Orphan Basin Strategic Environmental Assessment

DRAFT

Prepared by

LGL LIMITED
environmental research associates

Prepared for

Canada-Newfoundland Offshore Petroleum Board
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25 August 2003
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1.0 Introduction

The Canada-Newfoundland Offshore Petroleum Board (C-NOPB) has prepared this strategic environmental assessment (SEA) for the northeast Newfoundland Shelf, Orphan Basin, and Orphan Knoll area. The C-NOPB has the responsibility pursuant to the *Canada/Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* to ensure that offshore oil and gas industrial activities proceed in an environmentally responsible manner. The C-NOPB occasionally conducts SEAs for a Newfoundland and Labrador offshore area that has potential for offshore oil and gas exploration activity but that has not been the subject of recent SEA or recent site-specific assessments.

The primary purpose of this SEA is to assist the C-NOPB (the 'Board') in their decision-making process and thus this document should be considered a planning tool. As such, it has not been intended to be an exhaustive compendium of all data ever collected in the Orphan Basin Study Area. For example, considerable physical and geological oceanographic data and some historic biological data (e.g., Russian data) have been collected in the area. A compilation or interpretation of these data was beyond the scope of the present study. Nonetheless, enough information has been reviewed to provide a complete overview of those factors of most relevance to assessing the effects of exploration activity, and perhaps more importantly, to identify key data gaps. A review of the SEA will be undertaken in five years to determine if updates are necessary to reflect any new information which may become available and to determine if the conclusions reached in the SEA remain valid.

In this particular case, the SEA considered petroleum-related activities that may occur offshore, if one or more exploration licenses are issued. Activities associated with exploration may include drilling of wells (either exploration or delineation wells), in addition to seismic and other geophysical surveys. All of these activities require the specific approval of the C-NOPB and each requires a project-specific assessment of its associated environmental effects. This SEA will not replace site-specific environmental assessments (EAs) but provides an overview of the existing environment in the Orphan Basin Study Area ('Study Area') and discusses, in broader terms than a typical site-specific EA, the potential environmental effects associated with offshore oil and gas exploration activities. It identifies knowledge and data gaps, highlights issues of concern, and makes recommendations for mitigation and planning. Information from this SEA will assist the C-NOPB in determining whether exploration rights should be offered in whole or in part for the area, and also identifies general restrictive or mitigative measures that may be considered for application to exploration activities within new or existing exploration licenses.

This SEA has considered biophysical conditions such as water depth, substrate, currents, and location relative to any special ecological or commercial areas, and to relevant exploration issues such as the types of seismic airguns, drilling fluids and drilling platforms. A relatively large amount of background information on fisheries is available for the Orphan Basin area, and the typical vessels, rigs, equipment and activities associated with offshore oil exploration are relatively well known. Data on marine birds and mammals and their forage species are sparse.

Document organization follows the following format:

- 1.0 Introduction
- 2.0 Oil and Gas Activities in Orphan Basin
- 3.0 Existing Environment
- 4.0 Environmental Effects of Exploration Activities
- 5.0 Cumulative Effects
- 6.0 Summary and Conclusions
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2.0 Oil and Gas Activities in Orphan Basin

2.1 Rights Issuance Process and Call for Bids

The C-NOPB issues offshore land rights in the form of exploration licenses (ELs), significant discovery licenses (SDLs) and production licenses. Exploration licenses may extend to a maximum nine-year term if a well is spudded within the first five years (six years with additional deposit in the present case) from the date of issuance. Discovery Licenses acknowledge an owner's right to hold interests in the offshore area for a longer period where the area has the potential for sustained production of petroleum. Production Licenses permit an owner to produce petroleum from an interest consistent with approvals and authorizations from the Board. Any person wishing to undertake work as activity respecting petroleum operations in the offshore area must obtain an operating license issued by the Board pursuant to the *Accord Implementation Acts*.

On April 15, 2003, the C-NOPB announced the details of the 2003 Call for Bids for the Newfoundland offshore area. This Call for Bids includes two on the northeast Newfoundland Shelf (Parcels 1 and 2), 10 in the Orphan Basin (Parcels 3 to 12), and two in the Flemish Pass area (Parcels 13 and 14) (Figure 2.1). These 14 parcels total 3,167,445 hectares. Additional detail is available at the C-NOPB website (www.cnopb.nfnet.com). The Call for Bids NF03-1 will allow for exploration on lands which have not been previously available. This Call for Bids incorporates several changes in process and terms under which exploration will be undertaken (see below).

The SEA will be completed prior to the close of the Call for Bids NF03-1 in order to identify at an early stage potential environmental concerns for a license area. This SEA provides a broad overview of the existing environment and considers the scope and nature of the likely environmental effects of activities and possible mitigative measures which may have to be addressed through license conditions. The SEA is available on the Board's website starting in the fall of 2003 in order to solicit public comment. This assessment, however, will not replace the more detailed and specific environmental assessments required for the issuance of any authorization for work or activity in the Newfoundland offshore area. The exploration licenses may be amended before the close of bids to accommodate mitigative measures identified during the SEA process.

As many of the lands offered in the Call for Bids NF03-1 are in deep water, consideration has been given to these areas, and where appropriate, changes made to encourage deep-water exploration and activity. As in Nova Scotia, the Board will now grant interest owners the option of extending the five-year drilling period by one year, upon payment of a drilling deposit. This extension may be necessary to accommodate unforeseen delays such as environmental issues to be mitigated or the unavailability of specialized drilling rigs to be used in deep water.

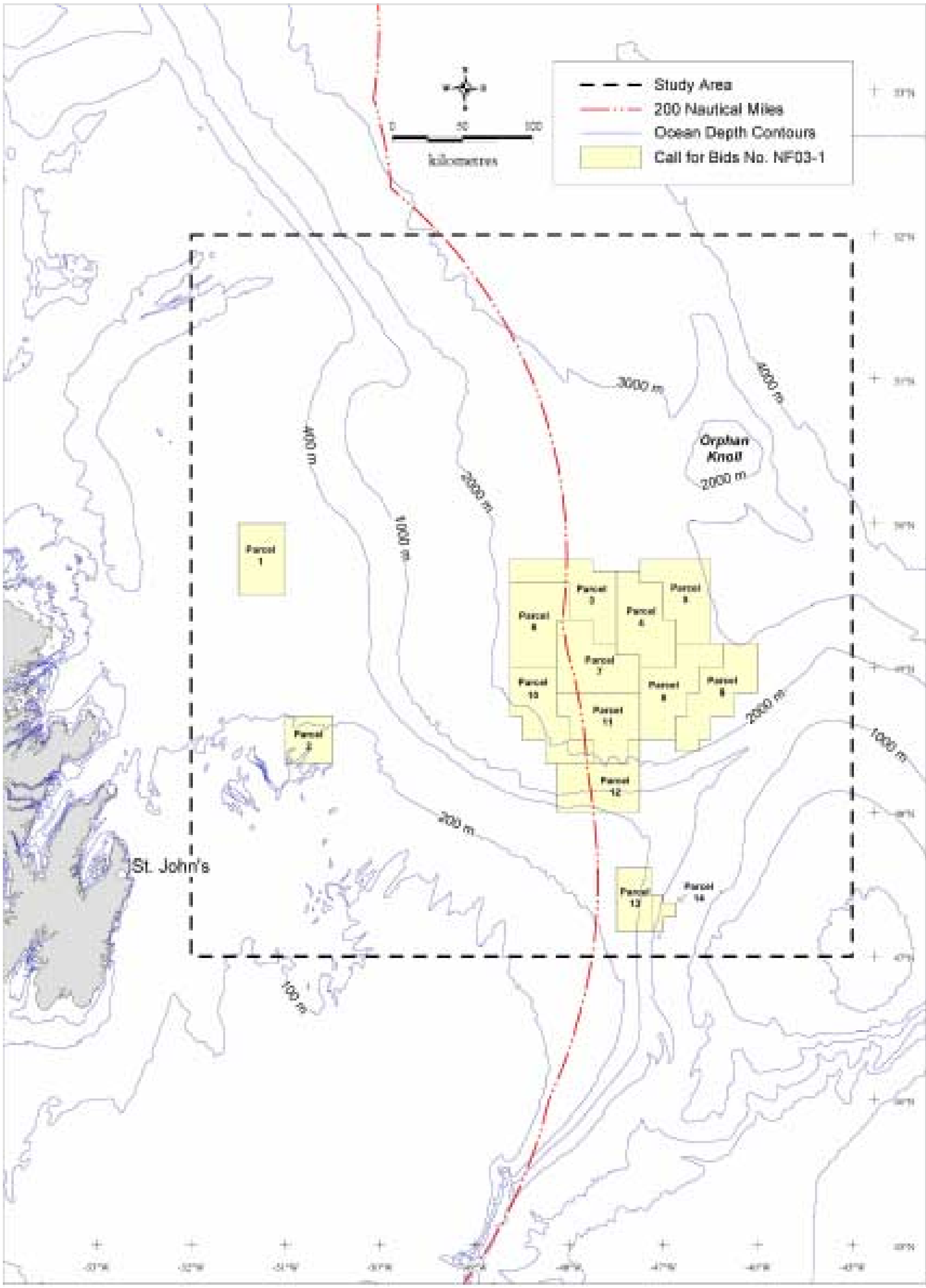


Figure 2.1 Parcels 1-14 on Offshore Newfoundland 2003 Call for Bids.

To encourage exploration activity, the allowable day rate for drilling costs has been increased from $450,000 to $600,000 recognizing the higher cost to drill in deep water areas of the Newfoundland offshore. Twenty-five percent of any allowable expenditure will be credited against the security deposit for the work commitment on the license. The actual expenditure cannot be claimed on an “at cost” basis because of the complicated uncertainty and auditing burden that would be placed upon both the interest owners and Board.

In response to demonstrated interest by interest owners and a desire to further encourage and facilitate expenditures for Research and Development and Education and Training in the Province, the Board has added a new provision (3.5(e)(iv)) to the Call for Bids NF03-1. Expenditures for Research and Development and Education and Training may be considered as “eligible expenditures”. Such expenditures up to a prescribed level are important contributions to the growth and development of the Research and Development and Education and Training capacity in the Province.

Interested parties will have until 4:00 p.m. on December 17, 2003, to submit sealed bids. The sole criterion for selecting winning bids will be the total amount of money the bidder commits to spend on exploration of the respective parcel during the first five years (Period I). The minimum bid for all parcels is $1 million dollars. Subject to Ministerial approval, successful bidders will be issued an exploration license for a term of nine years, and during Period I, a well must be spudded to validate the license for the full nine-year term. Period I may be extended to six years by posting an additional deposit of $1 million dollars as security for drilling a well.

2.2 Exploration

There has been oil and gas interest and some activity within the Orphan Basin Study Area for a number of years. Seismic survey coverage has been extensive particularly in the western half of the Study Area (see the Natural Resources Canada mapping of seismic at www.gsca.nrcan.gc.ca. The northeast quarter of the area is the exception where few survey lines are available north of Orphan Knoll. Several recent seismic programs have been conducted in the Study Area and have undergone environmental assessment (K. Coady, C-NOPB, pers. comm.). Geophysical Services Inc. (GSI) conducted 10,449-km of 2D seismic in Orphan Basin in 2000, 6,844-km in 2001, and 1,295-km in 2002 (Smee et al. 2003). The TGS-NOPEC Geophysical Company ASA also conducted 2D seismic surveys in much of the area during 2002 (see Canning and Pitt 2002). At present, there are two approved seismic programs for 2003 that include part of Orphan Basin (K. Coady, C-NOPB, pers. comm.).

There are a number of existing exploration licenses that have been issued by the Board (see www.cnopb.nfnet.com for the most recent information). There have been at least a dozen exploratory wells drilled in the Study Area, mostly on the Shelf (Figure 2.2). Only one exploratory well has been drilled in the Basin proper by Texaco Shell et al. (Blue H-28) and Orphan Knoll was drilled as part of the Deep Sea Drilling Program (Joides, #111) (Smee et al. 2003).

2.3 Future Exploratory Activity

In consideration of the size of past exploration licenses and the number of parcels offered in the 2003 Call for Bids, it could be assumed for the purposes of the SEA that there would be a maximum of 14 exploration licenses issued if the 2003 Call is successful. Under the Boards' rights issuance processes for the 2003 Call, licenses must be relinquished if a well is not spudded within the first period of the license (typically 5 years, with an option for a 6th year). If the 2003 Call for Bids is successful, it is anticipated that there could be three to four seismic programs in the Orphan Basin Study Area in 2004, two of which may be 3D surveys, and the remaining 2D surveys. 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.

The following estimate has been 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 the end of 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 attracted 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.

Recent experience with exploratory drilling offshore Eastern Canada indicates that operators prefer to share the high mobilization costs of drilling units and to drill their respective prospects sequentially rather than simultaneously. Due to the small number of units worldwide that are capable of drilling deep-water prospects in harsh environments, one unit may be dedicated to the deepwater portions of the permit area and another selected for on-shelf portions.

In consideration of the above it is assumed that 4-6 exploration wells will be drilled during the period of the exploration licenses and that one discovery is made that attracts three further delineation wells during the nine-year license period - for a total of 7-9 wells during the period of the licenses. It is further assumed that no more than two drilling units will be active at any given time, and that for a fraction of the drilling time two pairs of wells "overlap".

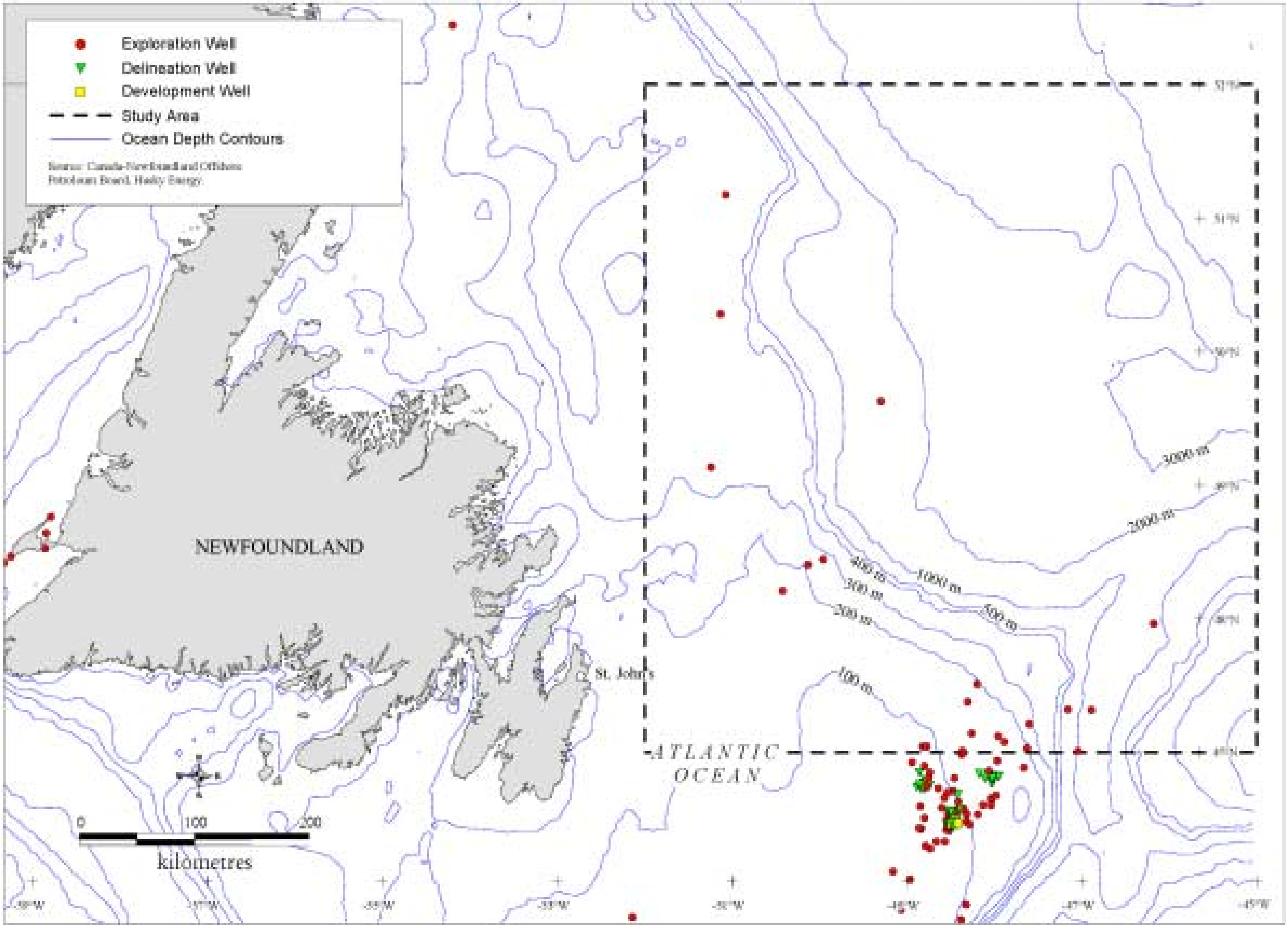


Figure 2.2 Offshore Wells Drilled in Newfoundland and Labrador Waters.

2.4 Production Activity

At present, there is no oil production activity in the Orphan Basin Study Area. The closest activity is to the south of the Study Area on the northeastern Grand Banks at Hibernia (a concrete gravity based system or 'GBS' presently producing about 204,000 barrels per day), Terra Nova (a floating production system and offloading facility or 'FPSO' presently producing about 143,000 barrels per day) and White Rose (production drilling). When in production, White Rose will use an FPSO producing about 92,000 barrels per day. [Hibernia and Terra Nova estimates are based on most recent 3-month data for March, April, May on the C-NOPB website and White Rose was based on peak annual average production data on the White Rose website].

For the purposes of the SEA for the Orphan Basin Study Area, the C-NOPB believes that the inclusion of production activities in the scope of the assessment is not meaningful at this time.

Unlike some other areas internationally (e.g., certain UK offshore sectors), the Newfoundland and Labrador offshore area is not a sufficiently mature exploration and production play that production scenarios can credibly be predicted. The uncertainties in defining the economic feasibility of production scenarios for harsh-environment remote locations, coupled with the technical uncertainties associated with the need to date for novel technological approaches to operations in sea ice and iceberg-prone areas, exacerbates this problem.

Historically in the Newfoundland and Labrador offshore a lengthy period has elapsed between the issuance of an exploration license and the issuance of a production license. If exploratory drilling activity is successful in identifying the presence of hydrocarbons in parts of the study area, it may be possible to identify a more credible suite of candidate production scenarios in a subsequent version of, or successor to, the present SEA document.

3.0 Existing Environment

3.1 Physical Environment

This section is not intended to be an exhaustive summary of the physical environment of the Study Area but rather a highlight of factors potentially unique to the area. It relies heavily on information contained in the three major environmental impact statements (EISs) conducted for the northern Grand Banks (Hibernia, Terra Nova, and White Rose contained in Mobil 1985; Petro-Canada 1996; Husky 2000). Other physical descriptions specific to the Study Area have been prepared by NORDCO (1977) and Canning and Pitt (2002).

The dominant physical feature of the Study Area is the southward-flowing cold Labrador Current. The Study Area has a wide range of depths from a 100-m or so down to abyssal depths of 4,000+m. The bathymetry almost forms a funnel for the Labrador Current between the Grand Banks and the Flemish Cap. Upwelling of nutrient-rich deep water likely occurs where the current runs into the northern edge of the banks. Pack ice and icebergs are common seasonal features of this area, at least in the western portion of the Study Area.

The above physical attributes and others influence the biological resources of the Study Area. In the following sections, relevant and determining features of the physical environment are discussed in light of their importance to the biological characteristics of the area such as marine birds and mammals, and fish and fisheries.

3.1.1 Geology

The topography of the Study Area is highly diverse and includes at least six distinct types as characterized by depths, location and physiography: (1) eastern portion of the northeast Newfoundland Shelf (depths ≤200-m), (2) northeast Newfoundland Shelf Slope (depths from >200 to 2000-m), (3) Orphan Basin proper (2,000 to 3,000-m), (4) Orphan Knoll) rising steeply from 3,000-m to 1,800-m, (5) Flemish Pass (deep water in excess of 1,000-m confined between the Grand Banks (≤200-m) and Flemish Cap (≤200-m), and a small area of abyssal depths to the northeast of Orphan Knoll where depths reach in excess of 4,000-m (see Figure 2.1).

Orphan Knoll is a fragment of continental crust that detached from North America during continental rifting (Keen and Beaumont 1990 *in* Toews and Piper 2002). Surficial sediments in the area are primarily hemipelagic, ice rafted and from glacial plume deposits (Toews and Piper 2002).

The Study Area contains several fault zones in the Flemish Pass area; it is bounded on the east by the East Newfoundland Hinge Zone and on the north by the Charlie Fracture Zone (Mobil 1985 *in* Petro-Canada 1996). Several earthquakes have occurred in the area up to 5.3 magnitude (Mobil 1985 *in* Petro-Canada 1996). Examination of cores and seismic profiles suggest that a major earthquake may occur in the Orphan Knoll area about once every 70,000 years (Toews and Piper 2002).

Considerable geological data have been collected for Flemish Pass by the Geological Survey of Canada over the past 30 years. Work has included over 70 sediment samples in Flemish Pass using box cores, gravity and piston cores, and extensive surveys with side scan sonar and high resolution seismic (Campbell et al. 2002). Flemish Pass is a saddle-shaped, mid-slope basin (1,000-m depth) bounded on the west by the Grand Banks and the east by Flemish Cap. Its topography is unusual in that it allows the trapping of sediments that elsewhere on most areas of the East Coast would be transported across the slope to the abyssal plain (Piper and Pereira 1992 *in* Campbell et al. 2002). The bottom is overlain by Miocene sediments over a thick Mesozoic sequence (Kennard et al. 1990 *in* Campbell et al. 2002). Geohazards such as slumping, shallow gas, gas hydrates, and boulder beds may exist in Flemish Pass as discussed in Campbell et al. (2002).

3.1.2 Climatology

The climate of the Orphan Basin Study Area is not unlike that of the northern Grand Banks. The climate of this area has been described in detail in the Terra Nova and White Rose EISs (Petro-Canada 1996; Husky 2000) and is not repeated here for two reasons, namely that it is highly unlikely that: (1) there are any unique aspects of the Study Area climate that would affect the outcome of any environmental assessment, and (2) the climate has changed significantly in the last three years since the last major EIS was completed.

Similar to the northern Grand Banks, the climate of the Study Area is very dynamic and largely influenced by passing systems, which can be very intense, particularly in fall and winter. Newfoundland and Labrador waters are among the stormiest in North America; the Study Area would be no exception being subject to disturbance from typical storm tracks to both the south and north of the island of Newfoundland.

February is the coldest month and August is the warmest month. Air temperatures at Terra Nova range from about -17ºC to 27ºC; mean temperatures range about minus 5ºC to plus 16ºC (Petro-Canada 1996). Total precipitation in St. John’s averages about 1,482-mm per year with 78% as rain (rain on 161 days per year) and the rest as snow.

3.1.3 Wind and Visibility

Dominant winds at Terra Nova are from the westerly quadrant in the winter, spring and fall while in summer the dominant direction is southwest. Winds of gale force or greater (>61-km/h) occur more often in winter than summer (e.g., 22% in January vs. 3% in July). Wind speeds as high as 145-175-km/h have been recorded in the Terra Nova area (Petro-Canada 1996).

Fog frequently occurs in the Study Area, particularly from May to July. July is the foggiest month at Terra Nova where visibility is less than one kilometer 52% of the time (Petro-Canada 1996). Ceiling heights generally follow the fog pattern.

3.1.4 Waves

Highest waves at Terra Nova occur during December and February with significant wave heights of 11 to 12-m with the highest significant wave height recorded at 13.8-m (Petro-Canada 1996). The most extreme crest-to-trough wave recorded for Terra Nova (1980-86 data) was 24.5-m (Petro-Canada 1996).

3.1.5 Water Currents

3.1.5.1 Labrador Current

The Study Area is strongly influenced by the cold Labrador Current which is part of the largest coastal current complex in the world, composed of the West Greenland, Baffin, Labrador and Nova Scotia currents (Figure 3.1). This complex is also influenced by the warm Gulf Stream and the North Atlantic Current (a mixture of the Gulf Stream and the Labrador Current). The Labrador Current consists of an inshore and offshore branch (Figure 3.1). The course of the inshore branch is mostly determined by bottom topography. The stronger offshore branch flows primarily along the upper continental slope at 300 to 1,500-m water depths (Petro-Canada 1996). The offshore branch further bifurcates south into Flemish Pass and to the east after being turned by Flemish Cap. Flemish Cap is characterized by a clockwise gyre.

Mean surface water velocities of the outer branch are on the order of 25 to 40-cm/s whereas the inner branch flows are weaker at 10 to 20-cm/s (Fissel and Lemon 1991). Mean flows in the outer branch have a strong seasonal component where mean flow velocities are nearly twice as large during September to October compared to March and April; this phenomenon is caused by ice melt in the North (Lazier and Wright 1993; Narayanan et al. 1995 *in* Petro-Canada 1996). Flows on the shelf between the two main branches are generally relatively weak.

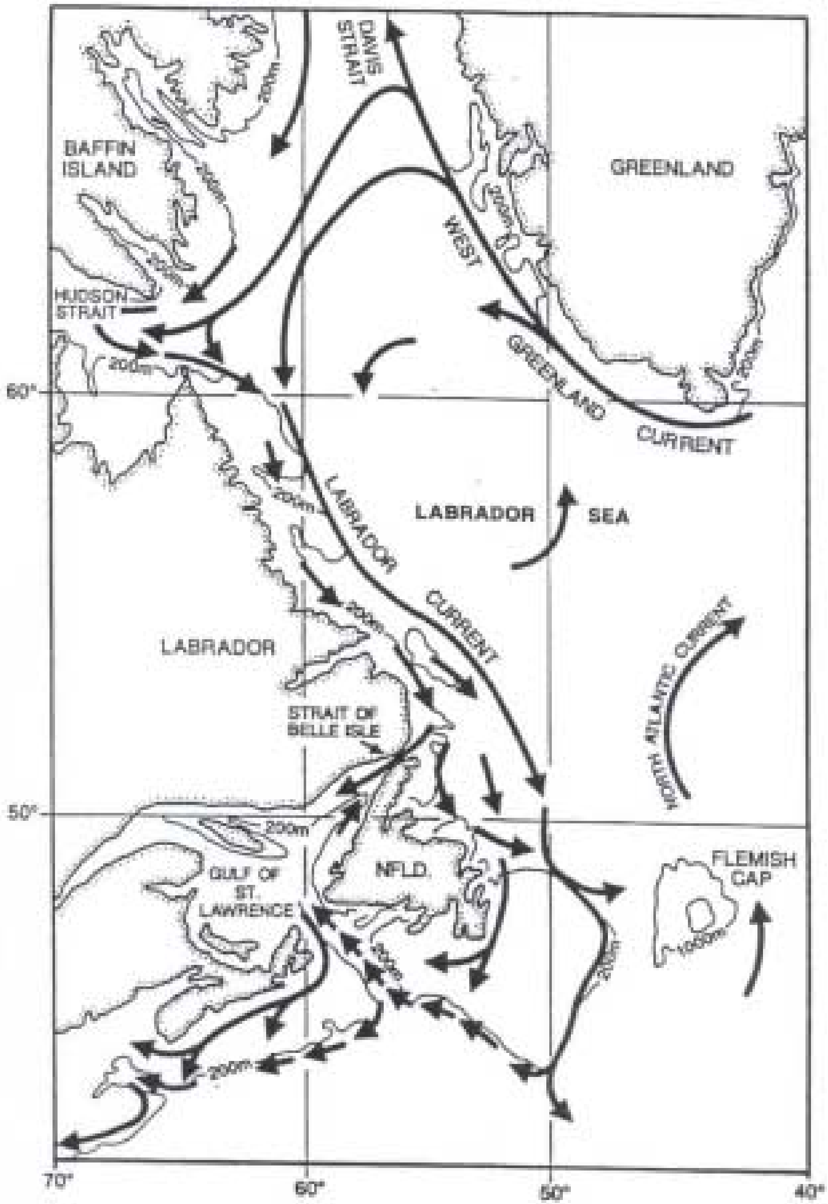


Figure 3.1 Labrador Current. (From Petro-Canada 1996.)

