated, the next step is to assess the effects of this sound on the marine animals of interest. This is clearly the most complicated and least understood component of the *Source → Path → Receiver* concept. For example, for a marine mammal to hear an underwater sound, the received level of the sound within a particular bandwidth relevant to the animal's hearing processes must, to a first approximation, be greater than the absolute hearing threshold of that animal at that frequency (Richardson et al. 1995; Davis et al. 1998). A sound whose received level is below this threshold is not detectable by the marine mammal. The hearing threshold varies with frequency and the frequencies of greatest hearing sensitivity vary among the different groups and species of marine mammals.

A marine animal's ability to detect sounds produced by anthropogenic activities also depends on the amount of natural ambient or background sound in the waters in which it is swimming. If background sound is high, then a source of anthropogenic sound will not be detectable as far away as would be possible under quieter conditions. Wind, thermal sound, precipitation, ship traffic and biological sources are all major contributors to ambient sound. However, ambient sound is highly variable on oceanic continental shelves (e.g., Chapman et al. 1998; Desharnais et al. 1999; Swift and Thompson 2000) and this probably results in significant variability in the range at which marine animals can detect anthropogenic sounds.

There are many gaps in the information on hearing capabilities and on the responses of marine animals to sounds that they hear. For example, marine mammals, like other highly intelligent vertebrates, exhibit individual variation in their behavioural patterns and responses to stimuli (e.g., Bonner 1968; Slater 1981; Suryan and Harvey 1999). They do not always respond behaviourally to sounds that are audible, and they do not always respond in the same way to a given received sound level. The received sound levels necessary to elicit different responses (e.g., subtle behavioural change vs. strong avoidance) often differ, and received levels necessary to cause hearing damage or injury to other organs will be higher than those that often elicit behavioural reactions. For these reasons, it is not yet possible to establish specific or unequivocal criteria for determining the zone of influence or zone of effects around a sound source.

A hierarchy of criteria for establishing zones of influence can be derived based on six factors:

1. ambient sound levels,
2. absolute hearing thresholds of the species of interest,
3. slight changes in behaviour of the species of interest (including habituation),
4. stronger disturbance effects (e.g., avoidance),
5. temporary hearing impairment, and
6. permanent hearing or other physical damage.

Based on these criteria, we can define a series of zones of potential sound influence of generally decreasing size. The zone within which the received level from a particular source of anthropogenic sound in at least one part of the frequency spectrum exceeds both the ambient level and the absolute detection threshold for a particular marine animal species (at that frequency) is often large. This is the zone of detection. However, the zones within which there is disturbance or displacement, and especially impairment to the animal, will be much smaller. The maximum possible zone of influence of anthropogenic sound is the distance beyond which its received level falls substantially below the ambient sound level or the hearing threshold in all frequency bands. Once the sound falls substantially below ambient or below the hearing threshold, marine animals will not be able to detect sound from the anthropogenic sound source. Ambient sound levels vary dramatically over time and season and among geographic areas. Thus, the radius of the zone of detection is also highly variable.

It is not realistic to use an ambient sound criterion alone to determine a zone of influence. In some cases, the sound level from an anthropogenic source may diminish below the marine animal's hearing threshold before the sound level reaches ambient levels. Even when this is not the case, detectable but weak anthropogenic sounds usually do not elicit overt behavioural reactions, and probably do not affect marine animals significantly (Richardson et al. 1995). It is necessary to distinguish between a zone of potential influence and a zone of actual effects. The former is a zone within which the marine animal might be aware or react mildly to an anthropogenic sound. The latter is the zone, generally much smaller, within which the received sound level is higher and the animal might be detrimentally affected.

4.1.5.1 Fish and Invertebrates

The various types of potential effects of exposure to seismic on fish and invertebrates can be considered in three categories: (1) pathological, (2) physiological, and (3) behavioural. Pathological effects include lethal and sub-lethal damage to the animals, physiological effects include temporary primary and secondary stress responses, and behavioural effects refer to changes in exhibited behaviours of the fish and invertebrate animals. The three categories should not be considered as independent of each other. They are certainly interrelated in complex ways. For example, it is possible that certain physiological and behavioural changes could potentially lead to the ultimate pathological effect on individual animals (i.e., mortality).

The following sections provide an overview of the information that exists on the effects of seismic on fish and invertebrates. The information is comprised of results from scientific studies of varying degrees of soundness as well as anecdotal information.

Pathological Effects

In water, acute injury or death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay (Hubbs and Rechnitzer 1952 *in* Wardle et al. 2001). Generally, the higher the received pressure and the less time it takes for the pressure to rise and decay, the greater the chance of acute pathological effects. Considering the peak pressure and rise/decay time characteristics of seismic airgun arrays used today, the pathological zone for fish and invertebrates would be expected to be small, i.e., within a few metres of the seismic source. Payne (2004), in his review of available data on the potential effect of seismic surveys on fish eggs, larvae and zooplankton, states that limited data indicate that some fish eggs and larvae may be damaged at a distance of approximately five metres from a typical seismic discharge. However, he adds that it is premature to suggest that five metres is the approximate injury zone for effects on the eggs and larvae of finfish and shellfish, zooplankton, or planktonic life stages in general.

Fish

Matishov (1992) reported that some cod and plaice died within 48 hours of exposure to seismic at two metres from the source. No other details were provided by the author, making this information source questionable. On the other hand, there are numerous examples of no fish mortality effect as a result of exposure to seismic sources (Falk and Lawrence 1973; Holliday et al. 1987; La Bella et al. 1996; Santulli et al. 1999; McCauley et al. 2000a, 2000b; Thomsen 2002; IMG 2002; McCauley et al. 2003; Hassel et al. 2003).

There are examples of damage to fish ear structures from exposure to seismic airguns (McCauley et al. 2000a,b, 2003; Enger 1981) but it should be noted the experimental fish were caged and exposed to high cumulative levels of seismic energy. Atlantic salmon were exposed within 1.5 m of underwater explosions (Sverdrup et al. 1994). Compared to airgun sources, explosive detonations are characterized by higher peak pressures and more rapid rise and decay times, and are considered to have greater potential to damage marine biota. In spite of this, no salmon mortality was observed immediately after exposure or during the seven-day monitoring period following exposure.

Studies have indicated that exposure to intense sound can affect the auditory thresholds of fish. Temporary threshold shift (TTS) can occur in fish under certain conditions, followed by complete recovery within 24 hours. Amoser and Ladich (2003) exposed two hearing specialist fish, the nonvocal goldfish (*Carassius auratus*) and the vocalizing catfish (*Pimelodus pictus*) to intense white sound (158 dB re 1 µPa; unspecified measure type) for periods of 12 and 24 hours and then tested their post-exposure hearing sensitivities using auditory brainstem response (ABR) immediately following exposure as well as at three, seven and 14 days after exposure. Hearing sensitivities were also measured prior to exposure to the intense sound. Both species exhibited loss of hearing sensitivity (maximum of 26 to 32 dB) immediately after exposure, the greatest loss occurring at the most sensitive frequencies. The catfish exhibited the highest maximum loss of hearing sensitivity. While the goldfish hearing sensitivity returned to normal within three days of exposure, the catfish hearing sensitivity took 14 days to return to normal. Smith et al. (2004) found that goldfish had significant threshold shift after only 10 minutes of exposure to white sound (160-170 dB re 1 µPa; unspecified measure type) and that these shifts increased linearly up to approximately 28 dB after 24 hours of exposure to the sound. Threshold shifts did not increase beyond the 24-hour exposure time. After 21 days of exposure to the sound, the goldfish hearing sensitivity required 14 days to recover to normal levels. It should be noted that TTS may seldom (or never) occur in the wild unless fish are prevented from fleeing the irritant.

Some studies have also provided some information on the effects of seismic exposure on fish eggs and larvae (Kostyuchenko 1973; Dalen and Knudsen 1987; Holliday et al. 1987; Matishov 1992; Booman et al. 1996; Dalen et al. 1996). Overall, effects appeared to be minimal and any mortality effect was generally not significantly different from the experimental controls. Generally, any observed larval mortality occurred after exposures within 0.5 to three metres of the airgun source. Matishov (1992) reported some retinal tissue damage in cod larvae exposed at one metre from the airgun source. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae and concluded that mortality rates caused by exposure to seismic are so low compared to the natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

Invertebrates

The pathological impacts of seismic energy on marine invertebrate species have also been investigated. Christian et al. (2004) exposed adult male snow crabs, egg-carrying female snow crabs and fertilized snow crab eggs to the energy from seismic airguns. Neither acute nor chronic (12 weeks after exposure) mortality was observed for the adult male and female crabs. There was a significant difference in development rate noted between the exposed and unexposed fertilized eggs. The egg mass exposed to seismic energy had a higher proportion of less-developed eggs than the unexposed mass. It should be noted that both egg masses came from a single female and any measure of natural variability was unattainable.

In 2001 and 2003, there were two incidents of multiple strandings of the giant squid (*Architeuthis dux*) on the north coast of Spain. The strandings occurred at about the same time as geophysical seismic surveys in the Bay of Biscay. A total of nine giant squids, either stranded or moribund surface-floating, were collected at these times. Guerra et al. (2004) presented evidence of acute tissue damage in the stranded and surface-floating giant squids after conducting necropsies on seven (six females and one male) of the relatively fresh nine specimens. The authors speculated that one female with extensive tissue damage was affected by the impact of acoustic waves. However, little is known about the physical impact of marine acoustic technology on cephalopods and unfortunately, the authors did not describe the seismic sources, locations, and durations of the Bay of Biscay surveys so no valid conclusions can be drawn from this study.

McCauley et al. (2000a) reported behavioural effects of exposure of caged cephalopods (50 squid and two cuttlefish) to sound from a single 20 in^3 airgun but no physical effects, other than the fact that no acute or chronic mortality was observed in the squid after exposure to the airgun sound. The cephalopods were exposed to both stationary and mobile sound sources. The two-run total exposure times of the three trials ranged from 69 to 119 minutes at a firing rate of once every 10 to 15 seconds. Maximum zero-to-peak exposure levels were greater than 200 dB re 1 µPa. Statocysts were removed and preserved but at the time of the study report publication, results of the statocyst analyses were not available. Some of the squid fired their ink sacs apparently in response to the first shot of one of the trials and then moved quickly away from the airgun. However, the ink sac firing was not observed for similar or greater received levels if the signal was ramped up. In addition to the above-described startle responses, some squid also moved towards the water surface as the airgun approached. Sound shadows, areas of lower sound pressure levels, are known to occur there (Richardson et al. 1995). An increase in swimming speed was also exhibited by some of the squid. No squid or cuttlefish mortalities were reported as a result of these exposures.

Pearson et al. (1994) exposed Stage II larvae of the Dungeness crab to single discharges from a seven-airgun seismic array and compared their mortality and development rates with those of unexposed larvae. For immediate and long-term survival and time to molt, this field experiment did not reveal any statistically significant differences between the exposed and unexposed larvae, even those exposed within one metre of the seismic source.

Bivalves of the Adriatic Sea were also exposed to seismic energy and subsequently assessed (LaBella et al. 1996). No effects of the exposure were noted.

Summary of Pathological Effects

To date, there have not been any well-documented cases of acute post-larval fish or invertebrate mortality as a result of exposure to seismic sound under normal seismic operating conditions. Sub-lethal injury or damage has been observed but generally as a result of exposure to very high received levels of sound, higher than would be expected in the field under normal seismic operating conditions. Acute mortality of eggs and larvae have been demonstrated in experimental exposures but only when the eggs and larvae were exposed very close to the seismic sources and the received pressure levels were presumably very high. Limited information has not indicated any chronic mortality as a direct result of exposure to seismic.

Physiological Effects

Biochemical responses by marine fish and invertebrates to acoustic stress have also been studied, albeit in a limited way. Studying the variations in the biochemical parameters influenced by acoustic stress might give some indication of the extent of the stress and perhaps forecast eventual detrimental effects. Such stress could potentially affect animal populations by reducing reproductive capacity and adult abundance.

McCauley et al. (2000a,b) used various physiological measures to study the physiological effects of exposure to seismic energy on various fish species, squid and cuttlefish. No significant physiological stress increases attributable to seismic were detected. Sverdrup et al. (1994) found that Atlantic salmon subjected to acoustic stress released primary stress hormones, adrenaline and cortisol as a biochemical response although there were different patterns of delayed increases for the different indicators. Caged European sea bass were exposed to seismic energy and numerous biochemical responses were indicated. All returned to their normal physiological levels within 72 hours of exposure.

Stress indicators in the haemolymph of adult male snow crabs were monitored after exposure of the animals to seismic energy (Christian et al. 2004). No significant differences between exposed and unexposed animals in terms of the stress indicators (e.g., proteins, enzymes, cell type count) were indicated.

In December 2003, egg-bearing female snow crabs (*Chionoecetes opilio*) off Cape Breton, Nova Scotia were caught, caged and subsequently exposed to seismic energy released during a commercial seismic survey. Both acute and chronic effects on the adult female crabs, embryos and larvae hatched from the eggs were studied in this DFO study. According to DFO (DFO 2004i), there were three definitive observations from the study.

1. The seismic survey did not cause any acute or chronic (five months) mortality of the crab, or any changes to the feeding activity of the treated crabs being held in the laboratory.
2. Neither the survival of embryos being carried by the female crabs during exposure nor the locomotion of the larvae after hatch appeared to be affected.
3. There was acute soiling of gills, antennules and statocysts of the crabs at the exposure site but after five months, all structures had returned to their clean state.

The third observation regarding the soiling of crab structures cannot be attributed to exposure to seismic energy.

Lagardère (1982) presented results from laboratory experimentation that suggested that behavioural and physiological reactions of brown shrimp (*Crangon crangon*) were modified by exposure to increased background sound in tanks. Shrimp were kept in two environments for about three months, one noisier than the other. The mean difference in sound level in the 80 to 400 Hz range was 30 to 40 dB (unspecified measure type). There was a significant difference in growth rate and reproduction rate between the two groups. Those shrimp in the noisier environment had lower rates of each compared to those in the quieter environment. Increased sound levels also appeared to increase aggression (cannibalism) and mortality rate, and decrease food uptake. It is unclear how tank experiments with sound relate to conditions in the wild.

Summary of Physiological Effects

Primary and secondary stress responses of fish after exposure to seismic energy all appear to be temporary in any studies done to date. The times necessary for these biochemical changes to return to normal are variable depending on numerous aspects of the biology of the species and of the sound stimulus.

Behavioural Effects

Because of the relative lack of indication of serious pathological and physiological effects of seismic energy on marine fish and invertebrates, most concern now centers on the possible effects of exposure to seismic on the distribution, migration patterns and catchability of fish (i.e., behavioural effects).

Fish and Invertebrate Acoustic Detection and Production

Hearing in fishes was first demonstrated in the early 1900s through studies involving cyprinids (Parker 1903 and Bigelow 1904 *in* Kenyon et al. 1998). Since that time, numerous methods have been used to test auditory sensitivity in fishes, resulting in audiograms of over 50 species. These data reveal great diversity in fish hearing ability, mostly due to various peripheral modes of coupling the ear to some internal structures, including the swim bladder. However, the general auditory capabilities of less than 0.2% of fish species are known so far.

For many years, studies of fish hearing have reported that the hearing bandwidth typically extends from below 100 Hz to approximately 1 kHz in fishes without specializations for sound detection, and up to about 7 kHz in fish with specializations that enhance bandwidth and sensitivity. Recently there have been suggestions that certain fishes, including many clupeiforms (i.e., herring, shads, anchovies, etc.) may be capable of detecting ultrasonic signals with frequencies as high as 126 kHz (Dunning et al. 1992; Nestler et al. 1992). Studies on Atlantic cod, a non-clupeiform fish, suggested that this species could detect ultrasound at almost 40 kHz (Astrup and Møhl 1993).

Mann et al. (2001) showed that the clupeiform fish, the American shad, is capable of detecting sounds up to 180 kHz. They also demonstrated that the gulf menhaden is also able to detect ultrasound while other species such as the bay anchovy, scaled sardine, and Spanish sardine only detect sounds with frequencies up to about 4 kHz. Nedwell et al. (2004) have recently compiled a summary of available fish audiograms.

Among fishes, at least two major pathways for sound to get to the ear have been identified. The first and most primitive is the conduction of sound directly from the water to tissue and bone. The fish’s body takes up the sound’s acoustic particle motion and subsequent hair cell stimulation occurs due to the difference in inertia between the hair cells and their overlying otoliths. The second sound pathway to the ears is indirect. The swim bladder or other gas bubble near the ears expands and contracts in volume in response to sound pressure fluctuations, and this motion is then transmitted to the otoliths. While present in most bony fishes, the swim bladder is absent or reduced in many other fish species. Only some species of fish with a swim bladder appear to be sound pressure-sensitive via this indirect pathway to the ears and are called ‘hearing specialists’. These hearing specialists have some sort of connection with the inner ear, either via bony structures known as Weberian ossicles, extensions of the swim bladder, or simply a swim bladder more proximate to the inner ear. Hearing specialists’ sound pressure sensitivity is high and their upper frequency range of detection is extended above those species that hear only by the previously described direct pathway. The species having only the direct pathway are known as ‘hearing generalists’ (Fay and Popper 1999). Typically, most fish detect sounds of frequencies up to 2,000 Hz but, as indicated, others have detection ranges that extend to much higher frequencies.

Fish also possess lateral lines that detect water movements. The essential stimulus for the lateral line consists of differential water movement between the body surface and the surrounding water. The lateral line is typically used in concert with other sensory information, including hearing (Sand 1981; Coombs and Montgomery 1999).

Elasmobranchs, including sharks and skates, lack any known pressure-to-displacement transducers such as swim bladders. Therefore, they presumably must rely on the displacement sensitivity of their mechanoreceptive cells. Unlike acoustic pressure, the kinetic stimulus is inherently directional but its magnitude rapidly decreases relative to the pressure component as it propagates outward from the sound source in the near field. It is believed that elasmobranches are most sensitive to low frequencies (i.e., <1 kHz) (Corwin 1981).

Because they lack air filled cavities and are often the same density as water, invertebrates detect underwater acoustics differently than fish. Rather than being pressure sensitive, invertebrates appear to be most sensitive to particle displacement. However, their sensitivity to particle displacement and hydrodynamic stimulation seem poor compared to fish. Decapods, for example, have an extensive array of hair-like receptors both within and upon the body surface that could potentially respond to water- or substrate-borne displacements. They are also equipped with an abundance of proprioceptive organs that could serve secondarily to perceive vibrations. Crustaceans appear to be most sensitive to sounds of low frequency (i.e., <1,000 Hz) (Budelmann 1992; Popper et al. 2001).

Many fish and invertebrates are also capable of sound production. It is believed that these sounds are used for communication in a wide range of behavioural and environmental contexts. The behaviours most often associated with acoustic communication include territorial behaviour, mate finding, courtship and aggression. Sound production provides a means of long distance communication as well as communication when underwater visibility is poor (Zelick et al. 1999).

Behavioural Effects of Seismic

Studies investigating the possible effects of seismic on fish and invertebrate behaviour have been conducted on both uncaged and caged animals. Studies looking at change in catch rate regard potential effects of seismic on larger spatial and temporal scales than are typical for close range studies that often involving caged animals (Hirst and Rodhouse 2000). Hassel et al. (2003) investigated the behavioural effects of seismic on caged sand lance in Norwegian waters. The sand lance did exhibit responses to the seismic, including an increase in swimming rate, an upwards vertical shift in distribution and startle responses. Normal behaviours were resumed shortly after cessation of the seismic. None of the observed sand lance reacted to the seismic by burying into the sand.

Engås et al. (1996) assessed the effects of seismic surveying on cod and haddock behaviour using acoustic mapping and commercial fishing techniques. Results indicated that fish abundance decreased at the seismic survey area and the decline in abundance and catch rate lessened as one moved away from the survey area. Engås et al. (1996) found that fish abundance and catch rates had not returned to pre-shooting levels five days after cessation of shooting. Other studies that used fishing catch rate as an indicator of behavioural shift also showed reduced catch rates, particularly in the immediate vicinity of the seismic survey (Løkkeborg 1991; Skalski et al. 1992). Anecdotal information from Newfoundland, Canada indicated that snow crab catch rates showed a significant reduction immediately following a pass by a seismic survey vessel. Other anecdotal information from Newfoundland, Canada indicated that a school of shrimp showing on a fishing vessel sounder shifted downwards and away from a nearby seismic source. Effects were temporary in both the snow crab and shrimp anecdotes.

Christian et al. (2004) conducted an experimental commercial fishery for snow crab before and after the area was exposed to seismic shooting. No drastic decrease in catch rate was observed after seismic shooting commenced. It should be noted that there were study limitations associated with the experimental fishery conducted by Christian et al. (2004). In addition to the high variability inherent in catchability studies, poor weather conditions resulted in considerable variability in set durations and a relatively low number of sets. Another behavioural investigation by Christian et al. (2004) involved caging snow crabs, positioning the cage 50 m below a seven-gun array, and observing the immediate responses of the crabs to the onset of seismic shooting by remote underwater camera. No obvious startle behaviours were observed.

Marine fish inhabiting an inshore reef off the coast of Scotland were monitored by telemetry and remote camera before, during and after airgun firing (Wardle et al. 2001). Although some startle responses were observed, the seismic gun firing had little overall effect on the day-to-day behaviour of the resident fish.

Studies on the effects of sound on fish behaviour have also been conducted using caged or confined fish. Such experiments were conducted in Australia using fish, squid and cuttlefish as subjects (McCauley et al. (2000a,b). Common observations of fish behaviour included startle response, faster swimming, movement to the part of the cage furthest from the seismic source (i.e., avoidance), and eventual habituation. Fish behaviour appeared to return pre-seismic state 15 to 30 minutes after cessation of seismic. Squid exhibited strong startle responses to the onset of proximate airgun firing by releasing ink and/or jetting away from the source. The squid consistently made use of the ‘sound shadow’ at surface where the sound intensity was less than at 3-m depth. These Australian experiments provided more evidence that fish and invertebrate behaviour will be modified at some received sound level. Again, these behavioural changes seem to be temporary.

The influence of seismic activity on pelagic fish (i.e., herring, blue whiting and mesopelagic species) was investigated using acoustic mapping off western Norway in 1999 (Slotte et al. 2004). The distribution and abundance of pelagic fish within the survey area and in surrounding waters out to 50 km from the survey area were mapped three times and compared, and the abundance was recorded immediately prior to and after shooting along some of the survey transects. Results suggested that the acoustic abundance of pelagic fish was higher outside the survey area than inside. At the same time, the abundance of pelagic fish prior to shooting was not significantly different than abundance immediately after shooting along some of the survey transects, indicating that no significant short-term horizontal movement occurred. However, there were indications that some of the pelagics might have moved downwards in response to the seismic shooting.

Other species involved in studies that have indicated fish behavioural responses to underwater sound include rockfish (Pearson et al. 1992), Pacific herring (Schwarz and Greer 1984), and Atlantic herring (Blaxter et al. 1981). Again, the responses observed in these studies were relatively temporary. However, what is not known is the effect of exposure to seismic on fish and invertebrate behaviours that are associated with reproduction and migration.

Using telemetry techniques, Shin et al. (2003) investigated changes in the swimming behaviour of caged Israeli carp (*Cyprinus carpio*) in response to underwater explosions. The received sound levels ranged from 140 to 156 dB re 1 µPa (unspecified type of measurement). Immediately after an explosion, the fish swimming area was reduced. After one hour, the area had returned to pre-explosion size. Other behavioural reactions included downward movement and increased swimming speed but these behavioural shifts also returned to normal shortly after cessation of explosions. Considering that underwater explosions are considered worst-case scenarios compared to airgun discharges and that these fish exhibited minor short-term behavioural changes in response to underwater explosions, reactions of these fish to airgun discharges should be minimal.

Behavioural Effects of Ultrasound

As mentioned in a previous section, a number of clupeid species can detect and respond to ultrasonic sounds of frequencies up to 180 kHz. Behavioural studies of responses of American shad (*Alosa sapidissima*) to ultrasound demonstrated that these fish show a graded series of responses depending on the received SPL, and to a lesser degree, the frequency of the source sound (Plachta and Popper 2002 *in* Popper et al. 2004). The American shad exhibited negligible response to sounds below 160 dB re 1 µPa at any frequency. Received SPLs of 175 dB re 1 µPa at 30 to 120 kHz with stimuli of at least one second duration, the shad showed mild reactions to the onset of the sound. Between 175 and 184 dB re 1 µPa at stimulus frequencies ranging between 70 and 110 kHz, the fish showed rapid and directional responses directly away from the sound source. At received SPLs above 185 dB re 1 µPa, the shad exhibited very rapid and random patterns of behaviours that resulted in some animals attempting to jump from the experimental tank. A field study by Wilson and Dill (2002) showed that Pacific herring (*Clupea pallasi*) reacted in a manner similar to that of the shad in the tank experiment. There is speculation that these responses to ultrasound evolved to help these fish, particularly shallow-water species, detect and avoid echolating cetacean predators.

Summary of Behavioural Effects

The full determination of behavioural effects of exposure to seismic is difficult. There have been well-documented observations of fish and invertebrates exhibiting behaviours that appeared to be in response to exposure to seismic (i.e., startle response, change in swimming direction and speed, change in vertical distribution), but the ultimate importance of these behaviours is unclear. Some studies indicate that such behavioural changes are very temporary while others imply that marine animals might not resume pre-seismic behaviours/distributions for a number of days. As is the case with pathological and physiological effects of seismic on fish and invertebrates, available information is relatively scant and often contradictory.

There is also evidence that certain clupeids show a graded series of responses to exposure to ultrasound. The strongest responses involve rapid movement away from the sound source.

4.1.5.2 Commercial Fisheries

The chief sources for potential impacts of underwater sound, particularly seismic sound, on the commercial fisheries are related to (1) changes in catch rates resulting from sound-induced behavioural changes (scaring) of fish, (2) as a result of effects on stock assessments and DFO research, which is used, among other purposes, for setting fishing quotas or exploring new fisheries. The first issues were raised during SEA consultations in July 2005. Impacts related to physical effects on fish and invertebrates were discussed in the preceding section.

As discussed in Section 3.4.4, commercial fisheries are prosecuted throughout the Study Area. Fisheries industry representatives have registered concerns that seismic survey sound sources may scare finfish from their fishing locations, or discourage benthic species (such as snow crab) from entering fishing gear. Indeed, the likelihood that finfish will move away to a comfortable distance as the array approaches is considered a factor that helps prevent physical impacts on these species.

The discussion of the behavioural effects on fish and invertebrates in Section 4.1.5.1 presents the results of studies on the effects of seismic noise on catch rates. While most - though not all - of these studies report some decrease in catch rates near seismic arrays, there is less agreement on the duration and geographical extent of the effect, ranging from a quick return to several days, and from very localized effects to decreased catch rates as far as 15-km to 20-km away.

Depending on the juxtaposition of the survey sound source, the fish being harvested, and the fishing gear, the impact on fishing success could be either negative or positive. The effect would be positive if, for instance, the fish were driven away from the sound source and towards fishing gear (e.g., fixed gillnets). Snow crab, being sedentary benthic species, are not likely to disperse and catch rates are not expected to be affected.

Potential impacts on fishing catch rate will be mitigated by avoiding heavily fished areas when these fisheries are active to the greatest extent possible.

There is also the potential for interaction between sound and DFO research surveys in the area. The standard mitigative measure for this is coordination between the seismic survey operators and DFO. DFO recommends a seven to 10 day temporal buffer and a 30 to 40 km spatial buffer between the seismic surveys and DFO surveys in order to reduce the potential for gear conflict and disruption of fish distribution patterns. It will be necessary for operators to develop mitigative protocols in collaboration with DFO prior to the commencement of seismic operations.

4.1.5.3 Marine-associated Birds

There are few data on the effects of underwater sound on birds. A study on the effects of underwater seismic surveys on moulting Long-tailed Ducks in the Beaufort Sea showed little effect on the movement or diving behaviour (Lacroix et al. 2003). However, the study did not monitor the physical effects on the ducks. The authors suggested caution in interpretation of the data because they were limited in their ability to detect subtle disturbance effects and recommended studies on other species to fully understand the potential effects of seismic testing.

Most species of seabirds that are expected to occur in the Study Area feed at the surface or at less than one metre below the surface of the ocean. This includes *Procellariidae* (Northern Fulmar, Greater Shearwater, Sooty Shearwater and Manx Shearwater), *Hydrobatidae* (Wilson's Storm-Petrel and Leach's Storm-Petrel), *Phalaropodinae* (Red Phalarope and Red-necked Phalarope), *Laridae* (Great Skua, Pomarine Jaeger, Parasitic Jaeger, Long-tailed Jaeger, Herring Gull, Iceland Gull, Glaucous Gull, Great Black-backed Gull, Ivory Gull, Black-legged Kittiwake and Arctic Tern). Northern Gannet plunge dive to a depth of 10 metres. These species are under the surface for a few seconds during each dive so would have minimal opportunity to receive underwater sound.

There is only one group of seabirds occurring regularly in the Study Area that require considerable time under water to secure food. They are the *Alcidae* (Dovekie, Common Murre, Thick-billed Murre, Razorbill and Atlantic Puffin). From a resting position on the water they dive under the surface in search of small fish and invertebrates. Alcids use their wings to propel their bodies rapidly through the water. All are capable of reaching great depths and spending considerable time under water (Gaston and Jones 1998). An average duration of dive times for the five species of *Alcidae* is 25-40 seconds reaching an average depth of 20-60 m, but murres are capable of diving to 120 m and have been recorded underwater for up to 202 seconds (Gaston and Jones 1998).

The sound created by airguns is focused downward below the surface of the water. Above the water the sound is reduced to a muffled shot that should have little or no effect on birds that have their heads above water or are in flight. It is possible birds on the water at close range would be startled by the sound, however, the presence of the ship and associated gear dragging in the water should have already warned the bird of unnatural visual and auditory stimuli.

Only the *Alcidae* have some potential to be exposed to the sounds produced by the seismic and geohazard surveys. It is unknown what, if any, effects the high frequency sounds of the boomer, echo scanner and side scan sonar or the low frequency sound of the array would have on seabirds.

The effects of underwater sound on *Alcidae* are not well known but sound is probably not important to *Alcidae* in securing food. On the other hand, all six species are quite vocal at breeding sites indicating auditory capabilities are important in that part of their life cycle. The 'laughing call' of the Thick-billed Murre is shown to cover a frequency range of 1.0-4.0 khz (Gaston and Jones 1998).

4.1.5.4 Marine Mammals

Marine mammals rely heavily on the use of underwater sounds to communicate and gain information about their environment. The reactions of marine mammals to sound can be variable and depend on the species involved and the activity of the animal at the time of exposure to sound. Because underwater sound sometimes propagates for long distances, the radius of audibility can be large for a strong sound. However, marine mammals usually do not respond overtly to audible, but weak, man-made sounds (Richardson et al. 1995). Thus, the zone of "responsiveness" is usually much smaller than the zone of audibility. Potential effects of sound on marine mammals include masking, disturbance (behavioural), hearing impairment (temporary threshold shift [TTS] and permanent threshold shift [PTS]), and non-auditory physiological effects.

Background

Masking

Masking is the obscuring of sounds of interest by other sounds, often at similar frequencies. Marine mammals are highly dependent on sound, and their ability to recognize sound signals amid sound is important in communication, predator and prey detection, and, in the case of toothed whales, echolocation.

Even in the absence of man-made sounds, the sea is usually noisy. Background ambient sound often interferes with or masks the ability of an animal to detect a sound signal even when that signal is above its absolute hearing threshold. Natural ambient sound includes contributions from wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal sound resulting from molecular agitation (see Chapter 5 of Richardson et al. 1995). Background sound can also include sounds from distant human activities such as shipping and oil exploration and production. Masking of natural sounds can result when human activities produce high levels of background sound. Conversely, if the background level of underwater sound is high (e.g., on a day with strong wind and high waves), an anthropogenic sound source will not be detectable as far away as would be possible under quieter conditions, and will itself be masked. Ambient sound is highly variable on continental shelves (e.g., Thompson 1965; Myrberg 1978; Chapman et al. 1998; Desharnais et al. 1999). This inevitably results in a high degree of variability in the range at which marine mammals can detect anthropogenic sounds.

Although masking is a natural phenomenon to which marine mammals must be adapted, introduction of strong sounds into the sea at frequencies important to marine mammals will inevitably increase the severity and the frequency of occurrence of masking. For example, if a baleen whale is exposed to continuous low-frequency sound from an industrial source, this will reduce the size of the area around that whale within which it will be able to hear the calls of another whale. In general, little is known about the importance to marine mammals of detecting sounds from conspecifics, predators, prey, or other natural sources. In the absence of much information about the importance of detecting these natural sounds, it is not possible to predict the impacts if mammals are unable to hear these sounds as often, or from as far away, because of masking by industrial sound (Richardson et al. 1995). In general, masking effects are expected to be less severe when sounds are transient than when they are continuous.

Although some degree of masking is inevitable when high levels of man-made broadband sounds are introduced into the sea, marine mammals have evolved systems and behaviour that function to reduce the impacts of masking. Structured signals such as echolocation click sequences of small toothed whales may be readily detected even in the presence of strong background sound because their frequency content and temporal features usually differ strongly from those of the background sound (Au and

Moore 1988; 1990). It is primarily the components of background sound that are similar in frequency to the sound signal in question that determine the degree of masking of that signal. Low-frequency industrial sound has little or no masking effect on high-frequency echolocation sounds. Redundancy and context can also facilitate detection of weak signals. These phenomena may help marine mammals detect weak sounds in the presence of natural or man-made sound.

Most masking studies in marine mammals present the test signal and the masking sound from the same direction. The sound localisation abilities of marine mammals suggest that, if signal and sound come from different directions, masking would not be as severe as the usual types of masking studies might suggest (Richardson et al. 1995). The dominant background sound may be highly directional if it comes from a particular anthropogenic source such as a ship or industrial site. Directional hearing may significantly reduce the masking effects of these sounds by improving the effective signal-to-sound ratio. In the cases of high-frequency hearing by the bottlenose dolphin, beluga whale, and killer whale, empirical evidence confirms that masking depends strongly on the relative directions of arrival of sound signals and the masking sound (Penner et al. 1986; Dubrovskiy 1990; Bain et al. 1993; Bain and Dahlheim 1994).

Toothed whales, and probably other marine mammals as well, have additional capabilities besides directional hearing that can facilitate detection of sounds in the presence of background sound. There is evidence that some toothed whales can shift the dominant frequencies of their echolocation signals from a frequency range with much ambient sound toward frequencies with less sound (Au et al. 1974, 1985; Moore and Pawloski 1990; Thomas and Turl 1990; Romanenko and Kitain 1992; Lesage et al. 1999). A few marine mammal species are known to increase the source levels of their calls in the presence of elevated sound levels (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999).

These data demonstrating adaptations for reduced masking pertain mainly to the very high-frequency echolocation signals of toothed whales. There is less information about the existence of corresponding mechanisms at moderate or low frequencies, or in other types of marine mammals. For example, Zaitseva et al. (1980) found that, for the bottlenose dolphin, the angular separation between a sound source and a masking sound source had little effect on the degree of masking when the sound frequency was 18 kHz, in contrast to the pronounced effect at higher frequencies. Directional hearing has been demonstrated at frequencies as low as 0.5-2 kHz in several marine mammals (including killer whales) (see Section 8.4 in Richardson et al. 1995). This ability may be useful in reducing masking at these frequencies.

In summary, high levels of sound generated by anthropogenic activities may act to mask the detection of weaker biologically important sounds by some marine mammals. This masking may be more prominent for lower frequencies. For higher frequencies, such as used in echolocation by toothed whales, several mechanisms are available that may allow them to reduce the effects of such masking.

Disturbance

Disturbance includes a variety of effects, such as subtle changes in behaviour, more conspicuous dramatic changes in activities, and displacement. Disturbance is one of the main concerns of the potential impacts of man-made sound on marine mammals. For many species and situations, there is no detailed information about reactions to sound. Behavioural reactions of marine mammals to sound are difficult to predict. Marine mammal reactions to sound are dependent on numerous factors including species, state of maturity, experience, current activity, reproductive state, time of day, and weather state. If a marine mammal does react to an underwater sound by changing its behaviour or moving a small distance, the impacts of the change may not be important to the individual, the stock, or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be important.

Hearing Impairment

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. The minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely detectable temporary hearing loss or TTS. The level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. Current U.S. NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 µPa (rms), respectively (NMFS 2000). Given a seismic source level of 234 dB re 1 μPa_{rms}, and presuming spherical spreading of sound, received sound pressure levels of 180 and 190 dB re 1 μPa_{rms}, would occur at approximate distances of 512 and 170 m, respectively, from the sound source.

Temporary Threshold Shift

TTS is the mildest form of hearing impairment. It is the process whereby exposure to a strong sound results in a non-permanent elevation in hearing sensitivity (Kryter 1985). TTS can last from minutes or hours to days. The magnitude of the TTS depends on the level and duration of sound exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS level, hearing sensitivity recovers rapidly after exposure to the sound ends. TTS commonly occurs in mammals, including humans.

Only a few data on sound levels and durations necessary to elicit mild TTSs have been obtained for marine mammals, and all of these data are quite recent. TTS studies in humans and terrestrial mammals provide information helpful in understanding general principles of TTS, but it is unclear to what extent these data can be extrapolated to marine mammals.

Permanent Threshold Shift

There are no data on sound levels that might induce permanent hearing impairment in marine mammals. In theory, physical damage to a marine mammal's hearing apparatus could occur immediately if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. Also, very prolonged exposure to a sound strong enough to elicit a TTS, or shorter-term exposure to sound levels well above the TTS level, could cause hearing injury. Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

Richardson et al. (1995) hypothesized that permanent hearing impairment caused by prolonged exposure to continuous man-made sound is not likely to occur in marine mammals for sounds with source levels up to ~200 dB re 1 μPa-m.

Single or occasional occurrences of mild TTS do not cause permanent auditory damage in humans or other terrestrial mammals, and presumably do not do so in marine mammals. Sound impulse duration, peak amplitude, and rise time are the main factors thought to determine the onset and extent of a PTS. Based on existing data, Ketten (1995) noted that the criteria for differentiating the sound pressure levels that result in a PTS (or TTS) are location and species specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

For sound exposures at or somewhat above the TTS level, hearing sensitivity recovers rapidly after exposure to the sound ends. At least in terrestrial mammals, the received sound level from a single sound exposure must be far above the TTS level for there to be any risk of PTS (Kryter 1985, 1994; Richardson et al. 1995). Relationships between TTS and PTS levels have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals.

Non-Auditory Physiological Effects

Non-auditory physiological effects may also occur in marine mammals exposed to strong underwater sound. Possible types of non-auditory physiological effects or injuries that, in theory, might occur, include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strongly pulsed sounds, particularly at higher frequencies.

Seismic Surveying

Masking

Masking effects of seismic survey sound on marine mammal calls and other natural sounds are believed to be limited. Some whales are known to continue calling in the presence of seismic pulses, which are typically 20 ms in duration and occur every 11 s. Their calls can be heard between seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene and McLennan 2000). Although there was one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), more recent studies have reported that sperm whales continued calling in the presence of seismic pulses (Madsen et al. 2002a; Jochens and Biggs 2003). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses and the fact that sounds important to them are predominantly at much higher frequencies than airgun sounds. Most of the energy in the sound pulses emitted by airgun arrays is at low frequencies, with the strongest spectrum levels below 200 Hz, and considerably lower spectrum levels above 1,000 Hz. These frequencies are mainly used by baleen whales, but not by toothed whales or true seals. Furthermore, the discontinuous nature of seismic pulses makes significant masking effects unlikely even for baleen whales.

Disturbance

There have been studies of the behavioural responses of several types of marine mammals to airgun discharges. Detailed studies have been done on humpback whales, grey whales (*Eschrichtius robustus*), bowhead whales (*Balaena mysticetus*), sperm whales, and ringed seals (*Pusa hispida*). Data from less intensive studies are available for some other species of baleen and small toothed whales.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales have often been reported as showing no overt reactions to airgun pulses at distances beyond a few kilometres. However, recent studies of humpback and bowhead whales indicate that reactions, including avoidance, sometimes occur at greater distances from the seismic source than previously documented. Avoidance distances often exceed the distances at which boat-based observers can see whales.

Studies of humpback whales have determined that received levels of pulses in the 160-170 dB re 1 µPa rms range seem to cause obvious avoidance behaviour in a substantial fraction of the animals exposed. In some areas, seismic pulses will have diminished to these levels at distances of 4.5 to 14.5 km from the source. Thus, a substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the seismic array.

On the other hand, some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioural changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which marine mammal reactions to seismic occur.

Migrating humpback, grey, and bowhead whales have reacted to sound pulses from marine seismic exploration by deviating from their normal migration route and/or interrupting their feeding and moving away (e.g., Malme et al. 1984, 1985, 1988; Richardson et al. 1986, 1995; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a,b; Miller et al. 1999). Finback and blue whales have also displayed some behavioural reactions to airgun sound (McDonald et al. 1995; Stone 1997, 1998, 2000). Prior to the late 1990s, it was thought that migrating bowhead whales, grey whales, and humpback whales all begin to show strong avoidance reactions to seismic pulses at received levels of about 160 to 170 dB re 1 µPa rms. Subtle behavioural changes sometimes became evident at somewhat lower received levels. Recent studies have shown that some species of baleen whale may show strong avoidance at received levels somewhat lower than 160-170 dB re 1 µPa rms. The observed avoidance reactions included movement away from feeding locations or statistically significant deviations in the whales' direction of swimming and/or migration corridor as they approached or passed the sound sources. In the case of the migrating whales, the observed changes in behaviour appeared to be of little biological consequence to the animals. They simply avoided the sound source by slightly displacing their migration route yet remained within the natural boundaries of the migration corridors.

McCauley et al. (1998, 2000a,b) studied the responses of humpback whales off western Australia to a full-scale seismic survey with a 16-gun 2678-in^3 array, and to a single 20-in^3 airgun with a source level of 227 dB re 1 µPa-m (peak-peak). They found that the overall distribution of migrating humpbacks through their study area was not affected by the full-scale seismic program. McCauley et al. (1998) did, however, document localized avoidance of the array and of the single gun. Avoidance reactions began at five to eight kilometres from the array, and those reactions kept most pods about three to four kilometres from the operating seismic boat. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km. Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. The mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1 µPa rms; this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. The startle response occurred at a mean received level of 122 dB rms. The standoff range, that is, the closest point of approach of the airgun to the whales, corresponded to a received level of 143 dB rms. The initial avoidance response generally occurred at distances of five to eight kilometres from the airgun array and two kilometres from the single gun. However, some individual humpback whales, especially males, approached within distances of 100 to 400 m, where the maximum received level was 179 dB re 1 µPa rms.

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150-169 dB re 1 µPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 µPa effective pulse pressure level.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive sounds do not necessarily provide information about long-term effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. Grey whales continue to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic and an existing developed oil field) in that area for decades (Malme et al. 1984). Bowhead whales continue to travel to the eastern Beaufort Sea each summer despite long-term seismic exploration in their summer and autumn range. Bowheads are often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. It is also not known whether whales that tolerate exposure to seismic pulses are stressed.

Toothed Whales

Little systematic information is available on the reactions of toothed whales to seismic pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales, and none similar in size and scope to the studies of bowhead and grey whales mentioned above. Toothed whales reactions to seismic surveying are variable and not well characterized. Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the UK, showed localized (~one kilometre) avoidance. Recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications. There are no specific data on responses of beaked whales to seismic surveys. There is increasing evidence that some beaked whales may strand after exposure to strong sound from mid-frequency sonars. Whether they ever do so in response to low frequency seismic survey sound is unknown.

Dolphins

Seismic operators sometimes see species of toothed whales near operating airgun arrays (e.g., Duncan 1985; Arnold 1996; Stone 2003). When a 3,959-in^3, 18-gun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel, seemingly unperturbed by firing guns. However, in Puget Sound, Dall's porpoises (*Phocoenoides dalli*) observed when a 6,000-in^3, 12-16 gun array was firing, tended to be heading away from the boat (Calambokidis and Osmek 1998). White-beaked (*Lagenorhynchus albirostris*) and white-sided dolphins (*L. acutus*) in the U.K. showed fewer positive interactions (approaching, bow riding, swimming alongside) with a seismic vessel while its airgun array was operating. These species, along with killer whales, harbour porpoises (*Phocoena phocoena*), and bottlenose dolphins all were seen further away from the seismic vessel when its airguns were firing than when they were not (Stone 2003).

Goold (1996a,b,c) studied the effects of 2-D seismic surveys in the Irish Sea on common dolphins (*Delphinus delphis*). Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180 m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km radius from the guns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

Beaked whales

There are no data on the behavioural reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). It is likely that these beaked whales would normally show strong avoidance of an approaching seismic vessel, but this has not been documented explicitly.

Much attention has been given to a recent (September 2002) stranding of Cuvier's beaked whales (*Ziphius cavirostris*) in the Gulf of California (Mexico) while a seismic survey was under way in the general area (Malakoff 2002). The evidence linking the Gulf of California strandings to the seismic surveys is inconclusive, and to this date is not based on any physical evidence. However, it may be noteworthy that the ship implicated in the stranding was operating its multi-beam bathymetric sonar, which emits high-frequency sound thought to be in the best hearing range of toothed whales like the Cuvier's beaked whale.

Sperm whales

Sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998). Thus, it is to be expected that they would tend to avoid an operating seismic survey vessel. There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak sound pulses from extremely distant (>300 km) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, but there are other more plausible explanations. However, sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in UK waters suggest that sperm whales in that area show little evidence of avoidance or behavioural disruption in the presence of operating seismic vessels (Stone 2003). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. A recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel, with received levels of up to 146 dB re 1 µPa peak-

peak, and remained in the area throughout the survey (Madsen et al. 2002a). Similarly, sperm whales in the Gulf of Mexico did not alter their calling behaviour in the presence of seismic pulses, and there was no indication that they moved away from the sound source at received levels of up to 148 dB (Jochens and Biggs 2003). A study conducted off Nova Scotia detected no difference in the acoustic abundance of male sperm whales between years without any seismic survey activity and years with an active seismic program, with received levels of 130 to 150 dB re 1 µPa (McCall Howard 1999). In addition, in the Gulf of Mexico, Davis et al. (2000) found no differences in sighting frequencies of sperm whales among areas with and without seismic surveys, with received levels of up to >12 dB above ambient sound levels.

Pinnipeds

Few studies on the reactions of pinnipeds to sound from open-water seismic exploration have been published (for review, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies in recent years. Monitoring studies in the Beaufort Sea during 1996-2001 provide a substantial amount of information on avoidance responses (or lack thereof) and associated behaviour. Pinnipeds exposed to seismic sound have also been observed during recent seismic surveys along the U.S. west coast. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals (*Halichoerus grypus*) exposed to sound from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* G.D. Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong sound pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the UK, a radio-telemetry study has demonstrated short-term changes in the behaviour of harbour seals (*Phoca vitulina*) and grey seals exposed to airgun pulses (Thompson et al. 1998). In that study, harbour seals were exposed to seismic pulses from a 90-in^3 array (3 × 30-in^3 airguns), and behavioural responses differed among individuals. One harbour seal avoided the array at distances up to 2.5 km from the source and only resumed foraging dives after the seismic survey stopped. Another harbour seal exposed to the same small airgun array showed no detectable behavioural response, even when the array was within 500 m. All grey seals exposed to a single 10-in^3 airgun showed an avoidance reaction. Seals moved away from the source, increased swimming speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as interindividual differences in seal responses to seismic sounds.

Monitoring work in the Alaskan Beaufort Sea during 1996-2001 provided considerable information regarding the behaviour of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1,500 in^3. The combined results suggest that some seals avoided the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating than when they were not (Moulton and Lawson 2002). However, these movements were relatively small and were on the order of 100 m to (at most) a few hundreds of metres, and many seals remained within 100-200 m of the trackline as the operating airgun array passed.

The operation of the airgun array had minor and variable effects on the behaviour of seals visible at the surface within a few hundred meters of the array. The behavioural data indicate that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim toward or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun sound and the proportions of seals engaged in other recognizable behaviours, e.g., "looked" and "dove." Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun sound levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behaviour. These studies show that pinnipeds frequently do not avoid the area within a few hundred metres of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioural reactions may be stronger for some individuals than evident to date from visual studies.

Hearing Impairment

There are no data on the levels or properties of sound that are required to induce a TTS in any baleen whale, as it is not possible to study hearing directly in such a large, free-living marine animal. TTSs for pinnipeds exposed to brief pulses (either single or multiple) have not been measured.

Toothed Whales

Finneran et al. (2002) exposed a beluga whale and a bottlenose dolphin to single pulses using an 80-in^3 water gun. Water gun pulses contain proportionally more energy at higher frequencies than do airgun pulses (Hutchinson and Detrick 1984). Masked TTS (MTTS), defined as a TTS that occurred with considerable background sound, was observed in a beluga after exposure to a single impulse with a peak-to-peak pressure of 226 dB re 1 µPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 µPa2·s. Thresholds returned to within 2 dB of the pre-exposure value approximately four minutes after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with a peak-to-peak pressure of 228 dB re 1 µPa, equivalent to a peak pressure of 207 kPa and total energy flux of 188 dB re

1 µPa2·s (Finneran et al. 2000, 2002). In that study, TTS was defined as occurring when the post-exposure threshold was ≥6 dB higher than the pre-exposure threshold. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10-13 ms.

The data quoted above concern the exposure of small odontocetes to single pulses, generally at frequencies higher than the predominant frequencies in airgun pulses. Additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound. Given the results of the aforementioned study and a seismic pulse duration (as received at close range) of approximately 20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 µPa rms (approximately 221-226 dB peak-peak) in order to produce a brief, mild TTS. Exposure to several seismic pulses at received levels near 200-205 dB (rms) might result in a slight TTS in a small odontocete. Seismic pulses with received levels of 200-205 dB or more are usually restricted to a radius of no more than 100 m around a seismic vessel.

Non-Auditory Physiological Effects

Very little is known about the potential for seismic survey sounds to cause non-auditory physiological effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances from the sound source. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioural avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

Toothed Whales

Romano et al. (2004) exposed a beluga whale and a bottlenose dolphin to single underwater impulsive sounds (up to 200 kPa) from a seismic water gun and measured nervous system and immune system indicators before and after these exposures. In the beluga whale, levels of norepinephrine, epinephrine, and dopamine increased significantly with increasing sound levels and were significantly greater after sound exposures >100 kPa than after sound exposures <100 kPa and after control exposures. In the bottlenose dolphin, there was a significant increase in aldosterone level and a significant decrease in monocyte count after exposure to impulsive sounds. How short-term stress responses might affect the long-term health of cetaceans is unknown.

Sound Other than Seismic

Sound produced during exploration and production drilling emanates from the drill rig, supply vessels, and associated aircraft. Seismic guns may also be discharged periodically from the rig or supply ship (vertical seismic profiling [VSP]) in order to get more detailed information on the hole or reservoir (this aspect is covered in the previous section). The effects of underwater sound produced by offshore oil and gas development and production activities have been studied for only a few marine mammal species, and under only a limited number of circumstances. Thus, the broader literature on general effects of underwater sound must be used to estimate possible reactions of marine mammals to the kinds of sounds being considered in this assessment.

Offshore oil development and production activities produce sounds that can be classified into three broad categories. Sounds that are produced intermittently or at regular intervals, such as sounds from pile driving and seafloor pingers, are classed as "pulsed." Sounds produced for extended periods, such as sounds from power generation and drilling at exploration and production platforms, are classified as "continuous." Sounds from moving sources such as ships or aircraft can be continuous but, for a mammal at a given location, these sounds are "transient" (i.e., increasing in level as the ship or aircraft approaches, and then diminishing as it moves away). Studies indicate that marine mammals respond somewhat differently to the three categories of sound.

Based on the literature reviewed in Richardson et al. (1995), it is apparent that most small and medium-sized toothed whales exposed to prolonged or repeated underwater sounds are unlikely to be displaced unless the overall received level is at least 140 dB re 1 µPa. The limited available data indicate that the sperm whale is sometimes, though not always, more responsive than other toothed whales. Baleen whales probably have better hearing sensitivities at lower sound frequencies, and in several studies have been shown to react at received sound levels of approximately 120 dB. In general, baleen whales tend to react to lower received levels of continuous sound than of pulsed sound.

Toothed whales (odonocetes) appear to exhibit a greater variety of reactions to man-made underwater sound than do baleen whales (mysticetes). Toothed whale reactions can vary from approaching vessels (e.g., to bow ride) to strong avoidance, while baleen whale reactions range from neutral (little or no change in behaviour) to strong avoidance. In general, pinnipeds seem more tolerant of, or at least habituate more quickly to, potentially disturbing underwater sound than whales.

Pulsed Sounds

Baleen Whales

There are no data on hearing thresholds versus pulse duration in baleen whales. However, there is some evidence that disturbance response thresholds in gray and bowhead whales may be related to pulse duration in a manner similar to the relationship between hearing threshold and pulse duration in toothed whales and seals. Malme (1993) summarised the received levels of seismic (airgun) sounds at which an estimated 50% of bowhead and gray whales avoided the source. He then examined the received levels in relation to effective pulse pressure and in relation to response thresholds of the same two species to continuous sound. With pulsed (airgun) sounds, the sound pressure necessary to elicit avoidance in 50% of the whales was about 50 dB higher than that for continuous sounds.

In summary, whereas reactions of baleen whales to pulsed sounds varied depending on the sound source level, type of whale exposed to the sounds, and the whales' activity when the sounds were heard, most baleen whales exhibited some displacement from strong pulsed sounds. In most cases, the displacement was temporary and/or of limited extent. Under some circumstances, some species avoid such sounds when source levels are 115 dB (e.g., continuous sounds), whereas at other times, avoidance or disturbance occurs only when received levels exceed 140 dB (e.g., impulsive sounds).

Toothed Whales

Experimental results (e.g., Würsig et al. 2000; Akamatsu et al. 1993) show that responses to impulsive sound sources are highly variable among toothed whales. Under some circumstances, some species will avoid such sounds when received levels exceed 180 dB (e.g., impulsive sounds). The variability is presumably related to the fact that the observations and experiments on toothed whales involved a variety of species in a variety of situations, and involved sources that emitted sounds at widely varying source levels and at differing frequencies, pulse lengths, and inter-pulse intervals.

Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTSs generally became evident at received levels of 192-201 dB re 1 µPa rms at 3, 10, 20, and 75 kHz. At 75 kHz, one dolphin exhibited a TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited a TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss, as all hearing thresholds returned to baseline values at the end of the study.

Pinnipeds

Data on the reactions of seals to pulsed sounds are limited, but the few reports available (e.g., Richardson et al. 1995; Yurk and Trites 2000) suggest that they would exhibit either no, or short-term, behavioural responses. Some seals exhibited some displacement from strong-pulsed sounds and others showed high tolerance for strong underwater sound pulses. Seals' reactions to pulsed sounds varied depending on sound source level, type of seal exposed to the sounds, and activity at the time of exposure. In most cases, the displacement was temporary and/or of limited extent, with some species showing high tolerance for strong underwater sound pulses.

Pulsed Sounds: Sonar

The effects of most types of sonar on marine mammals are relatively poorly studied given their widespread use. Observed effects vary depending on the species group involved and the frequency of the sonar, and range from no apparent affect at all to mortality.

Baleen Whales

Humpback, finback, and right whales reportedly do not react to pingers and sonars at frequencies of 36, 40, 50, and 60 kHz and higher as long as the signals contain little energy in the lower frequencies (Watkins 1986). Most of those whales react to sounds with frequencies from 15 Hz to 28 kHz.

Humpback whales in Hawaii displayed apparent avoidance behaviour of a 3.3-kHz sonar pulse and a sonar frequency sweep from 3.1 to 3.6 kHz (Maybaum 1993). The whales reacted by increasing their swimming speed and the linearity of their course, while diving and calling were not affected.

Male humpback whales were reported to increase the length of their songs during the transmission of military low-frequency active (LFA) sonar at less than full strength (Miller et al. 2000). The transmission consisted of ten 42-s LFA signals at 6-min intervals. The response was of limited duration, as song length returned to normal after exposure. In five cases, singing humpbacks ceased singing, apparently in response to the sound. Singing is thought to be a sexual display used to attract mates, and the effect of a change in this behaviour on reproductive success is unknown.

Toothed Whales

Responses of toothed whales to sonar vary according to species and the type of sonar used and include avoidance, changes in calling rates, and recently, death. Dall's porpoises and some Delphinids show apparent avoidance (Richardson et al. 1995). Sperm whales react strongly to many types of sonar usually by ceasing vocalizing. Conversely, pilot whales in the Ligurian Sea apparently responded to a military sonar signal by calling in response (Rendell and Gordon 1999). While beaked whale strandings have been linked to the use of military mid-frequency sonar (see below), strandings of 14 harbour porpoises in Washington State in May–June of 2003 that coincided in space and time with the use this type sonar could not be definitively linked to its use (NOAA Fisheries 2004).

Beaked Whales

Military sonar has been implicated in strandings of beaked whales and, occasionally, other cetacean species. Frantzis (1998) reported on a mass live stranding in 1996 of 12 Cuvier's beaked whales in the Mediterranean Sea that corresponded closely in time and space to NATO testing of an LFA sonar system, which produces a broadband signal with a maximum intensity of ≥230 dB re 1 µPa at frequencies ranging from 250–3000 Hz. In March of 2000, a mass stranding of Cuvier's beaked whales and Blainville's beaked whales (*Mesoplodon densirostris*) that occurred in The Bahamas was most likely caused by tactical mid-range frequency military sonar (U.S. Department of Commerce and U.S. Navy 2001; Schrope 2002). Finally, eight Cuvier's beaked whales, one Blainville's beaked whale, and one Gervais' beaked whale (*Mesoplodon europaeus*), which were part of a group of 14 beaked whales that stranded in the Canary Islands close to the site of an international naval exercise in September 2002, were found to have gas-bubble lesions consistent with acute trauma due to in vivo bubble formation as a result of rapid decompression (Jepson et al. 2003).

Sperm Whales

Watkins and Schevill (1975) reported that sperm whales ceased calling in response to the calibration sequences of their pingers, which had frequencies that varied from 6–13 kHz and sound levels that varied from 110–130 dB re 1 µPa at 1 m. Sperm whales did not react to 36-, 40-, 50-, and 60-kHz calibration pingers or sonars (Watkins et al. 1985). Sperm whales in the Caribbean exhibited a dramatic reaction to military sonar, heard as short sequences of four to twenty 0.145- to 0.45-second pulses at rates of 1–5 signals per minute with frequencies ranging from 3250–8400 Hz, by falling silent and dispersing (Watkins et al. 1985, 1993).

Pinnipeds

The possible effects of sonar on pinnipeds are not well studied. Richardson et al. (1995) reviewed the available data and found harp seals to alter their swimming patterns in relation to a 200-kHz echosounder, while other species showed no apparent responses to 60-69 kHz acoustic pingers.

Pulsed Sounds: Underwater Explosions

Baleen Whales

Humpback whales in Trinity Bay Newfoundland (Todd et al. 1996) apparently did not react to underwater explosions related to industrial activity in the Bay, with behaviour, distribution, and residency time apparently unaffected by the blasts. Charges were generally 1,000-2,000 kg and peak source levels were typically 140-140 dB re 1 µPa near 400 Hz.

Toothed Whales

Observations of toothed whale responses to sound pulses from underwater explosions have also been made over the years. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were "not always effective" in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by "scare" charges.

Captive false killer whales (*Pseudorca crassidens*) showed no obvious reaction to single sound pulses from small (10-g) charges; the received level was approximately 185 dB re 1 µPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of sound pulses from small explosive charges on killer whales and other odontocetes. Excluding the potential for hearing loss, the tolerance to these charges may indicate a lack of effect or the failure to move away may simply indicate a stronger desire to eat, regardless of circumstances.

Finneran et al. (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1-13 ms in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received sound pressure level of 221 dB re 1 µPa produced no more than a slight and temporary reduction in hearing.

Sperm Whales

Male sperm whales off Andenes in northern Norway did not change their click rates in response to detonations used to calibrate a hydrophone array, with estimated received sound levels of 173–179 dB re 1 µPa (Madsen and Møhl 2000).

Pinnipeds

The available evidence suggests that pinnipeds are quite tolerant of sound pulses from underwater explosions, with little reaction to blasting sounds and only temporary reactions to firecracker-like explosives designed to deter them from feeding around fishing gear (Richardson et al. 1995). However, it is unknown whether these animals incur any hearing damage or other injuries.

Continuous Sounds: Drilling

Broadband source levels produced by a working semi-submersible drilling rig may be about 154 dB re 1 µPa-m (Greene 1986)—quite a low source level. Assuming spherical spreading close to the source, received levels would diminish to about 114 dB within 100 m. A semi-submersible drilling rig has large underwater hulls, which act to radiate sound efficiently into the water. In contrast, a drilling rig that is standing on steel legs would likely radiate much less sound into the water during operations (Gales 1982). Based on the documented reactions by cetaceans to floating drillships with large areas of hull in contact with the water, and the lower sound output from a bottom-founded platform, behavioural reactions to a bottom-founded platform could be limited to a very small area.

Baleen Whales

Baleen whales sometimes show behavioural changes in response to received broadband drillship sounds of 120 dB or greater. On their summer range in the Beaufort Sea, bowhead whales reacted to drillship sounds within four to eight kilometres of a drillship at received levels 20 dB above ambient or about 118 dB (Richardson et al. 1990). Reactions were stronger at the onset of the sound (Richardson et al. 1995). Migrating bowhead whales avoided an area with a radius of 10-20 km around drillships and their associated support vessels, corresponding to a received sound level around 115 dB (Greene 1987; Koski and Johnson 1987; Hall et al. 1994; Davies 1997; Schick and Urban 2000). For gray whales off California, the predicted reaction zone around a semi-submersible drill rig was less than one kilometre, at received levels of ~120 dB (Malme et al. 1983, 1984). Humpback whales showed no obvious avoidance response to broadband drillship sounds at a received level of 116 dB (Malme et al. 1985).

Toothed Whales

Dolphins and other toothed whales may show considerable tolerance of floating and bottom-founded drillrigs and their support vessels. Kapel (1979) reported many pilot whales within visual range of drillships and their support vessels off West Greenland. Belugas have been observed swimming within 100-150 m of an artificial island while drilling was underway (Fraker and Fraker 1979; 1981), and within 1,600 m of the drillship *Explorer I* while the vessel was drilling (Fraker and Fraker 1981). Of the seven occasions when the whales were observed near an artificial island while drilling was being conducted, calves were present. Some belugas in Bristol Bay and the Beaufort Sea, Alaska, when exposed to playbacks of drilling sounds, altered course to swim around the source, increased swimming speed, or reversed direction of travel (Stewart et al. 1982; Richardson et al. 1995). Reactions of beluga whales to semi-submersible drillship sound were less pronounced than were reactions to motorboats with outboard engines. Captive belugas exposed to playbacks of recorded semi-submersible sound seemed quite tolerant of that sound (Thomas et al. 1990).