3.1.5.2 Eddies, Fronts and Upwelling

Mesoscale eddies and meanders (time scales 2 to 50 days and 10 to 100-km in size), as observed using drifter buoys, appear to be relatively common near the offshore branch of the Labrador Current and on the northeast Newfoundland Shelf (Petro-Canada 1996).

Oceanic fronts are narrow bands where dissimilar water masses converge, often coinciding with areas of strong current shear where vertical mixing occurs. Such areas are important biologically because they may concentrate prey and may enhance productivity. While not as pronounced or permanent as the major frontal zone at the Gulf Stream south of the Grand Banks, fronts have been observed near the shelf edge and near the offshore branch of the Labrador Current (Narayanan et al. 1991 *in* Petro-Canada 1996). Fronts can be expected to occur in the Study Area near the shelf break.

Upwelling is an important oceanographic process where a combination of currents, winds, water mass characteristics, and bottom topography transport nutrient-rich deep water to the surface where it may stimulate primary production by phytoplankton. It can occur along the coast or at continental margins. Upwelling has been reported to occur at localized areas within 10-km of the edge of the Scotian Shelf (Petrie 1983 *in* Petro-Canada 1996). Localized upwelling may also occur episodically within the Study Area under very specific environmental conditions. There are some indications from remote sensing of chlorophyll that enhanced phytoplankton biomass may occur in the Study Area during spring (sometimes but not always) along certain areas of shelf edges (see 'Plankton' below).

3.1.6 Water Characteristics

There are considerable temperature and salinity data available for most of the Study Area because of two long-term transects established and routinely sampled by the Department of Fisheries and Oceans (DFO): (1) the Bonavista line which runs from the entrance to Bonavista Bay almost out as far as Orphan Knoll, and (2) the Flemish Cap transect which runs from the Avalon Peninsula along the 47ºN line of latitude (Figure 3.2). A long-term station (Station 27) is also maintained off St. John's and this station is considered a good indicator of the Labrador Current's inshore branch. In addition, various researchers have collected data at discrete stations over the years.

Water masses in the Study Area include the cold, relatively fresh Labrador Current water, the warmer, more saline Slope Water, and Deep Atlantic Water. A cold (0.0 to -1.8ºC) intermediate layer (CIL) is present during summer over the shelf between a warmer upper layer and the warmer Slope Water (Petrie et al. 1988 *in* Petro-Canada 1996). The CIL forms in the winter through heat loss at the surface and salt releases during ice formation; it remains cold during the summer because it is covered by a stratified

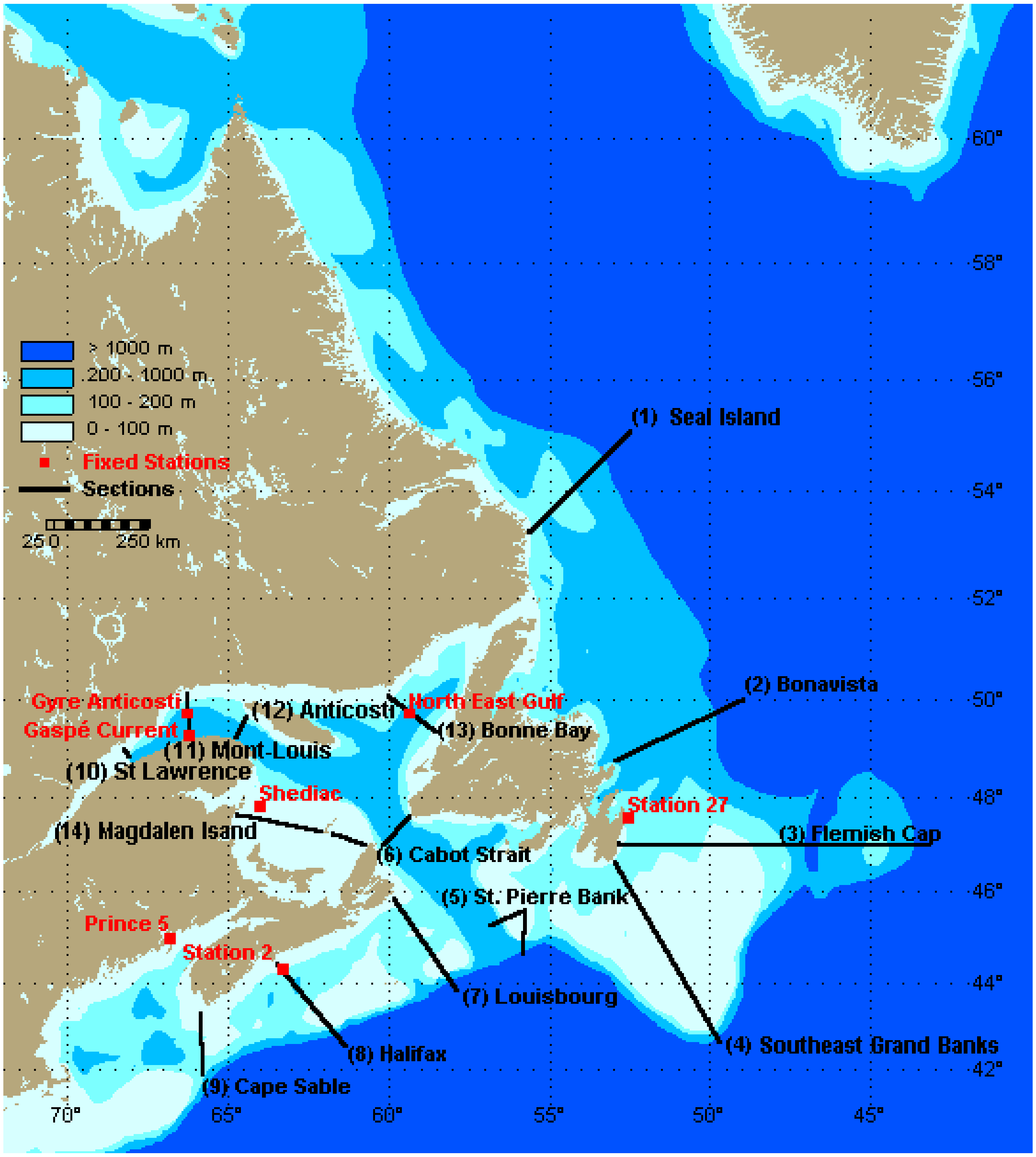


Figure 3.2 Location of DFO Long-term Temperature and Salinity Monitoring Stations and Transects.

upper layer caused by surface warming and ice melt which hinders heat transfer. The Deep Atlantic Water is remarkably uniform throughout the Atlantic Ocean and temperatures and salinities near bottom are about 2.2ºC and 3.5ºC, and 34.90 and 34.97-ppt (Sverdrup et al. 1942).

Information on the variability in temperature and salinity conditions in the Study Area is found in Colbourne (2000, 2002), DFO (2002a,b), and others. Colbourne et al. (2002) compared 1961-1990 to 1971-2000 temperature and salinity data (monthly means) from Flemish Cap and Station 27 and concluded there are three cold-fresh periods evident in the data: (1) early 1970s, (2) mid-1980s, and (3) early 1990s. The 1960s were characterized as warm and salty.

Temperature and salinity data compiled for Terra Nova on the northern Grand Banks provide an idea of the probable range of temperature and salinity to be encountered in the upper 100-m at least in the southern part of the Study Area (Table 3.1.)

Table 3.1 Year-round Temperature and Salinity Ranges for 0, 20, 50-m, Near-bottom from Historical (1900-1987) Bottle Data Near Terra Nova. Summarized from Petro-Canada (1996).

Depth (m)	TºC minimum (month)	TºC maximum (month)	Salinity minimum (ppt) (month)	Salinity maximum (ppt) (month)
0	-1.69 (Feb)	15.40 (Sep)	31.55 (Aug)	33.87 (May)
20	-1.67 (Mar)	14.30 (Sep)	31.89 (Jul)	33.34 (Apr)
50	-1.66 (Mar)	5.59 (Nov)	32.13 (Oct)	33.49 (Jul)
10-m off-bottom	-1.68 (Mar)	3.00 (Jul)	32.24 (May)	34.86 (Jul)

3.1.7 Ice Conditions

An important physical feature of the Study Area is the presence of sea ice and icebergs throughout much of the year. Ice is important biologically because it affects sea state, air and water temperatures, salinity, and light penetration. The underside of the ice provides habitat for specialized algal and invertebrate species, and food for certain species of fish and seabirds. Ice edges may provide important feeding habitat for marine birds and mammals. The ice 'front' off southern Labrador provides important whelping habitat for harp and hooded seals.

Median extent of coverage by sea ice by month over a 30-year period is shown in Figure 3.3. Sea ice begins to form on the coast of southern Labrador in mid December and spreads south to Newfoundland waters in early January. During median years, only the western one third of the Study Area would have at least some ice cover whereas in extreme years, ice cover could occur throughout the Study Area with the exception of the northeastern portion (Figure 3.3) (Petro-Canada 1996; Husky 2002). Pack ice velocities up to 0.5 – 0.75-m/s can be expected flowing south through the middle of the Study Area between the 1,000 and 2,000-m contours (Peterson 1990 *in* Petro-Canada 1996).

The regional sea ice conditions are correlated with iceberg severity off Newfoundland (Marko et al. 1994). Major iceberg drift paths are shown in Robe (1980) *in* Petro-Canada (1996) and they branch in the northwest corner of the Study Area, flowing southward along the western border of the Study Area and through the center from the northwest corner to the southeast. Maximum numbers of iceberg sightings (Provincial Airlines Limited (PAL) database 1989-2001) in the Study Area range from 0 in the northeast corner to 454 in the Flemish Pass (Petro-Canada 1996; Husky 2002). Mean numbers have been reported to range from 0 to 106 (Husky 2002) or 135 (Petro-Canada 1996) in the same areas. In general, in the Newfoundland offshore area, with the exception of the Flemish Pass, highest numbers are sighted along the northeast coast and numbers generally decrease to the east. Aside from the two parcels in Flemish Pass (Parcels 13 and 14) where iceberg sightings are relatively high, the sightings in the grids corresponding to the other parcels are comparable to the numbers in the vicinity of existing developments such as Hibernia, Terra Nova and White Rose.

Iceberg scouring is relatively severe in the southwestern half of the Study Area where shallow shelf waters coincide with large numbers of icebergs carried on the inshore branch of the Labrador Current (e.g., up to 3,000-scours/km^2 just to the northeast of the Avalon Peninsula) (Lewis et al. 1987 *in* Petro-Canada 1996). Scouring reduces to zero in deep water although very large fast-moving icebergs may be present, at least in the central part of the Study Area.

3.1.8 Planning Implications

Planning implications in regard to the physical environment include:

Bathymetry. There is a wide range of water depths within the Study Area from 100-m to 4,000+m and a complicated bottom topography. Most of the parcels are below the 2,000-m contour which means that most drilling will be done using dynamically positioned drill ships. Furthermore the bottom topography is probably one of the primary ‘drivers’ for any ‘special areas’ of enhanced production and feeding (e.g., shelf edge). The C-NOPB, in conjunction with other regulators, may decide to classify or ‘zone’ the Study Area by depth as suggested by stakeholders at the scoping meeting because technological, operational, and biological are all constrained by water depth. Refer to Section 6.4 Planning Considerations for detailed discussion on a potential zoning approach.

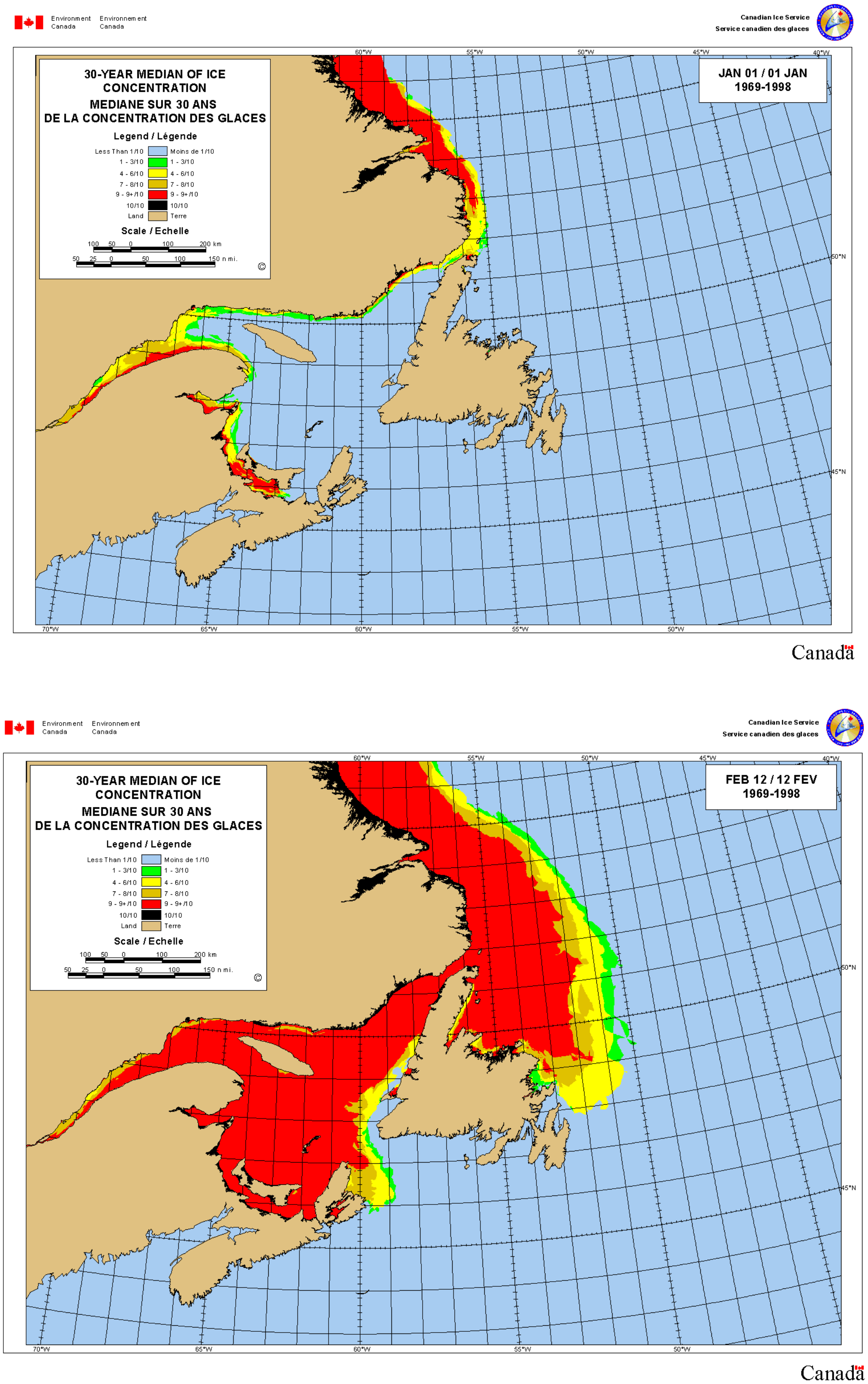
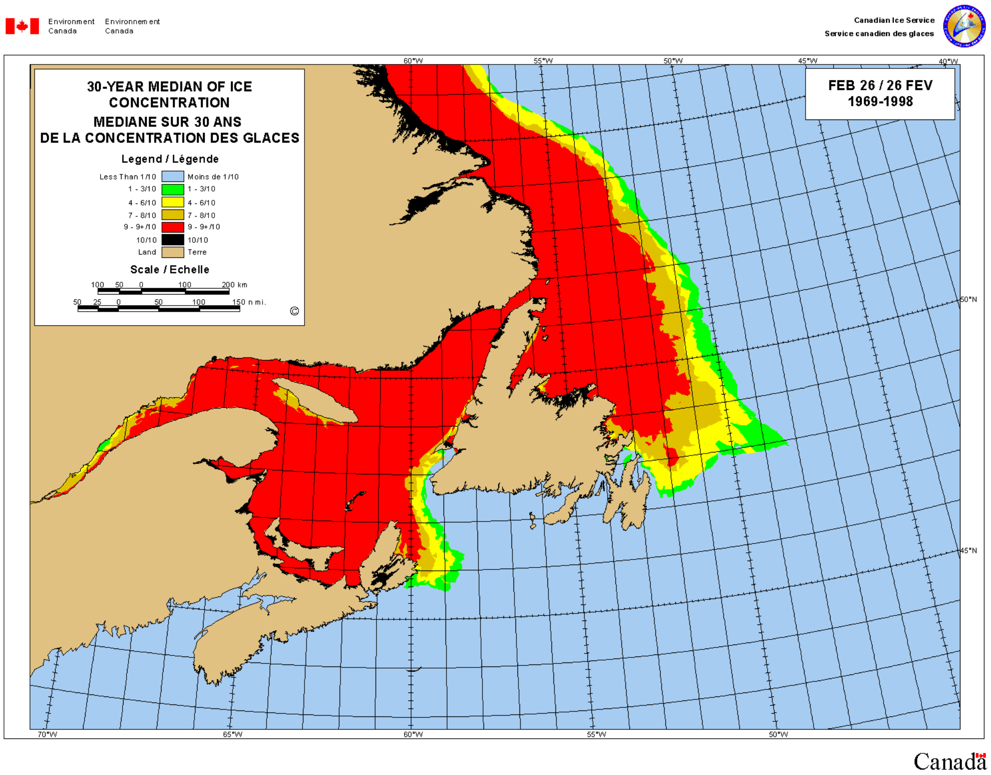


Figure 3.3 Ice Concentration on Northeast Coast and Shelf, 1969-98.



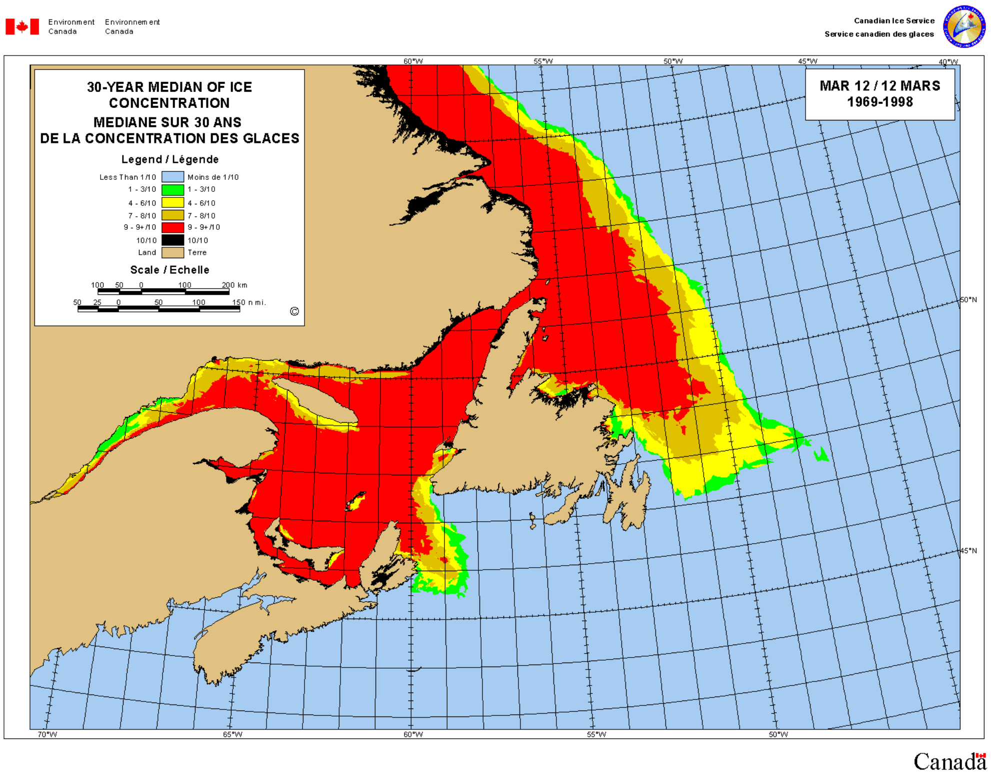


Figure 3.3. Ice Concentration on Northeast Coast and Shelf, 1969-98 (Continued).

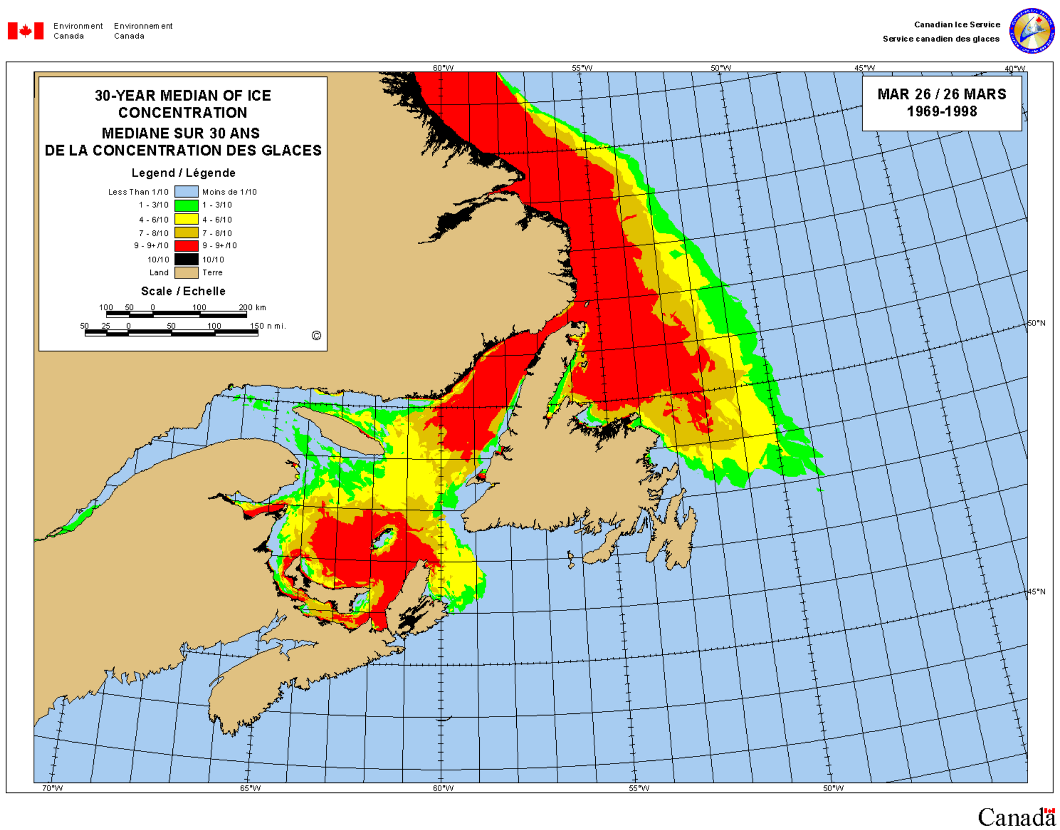


Figure 3.3. Ice Concentration on Northeast Coast and Shelf, 1969-98 (Continued).

Currents. The currents in the Study Area are certainly of operational concern (e.g., effects of the environment on the project) and if drilling occurs, current meter data will be collected which will enhance the physical database for the area. The edges of the Labrador Current, particularly the outer branch may be important in a planning context as they appear to be areas of enhanced production (Figure 3.4).

Ice. Ice and icebergs are, of course, of paramount concern from an operational and safety point of view. Some of the parcels may have somewhat more severe ice conditions on average than others, but none would have conditions so severe as to preclude exploration activity entirely. Ice coverage, iceberg incursions, and ice scouring (shallow parcels) conditions may be somewhat more severe than farther south in Flemish Pass or on the Grand Banks but conditions, at least in an average year, are probably within the range previously encountered farther south by the offshore oil industry. The majority of parcels are in deep water where bottom scouring by icebergs will not occur; on the other hand, icebergs will be larger than those encountered on the Grand Banks. Operators, when undertaking site-specific EAs, will be required to carefully examine the impacts of ice on design and operational conditions. Specific monitoring programs, in addition to the typical ice management strategies may also be required depending on the nature and timing of exploration activities. Scouring intensities, however, have severe implications for development scenarios. Each operator will be required to submit an Ice Management Plan to the Board.

Climatology, Winds, Waves, Temperature, and Salinity. These physical variables are all of concern to operations and such information should be compiled for site-specific EAs. However, none of these attributes of the Study Area are sufficiently different from those previously encountered by the oil industry on the Grand Banks or Flemish Pass to warrant special consideration in planning. [The exception could be if temperature and salinity characteristics were used as indicators of special areas.] Operators will be required to collect meteorological and oceanographic data to support operations.

3.2 Biological Environment

This section presents an overview of the Study Area ecosystem with emphasis on valued ecosystem components (VECs). Typical VECs include fish and fisheries, seabirds, sea turtles, and marine mammals, and possibly others.

3.2.1 Plankton

Plankton are those free-floating organisms that from the basis of the pelagic ecosystem. Members include bacteria, fungi, phytoplankton, and zooplankton (invertebrates, and fish eggs and larvae, termed ichthyoplankton). In simplest terms, phytoplankton (e.g., diatoms) produce carbon through the

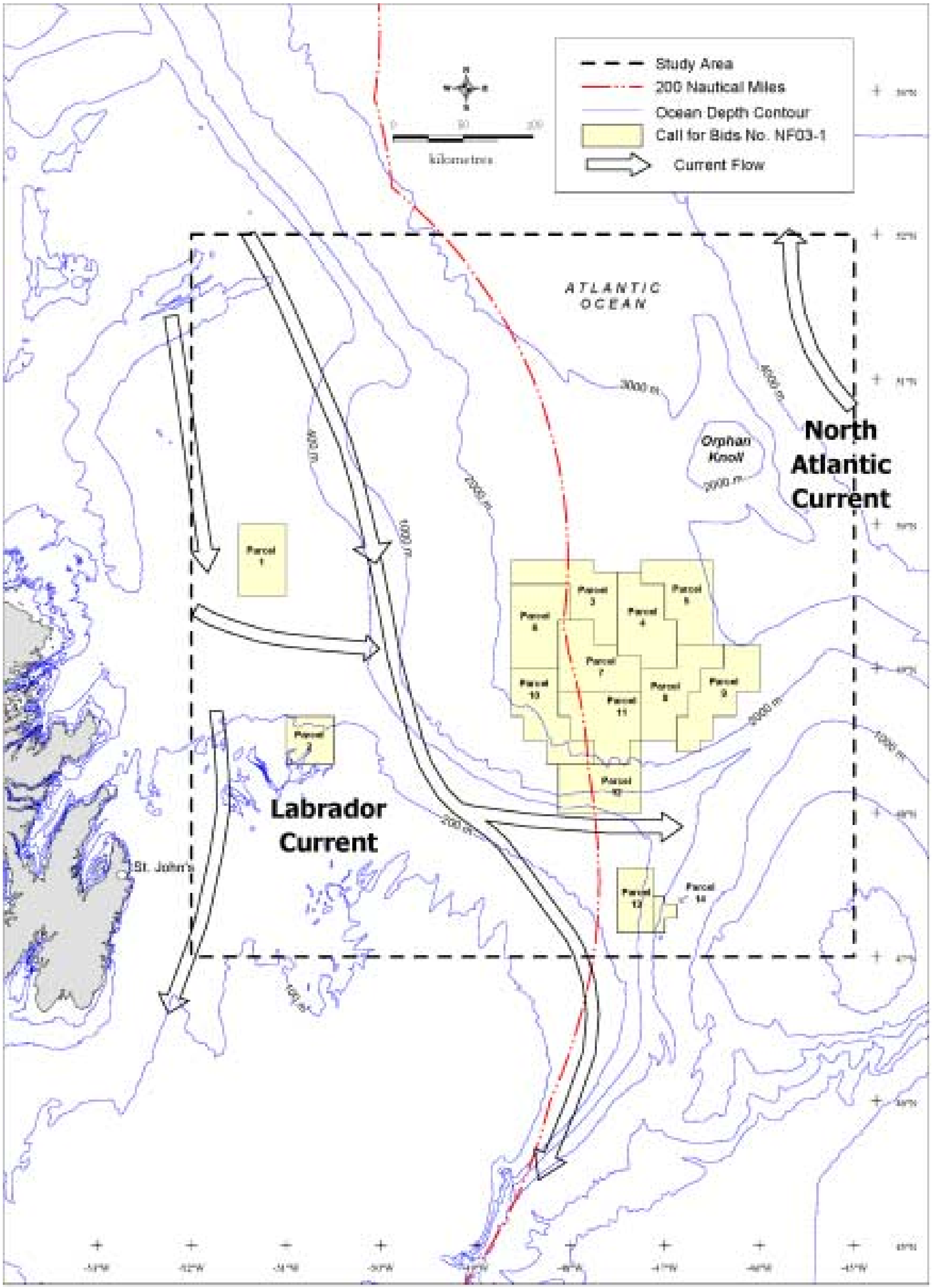


Figure 3.4 General Paths of Inner and Outer Branches of the Labrador Current and the North Atlantic Current Relative to the Study Area.