Pinnipeds

Responses of pinnipeds to drilling sound have not been well studied. Richardson et al. (1995) summarized the few available studies, which showed ringed seals and bearded seals (*Erignathus barbatus*) in the Arctic to be rather tolerant of drilling sound. Seals were often seen near active drillships and approached, to within 50 m, a sound projector broadcasting low-frequency drilling sound.

Other Continuous Sounds

Toothed Whales

Harbour porpoises off Vancouver Island, British Columbia, were found to be sensitive to the simulated sound of a 2 MW offshore wind turbine (Koschinski et al. 2003). Harbour porpoises remained significantly further away from the sound source when it was active and this effect was seen out to a distance of 60 m. The device used in that study produced sounds in the frequency range of 30–800 Hz, with peak source levels of 128 dB re 1 µPa at 1 m at the 80 and 160 Hz frequencies.

TTSs were measured in a single bottlenose dolphin after exposure to a continuous tone with maximum sound pressure levels at frequencies ranging from 4–11 kHz that was gradually increased in intensity to 179 dB re 1 µPa and in duration to 55 minutes (Nachtigall et al. 2003). No threshold shifts were measured at sound pressure levels of 165 or 171 dB re 1 µPa. However, at 179 dB re 1 µPa TTSs >10 dB were measured during different trials with exposures ranging from 47–54 minutes. Hearing sensitivity apparently recovered by 45 minutes after sound exposure.

Pinnipeds

Reactions of harbour seals to the simulated sound of a 2-MW windpower generator were measured by Koschinski et al. (2003). Harbor seals surfaced significantly further away from the sound source when it was active and did not approach the sound source as closely. The device used in that study produced sounds in the frequency range of 30–800 Hz, with peak source levels of 128 dB re 1 µPa at 1 m at the 80 and 160 Hz frequencies.

Kastak et al. (1999) reported that they could induce mild TTSs in California sea lions (*Zalophus californianus*), harbour seals, and northern elephant seals (*Mirounga angustirostris*) by exposing them to underwater octave-band sound at frequencies in the 100-2000 Hz range for 20-22 minutes. Mild TTSs became evident when the received levels were 60-75 dB above the respective hearing thresholds, that is, at received levels of about 135-150 dB. Three of the five animals tested showed shifts of approximately 4.6-4.9 dB, and all recovered to baseline hearing sensitivity within 24 hours of exposure. Schusterman et al. (2000) showed that TTSs of these seals were somewhat lower when the animals were exposed to the sound for 40 minutes than for 20-22 minutes, confirming that there is a duration effect in pinnipeds. There are some indications that, for corresponding durations of sound, pinnipeds may incur a TTS at a somewhat lower received level than do small odontocetes (Kastak et al. 1999; cf. Au 2000).

Transient Sounds: Vessels

Broadband source levels (at 1 m) for most small ships are in the 170-180 dB re 1 µPa range, excluding infrasonic components (Richardson et al. 1995). Broadband underwater sounds from the supply ship *Robert Lemeur* in the Beaufort Sea were 130 dB at a distance of 0.56 km (Greene 1987), and were 11 dB higher when bow thrusters were operating than when they were not (Greene 1985, 1987). The *Robert Lemeur* has nozzles around the thruster propellers. Broadband sound levels from ships lacking nozzles or cowlings around the propellers can be about 10 dB higher than those from ships with the nozzles (Greene 1987).

Baleen Whales

Reactions of baleen whales to boat sounds include changes in swimming direction and speed, blow rate, and the frequency and kinds of vocalisations (Richardson et al. 1995). Baleen whales, especially minke whales (*Balaenoptera acutorostrata*), occasionally approach stationary or slow-moving boats, but more commonly avoid boats. Avoidance is strongest when boats approach directly or when vessel sound changes abruptly (Watkins 1986; Beach and Weinrich 1989). Humpback whales responded to boats at distances of at least 0.5 to 1 km, and avoidance and other reactions have been noted in several areas at distances of several kilometres (Jurasz and Jurasz 1979; Dean et al. 1985; Bauer 1986; Bauer and Herman 1986). During some activities and at some locations, humpbacks exhibit little or no reaction to boats (Watkins 1986).

Right whales (*Eubalaena glacialis*) also show variable responses to boats. There may be an initial orientation away from a boat, followed by a lack of observable reaction (Atkins and Swartz 1989). A slowly moving boat can approach a right whale, but an abrupt change in course or engine speed will elicit a reaction (Goodyear 1989; Mayo and Marx 1990; Gaskin 1991). When approached by a boat, right whale mothers will interpose themselves between the vessel and calf and will maintain a low profile (Richardson et al. 1995). In a recent study, using a multi-sensor acoustic recording tag and controlled sound exposure experiments, right whales were found to show no response to playbacks of the sound of an approaching 120-m container ship or to actual vessels (Nowacek et al. 2004). The closely related bowhead whale typically begins avoiding diesel powered boats at distances of ~four kilometres; the whale often first attempts to "outrun" the vessel, but may turn to swim perpendicular to the boat’s track when it approaches within a few hundred metres (Richardson et al. 1985a,b; Koski and Johnson 1987). Bowheads may be displaced by a few kilometres when fleeing, although some return to the area within a day.

Toothed Whales

Some species of small toothed cetaceans avoid boats when they are approached to within 0.5-1.5 km, with occasional reports of avoidance at greater distances (Richardson et al. 1995). Some toothed whale species appear to be more responsive than others. Beaked whales and beluga whales seem especially responsive to boats.

Dolphins and Porpoises

Dolphins may tolerate boats of all sizes, often approaching and riding the bow and stern waves (Shane et al. 1986). At other times, dolphin species that are known to be attracted to boats will avoid them. Such avoidance is often linked to previous boat-based harassment of the animals (Richardson et al. 1995).

Coastal bottlenose dolphins that are the object of whale-watching activities have been observed to swim erratically (Acevedo 1991), remain submerged for longer periods of time (Janik and Thompson 1996; Nowacek et al. 2001), display less cohesiveness among group members (Cope et al. 1999), whistle more frequently (Scarpaci et al. 2000), and rest less often (Constantine et al. 2004) when boats were nearby. Pantropical spotted dolphins (*Stenella attenuata*) and spinner dolphins (*Stenella longirostris*) in the eastern Tropical Pacific, where they have been targeted by the tuna fishing industry because of their association with these fish, show avoidance of survey vessels up to six nautical miles away (Au and Perryman 1982; Hewitt 1985), whereas spinner dolphins in the Gulf of Mexico were observed bowriding the survey vessel in all 14 sightings of this species during one survey (Würsig et al. 1998).

Harbour porpoises tend to avoid boats. In the Bay of Fundy, Polacheck and Thorpe (1990) found harbour porpoises to be more likely to be swimming away from the transect line of their survey vessel than swimming toward it and more likely to be heading away from the vessel when they were within 400 m of it. Similarly, off the west coast of North America, Barlow (1988) observed harbour porpoises to avoid a survey vessel by moving rapidly out of its path within one kilometre of that vessel.

Beluga Whales

Beluga whales are generally quite responsive to vessels. Belugas in Lancaster Sound in the Canadian Arctic showed dramatic reactions in response to icebreaking ships, with received levels of sound ranging from 101 dB to 136 dB re 1 µPa in the 20–1,000-Hz band at a depth of 20 m (Finley et al. 1990). Responses included emitting distinctive pulsive calls that were suggestive of excitement or alarm and rapid movement in what seemed to be a flight response. Reactions occurred out to 80 km from the ship.

Although belugas in the St. Lawrence River occasionally show positive reactions to ecotourism boats by approaching and investigating those boats, one study found the belugas to surface less frequently, swim faster, and group together in the presence of boats (Blane and Jaakson 1994). Another study found belugas to use higher-frequency calls, a greater redundancy in their calls (more calls emitted in a series), and a lower calling rate in the presence of vessels (Lesage et al. 1999).

Beaked Whales

Most beaked whales tend to avoid approaching vessels (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001).

Sperm Whales

Sperm whales generally show no overt reactions to vessels unless they are approached to within several hundred meters (Watkins and Schevill 1975; Würsig et al. 1998; Magalhães et al. 2002). Observed reactions include spending more (Richter et al. 2003) or less (Watkins and Schevill 1975) time at the surface, increasing swimming speed or changing heading (Papastavrou et al. 1989; Richter et al. 2003), and diving abruptly (Würsig et al. 1998).

Pinnipeds

Ship and boat sound do not seem to have strong effects on seals in the water, but the data are limited. When in the water, seals appear to be much less apprehensive of approaching vessels. Some will approach a vessel out of apparent curiosity, including noisy vessels such as those operating seismic airgun arrays (Moulton and Lawson 2000). Grey seals have been known to approach and follow fishing vessels in an effort to steal catch or the bait from traps. In contrast, seals hauled out on land often are quite responsive to nearby vessels. Terhune (1985) reported that Northwest Atlantic harbour seals were extremely vigilant when hauled out, and were wary of approaching (but less so passing) boats. Suryan and Harvey (1999) reported that Pacific harbour seals commonly left the shore when powerboat operators approached to observe the seals. Those seals detected a powerboat at a mean distance of 264 m, and seals left the haul-out site when boats approached to within 144 m.

Transient Sounds: Aircraft

Sound from an elevated source in the air is refracted upon transmission into water because of the difference in sound speeds in the two media (a ratio of about 0.23). The direct sound path is totally reflected if the sound reaches the surface at an angle more than 13 degrees from vertical. Because of the large difference in the acoustic properties of water and air, the pressure field is doubled at the surface of the water, resulting in a 6-dB increase in pressure level at the surface.

For a passing airborne source, peak received levels at and below the surface diminish with increasing source altitude. With increasing horizontal distance from the airborne source, underwater sound diminishes more rapidly than does the airborne sound.

There are published observations of marine mammal reactions to aircraft (for a review, see Richardson et al. 1995). In most cases, airborne or waterborne sound from the aircraft was the apparent stimulus, although vision was probably involved in some cases. Responses to aircraft were variable, partly because of differences in aircraft type, altitude, and flight pattern (e.g., straight-line overflight, circling, or hovering). Such factors can affect the spectral properties, temporal properties, and level of sound received by animals.

Baleen Whales

Minke, bowhead, and right whales sometimes react to aircraft overflights at altitudes of 150-300 m by diving, changing dive patterns, or leaving the area (Leatherwood et al. 1982; Watkins and Moore 1983; Payne et al. 1983; Richardson et al. 1985a,b, 1995). However, the majority of the bowheads do not react noticeably even to a low-altitude (~150 m) overflight. Helicopter disturbance to humpback whales is a concern off Hawaii, where helicopters are prohibited from approaching humpbacks to within 305 m (Tinney 1988; Atkins and Swartz 1989; NMFS 1987). In general, baleen whales are more likely to react to an aircraft at low than at high altitude, that passes directly overhead rather than well to the side, and that circles or hovers rather than simply flying over (Richardson et al. 1985a,b).

Toothed Whales

Most species of toothed whales do not appear to react overtly to aircraft overflights, except when the aircraft fly at low altitudes. Beaked whales, pygmy sperm whales (*Kogia breviceps*), dwarf sperm whales (*K. sima*), and Dall’s porpoises appear to react more strongly to low-level aircraft overflights than do bottlenose dolphins or sperm whales. Whales that do react dive hastily, turn, or swim away from the flight path. Feeding or socialising whales and dolphins are less likely to react than those engaged in other activities.

Bottlenose dolphins did not react as strongly to the presence of an aircraft as did some other odontocete species during aerial surveys from Twin Otter turboprop aircraft operating at 230 m altitude and 110 knots. The bottlenose dolphins changed their behaviour in response to the overflights during only a relatively small proportion of the encounters (Würsig et al. 1998). They were most likely to change their behaviour (usually by diving) when they were milling or resting. Spinner dolphins reacted in all cases to aircraft overflights at 230 m, while pantropical spotted, Atlantic spotted (*S. frontalis*), clymene (*S. clymene*), and striped (*S. coeruleoalba*) dolphins reacted less than half the time (Würsig et al. 1998). During earlier surveys with a similar aircraft and methodology, bottlenose dolphins did not appear to react aversively to the aircraft except when its shadow passed directly over them, in which case they would make a startled dive (Mullin et al. 1991).

Larger toothed whales show variable reactions to aircraft. Some belugas ignored aircraft at flying at 500-m altitude but dove for longer periods and sometimes swam away when it was at 150-200 m (Bel'kovich 1960; Kleinenberg et al. 1964). Lone animals sometimes dove in response to flights at 500 m. Off Alaska, some belugas showed no reaction to airplanes or helicopters at 100-200-m altitude, whereas a minority dove abruptly or swam away in response to overflights at altitudes up to 460 m (Richardson et al. 1995). Belugas in the Alaskan Beaufort Sea reacted to a Twin Otter aircraft and a helicopter with immediate dives, changes in heading, changes in behavioural state, and apparent displacements, with most reactions occurring when the aircraft was at an altitude ≤ 182 m and a lateral distance from the animals of ≤ 250 m (Patenaude et al. 2002). Narwhals (*Monodon monoceros*) dove in response to helicopters flying at altitudes below 244 m and, to a lesser degree, at 305 m (Kingsley et al. 1994). Beaked whales responded almost 90% of the time to the overflight of a Twin Otter aircraft at an altitude of 230 m and speed of 110 knots in the Gulf of Mexico (Würsig et al. 1998).

Some sperm whales showed no reaction to helicopters and airplanes flying over at altitudes of 150 m, but some dove immediately (Clarke 1956; Mullin et al. 1991). Sperm whales in the Gulf of Mexico were more responsive to the overflight of a survey aircraft when they were encountered resting (the animals dove 40% of the time) and nonresponsive when they were encountered travelling (Würsig et al. 1998). Male sperm whales off Kaikoura, New Zealand, spent more time at the surface and showed more frequent heading changes in the presence of small fixed-wing planes and helicopters involved in whale-watching activities (Richter et al. 2003). Smultea et al. (2001) report only occasional reactions (consisting of a quick dive) by sperm whales when their small-fixed wing aircraft passed within 360 m from the whales, typically at an altitude of 244 m and speed of 100 knots, and one case of defensive posturing by a group of 11 sperm whales (including one calf) when their aircraft was circling them at altitudes of 245–335 m.

Pinnipeds

Seals hauled out for pupping or moulting have variable sensitivities to aircraft disturbance, but at times react strongly, generally by moving abruptly into the water (Richardson et al. 1995). Fixed-wing aircraft flying at altitudes below 60-120 m and helicopters flying below 305 m at times cause panic among adult common seals and mortality of young at haul-out beaches (Johnson 1977; Bowles and Stewart 1980; Osborn 1985). However, seals that have become habituated to aircraft may show little or no reaction (M. Bigg *in* Johnson et al. 1989:53). There are few observations of the reactions of seals in the water to aircraft. Overflights at low altitudes cause some animals to dive (Richardson et al. 1995).

4.1.5.5 Sea Turtles

There have been far fewer studies of the effects of airgun sound (or indeed any type of sound) on sea turtles than on marine mammals and fish. Three such studies have focused on short-term behavioural responses of sea turtles in enclosures to single airguns. Comparisons of results among studies are difficult, because experimental designs and reporting procedures have varied greatly, and only one of the studies provided specific information about the levels of the airgun pulses received by the turtles. We are not aware of any studies on responses of free-ranging sea turtles to seismic sounds or on the long-term effects of seismic or other sounds on sea turtles. Results from some recent seismic monitoring programs provide some data.

The most recent of the studies of caged sea turtles exposed to airgun pulses was a study by McCauley et al. (2000a,b) off Western Australia. This is apparently the only such study in which received sound levels were estimated carefully. McCauley et al. (2000a,b) exposed caged green and loggerhead sea turtles (one of each) to pulses from an approaching and then receding 20 in^3 airgun operating at 1,500 psi and 5 m gun-depth. The single airgun fired every 10 s. There were two trials separated by two days; the first trial involved ~2 h of airgun exposure and the second ~1 h. The results from the two trials showed that, above a received level of 166 dB re 1 μPa (rms), the turtles noticeably increased their speed of swimming relative to periods when no airguns were operating. The behaviour of the sea turtles became more erratic when received levels exceeded 175 dB re 1 μPa (rms). The authors suggested that the erratic behaviour exhibited by the caged sea turtles would likely, in unrestrained turtles, be expressed as an avoidance response (McCauley et al. 2000a,b).

O'Hara and Wilcox (1990) tested the reactions to airguns of loggerhead sea turtles held in a 300 × 45 m area of a canal 10 m deep in Florida. Nine turtles were tested at different times. The sound source consisted of one 10 in^3 airgun plus two 0.8 in^3 "poppers" operating at 2,000 psi [5] and gun-depth 2 m for prolonged periods: 20–36 hours in duration. The turtles maintained a standoff range of about 30 m when exposed to airgun pulses every 15 sec or every 7.5 sec. It was also possible that some turtles remained on the bottom of the enclosure when exposed to airgun pulses. O'Hara and Wilcox (1990) did not measure the received airgun sound levels. McCauley et al. (2000a,b) estimated that "the level at which O'Hara saw avoidance was around 175–176 dB re 1 μPa (rms)". The levels received by the turtles in the Florida study probably were actually a few dB less than 175–176 dB because the calculations by McCauley et al. (2000a,b) apparently did not allow for the shallow 2 m gun depth in the Florida study. The effective source level of airguns is less when they are near 2 m depth than at 5 m (Greene and Burgess 2000).

Moein et al. (1994) investigated the avoidance behaviour and physiological responses of loggerhead turtles exposed to an operating airgun, as well as the effects on their hearing. The turtles were held in a netted enclosure about 18 m by 61 m by 3.6 m deep, with an airgun of unspecified size at each end.

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[5] There was no significant reaction by five turtles during an initial series of tests with the airguns operating at the unusually low pressure of 1,000-psi. The source and received levels of airgun sounds would have been substantially lower when the air pressure was only 1,000-psi than when it was at the more typical operating pressure of 2,000-psi.

Only one airgun was operated at any one time; firing rate was one shot every 5–6 sec. Ten turtles were tested individually, and seven of these were retested several days later. The airgun was initially discharged when the turtles were near the center of the enclosure and the subsequent movements of the turtles were documented. The turtles exhibited avoidance during the first presentation of airgun sounds at a mean range of 24 m, but the avoidance response waned quickly. Additional trials conducted on the same turtles several days later did not show statistically significant avoidance reactions, although there was an indication of slight initial avoidance followed by rapid waning of the avoidance response. The authors described the rapid waning of the avoidance response as "habituation". Their auditory study indicated that exposure to the airgun pulses may have resulted in temporary hearing impairment (TTS, see later section). Reduced hearing sensitivity may also have contributed to the waning response upon continued exposure. There was some evidence from the physiological measurements of increased stress in the sea turtles, but this stress could also have been a result of handling of the turtles.

Inconsistencies in reporting procedures and experimental design prevent direct comparison of Moein's study with either McCauley et al. (2000b) or O'Hara and Wilcox (1990). Moein et al. (1994) stated, without further details, that "three different decibel levels (175, 177, 179) were utilized" during each test. These Figures probably are received levels in dB re 1 μPa, and probably relate to the initial exposure distance (mean 24 m), but these details were not specified. Also, it was not specified whether these values were measured or estimated, or whether they are expressed in peak-peak, peak, rms, SEL, or some other units. Given the shallow water in the enclosure (3.6 m), any estimates based on simple assumptions about propagation would be suspect.

Despite the problems in comparing these three studies, there is a consistent trend showing that, at some received level, sea turtles show avoidance of an operating airgun. McCauley et al. (2000b) found evidence of behavioural responses when the received level from a single small airgun was 166 dB re 1 μPa *rms*, and avoidance responses at 175 dB re 1 μPa (rms). Based on these data, McCauley et al. (2000b) estimated that, for a typical airgun array (2,678 in^3, 12-elements) operating in 100–120 m water depth, sea turtles may exhibit behavioural changes at ~two kilometres and avoidance around one kilometre. These estimates are subject to great variation, depending on the seismic source and local propagation conditions.

There have been no specific studies of free-ranging sea turtles exposed to seismic pulses, and potential long-term behavioural effects of seismic exposure have not been investigated. Sea turtle sightings have been made during L-DEO seismic monitoring programs. During the L-DEO seismic monitoring program in the Eastern Pacific, six sea turtle sightings (two green, two leatherback, and two Olive Ridley sea turtles) were made (Smultea and Holst 2003). Five of these sightings occurred during airgun operations (all within 100 m of the seismic ship), and one turtle appeared to react to the airguns. This turtle was initially sighted ~100 m from the bow, floated by the ship to within 10 m of the airgun array, and then swam away. During the L-DEO seismic monitoring program in the Northwest Atlantic, 26 sea turtle sightings (25 unidentified and one leatherback sea turtle) were made (Haley and Koski 2004). Nine of the 25 sea turtles seen during seismic periods (one 75 in^3 airgun) were actively moving away from the vessel. The 16 other sea turtles did not exhibit avoidance response. Sea turtles were also observed during seismic operations in the SE Caribbean by L-DEO (Smultea et al. 2004). Two sea turtles (hawksbill and unidentified sea turtle) were seen between 10-20 m from the 20-airgun array. Both turtles swam vigorously away from the seismic vessel.

The paucity of data precludes specific predictions as to how free-ranging sea turtles respond to seismic sounds. The possible responses could include one or more of the following: (1) avoid the entire seismic survey area to the extent that the turtles move to less preferred habitat; (2) avoid only the immediate area around the active seismic vessel, i.e., local avoidance of the source vessel but remain in the general area; and/or (3) exhibit no appreciable avoidance, although short-term behavioural reactions are likely.

The potential alteration of a migration route might have negative impacts. However, it is not known whether the alteration would ever be on a sufficient geographic scale, or be sufficiently prolonged, to prevent turtles from reaching an important destination.

Avoidance of a preferred foraging area because of seismic survey sound may prevent sea turtles from obtaining preferred prey species and hence could impact their nutritional status. However, it is highly unlikely that sea turtles would completely avoid a large area along a migration route. Available evidence suggests that the zone of avoidance around seismic sources is not likely to exceed a few kilometres (McCauley et al. 2000b). Avoidance reactions on that scale could prevent sea turtles from using an important coastal area or bay if there was a prolonged seismic operation in the area. Sea turtles might be excluded from the area for the duration of the seismic operation, or they might remain but exhibit abnormal behavioural patterns (e.g., lingering at the surface where received sound levels are lower). Whether those that were displaced would return quickly after the seismic operation ended is generally unknown.

The results of experiments and monitoring studies on responses of marine mammals and fish to seismic surveys show that behavioural responses are possible, depending on species, time of year, activity of the animal, and other unknown factors. The same species may show different kinds of responses at different times of year or even on different days (Richardson et al. 1995). It is reasonable to expect similar variability in the case of sea turtles exposed to airgun sounds. For example, sea turtles of different ages have very different sizes, behaviour, feeding habits, and preferred water depths. Nothing specific is known about the ways in which these factors may be related to airgun sound effects on sea turtles. However, it is reasonable to expect lesser effects in young turtles concentrated near the surface (where levels of airgun sounds are attenuated) as compared with older turtles that spend more time at depth where airgun sounds are generally stronger.

In summary, most studies have been conducted in shallow water, enclosed areas and thus are somewhat directly applicable to the Study Area. The limited available data indicate that sea turtles will hear airgun sounds. Based on available data, it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. Seismic operations in or near areas where turtles concentrate are likely to have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Western Newfoundland and Labrador Offshore Area Study Area is not a breeding area for sea turtles and it is not known or thought to be an important feeding area, and thus high concentrations of sea turtles are unlikely.

Hearing Impairment and Physical Effects

There have been few studies that have directly investigated hearing or sound-induced hearing loss in sea turtles.

Moein et al. (1994) used an evoked potential method to test the hearing of loggerhead sea turtles exposed to a few hundred pulses from a single airgun. Turtle hearing was tested before, within 24 h after, and two weeks after exposure to pulses of airgun sound. Levels of airgun sounds to which the turtles were exposed were not specifically reported. The authors concluded that five turtles (of ~11 tested) exhibited some change in their hearing sensitivity when tested within 24 h after exposure to airgun sound relative to pre-exposure sensitivity, and that hearing had reverted to normal when tested two weeks after exposure. These results are consistent with the occurrence of TTS upon exposure of the turtles to airgun pulses. The report did not state the size of the airgun used, or the received sound levels at various distances. The distances of the turtles from the airgun were also variable during the tests; the turtle was about 30 m from the airgun at the start of each trial, but it could then either approach the airgun or move away to a maximum of about 65 m during subsequent airgun pulses. Thus, the levels of airgun sounds that apparently elicited TTS are not known. Nonetheless, it is noteworthy that there was evidence of TTS from exposure to pulses from a single airgun. However, it may be relevant that these turtles were confined and unable to move more than about 65 m away. Turtles in the open sea might move away, and even if they did not move away, turtles near the seismic line would receive only a few pulses at near-maximum level as the seismic vessel went by.

Studies with terrestrial reptiles have also demonstrated that exposure to impulse sound can cause hearing loss. Desert tortoises (*Gopherus agassizii*) exhibit TTS after exposure to repeated high intensity sonic booms (Bowles et al. 1999). Recovery from these temporary hearing losses was usually rapid (<1 h), which suggested that tortoises can tolerate these exposures without permanent injury (Bowles et al. 1999).

The apparent occurrence of Temporary Threshold Shift in loggerhead turtles exposed to many pulses from a single airgun ≤65 m away suggests that sounds from an airgun array could cause at least temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs. There is also the possibility of permanent hearing damage to turtles close to the airguns. However, there are few data on temporary hearing loss and no data on permanent hearing loss in sea turtles exposed to airgun pulses.

The study by Moein et al. (1994) indicates that sea turtles can experience TTS when exposed to moderately strong airgun sounds. However, there are no data to indicate whether or not there are any plausible situations in which exposure to repeated airgun pulses at close range could cause permanent hearing impairment in sea turtles.

Behavioural avoidance and hearing damage are related. If sea turtles exhibit little or no behavioural avoidance, or if they acclimate to seismic sound to the extent that avoidance reactions cease, sea turtles might sustain hearing loss if they are close enough to seismic sources.

Turtles in the area of seismic operations prior to start-up may not have time to move out of the area even if standard ramp-up (=soft-start) procedures are in effect. It has been proposed that sea turtles require a longer ramp-up period because of their relatively slow swimming speeds. However, it is unclear at what distance from a seismic source sea turtles might sustain temporary hearing impairment, and whether there would ever be a possibility of exposure to sufficiently high levels for a sufficiently long period to cause irreversible hearing damage (PTS).

In theory, a reduction in hearing sensitivity, either temporary or permanent, may be harmful for sea turtles. However, very little is known about the role of sound perception in the sea turtle's normal activities. Hence, it is not possible to estimate how much of a problem it would be for a turtle to have either temporary or permanent hearing impairment. It is noted above that sea turtles are unlikely to use passive reception of acoustic signals to detect the hunting sonar of killer whales, because the echo-location signals of killer whales are likely inaudible to sea turtles. Hearing is also unlikely to play a major role in their navigation. However, hearing impairment, either temporary or permanent, might inhibit a turtle's ability to avoid injury from vessels, because they may not hear them in time to move out of their way. In any event, sea turtles are unlikely to be at great risk of hearing impairment.

Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that might occur in sea turtles exposed to strong underwater sound might, in theory, include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in sea turtles exposed to sound from airgun arrays. If any non-auditory physiological effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods. This is unlikely to occur in a deep-water open-ocean situation where there is no nearby land or shoals to confine the movements of the animals. Long-term exposure to anthropogenic sound may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). It is doubtful that any single sea turtle would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop.

In summary, very little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in sea turtles. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of sea turtles that might be affected in these ways.

Effects of Helicopter Overflights

To the best of our knowledge, there are no systematic data on sea turtle reactions to helicopter overflights. Given the hearing sensitivities of sea turtles, they can likely hear helicopters, at least when the helicopters are at lower altitudes and the turtles are in relatively shallow waters. It is unknown how sea turtles would respond, but single or occasional overflights by helicopters would likely only elicit a brief behavioural response.

Effects of Presence of Vessels

To the best of our knowledge, there are no systematic data on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound.

Effects of Accidental Spills

It is possible that small amounts of Isopar could leak from the streamers or that a fuel spill may occur from the seismic ship and/or its support vessels. Any spills would likely be small and quickly dispersed by wind, wave, and ship’s propellor action. The effects of hydrocarbon spills on sea turtles are discussed in Section 4.3.3.5. Sea turtles are thought to be more susceptible to the effects of oiling than marine mammals but any effects are believed to be sublethal (Husky 2000). Effects of an Isopar spill on sea turtles would be negligible.

Effects of Other Activities Associated with Seismic Surveying

There is potential for sea turtles to interact with the lights, domestic and sanitary wastes, and air emissions from the seismic ship and its support vessels. As discussed previously, any effects from these interactions are predicted to be negligible.

4.1.5.6 Mitigations and Planning

There are standard environmental mitigative measures that are required during geophysical surveys in the offshore Newfoundland and Labrador area consistent with the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NOPB 2004). The following items are a list of typical mitigations that must be conducted in a manner consistent with the Guidelines (C-NOPB 2004).

Ramping up

Ramping-up or ‘soft starting’ the airgun array over a period of 20 to 30 minutes provides time for nearby fish, mobile invertebrates, marine mammals, sea turtles and sea birds to leave the immediate area before the seismic sounds become sufficiently strong to have any potential of causing physical effects. This is a standard mitigation used in the East Coast offshore.

Shutdown of Seismic Array

The operator is required to shut down the airgun array if a Species at Risk is observed within a 500 m radius of the array.

Observers

The placement of trained observers aboard the seismic vessel to monitor the immediate area for presence of marine mammals and sea turtles is a typical practice during seismic operations. If marine mammals are observed within a set distance (i.e., 500 or 1,000 m monitoring zone) from the vessel during ramp-up, airguns are shut down. Shutdowns of the airgun array could be implemented if deemed necessary due to the proximity of particular species of concern. Shutdown ‘triggers’ may vary by location and species. Fishery liaison observers (FLOs) are used to communicate and mitigate potential conflicts with fishing vessels.

Optimal Scheduling of Seismic Surveys

Selected timing of the seismic surveys to minimize conflict with biota for fisheries in key areas (e.g., spawning, feeding, migration) at particular times of the year can mitigate any potential effects. These spatial and temporal scheduling mitigations could potentially apply to the identified sensitive fish/fisheries areas in the Study Area. Optimal scheduling to avoid sensitive life stages is particularly important in regards to species deemed to be Species at Risk. Surveys also should be coordinated with DFO to avoid conflicts with research vessel surveys.

Seismic activities should be scheduled to avoid heavily fished areas, to the extent possible. The operator should implement operational arrangements to ensure that the operator/survey contractor and the local fishing interests are informed of each other’s planned activities (i.e., FLOs and guard vessels).

Guard Vessels

Guard vessels, preferably crewed by commercial fishermen, may accompany the seismic vessel in order to monitor the immediate area for active commercial fishing vessels and thereby minimize potential conflict between the seismic survey activities and commercial fishing activities through good communication.

Communication Between Operators and Marine Users

Where more than one survey operation is active in a region, the operator(s) should arrange for a ‘Single Point of Contact’ for marine users to facilitate communication. The operator should publish a Canadian Coast Guard ‘Notice to Mariners’ and a ‘Notice to Fishers’ via the CBC Radio program Fisheries Broadcast.

Compensation for Gear and Vessel Damage

In case of accidental damage to fishing gear or vessels, the operator will implement damage compensation plans to provide appropriate and timely compensation to any affected fisheries participants. The operator will follow the procedures employed successfully in the past for documenting any incidents. Procedures must be in place on the survey vessels to ensure that any incidents of contact with fishing gear are clearly detected and documented.

Other Mitigations

The Laurentian Subbasin SEA (C-NOPB and C-NSOPB 2003), Orphan Basin SEA (C-NOPB 2003) and the TGS-NOPEC 2002 EA (Canning and Pitt 2002) listed other mitigations including:

- Minimization of airgun source level to one practical for the survey
- Compliance with all applicable regulations concerning discharges

Planning Implications

Special mitigation measures may be required to reduce impacts in areas such as the Cape St. George Cod Spawning Area, lobster spawning and nursery areas, and herring spawning areas, and will be determined in consultation with regulatory agencies. Mitigations could include timing restrictions for seismic surveys to avoid sensitive life stages of Atlantic cod, lobsters and other relevant species.

4.1.5.7 Data Gaps

Data gaps specific to seismic exploration include the lack of sound measurement and modeling in the Western Newfoundland and Labrador Offshore Area Study Area. Sound measurements and modeling may be useful in impact assessment and in designing mitigations.

Data gaps specific to the marine fauna groups potentially affected by seismic operations are numerous. The fauna of greatest concern would vary depending on the location of proposed exploration activities. Data gaps relating to marine fauna include information on the general biology and distribution as well as information on the specific effects of seismic energy on the animals.

4.2 Routine Exploratory/Delineation Drilling and Production Activities (Non-Sound Issues)

4.2.1 Drilling Activities

Drilling is conducted by the oil and gas industry for three main reasons: (1) to confirm the presence of petroleum subsequent to geophysical surveys, (2) delineate the resource, and (3) during production to increase access to the resource. The first two can be considered exploratory and the third production drilling. They all involve similar equipment and activities and thus no real distinction is made in the description and discussion that follow. Drilling and testing the typical exploration well on the shelf may take about 40 days for drilling and an additional 20 days for testing if hydrocarbons are found.

At present, every exploratory drilling program on the East Coast is subject to a site-specific environmental assessment (EA) under the *Canadian Environmental Assessment Act* (*CEAA*).
Typical issues addressed in site-specific EAs include:

- Noise generated by well site geohazard or vertical seismic profiling (VSP) surveys (i.e., small scale seismic of short duration), drill rig machinery, supply vessels, and helicopters
- Effluents and emissions of the drill rig (e.g., sanitary, grey water, mud and cuttings, etc.)
- Accidental events (e.g., blowouts and spills)
- Well abandonment activities

Normally if there any concerns with offshore drilling, they tend to revolve around the disposition of mud and cuttings on the sea floor, discharge and disposal of cuttings from onshore to offshore directional drilling activities, accidental events such as spills or blowouts, and disturbance of marine birds and mammals, if the area is deemed to be an important area for these species. To date, all EAs for drilling have predicted that any environmental effects will be not significant with the possible exception of a major oil blowout (e.g., Petro-Canada 1996; Husky 2000, 2002, 2003; LGL 2005, and others). In the case of offshore West Newfoundland, additional issues will likely concern aesthetics (i.e., effects on viewscapes) and nearshore oil spill impacts because of the importance of the tourist industry there and the proximity to shore of at least some potential developments. Onshore to offshore drilling operations are considered to be safer from an environmental effects perspective compared to drilling in the offshore.

The following sections provide a brief description of typical exploratory drilling equipment, procedures and activities.

4.2.1.1 Drill Rigs

Worldwide, there is a wide variety of drill rigs in common use. The offshore drill rig usually contains the drilling equipment, working and living quarters and is serviced by helicopters and supply vessels.

To date, the most common drill rig on the Grand Banks has been the semi-submersible (e.g., the *Glomar Grand Banks*) (Figure 4.4). Semi-submersibles are normally anchored but some can be dynamically positioned without anchors. Most of Hibernia's drilling is conducted from the concrete, gravity base structure (GBS) that also houses the production facilities. (Figure 4.5) In Nova Scotia, 'jack-up', bottom-founded rigs have been typical and this type of rig has been used on the west coast of Newfoundland (Figure 4.6). This rig type has been recently approved for the Grand Banks under certain conditions (e.g., ice-free season) and was drilling there in 2005. As drilling moves into deep water off the continental shelf there will be a trend toward semi-submersibles or drill ships.

The widest variety of drilling equipment occurs in the Gulf of Mexico where offshore drilling has been conducted since the 1940s over thousands of wells and ranges from drilling barges in very shallow water (i.e., a few metres), bottom-founded and jack-ups at moderate depths, semi-submersibles in deeper water and drill ships in very deep water (a few thousand meters). There are also multi-use platforms that can drill, produce and service wells.

Any of the above-mentioned rig types could be used on the west coast depending upon the water depth, proximity to land, nature of the resource, and other factors.

Another drilling scenario relevant to the west coast is directional drilling from land. This approach is presently only feasible if the resource is close to shore but the technology has already been used on the Port au Port Peninsula on the west coast of Newfoundland (e.g., Shoal Point K-39, Long Point M-16, Long Range A-09). To date, only conventional rotary drill rigs have been used for the directional drilling on the west coast. Coil tubing drilling is another technology being applied to directional drilling but to date has not been employed on the west coast (D. Hawkins, C-NLOPB, pers. comm., W. Foote, Government of Newfoundland and Labrador, pers. comm.). Hibernia has directional drilled (i.e., horizontal or deviated) at least as far as about six kilometres from the GBS and the technology is capable of at least 10 km (CAPP 2001a).

There may be some minor differences between and within rig types in terms of capabilities, treatment facilities, effluent discharge depths, and so forth but, for the most part, each rig is fairly 'typical' in terms of characteristics, volumes and types of discharges. All must conform to the *Offshore Waste Treatment Guidelines* (*OWTG*) (NEB et al. 2002). Rig types do differ in terms of the noise emitted with dynamically positioned drill ships being the noisiest and the 'jack-up' being the quietest.

Drill mud handling is an important duty of the rig (see below). Other equipment and material includes casings, cement to bond the casings, risers and blowout preventers (BOP).

Figure 4.4. Semi-submersible Drill Rig *Glomar Grand Banks*.

Figure 4.5. *Hibernia* GBS.

Figure 4.6. ***Rowan Gorilla*** **Jack-up Rig.**

4.2.1.2 Drill Muds

Drilling mud is needed to convey drill cuttings out of the hole and to keep formation fluids from entering the well. Hibernia re-injects some of their cuttings but this approach is not presently feasible for the single offshore exploratory wells using existing drilling units on the East Coast. The re-injection of cuttings is more feasible with fixed platforms than floating platforms, and is also dependent on the site-specific geography.

All exploratory drilling on the East Coast is conducted using either water-based drilling muds (WBM) or synthetic-based muds (SBM). Drilling on the west coast of Newfoundland has used mostly WBM although sections of the onshore to offshore directionally drilled wells have required the use of SBM (D. Hawkins, C-NLOPB, pers. comm., W. Foote, Government of Newfoundland and Labrador, pers. comm.). It is debatable which type is more or less ‘environmentally friendly.’ For example, it can be argued that WBM is better because it is mostly water and cannot form sheens on the surface whereas some types of SBM may form one under very calm conditions. On the other hand, SBM generally stays closer to the well site and does not disperse as widely as WBM. In the case of onshore to offshore operations, drilling fluids are stored in tanks at the rig site and eventually trucked to lined pits/containment areas for storage (D. Hawkins, C-NLOPB, pers. comm., W. Foote, Government of Newfoundland and Labrador, pers. comm.). All drilling fluids should be handled and treated in accordance with C-NLOPB policies, the *OWTG*, and any applicable provincial regulations.

After installation of the initial casing strings, the riser provides a conduit from the seabed to the rig that takes the drilling mud and cuttings back to the surface mud system. Once on board the rig, the drill cuttings are removed from the mud in successive separation stages and discharged. Drill mud is expensive and therefore as much mud is recovered as possible but some mud remains with the discharged cuttings. At several stages during drilling and at the end of the drilling process, some WBM is discharged.

The main component of WBM is either fresh water or seawater. The primary WBM additives include bentonite (clay) and/or barite. Other chemicals such as potassium chloride, caustic soda, soda ash, viscosifiers, filtration-control additives and shale inhibitors are added to control mud properties. Low toxicity chemicals are used for the water-based drilling mud to reduce the effect on the environment.

From the top down, a typical exploratory hole involves a conductor, surface and progressively smaller casings, perhaps as many as five. Mud and cuttings cannot be returned to the rig until the surface casing is in place and thus mud and cuttings from the conductor and surface parts of the hole are initially discharged directly to the seabed. Once the surface casing is complete, the risers are installed, and the mud and cuttings are returned to the rig through a closed system for recycling and cleaning before cuttings and any residual mud are discharged. The discharge is treated and exits via shute below the water's surface, subject to Board approval. The mud and cuttings are dispersed in the water column and settle on the sea floor with the heavier particles near the hole and the fines at increasing distances from the rig. The pattern of dispersal can be very irregular and in some cases it is difficult to find obvious signs of drilling after a year or so; in sheltered situations with little bottom circulation, cuttings piles may last for some years.

The conductor setting depth is site-specific and subject to Board approval but a typical depth on the Grand Banks might be about 250-m as measured from the rotary table (i.e., MD). The typical surface casing setting depths may be on the order of 1,200-m MD. Estimated volumes of water-based mud and cuttings discharges associated with initial casings for a typical Grand Banks (White Rose area) well are shown in Table 4.1. It should be noted that the mud/cuttings from the production casing phase are passed through the solids control system that consists of shale shakers and centrifuges.

Drilling muds and cuttings, and their potential effects were discussed in detail in the White Rose Comprehensive Study (Husky 2000) and Supplement (Husky 2001). Modeling of the fate of drill mud and cuttings discharges was conducted for the White Rose EA. The White Rose EA analyzed the effects of the discharge of drilling wastes from development drilling of 25 wells using SBM at multi-well drilling sites. As such, the White Rose scenario can be considered a 'much worse case' than the exploratory drilling of one individual well. The White Rose development drilling was deemed to create no significant effect on fish and fish habitat, the fishery, seabirds, marine mammals, or sea turtles. Additional relevant documents not available during the White Rose EA include MMS (2000); CAPP (2001a,b), NEB et al. (2002), the White Rose baseline studies (Husky 2001, 2003), and Husky exploratory drilling EAs (Husky 2002, 2003; LGL 2005) all of which discuss the discharge of mud and

Table 4.1. Typical Mud Components and Cuttings Discharge Volume for a Grand Banks Exploration Well.

	Unit	Casing Strings			
		Conductor	**Surface**	**Main**	
Hole Section	inch	36	16	12 1/4	Notes: 1. Three scenarios were taken into account. The 12 ¼" hole section varies in depth with each scenario. 2. 36" and 16" hole sections–Near seabed discharge. 3. WBM used for complete well. 4. All depths are measured below rotary table (brt). The rotary table is 145-m above the seafloor.
DF System		Gel/SW	Gel/SW	WBM	
Depth (See Note 4)	Meter (brt)	220	1200	3600	
Volume Usage	bbl	897	4199	5246	
Wash Out	%	50%	30%	10%	
Products					
Barite	MT		58	115	
Bentonite	MT	16	65		
Calcium Carbonate	kg				
Caustic	kg	116	482	138	
Fluid Loss Agent	kg			2385	
Inhibitor	kg			4769	
Fluid Loss Agent	kg			9538	
Potassium Chloride	kg			100153	
Lime	kg	116	482		
Glycol Inhibitor	L			25024	
Soda Ash	kg	116	482	238	
Viscosifier	kg			3577	
Biocide	L			72	
Drilled Cuttings	kg	192032	429562	521786	
Volume of Cuttings	m^3	74	165	201	

Source: Husky (2003).

cuttings and associated effects. These recent reports have further confirmed the conclusions of the White Rose work that routine drilling, particularly small scale drilling, has no significant effect on the marine environment of the Grand Banks. The salient points are briefly summarized in the two following sections.

Water-Based Muds

In recent years, most shallow exploratory wells on the East Coast have been drilled with WBM unless unexpected, difficult or highly deviated conditions are encountered and then, with the approval of the Board, they may use SBM (discussed in a following section). Composition of one typical WBM formulation for an exploratory program is shown in Table 4.1.

The following points are relevant to the discharge of WBM and cuttings.

- WBMs are essentially non-toxic. The main component of WBMs is seawater and the primary additives are bentonite (clay), barite and potassium chloride.
- Chemicals such as caustic soda, soda ash, viscosifiers, and shale inhibitors are added to control mud properties. All constituents are normally screened using the *Offshore Chemical Selection Guidelines* (NEB et al. 1999).

- Discharge of WBM and associated cuttings is regulated by the C-NLOPB. Spent and excess WBM and cuttings can be discharged without treatment (NEB et al. 2002).
- The discharge of WBM may increase metals in sediments such as barium, arsenic, cadmium, copper, mercury, lead, and zinc, generally within 250 to 500-m of the drill site but occasionally farther (usually zinc and sometimes chromium) depending upon mud volumes and environmental conditions. However, these metals are not in a bioavailable form and few if any biological effects have been associated with these increases in metals from drill rig discharges (CAPP 2001b).
- The primary effect of WBM appears to be smothering of benthos in a small area near the hole. The exact area of effect cannot be predicted because of variable coverage and animals' reactions range from simply avoiding the immediate area of deposition to direct mortality of sessile organisms. Nonetheless, the White Rose EA indicated a worst-case scenario of an area of less than 1-km^2 around each well would have a depth sufficient to result in some smothering (Husky 2000, 2001). The exploratory drilling for one well would be well below the worst-case scenario used for the White Rose EA. The benthos can be expected to recover in anywhere from several months to several years (and most likely within one year) after the drilling ceased, based upon the published literature (reviewed in Husky 2000, 2001; MMS 2000; CAPP 2001b). Actual monitoring data from other operators indicate that the actual area of smothering appears to be much less than predicted (Fechhelm et al. 2001; JWEL 2001; 2002).

Synthetic-based Muds

Synthetic-based muds (SBM) may be used in an exploratory program especially for long horizontal reach drilling (e.g., onshore to offshore) or in very deep water. Synthetic muds were developed to replace oil-based muds which were considered toxic to varying degrees and which appeared at least partially responsible for the longevity of cuttings piles. In general, SBM is essentially non-toxic, has the potential to biodegrade relatively rapidly (perhaps too rapidly under certain conditions creating some localized anoxic conditions), and less mud is required than for WBM for the same distance drilled. SBM tend to 'clump' cuttings together more than WBM thus SBM cuttings tend to disperse less and fall closer to the rig.

The following points concerning SBM are relevant to an exploratory drilling program EA on the west coast.

- For multiple wells, biological effects have been attributed to smothering under the patches of mud/cuttings from physical and/or chemical (i.e., anoxia caused by rapid biodegradation) conditions (e.g., EPA 2000).
- SBMs have been handled in a number of ways including shipping to shore, injection, and discharge. The feasibility of injection depends upon type of rig (i.e., usually only with certain bottom-founded rigs) and local geology.

- In the deepwater (500+-m), Gulf of Mexico, organic enrichment with attendant increases in biota, including fishes and crabs, has been reported after a two year multi-well drilling program (Fechhelm et al. 2001). No large cuttings piles were observed by ROV during that study.
- Biological effects are not normally found beyond about 250-500-m from the drilling platform (Husky 2000, 2001, 2002, 2003; MMS 2000; CAPP 2001b; Buchanan et al. 2003; Hurley and Ellis 2004; LGL 2005). The Husky EAs (White Rose, Jeanne d'Arc Basin, and South Whale Basin) concluded a total area of impact of less than 1-km^2 from multi-well drilling based upon a modeling exercise and published literature. It can reasonably be expected that a single exploratory well would affect a much smaller area.
- In the event that SBM must be used, the cuttings are treated prior to discharge in accordance with the *OWTG* (NEB et al. 2002). All discharges are subject to approval by the Boards and discharge of whole SBM is not permitted. The limit at present is 6.9% synthetic fluid on cuttings.

There are numerous synthetic fluid drilling systems. Petro-Canada has had good results with the very low toxicity, odour-free PureDrill IA-35 (Williams et al. 2002). Its formulation is contained in Table 4.2.

Table 4.2. Composition of the SBM PARADRIL-IA.

Component	**Purpose**
PureDrill IA-35	Base Fluid
NOVAMULL L	Primary Emulsifier
NOVAMOD L	Rheology Modifier
NOVATHIN L	Thinner
MI-157	Wetting Agent
HRP	Rheology Modifier
TRUVIS	Viscosity
VERSATROL	Filtration Control
ECOTROL	Filtration Control (Alternative)
LIME	Alkalinity
CALCIUM CHLORIDE	Salinity
WATER	Internal Phase
BARITE	Density

Source: Williams et al. (2002).

4.2.1.3 Vertical Seismic Profiles and Geohazard Surveys

A checkshot survey is required by the C-NLOPB for all exploration and delineation wells. The Board, in conjunction with the Operator, may request a vertical seismic profile (VSP) where it would contribute to resolving uncertainty associated with seismic interpretation. A sound source (airgun array, typically smaller than that used for seismic surveys) is deployed from the rig or supply vessel. Receivers are located in the water and within the well. The sound source is located at a fixed distance from the wellhead from as close as possible to as distant as 2.0-km. Surveys typically run from about 8 to 36 hours, although they may run as long as a week, and procedures require approval by C-NLOPB.

Shallow geohazard surveys are conducted prior to drilling to determine the potential for hazards such as slope instability or shallow gas. These surveys may consist of multi-beam sonar, side scan sonar, bottom sampling and/or video and a small seismic array.

Typical mitigations include ramp-ups and a safety zone for marine mammals and sea turtles. Refer also to the *Guidelines for Geophysical Surveys* (C-NOPB 2004).

4.2.1.4 Well Abandonment

Offshore exploratory wells are abandoned and decommissioned by removal of the wellhead and mechanical severance one metre or so below the mudline. If mechanical severance is not possible then a small shaped charge may be detonated below the mudline. Well termination programs require approval from the C-NLOPB and will include mitigations such as marine bird, turtle, and mammal monitoring to maintain a safe ‘stand-off’ distance. Also, careful attention should be paid to the shape and size of the charge.

4.2.1.5 Discharge of Other Fluids and Solids

Other fluids associated with the drilling include cement slurry and BOP fluid. Mitigations include careful selection and use of chemicals in order to minimize any potential toxic effects.

Based on experience with previous exploratory wells, approximately 33-t (26.4-m^3) of excess cement may be released to the marine environment per well (Husky 2000), and may smother or displace some benthos locally. If the cement remains in a pile, it will act as an artificial reef, be colonized by epifaunal animals and attract fish. The effects (either negative or positive) of the cement on benthos are likely negligible.

Blowout preventer (BOP) fluid is used in the blowout preventer stacks during drilling. The fluids are normally glycol-water mixes. Periodic testing of the blowout preventer is required by regulation. On semi-submersibles, approximately 1-m^3 of the fluid is released per test; jack-up rigs do not release BOP fluid. In any event, periodic releases of this small amount of glycol likely have a negligible effect on marine biota.

If produced water is encountered during flow testing, then it is either treated prior to discharge, atomized in the flare, or disposed of on shore.

Concerns about birds and mammals are normally related to accidental events and/or the perceived importance of a particular area. For example, bird (particularly petrels) attraction to rigs was an issue during both Terra Nova and White Rose hearings because the areas are known to support large numbers of petrels, which may be particularly sensitive to this type of disturbance. Similarly, noise of drilling and support activities may be an issue near known concentrations of whales (e.g., bottlenose whale population in the Gully, offshore Nova Scotia). Sensitive areas and times on the west coast are detailed in Section 3.0.

Other discharges and emissions of potential concern are galley and sanitary waste and air emissions.

4.2.2 Production

Production infrastructure and activities on the west coast, of course, will only occur if commercial quantities of oil and/or gas are discovered and all permits and approvals (including a review under the *Accord Acts* and the *Canadian Environmental Assessment Act*) can be successfully obtained. Based on the history of East Coast offshore developments to date, from the time a discovery is made to the submission of a development application can take over ten years. Given that the production scenarios will vary drastically with technologies and regulations current at the time of development, the type, quantity, and location of the resource, only general information can be provided at this time.

4.2.2.1 Platform Types

Production platform types in use on the East Coast include Hibernia's concrete GBS, the Terra Nova and White Rose FPSOs (floating production, storage and offloading), and leg or jacket structures (e.g., Sable Offshore Energy Project) (see Figures 4.4 to 4.6). The GBS sits on the bottom and is a more or less permanent structure that drills and maintains wells; gathers the petroleum, processes and separates water, sand, gas and oil, and stores it for subsequent offloading. The FPSO is anchored, revolves on a turret, and performs all the production and storage functions except the drilling and maintaining of production wells. The jacket structures are anchored to the bottom with pilings driven into the seabed, and in the case of offshore Nova Scotia, gather and produce the gas, which is subsequently transported to shore via underwater pipeline.

All of the above systems contain accommodations and topsides processing facilities and are supported by supply vessels and helicopters. Any of these systems could be used on the west coast depending upon the specific development scenario. Other potential development systems could include barge-mounted, subsea, or land-based facilities, or various combinations of any of the above, including numerous pipeline configurations.

4.2.2.2 Discharges and Emissions

Discharges and emissions associated with production usually include:

- Produced water
- Air emissions
- Domestic and sanitary waste

- Cooling water
- Noise
- Light

During production petroleum must be separated from water which results in increasing amounts of produced water as the well ages. The composition of produced water varies greatly by well and age of well and may contain a wide variety of chemicals, including hydrocarbons, from the formation plus additives such as biocides. The discharge of produced water is regulated by the *OWTG*. It may not be particularly toxic as determined by routine toxicity testing or through environmental monitoring (in fact it is often difficult to locate the plume). Nonetheless, there is concern because of the potential light hydrocarbon content and often (but not always) the sheer volume of discharge.

It is difficult to “typify” produced water because it differs by well, region, age of well, and other factors. Some composition data from the North Sea is contained in Table 4.3 (from Røe and Johnsen 1996).

Air emissions during production originate from flaring, fugitive emissions from storage tanks, generator exhaust, support vessel exhausts, helicopter exhaust, and so forth. To date, air emissions from the East Coast offshore have not been of particular concern because of the distance from human settlement, the relatively small number of developments, the prevailing westerly winds, and generally strong mixing and dispersion in the windy offshore environment. However, with increasing societal focus on greenhouse gas, prevailing onshore winds, and potential proximity to land, air emissions may be a larger issue on the west coast than on the east coast of Newfoundland.

Domestic and sanitary waste originates from perhaps 50-100 personnel on a production facility. These discharges can be mitigated to a negligible effect level and thus should be of little concern in most situations.

Water is used to cool equipment and the cooling system may be closed (no discharge) or open (discharge), and may or may not contain biocides such as chlorine. Any concern is usually related to volume and temperature differentials between the effluent and the receiving water.

Broadband noise is generated by production machinery, support vessels, and aircraft. Any concerns are related to the source levels of the noise, the frequencies, and the proximity to sensitive species such as certain species of marine mammals.

As with drill rigs, lights may attract certain species of birds which may then become stranded on the rig. On the Grand Banks, storm petrels appear to be the most sensitive group in this regard because once grounded, they have difficulty becoming airborne again. Programs are presently undertaken by operators to gently capture, hold and release petrels that become stranded (Williams and Chardine nd).

Table 4.3. Chemical Composition of Produced Water from Norwegian North Sea Platforms.

Fields	Unit	Statfjord	Gullfaks	Ekofisk 2/4B-K	Ekofisk 2/4T	Tor	Ula
Compounds							
TOC	mg/l	850	61	180		85.5	71
THC	mg/l	15	35				50
Sum Aromatics	mg/l	6.00	9.56	5.67	66.95		15
BTX	mg/l	4	5	5.41	66.90	1.1	12
Naphthalenes	mg/l	0.942	2.16	0.247	0.052	0.597	
Naphthalene	mg/l	0.261	0.398	0.157	0.038	0.073	
C1-naph	mg/l	0.35	0.629	0.062	0.012	0.17	
C2-naph	mg/l	0.199	0.584	0.018	0.002	0.204	
C3-naph	mg/l	0.132	0.55	0.010	0.0005	0.155	
Phenanthrenes	µg/l	45	90	6.26	0.28	135	
Phenanthrene	µg/l			2.09	0.08		
C1-phenanthrene	µg/l			2.43	0.12		
C2-phenanthrene	µg/l			1.74	0.08		
C3-phenanthrene	µg/l			n.d.	n.d.		
Dibenzothiophenes	µg/l	8.6	22.7	1.39	0.15	10	
Dibenzothiophene	µg/l			n.d.	n.d.		
C1-dibenzothiophene	µg/l			1.39	0.03		
C2-dibenzothiophene	µg/l			n.d.	0.12		
C3-dibenzothophene	µg/l			n.d.	n.d.		
Sum NPD	µg/l	1.00	2.27	0.254	0.055	0.74	
Acenaphtylene	µg/l			0.89	0.02		
Acenaphthene	µg/l	0.001	0.001	n.d.	0.04	0	
Fluorene	µg/l	12	11.3	n.d.	0.33	8.1	
Fluoranthene	µg/l	0.0854	0.195	n.d.	n.d.	0.24	
Pyrene	µg/l	0.0897	0.194	n.d.	0.08	0.42	
Chrysene	µg/l	0.226	0.398			0	
Benz(a)anthracene	µg/l	0.0193	0.311	n.d.	n.d.	0.23	
Benzo(a)pyrene	µg/l	0.001	0.001	n.d.	n.d.	0	
Benzo(ghi)perylene	µg/l	0.001	0.001	n.d.	n.d.	1.35	
Benzo(k)fluoranthene	µg/l	0.0197	0.0528	n.d.	n.d.	0.016	
Sum PAH 3-6 ring	µg/l	66.04	125.15	0.89	0.47	155.36	
Sum phenol	mg/l	8.3	2.7	1.03	2.65	3.62	0.09
Phenol	mg/l	5.1	0.8	0.61	0.97	2.19	0.033
C1-phenol	mg/l	2.5	0.86	0.19	0.83	1.1	0.028
C2-phenol	mg/l	0.4	0.6	0.14	0.57	0.254	0.02
C3-phenol	mg/l	0.13.	0.18	0.06	0.26	0.0316	0.0006
C4-phenol	mg/l	0.026	0.1	0.03	0.02		
C5-phenol	mg/l	0.016	0.065	n.d.	n.d.		
C6-phenol	mg/l	0.013	0.11	n.d.	n.d.		
C7-phenol	mg/l	0.005	0.012	n.d.	n.d.		
Sum organic acids	mg/l	895	55	323	577	234	
Formic acid	mg/l			148	275		
Acetic acid	mg/l	732	15.6	132	267	104	9.5

Table 4.3 Concluded.

Propionic acid	mg/l	106	8.9	35.2	27.4	10	1.2
Butylic acid	mg/l	39	14.1	6.35	5.18		1.5
Valeric acid	mg/l	18	8.2	1.61	2.17		0.6
Caprioic acid	mg/l	9	8.2	n.d.	0.09		
Organic acids > C6	mg/l			n.d.	n.d.		
Methanol	mg/l			6.3	33.9		
Salinity C1-	mg/l			30400		90500	40440
Amonium	mg/l	25.4	26.9				0.1
Lead	µg/l	50	50	n.d.		80	270
Copper	µg/l	2	2	20		600	20
Iron	mg/l			4		8.9	23
Barium	mg/l			28.2		42.1	12
Cr-VI	µg/l	10	10	6		0.08	40
Mercury	µg/l	1.9	1.9	n.d.			9
Zinc	µg/l	6.8	13	13		200	0.26
Cadmium	mg/l	10	10	n.d.			0.02
H2S	mg/l	0.12	0.17				
Total radioactivity	Bql						
40K	Bql						
226Ra	Bql						

Source: Røe and Johnsen (1996).

An exploration well is drilled first to determine if ‘traps’ identified by seismic surveys contain oil, and then if hydrocarbons are found, delineation drilling may be conducted to define the size and shape of the reservoir. The activities and discharges are essentially the same and they are both defined as exploration activity under the *Newfoundland Offshore Petroleum Drilling Regulations* and thus they are considered together here as the same activity.

Offshore drilling has been occurring since the 1940s and thus the state of knowledge is reasonably advanced, including data on many of the direct and indirect effects on the environment. There have been some extensive baseline surveys, research studies and environmental effects monitoring studies conducted in the Gulf of Mexico (e.g., GOOMEX), the North Sea, and the Canadian East Coast (Scotian Shelf and Sable Island, Hibernia, Terra Nova and White Rose). While accidental oil and gas blowouts and spills are rare offshore, there is extensive information on their probabilities, fate and effects from the study of accidental events such as the Ixtoc blowout in the Gulf of Mexico, the Exxon Valdez tanker spill in Alaska, Ekofisk in the North Sea, and Uniake G-72 gas blowout off Nova Scotia, and others.

There are a number of potential concerns related to offshore activity ranging from the relatively minor ones such as galley waste to major ones such as large oil spills. Most of these concerns are now essentially eliminated by modern industrial, more or less standard, practices. Nonetheless, there are a number of outstanding and recurring issues and concerns on offshore exploratory drilling on the East Coast. Outstanding issues include:

- Area of benthos affected under different environmental conditions
- Attraction of birds such as storm-petrels (and potentially Dovekies) to the rigs
- Noise disturbance of marine animals, primarily whales
- Effects on little known sensitive deep sea fauna such as deepwater corals
- Effects of discharges on receiving environment
- Major blowouts or spills
- Cumulative effects

Disturbance to fisheries is an ever-present concern either directly through temporary displacement of activity due to the exclusion zone, loss or damage to gear, effects on marketability due to perception of taint in the event of a blowout, or indirectly through effects on plankton or benthos. To date, mitigations of communication and design of compensation programs have alleviated most of these concerns.

These issues are discussed further in following sections.

4.2.3 Ice Management

In areas subject to ice encroachment, operators are required to have an ice management plan in place. Typical elements of the plan include a description of the proposed ice management system for detecting, tracking, predicting movements of icebergs that may jeopardize the safety and integrity of the drilling operations (P. Rudkin, PAL, pers. comm.). Personnel duties, operational procedures and safety zones are described in the plan.

A drilling operator in the Western Newfoundland and Labrador Offshore Area will have access to some regional iceberg data but will essentially be responsible for collecting data relevant to their specific operations using a combination of rig-based radar, aerial and/or ship-based surveys, specialized software and personnel. Techniques available for altering iceberg behaviour include towing, ice cannons or propwash, operated by offshore supply vessels and crews experienced in ice management. In general, large icebergs are more amenable to towing than the small ones (Rudkin and Dugal 2000). Icebergs are not expected to be an issue in the Study Area whereas sea ice could be at certain times and locations.