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 secondary production. The herbivores in turn are fed upon by predators (i.e., tertiary production) such as predacious zooplankton (e.g., chaetognaths, jellyfish, etc.), all of which may be grazed by higher predators such as fish, seabirds, and marine mammals, and so forth. 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 of relevance to this SEA because areas of enhanced production and or biomass are areas where fish, seabirds, and marine mammals congregate to feed. Production is enhanced by 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 which 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.

Data on nutrients, phytoplankton, zooplankton, icthyoplankton, or production rates are not extensive within the Orphan Basin Study Area. Much of the early work has been conducted under Russian auspices. Relevant Russian studies from within and immediately adjacent to the Study Area include Ponomarenko and Istoshina (1962) and Fedosov (1962) on nutrients, Movchan (1963) and Semenova (1962) on phytoplankton, Semenova (1962) on zooplankton, and Serebryakov (1962) on ichthyoplankton, and others. More recent studies 'upstream' to the north on the Labrador Shelf are also of some relevance, for example, Buchanan and Foy (1980a,b) on nutrients, chlorophyll, phytoplankton and ichthyoplankton, and Buchanan and Browne (1981) on zooplankton, and Drinkwater and Harding (2001) on the biology of the Labrador Shelf. In addition, the more intensive DFO work covering at least four years of plankton and nekton sampling on the Grand Banks, including sampling along the northern edge of the Grand Banks, is at least of some relevance (see Dalley and Anderson 1998). Data from the Continuous Plankton Recording Program may also be relevant to the Study Area as at least one major shipping lane transits the Study Area (e.g., Myers et al. 1994). Based on examination of nutrient, chlorophyll *a*, and zooplankton data from Station 27 and the Bonavista transect, it is clear that plankton dynamics in the area are highly variable (Pepin and Maillet 2000). Dalley et al. (2000) further emphasize the year-to-year variability of zooplankton on the Newfoundland shelf and banks.

Some of the key points concerning plankton in the Study Area that can be concluded or inferred from the above studies include those shown below.

- Nitrogen is probably the limiting nutrient for primary production in the Study Area.
- Nutrient concentrations increase below 100-m during summer and fall, preceding the fall increase associated with the breakdown of stratification (Pepin and Maillet 2000).
- The Labrador Current is marked by a shallow nutricline and high chlorophyll concentrations compared to other areas on the shelf, which suggests that current shear may play some role in nutrient regeneration in the area (Pepin and Maillet 2000).
- Most primary production occurs in the upper 50-m or so.
- Plankton normally peaks in the spring with a lesser but not always occurring peak in the fall; zooplankton peaks generally follow peaks in phytoplankton.
- There is a south to north progression in the onset of the spring bloom.
- At least 60 species of phytoplankton, 160 species of zooplankton, and 30 species of ichthyoplankton can be expected in the Study Area (estimated from Movchan 1963, Buchanan and Foy 1980a,b; Buchanan and Browne 1981, Tremblay and Anderson 1984).
- Phytoplankton is likely dominated by microflagellates and diatoms, at least during summer.
- Zooplankton is likely dominated by calanoid copepods, at least in terms of biomass.
- The Study Area has not been studied intensively enough to definitively identify special areas of enhanced plankton production. However, there has been some suggestion that production may be highest along the northern edge of the northern Grand Bank (MacLaren Plansearch 1981a,b; Dalley and Anderson 1998) and at the outer edge of the Labrador Current, including Orphan Knoll and Basin (FAO 1972 *in* Northland Associates 1977). In 1999, Dalley et al. (2000) found highest total zooplankton biomass on the northeast Newfoundland Shelf, including parts of the Study Area.

From an environmental planning perspective, the important question is where are the areas of enhanced production that may cause congregations of fish, seabirds or marine mammals? Some of the remote sensing products now available may be able to shed some light on this issue, although not definitively so. Remote sensing has a great advantage over classical single-ship oceanographic surveys in that it allows a synoptic 'snapshot' of a large area whereas shipboard sampling only provides data for a very limited area at any specific point in time.

There is further evidence in the remote sensing data that the northern edge of the northern Grand Banks may support enhanced primary production, or at least a greater phytoplankton biomass than surrounding areas. For example, Figure 3.5 from the SeaWiFS chlorophyll data set (www.mar.dfo-mpo.gc.ca/science/ocean) is a composite for 16-30 April 1998, that shows chlorophyll *a* 'hotspots' just north of the Grand Banks. [Chlorophyll *a* is a standard measure in oceanography for overall phytoplankton biomass.]

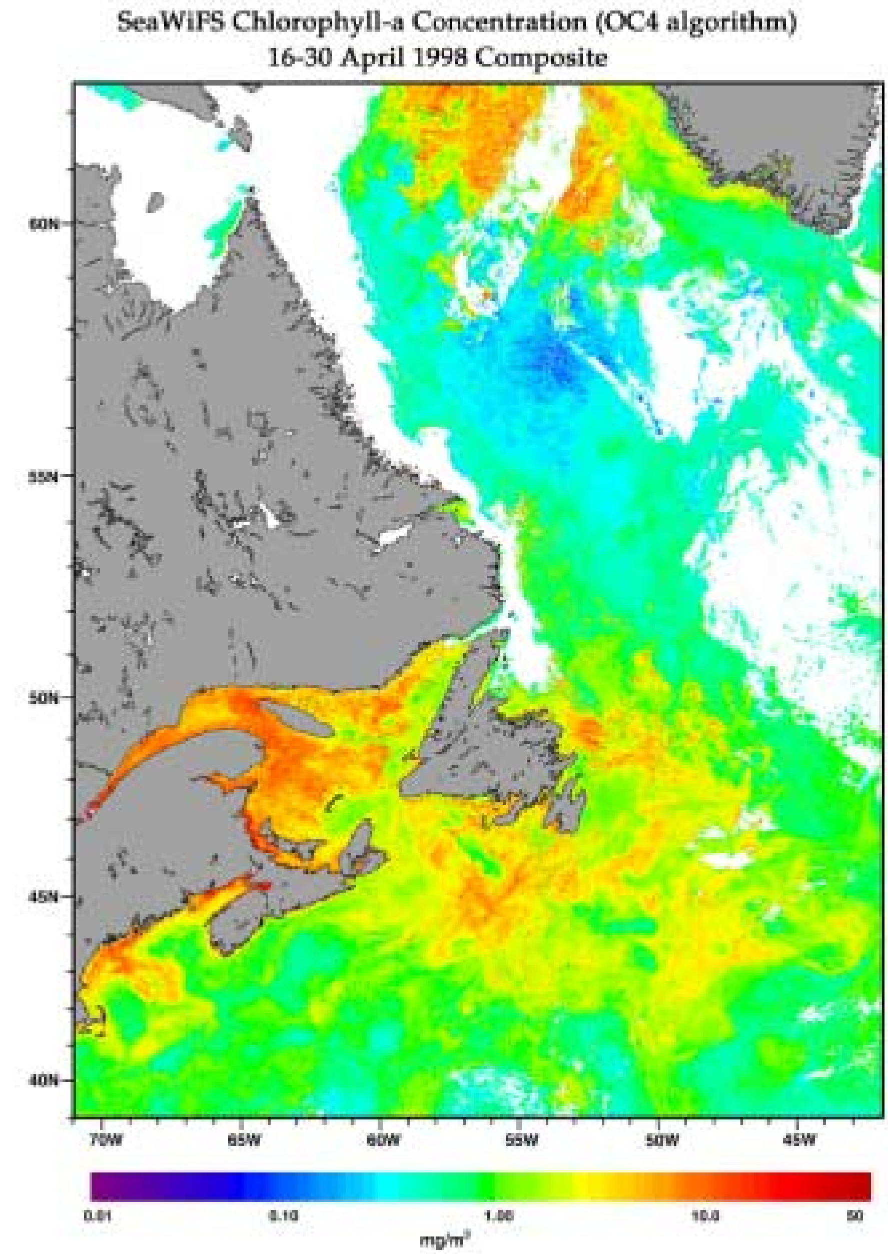


Figure 3.5 Sea WiFS chlorophyll-a concentration (OC4 algorithm) – 16-30 April 1998 Composite.

3.2.1.1 Planning Implications

There are no specific planning issues associated with plankton alone, although there may be areas of enhanced production being utilized by higher trophic levels.

3.2.2 Benthic Invertebrates

Benthic invertebrates are important to consider because this group of animals is potentially most affected by disturbances to the seabed. They form an important link to higher trophic levels such as fish, birds and mammals. Some members of this community such as deepwater corals may require special planning or mitigation procedures.

Several literature reviews which assess 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). While the existing literature may appear extensive, information tends to be spatially restricted and often species-specific. 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. EIS studies have mostly focussed on the Grand Banks continental shelf area with specific interest in the Hibernia oil-field region where benthic samples range in depth from 51 to 183-m. Published studies from Memorial University include epibenthic megafauna collected also from the outer Grand Banks Hibernia region (Schneider et al. 1987) and macrobenthic data collected from deeper regions in the Carson Canyon at depths of 76 to 1,129-m (Houston and Haedrich 1984). A functional study of benthic polychaete communities was also conducted in the Hermitage Channel to the south of Newfoundland in depths ranging from 305 to 375-m (Gagnon and Haedrich 1991). DFO has conducted a number of surveys to assess impacts of commercial otter trawling on the Grand Banks which provides additional information on macrofaunal communities in referenced untrawled areas (Gilkinson et al. 1998; Gordon et al. 1998; Prena et al. 1999; Kenchington et al. 2001). Allen (1965) and Nesis (1965) list benthic organisms recorded in the outer Grand Banks. While these authors reported on mollusc species and descriptive benthic species assemblages based on grab samples and incidental trawl catches collected during Fisheries Research Board cruises, the data are qualitative or else localized in scope and dated.

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 and deep sea abyssal habitats. Surveys that assess benthic community composition rather than species-specific studies are limited for this region. At present, no existing studies of benthic community composition specifically for the Orphan Basin Study Area could be identified. The Orphan Basin Study Area encompasses continental shelf and slope environments as well as abyssal habitats with depths that range from 100 to 4,000+m. This area is influenced by cold arctic and subarctic waters as well as warmer North Atlantic waters that also influence the eastern and southern edges of the Grand Banks. Therefore, in the absence of local data, in order to evaluate likely benthic species assemblages for this type of habitat the existing literature for the Grand Bank continental shelf region and data collected from deeper offshore environments such as the Carson Canyon in the northwest Atlantic has been assessed. Much of the data for the Grand Banks shelf region are concentrated near the southern edge of the Orphan Basin Study Area.

3.2.2.1 Grand Banks Continental Shelf (50 – 183-m)

In order to provide quantitative baseline data of macrobenthic community composition for the Grand Banks area and specifically the Hibernia region a survey was conducted by Mobil Oil in 1980 (Hutcheson et al. 1981). Hutcheson et al. provide a review of the limited existing studies of the benthos prior to 1981 and note that previous studies were either qualitative or else localized in scope hence the requirement for a more intensive sampling program. Benthic sampling stations were spatially restricted with four geographically distinct stations located on the Grand Banks and more intensive sampling (10 stations) conducted within a localized area of the then proposed Hibernia platform. At each station, Van Veen samples (0.10-m^2) 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 proportion of dominant 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. The polychaete worm *Exogone hebes* was the most abundant organism recorded, while an infaunal suspension feeding bivalve *Mesodesma deauratum* was the second most 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). Colour photographs were taken at 10-s intervals where the visible area in each photograph was 5.44-m^2. While grab sample data provide detailed benthic community information of infaunal assemblages (animals that live within the sediment) 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). This technique can allow data over larger spatial scales to be generated more rapidly providing a rapid assessment technique. 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. Interestingly Schneider et al (1987) identify 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. Therefore, large-scale processes need to be included in quantitative models of the distribution of epibenthic megafauna, especially when considering more mobile species. 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).

Data collected to assess the effects of trawling activities can be used to obtain information about the existing macrofaunal communities in reference areas. This information can also be used to identify species that are sensitive to disturbance events such as fishing, and the consequent recovery dynamics of identified species. DFO conducted a 3-year otter trawling experiment on a sandy bottom ecosystem on the Grand Banks of Newfoundland (120-146-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. Biomass was dominated by the propeller clams (*Cyrtodaria siliqua*) and sand dollars (*Echinarachnius parma*), while abundance was dominated by the polychaete *Prionospio steenstrupi* and the mollusc *Macoma calcarea* (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. In this case, macrofaunal community composition was sampled using epibenthic sleds and enabled a general description of the existing epifaunal community to be assessed. Dominant species were in decreasing order of mean biomass, the sand dollar *Echinarachnius parma*, the brittle star *Ophiura sarsi*, the sea urchin *Strongylocentrotus pallidus*, the snow crab *Chionoecetes opilio*, the mollusc *Astarte borealis*, the soft coral *Gersemia* sp. and the molluscs *Margarites sordidus*, *Clinocardium ciliatum* and *Cyclocardia novangliae*. The three most dominant species were echinoderms. The total number of species collected in all sled samples was 115.

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. The reported diversity of infaunal benthic communities collected using grab samples ranged from 246 to 343 species. These communities were dominated by polychaetes, crustaceans, echinoderms and molluscs. The reported diversity for epibenthic samples assessed using sled or photographic transects was 115 species. At the epifaunal level benthic communities were dominated by echinoderms, as well as molluscs, crabs, and soft corals. The predominant echinoderms included sand dollars, brittle stars, sea urchins, sea cucumbers and asteroids. Small-scale variations in species distributions with changing sediment type were also observed.

3.2.2.2 Carson Canyon (76 to 1,129-m)

The abundance, biomass and mean weight of macrofauna in the Carson Canyon region (Lat. 45º30'N, Long. 48º40'W) of the Grand Banks were estimated from 40 quantitative infaunal Ponar grab samples (0.053-m^2) taken during June of 1980 (Houston and Haedrich 1984). The research was part of a series of studies conducted by oceanographers from Memorial University that focused on the Carson Canyon region on the edge of the Bank to the east of Newfoundland. The aim was to relate biological observations to physical processes and determine what influence the canyon might have on the local physical oceanography and hence on local production. Submarine canyons, common features of the continental margins and continental slopes, tend to have higher sedimentation rates than surrounding regions. Higher rates are postulated because sediments collect within the depressions, and therefore the influx of organic material may also vary along the slope. Hence since submarine canyons are unique in their sedimentation features (Rowe et al. 1982) one would expect community differences in the faunal assemblages in such habitats.

Interestingly there were no significant differences in abundance, biomass or mean weight of macrofauna between samples taken in versus outside of the canyon. This similarity with benthic communities on the continental shelf suggests that while sediment may be continually flushed through, the canyon is not acting as a sink for sediment accumulation. Abundance and mean weight displayed no consistent relationship with depth, but stations grouped according to sediment type had differing dominant taxa. When considering the lack of a clear faunal depth gradient Houston and Haedrich (1984) note that extreme heterogeneity may be characteristic of the benthos in the area. Dominant taxa were echinoderms, crustaceans, polychaetes, and sipunculans. The muddy/silty stations, found within the canyon were dominated by tubicolous polychaetes (41.8%) and cumaceans (22.4%). Stations on the edge of the canyon with a sandy substrate were characterized by a higher number of sipunculans (53.2%) and isopods (13.7%). The stations with sand and gravel substrate contained a large number of cumaceans (26.8%) and echinoderms (24.4%).

3.2.2.3 Deep-water Coral Communities

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). Stable biogenic habitats are thought to be more susceptible to physical damage and have slower recovery rates (Collie et al. 2000; National Research Council 2002). This is due to their low growth rates which are assumed to be on the order of 1-2-cm/yr^{-1} (Risk et al. 2002) and arborescent growth forms. For example, studies on *Primnoa resedaeformis* indicate that this coral may reach an age of >300 years, although most colonies are younger (Risk et al. 2002; Andrews et al. 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). Coral habitats can form a complex three-dimensional habitat providing shelter and food for associated benthic species and fish communities. For example, the species richness of crustaceans associated with deep-water gorgonian corals has been documented to be high for North Atlantic waters (Buhl-Mortensen and Mortensen 2003). Sainsbury et al. (1997) conclude that trawl-induced habitat changes in Australia have probably altered fish communities dependent on larger benthic sponge and gorgonian communities. Hence 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 which we would predict the highest abundances of these vulnerable coral-assemblage communities.

3.2.2.4 Biodiversity in Deep-sea Habitats

Deep-water coral communities in general are reported to occur commonly at depths on the order of 200-1,500-m. The gorgonian coral communities observed for the Northwest Channel off the Nova Scotian shelf were studied using ROV's at depths between 330-500-m. Hence there is still a considerable data gap in our knowledge of existing benthic communities that occur on deeper continental slope environments and in abyssal habitats for the Orphan Basin region. Most regional deep-sea diversity studies have generally taken place at bathyal depths (200-4,000-m) on continental margins; much less is known about large-scale spatial variation in abyssal (>4,000-m) communities (Levin et al. 2001). However, in order to provide some benthic community information for abyssal habitats diversity trends proposed mostly from studies conducted in the western North Atlantic have also been considered.

Diversity patterns or gradients postulated for the marine environment suggest high diversity in deep-sea environments and lower diversity in coastal intertidal and continental shelf habitats (Hessler and Sanders 1967; Sanders 1968). This initial hypothesis of a coast to deep-sea gradient in diversity has since been the subject of considerable study and debate. Early attention focused on bathymetric gradients in the western North Atlantic and included both qualitative (Rex 1981) and quantitative (Etter and Grassle 1992) sampling that indicated that diversity-depth patterns in the deep-sea are unimodal with a peak at intermediate depths and depressed diversity at upper bathyal and abyssal depths. It was suggested that the gradient does not increase linearly but tends to show a maxima between 2,000 and 3,000-m on the continental slope and decreases on the abyssal plain. However, unimodal patterns do not appear to be universal, and where they do occur in other basins, have been attributed to varying environmental gradients.

In review of environmental controls on regional deep-sea diversity, Levin et al. (2001) note that recent assessments of macrofaunal benthic diversity using species accumulation curves confirms the often-disputed claim that the deep-sea supports higher diversity than the continental shelf. They also consider persistent problems in measuring diversity that render comparisons between deep-sea studies and surface environments problematic. For example, Gray (1997) provides evidence of similarly high diversity from shallow coastal soft-sediment habitats and suggests that Sanders original paradigm may be incorrect. However, these comparisons were confounded by the shallow-water samples being collected from broader geographic areas at differing latitudes and by using varying sieve sizes which can both influence diversity estimates. In order to re-examine the question of whether deep-sea habitats support more species than shallow-water habitats Levin et al. (2001) compare diversity between a series of deep-water samples collected off the coast of Massachusetts (the North data collected as part of the Atlantic Continental Slope and Rise Study (ACSAR) (Maciolek et al. 1987) to a very similar set of samples collected from nearby shallow waters of the Georges Bank. Both sets of samples were collected in a similar way using the same sieve size, and were geographically adjacent with both deep and shallow samples taken just off the coast of Massachusetts. They provide strong evidence that diversity relationships (including species richness, species/area, species/individual relationships) are much lower on the shelf than at bathyal depths. For the deep-water samples (250-2,180-m), on average 278 species were found to coexist in an area of 1-m^2. In contrast the shallow-water samples produced an average of 165 species m^{-2}. The macrofauna of soft-sediment deep-water samples in general has been found to be dominated particularly by polychaete worms, peracarid crustaceans, and molluscs (Gage and Tyler 1991). While it is noted that the diversity of shallow-water communities in some parts of the World Ocean may equal or exceed that of the deep sea, studies conducted at least for the northwest Atlantic provide strong evidence to support increasing benthic diversity with increasing depth for soft-sediment macrofauna.

3.2.2.5 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 (Brenchly 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) include reductions in the abundance and biomass of large long-lived epifaunal species and sessile organisms. This includes species such as sand dollars, brittle stars, and soft corals which have been identified as characteristic dominant species of the Grand Banks benthos. 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 that have key roles in the functioning and structure of benthic communities also require careful consideration in order to assess large-scale impacts associated with anthropogenic disturbances.

3.2.2.6 Existing Anthropogenic Disturbances in the Orphan Basin

The main identifiable anthropogenic disturbance presently occurring in Canadian Atlantic waters is due to commercial fishing activities that cause disturbance of the environment ranging 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).

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 (Figure 3.6). 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

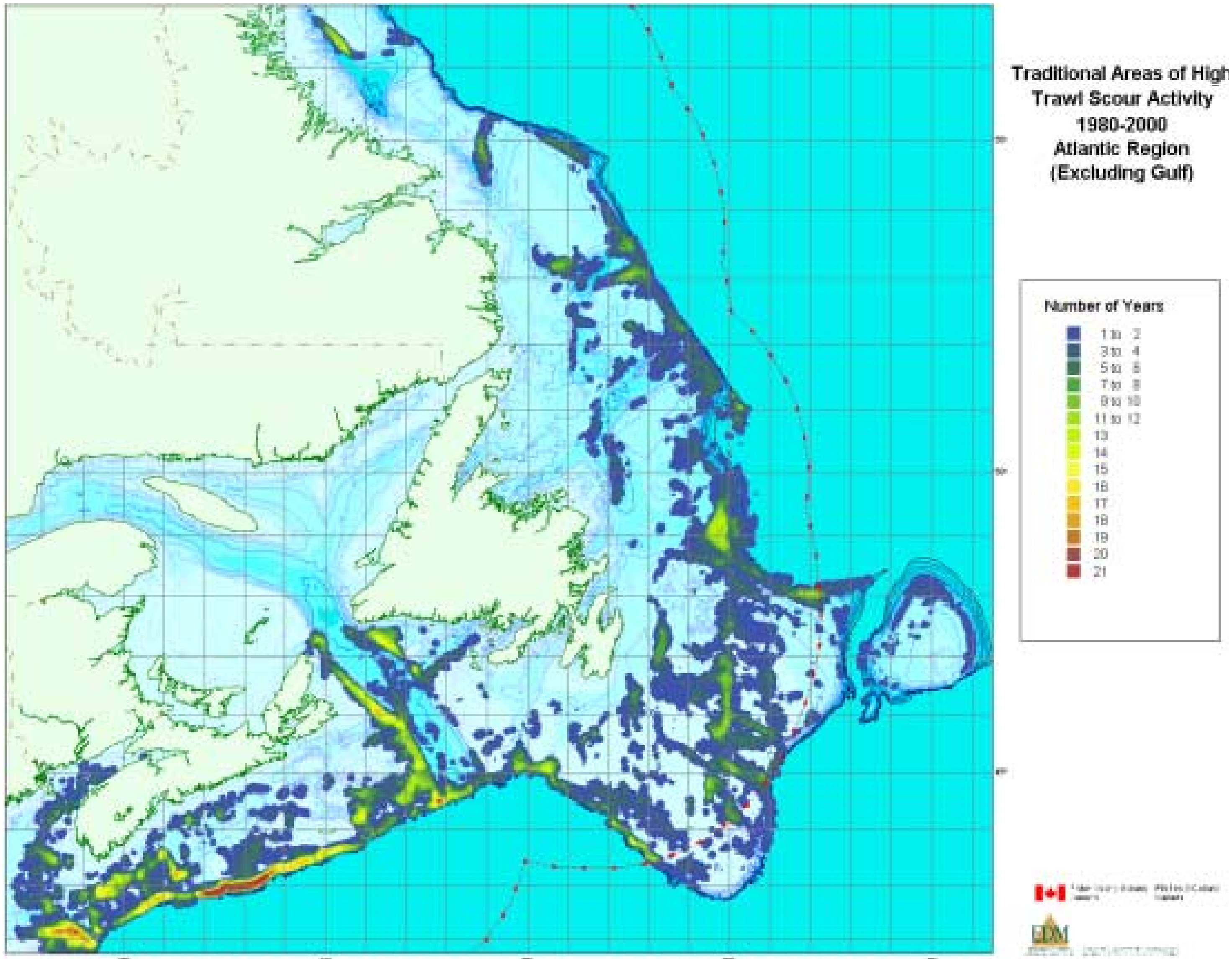


Figure 3.6 Traditional Areas of High Trawl Scour Activity 1980-2000 Atlantic Region (Excluding Gulf).

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 (Figure 3.7). These areas fall within the Orphan Basin Study Area. 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). Besides trawling activities that occur on the continental shelf, the Orphan Basin Study Area also encompasses deeper offshore habitats. These benthic habitats are not subject to mobile fishing activities such as trawling (D. Kulka, DFO, pers. comm.). Fishing for various species using longline methods has occurred in deeper offshore environments, for example the longline fishery for swordfish south of the Flemish Cap, however, these fisheries were concentrated in waters outside of the Orphan Basin Study Area.

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. The information also enables areas presently not disturbed to be identified and if incorporated with information of diverse and/or sensitive benthic habitats would contribute to the sustainable management of the region.