4.2.4 Interactions and Potential Effects

4.2.4.1 Effects on Benthos

Drilling muds and cuttings, and their potential effects were discussed in detail in the White Rose EA/Comprehensive Study (Husky 2000) and Supplement (Husky 2001), Orphan Basin Exploratory Drilling EA (LGL et al.-in prep.), and Husky's Jeanne d'Arc Basin Exploratory Drilling EA (LGL 2005). Modeling of the fate of drill mud and cuttings discharges was conducted for the White Rose EA, for the Lewis Hill exploratory drilling EA (Husky 2003), and for the Orphan Basin Exploratory Drilling EA (LGL et al.-in prep). White Rose EA analyzed the effects of the discharge of drilling wastes from development drilling of 25 wells using SBM at multi-well drilling sites.

Additional relevant documents not available during the White Rose EA include MMS (2000), CAPP (2001b) and NEB et al. (2002), all of which discuss the discharge of mud and cuttings and associated effects. These recent reports have further confirmed the conclusions of the White Rose work. In addition, a number of presentations at a recent BIO workshop (26-30 May 2003) concerning the Gulf of Mexico, the North Sea, and the East Coast concluded that effects on benthos are generally confined to within 500 m of the drill rig (review presentation of Buchanan et al. 2003; Hurley and Ellis 2004; Armsworthy et al. 2005; Cranford et al. 2005).

4.2.4.2 Seabird Attraction to Rigs

Seabirds, particularly storm-petrels, are known to be attracted to offshore rigs on the East Coast, presumably due to attraction by light (Montevecchi et al. 1999; U. Williams, Petro-Canada, pers. comm.; D. Taylor, Husky, pers. comm.). Concern has been expressed during both Terra Nova and White Rose public hearings that this attraction could lead to mortalities if the birds flew into the flare, flew around the flare until exhausted, or collided with the rig. Dovekies have also been mentioned as a potential concern. This issue has recently been addressed on the Grand Banks by:

- Production and drilling installations in the Newfoundland and Labrador offshore area are involved in a seabird and marine mammal monitoring programs
- An ESRF-funded study to conduct seabird surveys from supply boats to provide some data on densities on vessel routes and near the drilling rigs
- An ESRF study on seabird and marine mammal monitoring protocols.
- An ESRF study on remote technologies for monitoring bird movements relative to the flare boom
- Programs undertaken by operators to gently capture, hold and release petrels that become stranded on offshore vessels or rigs (Williams and Chardine nd).

4.2.4.3 Effects of Onshore to Offshore Drilling on Marine Biota

Since the rig used in onshore to offshore drilling is located on land, there is potential for the drilling operations to interact with shorebirds and nesting seabirds and waterfowl. Identification of these habitats and knowledge regarding the timing of use of these habitats would allow operators to minimize impact on the birds through spatial and temporal scheduling mitigations. The probability of interaction between onshore to offshore drilling operations and other marine biota is negligible, particularly with the construction of an impermeable berm around the rig site.

4.2.4.4 Effects of Underwater Sound (Other than Seismic) on Marine Animals

All sound sources associated with exploratory/delineation drilling and production, and the potential effects of exposure to these sounds were discussed in Section 4.1 on ‘Sound’.

4.2.5 Mitigations and Planning

4.2.5.1 Drill Muds and Cuttings

Mitigation measures for the drilling include the selection of non-toxic or low toxicity chemicals and muds and treating any oil-contaminated cuttings to meet the *OWTG*. In addition to the treatment mitigations, drilling fluids produced by onshore to offshore directional drilling operations are typically stored temporarily in tanks at the rig site and then trucked to remote lined-pits for storage. The post-treatment non-toxic muds and cuttings are often put into a landfill. Hibernia now re-injects SBM-related cuttings as mitigation for production (not exploration) drilling. However, the Hibernia situation is atypical for the East Coast being a very large production development that does all its drilling from a centrally located gravity-base structure.

4.2.5.2 Potential Conflicts with Fisheries

Potential Effects

Routine exploratory and production activities could affect the commercial fisheries as a result of interference with fishing activities (caused by the presence of structures in the water and/or on the seabed, safety zones, ships and the use of seismic equipment during site profiling), behavioural effects on fish and invertebrates (caused by lights, or sound from drilling, vessels and vertical seismic profiling using airgun arrays and/or sonar), and physical effects on commercial species (from the placement of structures on fish habitat, and routine emissions and discharges, such as drilling muds and cuttings, produced water, greywater, deck drainage, etc). Behavioural and physical effects on fish and invertebrates are not discussed here. They were addressed in previous sections of the SEA (i.e., Section 4.1.5.1 on effects of sound and Section 4.2.4 on interactions and potential non-sound induced effects).

For drilling activities this SEA considers the following: (1) interference with fishing resulting from the presence of the drill rig, subsea hazards, and necessary safety zones; (2) changes in catch rates from sound-induced behavioural changes (changes in catch rates resulting from drilling-sound induced behavioural changes); and (3) interference owing to the presence of support vessels. Impacts related to possible VSP activities consider the following: (1) changes in catch rates from sound-induced behavioural changes (scaring) of fish caused by the sound source array; and (2) interference with fishing activities, particularly fixed gear, owing to gear/vessel conflicts.

It is also important to address potential effects of routine exploratory and production activities on stock assessments/DFO research activities, considering that they are used for the setting fishing quotas and exploration for new fisheries. Effects on assessment/research surveys would occur either as a result of behavioural responses, fishing interference or displacement, the same as impacts on commercial fish harvesting.

Mitigations

Communications/Notification

Fisheries representatives have frequently noted that good communication at sea is an effective way to minimize interference between offshore oil and gas exploration projects and fishing activities. Communications will be maintained (directly at sea by the rig and Project vessels) via marine radio to facilitate information exchange with fisheries participants. Relevant information about the rig locations, the safety zone and other relevant operations will also be publicized using established communications mechanisms, such as the *Notices to Shipping* (Continuous Marine Broadcast and NavTex) and CBC Radio's (Newfoundland and Labrador) *Fisheries Broadcast.*

Avoidance

With the information provided to the fishing industry, potential impacts on fishing (catch success as well as fishing gear interactions) can be mitigated by fishers avoiding the drilling locations and the designated safety zone. This area will be kept as small as feasible to ensure mutual safety and minimize interference with fishing activities.

Fishing Gear Interactions

Although there is typically very little fishing within the entirety of the Project Area, the great majority of the fish harvesting that does occur there (and in nearby waters) uses fixed gear, i.e., crab pots for snow crab. This poses more of a risk for gear conflict than does mobile gear.

In case of accidental damage to fishing gear, the operator will implement gear damage compensation plans to provide appropriate and timely compensation to any affected fisheries participants. The operator will follow the procedures employed successfully in the past for documenting any incidents.

Structures

As discussed, fishing (and other) vessels will not be able to enter a safety zone around the drill rig, and this information and the rig’s location will be publicized and communicated to the fishing industry. The typical safety zones for a semi-submersible is the anchor pattern plus 50 m. The typical safety zone for a jack-up rig is 500 m from the at-surface structure. Thus there should be no opportunity for conflict with fishing gear. Operators are required to check regulations regarding wellhead removal.

Survey Vessel Streamers

In previous surveys, concerns have been raised about seismic vessels or streamers becoming entangled with fishing gear, most specifically fixed gear (e.g., gillnets) if it is concurrent and co-locational with survey operations. In general, survey vessels will seek to avoid fishing gear in their path. Operators are required to have a gear compensation program in place to deal with any gear conflicts that may arise during program activities.

<u>Other Project Vessels</u>

Other project vessels, as well as the drill rig itself when in transit, will not pose a risk greater than other routine shipping and fishing vessels in the area. This study (and the fisheries maps) will help inform vessel operators of the likely locations of fixed fishing gear so that areas can be avoided. If other project vessels damage fishing gear, compensation will be assessed in accordance with the operator's gear compensation program.

DFO Research Surveys

Protocols to reduce interference between drilling activities and DFO research surveys must be established between the operator and DFO prior to the commencement of drilling activities.

4.2.5.3 Conflicts with Marine-associated Birds and Mammals

Concerns about birds and mammals are normally related to accidental events and/or the perceived importance of a particular area. For example, bird (particularly petrels) attraction to rigs was an issue during both Terra Nova and White Rose hearings because the areas are known to support large numbers of petrels, which may be particularly sensitive to this type of disturbance. It should be noted that while they are humane attempt to save individual animals impacted by oil, rehabilitation programs cannot be considered a form of mitigation for population recovery. Similarly, noise of drilling and support activities may be an issue near known concentrations of whales (e.g., bottlenose whale population in the Gully, offshore Nova Scotia). Section 4.1 discusses the interaction between industrial sound and marine mammals. Sensitive areas and times on the west coast are detailed in Section 3.0.

4.2.5.4 Planning Implications

Standard mitigative measures for routine exploratory/delineation drilling and production activities will be employed (see Section 5.4.3).

Planning considerations for VSP and wellhead severance include the standard mitigations and monitoring programs such as marine mammal monitoring and that acoustic or chemical explosives (e.g., during wellhead severance) are not to be released when marine mammals are within a certain distance from the energy source.

4.3 Accidental Events

Accidental events with potential for environmental damage offshore may range from small spills of fuels and chemicals (e.g., during loading or unloading), to medium spills of diesel fuel during a fuel tank rupture, to oil or gas blowouts. This section, based on work done by SL Ross for Husky (2003), addresses diesel fuel and oil blowouts as they are of most concern.

4.3.1 Blowout and Spill Probabilities

4.3.1.1 Blowout and Spill Probabilities

Two types of accidents that could occur during an exploratory drilling program are blowouts and "batch" spills. Blowouts are continuous spills lasting hours, days or weeks that could involve the discharge of petroleum gas into the atmosphere and crude oil into surrounding waters. Batch spills are instantaneous or short-duration discharges of oil that could occur from accidents on the drilling platforms where fuel oil and other petroleum products are stored and handled. The following sections provide estimates on the probability of these spills (based on SL Ross 2002a *in* Husky 2003).

4.3.1.2 Spill History of the Offshore Oil and Gas Industry

The industry of exploring, developing and producing offshore oil and gas has a relatively good record compared with other industries that have potential for discharging petroleum oil into the marine environment. The U.S. National Research Council (NRC 2002 *in* Husky 2003) indicates that accidental petroleum discharges from platforms contribute only 0.07% of the total petroleum input to the world's oceans (0.86 thousand tonnes per year versus 1,300 thousand tonnes per year - Table 4.4).

The spill record is particularly good for the U.S. Outer Continental Shelf (OCS) where 28,000 wells were drilled and over 10 billion (10^9) barrels[6] of oil and condensate were produced from 1972 to 2000. During that time, only ten blowouts occurred that involved any discharge of oil or condensate. The total oil discharged in the ten events was only 751 barrels.

Newfoundland and Labrador offshore operations are probably comparable from a safety viewpoint to operations in U.S. OCS waters and the North Sea (see Section 4.3.1.4).

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[6] The petroleum industry usually uses the oil volume unit of petroleum barrel (which is different than a US barrel and a British barrel). There are 6.29 petroleum barrels in one cubic metre (m^3). Most spill statistics used in this report are taken from publications that use the oil volume units of petroleum barrels.

Table 4.4. Best Estimate of Annual Releases [1990-1999] of Petroleum by Source.

	North America (tonnes x 10^3)	**Worldwide (tonnes x 10^3)**
Natural Seeps	**160**	**600**
Extraction of Petroleum	**3.0**	**38**
Platforms	0.16	0.86
Atmospheric Deposition	0.12	1.3
Produced waters	2.7	36
Transportation of Petroleum	**9.1**	**150**
Pipeline Spills	1.9	12
Tank Vessel Spills	5.3	100
Operational Discharges [Cargo Washings]	na[1]	36
Coastal Facility Spills	1.9	4.9
Atmospheric Deposition	0.01	0.4
Consumption of Petroleum	**84**	**480**
Land-Based [River and Runoff]	54	140
Recreational Marine Vessel	5.6	nd[2]
Spills [Non-Tank Vessels]	1.2	7.1
Operational Discharges [Vessels 100 GT]	0.10	270
Operational Discharges [Vessels <100 GT]	0.12	nd[3]
Atmospheric Deposition	21	52
Jettisoned Aircraft Fuel	1.5	7.5
TOTAL	**260**	**1300**

Source: NRC (2002) *in* Husky (2003).

1. Cargo washing is not allowed in U.S. waters, but is not restricted in international waters. Thus, it was assumed that this practice does not occur frequently in U.S. waters.
2. World-wide numbers of recreational vessels were not available.
3. Insufficient data were available to develop estimates for this class of vessels.

4.3.1.3 Spill Sizes

It is convenient to categorize spill sizes to correspond to statistical databases such as that maintained by the U.S. Minerals Management Service (MMS). The first category used here is “extremely large” spills, arbitrarily defined as spills larger than 150,000-bbl (23,800-m^3). The second and third categories are for “very large” and “large” spills, defined by the MMS as spills larger than 10,000 barrels (1590-m^3) and 1,000 barrels (159-m^3) respectively. The fourth category is for spills in the range of 50 to 999-bbl, and the fifth category is for spills in the 1 to 49-bbl category. The spill size classifications used here are summarized in Table 4.5. Note that the top three categories in the table are cumulative; that is, the large-spill category (>1,000-bbl) includes the very large and extremely large spills, and the very large category includes extremely large spills.

Table 4.5. Spill Size Categories.

Spill Category Name	Spill Size Range (in barrels)	Spill Size Range (in-m^3 and tonnes)
Extremely Large spills	>150,000-bbl	(>23,850-m^3 or >20,830-tonnes)
Very Large spills	>10,000-bbl	(>1590-m^3 or >1390-tonnes)
Large spills	>1,000-bbl	(>159-m^3 or >139-tonnes)
Medium spills	50 – 999-bbl	(7.95-m^3 - 158.9-m^3)
Small spills	1 - 49.9-bbl	(0.159-m^3 - 7.94-m^3)

4.3.1.4 Offshore Newfoundland

Spill frequencies for exploration units and development drilling/production units off Newfoundland are shown in Table 4.6. Here, both exploration and development wells were used to normalize the spill numbers. Small-spill frequencies will inevitably decrease over time as operators on the Grand Banks gain experience, as suggested by the experience in the Gulf of Mexico (Husky 2003).

Table 4.6. Platform Spills[1], Offshore Newfoundland, 1997-2000.

Spill Size	Number of Spills[3]	Spills Per Wells Drilled[2]
0 to 1.0-bbl	22	0.55
1.1 - 9.9-bbl	8	0.20
10.0-49.9	1	2.5×10^{-2}
50.0-499.9	0	0
500.0-999.9	0	0
1,000-bbl and greater	0	0

[1] Oil spills includes crude oil and refined petroleum products.
[2] Based on 40 exploration and development wells drilled from 1997 to 2000.
[3] Spill and well data provided by C-NOPB, March/April 2001.

In summary, large spills and blowouts are now very rare for offshore U.S. and the North Sea, and the same record can probably be expected for the Western Newfoundland and Labrador Offshore Area.

Based on recent spill statistics (see www.cnlopb.nl.ca) for offshore Newfoundland, the number of spills per year from 1997 to 2004 ranged from 10 to 55, and averaged ~27 spills per year (Table 4.7). In all but one year (2002) considered here, the number of crude oil spills was much less than the number of spills of "Other Hydrocarbons" (e.g., diesel, hydraulic and lubricating oils, diesel, condensate, synthetic-based drilling fluid). Similarly, in most years, the largest volumes of hydrocarbons accidentally released were of "Other Hydrocarbons". In 1997-2004, total spill volumes per year ranged from 1731 L to 274,603 L (Table 4.7), and averaged ~43,339 L per year. The average total spill volume per year is skewed upwards by the relatively large volumes of crude oil (165,000 L) and synthetic-based mud (96,600 L) spilled during late 2004. Average volume of hydrocarbons spilled per year excluding 2004 is 10,301 L.

Table 4.7. Summary of Offshore Newfoundland Hydrocarbon Spills for 1997-2004, Subdivided by Crude and Other Hydrocarbon Spill Types. Data derived from statistics posted on www.cnlopb.nl.ca.

	Exploration and Production		
	Crude	Other hydro-carbons	Total
1997			
Number of spills	2	9	11
Volume spilled (L)	1004	727	1731
1998			
Number of spills	8	20	28
Volume spilled (L)	1045	4747	5792
1999			
Number of spills	19	28	47
Volume spilled (L)	1812	8423	10235
2000			
Number of spills	2	8	10
Volume spilled (L)	222	4701	4923
2001			
Number of spills	2	14	16
Volume spilled (L)	<6	5726	5732
2002			
Number of spills	15	11	26
Volume spilled (L)	10.5	12270.5	12281
2003			
Number of spills	5	20	25
Volume spilled (L)	11.7	31403.3	31415
2004			
Number of spills	12	43	55
Volume spilled (L)	166409	108194	274603
TOTAL 1997-2004			
Number of spills	65	153	218
Volume spilled (L)	170514	176191.8	346712

Note: "Other hydrocarbons" includes synthetic-based drilling fluid. 1 bbl = 159 L.

During 1997-2004, most hydrocarbon spills from offshore Newfoundland oil and gas structures occurred during development drilling and production vs. exploration drilling. Overall, in 1997-2004, there were 35 spills totaling 5508 L during exploration drilling and 183 spills totaling 336,803 L during development drilling and production (Table 4.8). However, these data have not been standardized to account for amount of drilling activity.

Table 4.8. Summary of Offshore Newfoundland Hydrocarbon Spills for 1997-2004, Subdivided by Exploration Drilling vs. Development Drilling and Production. Data derived from statistics posted on www.cnlopb.nl.ca.

	1997-2004		
	Crude Oil	Other hydro-carbons	Total
Exploration Drilling			
Number of spills	17	18	35
Volume spilled (L)	1471	4037	5508
Develop. Drilling & Prod.			
Number of spills	48	135	183
Volume spilled (L)	167728	169075	336803
TOTAL			
Number of spills	65	153	218
Volume spilled (L)	169199	173112	342311

Note: "Other hydrocarbons" includes synthetic-based drilling fluid. 1 bbl = 159 L.

4.3.2 Fate and Behaviour

Oil releases in the marine environment from a spill or blowout may have quite different behaviours, depending upon the depth and size of the blowout, physical and chemical characteristics of the petroleum, physical environment, season, and so forth. The behaviour of a deepwater blowout can be quite complex and oil may surface some distance from the well, if at all. Diesel fuel is more immediately toxic in the marine environment, particularly to plankton, than an oil or gas release but it dissipates quickly in the offshore environment (e.g., sinking of *FV Katsheshuk* containing 200,000 litres of diesel that created a 1,300 m^2 slick off Cape St. Francis, NL in 2002; while there were some murres that likely succumbed to the spill there were no large scale bird mortalities reported to government).

A number of physical characteristics that enhance the biodiversity of the Study Area may, at the same time, potentially increase the adverse effects of an accidental event. As indicated in Section 2, ocean currents in the Gulf of St. Lawrence flow in a counter-clockwise direction while winds blow predominantly onshore along the western Newfoundland coast in the Study Area. Considering the enclosed nature of the Gulf of St. Lawrence combined with the cyclonic current flow and predominant onshore winds, there is a high probability that an accidental event would result in oil reaching the Study Area shoreline. Pack ice could potentially complicate efforts of oil spill remediation in the Study Area.

Modelling of potential oil spill trajectories was conducted for Newfoundland Hunt Oil Company Inc.'s Exploration Licence No. 1009, St. George's Bay A-36 (Davidson and Pinhorn 1995). This well is located off the Port au Port Peninsula at 48º 25' 05''N, 59º 19' 29''W, less than 10 km southwest of Cape St. George. The oil from the western Newfoundland that has been examined to date is a lighter crude than that encountered on the Grand Banks (51º API) (Newfoundland and Labrador Oil and Gas Report, March 2005). In Canada, crude oil is classified as either light oil (> 25.7º API) or heavy oil (< 25.7º API). These values measured in degrees refer to the oil's gravity as measured by the American Petroleum Institute (API) Scale (www.centreforenergy.com).

Modelling results were produced for the period of April to January, based on 30 years of available wind data. Wind was assumed to be the dominant advective force which would drive the displacement of oil slick from the spill site. This assumption was based on previously assembled knowledge of the rather weak nature of the residual surface currents in the area. The monthly probability plots produced by the modelling indicated a general northeastward slick movement. Results indicated a 50 to 100% probability that oil would reach the western tip of the Port au Port Peninsula in all months included in the model (i.e., April to January). Results indicated a 20 to 50% probability that oil would reach much of the southern and northwestern shore of the Port au Port Peninsula, and the southeastern shore of St. George's Bay in all months included in the model (i.e., April to January). The heads of St. George's Bay and Port au Port Bay were not touched by the oil in any of the monthly scenarios. Probability plots were most widespread in April, May, November and December (as far north as Parson's Pond in 4Rb). In all months, there was a 3 to 5% probability that the oil would reach shore north of Port au Port Bay (Davidson and Pinhorn 1995).

Reviews of the fate and behaviour of Grand Banks hydrocarbons are contained in Mobil (1985), Petro-Canada (1996), Husky (2000, 2001, 2002, 2003), and those of Nova Scotia in LGL et al. (2000).

4.3.3 Interactions and Effects

In this section, interactions between accidental spills and VECs and subsequent potential effects are discussed for the scenarios described in the preceding sections.

Interaction of coastal bird habitats and areas sensitive to oil contamination occur where areas are islands, archipelagos and/or in direct contact with the coastal ocean environment. In other words, estuarine components of habitats such as Grand Codroy, Stephenville Crossing and St. Paul's Inlet are less likely to be directly impacted because of isolation from the ocean by the bar lagoon; or alternatively contamination of such sites can be more easily contained because of narrow 'gut' through which the tidal waters move.

Outer beaches are vulnerable to oil contamination and this would implicate most of the critical habitats used by the *endangered* Piping Plovers. The offshore islands that receive extensive use as nesting habitat by terns and eiders in such areas as St. Paul's Inlet and St. John Bay, and St. George's Bay with the unique concentrations of shorebirds and waterfowl at Sandy Point/Flat Bay Island, are very vulnerable to oil contamination.

In pelagic areas interactions of seabirds with spilled oil is a function of location and time of year. The overall densities of pelagic seabirds in the Study Area are relatively low hence the prediction for mortality in event of a spill would be relatively low.

4.3.3.1 Effects on Fish and Fish Habitat

There has been extensive study of the effects of oil spills on fish and fish habitat (e.g., Armstrong et al. 1995; Rice et al. 1996, and many others).

Juvenile and Adult Fish

There is an extensive body of literature regarding the effects of exposure to oil on juvenile and adult fish. Although some of the literature describes field observations, most refers to laboratory studies. Reviews of the effects of oil on fish have been prepared by Armstrong et al. (1995), Rice et al. (1996), and numerous other authors. If exposed to oil in high enough concentrations, fish may suffer effects ranging from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects. Actual effects depend on a variety of factors such as the amount and type of oil, environmental conditions, species and life stage, lifestyle, fish condition, degree of confinement of experimental subjects, and others. Based on laboratory toxicity studies, pelagic fish tend to be more sensitive (LC_{50}s of 1 to 3 ppm) than either benthic (LC_{50}s of 3 to 8 ppm) or intertidal fish species (LC_{50}s of >8 ppm) (Rice et al. 1979). [An LC_{50} is based upon controlled laboratory experiments using confined fish, usually in a container of standing water. The result is expressed as the concentration of a contaminant that achieves a mortality rate of 50%. There are recognized problems in applying LC_{50} data to the "real world" but they are useful for "ball park" comparative information, especially in situations where it is very difficult to obtain good controlled field data.]

Reported physiological effects on fish have included abnormal gill function (Sanders et al. 1981 and Englehardt et al. 1981 *in* Brzorad and Burger 1994), increased liver enzyme activity (Koning 1987; Payne et al. 1987), decreased growth (Swatrz 1985 *in* Brzorad and Burger 1994; Moles and Norcross 1998), organ damage (Rice 1985), and increased disease or parasites loads (Brown et al. 1973; Steedman 1991 *in* Brzorad and Burger 1994; Carls et al. (1998); Marty et al. 1999).

Reported behavioural effects include avoidance of contamination by migrating salmon (Weber et al. 1981), and cod in laboratory studies at refined petroleum levels in excess of 100 µg/L (Bohle 1986 *in* Crucil 1989), and altered natural behaviours related to predator avoidance (Gardner 1975; Pearson et al. 1984) or feeding (Christiansen and George 1995).

Juvenile (i.e., those past the egg and larval stages) and adult fish can and probably will avoid any crude oil by swimming from the blowout/spill region (Irwin et al. 1997). Effects of oil spills on adult and juvenile fish are predicted to be negligible. For example, findings in the White Rose EA/Comprehensive Study, the Hibernia and Terra Nova EISs, the Lewis Hill EA, and the Jeanne d'Arc Basin EA concluded that neither surface spills nor subsea blowouts posed significant risks to either pelagic or demersal fish stocks (Mobil 1985; Petro-Canada 1996; Husky 2000, 2002, 2003).

Juvenile and adult fish in shallow/enclosed areas could be more susceptible to impact from accidental events such as oil spills in that the oil might be more persistent in these areas. Therefore, exposure of the fish to the oil could potentially be of longer duration. At the same time, juvenile and adult finfish are mobile and can avoid the contaminated areas. Less mobile invertebrates could not so easily avoid the oil. Contamination of shoreline habitats that are particularly important to fish with specific habitat requirements could potentially result in more adverse effects on the fish.

Fish Eggs and Larvae

Planktonic fish eggs and larvae (ichthyoplankton) are less resistant to effects of contaminants than are adults because they are not physiologically equipped to either detoxify them or actively avoid them. In addition, many eggs and larvae develop at or near the surface where oil exposure may be the greatest (Rice 1985; see also Section 3.2 for a description of ichthyoplankton in the Western Newfoundland and Labrador Offshore Area). It is estimated that sensitivities of fish larvae range from 0.1 to 1.0 ppm of soluble aromatic hydrocarbons, approximately 10 times the sensitivities of adults (Moore and Dwyer 1974). However, an organism's sensitivity to oiling is not simply a function of age.

Generally, fish eggs appear to be highly sensitive at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Larval sensitivity varies with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to high concentrations of oil generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. For example, although Atlantic cod eggs were observed to survive oiling, the hatched larvae were deformed and unable to swim (Kühnhold 1974). Atlantic herring larvae exposed to oil have exhibited behavioural abnormalities such as initial increased swimming activity followed by low activity, narcosis, and death (Kühnhold 1972). Similarly, Pacific herring (*Clupea pallasi*) eggs and larvae (possibly exposed as embryos) collected from beaches contaminated with *Exxon Valdez* oil in 1989 exhibited morphological and genetic damage (Hose et al. 1996; Norcross et al. 1996; Marty et al. 1997). Marty et al. (1997) indicated that herring larvae collected from oiled sites had ingested less food, displayed slower growth, and had a higher prevalence of cytogenetic damage than those sampled from 'clean' sites. However, these effects were not observed in eggs and larvae collected in later years (Hose et al. 1996; Norcross et al. 1996) and there is no conclusive evidence to suggest that these oiled sites posed a long-term hazard to fish embryo or larval survival (Kocan et al. 1996).

The natural mortality rate in fish eggs and larvae is so high that large numbers could be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985). Oil-related mortalities would probably not affect year-class strength unless >50% of the larvae in a large proportion of the spawning area died (Rice 1985). Herring are one of the most sensitive fish species to oiling. Hose et al. (1996) claim that even though 58% fewer than normally expected herring larvae were produced at a site oiled during the *Exxon Valdez* spill, no effect would be detected at the population level.

Ten-day exposures of large numbers of pink salmon smolt (*Oncorhynchus gorbuscha*) to the water-soluble fraction of crude oil (0.025 to 0.349 ppm) did not result in any detectable effects on their survival to maturity (Birtwell et al. 1999). However, it should be noted that pink salmon may be more resistant to environmental disturbance than other species because they spend so much time in the variable estuarine environment.

Typically, the occurrence, abundance and distribution of ichthyoplankton are highly variable by season and dependent on a variety of biological (e.g., stock size, spawning success, etc.) and environmental (temperature, currents, etc.) factors. In the unlikely event of a blowout or spill, there is potential for individual ichthyoplankters in the upper water column to sustain lethal and sublethal effects following contact with high concentrations of oil. The LC_{50} value at 25°C used by Hurlbut et al. (1991) to predict effects on ichthyoplankton was 0.0143 ppm.

As in the case of fish larvae, the sensitivity of invertebrate larvae to petroleum hydrocarbons varies with species, life history stage, and type of oil. Generally, invertebrate larvae are more sensitive to effects of oil than are adult invertebrates. Sublethal and lethal effects on individual larvae are possible during a spill or blowout.

American lobster larvae (Stages 1 to 4) showed a 24-h LC_{50} of 0.1 ppm to Venezuelan crude oil (Wells 1972). Larvae exposed to 0.1 ppm of South Louisiana crude oil swam and fed actively while those exposed to 1 ppm were lethargic (Forns 1977). Stage 1 crab larvae (king crab, *Paralithodes camtschatica* and Tanner crab (*Chionectes bairdi*)) succumbed to similar concentrations of crude oil (0.96 to 2 ppm; Brodersen et al. 1977) while larval shrimp generally had higher LC_{50} limits (0.95 to 7.9 ppm; Brodersen et al. 1977; Mecklenburg et al. 1977). Anderson et al. (1974) tested a variety of crude and refined oils and found that post-larval brown shrimp (*Penaeus aztecus*) were less sensitive than adult invertebrate species. Also, moulting larvae appear to be more sensitive to oil than intermoult larvae (Mecklenburg et al. 1977). Kerosene affected development of sea urchin embryos at concentrations of 15 ppb or greater, as did gasoline at concentrations of 28 ppb or greater (Falk-Petersen 1979).

Invertebrate larvae exposed to oil may exhibit reductions in food consumption and growth rate, and increases in oxygen consumption (Johns and Pechenik 1980). Despite these physiological changes, deleterious effects on invertebrate populations have not been detected, even after major oil spills

(Armstrong et al. 1995). Larval distribution and settlement, fecundity, recruitment and growth of juveniles and subadult crab, pandalid shrimp, clams and scallops were not significantly affected by the *Exxon Valdez* oil spill (Armstrong et al. 1995).

Fish Habitat

The highest polyaromatic hydrocarbon (PAH) concentration found in Prince William Sound at one and five metre depths within the six-week period following the *Exxon Valdez* spill was 0.00159 ppm, well below levels considered acutely toxic to marine fauna (Short and Harris 1996). The Hibernia and Terra Nova EISs and the White Rose and Jeanne d' Arc Basin EAs predicted that environmental (biophysical) effects on water quality and habitat would not be significant. As indicated in the preceding section, the chance of an accidental event is extremely low.

Plankton

Strictly speaking, plankton is not a VEC; however, the fish habitat VEC includes plankton because it is a source of food for larvae and some adult fish (i.e., the fish VEC). Thus, effects of an oil spill or blowout on plankton could affect fish. Dispersion and dissolution cause the soluble, lower molecular weight hydrocarbons to move from the slick into the water column. Effects of spills on pelagic organisms need to be assessed through examination of effects of water-soluble fractions of oil or light hydrocarbon products.

Effects of crude oil spills on plankton are short-lived, with zooplankton being more sensitive than phytoplankton. Zooplankon accumulate hydrocarbons in their bodies. The hydrocarbons may be metabolized and depurated (Trudel 1985). Hydrocarbons accumulated in zooplankton during a spill would be depurated within a few days after a return to clean water and thus, there is limited potential for transfer of hydrocarbons up the food chain (Trudel 1985). There is a potential for transfer of hydrocarbons up the food chain in an environment subject to chronic inputs of hydrocarbons, but there is no potential for biomagnification. Celewycz and Wertheimer (1996) concluded that the *Exxon Valdez* spill did not reduce the available prey resources, including zooplankton, of juvenile salmon in Prince William Sound.

Mortality of zooplankton can occur at diesel concentrations of 100 to 10,000 ppm (24 to 48 h LC_{50}, where LC_{50} is the concentration of toxicant that kills 50 percent of the test animals; Trudel 1985). Diesel oil is much more toxic, but shorter-lived in the open ocean than crude oil. There is great variability among species and some species are relatively insensitive. For example, the 96-h LC_{50} of crude oil for *Calanus hyperboreus*, a common cold water copepod, was 73,000 ppm (Foy 1982). Complete narcotization of copepods can occur after a 15-min exposure to 1,800 ppm of aromatic heating oil and mortality can occur after a 6-h exposure (Berdugo et al. 1979). Exposure to concentrations of 1,000 ppm of aromatic heating oil for three days had no apparent effect on mobility, but exposure for as little as 10 minutes shortened life span and total egg production (Berdugo et al. 1979). No. 2 fuel oil at concentrations of 250 to 1,000 ppm completely inhibited or modified copepod feeding behaviour, while concentrations of 70 ppm or lower may not affect feeding behaviour (Berman and Heinle 1980). Exposure to naphthalene at concentrations of 10 to 50 ppm for 10 days did not affect feeding behaviour or reproductive potential of copepods although egg development was not examined (Berdugo et al. 1979).

In summary, individual zooplankton could be affected by a blowout or spill through mortality, sublethal effects, or hydrocarbon accumulation if oil concentrations are high enough. However, the predicted maximum concentrations for batch and blowouts are well below those known to cause effects.

Benthic Animals

Under some circumstances, oil spilled in nearshore waters can become incorporated into nearshore and intertidal sediments, where it can remain toxic and affect benthic animals for years after the spill (Sanders et al. 1990).

4.3.3.2 Effect on Commercial Fisheries

Although physical effects on fish from a spill are deemed not significant, economic impacts might occur in the event of a spill, if the spill prevented or impeded a harvester's ability to access fishing grounds (because of areas temporarily excluded during the spill or spill clean-up), caused damage to fishing gear (through oiling) or resulted in a negative effect on the marketability of fish products (because of market perception resulting in lower prices, even without organic or organoleptic evidence of tainting).

If fishers were required to cease fishing, harvesting might be disrupted (though, depending on the extent of the slick, alternative fishing grounds might be available). An interruption could result in an economic impact because of reduced catches, or extra costs associated with having to relocate harvesting effort.

Effects due to market perceptions of poor product quality (no buyers or reduced prices, etc.) are more difficult to predict, since the actual (physical) impacts of the spill might have little to do with these perceptions. It would only be possible to quantify these effects by monitoring the situation if a spill were to occur and if it were to reach harvesting areas.

4.3.3.3 Effect on Marine-associated Birds

Marine-associated birds are the marine animals most at risk from oil spills and blowouts.

The Study Area is adjacent to the major shipping route that traverses the St. Lawrence River estuary and across the Gulf of St. Lawrence immediately south of Anticosti Island. Traffic density in this vicinity is four to eight ships per day, many of which are container vessels and potential sources for bunker C bilge waste that is a chronic source of pollution along the southeast coast of Newfoundland. Further north there is activity from commercial fishing vessel traffic from Port Au Choix to St. Anthony accessing the northern fishing banks (Lock et al. 1994).

Oil spills have been reported in marine waters proximate to Stephenville/Stephenville Crossing (UA 4Rd), Bay of Islands (UA 4Rc), Hawkes Bay (UA 4Rb), Port au Choix (UAs 4Rab) and St. Anthony, essentially anywhere where there is marine traffic. More spills are reported for the May to December period likely reflecting the fact that the Strait of Belle Isle is ice locked for significant portions of the winter (Lock et al. 1994).

Exposure to oil causes thermal and buoyancy deficiencies that typically lead to the deaths of affected seabirds. Although some may survive these immediate effects, long-term physiological changes may eventually result in death (Ainley et al. 1981; Williams 1985; Frink and White 1990; Fry 1990). Reported effects vary with bird species, type of oil (Gorsline et al. 1981), weather conditions, time of year, and duration of the spill or blowout. Although oil spills at sea have the potential to kill tens of thousands of seabirds (Clark 1984; Piatt et al. 1990), recent studies suggest that even spills of great magnitude may not have significant long-term effects on seabird populations (Clark 1984; Wiens 1995).

Considering the proximity of the Study Area to the coast of western Newfoundland, there are potential effects of accidental events on coastal bird habitats and sensitive areas, particularly the identified IBAs and Piping Plover critical habitat sites.

Immediate Effects

External exposure to oil occurs when flying birds land in oil slicks, diving birds surface from beneath oil slicks, and swimming birds swim into slicks. The external exposure results in matting of the feathers which effectively destroys the thermal insulation and buoyancy provided by the air trapped by the feathers. Consequently, oiled birds are likely to suffer from hypothermia and/or drown (Clark 1984; Hartung 1995). Most seabird losses occur during the initial phase of oil spills when large numbers of birds are exposed to floating oil (Hartung 1995). Birds living in coldwater environments are most likely to succumb to hypothermia (Hartung 1995).

Short-term Effects

Oiled birds that escape death from hypothermia and/or drowning often seek refuge ashore where they engage in abnormally excessive preening in an attempt to rid themselves of the oil (Hunt 1957 in Hartung 1995). The preening leads to the ingestion of significant quantities of oil which, although apparently only partially absorbed (McEwan and Whitehead 1980), can cause lethal effects. Noted effects on Common Murres and Thick-billed Murres oiled off Newfoundland’s south coast include emaciation, renal tubular degeneration, necrosis of the duodenum and liver, anemia and electrolytic imbalance (Khan and Ryan 1991). Glaucous-winged Gulls (*Larus glaucescens*) experienced similar effects after they ingested bunker fuel oil during preening (Hughes et al. 1990). Another commonly observed effect is adrenal hypertrophy. This condition tends to make birds more vulnerable to adrenocortical exhaustion (e.g., Mallards [Hartung and Hunt 1966; Holmes et al. 1979], Black Guillemots [Peakall et al. 1980], and Herring Gulls [Peakall et al. 1982]). The adrenal gland maintains water and electrolyte balance that is essential for the survival of birds living in the marine environment. Hartung and Hunt (1966) found that ingested oils can cause lipid pneumonia, gastrointestinal irritation, and fatty livers in several species of ducks. Aromatic hydrocarbons have been detected in the brains of Mallards (Lawler et al. 1978) and are probably associated with observed symptoms (e.g., lack of coordination, ataxia, tremors and constricted pupils) of nervous disorders (Hartung and Hunt 1966).

Birds exposed to oil are also at risk of starvation (Hartung 1995). For example, oiled Common Eiders generally deplete all of their fat reserves and much of their muscle protein (Gorman and Milne 1970). In addition, energy demands are higher because the metabolic rate of oiled birds increases to compensate for the heat loss caused by the reduced insulating capacity of their plumage. This can expedite starvation (Hartung 1967; McEwan and Koelink 1973).

Long-term Effects

It appears that direct, long-term sublethal toxic effects on seabirds are unlikely (Hartung 1995). The extent of bioaccumulation of the chemical components of oil in birds is limited because vertebrate species are capable of metabolizing them at rates that minimize bioaccumulation (Neff 1985 *in* Hartung 1995). Birds generally excrete much of the hydrocarbons within a short time period (McEwan and Whitehead 1980). However, nesting seabirds that are contaminated with oil but still survive generally exhibit decreased reproductive success.

Nesting seabirds transfer oil from their plumage and feet to their eggs (Albers and Szaro 1978). Very small quantities of oil (1 to 20 µl) on eggs have produced developmental defects and mortality in avian embryos of many species (Albers 1977; Albers and Szaro 1978; Hoffmann 1978, 1979a; Macko and King 1980; Parnell et al. 1984; Harfenist et al. 1990). The resultant hatching and fledging success of young appears to be related to the type of oil (Hoffman 1979b; Albers and Gay 1982; Stubblefield et al. 1995) and the timing of exposure during incubation. Embryos are most sensitive to oil during the first half of incubation (Albers 1978; Leighton 1995). Breeding birds that ingest oil generally exhibit a decrease in fertilization (Holmes et al. 1978), egg laying and hatching (Hartung 1965; Ainley et al. 1981), chick growth (Szaro et al. 1978) and survival (Vangilder and Peterle 1980; Trivelpiece et al. 1984). Similar effects on ducklings occur when they ingest oil directly (Miller et al. 1978; Peakall et al. 1980; Szaro et al. 1981). Oil spills can also cause indirect reproductive failure. Eppley and Rubega (1990) suggest that exposure to an Antarctic oil spill caused changes in the normal parental behaviour of South Polar Skuas (*Catharacta maccormicki),* thus exposing young to increased predation and contributing to reproductive failure in that population. In another case, abandonment of nesting burrows by oiled adult Leach's Storm-Petrels may have contributed to reproductive failure in that population (Butler et al. 1988). Therefore, a spill that occurs during the reproductive period could cause mortality of young even if the adults survived the exposure to oil.

There is no conclusive evidence that oil spills have either caused marked reductions in bird populations or have changed community structure at a large scale (Leighton 1995). Some studies have suggested that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics (Clark 1984; Butler et al. 1988; Boersma et al. 1995; Wiens 1995) while others suggest the opposite (Piatt et al. 1990; Walton et al. 1997). Natural interannual variation in other factors that affect populations (e.g., prey availability and weather) reduces the ability of scientists to assess the full effect of oil spills on bird populations.

Sensitive Species

It is clear that truly aquatic and marine species of birds are most vulnerable and most often affected by exposure to marine oil spills. Diving species such as Black Guillemots, murres, Atlantic Puffins, Dovekies, eiders, Oldsquaws, scoters, Red-breasted Mergansers, and loons are considered to be the most susceptible to the immediate effects of surface slicks (Leighton et al. 1985; Chardine 1995; Wiese and Ryan 1999, 2003). Alcids often have the highest oiling rate of seabirds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland. They were the only group of seabirds to show an annual increase over a 13-yr period (2.7 percent) in the proportion of oiled birds (Wiese and Ryan 1999, 2003). Within the diving species group, murres appear to be the most affected by exposure to oil. Also, there also appears to be a strong seasonal effect as significantly higher proportions of alcids (along with other seabird groups) are oiled in winter versus summer (Wiese and Ryan 1999, 2003).

Other species such as Northern Fulmars, shearwaters, storm-petrels, gulls and terns are vulnerable to contact with oil because they feed over wide areas and make frequent contact with the water's surface. They are also vulnerable to the disturbance and habitat damage associated with oil spill cleanup (Lock et al. 1994). The greatest decrease in use of contaminated habitats immediately following a spill occurs in species that feed on or close to shore, and that either breed along the coast or are full-year residents (Wiens et al. 1996). In the Project Area, this would include species like terns and storm-petrels. Oil residues in bedrock habitat, like that used by most seabirds in Newfoundland, do not persist as long as residues in sedimentary habitat (e.g., sand beaches) (Gilfillan et al. 1995).

Birds are particularly vulnerable to oil spills during nesting, moulting, and prior to young seabirds gaining the ability to fly. Newly fledged murres and Northern Gannets are unable to fly for the first two to three weeks at sea, and are, therefore, less likely to avoid contact with oil during this time (Lock et al. 1994). Gannets do not nest in the Study Area so most of the concern relating to effects on nesting seabirds is with waterfowl and larids (gulls and terns). Before and during moult, the risks of hypothermia and drowning (Erasmus and Wessels 1985) are increased because feather wear and loss reduce the ability to repel water by about 50% (Stephenson 1997). As discussed in Section 3.0, a small number of pairs of the *endangered* Piping Plover nest on coastal beaches in the Study Area. Sandy beaches are rare on the coast of Newfoundland and Piping Plovers are vulnerable to oil washed ashore and to human disturbance (Lock et al. 1994). Consequently, most of such beaches are officially protected to preserve breeding habitat. Terns are less vulnerable to oil, but spill clean-up activities may disturb nesting terns and cause nesting failure (Lock et al. 1994).

For the west coast of Newfoundland and areas around the Port aux Port Peninsula, sedimentary habitats (i.e., beaches) are prevalent and highly used by migratory birds. Species most vulnerable would be the *endangered* Piping Plover, other shorebirds, gulls, terns and waterfowl. Storm-petrels are not as great an issue.

Past Oil Spills in Eastern Canada

Several major oil spills have occurred on the Grand Banks, and "small" oil releases (most likely from bilge pumping and de-ballasting by vessel traffic) occur frequently. "Mystery" spills, most likely from ships that illegally dump waste oils into the ocean, killed an estimated 18,000 seabirds in Placentia Bay, Newfoundland (Anon. 1990). Many ships frequent the waters off the south coast of Newfoundland as they traverse between Europe and North America, thereby exposing seabirds to chronic levels of oil pollution (Chardine and Pelly 1994). In February 1970, the *Irving Whale* spilled between 3,000 and 7,000 gallons of Bunker C oil near St. Pierre and Miquelon, which subsequently spread along Newfoundland's southeast coast. It was estimated that 7,000 birds, primarily Common Eiders, were killed (Brown et al. 1973). During the same month, the *Arrow* ran aground in Chedabucto Bay, Nova Scotia. Approximately 2.5 million gallons of Bunker C fuel oil were spilled and at least 2,300 birds were killed in the bay itself (Brown et al. 1973). Primarily diving birds were affected, most notably Oldsquaws, Red-breasted Mergansers, murres, Dovekies, and grebes (Brown et al. 1973). The spill spread offshore to Sable Island where mostly murres, Dovekies, and Northern Fulmars were killed. The lowest estimate of seabird mortality due to this part of the slick was 4,800 birds (Brown et al. 1973).

On a broader geographical scale, it is estimated that 21,000 birds die annually from operational spills on the Atlantic coast of Canada and that 72,000 birds die annually from all operational spills in Canada (Thomson et al. 1991). Wiese and Robertson (2004), using a general mathematical Oiled Seabird Mortality Model (OSMM), estimated that between 1998 and 2000, an average of 315,000±65,000 Common Murres, Thick-billed Murres and Dovekies were killed annually in southeastern Newfoundland due to illegal oil discharges from ships. They estimated that Thick-billed Murres made up about 67% of the kill. Clark (1984) estimates that 150,000 to 450,000 birds die annually in the North Sea and North Atlantic from oil pollution of all sources. There is no clear correlation between the size of an oil spill and numbers of seabirds killed (Burger 1993). The density of birds in a spill area, wind velocity and direction, wave action, and distance to shore may have a greater bearing on mortality than the size of the spill (Burger 1993).

In November 2004, a spill of crude oil occurred from the production platform of the Terra Nova oil field. Canadian Wildlife Service has estimated that mortality to seabirds in the area may have been in the order of 10,000. Other seabird experts have cautioned that such estimates are not supported by sufficient data because surveys of the site did not occur for five days following the incident, and there was no information on drift trajectories of dead or contaminated birds. Possible mortality of seabirds has been speculated to range from hundreds to 100,000 or more (see www.mun.ca/acwern/terranova.html). It is known that many thousands of pelagic seabirds occur in the Terra Nova area in November.

Even small spills can cause cumulative mass mortality of seabirds (Joensen 1972). A major spill that persists for several days near a nesting colony could kill a high proportion of the pursuit-diving birds (e.g., murres) within the colony (Cairns and Elliot 1987). In contrast, relatively low mortalities have been recorded from some huge spills. For example, the *Amoco Cadiz* spilled 230,000 tonnes of crude oil along the French coast, causing the recorded deaths of 4,572 birds (Clark 1984).

Rehabilitation

The rescue, cleaning, and rehabilitation of oiled birds have been practised in several parts of the world for a number of years (Clark 1984). Considerable effort has been made to improve rehabilitation techniques (Berkner et al. 1977; Williams 1985; Frink and White 1990), and release rates of birds have generally increased (Randall et al. 1980; Williams 1985; Frink 1987).

Although rehabilitation is a humane attempt to save animals impacted by oil, it cannot be considered as a form of mitigation for population recovery. Success of rehabilitation cannot be measured in terms of numbers of birds released from treatment centres because cleaned seabirds often die shortly after release (Sharp 1996). Oiled and cleaned Black Guillemots, White-winged Scoters, and Western Grebes (*Aechmophorus occidentalis)* in North America had a much lower survival rate than non-oiled controls, regardless of cleaning techniques (Sharp 1996).

Piatt et al. (1990) estimated that 100,000 to 300,000 birds were killed by oil from the *Exxon Valdez*. Therefore, the massive rescue attempts associated with the *Exxon Valdez* spill managed to release (not save) only 0.3 to 0.8 percent of the birds that were potentially fatally oiled by the spill.

Recently, some oil companies operating on the Grand Banks have committed to conduct bird cleaning and rehabilitation programs on the basis of the following principles:

- Bird cleaning and rehabilitation operations will be carried out under the terms of permits issued by the CWS;
- Procedures and protocols to ensure safe effective and humane cleaning and rehabilitation of birds under the guidance of a qualified veterinarian will be put in place pursuant to the aforementioned permits;
- Procedures and protocols will make appropriate provision for triage and euthanasia under the direction of a qualified veterinarian and ensure appropriate focus for any *endangered* species that might be affected by an incident;
- Collection of birds offshore for cleaning and rehabilitation during a spill incident will be conducted with strict regard for safety of personnel involved.

Enhancement Techniques

In the unlikely event that seabird populations are significantly affected by oil spills (Clark 1984; Wiens 1995), it may be possible to restock certain species' populations. Although no efforts to restock birds in areas that have suffered from major oil spills have been conducted, there have been several programs to reintroduce birds into abandoned parts of their ranges. Approaches have included releasing captive-reared fledgling birds at natural sites, for example, the hatching, rearing and release of Common Eiders in Hare Bay, Newfoundland, and releasing juvenile and adult birds into selected receiving areas (e.g., Atlantic Puffins off the Maine coast and along the Brittany coast, and Canada Geese in many areas).

These efforts have met with variable success. They all involved much planning, considerable labour and the programs were multi-year efforts that required a long-term commitment of personnel and resources.

The case most relevant to the Project Area involves the successful re-establishment of colonies of Common Eiders in Hare Bay, Newfoundland (Gilliland, CWS, in prep.), and Atlantic Puffins in New England and France (Duncombe and Reille 1980; Clark 1984). Puffins are alcids, close relatives of the murres and Black Guillemots that also nest abundantly in southern Newfoundland. However, the puffins nest in burrows, whereas murres are cliff-nesters and Black Guillemots nest among rocks and coastal debris. Consequently, it is unclear whether the techniques used in the successful reestablishment of nesting puffins would also work with these other alcids.

The nesting success of some species can be improved by manipulation of nesting habitat. Nest shelter programs have been ongoing in Newfoundland and Labrador for Common Eiders since the late 1980's (Goudie 1989, 1991c). Common Eider females nest preferentially in well-protected areas near logs and among driftwood and rocks (Johnson and Herter 1989). Therefore, on barren islands, numbers of nesting sites can be increased and/or nest success improved by adding artificial shelters and/or rearranging driftwood on breeding sites. In Iceland, the nesting habitat of eiders is manipulated to improve nesting success and to facilitate the collection of the eider down that lines the nests (Doughty 1979).

One option for enhancing recovery of depleted species is the elimination of hunting of that species, if it is a hunted species. Depending upon the severity of the situation, hunting could be spatially and temporally curtailed to whatever degree necessary.

The techniques to rescue and rehabilitate oiled birds are not very effective. Consequently, the best mitigation technique is to do all that is possible to avoid an oil spill in the first place. Otherwise, deploy countermeasures that reduce the numbers of birds that become oiled (e.g., directing the oil away from seabird concentration areas). It is much better to direct efforts to techniques that prevent birds from becoming oiled in the first place. Successful and efficient techniques are not yet available to restore bird populations and habitat once they are oiled.

Of the marine-associated bird species occurring in the Study Area, eiders, cormorants, kittiwakes and Black Guillemots are the most likely species to be oiled in the event of a spill (Lock et al. 1994). Inshore, loons, grebes and other species of diving ducks are equally vulnerable to oiling.

4.3.3.4 Effects on Marine Mammals

Most marine mammals, with the exception of fur seals, polar bears, and sea otters, are not very susceptible to deleterious effects of oil. However, newborn hair seal pups, and weak or highly stressed individuals, may be vulnerable to oiling. Other marine mammals exposed to oil are generally *not at risk* because they rely on a layer of blubber for insulation and oiling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman et al. 1976; 1977; Geraci 1990; St. Aubin 1990). Population-level effects are unlikely, as no significant long-term and lethal effects from external exposure, ingestion, or bioaccumulation of oil have been demonstrated.

Cetaceans

There is no clear evidence that implicates oil spills, including the much studied *Santa Barbara* and *Exxon Valdez* spills, with mortality of cetaceans (Geraci 1990). Migrating gray whales were apparently not adversely affected by the *Santa Barbara* spill. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill was a result of increased survey effort related to the spill (Geraci 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci 1990).

There was a significant decrease in the size of a killer whale pod resident in the area of the *Exxon Valdez* spill, but no clear cause and effect relationship between the spill and the decline could be established (Dahlheim and Matkin 1994). There were no evident effects on humpback whales in Prince William Sound after the *Exxon Valdez* spill (von Ziegesar et al. 1994). There was some temporary displacement of humpback whales out of Prince William Sound, but oil contamination, boat and aircraft disturbance, or displacement of food sources could have caused this displacement.

Avoidance and Behavioural Effects

Studies of both captive and wild cetaceans indicate that they can detect oil spills. Captive bottlenose dolphins avoided most oil conditions during daylight and darkness, but had difficulty detecting a thin sheen of oil (St. Aubin et al. 1985). Wild bottlenose dolphins exposed to the *Mega Borg* oil spill in 1990 appeared to detect, but did not consistently avoid contact with, most oil types (Smultea and Würsig 1995). This is consistent with other cetaceans behaving normally in the presence of oil (Harvey and Dahlheim 1994; Matkin et al. 1994). It is possible that cetaceans swim through oil because of an overriding behavioural motivation (for example, feeding). Some evidence exists that indicates dolphins attempt to minimize contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig 1995).

Oiling of External Surfaces

Whales rely on a layer of blubber for insulation and oil has little if any effect on thermoregulation. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's health (Geraci 1990). It can be assumed that if oil contacted the eyes, effects would be similar to that observed in ringed seals (conjunctivitis, corneal abrasion, and swollen nictitating membranes) and that continued exposure to eyes could cause permanent damage (St. Aubin 1990).

Ingestion and Inhalation of Oil

Whales could ingest oil with water, contaminated food, or oil could be absorbed through the respiratory tract. Species like the humpback whale, right whale, beluga, and harbour porpoise that feed in restricted areas (for example, bays) may be at greater risk of ingesting oil (Würsig 1990). Some of the ingested oil is voided in vomit or feces but some is absorbed and could cause toxic effects (Geraci 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978; 1982). Whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982). Only small traces of oil were found in the blubber of a gray whale and liver of a killer whale exposed to *Exxon Valdez* oil (Bence and Burns 1995).

Cetaceans may inhale vapours from volatile fractions of oil from a spill and blowout. The most likely effects of inhalation of these vapours would be irritation of respiratory membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Stressed individuals that could not escape a contaminated area would be most at risk.

Fouling of Baleen

In baleen whales, crude oil could coat the baleen and reduce filtration efficiency. However, effects are minimal and reversible. Baleen experimentally fouled with oil did not change enough to alter its filtration efficiency (St. Aubin et al. 1984) and most adherent oil was removed within 30 min after fouling (Geraci and St. Aubin 1985 *in* Geraci 1990). The effects of oiling of baleen on feeding efficiency appear to be only minor (Geraci 1990).

Pinnipeds

Reports of the effects of oil spills and blowouts have shown that some mortality of hair seals may have occurred as a result of oil fouling; however, large-scale mortality has never been observed (St. Aubin 1990). The largest effect of a spill was on young hair seals in cold water (St. Aubin 1990).

Effects on seals have not been well studied at most spills because of lack of baseline data and/or the brevity of the post-spill surveys. There is little information about the mortality rate of harp seals exposed to oil from a ruptured storage tank in New Brunswick in 1969. It is believed that 10,000 to 15,000 harp seals were coated with oil but the exact number of dead seals recovered is unknown (Sergeant 1991). The release of fuel oil from the *Arrow* into Chedabucto Bay, Nova Scotia in 1970 resulted in the fouling of 500 seals within the bay and 50 to 60 harbour and 200 grey seals on Sable Island (200 km south of the spill). Twenty-four seals were found dead and some had oil in their mouths and stomachs (Anon. 1970; 1971 *in* St. Aubin 1990). Oiled grey and harbour seals were found on the coast of Nova Scotia and Sable Island again in 1979 when the oil tanker *Kurdistan* sank in Cabot Strait. No causal relationship between oiling and death was determined (Parsons et al. 1980 *in* St. Aubin 1990). No mortalities were reported after a well blowout near Sable Island in 1984 and only two oiled grey seals were observed (St. Aubin 1990).

Intensive and long-term studies were conducted after the *Exxon Valdez* spill in Alaska. There may have been a long-term decline of 36% in numbers of moulting harbour seals at oiled haul-out sites in Prince William Sound, following the *Exxon Valdez* spill (Frost et al. 1994). Harbour seal pup mortality at oiled beaches was 23 to 26%, which may have been higher than natural mortality (Frost et al. 1994). However, attributing cause to the decreasing trend in harbour seal numbers since the spill (4.6% per year) is complicated because seal populations were declining prior to the spill (Frost et al. 1999).

Further analyses of harbour seal population trends and movements in Prince William Sound does not support high mortality, but indicates that seals moved away from some oiled haul-out sites (Hoover-Miller et al. 2001).

Avoidance and Behavioural Effects

There is conflicting evidence on whether seals detect and avoid spilled oil. Some oiled seals hauled out on land are reluctant to enter the water, even when disturbances from intense cleanup activities occur nearby (St. Aubin 1990; Lowry et al. 1994). In contrast, several thousand grey and harbour seals apparently left Chedabucto Bay, Nova Scotia, after the grounding of the *Arrow* (Mansfield 1970 *in* St. Aubin 1990), although this movement may have been caused by the increased human disturbance during cleanup activities rather than by the presence of oil (St. Aubin 1990). Harbour seals observed immediately after oiling appeared lethargic and disoriented, which may be attributed to lesions observed in the thalamus of the brain (Spraker et al. 1994). Other seals have been observed swimming in the midst of oil spills (St. Aubin 1990). Oiling of both mother and pups does not appear to interfere with nursing (Lowry et al. 1994).

Oiling of External Surfaces

Adult and juvenile hair seals (includes harbour, grey, harp and hooded seals) are at virtually no risk of thermal regulatory effects from oil fouling because their blubber, not their fur, provides insulation (Kooyman et al. 1976; 1977; St. Aubin 1990). It is questionable whether young seal pups, which rely on their birth coat and brown fat stores, could survive the deleterious effects of oiling (St. Aubin 1990). Contact with oil on the external surfaces can cause increased stress and can irritate the eyes of ringed seals (Geraci and Smith 1976; St. Aubin 1990). Harbour seals oiled during the *Exxon Valdez* spill had difficulty keeping their eyes open and experienced conjunctivitis (Spraker et al. 1994). These effects seem to be temporary and reversible, but continued exposure of oil to eyes could cause permanent damage (St. Aubin 1990). Damage to a seal’s visual system would likely limit foraging abilities, as vision is an important sensory modality used to locate and capture prey (Levenson and Schusterman 1997). Mucous membranes that line the oral cavity, respiratory surfaces, and anal and urogenital orifices are also sensitive to oil exposure (St. Aubin 1990). Seals fouled externally with heavy oil may also encounter problems with locomotion. The flippers of young harp seals and grey seal pups were impeded by a heavy coating of oil that became stuck to their sides (Davis and Anderson 1976; Sergeant

1991). This led to the drowning of the grey seal pups. The coating of seals and their subsequent deaths were also observed in seals exposed to heavy bunker oil during the *Arrow* and *Kurdistan* spills (Engelhardt 1987 *in* Lowry et al. 1994).

Oil Ingestion and Inhalation

Seals can ingest oil if their food is contaminated or by nursing contaminated milk. Oil can also be absorbed through the respiratory tract (Geraci and Smith 1976; Engelhardt et al. 1977). Some ingested oil is voided in vomit/feces or metabolized at rates that prevent significant bioaccumulation (Neff 1985 *in* Hartung 1995) but some is absorbed and can cause toxic effects (Engelhardt 1981). These effects may include minor kidney, liver and brain lesions (Geraci and Smith 1976; Spraker et al. 1994). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978; 1982; 1985). Seals exposed to an oil spill and especially a blowout are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982) and any effects are probably reversible (Spraker et al. 1994). There were no significant quantities of oil in the tissues (liver, blubber, kidney and skeletal muscles) of harbour seals exposed during the *Exxon Valdez* spill (Bence and Burns 1995).

Seals are also at risk from hydrocarbons and other chemicals that evaporate from spills and blowout areas. Seals generally keep their nostrils close to the water surface when breathing, so they are likely to inhale vapours if they surface in a contaminated area. Grey seals that presumably inhaled volatile hydrocarbons from the *Braer* oil spill exhibited a discharge of nasal mucous, but no causal relationship with the oil was determined (Hall et al. 1996). Laboratory studies of ringed seals indicate that the inhalation of hydrocarbons may cause more serious effects like kidney and liver damage (St. Aubin 1990). However, exposure conditions were much higher than would be expected in a natural setting.

Factors Affecting the Severity of Oil Exposure

Seals that are under some type of natural stress, such as lack of food or a heavy infestation by parasites, could die as a result of the additional stress of oiling (Geraci and Smith 1976; St. Aubin 1990). Seals that are not under natural stress would most likely survive oiling.

Seals exposed to heavy doses of oil for prolonged periods of time could die. Harbour seals may be particularly at risk because they exhibit site fidelity (Boulva and McLaren 1979; Yochem et al. 1987). Prolonged exposure from oil at a preferred haul-out site could cause the death of some seals. However, Jenssen (1996) reported that oil has produced little visible disturbance to grey seal behaviour and there has been little mortality despite the fact that approximately 50 percent of grey seal pups at Norway’s largest breeding colony are polluted each year by oil.

4.3.3.5 Sea Turtles

It is not known whether sea turtles can detect and avoid oil slicks. Gramentz (1988) reported that sea turtles did not avoid oil at sea, while sea turtles exposed to oil under experimental conditions had a limited ability to avoid oil (Vargo et al. 1986).

Loggerhead sea turtles experimentally exposed to oil had marked gross and histologic lesions present in the skin. Most effects were reversed by the tenth day following cessation of oil exposure (Bossart et al. 1995). Other effects of oil on sea turtles include reduced lung diffusion capacity, decreased oxygen consumption, decreased digestion efficiency, and damaged nasal and eyelid tissue (Lutz et al. 1989).

There are few field observations of sea turtles exposed to oil. After the Ixtoc 1 oil well blowout in 1979, seven live and three dead sea turtles were recovered (Hall et al. 1983). Two of the three carcasses had oil in the gut but no lesions. There was no evidence of aspirated oil in the lungs but hydrocarbon residues were found in kidney, liver, and muscle tissue of all three dead turtles. The authors suggested prolonged exposure to oil may have disrupted the feeding behaviour and weakened the turtles.