3.2.2.7 Summary of Existing Data/Data Gaps

The existing biological information for benthic ecosystems is localized and limited to specific areas of interest such as the Grand Banks continental shelf with specific interest in the Hibernia near-field zone, while information for deeper offshore habitats such as continental slope and abyssal environments is more limited. Data collected from the continental shelf of the Grand Banks indicates the diversity of benthic communities in this area is high, with a high number of epibenthic species and high benthic biomass. The reported diversity of infaunal benthic communities collected using grab samples ranged from 246 to 343 species. These communities were dominated by polychaetes, crustaceans, echinoderms and molluscs. The reported diversity for epibenthic samples assessed using sled or photographic transects was 115 species. Benthic communities at the epifaunal level were dominated by echinoderms, as well as molluscs, crabs, and soft corals. The predominant echinoderms included sand dollars, brittle stars, sea urchins, sea cucumbers and asteroids. Small-scale variations in species distributions with changing sediment type were also observed. Hard bottom structures in these shallower continental shelf areas, such as mussel reefs, were documented only in low densities. Data collected from deeper habitats such as the Carson Canyon indicate no significant differences in abundance, biomass or mean weight of

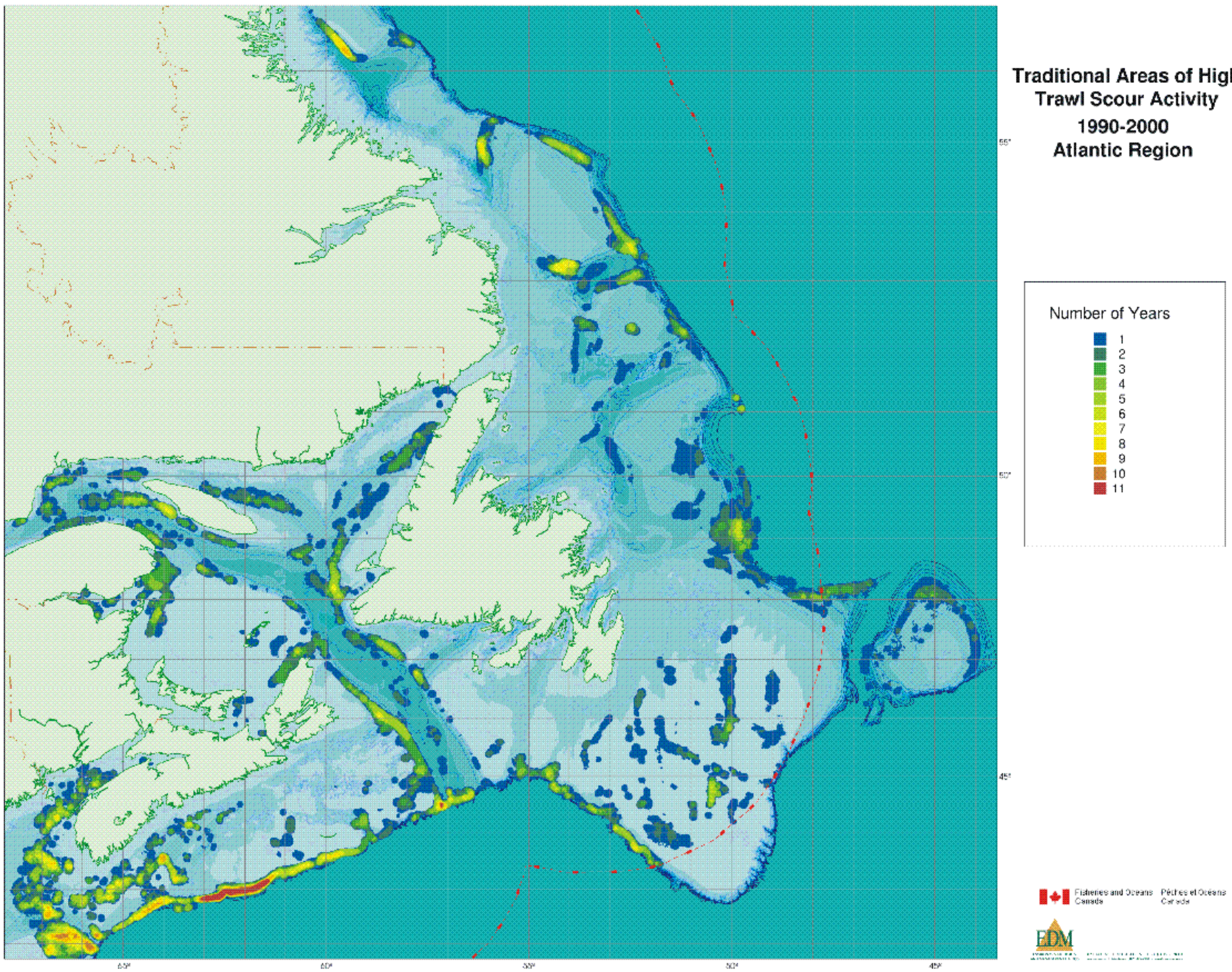


Figure 3.7 Traditional Areas of High Trawl Scour Activity 1990-2000 Atlantic Region.

macrofauna between samples taken in versus outside of the canyon. The benthic communities were functionally similar to benthic communities on the continental shelf where the dominant taxa were echinoderms, crustaceans, and polychaetes. However, there was a higher percentage of sipunculans in these deeper habitats.

While existing studies of benthic community composition for the Orphan Basin region specifically could not be identified, it is likely that the continental shelf areas that lie within the Grand Banks will be similar to the communities described above. However, it is more difficult to evaluate the communities that are likely to occur in the deeper slope and abyssal habitats that also occur within the Orphan Basin Study Area. The limited existing information suggests that the benthic assemblages are similar to those on the continental shelf in terms of abundance, biomass and macrofaunal composition. However, care should be taken in extrapolating this information as it is taken from one survey of the benthic communities in the Carson Canyon region. Research conducted on the Scotian Shelf that presents a new approach to map sea floor environments identified six diverse habitats and corresponding benthic community associations across a spatially limited area. Structurally complex gravel habitats (i.e. exhibiting a wide variability in grain size) were found to be the most diverse and had the greatest abundance of sessile epifauna. Lowest species richness was recorded in shallower sandy substrate environments, high-energy environments with mobile sediment. This research highlights the potential for habitat complexity and heterogeneity to promote benthic diversity even at limited spatial scales. It also highlights the importance of stable low-energy environments for the development of vulnerable benthic assemblages such as leafy bryozoan, sponge, and ascidian communities that have high species diversity.

Consistent responses of benthic communities to anthropogenic disturbances such as fishing and oil production activities were assessed in order to identify potentially sensitive habitats or species. Reductions in the abundance and biomass of large long-lived epifaunal species and sessile organisms (e.g., sand dollars, brittle stars, soft corals) to disturbance were documented. The most vulnerable seabed habitats are therefore likely to be 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 that have key roles in the functioning and structure of benthic communities also require careful consideration in order to assess large-scale impacts associated with anthropogenic disturbances.

In order to assess anthropogenic impacts associated with exploration or production activities knowledge of existing impacts and natural variation is required. The main identifiable anthropogenic disturbance presently occurring in Canadian Atlantic waters is due to commercial fishing activities. The ICES report (2001) provides an excellent source of knowledge of historical disturbance due to fishing activities as well as information of undisturbed benthic habitats. This report indicates that trawling was moderately persistent on the central part of the Grand Bank and along the shelf edge centered at Lat 49º (see Figures 3.6 and 3.7). These areas fall within the Orphan Basin Study Area that encompass continental shelf habitats. Deep sea habitats are not subject to mobile fishing activities such as trawling (D. Kulka, pers. comm.). While some non-mobile forms of fishing occur in deeper offshore water, these fisheries were concentrated in waters outside of the Orphan Basin Study Area. Hence identifiable anthropogenic disturbances in these deeper abyssal environments are presently very limited in comparison to continental shelf environments where commercial fishing activities are concentrated. These deeper offshore habitats are also subject to less natural physical disturbance imposed by storm waves, tidal currents, ice scour, and sediment transport than shallow continental habitats, and are the habitats for which we have the most limited available information of existing benthic community structure. Recently sea floor mapping methods have been used as a rapid assessment technique to extrapolate benthic habitat characteristics across large areas of the sea floor. This provides fundamental information for monitoring environmental change and for assessing impacts of anthropogenic disturbance on benthic organisms. However, this technique requires adequate integration of bathymetric information, surficial geology and benthic data which is currently lacking for Newfoundland waters.

3.2.2.8 Planning Implications

Benthos is relevant to planning because these communities are relatively immobile, directly affected by drilling discharges, are an important link to commercial fisheries, and usually show some zonation in their distribution. In most coastal and slope areas of North America such as the West Coast, Gulf of Mexico, and US East Coast, sufficient information exists to link specific benthic assemblages to specific depth ranges. In some cases, the data are sufficient to allow mapping. Unfortunately, this is not the case in the waters of Newfoundland and Labrador where very little benthic work has been conducted, especially in the Orphan Basin Study Area. The planning implication of this data gap is that EAs for exploration work may be delayed until data are collected. The C-NOPB may require that operators collect baseline benthic data to support their applications.

3.2.3 Fish and Fisheries

3.2.3.1 Overview of Commercial Fisheries

The Newfoundland commercial fishery landings data for 1998 to 2002 period were used to describe recent commercial fishing activity in some of the Orphan Basin Study Area. A large portion of the Study Area lies outside the 200-nm Economic Exclusion Zone (EEZ). A total of eleven Northwest Atlantic Fisheries Organization (NAFO) Unit Areas (UAs) occur either fully or partially within the Study Area. The UAs that occur partially or entirely outside of the EEZ include, from north to south, 3Kk, 3Kg, 3Le, 3Ma and 3Li. Those that occur partially or entirely inside of the EEZ include 3Kc, 3Kf, 3Kg, 3Lc, 3Ld, 3Le, 3Lg, 3Lh, and 3Li (Figure 3.8).

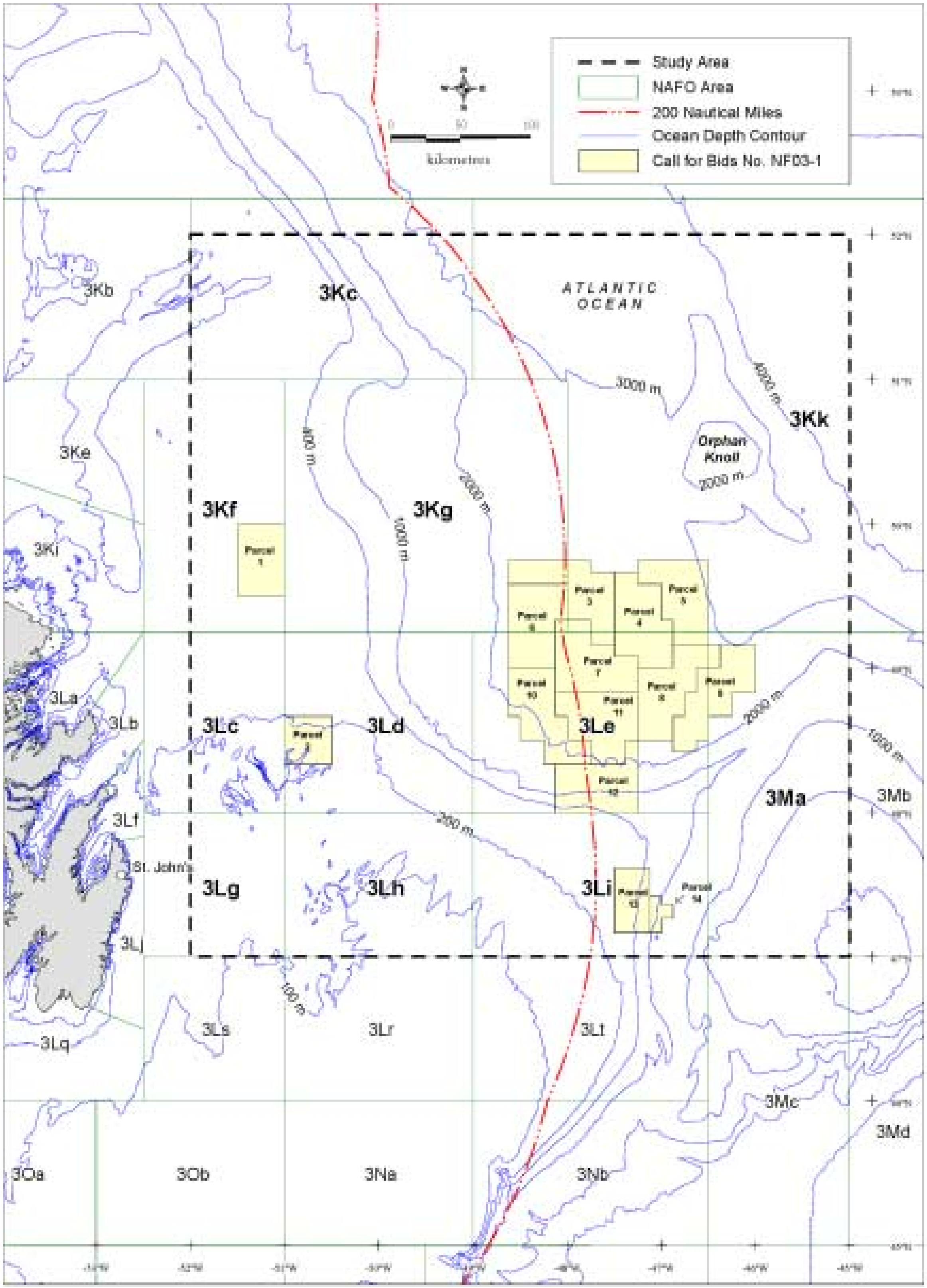


Figure 3.8 NAFO Unit Areas Occurring within the Orphan Basin Study Area.

Between 1998 and 2002, species that accounted for the highest landing values (five-year totals) in and adjacent to the Study Area (i.e., the 11 UAs) included snow crab (~$370 million), northern shrimp (~$104 million), and Greenland halibut (~$20 million) (Table 3.2). These three species accounted for over 99.5% of the total landing values from the Study Area during the five-year period. Other commercial species whose five-year landing values exceeded $100,000 included American plaice (~$459,000), witch flounder (~$319,000), bigeye tuna (~$292,000), rough-head grenadier (~$288,000), albacore tuna (~$158,000), swordfish (~$134,000), Atlantic cod (~$130,000), and redfish (~$122,000) (Table 3.2).

Table 3.2 Most Highly Valued Newfoundland Commercial Landings from the Eleven NAFO Unit Areas Occurring within the Orphan Basin Study Area, 1998-2002.

SPECIES	**Landed Value ($)**					
	1998	**1999**	**2000**	**2001**	**2002**	**Total**
Snow crab	44.8M	93.8M	99.6M	67.9M	64.0M	**370.1M**
Northern shrimp	8.1M	16.8M	33.3M	22.1M	23.4M	**103.9M**
Greenland halibut	3.0M	2.8M	6.0M	4.2M	4.5M	**20.4M**
American plaice	1.2K	2.3K	50.6K	157.9K	247.2K	**459.1K**
Witch flounder	<1.0K	1.0K	62.9K	116.1K	138.1K	**318.7K**
Bigeye tuna			158.2K		133.7K	**291.9K**
Roughhead grenadier	26.1K	57.3K	67.8K	56.1K	81.2K	**288.5K**
Albacore tuna			27.2K		130.4K	**157.6K**
Swordfish			102.1K		32.3K	**134.4K**
Atlantic cod	24.0K	9.0K	51.0K	37.1K	8.6K	**129.8K**
Redfish	2.5K	1.0K	30.6K	37.2K	50.8K	**122.1K**
Total of above eleven species	**56.0M**	**113.5M**	**139.5M**	**94.6M**	**92.7M**	**496.3M**
Total of all species landed	**56.0M**	**113.5M**	**139.5M**	**94.6M**	**92.9M**	**496.5M**

'M' denotes million; 'K' denotes thousand

Species whose total landings values exceeded $50,000 during the 1998-2002 period included Iceland scallop ($94K), bluefin tuna ($72K), and wolffish ($63K).

Since much of the Orphan Basin Study Area lies outside of the EEZ, it was necessary to estimate the commercial catches in the outside areas of 3K and 3L, as well as 3M (Table 3.3.). This was done by subtracting the Newfoundland landings from the total catches indicated in the NAFO Fishery Statistics. This is an estimation since some of the non-Newfoundland-landed catches was also caught inshore of the EEZ.

Table 3.3 Estimation of Non-Newfoundland Landed Commercial Catches in Divisions 3KLM, 2000-2001. All data represent landings weight (metric tons).

SPECIES	2000			2001		
	3K	3L	3M	3K	3L	3M
Northern shrimp	5	926	49,754		691	38,855
Snow crab		32			14	
Greenland halibut		15,346	3,643	25	15,626	3,784
American plaice		544	251	5	548	198
Witch flounder	1	384	744		407	493
Roughhead grenadier	1	4,570	1,687		2,236	1,247
Atlantic cod			36		73	54
Redfish	1	625	3,777		615	3,185
Skate		985	739		1,148	348
Yellowtail flounder		63	11		41	109
Atlantic halibut		22	27		57	6

Source: NAFO Fishery Statistics (2003).
Shading identifies cases >1,000-mt

During 2000 and 2001, almost 61% of the northern shrimp (98% of which was caught in Division 3M) caught in NAFO Divisions 3KLM was not landed in Newfoundland. During the same two years, almost 72% of the Greenland halibut reported caught in 3KLM was not landed at Newfoundland ports. Eighty-one percent of the non-Newfoundland-landed Greenland halibut was taken in 3L and the remainder in 3M. Ninety-six percent of the roughhead grenadier taken in 3KLM during 2000 and 2001 was not landed in Newfoundland. Approximately two-thirds of it was caught in 3L and the remainder in 3M. Over 98% of the redfish reported caught in 3KLM was landed somewhere other than Newfoundland. Of this catch, 85% was taken in 3M and the remainder in 3L. Other species that were caught in substantial quantity in 3KLM but not landed in Newfoundland included American plaice, witch flounder and skate. These species were also caught in 3L and 3M. Some cod catches were reported for 3L and 3M during 2000 and 2001 that were not landed in Newfoundland. Similar to Newfoundland-landed catches during the 1998-2002 period, relatively low non-Newfoundland landed catches were reported in 3K during 2000 and 2001.

3.2.3.1.1 Snow Crab

Snow crab (*Chionoecetes opilio*) landing values for the 1998-2002 period were highest in UAs 3Lc ($96.7 million), 3Lg ($62.5 million), 3Li ($52.5 million), 3Ld ($40.2 million), 3Kg ($38.8 million), 3Lh ($28.5 million), 3Kc ($25.8 million), and 3Kf ($24.3 million) (Figure 3.9).

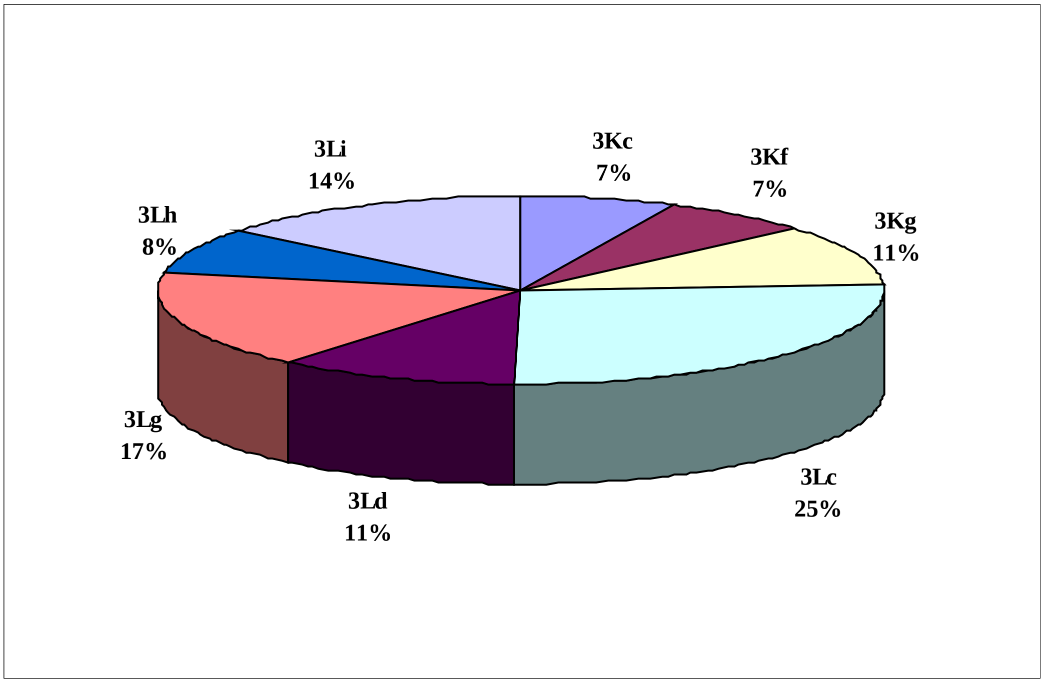


Figure 3.9 Percentage of Total Newfoundland Snow Crab Commercial Landings Values from each of the Study Area UAs, 1998-2002 Combined (3Le landings <1% and were not Included).

Essentially all of the crab was caught in the relatively shallow western and southwestern parts of the Study Area (Figure 3.10; ~85% of catches georeferenced) although some catches were also reported beyond the 2,000-m isobath. The most lucrative months for the snow crab fishery in Study Area between 1998 and 2002 were May (34%), June (32%) and July (19%) (Table 3.4). Substantial landings were also made in April and August to December. Fixed pots are the primary gear type used to harvest snow crab.

Table 3.4 Timing of Commercial Snow Crab Fishery in Study Area UAs, 1998-2002 Combined. Values are percentages of total landings in each of the UAs.

Unit Area	Jan - Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3Kc [7]		<1	23.5	40.1	25.1	6.3	2.0	2.2	<1	<1
3Kf [8]		3.6	43.3	25.6	19.2	3.6	1.6	2.6	<1	<1
3Kg [4]		1.1	33.6	29.7	18.0	2.7	4.1	6.5	4.1	<1
3Kk										
3Lc [1]		3.0	27.8	40.5	19.4	4.3	1.1	1.8	1.7	<1
3Ld [5]		13.7	45.1	19.3	12.5	4.2	1.6	2.3	1.0	<1
3Le [9]			36.5	30.7	28.3	3.9	<1		<1	
3Lg [2]		2.0	18.0	42.3	23.3	5.7	3.5	2.7	1.9	<1
3Lh [6]		11.3	43.5	24.4	14.6	2.4	<1	2.6	<1	<1
3Li [3]		12.0	49.1	20.6	12.4	2.0	<1	1.0	1.8	<1
3Ma										

Superscripts after Unit Area indicate the ranking of the UA in terms of total landings for 1998-2002.

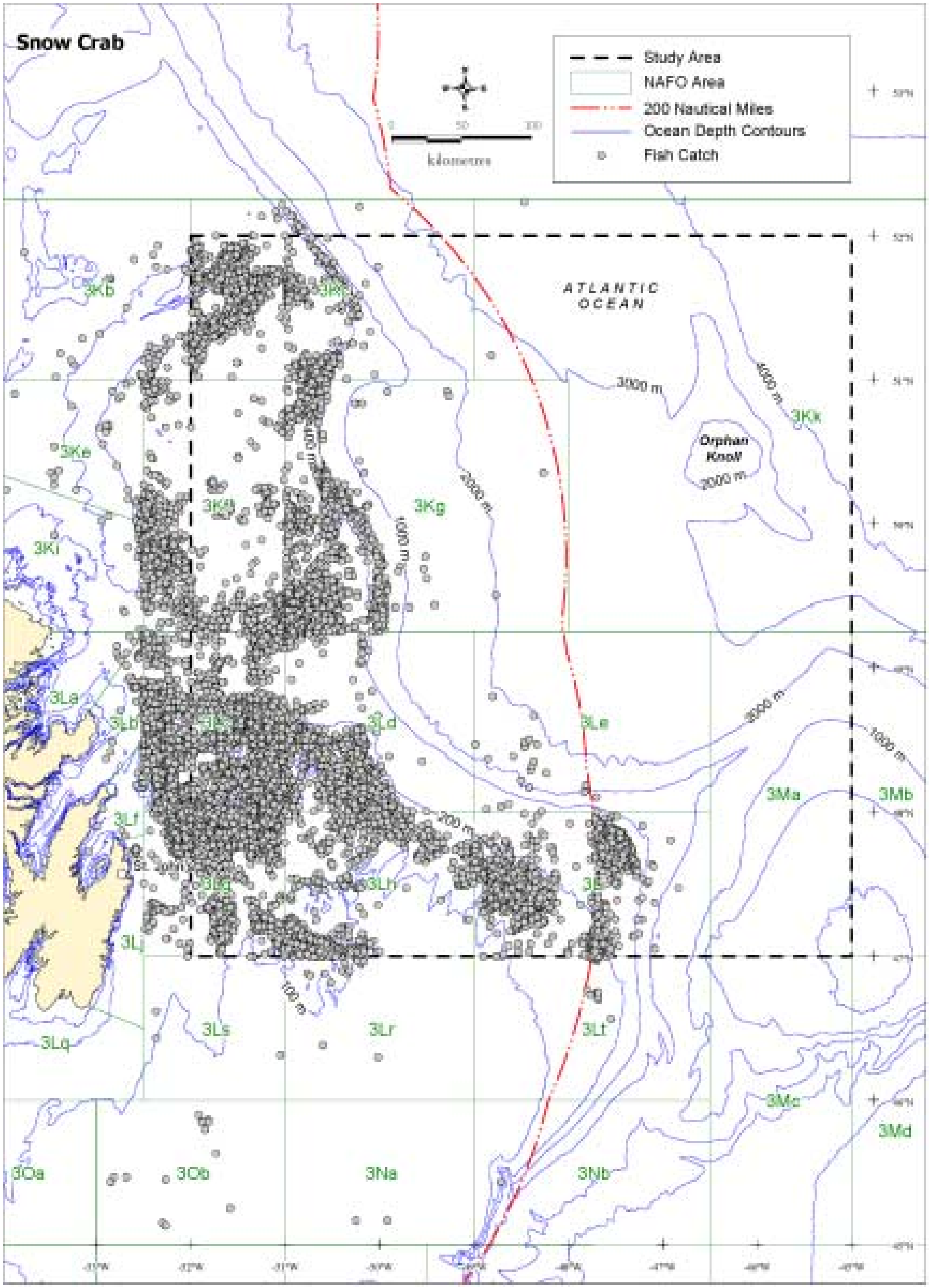


Figure 3.10 Distribution of Catch Locations of Snow Crab Landed at Newfoundland Ports, 1998-2002.

3.2.3.1.2 Northern Shrimp

Northern shrimp (*Pandalus borealis*) landing values during 1998 to 2002 period were highest in UAs 3Kg ($40.0 million), 3Kf ($24.9 million), 3Li ($17.s million), 3Kc ($10.0 million), 3Le ($6.1 million), 3Ma ($3.1 million), and 3Ld ($2.0 million) (Figure 3.11).

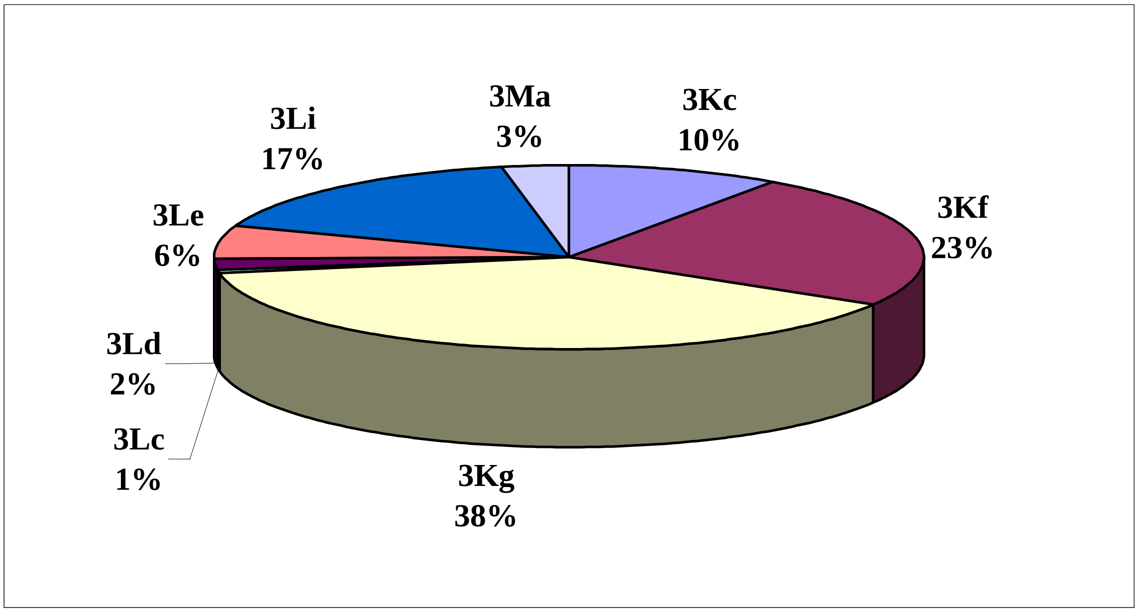


Figure 3.11 Percentage of Total Newfoundland Northern Shrimp Commercial Landings Values from each of the Study Area UAs, 1998-2002 Combined (3Kk, 3Lg and 3Lh landings <1% and were not Included).

Northern shrimp catches tended to be made in deeper water areas, usually beyond the 200-m isobath, compared to the snow crab fishery (Figure 3.12; ~99% of catches georeferenced). Catches in 3Li, 3Le and 3Ma (Flemish Pass area) accounted for about 26% (~ $27 million) of the total northern shrimp landings in Newfoundland during the five-year period. Some catches were reported beyond the 2,000-m isobath. The most lucrative months for the northern shrimp fishery in Study Area between 1998 and 2002 were June (18%), July (23%), August (16%), September (16%) and October (14%). Substantial landings were also made in February to May, and November to December (Table 3.5). The shrimp trawl is the primary gear type used to harvest this shellfish.