4.3.3.6 Species at Risk (SAR)

Species that are legally protected under *SARA* (i.e., Schedule 1 *threatened* or *endangered*) and which may occur in the Study Area include the following:

- Blue whale
- North Atlantic right whale
- Piping Plover
- Leatherback sea turtle
- Northern wolffish
- Spotted wolffish
- Beluga whale

Critical habitat of Species at Risk is also protected under *SARA*. The protection of critical habitats is a major aspect of *SARA* Recovery Strategies (e.g., identified Piping Plover critical habitat sites in the southern part of the Study Area).

Sections 4.3.3.1 to 4.3.3.5 address the potential interactions and effects between accidental events and the animals presently listed on Schedule 1 of *SARA* that could occur in the Study Area. It is likely that shallow subtidal, intertidal and backshore habitats would be most susceptible to impact by accidental events.

Of the species listed above, Piping Plover and their habitat could be the most affected depending upon the timing and location of a spill.

4.3.3.7 Summary of Interactions and Effects

The literature on the effects of petroleum hydrocarbons is very extensive. Thorough reviews are contained in Mobil (1985), Petro-Canada (1996), Husky (2000, 2001, 2003), LGL et al. (2000), and others, and they are not repeated here. It should be noted that at the project-specific EA stage, environmental effects assessment of accidental events are required in accordance with the C-NOPB *Guidelines Respecting Drilling Programs* (2000). Spill trajectory analysis is also often required. The key points of relevance to offshore planning for the Western Newfoundland and Labrador Offshore Area Study Area are listed below.

- Magnitude, geographic extent, and duration of effects are very sensitive to oil behaviour (see preceding section), timing and location of the blowout or spill.
- Plankton, particularly sensitive eggs and larvae, may be affected by an oil spill.
- Benthos may be unaffected by an oil or gas blowout or surface release that will rise to the surface. A subsurface blowout will physically disrupt benthic communities near the well as the gas escapes under pressure.
- Adult fish can likely detect and avoid a spill or blowout; however, ichthyoplankton (planktonic eggs and larvae) cannot avoid it and can suffer lethal and sublethal effects.
- Marine mammals and sea turtles are generally believed to be able to avoid most spills. Sea turtles may be somewhat more sensitive than marine mammals in this regard.
- Seabirds, particularly those such as murres and Dovekies that spend a lot of time on the surface, are the most sensitive group to the effects of oil because they lose the insulation value of their feathers in contact with even small amounts of oil, they tend to congregate in groups, and because they are also affected by other human pressures such as hunting (sea ducks and murres) and illegal dumping of oily bilges by disreputable tankers and freighters in Canadian waters.
- All seabirds are vulnerable to oil pollution but those that spend most of their time on the water's surface and dive are the most vulnerable (Wiese 1999). Diving-feeders occurring within the Western Newfoundland and Labrador Offshore Area Study Area include Greater Shearwaters, Sooty Shearwaters, Manx Shearwaters, Northern Gannets, Terns, Dovekies, Common Murres, Thick-billed Murres, Razorbills, Black Guillemots, and Atlantic Puffins.
- Coastal marine bird habitats and sensitive areas are vulnerable to oil pollution and possibly to other activity aspects associated with onshore to offshore directional drilling.

- As implied by the potential interactions with the various VECs, sensitive areas within the Study Area (e.g., Cod Spawning Area, lobster spawning and nursery areas, The Hole) are vulnerable to oil pollution.

- Intertidal and shallow subtidal benthos is vulnerable to oil washing ashore. Given the proximity of any future oil drilling in Parcels 4 to 7, typical onshore winds, there is likely a high probability that at least some oil from an accidental spill or blowout could reach the shoreline.

- Proximity to major shipping routes or offshore production sites can also increase the potential for exposure. Ninety-seven percent of oil encountered on birds or on beaches in the Newfoundland area originates from large ships (T. Lock, pers. comm. *in* Montevecchi et al. 1999). The threat of oil pollution to seabirds in the Atlantic Region of Canada is highest during non-breeding season when populations are dominated mainly by aquatic species (auks), water temperatures are lowest and populations expand their range into oil development or shipping areas (Lock et al. 1994; Montevecchi et al. 1999). The life history strategy of seabirds characterized by a long lifespan, delayed sexual maturity, small numbers of offspring, and aggregative behaviour (breeding colonies) render seabirds highly vulnerable to quick declines in the numbers of breeding individuals.

- The only potential biophysical effect at the population level from a large offshore oil spill or blowout may be with seabirds or waterfowl in situations where the releases coincided in time and space with large concentrations of birds. This conclusion was reached by all previous offshore EAs on the Grand Banks and is likely true for western Newfoundland as well, although further analysis would need to be done for site-specific situations.

- A large offshore spill could affect the commercial fishery by exclusion and market perception issues, again depending upon timing and location.

4.3.4 Mitigations and Planning

The effects conclusions presented in the previous sections assume that mitigations will be in place and thus the effects could be considered what is termed ‘residual.’ The oil industry operating in Newfoundland and Labrador waters has strict policies and procedures concerning spills of all sizes, which must be reported to the C-NLOPB. All offshore operators are required to submit to the Board and operate under an Oil Spill Response Plan (OSRP), or equivalent. In addition, all operators are required to have an arrangement with a spill response agency to provide spill response capabilities in the event of a spill.

Impermeable berms are constructed around the rig site in the case of onshore to offshore directional drilling operations in order to contain any accidentally released substances at the land-based site. Buffer areas are typically established to provide separation between the rig site and proximate water bodies, and are typically established on a project by project basis D. Hawkins, C-NLOPB, pers. comm., W. Foote, Government of Newfoundland and Labrador, pers. comm.).

Given the proximity of potential drilling activities to coastal areas and identified sensitive areas, spill response capabilities are even more critical than when activities are conducted further offshore. The increased probability of oil reaching shore or any of the identified offshore sensitive areas further necessitates that operators be prepared with a spill response strategy.

In summary, the most effective planning tool for minimizing the effects of oil spills is by all parties concentrating their efforts on avoidance firstly on accidents and secondly on sensitive areas and times. The latter are identified through efforts such as this SEA, generic EAs (where a scenario approach can be used to analyze different areas time and spill variables), and the site-specific EA. All operators are required to submit OSRPs to the Board.

4.3.5 Data Gaps

While the effects of different types of petroleum hydrocarbons are fairly well known, the physical characteristics of hydrocarbons in the Study Area are not well known. The crude oil discovered in the Study Area to date is lighter than that on the Grand Banks (51º API). The distribution of the fisheries in the Study Area is well known in time and space. The key data gaps in assessing the potential effects of a large oil spill or blowout are listed below.

Distribution of key VECs such as fish eggs and larvae, seabirds, marine mammals and sea turtles in the Study Area are not completely understood.

Specific characteristics, fate and behaviour of oil spills in most of the Western Newfoundland and Labrador Offshore Area are unknown. Only one oil spill trajectory modelling exercise has been conducted thus far in the Study Area. It was for a nearshore well located southwest of Cape St. George in Unit Area 4Rd. Trajectory analyses as per guidelines will be run as part of the project-specific EA process.

4.4 Cumulative Effects

In consideration of the number of parcels offered in the 2005 Call for Bids, it could be assumed for the purposes of the SEA that there would be a maximum of four exploration licenses issued if the 2005 Call is successful. Under the Boards' rights issuance processes for the 2005 Call, licenses must be relinquished if a well is not spudded within the first period of the license (typically five years, with an option for a 6th year). The current level of information available on the resource potential of the area does not permit an exact prediction of the number of exploration wells likely to be drilled during the period of these licenses. There are also five active exploration licences in the Study Area.

The following estimate is used for planning purposes without attempting explicitly to take into account the area's resource potential. Since the mid-1980's, approximately 75% of exploration licenses that expired or were relinquished in the Newfoundland and Labrador offshore area did not have a well drilled on the license.

Further, historical experience in the Newfoundland and Labrador offshore area indicates that (to end 2002) 23 significant discoveries have been made as a result of 129 "wildcat" exploration wells - a proportion of about 18% or 1 in 5.5. Of these discoveries, four to date (Hibernia, Terra Nova, White Rose and the potential Hebron development) have resulted in more than one delineation well (approximately 3% of exploration wells or 1 in 32). Full pre-development field delineation offshore Newfoundland and Labrador to date has involved 7-9 wells in addition to the initial discovery well; this drilling typically has extended considerably beyond the nine-year period of the original exploration license.

Given today’s high oil prices and increasing worldwide demand for oil and gas, it is difficult to predict future levels of offshore activity based upon past history. Nonetheless, given the relatively small area covered by the parcels in question, what is known of past decisions offshore Newfoundland, and other factors, the following may be a reasonable scenario for the west coast.

There likely would be no more than two seismic programs running concurrently. This is deduced based on past history, the high demand for seismic vessels, the need to maintain distance to avoid affecting each other’s data, and the general propensity of the oil industry to utilize resources sequentially to realize potential cost savings. [There is presently one 30 day 2-D/3-D program planned for 2005/2006 by Ptarmigan Resources Ltd. according to the C-NLOPB website.]

There likely would be no more than two exploratory drill rigs (one shallow and one deep), excluding any drilling from land, operational at any one time. This is deduced based on past history, the high demand for drill rigs, and the general propensity of the oil industry to utilize resources sequentially to realize potential cost savings.

There is typically no more than two exploratory wells drilled per parcel; given that there are four parcels and that exploration licenses typically last for five years then one may see eight wells over five years plus whatever activity existing licenses may generate over the next few years.

In the statistically unlikely event that enough significant discoveries are made to justify a production development, one would be the maximum number.

If a production development was proposed it can be speculated that in shallow water, say less than 100 metres, a bottom-founded unit might be used, whereas in deeper water an FPSO might be used. Production platforms would be tied into some unknown number of satellite wells with flow lines. Production developments could also be on land if directional drilling was used.

4.4.1 Oil and Gas Activities

4.4.1.1 Seismic Surveys

Any geophysical programs (2-D, 3-D, VSP, or other) will not overlap as they would interfere with data collection. Effects of noise may be additive on those animals such as certain species of fish (e.g., herring) and marine mammals (e.g., humpback whales) that may be sensitive to seismic survey noise. Although migratory animals may be subject to disturbance from noise outside the Study Area from other surveys on the East Coast. Mitigations such as ramp-ups and avoidance of sensitive areas and times should mitigate any potential cumulative effects to acceptable levels.

Considering that environmental assessments to date have concluded that the effects of individual seismic programs on marine animals (e.g., marine mammals, marine birds, sea turtles, fish, and invertebrates) are not significant given the proper implementation of mitigation measures (Davis et al. 1998) and that spatial and temporal overlap between different seismic programs can be readily minimized, seismic cumulative effects should be minimal. Nonetheless, individual seismic programs will require a site-specific EA pursuant to CEAA which will examine cumulative effects in detail. The more detailed cumulative effects assessment, including background noise levels, would be contained in the site-specific EA. Standard mitigations such as a marine mammal monitoring program, ramp-up procedures and the use of FLOs are typically employed by operators to reduce potential effects.

4.4.1.2 Drilling

Any cumulative effects will not be overlapping or synergistic within the Western Newfoundland and Labrador Offshore Area, unless supply vessels follow the same routes at the same time. Cumulative effects will, however, be additive; this is a potential issue with migratory species that may be subject to repeated disturbances as they transit the East Coast.

Any cumulative effects on the Gulf of St. Lawrence ecosystem from routine exploratory drilling in the Study Area will probably not overlap in time and space and thus, will be additive but not multiplicative. This level of activity will not change any effects predictions when viewed on a cumulative basis unless significant oil spills or blowouts occur.

Barring major accidents, effects of a single exploratory well in the Study Area should be minimal (Buchanan et al. 2003). In any event, it is unlikely that any effects, mostly confined to within 500 m, would overlap with another exploratory well, on or off the shelf; they will be simply additive. An exception could be the effects of drill rig noise and/or supply vessel noise. [The lack of modeling and measurements of noise in the Study Area has been identified as a data gap.]

4.4.2 Commercial Fisheries

The Study Area undergoes intensive fishing pressure (Section 3.4.4), so much so that the environmental effects of trawling on benthos and fish, the effects of longlines and gillnets on fish populations, seabirds, sea turtles, and marine mammals greatly exceed any potential effects from oil exploration. Nonetheless, effects of exploration activities will add some negligible, but not measureable, additional stress on fish and fisheries.

4.4.3 Shipping

The west coast sees some shipping activity, nationally through ports in Stephenville and Corner Brook, and internationally through the Strait of Belle Isle, mostly active during summer for ships coming from Europe. There is also local boat traffic, mostly fishing vessels. Seabirds, marine mammals, and sea turtles are the primarily affected VECs. These issues are typically considered at the EA stage.

4.4.4 Other Activities

Other activities with some potential for cumulative effects are hunting (marine birds), naval exercises (marine mammals), and research activity (e.g., DFO surveys). The specifics of these activities and potential effects will be considered during any site-specific assessments.

5.0 Summary and Conclusions

5.1 Potential Issues

Potential issues that are generally applicable to East Coast oil and gas exploration activity, including the Study Area, include:

- Effects of accidental spills on marine flora and fauna,
- Effects of industrial sound on marine mammals, and to a lesser extent on commercial invertebrates and fish,
- Disturbance of sensitive benthic communities,
- Attraction of seabirds, particularly petrels, to rigs and supply vessels.

Potential issues specific to the Western Newfoundland and Labrador Offshore Area Study Area identified during this SEA include:

- Sensitivity of shallow subtidal and intertidal areas to an accidental spill, particularly with respect to coastal seabirds, coastal waterfowl and shorebirds, and their respective habitats,
- Potential sensitivity of the Cape St. George Spawning Area off the Port au Port Peninsula where there may be aggregations of spawning Atlantic cod,
- Potential sensitivity of key lobster spawning and nursery areas,
- Potential sensitivity of The Hole, a highly productive steep slope area at the northern extent of the Esquiman Channel,
- Intensive exploitation of fisheries throughout the Study Area,
- Effects on aesthetics associated with the presence of oil and gas infrastructure nearshore.

5.2 Data Gaps

There is a considerable database on fishery landings in the Study Area and it is clear that the entire Study Area is very important to the fishery, particularly for invertebrate species such as American lobster, snow crab, and northern shrimp, and finfish species such as herring, mackerel, and historically, Atlantic cod. Inshore regions of the Study Area are known to be important bird nesting areas.

Key data gaps identified during this SEA include:

- Distribution of VECs in time and space, specifically fish eggs and larvae, marine birds, marine mammals and sea turtles, particularly for *SARA*-listed species such as wolffish, leatherback sea turtles, and various whale species,
- Locations of enhanced areas of production and/or concentrations of feeding seabirds and marine mammals,

- Locations of important habitat for coastal waterfowl and shorebirds,
- Locations of spawning areas or other critical habitat for commercial invertebrates and fish,
- Almost total lack of information on benthic communities in the Study Area, particularly those in the deeper areas,
- Lack of underwater noise data in the Study Area, modeled or measured,
- Information of oil and gas physical and chemical properties for the Study Area,
- Oil spill trajectory modeling for the different Bid Parcels and existing Exploration Licences within the Study Area.

5.3 Addressing Data Gaps

Depending on timing and nature of exploration activities, the Board may require baseline data collection, modeling studies, or monitoring programs associated with project activities.

Some of the data gaps can be addressed by the relevant government departments under their respective mandates, some by collaborative efforts between industry and government, some during monitoring programs during exploration, and some as part of site specific EAs. Some examples are listed below.

- Additional spatial and temporal distribution data on fish spawning aggregations would be valuable for managing the fisheries as well as for use in impact assessment. It is likely that the Board in collaboration with DFO and others in industry will find means to continue gathering these types of data.
- Additional distributional data on marine-associated birds and marine mammals will likely be collected by operators through seabird and marine mammal observation programs carried out in conjunction with exploration activities. These monitoring and observation programs have been undertaken for many of the exploration activities undertaken in the northeast Grand Banks, the Laurentian Subbasin and the Orphan Basin.
- Government provides oversight and their data archives are the ultimate beneficiaries.
- Site-specific EAs typically provide reviews of all relevant data and in some cases also provide original data (e.g., benthic surveys).
- Generally applicable information such as sound propagation modeling may be done through government and industry partnerships (e.g., ESRF, PRAC, PERD).
- Oil spill trajectory modeling (and potentially drill cuttings deposition modeling) during the site-specific EA process.

5.4 Planning Considerations

5.4.1 Important Invertebrate/Fish Spawning and Nursery Areas

One of the primary findings of this SEA was the potential need for special planning in the vicinity of the key spawning area for Atlantic cod (Cod Spawning Area off Cape St. George), the key spawning and nursery areas for American lobster in Unit Areas 4Rbc, and The Hole off Port au Choix (see Figure 5.1.). The C-NLOPB may require special restrictions on activities in these areas.

5.4.2 Shallow Subtidal/Intertidal Areas

Various shore types exist along the west coast of Newfoundland, some more sensitive than others to potential impact from oil and gas activities. For example, more unique shore type habitats (e.g., salt marsh, tidal flats, sandy beaches) would likely retain spilled oil for a longer period than more exposed shore types if cleanup were left to natural processes. Therefore, spill prevention and response are very important issues in the Study Area. The other issue that is further complicated by shallow water is acoustics. Sound propagation is complex in deepwater areas but is further complicated in shallow water. Sufficient acoustic modelling may be required to better predict the propagation of sound from sources such as seismic surveying.

5.4.3 Available Mitigations

Operators will be required by the C-NLOPB to comply with all applicable legislation and guidelines, including the C-NLOPB guidelines (e.g., *Geophysical, Geological, Environmental and Geotechnical Program Guidelines*-C-NOPB 2004*; Offshore Waste Treatment Guidelines* – NEB et al. 2002; *Offshore Chemical Selection Guidelines* – NEB et al. 1999)

Mitigations have been discussed throughout the SEA.

For seismic exploration (including vertical seismic profiling or VSP), mitigations employed by operators include:

- Ramping up (‘soft start’) of airguns at the start of survey,
- Monitoring of marine mammals and sea turtles,
- Communication with the fishing industry,
- Notice to mariners and fisheries broadcasts,
- Use of fisheries guard vessels and observers (FLOs) to help avoid conflicts with fishing vessels and gear,
- Compensation for gear losses attributable to seismic survey activity,
- Design/selection of equipment to optimize source levels,

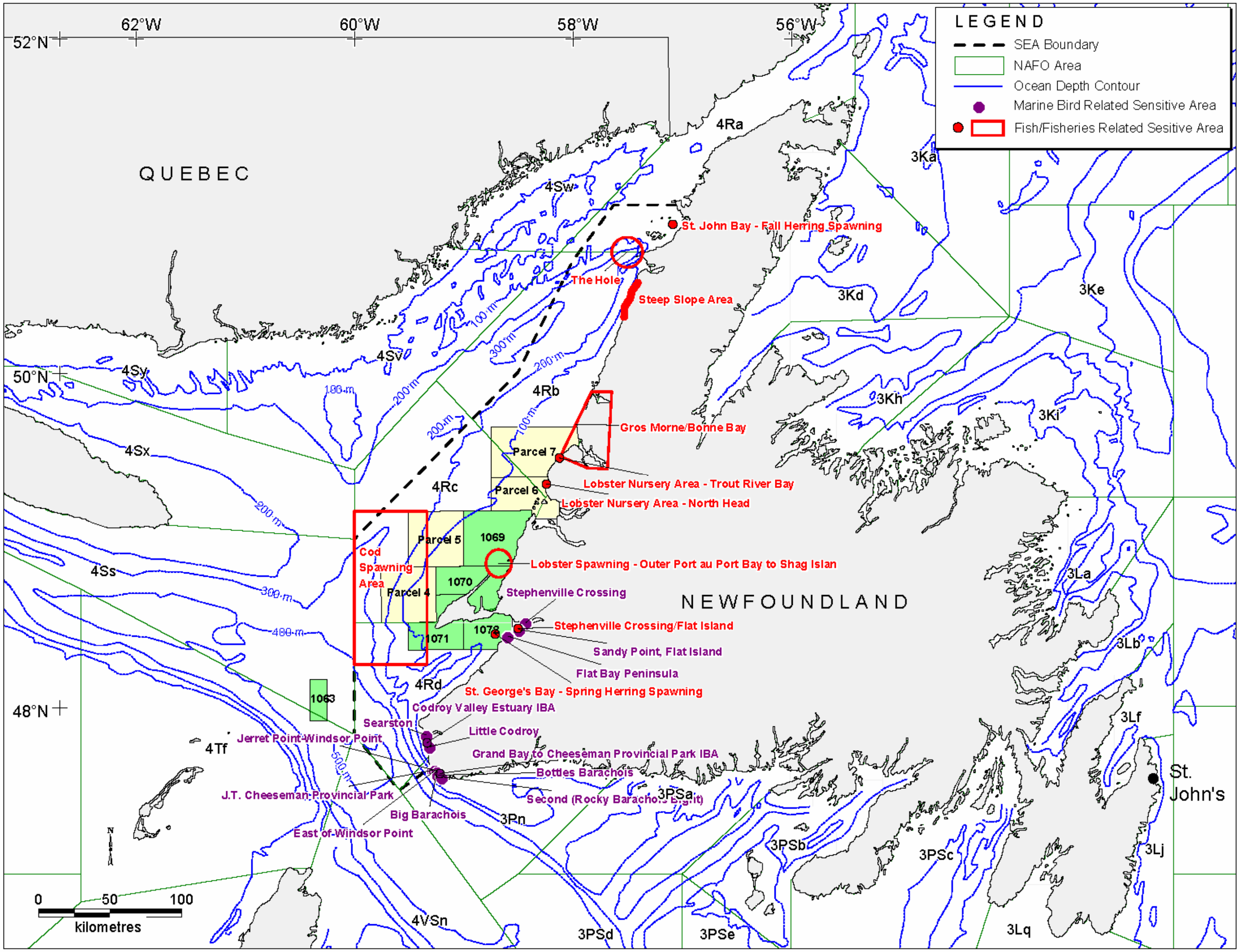

Figure 5.1. **Potentially Sensitive Areas within the Study Area.**

- Avoidance of sensitive areas and/or times (e.g., spring cod spawning within off Port au Port Peninsula; key lobster spawning and nursery areas, herring spawning in St. George's Bay (spring) and St. John Bay (fall), and
- Shutdowns if certain sensitive species of marine mammals and sea turtles (e.g., Schedule 1 *SARA* species) are within a pre-determined safety zone.

These mitigations are now more or less standard practice on the East Coast, including Newfoundland and Labrador waters.

Mitigations for exploratory drilling activity include

- Adherence to *OWTG* limits on discharges,
- Screening and selection of chemicals used in drilling,
- Design and implementation of a Waste Management Plan (WMP) to be approved by the C-NLOPB,
- Use of environmental criteria (to minimize emissions) in selection of any new equipment to be installed,
- Well abandonment procedures to be approved by C-NLOPB (mechanical procedures are much preferred over explosive means; if explosives are used, safety zones, appropriate marine mammal and sea turtle monitoring, and restrictions on timing, type, placement and shape of charges may be imposed),
- Selection of supply vessel and aircraft routing to avoid sensitive areas and/or times,
- Communication with fishing industry and other mariners in regard to vessel routing and safety zone, and other issues that may arise,
- Use of seabird observers (also to record marine mammals and sea turtles) on drilling rigs,
- Implementation of a fishing gear compensation program in the event that gear is damaged by an operator.

Mitigations for oil spills include:

- Emphasis on prevention through education, procedures and policies,
- Design and implementation of an Oil Spill Response Plan (OSRP) to be approved by C-NLOPB,
- Immediate spill response material (e.g., absorbents and booms) on the drill rig and/or attendant vessels,
- Fishery compensation programs for damaged gear and lost markets in the event of damage attributable a major spill or blow out,
- Construction of impermeable berm around the drill rig area of an onshore to offshore directional drilling operation.

In addition, existing and future research under ESRF, PRAC, PERD, and others will assist in refining mitigations by filling data gaps (e.g., acoustical environment).

5.5 Conclusion

The Western Newfoundland and Labrador Strategic Environmental Assessment Report concludes that petroleum exploration activity generally can proceed in the Western Newfoundland and Labrador Offshore Area with the application of standard mitigation measures currently applied to offshore exploratory activities elsewhere in the NL offshore. However, the SEA Report identifies sensitive fish habitat in the Study Area. The implementation of non-standard mitigations or restrictions on activities would likely be required in the following areas:

- The Cape St. George Spawning Area off the Port au Port Peninsula – within or adjacent to Parcels 4 and 5 and EL 1071
- The North Head Lobster Nursery Area – within the nearshore area of Parcel 6
- The Trout River Lobster Nursery Area – within the nearshore area of Parcel 7
- The St. George’s Bay Spring Herring Spawning area – within EL 1072
- The outer Port au Port Bay - Shag Island lobster spawning area – within the nearshore area of ELs 1069 and 1070
- The St. John Bay fall herring spawning area – within or adjacent to the northern portion of the Study Area.

The sensitivity of marine-associated birds in the Study Area is also an important issue. There are times and locations throughout the Study Area when and where seabirds, coastal waterfowl and shorebirds are most vulnerable to perturbation, particularly oil spills.

A project-specific environmental assessment will determine the nature and extent of these restrictions or non-standard mitigations for each activity proposed in each area. If it is determined during an assessment process that baseline information is required in order to assess impact predictions, the operator may then be required to undertake data collection. It is likely that during the early exploration phase such data collection can be conducted opportunistically as part of ongoing industry activity. In the event that petroleum resources with development potential are discovered, the C-NLOPB will consult with the appropriate operator, government agencies and interested parties in the public to determine the specifics of data collection effort that would be required to support a future development application.

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Appendix 1

Report on Community and Agency Consultations:
West Coast SEA – June 2005

Report on Fisheries Industry Consultations:
West Coast SEA – July 2005

Report on Community and Agency Consultations: West Coast SEA – June 2005

Introduction

Consultations for the preparation of the West Coast SEA report were undertaken during 13-17 June 2005 under the auspices of One Ocean and were planned and co-ordinated by Canning and Pitt Associates, Inc. The consultation team also included the C-NLOPB's Environmental Assessment Officer. A member of the LGL consulting team also attended the two meetings in Rocky Harbour.

This round of SEA consultations involved meetings and discussions with various regional and community level economic organizations and agencies, related interest groups, business operators and other interested individuals, and managers with Parks Canada in Gros Morne. Six separate meetings were held in the following communities: Rocky Harbour (two); Corner Brook; Stephenville (two); and Port aux Basques.

Meetings were organized with the assistance of the four relevant Regional Economic Development Boards (REDBs), Parks Canada managers, the Federation of Newfoundland Indians and representatives of the Viking Trail Tourism Association. In addition to managers and board members from each of the four REDBs, as well as Parks Canada officials, participants in the meetings in each area included representatives from various town councils, local and area-level environmental agencies and interest groups, tourism operators, ACOA managers and others.

A complete list of the agencies and individuals who participated in the first round of meetings may be found below in a later section.

General Procedure for the Meetings

Following general introductions and a short discussion of the purpose of the consultations by Canning and Pitt and One Ocean, Kim Coady - the C-NLOPB's representative - presented an overview which outlined the Board's role and mandate, the purpose and scope of the Strategic Environmental Assessment process and a review of the various environmental components which are expected to be addressed in the SEA Environmental Assessment Report.

Following this, there was a general round table discussion which included comments and questions from participants about various aspects of the SEA process and issues and concerns associated with offshore exploration and development. All of the comments, questions or issues raised by participants were noted and recorded.

The following sections provide a summary of the topics and issues discussed at each meeting location.

Red Ochre Board Meeting

The study team met with representatives of the Red Ochre Regional Economic Development Board in Rocky Harbour. Following the presentation, Board representatives raised asked a number of general questions and noted several concerns.

There were several questions about future oil and gas exploration activities and the SEA process. A Board member asked if potential bidders on any new lease areas know if they contain oil resources. In response, it was noted that some information is available from previous exploration work, but more seismic surveys are need to assess the potential for development. There were also a few questions about the length of time exploration companies can hold onto their lease area. K. Coady responded that potential lease holders are required to undertake a specified amount of investment in order to retain their exploration rights.

One concern noted was the potential effects of future oil and gas development on the area's tourism sector, in particular the "aesthetic" and visual impacts. The Gros Morne area is marketed as a "pristine", natural setting, and some visitors might regard an onshore or offshore oil rig as a visual intrusion on the landscape.

Protection of the area's lobster grounds was also raised. Given the economic value of this fishery, and in light of the decline in cod resources, it would be very important to protect lobster grounds from any negative impacts from future oil and gas activities. The Eastern Arm of Bonne Bay was noted as a particularly sensitive and important area for the region. Various groups have been involved in the DFO Integrated Coastal Zone Management process, but this part of the bay, and other marine areas, are still being studied and assessed. Relevant information from the Coastal Community Resource Inventory should be incorporated into the SEA report, and Eastern Arm should be identified as a special, sensitive area.

Board representatives asked if there were any national environmental groups, e.g., the Sierra Club, represented on the SEA Working Group. It might be useful for the Board to consult with such groups, for example to obtain information and advice about how to manage possible impacts, as well as the "perception" of potential impacts.

Board members said that they may receive comments on or further information for the SEA report from other groups and individuals in their zone. If so, would the Board hold another public meeting in this area? K. Coady said that the Board would have to consider this depending on the circumstances. In any case, when the SEA report is ready, it will be available for further public comment and input. Board representatives said they would undertake to circulate the draft report to its membership.

Parks Canada and Tourism Representatives

Parks Canada managers and a representative of the Viking Trail Tourism Association (VTTA) attended the afternoon meeting in Rocky Harbour.

Following the presentation, there were a few general questions about the SEA process, and also about the CEAA process. Parks Canada managers asked if a Comprehensive Study was triggered only if there is a discovery, and K. Coady explained that a Comprehensive Study could be undertaken for several different reasons.

Parks Canada managers noted that although Bonne Bay is not part of Gros Morne Park, it is deemed to be an "ecologically significant area", and it is also an important centre for marine-related research activities. Obviously there is a concern that future oil activities might disturb, or have negative impacts on, salt marsh areas and the estuaries within the bay. St. Paul's inlet is also considered an important area for sea birds, and this area contains the largest tern colony in the province. While the coastline in between Bonne bay and St. Paul's inlet is not as significant, Parks Canada would not want to see any of this shoreline area polluted by oil activities (i.e., oil spills). Other areas of special interest include the four scheduled salmon rivers within Gros Morne. According to Parks Canada there is also a possible cod grow-out site in Neddy Harbour.

The VTTA representative noted that there are some boat tour operators involved in whale watching (mostly minke whales), and there are also kayaking activities within Bonne Bay as well as in St. Paul's Inlet. He also mentioned potential aesthetic and visual impacts from oil activities as a concern, and suggested that these might be minimized if drilling activities occurred outside of the main tourist season. He noted that Gros Morne is a World heritage Site and thus it will be very important to ensure that oil activities do not undermine the region's reputation as a pristine and scenic area.

Parks Canada managers were asked if there were any plans to establish Marine Protected Areas (MPAs) within the Bonne Bay area. Parks Canada managers noted that several sites, particularly within the East and South Arms of Bonne Bay, are now being considered "special" areas, and at some future time maybe declared MPA's. It was also noted that DFO is planning to prepare an annotated bibliography for the Bonne Bay area. This research will compile existing data on physical, chemical and biological parameters and collect other baseline data. A student researcher will be hired for this work this summer and it is expected to be completed by March 2006. It was noted that this research would be a good source of data for future, site-specific environmental assessments.

Corner Brook Meeting

The Corner Brook meeting was attended by representatives from Humber Economic Development Board (HEDB), the City of Corner Brook, the Board of Trade and the Humber Arm ACAP.

Following the presentation, there were some general questions about seismic surveys and the data, which the SEA expects to obtain.

The HEDB representative asked what data exists about the potential impacts of seismic operations, and whether there has been any laboratory research on this subject, particularly on lobster. He also asked what the availability of current research on cuttings and discharges from drilling operations. In response, K. Coady outlined the various research that has been undertaken to date.

HEDB's representative suggested that the West Coast area in general would be an ideal place to conduct further research on seismic operations and there effects on lobster. For example, the Centre Of Excellence in Bonne Bay would likely be an ideal agency to undertake any such research.

ACAP's representative asked what happens when an SEA report identifies a data or information gaps. She also asked what recommendations might be made in the SEA report regarding any concerns about potential impacts on crab and lobster resources from seismic surveys, and also where the SEA expects to obtain its biological data. In response, K. Coady noted that, in cases where information gaps are identified, a potential operator might be asked, or required, to undertake further research on such topics. With respect to potential mitigations to minimize possible impacts on crab or lobster, she noted that a seismic operator could be asked to avoid certain areas during any "sensitive" periods. As for available biological information, she noted that most of this would come from existing DFO and Environment Canada data sources.

ACAP noted that it plans to undertake an ROV survey in the Bay of Islands this summer. This survey will examine sea-bed conditions at the outfall of the paper mill, undertake some sediment sampling in key locations and also gather information on the fecal problems (due to septic outflows) in the Lark Harbour area.

Port aux Basques Meeting

This meeting was attended by representatives of the Marine and Mountain Zone Corporation, the Town of Channel-Port aux Basques, the Southwest Coast Development Association and HRSDC.

Following the presentation, there were a number of general questions and comments concerning the SEA process, and potential impacts from offshore exploration activities.

These included questions about the Board's jurisdiction over onshore wells and whether or not there has been any interest from exploration companies about lease areas in this part of the West Coast. There was also a few questions and a short discussion about the potential impacts on fisheries habitat from seismic operations.

Stephenville Meeting (Morning Session)

Participants in this meeting included representatives of the Long Range Regional Economic Development Board and the area's Mi'kmag groups.

Following the Board's presentation, the discussion focused on a discussion of aboriginal people's jurisdiction and involvement in land claims' issues, environmental protection and onshore/offshore oil and gas activities.

The two representatives of the area's Mi'kmag residents offered some general comments on land jurisdiction and ownership as these issues pertain to the province's requirement to notify aboriginal peoples about any land development issues. It was noted that these issues are important because of ongoing land claims' discussions with the province. K. Coady responded noting that the Board is aware of its fiduciary responsibilities with respect to First Nations' land claims.

One of the Mi'kmag representatives asked what agencies would be involved once the SEA is completed and other site-specific assessments are undertaken in future, and whether federal agencies would have the final say on these assessments. In response, K. Coady noted described the CEAA process and the fact that the C-NLOPB is considered a federal agency under that process. With respect to any environmental assessments studies undertaken by potential operators, she said that these would be "self assessments", but the CEAA and other federal agencies would determine whether a project could or should proceed.

One of the Mi'kmag representatives noted that, although you can separate the respective federal-provincial jurisdictional responsibilities and areas (e.g., between the high and low water marks) in legislation, these cannot really be separated in the "real" environment.

Following this, there was a general discussion on various aspects of the SEA process. One participant asked what was driving this SEA process; for example, did this mean that there is now an increased interest in this region from exploration and oil development companies? K. Coady explained that the SEA process is part of the Board's "normal" land issuance procedures, which it undertakes before offering up new lease areas for potential exploration activities.

Another participant asked if there were any areas in the province where, following an environmental assessment report, the Board has recommended that the area not be explored for oil and gas resources? K. Coady noted that the Board has not yet prevented an area from being developed for extraction, however in some cases it has placed various restrictions on exploration activities (e.g., seismic programs).

In response to a question as to whether the SEA would attempt to deal with the issue of climate change, it was noted that this issue would be considered at a later stage in the assessment process.

There were some final questions about the overall SEA consultation process. One participant asked if there would be any further consultations or meetings with local and area groups once the SEA report is completed, and how the Board planned to get the report to the general public. K. Coady responded that the SEA consultation process would involve additional meetings with fisheries industry participants and that the draft SEA report would be made available for further public review and comment.

Stephenville: Evening Session (Long Range Regional Economic Development Board)

The evening meeting with full Board of the LRREDB the involved a general discussion of the SEA process, and the public consultation process. Board members suggested that it would be useful to consult with various Harbour Authorities in Bay St. George (e.g., the port of Harmon and Cape St. George). K. Coady noted that representatives of these local agencies would likely participate in the consultations with fisheries industry participants planned for July.

The Chair of the LRREDB suggested that other groups in this area might wish to comment on the SEA report, and also that his Board might offer further input when it has had a chance to read the report. The meeting ended with a short discussion of the potential economic benefits to the area from future oil and gas development activities.

List of Persons Involved in the SEA Community and Agency Consultations

Rocky Harbour Sessions

Colleen Kennedy, Chair, Red Ochre Board, Rocky Harbour
Jennifer Payne, Red Ochre Board member, Parson's Pond
Sean St. George, Executive Director, Red Ochre Board, Parson's Pond
Peter Deering, Parks Canada, Rocky Harbour
Tom Knight, Parks Canada, Rocky Harbour
Bob Hicks, President, VTTA, Rocky Harbour

Stephenville Sessions

Calvin White, LRREDB Chair, Flat Bay
Ian Stewart, LRREDB member, Ramea
Roger Hulan, LRREDB member, Stephenville
Cynthia Downey, LRREDB member, Stephenville Crossing
Terri Blanchard, LRREDB Administrative Assistant, Stephenville
Michael Tobin, Stephenville Town Council, Stephenville
Blaine Marks, Stephenville Town Council, Stephenville
Mark Tierney, ACOA, Stephenville
Lorraine Sheehan, Women's Centre, Stephenville
Litty MacDonald, Aboriginal People, Bay St. George
Beverly Kirby, Community Education Network, Stephenville
Catherine Fenwick, Association Regionale de la Colionest [?], Port au Port Peninsula
Len Muise, LRREDB Co-ordinator, Stephenville
Debbie Coughlin, LRREDB, Stephenville
Bert Alexander, Ktaqamkuk Mi'kmag Alliance, Western Newfoundland
Frank Russell, Mi'kmag People, Port au Port
Ryan Crocker, The Georgian, Stephenville

Corner Brook Session

William A. Lundrigan, Board of Trade, Corner Brook
Paul Hunt, Humber Economic Development Board, Corner Brook
Mike Dotter, City of Corner Brook
Tara Martin, ACAP Humber Arm, Corner Brook

Port aux Basques Session

Gerard Merrigan, Executive Director, MMZ Corporation, Channel-Port aux Basques
Doreen Hardy, MMZ Corporation, Channel-Port aux Basques
Cheryl Reynolds, Town of Channel-Port aux Basques, Channel-Port aux Basques
Rita Anderson, Southwest Coast Development Association, Channel-Port aux Basques
Dwight Kettle, HRSDC, Channel-Port aux Basques
Natalie Musseau, The Gulf News, Channel-Port aux Basques

Report on Fisheries Industry Consultations: West Coast SEA - July 2005

Introduction

Fisheries consultations for the preparation of the West Coast SEA Environmental Assessment report were undertaken during 20-21 July 2005 under the auspices of One Ocean and were planned and co-ordinated by Canning and Pitt Associates, Inc. and One Ocean. The SEA consultation team also included the C-NLOPB's Environmental Assessment Officer and a representative of LGL Consultant's Ltd.

These SEA fisheries consultations involved discussions with FFAWU officials and individual fishers. Three separate meetings were held in the following communities: Hawke's Bay, Corner Brook and Stephenville.

Meetings were organized with the assistance of Guy Perry, Staff Representative, and Jason Spingle, Science Co-ordinator, with the FFAWU's office in Corner Brook, the Union's Staff Representative for the area north of Trout River and the chairs of relevant Fishers Committees in the three areas. The Executive Director of the North of Fifty Association also helped organize the meeting in Hawke's Bay.

A complete list of the FFAWU and fisher representatives who participated in these SEA consultations are listed above.

General Procedure for the Meetings

Following general introductions and a short discussion of the purpose of the consultations by Canning and Pitt and One Ocean, Kim Coady - the C-NLOPB's representative - presented an overview of the Board's role and mandate, the purpose and scope of the Strategic Environmental Assessment process and a review of the various environmental components which are expected to be addressed in the SEA Environmental Assessment Report.

Following this, there was a general round table discussion which included comments and questions from participants about various aspects of the SEA process, offshore exploration and development and issues and concerns about potential impacts on fishing activities and fisheries resources. All of the comments, questions or issues raised by participants were noted and recorded.

The next section presents a summary of the issues, topics and concerns raised at each meeting.

Hawke's Bay Meeting

Following the presentation several general points issues were raised and discussed. These included questions about the number of seismic surveys undertaken in the past several decades, which agency decides what areas are offered for exploration and the fact that some of the lines proposed for a 2005 survey go beyond the lease area in question (Parcel 1069). K. Coady explained the Board's rights issuance procedures, and explained the reason why one of the lines in the planned 2005 Ptarmigan survey extend beyond the lease area.

Fishers asked if there are policies and procedures in place that would ensure fishers were protected in the event of a spill, or whether they might be compensated if they were displaced from a good fishing area in which an oil rig was operating. In response, team members explained the provisions in place for oil spill compensation and noted that the "safety area" from which fishing activities might be excluded would be very small.

Fishers asked several questions about seismic technology and how it operates, and there was also some discussion of the difference between the SEA process and the more site-specific assessment process associated with an Environmental Assessment for a seismic survey. Fishers noted that would expect to be consulted further if a survey was being considered with their area.

With respect to special, or potentially sensitive, areas in this part of the study area, there was a relatively lengthy discussion of the nearshore area between Port aux Choix and Bellburns. A deep-water area relatively close to shore just off Port aux Choix known locally as "The Hole" is considered to be a very sensitive fisheries resource zone, and a very productive fishing area. Fishers noted that, given the convergence of sea-bed contour lines in that area in conjunction with water current patterns along the West Coast, a large and diverse number of mature and immature fish species (cod, capelin, etc.) tend to congregate in the Hole, and many of them tend to over-winter there as well. In the past, many of the larger fishing vessels have harvested shrimp in this area, and have had very good catches on shrimp grounds just a few miles from the shore.

According to fishers, DFO has been considering the Hole as a candidate for a Marine Protected Area. Fishers have recommended that otter trawlers be excluded from this area and that it be reserved for just pots and hook and line gears.

A portion of the coastal zone close to the shore between approximately Bellburns and River of Ponds was also cited as a special area. Fishers noted that, as is the case in the Hole, many fish species congregate in the deep water close to shore along this part of the coast. It is a particularly good herring spawning area, and this species generally spawns here in May during the lobster season. Bad Bay just north of the community of River of Ponds, and La Fontaine Point just a short distance south of that community, were noted as particularly productive fishing and spawning locations. Fishers noted that these two areas are especially prolific given the nutrients in the fresh water that flows into the coastal area from the River of Ponds.

Two other areas were also noted as special or sensitive fisheries resource locations. These include the East Arm of Bonne Bay, and the large cod spawning area off Cape St. George.

In their concluding comments, participants indicated their concern about the potential, or unknown, effects of seismic operations on various fish species, and noted that they would like to see more research on any such effects. R. Hedderson mentioned anecdotal evidence of halibut being scared away from some fishing grounds after a survey undertaken a few years ago. He also noted that fishers had asked that a previous seismic operation (2003) be delayed until after the cod spawning season. M. Murphy mentioned that One Ocean has asked ESRF to make catch and catchability research a high priority for studies now being planned by that agency for 2006.

Corner Brook Meeting

Following the opening presentation, and in response to maps showing the 2001 and 2002 fish harvesting locations within the study area, there was a discussion of the lack of geo-referenced data for vessels < 34'. In her presentation, K. Coady had noted that this SEA study was somewhat different than others that the Board has undertaken in the past few years in that many of the lease areas touch the shoreline. As such, any subsequent site-specific Environmental Assessment studies would probably require more detailed information on the location of coastal and nearshore fishing activities and gear locations.

J. Spingle, the FFAWU's Science Co-ordinator, responded that the availability of positional data for the coastal area should not be a significant problem. He stated that most of the < 34' vessels generally fish cod within 6 miles of the shore and other species, such as lobster, are taken very close to the coast. As such, one can assume that much of the coastal, inshore area along the West Coast out to say 6 miles is heavily fished. In addition, he noted, some of the data that would be required are presently collected through the Dockside Monitoring Program. This includes information on the number of vessels, species landed and the pattern of monthly landings.

With respect to the appropriate time to conduct future seismic surveys, one fisher said that the best time would be in the late summer early fall. It was noted that the region's crab fisheries are generally over by mid-July, and most of the other species fisheries – with the possible exception of halibut - are over by the end of that month. While there are herring and mackerel fishing activities taking place in the fall, this would not be a significant problem for survey vessels since most of these catches are by mobile gears.

In response to the usefulness of information on special or sensitive fishing and resource areas in this part of the study area, a number of specific locations were noted and discussed as areas that might be affected by oil-related activities.

One fisher who usually fishes the area between the Bay of Islands and Port au Port Bay noted that the inshore area between the outer portion of Port au Port Bay up to Shag Island is a very good lobster spawning area, and very dense kelp grounds provide an excellent habitat for lobster. Lobster fishing grounds in the area between Long Point and Shag Island generally yield very large females.
Another fisher noted that, within LFA 13B, there is a lobster nursery area in a small cove close to Shoal Point located just above North Head (located on the north side of the mouth of the Bay of Islands), and there is another nursery area closer to Trout River within LFA 14A. Fishers from the Bay of Islands, and from Trout River to the north, have voluntarily agreed not to fish these two areas. The co-ordinates of these two lobster nursery areas are: [Elaine Lynch 637-4308]

Mention was also made again of the cod spawning area off of Cape St. George. As noted, fishing does not occur in that area during the period 1 April – 15 June.

Following this there was a general discussion about potential impacts from oil and gas activities, and also about some of the fisheries research and data which might be collected in future during a site-specific environmental assessment study or as part of other data gathering programs which potential exploration companies or operators might be required to undertake in their environmental assessment process, or monitoring programs.

Fishers expressed their concerns about possible impacts of seismic operations on crab resources, or on other fish species resulting from the release of toxic materials, such as drill cuttings. Fishers are also concerned about potential oil spills and effects on fishing and fisheries resources. It was noted, for example, that spilled oil coming onshore would be disastrous for the lobster fishing and kelp grounds in the Long Point-Shag Island area. (It was also noted that fishers would not like to see any drilling in this area.). The FFAWU's Science Co-ordinator suggested that, given the "contained" area of the Gulf of St. Lawrence, an oil spill off the province's West Coast would likely have a more significant impact on the fisheries than one which occurred in an offshore area of the Grand Banks. Given the proximity of the lease areas to the coast (as well as prevailing wind) spilled oil would quite likely reach shoreline areas. Fishers also asked about economic compensation in the event of an oil spill.

Another fisher asked if any research has been undertaken to determine whether seismic noise has any negative effects on herring and mackerel. In response, K. Coady and J. Christian both spoke to this matter indicating the various research studies that have been undertaken in Atlantic Canada to assess the effects of seismic operations on crab, as well as on finfish species in other regions such as the North Sea. The FFAWU's Science Co-ordinator noted that he has read a number of studies on the potential impacts of seismic operations on various fish species. Considering this research, he said it does not appear that seismic operations have any significant impacts on halibut, crab or lobster. Another fisher agreed with this conclusion, but he remained concerned about the potential effects on fisheries resources from the release of toxins and drill cuttings into the marine environment, as well as the negative effects of a potential oil spill at some point in the future.

If at some point oil companies undertake marine environmental research as part of their plans to develop production facilities, the FFAWU suggests that some of this research should be focused on topics and issues that would help expand and enhance knowledge about the region's fisheries environment. As such, this would include the acquisition of research data on such things as cod larvae and recruitment, the abundance and timing of larvae and other oceanographic data such as water temperatures and currents, among others. Research might also be undertaken to identify areas where cod overwinter. The FFAWU and DFO are currently involved in a research initiative designed to increase knowledge on this matter. This research project involves the placement of hydrophones on the 4R/3PN line and on the 3PN/3PS line and is designed to gather information on the migration of cod using a sample of 300 tagged fish.

Stephenville Meeting

The meeting in Stephenville involved fishers from both sides of Bay St. George, as well as fisher representatives based in Port au Port Bay. (Fishers from the Codroy Valley-Port aux Basques area were also expecting to attend the meeting but were not able to do so because they were still busy with their cod fisheries.) Because there have been several seismic surveys in this part of the SEA study area, as well as drilling of a number of onshore and offshore oil wells, fishers from the area are relatively familiar with potential interactions between the fisheries and oil industry activities.

Following the presentation on the SEA process, questions focused mainly on potential effects of seismic survey operations on fisheries resources. One fisher asked about what research has been done to identify possible effects on crab and lobster resources, and another asked about research on the scaring of cod (and other fish species) by seismic noise, physical effects on their hearing capability or the long term effects on fish stocks. Several fishers commented that there was a noticeable drop in lobster and scallop catches in Port au Port Bay following seismic surveys in that area during the mid-1990s; however it was noted that these changes might also have been due to relatively heavy fishing effort in subsequent years. The Board’s Environmental Assessment Officer as well as the SEA consultants noted and described the various research studies that have been undertaken both in the North Sea and in Atlantic Canada.

With respect to any possible effects on mackerel from offshore oil activities, the FFAWU’s Science Co-ordinator noted that the West Coast mackerel fishery has been very good in the past few years, and that the 2004 quota (75,000 tonnes – PQ and NL combined) for this species was taken.

List or Persons Involved in the SEA Fisheries Industry Consultations

FFAWU

Jason Spingle, Science Co-ordinator, Corner Brook
Guy Perry, Staff Representative, Corner Brook
Roland Hedderson, Staff Representative, [community)

North of Fifty Association

Vachon Noel, Executive Director, Flowers Cove

Fisher Representatives

Lumis Way, Green Island Cove
Eugene Caines, Port aux Choix
Alan Sheppard, Lark Harbour
Wayne Tucker (FFAWU Inshore Council), Meadows
Rex King, Stephenville
Jack Duffy, Stephenville
Jeffrey Leroy, Fox Island River
Gus Hynes, Fox Island River
Jack Harris, Jeffreys

Other

Len Muise, Chair, Natural Resources Committee, Long Range REDB, Stephenville

Appendix 2

Coastal Aerial Surveys[1] for Tern and Gull Colonies Conducted in mid June 2001 (north of Bay of Islands) and 2002 (south of Bay of Islands) by Canadian Wildife Service.

SPECIES	LATITUDE	LONGITUDE	NUMBER
Tern species	49.862310000	-57.815020000	5
Tern species	50.625700000	-57.317000000	6
Tern species	48.248520000	-58.820060000	9
Tern species	48.696830000	-58.678900000	10
Common Eider	48.870840000	-58.593240000	Small 1-100 Ind
Tern species	51.163600000	-56.812500000	20
Tern species	48.208333000	-58.866667000	25
Tern species	50.789200000	-57.276800000	30
Common Eider	48.887850000	-58.679640000	Small 1-100 Ind
Tern species	50.819100000	-57.201900000	35
Tern species	51.027800000	-56.962100000	35
Tern species	51.289500000	-56.772100000	35
Tern species	50.895400000	-57.278400000	40
Tern species	51.006100000	-56.958600000	45
Tern species	50.922800000	-57.104700000	50
Tern species	48.450000000	-58.516667000	50
Tern species	48.646850000	-58.672210000	50
Common Eider	49.230000000	-58.345000000	Small 1-100 Ind
Tern species	51.160400000	-56.827200000	65
Tern species	48.501370000	-58.416360000	70
Tern species	51.177000000	-56.816400000	80
Tern species	51.284200000	-56.765700000	90
Tern species	50.622700000	-57.162800000	100
Tern species	51.162900000	-56.819000000	100
Tern species	49.840450000	-57.777930000	100
Tern species	49.827240000	-57.786990000	105
Tern species	50.883800000	-57.128200000	130
Tern species	50.918100000	-57.123700000	150
Tern species	50.931900000	-57.018800000	150
Tern species	48.497500000	-58.430800000	150
Tern species	48.558000000	-58.727740000	210
Tern species	49.069630000	-58.324130000	425
Tern species	50.800900000	-57.222600000	1000
Tern species	49.853760000	-57.787740000	1100
Tern species	49.853610000	-57.787860000	1200
Black-legged Kittiwake	48.466700000	-59.270000000	large (501-1000 ind)
Herring Gull	49.075680000	-58.324130000	large (501-1000 ind)
Black-legged Kittiwake	49.250000000	-58.333333000	large (501-1000 ind)
Ring-billed Gull	50.718200000	-57.331500000	Medium 101-500 Ind
Ring-billed Gull	50.722900000	-57.320200000	Medium 101-500 Ind
Great Black-backed Gull	50.727200000	-57.313900000	Medium 101-500 Ind
Great Black-backed Gull	50.839200000	-57.104600000	Medium 101-500 Ind
Herring Gull	50.839300000	-57.096700000	Medium 101-500 Ind
Ring-billed Gull	50.839300000	-57.096700000	Medium 101-500 Ind
Herring Gull	50.885300000	-57.149500000	Medium 101-500 Ind
Herring Gull	50.891900000	-57.288000000	Medium 101-500 Ind
Herring Gull	50.900600000	-57.283600000	Medium 101-500 Ind
Herring Gull	50.919300000	-57.179400000	Medium 101-500 Ind
Great Black-backed Gull	50.919300000	-57.179400000	Medium 101-500 Ind

Herring Gull	50.919800000	-57.109700000	Medium 101-500 Ind
Ring-billed Gull	51.101400000	-56.885500000	Medium 101-500 Ind
Ring-billed Gull	51.136900000	-56.856300000	Medium 101-500 Ind
Herring Gull	51.160900000	-56.838700000	Medium 101-500 Ind
Ring-billed Gull	51.308900000	-56.734200000	Medium 101-500 Ind
Ring-billed Gull	51.308900000	-56.736500000	Medium 101-500 Ind
Ring-billed Gull	48.450000000	-58.516667000	Medium 101-500 Ind
Herring Gull	48.561300000	-59.235330000	Medium 101-500 Ind
Great Black-backed Gull	48.870840000	-58.593240000	Medium 101-500 Ind
Herring Gull	48.870840000	-58.593240000	Medium 101-500 Ind
Cormorant species	48.870840000	-58.593240000	Medium 101-500 Ind
Herring Gull	49.081600000	-58.302880000	Medium 101-500 Ind
Herring Gull	49.106660000	-58.238220000	Medium 101-500 Ind
Ring-billed Gull	49.163780000	-58.147230000	Medium 101-500 Ind
Cormorant species	49.250000000	-58.333333000	Medium 101-500 Ind
Herring Gull	49.283333000	-58.300000000	Medium 101-500 Ind
Cormorant species	49.283333000	-58.300000000	Medium 101-500 Ind
Ring-billed Gull	49.933333000	-57.833333000	Medium 101-500 Ind
Herring Gull	49.933333000	-57.833333000	Medium 101-500 Ind
Caspian Tern	51.177000000	-56.816400000	possible
Herring Gull	50.727200000	-57.313900000	Small 1-100 Ind
Herring Gull	50.752400000	-57.243800000	Small 1-100 Ind
Great Black-backed Gull	50.752400000	-57.243800000	Small 1-100 Ind
Common Eider	50.753700000	-57.247200000	Small 1-100 Ind
Common Eider	50.825400000	-57.159400000	Small 1-100 Ind
Common Eider	50.840900000	-57.294600000	Small 1-100 Ind
Great Black-backed Gull	50.891900000	-57.288000000	Small 1-100 Ind
Great Black-backed Gull	50.895400000	-57.278400000	Small 1-100 Ind
Common Eider	50.895400000	-57.278400000	Small 1-100 Ind
Great Black-backed Gull	50.900600000	-57.283600000	Small 1-100 Ind
Common Eider	50.923000000	-57.139600000	Small 1-100 Ind
Common Eider	50.924100000	-57.172900000	Small 1-100 Ind
Ring-billed Gull	51.006100000	-56.958600000	Small 1-100 Ind
Herring Gull	51.015800000	-56.933700000	Small 1-100 Ind
Common Eider	51.018400000	-56.930100000	Small 1-100 Ind
Great Black-backed Gull	51.029600000	-56.969400000	Small 1-100 Ind
Common Eider	51.149200000	-56.838400000	Small 1-100 Ind
Great Black-backed Gull	51.152900000	-56.841700000	Small 1-100 Ind
Great Black-backed Gull	51.160900000	-56.838700000	Small 1-100 Ind
Great Black-backed Gull	51.160900000	-56.838700000	Small 1-100 Ind
Great Black-backed Gull	51.164000000	-56.810300000	Small 1-100 Ind
Great Black-backed Gull	51.308900000	-56.734200000	Small 1-100 Ind
Black-legged Kittiwake	49.939890000	-57.784930000	Small 1-100 Ind
Great Black-backed Gull	49.939890000	-57.784930000	Small 1-100 Ind
Herring Gull	49.939890000	-57.784930000	Small 1-100 Ind
Great Black-backed Gull	49.936290000	-57.829600000	Small 1-100 Ind
Herring Gull	49.936290000	-57.829600000	Small 1-100 Ind
Ring-billed Gull	49.936290000	-57.829600000	Small 1-100 Ind
Cormorant species	49.936290000	-57.829600000	Small 1-100 Ind
Great Black-backed Gull	47.875760000	-59.403540000	Small 1-100 Ind
Herring Gull	47.875760000	-59.403540000	Small 1-100 Ind
Cormorant species	48.066667000	-59.133333000	Small 1-100 Ind

Great Black-backed Gull	48.208333000	-58.866667000	Small 1-100 Ind
Ring-billed Gull	48.208333000	-58.866667000	Small 1-100 Ind
Great Black-backed Gull	48.450000000	-58.516667000	Small 1-100 Ind
Herring Gull	48.508370000	-58.969370000	Small 1-100 Ind
Great Black-backed Gull	48.508370000	-58.969370000	Small 1-100 Ind
Great Black-backed Gull	48.561300000	-59.235330000	Small 1-100 Ind
Black Guillemot	48.870840000	-58.593240000	Small 1-100 Ind
Black-legged Kittiwake	48.870840000	-58.593240000	Small 1-100 Ind
Great Black-backed Gull	49.022670000	-58.475580000	Small 1-100 Ind
Great Black-backed Gull	49.081600000	-58.302880000	Small 1-100 Ind
Great Black-backed Gull	49.075680000	-58.324130000	Small 1-100 Ind
Great Black-backed Gull	49.106660000	-58.238220000	Small 1-100 Ind
Herring Gull	49.120120000	-58.233360000	Small 1-100 Ind
Great Black-backed Gull	49.120120000	-58.233360000	Small 1-100 Ind
Herring Gull	49.123770000	-58.237320000	Small 1-100 Ind
Great Black-backed Gull	49.123770000	-58.237320000	Small 1-100 Ind
Herring Gull	49.163780000	-58.147230000	Small 1-100 Ind
Great Black-backed Gull	49.163780000	-58.147230000	Small 1-100 Ind
Great Black-backed Gull	49.230000000	-58.345000000	Small 1-100 Ind
Herring Gull	49.230000000	-58.345000000	Small 1-100 Ind
Great Black-backed Gull	49.220860000	-58.322130000	Small 1-100 Ind
Herring Gull	49.220860000	-58.322130000	Small 1-100 Ind
Herring Gull	49.233333000	-58.333333000	Small 1-100 Ind
Herring Gull	49.250000000	-58.333333000	Small 1-100 Ind
Great Black-backed Gull	49.250000000	-58.333333000	Small 1-100 Ind
Great Black-backed Gull	49.283333000	-58.300000000	Small 1-100 Ind
Great Black-backed Gull	49.933333000	-57.833333000	Small 1-100 Ind
Common Eider	50.917900000	-57.130500000	Small 1-100 Ind 1-100 Ind
Tern species	47.843000000	-59.268500000	unknown
Black-legged Kittiwake	48.494670000	-59.244930000	Very large > 1000 ind

[1] *Date source – Conservation Data Centre*

Appendix 3

Average Abundance and Diversity of Shorebirds Species Present at Coastal Sites in the Study Area

Average abundance and diversity of shorebirds species present at coastal sites in the Study Area.

SITE	DATE	SEPL	PIPL	BBPL	RUTU	WHIM	SPSA	GRYE	PESA	WRSA	LESA	SBDO	SESA	SAND	Average No. of Individ.	Average No. of Spp.
Eddies Cove East	Jul-Sep	16.0	0.0	3.6	18.4	2.5	3.2	93.1	3.0	39.9	4.5	4.6	43.2	6.0	0.0	5.6
Eddies Cove East	Oct-Nov	1.0	0.0	8.7	6.7	0.0	0.0	16.3	0.0	52.0	3.0	1.0	13.0	26.5	3.3	1.7
Flat Bay Spit	Jul-Sep	132.3	8.0	100.0	11.5	2.0	3.7	92.8	1.0	55.0	40.0	6.3	221.0	32.5	768.4	9.8
Stephenville Crossing	Jul-Sep	29.1	0.1	24.2	2.6	0.1	3.0	19.9	1.1	10.1	21.3	0.8	38.5	0.1	153.5	6.9
Stephenville Crossing	Oct-Nov	0.7	0.0	24.0	3.7	0.0	0.0	7.2	3.3	71.8	4.3	0.0	39.5	67.7	219.0	6.6
Picadilly Head Beach	Aug-Sep	6.0	0.0	14.6	0.0	0.0	0.0	29.0	0.0	0.0	3.5	2.0	2.3	0.3	59.3	4.6
St-Paul's Inlet	Jul-Sep	13.7	0.0	16.0	11.3	4.3	0.4	13.4	1.0	64.0	7.9	2.9	44.4	1.5	180.0	7.5
St-Paul's Inlet	Sep-Nov	0.9	0.0	2.6	0.0	0.0	0.0	1.4	0.0	33.9	0.0	0.0	5.4	0.3	44.4	2.5
Piccadilly Lagoon	Oct	7.3	0.0	9.3	5.7	2.2	0.2	7.4	0.5	48.9	3.9	1.5	24.9	0.9	112.2	5.0
Parson's Pond	Aug	26.2	0.0	4.3	0.2	0.0	0.3	4.2	1.0	5.0	2.7	0.0	16.0	0.0	59.8	5.3
Parson's Pond	Nov	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	6.3	1.3
Sandy Point	Jul-Sep	3.0	0.0	21.8	12.5	9.5	3.7	25.4	1.0	6.0	19.5	1.0	8.5	5.7	81.3	5.4
Point au Mal	Jul-Aug	73.7	0.0	14.0	2.0	0.0	1.0	8.5	0.0	15.0	5.0	0.0	40.5	0.0	127.7	5.0

Source: Conservation Data Centre.