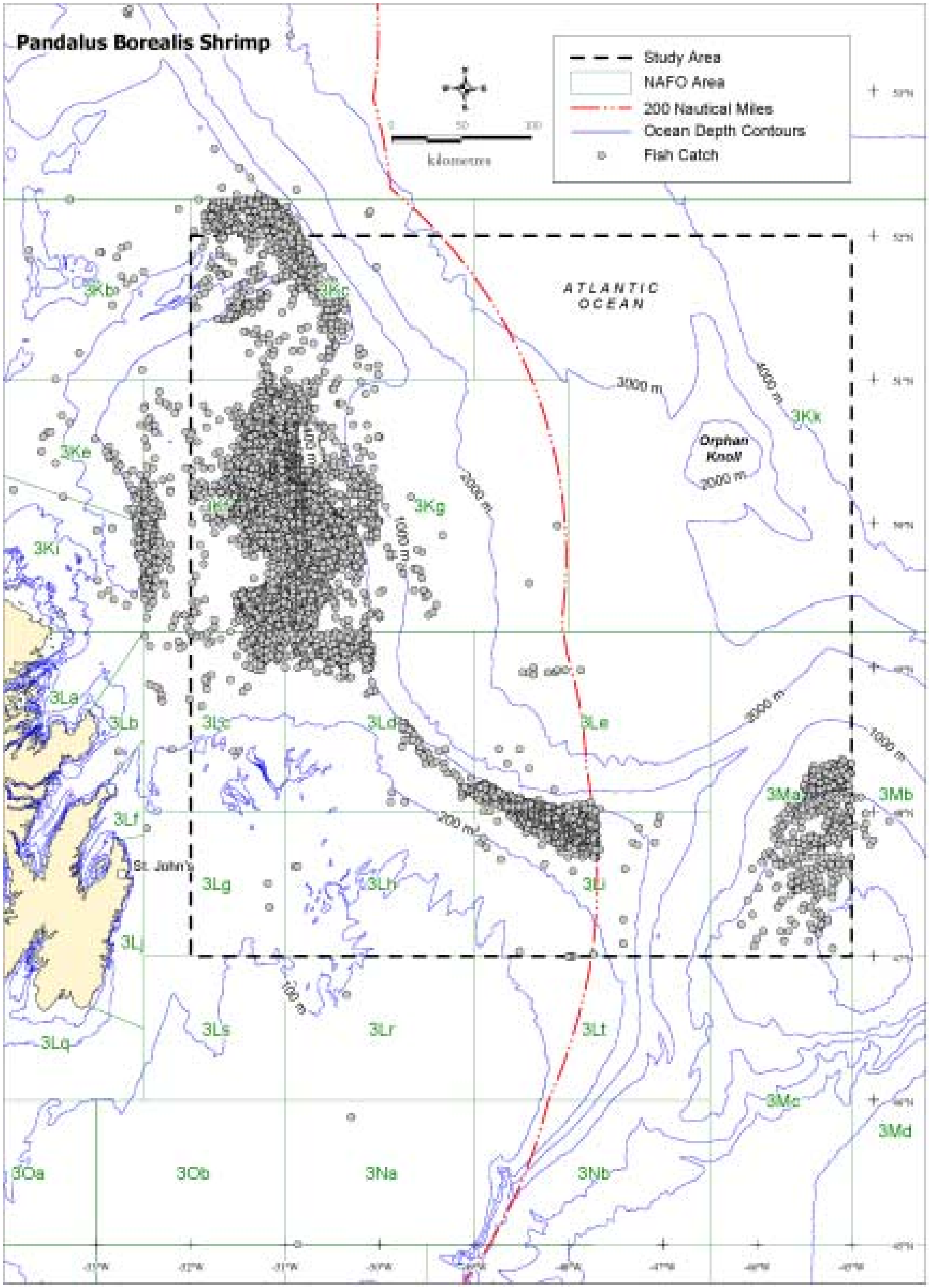


Figure 3.12 Distribution of Catch Locations of Northern Shrimp Landed at Newfoundland Ports, 1998-2002.

Table 3.5 Timing of Commercial Northern Shrimp Fishery in Study Area UAs, 1998-2002 Combined. Values are percentages of total landings in each of the UAs.

Unit Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3Kc [4]	<1	<1	1.6	<1	<1	4.8	5.8	12.2	34.0	29.5	6.7	3.7
3Kf [2]			<1	2.7	1.9	12.8	32.6	37.1	9.1	3.3	<1	<1
3Kg [1]			<1	1.4	1.3	10.8	21.6	12.6	20.3	27.4	3.9	<1
3Kk								72.4				27.6
3Lc [8]				<1	4.1	6.8	3.2		78.5	6.6	<1	<1
3Ld [6]				17.8	21.5	9.7	<1	<1	37.8	10.4	<1	1.6
3Le [5]		4.9	2.0	9.5	8.5	49.2	20.2		4.3	1.4		
3Lg						1.8	56.9	12.6	1.8	26.9		
3Lh									100.0			
3Li [3]		3.9	<1	3.5	8.8	44.4	14.8	1.3	17.1	5.4		
3Ma [7]			3.5		55.1	37.5	3.1					<1

Superscripts after Unit Area indicate the ranking of the UA in terms of total landings for 1998-2002.

3.2.3.1.3 Greenland Halibut

Greenland halibut (turbot) (*Reinhardtius hippoglossoides*) landing values in the Study Area between 1998 and 2002 were highest in UAs 3Kg ($9.1 million), 3Ld ($4.1 million), 3Kc ($3.2 million), 3Le ($2.4 million), 3Kf ($905,000) and 3Lc ($637,000) (Figure 3.13).

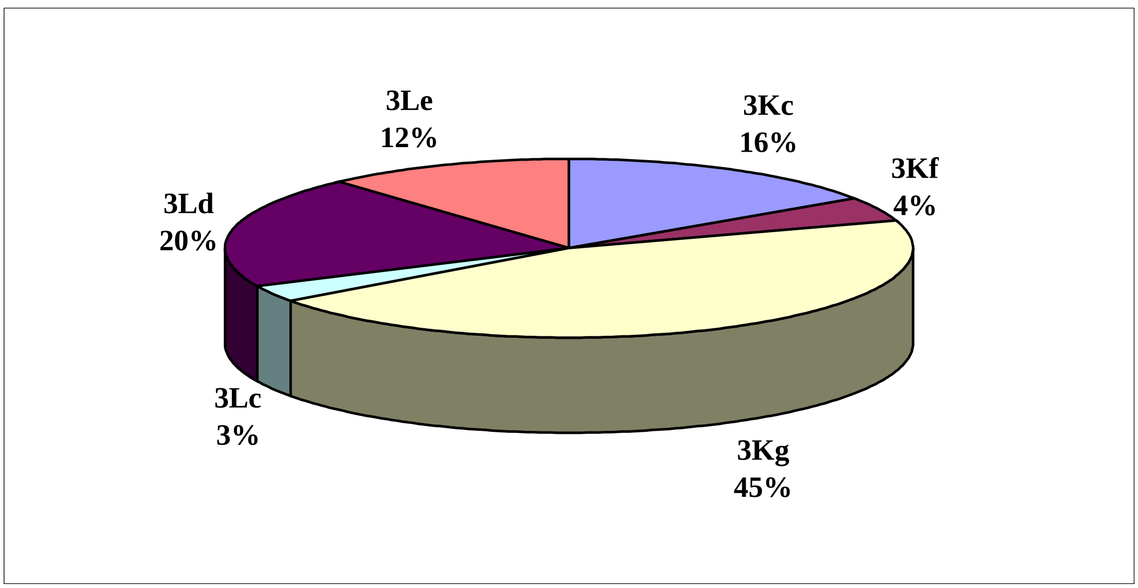


Figure 3.13 Percentage of Total Newfoundland Greenland Halibut Commercial Landings Values from Each of the Study Area UAs, 1998-2002 Combined (3Kk, 3Lg, 3Lh, 3Li, and 3Ma Landings <1% and were not Included).

Greenland halibut catches were highest in regions where water depths were greater than 400-m, particularly in the 400 to 1,000-m range (Figure 3.14; ~99% of catches georeferenced). Of the three Study Area UAs in the Flemish Pass area, only 3Le (~$2.4 million) had five-year Greenland halibut catch values that exceeded $20,000. Catches were also reported beyond the 2,000-m isobath. The most lucrative months for the Greenland halibut fishery in Study Area between 1998 and 2002 were May (9%), June (22%) July (30%), August (23%), and September (11%). Substantial landings were also made in April and October (Table 3.6). The gill net was the primary gear type (80%) and the bottom otter trawl was the secondary gear type (20%) used to harvest Greenland halibut in the Study Area.

Table 3.6 Timing of Commercial Greenland Halibut Fishery in Study Area UAs, 1998-2002 Combined. Values are percentages of total landings in each of the UAs.

Unit Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3Kc [3]	<1		<1	1.1	2.9	21.2	42.7	24.9	5.3	<1		
3Kf [5]			<1				<1	28.6	69.4	1.4		
3Kg [1]	<1	<1	<1	2.5	8.6	24.6	37.2	21.6	4.3	<1	<1	
3Kk												
3Lc [6]						<1	2.0	46.8	45.1	6.2	<1	<1
3Ld [2]	<1	<1	1.2	7.1	15.2	22.5	22.3	20.3	9.2	2.4	<1	<1
3Le [4]				4.9	20.2	21.5	8.9	22.9	15.8	5.2	<1	<1
3Lg							<1	7.4	92.5			<1
3Lh								99.8	<1			<1
3Li					79.4				18.9			1.7
3Ma					92.2							7.8

Superscripts after Unit Area indicate the ranking of the UA in terms of total landings for 1998-2002.

3.2.3.1.2 Other Commercial Species With Landings Values > $100,000

With respect to the other commercial species that accounted for more than $100,000 five-year catch values, American plaice, witch flounder, rough-head grenadier and redfish were taken primarily in UAs 3Ld and 3Kg. American plaice, witch flounder and redfish catches in 3Kg and 3Ld were concentrated primarily between the 400-m and 1,000-m isobaths; the rough-head grenadier catches were also concentrated between 400 and 1,000-m as well as in slightly deeper water (>1,000-m) (Figures 3.15 to 3.18; >99% of catches georeferenced).

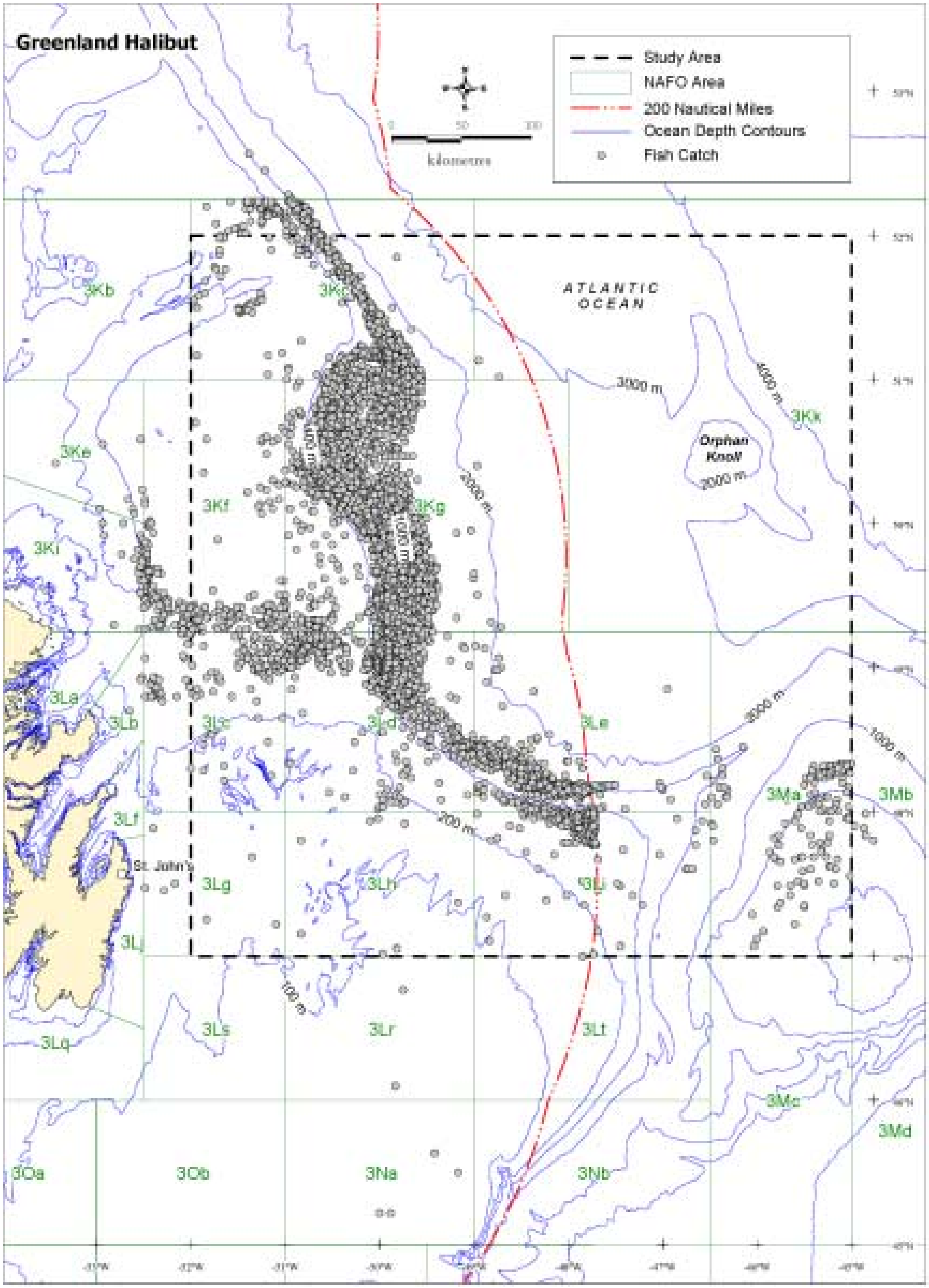


Figure 3.14 Distribution of Catch Locations of Greenland Halibut Landed at Newfoundland Ports, 1998-2002.

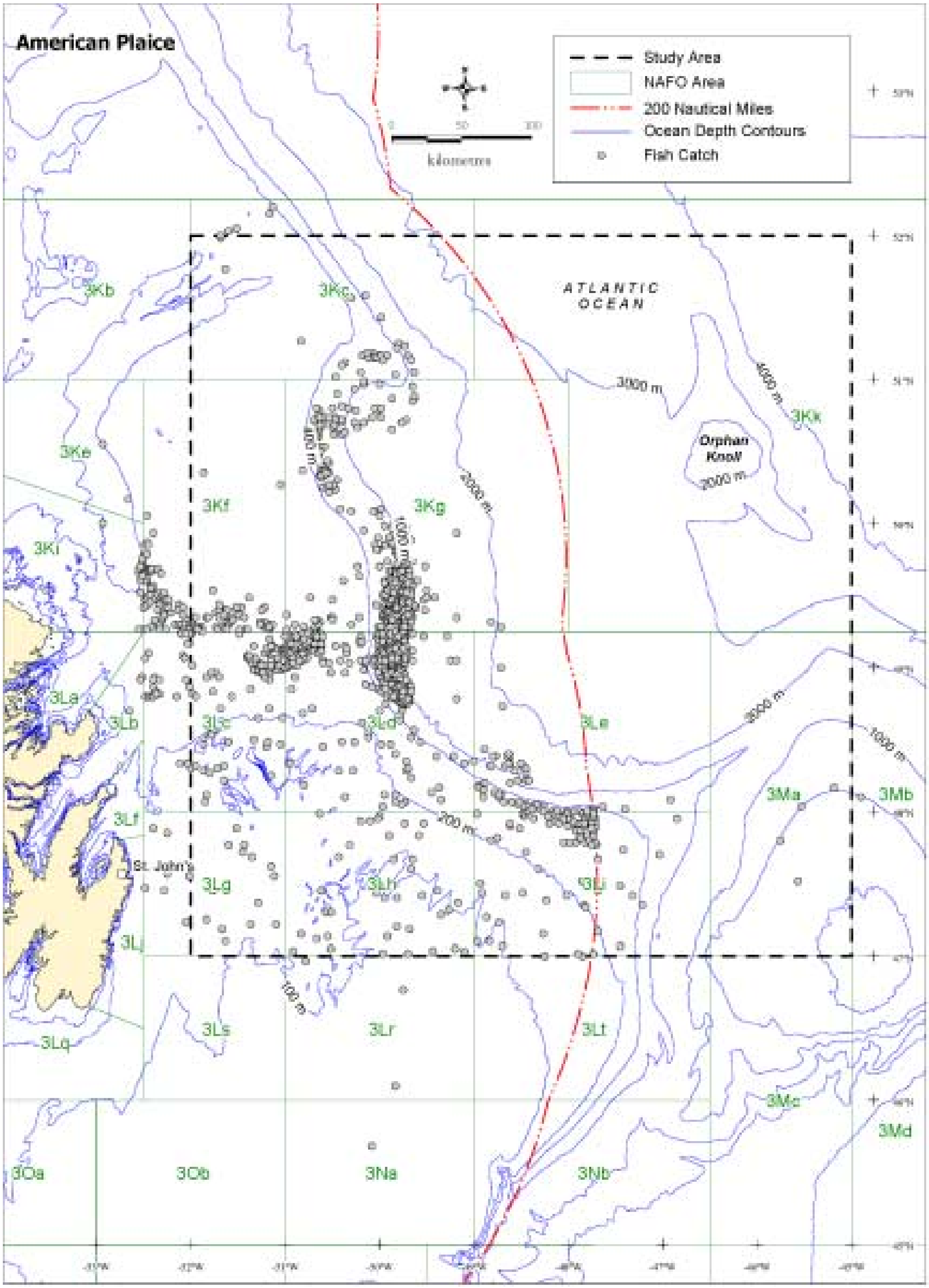


Figure 3.15 Distribution of Catch Locations of American Plaice Landed at Newfoundland Ports, 1998-2002.

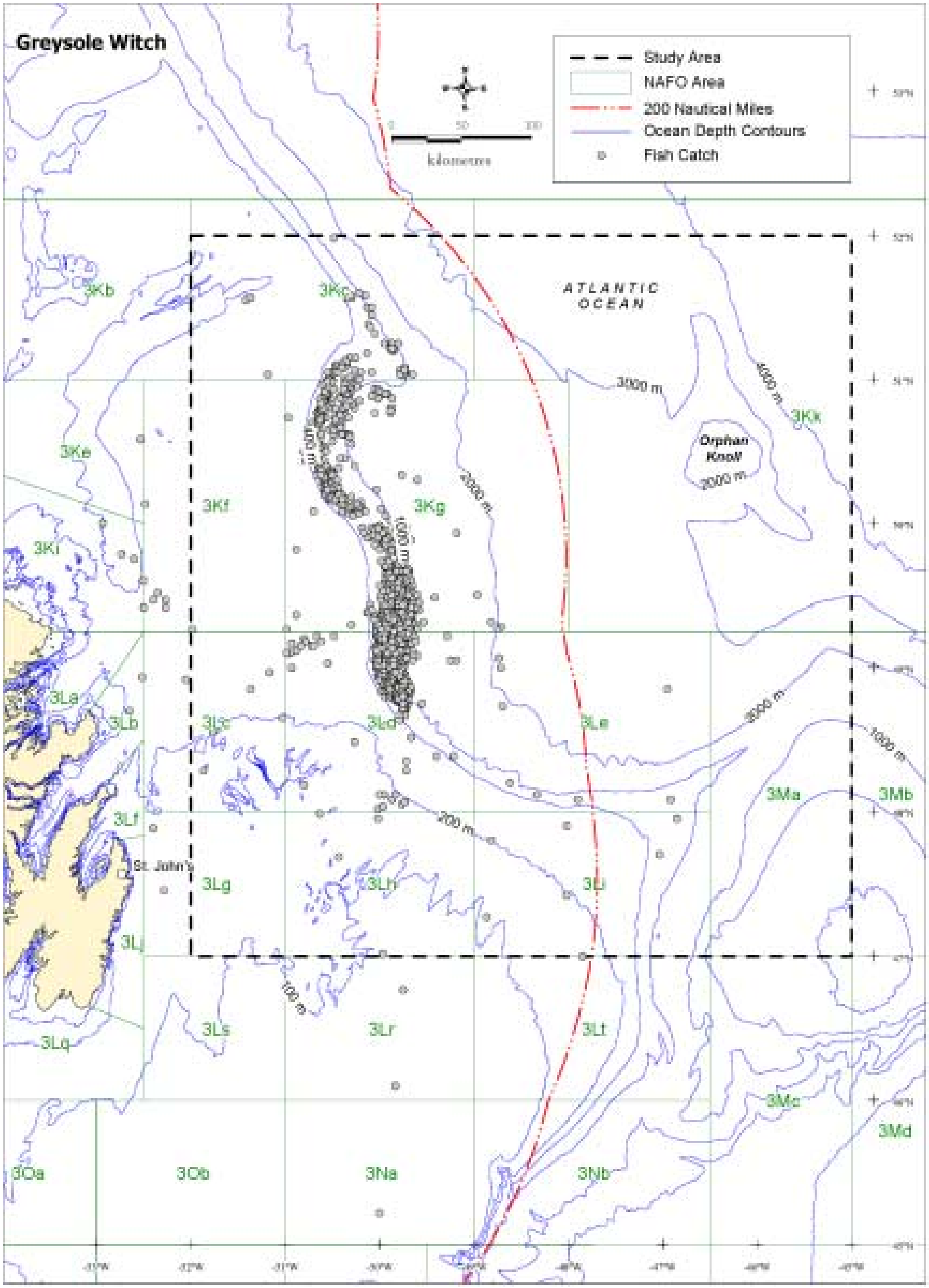


Figure 3.16 Distribution of Catch Locations of Witch Flounder Landed at Newfoundland Ports, 1998-2002.

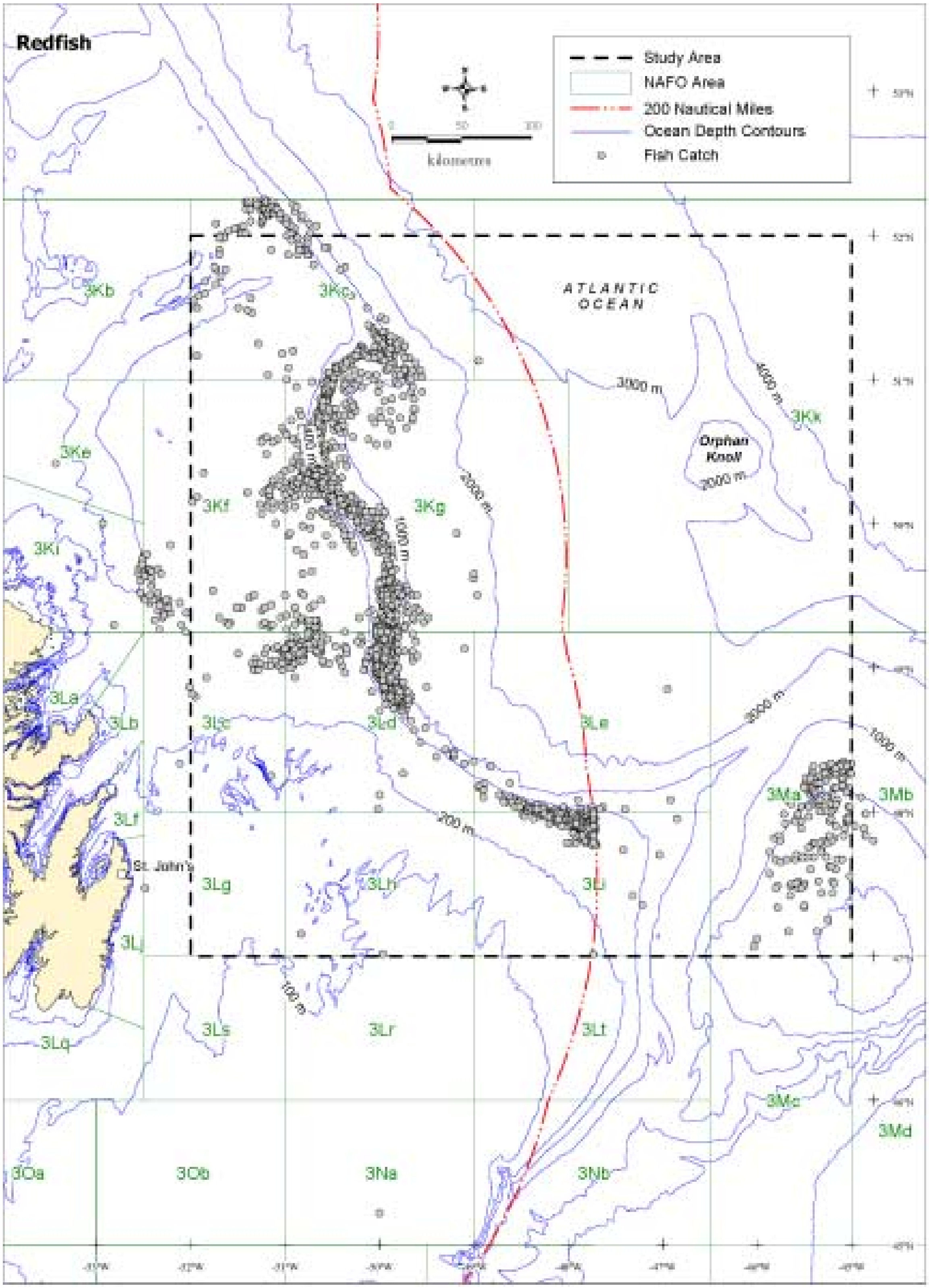


Figure 3.17 Distribution of Catch Locations of Redfish Landed at Newfoundland Ports, 1998-2002.

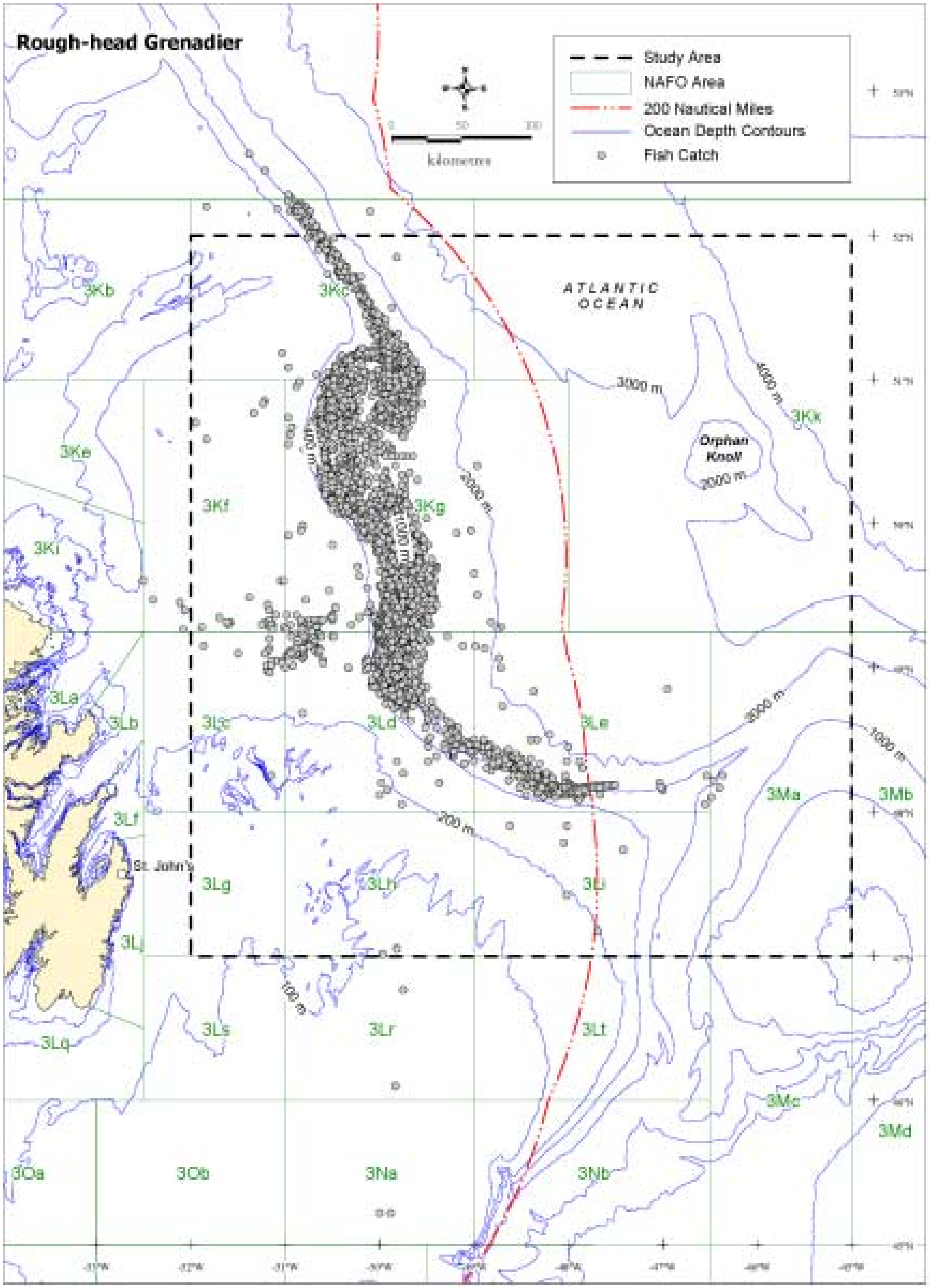


Figure 3.18 Distribution of Catch Locations of Roughhead Grenadier Landed at Newfoundland Ports, 1998-2002.

Catches of American plaice, witch flounder, redfish and roughhead grenadier were made primarily during April to May, April to June, June to July, and May to September, respectively (Table 3.7). The bottom otter trawl was the primary gear type used to harvest American plaice, witch flounder and redfish, while the gill net was the primary means of catching roughhead grenadier. Substantial catches of American plaice and redfish were also made with gill net while the otter trawl was also a secondary gear type for the roughhead grenadier harvest.

The large pelagics (tunas and swordfish) were caught primarily in UA 3Kk. The only large pelagic catches inside of 4,000-m occurred in 3Kg just inside the 1,000-m isobath (tuna and swordfish) (Figure 3.19; >95% of catches georeferenced). Tunas and swordfish were caught primarily in August and September by longlining except for bluefin which was caught by rod and reel (Table 3.7).

Atlantic cod were caught mainly in UAs 3Lc, 3Ld and 3Kf. Most cod catches were made inside of the 1,000-m isobath although some were reported between 1,000 and 2,000-m in 3kg, 3Ld and 3Le (Figure 3.20; >96% of catches georeferenced). July to October period accounted for most of the cod catch (Table 3.7). The gill net was the primary gear type used to harvest cod although other gear types included traps, bottom otter trawls, hand lines and longlines.

Table 3.7 Timing of Other Commercial Fisheries in Study Area UAs, 1998-2002 Combined. Values are percentages of total landings in all UAs combined.

SPECIES	Predominant Fishery UAs (>90% of catch)	Jan - Mar	Apr – Jun	Jul – Sep	Oct – Dec
American plaice	3Ld, 3Kg, 3Kf	18.8	61.8	15.9	3.5
Witch flounder	3Ld, 3Kg	4.2	86.8	7.4	1.6
Bigeye tuna	3Kk			100.0	
Roughhead grenadier	3Kg, 3Ld, 3Le, 3Kc	<1	47.2	49.9	2.6
Albacore tuna	3Kk			100.0	
Swordfish	3Kk			100.0	
Atlantic cod	3Lc, 3Ld, 3Kf, 3Le, 3Kg	<1	5.6	81.0	12.6
Redfish	3Ld, 3Kg, 3Kc	1.4	56.2	42.0	<1

3.2.3.1.5 Other Finfish Species of Note

3.2.3.1.6 Wolffish

Wolffish (*Anarhicus* spp.) catches in the Study Area occurred primarily in UAs 3Ld (67%) and 3Kg (23%) during the 1998 to 2002 period. Most wolffish catches occurred along the slope in the 400-m to 1,000-m depth range although there were catches reported in areas where water depth exceeded 2,000-m (Figure 3.21; >99% of catches georeferenced). Most wolffish were taken between May and July with bottom otter trawls (82%) and gill nets (14%).

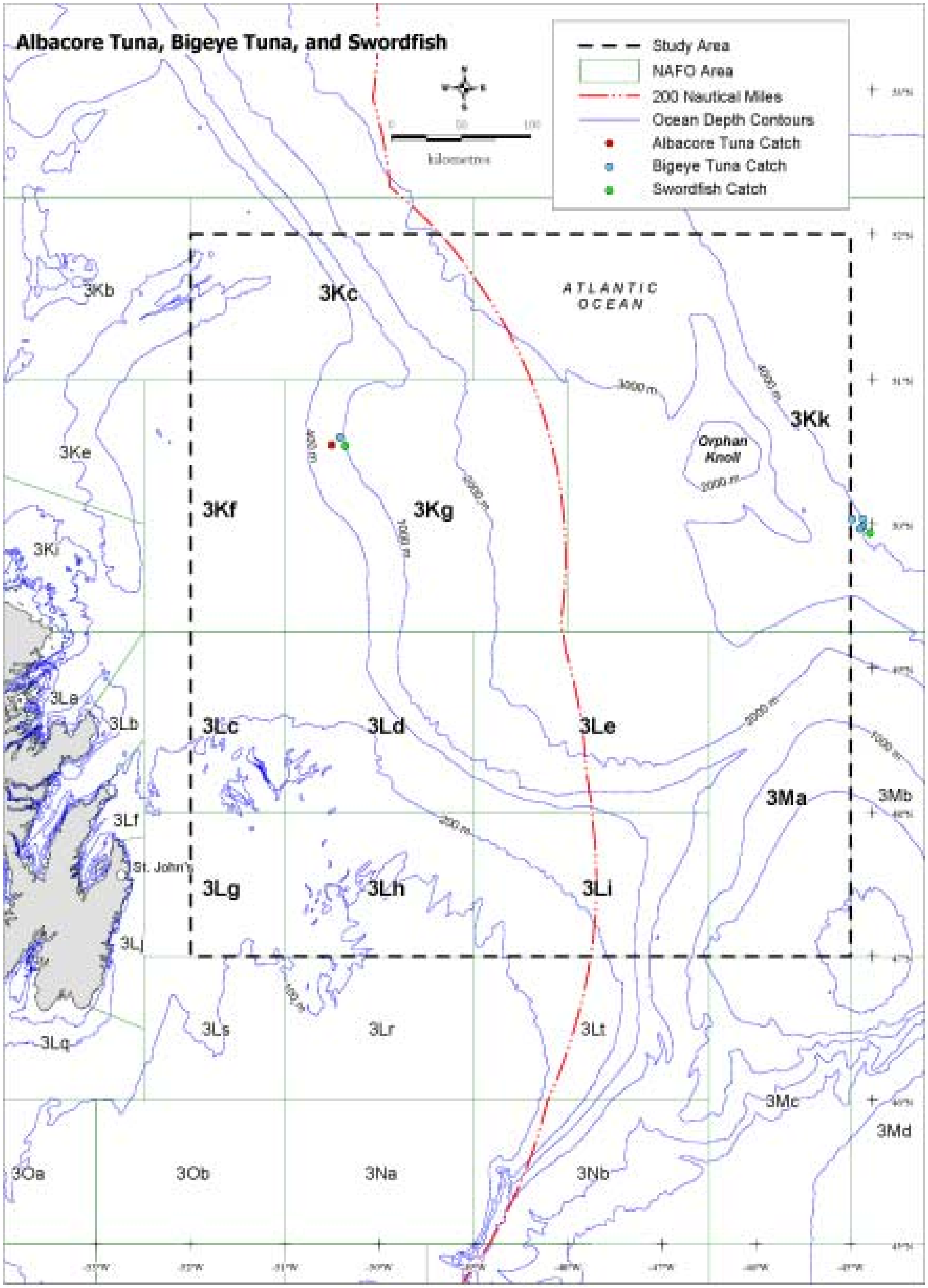


Figure 3.19 Distribution of Catch Locations of Tuna and Swordfish Landed at Newfoundland Ports, 1998-2002.

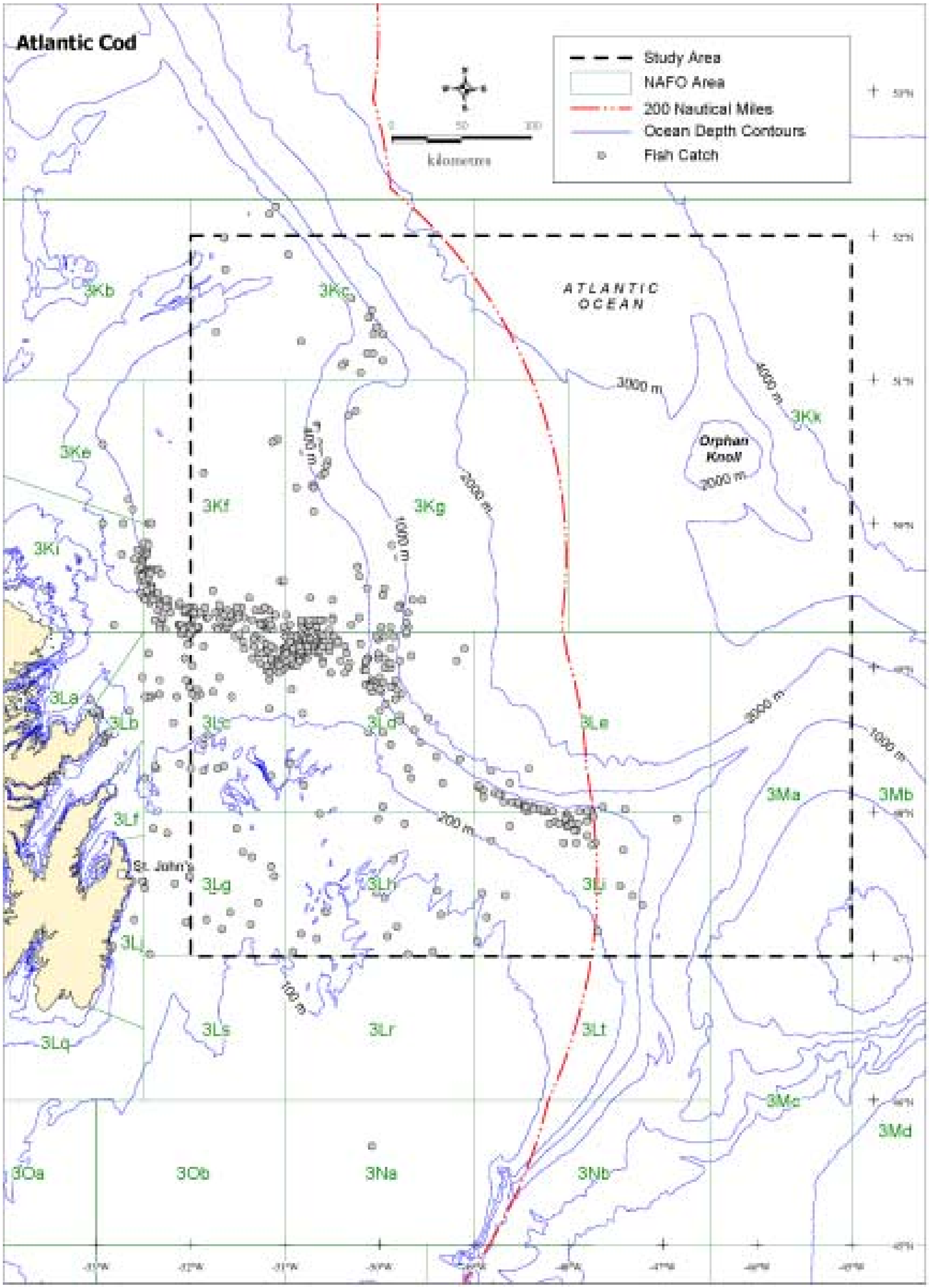


Figure 3.20 Distribution of Catch Locations of Atlantic Cod Landed at Newfoundland Ports, 1998-2002.

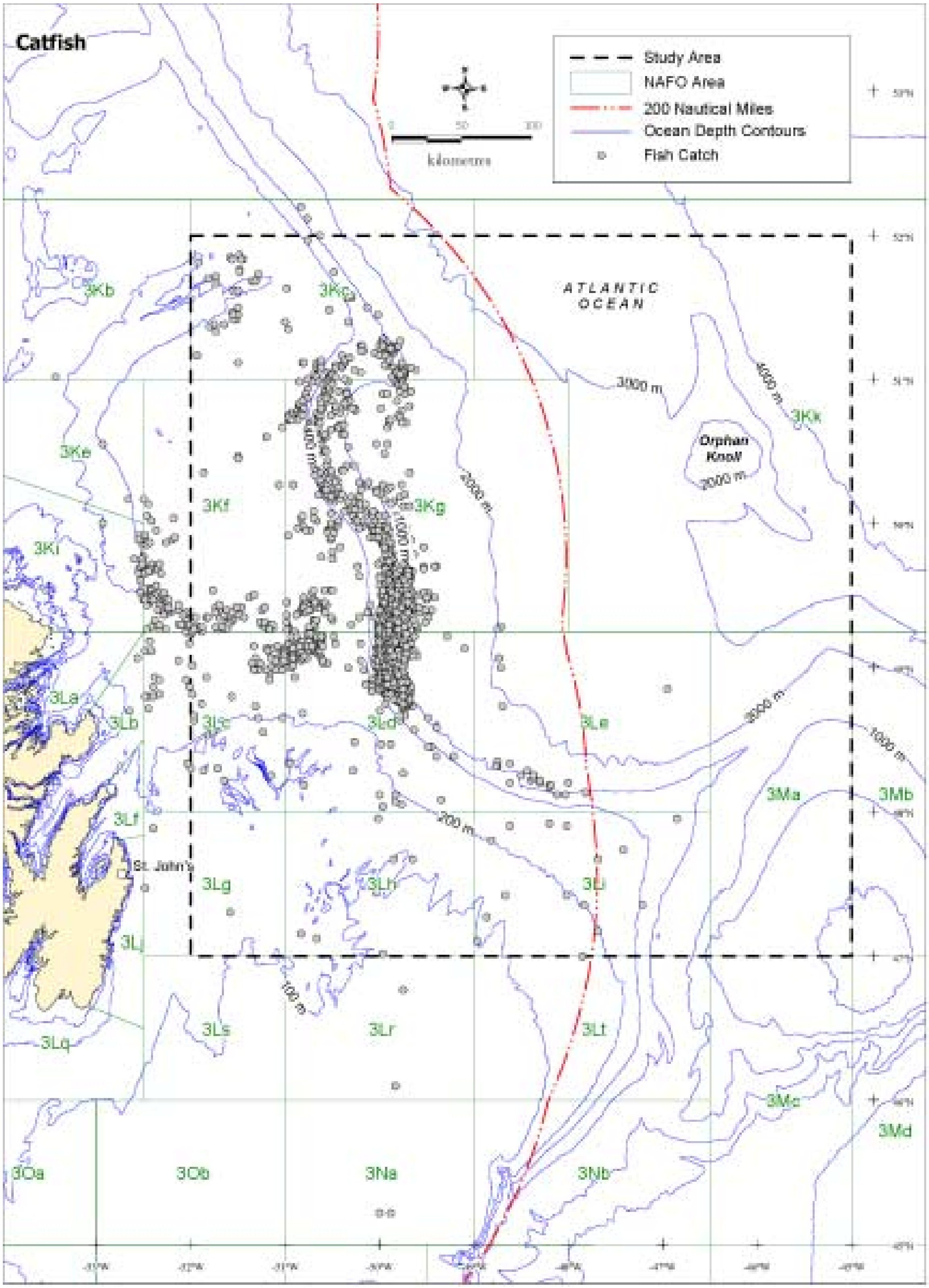


Figure 3.21 Distribution of Catch Locations of Wolffish (Catfish) Landed at Newfoundland Ports, 1998-2002.

3.2.3.1.7 Skate

Skate catches, presumably thorny skate, in the Study Area were highest in UAs 3Kg (72%), 3Kc (16%), 3Ld (6%) and 3Le (3%) during the five-year period. Most skate catches occurred along the slope in the 400-m to 1,000-m depth range. There were also catches reported in areas where water depth exceeded 2,000-m (Figure 3.22; >99% of catches georeferenced). June to September gill net fishing accounted for most of the skate catch.

3.2.3.2 Invertebrate Species Profiles

3.2.3.2.1 Snow Crab

Snow crabs occur over a broad depth range (20 to >400-m) in the northwest Atlantic. The distribution of this decapod species in waters off Newfoundland and southern Labrador is widespread but the stock structure remains unclear. While commercial-sized snow crabs (≥95-mm carapace width or CW) most commonly occur on mud or mud/sand substrate, smaller snow crabs often occur on harder substrates as well as on softer types (DFO 2003a). Snow crab mating generally occurs during the spring months. The female crabs carry the fertilized eggs for one to two years, depending on location, prior to larval hatch. Hatching normally occurs in late spring and summer after which the larvae remain planktonic for up to three to four months before settlement to the benthic habitat (DFO 2003a). Snow crab diet includes fish, clams, polychaetes, brittle stars, shrimp, crabs and other crustaceans. Common predators of this crab include various ground fish, seals and itself (DFO 2003a).

Based on the DFO multispecies bottom trawl survey conducted in the fall 2001, legal-sized (>94-mm CW) male snow crab were most abundant (up to >50 animals/tow) in the southern 3L portion of the Study Area. The same trend was evident for male snow crabs with carapace width range of 60 to 94-mm although the catch numbers were lower (1 to 30 animals/tow). The smallest males (<60-mm CW) were abundant throughout the 3K and 3L Shelf areas of the Study Area (up to >50 animals/tow). The 'hottest spot' for mature female snow crabs (>50 animals/tow) occurred in the northern section of UA 3Kc. They were also found elsewhere (1 to 20 animals/tow) on the Study Area Shelf area (Dawe et al. 2002). In 2001, the highest catch per set for legal-sized males in 3K was in the 400 to 500-m depth range while in 3L, catch was quite consistent across the depth range of 100 to 600-m (Dawe et al. 2002).

3.2.3.2.2 Northern Shrimp

Northern shrimp are distributed in the northwest Atlantic from Davis Strait to the Gulf of Maine, primarily in areas where the substrate is soft mud and bottom water temperatures range between 2 and 6ºC. These conditions are found in waters offshore of Newfoundland and Labrador where depths range between 150 and 600-m, thus resulting in a vast area of suitable habitat for *P. borealis*. Northern shrimp

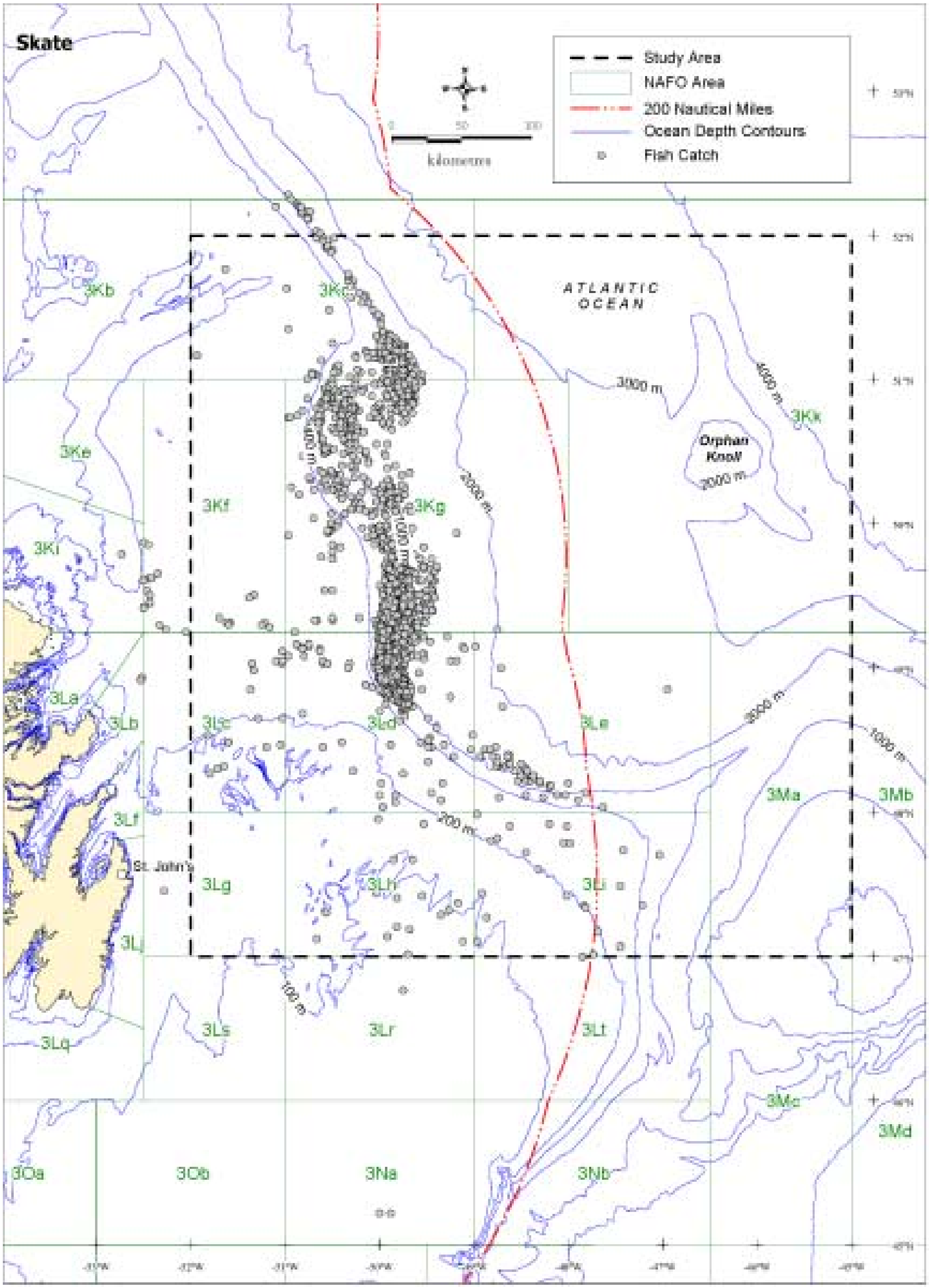


Figure 3.22 Distribution of Catch Locations of Skate Landed at Newfoundland Ports, 1998-2002.

exhibit diel vertical migration, remaining relatively deep in the water column during the day and then moving upwards in the water column during the night to feed on zooplankton. Predators of northern shrimp include cod, Greenland halibut, Atlantic halibut, skates, wolffish and harp seals (DFO 2003b).

Northern shrimp spawn once a year, usually in late June or early July. In eastern Canadian waters, the shrimp eggs are extruded during late summer and fall and they remain attached to the female until larval hatch the following spring/summer. Females may move into shallower areas to maximize the rate of embryonic development. The larvae remain planktonic in the upper water column for a few months after which they move downwards through the water column and metamorphose to adulthood (DFO 1993).

Research vessel survey biomass and abundance indices for SFA 6 (includes NAFO Division 3K) indicated an increase between 1997 and 2001 and then remained unchanged for 2002. Despite an apparent decline in the mean size of female northern shrimp since 1992 and the associated reduced individual fecundity, there has been a minimal impact upon total egg production given the current historically high biomass/abundance indices (Orr et al. 2002; DFO 2003b).

There is an active Russian fishery for northern shrimp that is conducted on the portion of the Flemish Cap area that occurs in the Study Area. The highest catch rates in 2001 and 2002 were reported for January to May 2001, and February 2002, particularly in the depth range of 200 to 300-m. The most common bycatch species were redfish, followed by spotted wolffish, roughhead grenadier and Greenland halibut (Bakanev 2002).

3.2.3.3 Finfish Species Profiles

3.2.3.3.1 Greenland Halibut

The Greenland halibut (turbot) is a deepwater flatfish species that occurs in water temperatures ranging between –0.5 to 6.0ºC, with a preference for 0.0 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 off bottom, acting pelagically (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 to 5-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 downwards 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).

Greenland halibut are widely distributed throughout the Labrador-eastern Newfoundland area (Bowering 2002). During the late 1970s and most of the 1980s, they were plentiful along the deep slopes of the continental shelf and in the deep channels running between fishing banks, particularly in NAFO Divisions 2G, 2H, 2J and 3K. By 1991, the Greenland halibut distribution in the northern areas was greatly reduced and most of these fish were located in Division 3K and along the northern slope of Division 3L. By 1996-2001, its distribution to some of the more northern areas of historical high abundance began to reoccur (Bowering 2002).

Between 1995 and 2001, the DFO stratified random fall surveys in Division 3K were conducted primarily over a depth range of 100 to 1,500-m with a Campelen 1800 shrimp trawl. In Divisions 3L and 3M, surveys conducted between 1996 and 2001 extended to at least 730-m and, where possible, to 1,500-m. These Divisions were sampled during both the spring and fall, again using the Campelen 1800 shrimp trawl (Bowering 2002). The surveys in 1999 showed larger catches in 3K and along the northern slope of 3L. Catches have remained relatively low along the eastern slope of 3L and in 3M. In 2000, survey results showed improved catches along the northeast slope of 3L while results in 3K were similar to 1999 (Bowering 2002). European Union (EU) trawl surveys conducted during July at the Flemish Cap since 1988 showed increasing Greenland halibut biomass up to 1998 after which the biomass has decreased. These surveys have been conducted over a depth range of 200 to 730-m (Vázquez 2002).

3.2.3.3.2 American Plaice

The American plaice distribution in the western Atlantic can be generalized as relatively deep water from Frobisher Bay, Baffin Island and western Hudson Bay southward along the Labrador coast, Newfoundland banks, Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy, Gulf of Maine to Rhode Island. This flatfish is commonly found at depths ranging from 70 to 275-m but it does occur in shallower (35 m) and deeper areas (700-m). American plaice appear to prefer water temperatures of -0.5 to 1.0ºC and substrate consisting of fine sand and/or mud. Adults appear to exhibit a limited seasonal movement (i.e., to deeper areas in winter and back to shallower areas in spring) (Scott and Scott 1988).

American plaice spawn in the spring (early April on the Flemish Cap and late April on the Grand Banks). The fertilized eggs float near the water's surface and substantial drift is speculated to occur. At 5ºC, hatching occurs as early as 1 to 2 weeks after fertilization (Scott and Scott 1988). Common prey of American plaice includes polychaetes, echinoderms, molluscs, crustaceans and various fish (e.g., capelin, sand lance, sculpin) (Scott and Scott 1988).

The American plaice stock in the Flemish Cap area has shown a steady decline since 1988 (Vázquez 2002). There has not been a directed fishery on 3LNO American plaice since 1993. Bycatch of American plaice between 1999 and 2001 was mainly from the NAFO Regulatory Area (NRA) outside of the EEZ. Based on the spring and fall Canadian research vessel surveys, the current American plaice biomass in the 3LNO survey area is only 26 to 30% of that in the mid- to late 1980s. There may be a slight increasing trend in both surveys over the last few years. The highest concentrations of American plaice found during the spring and fall surveys of the last few years have occurred in the southern regions of 3NO, well outside of the Study Area (Morgan et al. 2002).

3.2.3.3.3 Witch Flounder

The distribution of witch flounder (*Glyptocephalus cynoglossus*) in the western North Atlantic extends from Labrador at about 54ºN southward over the Newfoundland banks, Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy, and Gulf of Maine to North Carolina (Scott and Scott 1988).

This offshore, moderately deepwater flatfish occurs primarily within a depth range of 45 to 275-m but has been reported as shallow as 18-m and as deep as 1,570-m. Its occurrence is often associated with deep holes and interbank channels. This relatively non-migratory fish prefers mud and mud/sand substrates where water temperatures range from 2 to 6ºC (Scott and Scott 1988).

Witch flounder in the northwest Atlantic exhibit prolonged spawning from March to September. In the southern Labrador-Newfoundland shelf region, spawning occurs from March to July, most intensely between March and May. Witch flounder spawning on the Grand Bank occurs principally in July and August. Spawning generally occurs along the continental slope and in deepwater channels at depths of at least 500-m. Fertilized eggs are pelagic and hatching occurs about one week after spawning at water temperatures of 8ºC. Young flounder may remain pelagic for up to one year after hatching before settling to the bottom. Witch flounder have the longest pelagic stage of any of the flatfishes occurring in the area (Scott and Scott 1988). This predaceous flatfish has a relatively small gape size and is therefore limited in its choice of food items. Prey includes polychaetes, crustaceans (e.g., amphipods), small fish, molluscs, and small echinoderms. Harp seals are known to be predators of witch flounder (Scott and Scott 1988).

In 3KL, Canadian fall research vessel surveys in the late 1970s found wide distribution throughout the shelf and in deeper channels around fishing banks. By the mid-1980s, witch flounder were beginning to disappear from this area and by the early 1990s, they had virtually disappeared except for some very small catches along the slope in 3L. Fall surveys conducted during 1998-2001 indicated no change in this distribution pattern (Bowering 2002).

In recent years, witch flounder has been reported more frequently as a bycatch in the Greenland halibut fishery in the deep waters of the Flemish Pass (southeastern Study Area). Canadian Flemish Cap surveys between 1978 and 1985 showed witch flounder to be widely distributed in small numbers over the west side of the Flemish Cap. In 1994, a winter survey caught witch flounder in most sets on both the Grand Bank and the Flemish Cap sides of the Pass, although sets in the central deepest area yielded no fish. Between 1996 and 2001, the Grand Bank side of the Pass again yielded the highest catches during survey sets but on the Flemish Cap side of the Pass, catches were now highest on the shallower parts of the Cap. During the Canadian surveys between 1978 and 1985, the depth zone of highest witch flounder density shifted from 257 to 366-m in 1978 to 147 to 184-m in 1981. The EU surveys conducted between 1988 and 2001 showed a depth zone with highest density of 128 to 184-m (Bowering and Vázquez 2002).

3.2.3.3.4 Large Pelagic Fish (Tunas and Swordfish)

Bigeye tuna (*Thunnus obesus*) reportedly appear to have a water temperature preference of between 8 and 18ºC (Scott and Scott 1988).

The albacore tuna (*Thunnus alalunga*) occurs worldwide in both tropical and temperate seas. It generally occurs as far north as 50ºN. The albacore tuna is a deep swimming species that is known to occur in water temperatures ranging from 9.5 to 25.2ºC (Scott and Scott 1988).

Swordfish (*Xiphias gladius*) are oceanic travelers that typically enter Canadian waters around June and then leave around October/November. It is thought that they move in from the offshore in the spring and then move back to the offshore in the fall. These fish may occur at a wide range of depths (surface to >1,000-m). They are normally deeper in the water column during the day and then move upwards in the water column at night. Despite this generally accepted diel behaviour, larger swordfish are known to bask at surface during broad daylight, possibly a response to colder water in the area. The preferred lower thermal limit of this large pelagic species is thought to be around 8ºC (Scott and Scott 1988). Western North Atlantic swordfish appear to spawn in the Caribbean Sea, the Gulf of Mexico and in waters off of Florida (Scott and Scott 1988).

Swordfish are regarded as opportunistic feeders although most of the diet consists of fish and cephalopods, particularly shortfin squid. Some of the fish that occur most often in the swordfish diet include Atlantic mackerel, barracudinas, silver hake, redfish, herring, and lanternfishes. Adult swordfish seem to have few natural enemies. Mako sharks appear to be most frequently associated with attacks on hooked or harpooned swordfish (Scott and Scott 1988).

3.2.3.3.5 Roughhead Grenadier

The roughhead grenadier (*Macrourus berglax*) occurs in deep water along coasts in subarctic to temperate waters on both sides of the North Atlantic Ocean. In the western North Atlantic, this species of grenadier occurs from Davis Strait along the continental slope, off Newfoundland, off Nova Scotia on Banquereau, Sable Island and Browns Bank, and on Georges Bank. It inhabits bottom depths primarily ranging from 200 to 600-m. It has been found off Newfoundland as deep as 1,000-m. Catches tend to be highest at water temperatures ranging between 2.0 and 3.5ºC (Scott and Scott 1988). The roughhead grenadier is an abundant and widespread species in the northwest Atlantic. This fish generally occurs both on the shelf and on the continental slope at depths ranging from 400 to 1,200-m. It has been found at depths as shallow as 200-m and as deep as 2,700-m.

Spawning is thought to occur during the winter and early spring. Little is known about the spawning grounds of this fish off Newfoundland although some believe that some spawning does occur on the southern and southeastern slopes of the Grand Banks (Scott and Scott 1988). Food on the roughhead grenadier consists of a variety of benthic invertebrates including bivalve molluscs, shrimp, seastars, polychaetes and some fish. These grenadier have been found in the stomachs of Atlantic cod.

Since 1988, EU surveys have been conducted at the Flemish Cap in depths ranging between 200 and 730-m. These depths represent only part of the known vertical distribution of this species. Based on the results of these surveys, the estimated total biomass in 2001 was essentially the same as in 1988 (Murua 2002; Vázquez 2002).

This grenadier species is quickly becoming an important commercial fish in the NRA. Presently its fishery is unregulated since it is usually taken as bycatch in the Greenland halibut fishery.

3.2.3.3.6 Atlantic Cod

Atlantic cod (*Gadus morhua*) have historically been distributed throughout Newfoundland and Labrador waters. They spawn both inshore and offshore in the Newfoundland-Labrador region. Both the eggs and larvae of this gadoid are planktonic. Juvenile Atlantic cod eventually shift from a pelagic diet to a benthic diet. This occurs gradually over a standard length range of about 4 to 10-cm and seems to be related to change in fish gape size. At the smaller standard lengths, the gape size is appropriate for feeding on smaller pelagic prey only but as the fish grow, the larger gape size allows them to feed on larger benthic prey (Lomond et al. 1998). Cod larvae and pelagic juveniles are primarily zooplankton feeders but once the switch is made to the demersal lifestyle, benthic and epibenthic invertebrates become the main diet. As the fish grow, the array of prey also widens. Prey often includes various crustaceans (crab, shrimp, euphausiids) and fish (capelin, sand lance, redfish, other cod, herring).

The stock of Atlantic cod that occurs off northeast Newfoundland and Labrador is known as the 'northern' cod. The northern cod ecosystem historically encompassed a vast area from the northern Labrador Shelf to the Grand Bank. Declines in this stock occurred first in the northern part of its distributional area (NAFO Divisions 2GH) in the late 1950s, 1960s and 1970s, and then southward (NAFO Division 2J) in the late 1980s and early 1990s. By the mid-1990s, most of the remaining biomass was located in the southern part of the historical distributional area of this cod stock (NAFO Divisions 3KL) (Rose et al. 2000). There is one belief that the adult cod shifted their distribution southward in the late 1980s and early 1990s (deYoung and Rose 1993) while others claim that this apparent distributional shift was due to local overfishing, first in the north and then proceeding southward (Hutchings 1996; Hutchings and Myers 1994).

The northern cod has been called one of the least productive of the major cod stocks (Brander 1994). Historically, Atlantic cod spawned on the northeast Newfoundland shelf in late winter and spring, and then migrated shoreward across the shelf to the inshore feeding grounds, annually traversing distances of 500-km and more. Cross shelf migration routes in spring followed thermal highways along deeper basins and trenches wherein warmer, deeper northwest Atlantic waters undercut the colder surface waters of the Labrador Current (e.g., an area on the northeast shelf known as the 'Bonavista Corridor').

After spawning, cod on the northeast Newfoundland shelf initially move southward with the dominant currents. Once they turn shoreward, as they do within the Bonavista Corridor, the dominant currents may flow offshore, against and across the direction of migration. But flows in the deeper, warmer waters of the Bonavista Corridor at times reverse and flow shoreward. A preliminary coarse delineation, as provided by DFO, of the Bonavista Corridor 'box' is 50ºW to 52ºW, and 49.25ºN to 49.40ºN (Figure 3.23).

The offshore biomass index values from the fall research bottom trawl surveys in 2J3KL have been very low for the past 10 years. The average trawlable biomass of 28,000mt during 1999-2002 is about 2% of the average in the 1980s (DFO 2003c). The same trend has been evident on the Flemish Cap during recent years (Vázquez 2002).

In April 2003, R.G. Thibault, the Minister of Fisheries and Oceans, announced that special conservation measures are required in the Hawke Channel (off southern Labrador) and the Bonavista Corridor to protect spawning and juvenile concentrations of Atlantic cod and their habitat. These measures will include an area within the Bonavista Corridor that will be closed to otter trawling (www.dfo-mpo.gc.ca).

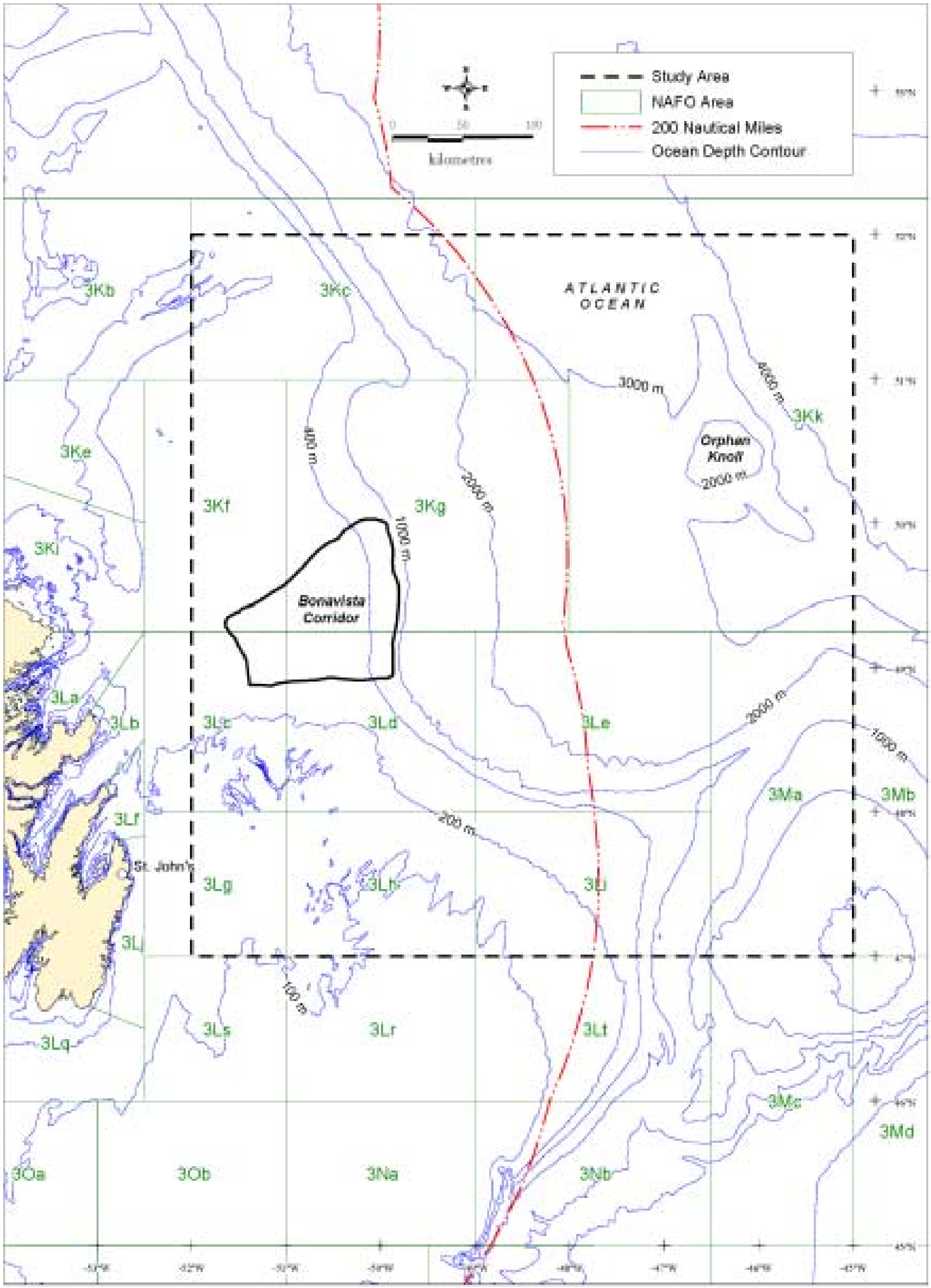


Figure 3.23 Location of Bonavista Corridor.

The closure of these areas to otter trawling was an idea put forth by the Fisheries Resource Conservation Council (FRCC) and an All-Party Committee (www.acoa.ca).

In March 2003, the FRCC released some recommendations for the Northern Cod. For the bank sub-stocks, the Council recommended a higher level of protection than has been in place since commencement of the moratorium. In order to reduce by-catch mortality and disturbance to spawning and juvenile cod, the FRCC recommended the establishment of experimental 'cod boxes' in both the Hawke Channel and the Bonavista Corridor. These areas would be protected from all forms of commercial fishery (except snow crab trapping) and other invasive activity such as seismic exploration (www.frcc-ccrh.ca).

3.2.3.3.7 Redfishes

Three species of redfish (*Sebastes* spp.) are present in the northwest Atlantic: (1) *Sebastes mentella*, (2) *S. fasciatus*, and (3) *S. marinus*. The first two species are known as 'beaked redfishes' and the latter one as a 'golden redfish'. These species are not considered separated from either the fishery or management perspectives (DFO 2001).

All three are benthic species that occur over rocky or clay/silt substrate. They generally occur in cool waters (3 to 8ºC) along the slopes of banks and deep channels. They remain low in the water column during the day but move upwards in the column at night to feed. *Sebastes faciatus* is considered the shallowest-living of the three, typically occurring in depths less than 400-m. *Sebastes. marinus* is considered intermediate of the three in terms of depth preference, sometimes occurring as deep as 750-m. Finally, *S. mentella* is considered the deepest-living of the three redfish species considered here. It generally occurs further offshore than the other two species, and it has been caught as deep as 1,100-m (Scott and Scott 1988).

All three species are ovoviviparous (i.e., hatching occurs internally and living young are subsequently released from the female). Spawning in the beaked redfish generally takes place between March and July, with the earliest spawning in deeper water. The golden redfish generally spawns during April to May period (Scott and Scott 1988).

Redfish are pelagic or bathypelagic feeders and they tend to prefer pelagic crustaceans such as amphipods, copepods and euphausiids. Large redfish tend to have a higher proportion of fish in their diet compared to smaller redfish. Predators of redfish include Atlantic halibut, Atlantic cod, swordfish and seals (Scott and Scott 1988).

Biomass estimates for redfish in the Flemish Cap area are available from EU July trawl surveys conducted in the area since 1988. Redfish shows the highest annual variability of all the monitored species, probably because the more pelagic lifestyle makes them less consistently available to the bottom gears used during the surveys (Vázquez 2002).

3.2.3.3.8 Capelin

Capelin (*Mallotus villosus*) are cold-water, pelagic schooling species inhabits Arctic and sub-Arctic zones in both the Atlantic and Pacific Oceans. The center of abundance and distribution in the northwest Atlantic has historically been in Divisions 2J3KL. They spend most of their lives offshore, only moving inshore to spawn in June and July. During the 1990s, the center of capelin distribution shifted south to northern 3L and southern 3K but by 1998, the distribution was more reminiscent of those observed during the 1980s.

An acoustic survey was conducted in May 2000 in the offshore areas of 3L. Both the Campelen and IYGPT trawls were used. Capelin was detected offshore at low densities throughout the 3L survey area. They were found primarily in carpet-like layers near the bottom in areas with water depths ranging between 150 and 400-m. Little or no vertical migration was observed. At times the capelin were mixed with arctic cod and shrimp (DFO 2000a). In 2000, capelin, a key food for many species of fish, seabirds and marine mammals, remained the main prey item in diets of Common Murres (primarily female capelin) and Northern Gannets (primarily male capelin) studied at Funk Island.

Higher than normal abundances of capelin have been reported on the Flemish Cap, generally regarded as being outside the normal capelin distribution area. This increase appears to coincide with below normal water temperatures (Frank et al. 1996).

Dramatic changes in the biology of capelin were evident during the 1990s, coincident with extreme oceanographic conditions and the collapse of major groundfish stocks. Commercial exploitation has not been a serious factor influencing the population biology of capelin in the northwest Atlantic. The overall patterns suggest the existence of a 'trophic cascade' within the distributional range of capelin in the northwest Atlantic during the 1990s primarily driven by declines in major finfish predators (Carscadden et al. 2001).

3.2.3.3.9 Thorny Skate

Of the ten skate species that occur in Newfoundland waters, the thorny skate is (*Amblyraja radiata*) by far the most common. This species accounts for more than 90% of the skates caught during research surveys on the Grand Banks. Thorny skates are distributed in depths ranging from 18 to over 1,500-m, and in water temperatures ranging between –1.4 to 6ºC. They occur on both hard and soft bottoms. There are indications that thorny skate on the Grand Banks migrate seasonally, moving towards the shelf edge in the winter/spring and returning to the shelf proper in midsummer/fall, probably to spawn.

Female thorny skates deposit between 6 and 40 egg cases per year, each one containing a single embryo (DFO 2003d).

The diet of this fish includes a wide variety of invertebrates (polychaetes, amphipods and decapods) and fish (sand lance, haddock and sculpins) (Scott and Scott 1988; DFO 2003d). Predators of this skate species include seals, halibut and Greenland sharks (Scott and Scott 1988).

Thorny skate have become increasingly concentrated in a smaller area, especially since the decline in biomass in the mid 1990s. Once fairly evenly distributed over the entire Grand Bank, thorny skate are now absent from much of the northern area (3L). Approximately 90% of the biomass is now concentrated near the southwest edge of the Bank. Most of the commercial catch of thorny skate occurs outside of the EEZ where there is doubt as to the reliability of the catch reports (DFO 2003d).

3.2.3.4 Fish Species Considered 'At-Risk'

This section considers fish 'species at risk' as defined by various national and international organizations. The primary focus is on those species listed under the *Canadian Species at Risk Act (SARA)* that was promulgated in June 2003.

3.2.3.4.1 Atlantic Cod

In May 2003, Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Atlantic cod population occurring in the inshore and offshore waters of Labrador and northeastern Newfoundland, including the Grand Bank, as 'endangered'. This population has declined approximately 97% since the early 1970s and has shown virtually no recovery of either abundance or age structure since the moratoria were imposed in 1992 and 1993. In 1998, this population and the Atlantic cod in the Northern Gulf of St. Lawrence were considered a single unit designated as a species of 'special concern' by COSEWIC. This single unit was split into separate populations in May 2003. The Laurentian North population is presently considered 'threatened' by COSEWIC (www.cosewic.gc.ca).

3.2.3.4.2 Cusk

The cusk (*Brosme brosme*) is a listed species under *SARA* because it was designated as 'threatened' by COSEWIC in May 2003. Cusk are solitary, sedentary, slow-swimming fish that are found throughout the North Atlantic. Little is known about the life history and genetics of this groundfish species. Cusk are distributed from Cape Cod to Labrador, and are most concentrated in the Gulf of Maine and the western Scotian Shelf (Scott and Scott 1988). In Newfoundland waters, cusk have been caught primarily to the south of the Study Area along the edge of the Grand Banks in NAFO Unit Areas 3PSh, 3Oc, 3Oe, but in relatively small numbers compared to catches on the Scotian Shelf (Harris et al. 2002).

Cusk typically occur more frequently on hard bottom (rocky, gravel) than on soft bottom (mud, sand). Based on July research surveys, cusk occur in water temperatures ranging from 3 to 11ºC, mostly in the 6 to 10ºC range (Scott and Scott 1988). During eastern Canadian research surveys, cusk were taken in depths ranging between 75 and 600-m. In other parts of the North Atlantic, cusk have been caught as deep as 1,100-m (Harris et al. 2002).

This fish species spawns on the Scotian Shelf between May and August, with peak spawning in June. Both the eggs and larvae of this species are planktonic (Scott and Scott 1988). Cusk diet includes invertebrates, crabs, shrimp, krill, and various fish species. Cod and halibut are known predators of this species (Scott and Scott 1988).

3.2.3.4.3 Barndoor Skate

In 2000, IUCN (Union for the Conservation of Nature and Natural Resources) listed the barndoor skate (*Dipturus laevis*) as 'vulnerable', based largely on the work by Casey and Myers (1998) with research survey data, and the 2000 assessment of skates in US waters (Kulka et al. 2002). The barndoor skate has not been assigned a risk designation by COSEWIC and is therefore not listed under *SARA*.

There is relatively little information on the life history of the barndoor skate (*Dipturus laevis*). This benthic species, one of the largest skates in the northwest Atlantic, is found on all types of bottom substrate on the continental shelf from shoal water to depths of 750-m (Scott and Scott 1988; Packer et al. 2003). Off the coast of Atlantic Canada, the barndoor skate has never been reported as a commonly caught species in research survey and commercial catches. It has been most commonly taken in otter trawl fisheries along the outer edge of the continental shelf, particularly in areas where water temperatures range from 3 to 5ºC (Kulka et al. 2002).

Spawning probably takes place during the winter months. Females produce a relatively small number of benthic egg cases and the juveniles that emerge from these egg cases are not planktonic. They tend to be distributed along shelf edges (Scott and Scott 1988). They are voracious predators, especially of bivalve molluscs, squid, crabs, lobsters, shrimp, marine worms and various fish including dogfish, alewife, Atlantic herring, butterfish, sand lance, cunner, hakes and flatfishes. It is speculated that the barndoor skate has few predators other than large sharks (Scott and Scott 1988).

According to commercial fishery data, barndoor skate are widely distributed in terms of depth across their range. Along the Scotian Shelf, the highest catch rate was at depths ranging from 500 to 850-m. In the northern area, the percentage of sets with barndoor skate is low at depths <650-m but it increases out to depths of 1,450-m. It has occurred as deep as 1,700-m. and perhaps deeper considering that this was the limitation of the commercial fishery. The northern barndoor skates appeared to be associated with water temperatures of 2 to 4.5ºC, while to the south, they were most plentiful in water temperatures of 4 to 9ºC.

A comprehensive examination was made of DFO research vessel (RV) and industry/science survey data on the occurrence of barndoor skate between Georges Bank and northern Labrador. There are three principal sources of data: (1) seasonal RV surveys with standard methods conducted by DFO, (2) RV surveys by DFO using non-standard methods (prior to 1970), and (3) industry/science surveys from mid-1990s onwards using either fixed or mobile gear. Most barndoor skate caught in Newfoundland waters was along the southwest slope of the Grand Banks in the 1950s and 1960s. These concentrations are no longer apparent. Commercial fisheries bycatch data indicate that the barndoor skate occurs much further north than indicated by RV data (e.g., shelf edge at 62ºN) (Simon et al. 2002).

3.2.3.4.4 Wolffish

Recently, COSEWIC designated the spotted wolffish (*Anarhichas minor*) and the northern wolffish (*A. denticulatus*) as 'threatened' (May 2001) and the striped (Atlantic) wolffish (*A. lupus*) as a species of 'special concern' (November 2000) (Simpson and Kulka 2002). These designations were based on decreased catches during DFO research trawl surveys and decreased bycatch landings during commercial fisheries. Based on their COSEWIC designations, the spotted and northern wolffish are priority species under the *SARA*.

In the northwest Atlantic, there are three wolffish species (*Anarhichus* spp.) that are distributed from Davis Strait to Maine. Striped wolffish are generally concentrated further to the south and at shallower depths (southern Grand Bank) than the spotted and northern wolffish (as deep as >475 m). Spotted wolffish are thought to spawn in late autumn or early winter. Distributions of young-of-the-year striped wolffish based on sampling with IYGPT trawl gear in August and September, 1996-1999, were concentrated in Division 3K. Lower abundances occurred in Divisions 2J and northern 3L (Simpson and Kulka 2002).

The spotted wolffish and striped wolffish are regarded as commercial species in Newfoundland waters while the northern wolffish is not (Simpson and Kulka 2002). The spotted and northern wolffish occur in deep water (475+ m) where water temperatures normally range between 3 and 4ºC. They are believed to spawn in late fall/early winter. The striped wolffish is normally found in water depths ranging from 100 to 350-m where water temperatures are as low as 0.4ºC. Striped wolffish in Newfoundland waters spawn in September and the early juvenile stage remains close to the spawning location. The juvenile stages of all three wolffish species appear to be semi-pelagic. They feed on a variety of benthic invertebrates and some fish.

While the decline in abundance and biomass estimates of all three species has occurred throughout Newfoundland 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).

3.2.3.4.5 Atlantic Salmon

Atlantic salmon (*Salmo salar*) is a sensitive, internationally high profile species presently listed as 'endangered' by the US National Marine Fisheries Service (NMFS). The Inner Bay of Fundy population of Atlantic salmon has been designated as 'endangered' by COSEWIC (May 2001) and is therefore listed under *SARA*. There is the possibility that fish from this population pass through the Orphan Basin Study Area during migrations between freshwater and at-sea feeding grounds. Other Eastern Canadian Atlantic salmon populations, including those in Newfoundland and Labrador, have not been assigned a risk designation by COSEWIC and are therefore not listed under *SARA*.

The Atlantic salmon seems very sensitive to environmental pressures and high-seas overfishing. The returns of wild Atlantic salmon to North American rivers has continued to decline during recent years despite increased restrictive management measures in both ocean and river fisheries (Atlantic Salmon Federation website: www.asf.ca).

At a length of approximately 12 to 24-cm, salmon parr undergo a transformation into smolt and subsequently leave their freshwater habitat to feed at sea. The Atlantic salmon are pelagic feeders. After one or more years at sea, they return to the freshwater rivers between April and November in order to spawn. The oceanic migration routes of this species are poorly understood. Atlantic salmon probably pass through the Orphan Basin Study Area during their migrations between the freshwater spawning and oceanic feeding habitats. Distribution, origin, abundance and biology of Atlantic salmon in surface waters over the Grand Bank and to the east of the Grand Bank were presented by Reddin (1985), based on May gill net surveys conducted between 1979 and 1980. Gill nets were set at a 3-m depth. It was noted that salmon were most abundant where sea-surface temperatures ranged between 3.0 and 8ºC. Catches in the off-Shelf sets were highest where water temperature ranged between 5.3 to 7.5ºC.

Of the off-Shelf sets, only two fish were caught in the northern Flemish Pass/Flemish Cap area. Most were taken immediately east of Carson Canyon and Lily Canyon in areas with water depth ranging between 2,000 and 4,000-m, and between Carson Canyon and the Flemish Cap in areas with water depth ranging between 1,000 and 3,000-m (Reddin 1985). Lear (1976) published information on migrating Atlantic salmon caught by otter trawls on the Newfoundland continental shelf. April to June catches of Atlantic salmon occurred at depths ranging from 55 to 238-m, most often in the 80 to 90-m range. The ones taken on the northern Grand Banks (north of 46ºN) were at depths ranging from 100 to 128-m.

3.2.3.5 Planning Implications

Fisheries are more concentrated in some parcels (e.g., shelf and slope) than others (e.g., deep water) (Figure 3.24). Some parcels may require additional communication and potentially some extra

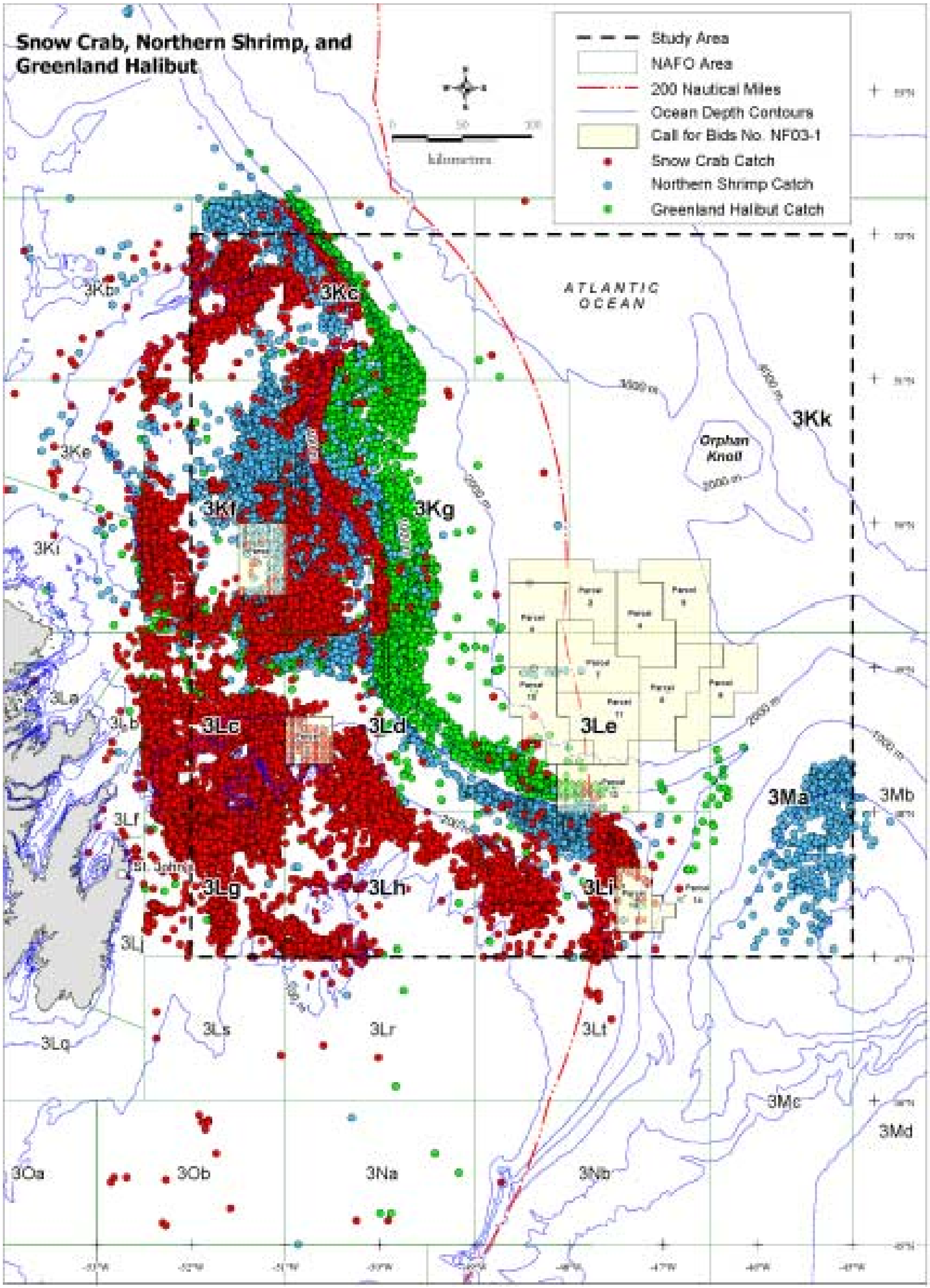


Figure 3.24 Snow Crab, Northern Shrimp, and Greenland Halibut Catches (1998-2002) Relative to Parcels.

mitigation measures, but for the most part, the types of mitigations presently used on the Grand Banks should suffice for exploration purposes. Site-specific EAs will examine these issues in detail. The major planning consideration is related to potentially sensitive areas for sensitive species/stages of fish. The major species and area identified during the present Orphan Basin SEA was Atlantic cod (listed by COSEWIC as 'endangered' and a listed species under *SARA*), and the Bonavista 'cod box.' Other sensitive areas may become evident as DFO completes their identification of key spawning areas. Such sensitive areas will merit special planning and mitigation measures such as avoidance or timing of activities.

Of the identified fish species 'at risk' within the Study Area, Atlantic cod is certainly the species with the highest profile and the one which has been most intensely studied. As discussed in Section 3.2.3.3.6, the Bonavista Corridor has been identified as an area requiring special conservation measures to protect spawning and juvenile concentrations of Northern cod and their habitat. Springtime spawning and migration occur in this area. The FRCC has recommended that this area be protected from all forms of commercial fishery (except snow crab potting) and invasive activities such as seismic exploration.

There is potential for conflict between exploration activities and commercial fishing and associated gear, more so on the shelf and slope than in the basin. This is discussed in more detail in a later section on the environmental effects of exploration activities. Most of the commercial fishing activity in the Study Area between 1998 and 2002 occurred between late spring and early fall (Table 3.8). Regulators may require spatial and temporal restrictions on exploration activities to minimize interference with commercial fishing in specific areas. Again, these issues will have to be examined during the site-specific EA process.

3.2.4 Seabirds

The northwest Atlantic Ocean is rich in seabird diversity and abundance. The Orphan Basin Study Area encompasses shelf water and deep water beyond the continental shelf. Shelf edges may produce upwelling areas that result in high productivity of zooplankton that directly or indirectly provide food for seabirds. Twenty-eight species of seabirds occur regularly in the Study Area (Table 3.9). Most of these are true pelagic species that come to land only to breed. While there are no landmasses in the Study Area, nearly five million seabirds of 12 species that feed within the Study Area nest in eastern Newfoundland.

3.2.4.1 Important Bird Areas and Rare Species

An Important Bird Area (IBA) is a site that provides essential habitat for one or more species of breeding or non-breeding birds. These sites may contain threatened species, endemic species, species

Table 3.8 Timing of different gear type use in Study Area Unit Areas, 1998-2002.

Gear Type	Unit Area	Landed Value ($M)	MONTH											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P	**3Kc**	**25.8**												
	3Kf	**24.3**												
	3Kg	**38.8**												
	3Lc	**96.7**												
	3Ld	**40.2**												
	3Lg	**62.5**												
	3Lh	**28.5**												
	3Li	**52.5**												
ST	**3Kc**	**10.0**												
	3Kf	**24.8**												
	3Kg	**39.9**												
	3Ld	**2.0**												
	3Le	**6.1**												
	3Li	**17.2**												
	3Ma	**3.1**												
GN	**3Kc**	**3.1**												
	3Kf	**1.0**												
	3Kg	**7.9**												
	3Ld	**1.8**												
	3Le	**2.4**												
BOT	**3Kg**	**1.7**												
	3Ld	**3.0**												
LL	**3Kk**	**0.6**												

Only includes unit areas from which at least $1 million of Newfoundland landings reported between 1998 and 2002 (except for longlining in 3Kk).
P = 'pots; ST = 'shrimp trawl'; GN = 'gill net'; BOT = 'bottom otter trawl'; LL = 'longline'
Darkest shaded cells: > 25% of landed value in Column # 3; intermediately-shaded cells: 5 to 25% of landed value; lightest shaded cells: < 5% of landed value

Table 3.9 General Distributions, Seasonal Abundances, and Foraging Strategies of Seabirds that Occur in the Orphan Basin Study Area.

Common Name	Scientific Name	General Area of Distribution	Abundance				Foraging Strategy
			Summer (June-Sept)	Autumn (Oct-Dec)	Winter (Jan-Mar)	Spring (April-May)	
Fulmars and Shearwaters							
Northern Fulmar	*Fulmarus glacialis* *	Offshore, coastal	Common	Common	Common	Common	SF
Greater Shearwater	*Puffinus gravis*	Offshore, coastal	Common	Common	Absent	Uncommon	PP
Sooty Shearwater	*Puffinus griseus*	Offshore, coastal	Common	Common	Absent	Uncommon	PP
Manx Shearwater	*Puffinus puffinus* *	Offshore, coastal	Scarce	Scarce	Absent	Scarce	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	Scarce	Scarce	Rare	Scarce	K
South Polar Skua	*Catharacta maccormicki*	Offshore	Scarce	Rare	Absent	Rare	K
Gannets							
Northern Gannet	*Sula bassanus* *	Offshore, coastal	Common	Common	Absent	Common	DP
Storm Petrels							
Wilson's Storm-Petrel	*Oceanites oceanicus*	Offshore	Uncommon	Absent	Absent	Rare	SF
Leach's Storm-Petrel	*Oceanodroma leucorhoa* *	Offshore	Common	Common	Absent	Common	SF
Red Pharalope	*Phalaropus fulicaria*	Offshore	Uncommon	Uncommon	Absent	Uncommon	SF
Red-necked Pharalope	*Phalaropus lobatus*	Offshore	Scarce	Scarce	Absent	Scarce	SF
Gulls and Kittiwakes							
Herring Gull	*Larus argentatus**	Coastal, offshore	Common	Common	Common	Common	SF
Iceland Gull	*Larus glaucoides*	Coastal, offshore	Absent	Common	Common	Uncommon	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	Common	Common	Common	Common	SF
Arctic Tern	*Sterna paradisaea**	Coastal, offshore	Uncommon	Rare	Absent	Uncommon	SF, PP
Alcids (Auks)							
Dovekie	*Alle alle*	Offshore, coastal	Absent	Common	Common	Uncommon	PD
Common Murre	*Uria aalge* *	Offshore, coastal	Common	Common	Scarce	Common	PD
Thick-billed Murre	*Uria lomvia* *	Offshore, coastal	Scarce	Common	Common	Common	PD
Razorbill	*Alca torda* *	Offshore, coastal	Scarce	Scarce	Rare	Scarce	PD
Black Guillemot	*Cepphus grille* *	Coastal	Common	Common	Common	Common	PD
Atlantic Puffin	*Fratercula arctica* *	Offshore, coastal	Common	Common	Scarce	Common	PD

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

representative of a biome, or highly exceptional concentrations of birds. IBAs are identified using a set of standardized and internationally agreed upon criteria. The first IBA program was initiated by BirdLife International, formerly the International Council on Bird Preservation (ICBP), a non-governmental organization dedicated to the conservation of the world's birds. The Canadian Nature federation (CNF) and Bird Studies Canada (BSC) are the BirdLife International partners in Canada (www.ibacanada.com).

There are eleven IBAs in coastal eastern Newfoundland containing bird species which are known to feed in the Orphan Basin Study Area. These are: Spring Island, Groais Island, Funk Island, Wadham Islands, Gull Island (Cape Freels), Cabot Island, Goldmine Head, Baccalieu Island, Quidi Vidi Harbour, Witless Bay Islands, and Cape St. Mary's (Figure 3.25).

The Canadian population of the Ivory Gull is classified as a species of 'special concern' by COSEWIC (2002). This species is generally associated with offshore pack ice that occurs commonly in winter off Newfoundland and occasionally off Atlantic Nova Scotia (Tufts 1986). A 1981 year-long monthly aerial survey of the southern Labrador Sea and northeastern Newfoundland coast recorded only 212 Ivory Gulls in offshore waters during winter and early spring (McLaren et al. 1983). They were most commonly sighted as single birds or small groups (maximum of five). Manx Shearwaters and Common Black-headed Gulls have small nesting populations in southern and eastern Newfoundland, but are primarily European species. The populations of Harlequin Duck and Barrow's Goldeneye in eastern Canada also are designated 'special concern' by COSEWIC (2002). However, those species are coastal in occurrence and typically do not occur offshore in the Orphan Basin Study Area.

3.2.4.2 Breeding Biology and Nesting Populations

The northeastern coast of Newfoundland and the Grand Banks are very important areas for many species of seabirds. Critical areas, times of year and species are outlined below (see Table 3.9). Most of this information was obtained from Lock et al. (1994).

Some of the largest seabird nesting colonies in eastern North America are located along Newfoundland's Avalon Peninsula and northeast coast (Table 3.10). Approximately 400,000 pairs of Common Murre, 6,000 pairs of Northern Gannets, 2,000 pairs of Atlantic Puffin, and significant numbers of Black-legged Kittiwake, other alcids, and other gull species nest on Funk Island. Approximately 2,600 pairs of Common Murres and lesser numbers of Leach's Storm-Petrels and terns nest on Cabot Island. Over 3.3 million pairs of Leach's Storm-Petrels nest on Baccalieu Island and approximately 87,000 pairs nest on the Witless Bay islands. Those two sites account for the majority of the entire Atlantic Ocean population of this species. The Witless Bay islands are also important breeding areas for Atlantic Puffins (216,000 pairs), Common Murres (approximately 75,000 pairs) and Black-legged Kittiwakes

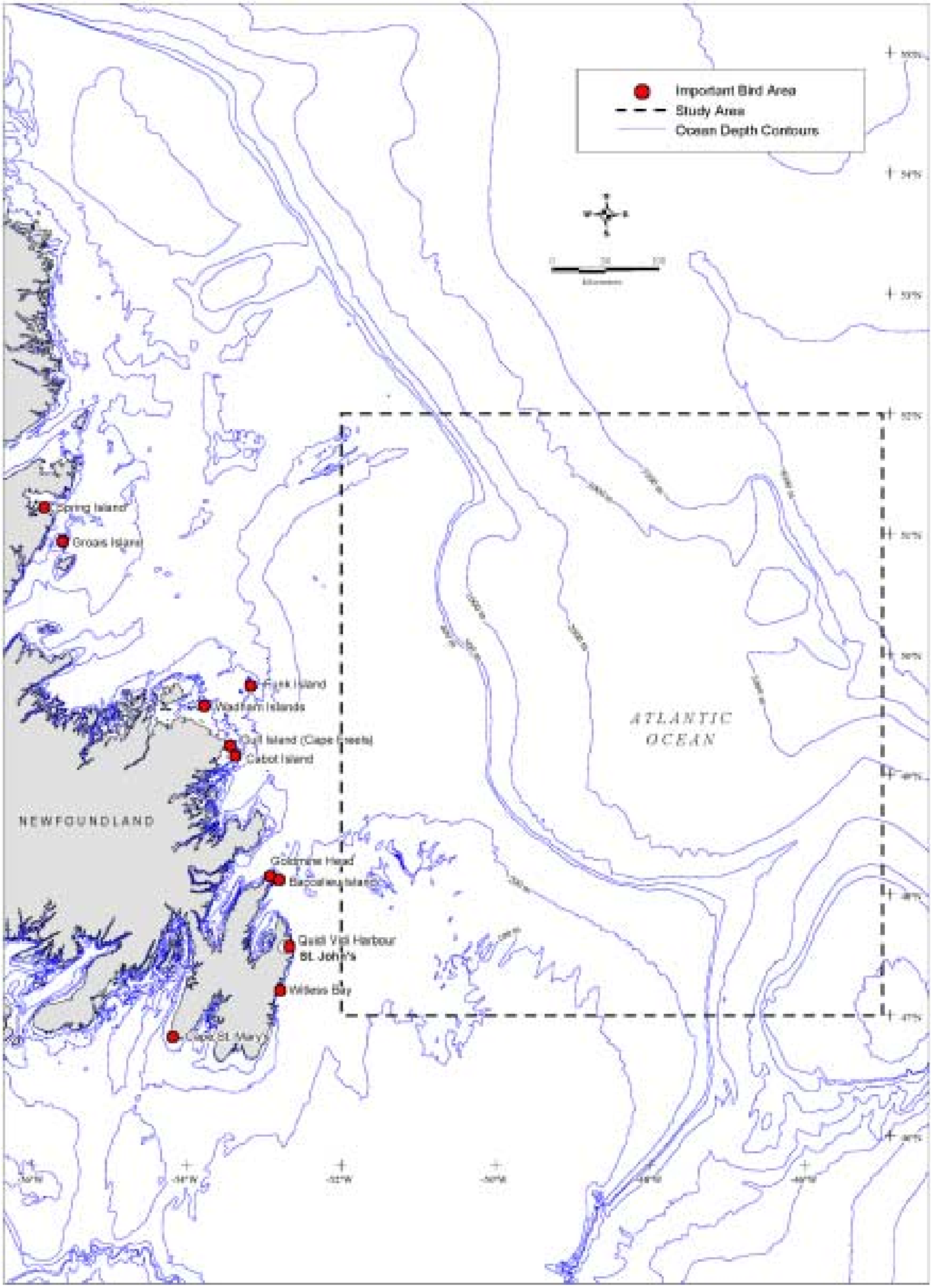


Figure 3.25 Location of Important Bird Areas (IBA) Near the Orphan Basin Study Area.

Table 3.10 Estimated Numbers of Seabirds Nesting in Eastern Newfoundland and Labrador Adjacent to the Orphan Basin Study Area.

	Nesting Sites Near Study Area		**Important Bird Areas**										
Species	# of Nesting Sites	# of Nesting Pairs	Spring Island	Groais Island	Funk Island	Wadham Islands	Gull Island (CF)	Cabot Island	Goldmine Head	Baccalieu Island	Quidi Vidi Harbour	Witless Bay Islands/ Tors Cove	Cape St. Mary's
Fulmars and Shearwaters													
Northern Fulmar	4	50			13					20		21	?
Manx Shearwater	2	?										?	
Gannets													
Northern Gannet	3	12,237		?	6.075					677		?	5,485
Storm Petrels													
Leach's Storm-Petrel	36	4,202,065			?	18,000	?	250		3,336,000		870,020	?
Gulls and Kittiwakes													
Herring Gull	91	19,702	200		500					UN		4,150	UN
Great Black-backed Gull	61	1,639	50		100					UN		163	UN
Black-legged Kittiwake	27	77,398			810				500	12,975	8	43,927	10,000
Arctic and Common Terns	47	2,975				376		250					
Alcids (Auks)													
Common Murre	11	490,605			396,461			2,600		4,000		74,687	10,000
Thick-billed Murre	3	2,031			250					181		600	1,000
Razorbill	12	710		?	200	30		25		100		230	100
Black Guillemot	54	999	UN		1	25	UN			100		20+	UN
Atlantic Puffin	23	143,665			2,000	17,470	UN	20		30,000		216,000	
TOTALS	**374**	**4,954,076**	**250**	**>0**	**>406,410**	**35,901**	**>0**	**3,145**	**500**	**>3,384,053**	**8**	**>1,209,818**	**>26,585**

Source: Modified from Husky (2000) and Russell and Fifield (2001).

'?' indicates possibility of nesting activity
'UN' indicates definite nesting activity but numbers of nesting pairs unknown

(approximately 44,000 pairs). The Cape St. Mary's area is one of only six nesting sites of Northern Gannets in North America. Large numbers of Common Murres and Black-legged Kittiwakes also nest there.

Most of the world population of Greater Shearwaters, estimated at five million birds, smaller numbers of Sooty Shearwaters and large numbers of Wilson's Storm-Petrels spend the summer on the Grand Banks, wintering from their nesting grounds in the south Atlantic Ocean (Lock et al. 1994). Most of these birds concentrate on the Southeast Shoal of the Grand Banks, where they moult and forage.

Almost four million Thick-billed Murres winter on the Grand Banks, over half of the five to six million that breed in western Greenland and the eastern Canadian Arctic. The Grand Banks is also the chief wintering area for the approximately 14 million Dovekies that nest along northwest Greenland. Thousands of waterfowl concentrate near Cape St. Mary's, with substantial concentrations also near Argentia and Jude Island, Placentia Bay and Mistaken Point (southeastern Avalon Peninsula). However, the locations of these winter concentration areas vary within a season and from year to year (Lock et al. 1994).

Most seabirds nesting near the Study Area have high survival rates, low fecundity and deferred maturity. The available information on various aspects of the reproductive biology of the species nesting in the Study Area is summarized in Table 3.11. Estimated dates and durations for egg laying, incubation, hatching, nesting and fledging of various seabird species using the Study Area are summarized in Table 3.12. Generally, egg laying occurs between mid-May and August, peaking from mid-May to mid-June, incubation continues for three to seven weeks from time of egg-laying, hatching occurs primarily between mid-June and mid-July, nesting continues from three to 10 weeks after hatching, and fledging occurs from mid-July to mid-November, peaking from late-July to late-September.

The number of breeding pairs of Atlantic Puffins on Great Island in Witless Bay was estimated at 123,000 in 1993-94 (Rodway et al. 1996). This represents 33 percent of the North American Atlantic Puffin population and more than doubles the previous estimate from 1979 (Cairns et al. 1989), which Rodway et al. (1996) attribute to sampling earlier in the breeding season, during incubation, when the confounding effects of breeding success are avoided. When the Great Island estimate is combined with previous estimates for Green Island (22,000) and Gull Island (71,000), 216,000 breeding pairs of puffin occur in the Witless Bay Ecological Reserve. This represents 57 percent of the North American Atlantic Puffin population. It appears that the number of Atlantic Puffins on Great Island (and probably off Newfoundland in general) is increasing, as puffins expand to inland areas of the Witless Bay islands (Rodway et al. 1996). Gull predation has not reduced the breeding success of puffins; a fledging rate of 0.42 chicks per burrow was observed in 1992-93 (Rodway et al. 1998).

Table 3.11 Reproduction Parameters of Seabirds Nesting Near the Orphan Basin Study Area.

Species	Mean Adult Survival Rate	Age of First Breeding (yr)	Clutch Size	Breeding Success [1]	Sources
Northern Fulmar	0.97	6-12	1	0.55	Dunnet et al. (1963); Dunnet and Ollason (1978)
Leach's Storm-Petrel	>0.70	3-5	1	0.79-0.94	Huntington (1963); Wilbur (1969); Morse and Buchheister (1977)
Manx Shearwater	0.90	5-6	1	0.69	Perrins et al. (1973)
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	Haycock and Threlfall (1975); Kadlec (1976); Pierotti (1982)
Great Black-backed Gull	-	4-5	3	0.50-2.11	Butler and Trivelpiece (1981)
Black-legged Kittiwake	0.81-0.86	3-7	2	0.54-0.58	Maunder and Threlfall (1972); Wooler and Coulson (1977)
Common and Arctic Terns	0.86	2-4	1-3	0.59-0.77	Cullen (1956); Kirkham (1980)
Common Murre	0.92	4-5	1	0.72	Birkhead and Hudson (1977)
Thick-billed Murre	0.91	3-5	1	0.68 0.76	Birkhead and Hudson (1977); Gaston and Nettleship (1981)
Razorbill	0.89-0.92	4-6	1	0.55-0.71	Bedard (1969); Lloyd and Perrins (1977); Hudson (1982)
Black Guillemot	0.77-0.89	2	1-2	0.12-0.78	Asbirk (1979); Cairns (1981)
Atlantic Puffin	0.95	4-6	1	0.60-0.66 0.42	Ashcroft (1979); Harris (1983); Rodway et al. (1998)

Source: From Mobil (1985) with updates.

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

Table 3.12 Summary of Seabird Nesting, Hatching and Fledging Near the Orphan Basin Study Area.

Species	Egg Laying	Incubation	Hatching	Nesting	Fledging	Comments
Northern Fulmar	2nd half May[1]	47-51 days[2]	observed July 10[1]	47-51 days[2]	late Aug-early Sept[2]	Canadian breeding population is 360,000 pairs[3]; NF colony may represent new colonization[2].
Manx Shearwater	-	-	-	-	-	Information on breeding activity in coastal NF is lacking. One colony has been identified on Middle Lawn Island[4].
Leach's Storm-Petrel	mid May to mid August [5,6,7] peak: first half of June	41-42 days [5,6,7]	peak: last half of July[5,6,7]	63-70	until mid Nov. peak: late Sept.	Baccalieu colony is probably largest in the world.[8,9]
Northern Gannet	mid to late May[10,11]	42 days [10,11]	late June to early July	91 days[10,11]	late Sept. to early Oct.[9,10]	NF breeding population represents 17% of the eastern Canadian population. NF's population is stable and increasing
Herring Gull; Great Black-backed Gull	mid to late May[12,13,14]	26-29 days [12,13,14]	mid-late June	45 days[12] 50-55 days [12,14]	late July - early August	Nest singly or in colonies at many locations along NF East Coast[15]. Study area breeding population is only a small proportion of total Canadian[3] population.
Black-legged Kittiwake	late May-early June[17]	27 days[17]	late June[17]	42 days[17]	early Aug.[17]	Three major colonies along Avalon Peninsula[16]. NF group represents approx. 33% total Canadian breeding population.
Common Tern; Arctic Tern	first half June[18]	22 days [18]	mid July	21-26 days[18]	late July-early Aug.[18]	Occur singly or in small colonies along the Avalon Peninsula[16]
Common Murre	mid May[19, 20]	32 days[19,20]		23 days[19,20]	mid-late July	Breeding population in Study Areas represents 17% total Canadian breeding population[3].
Thick-billed Murre	early June[19,20]				late July-early August	Nesting population in Study Area represents <1% of Canadian breeding population[21]
Razorbill	early June	34-39 days	early-mid July	24 days	late July - early August	Nesting population in Study Area represents 3% of the North American population[3]. Information extrapolated from data for Labrador [20].
Atlantic Puffin	mid-late May[22]	42 days[22]	early July[22]	40-45 days[22]	mid to late August[22]	Most abundant alcid in Study Area[3]. Includes approx. 72% of the N. American population[3].
Black Guillemot	mid May - early June[22]	28-33 days[22]	mid June - mid July[22]	34-39 days[22]	early - late August[22]	No estimate of the number of breeding birds in the Study Area, but considered to be low[3,24].

Source: Mobil (1985).

[1] Montevecchi et al. (1978)
[2] Cramp and Simmons (1977)
[3] Nettleship (1980)
[4] Lien and Grimmer (1978)
[5] Grimmer (1980)
[6] Huntington (1963)
[7] Wilbur (1969)
[8] Maccarone and Montevecchi (1981)
[9] Pitocchelli et al. (1981)
[10] Kirkham (1980)
[11] Montevecchi and Porter (1980)
[12] Haycock and Threlfall (1975)
[13] Pierotti (1982)
[14] Butler and Trivelpiece (1981)
[15] Erwin (1971)
[16] Brown et al. (1975)
[17] Maunder and Threlfall (1972)
[18] Hawksley (1950)
[19] Tuck (1961)
[20] Birkhead and Nettleship (1982)
[21] Gaston (1980)
[22] Cairns (1981)
[23] Renaud and Bradsteet (1980)
[24] Nettleship (1972)

Rodway et al. (1996) also censused other seabird species breeding on Great Island in 1993-94. They estimated that there were 23,787 pairs of Black-legged Kittiwakes on this island and suggest that there has been little change since the previous survey conducted in 1968. Approximately 340,000 pairs of Leach's Storm-petrels and 40 pairs of Great Black-backed Gulls were estimated to breed on Great Island.

The breeding population of Northern Fulmars in Atlantic Canada has increased steadily over the last 25 years (Stenhouse and Montevecchi 1999a). Site-holding pairs have been observed at Funk Island, at islands in Witless Bay, Cape St. Mary's, and Baccalieu Island.

Large numbers of Northern Fulmars, Black-legged Kittiwakes, Thick-billed Murres and Dovekies from Arctic breeding colonies spend the winter in offshore waters south of the ice edge off Newfoundland. Hundreds of thousands of Greater Shearwaters and Sooty Shearwaters that breed in the south Atlantic Ocean during November to March migrate to the continental shelf of Newfoundland to moult and feed during May to October. Parasitic Jaegers, Pomarine Jaegers and Long-tailed Jaegers migrate through the Study Area between breeding grounds in the Canadian Arctic and wintering areas at sea in the mid latitudes. Red-necked Phalaropes and Red Phalaropes, like the three species of jaegers, nest in the Arctic and feed on zooplankton concentrations along the edge of the continental shelf as they migrate through the Study Area to and from southern oceans.

3.2.4.3 Prey and Foraging Habits

Seabirds in the Study Area eat a variety of prey including capelin, copepods, amphipods and short-finned squid. Different species specialize in foraging at the surface, at shallow depths and by diving to deep depths. The main prey and foraging strategies of seabirds in the Study Area are summarized in Table 3.13.

Table 3.13 Foraging Strategy and Prey of Seabirds that Frequent the Orphan Basin Study Area.

Species (Species-group)	Foraging Strategy	Prey	Source
Seabirds			
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)
Northern Gannet	Deep plunging	Mackerel, capelin, squid	Kirkham (1980)
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)
Alcids			
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 seabird eggs and chicks and occasionally adults (Rodway et al. 1996; Stenhouse and Montevecchi 1999a).
Source: from Mobil (1985) with updates.

Studies suggest that the foraging strategy of seabirds is related to their breeding success during periods of limited food availability (Bryant et al. 1999; Regehr and Rodway 1999). Recent reductions in food availability in the Study Area occurred when the inshore spawning migration of capelin, a major prey for many seabird species, was delayed by one month in 1992 and 1993 in the northwest Atlantic, and the ground fisheries moratorium eliminated the production of fish offal, an important alternative food source for *Larus* gulls and Black-legged Kittiwakes (Regehr and Rodway 1999). Inshore surface feeders including Black-legged Kittiwakes, Herring and Great Black-backed Gulls, had lower hatching, fledging and breeding success than in previous years. Pursuit divers, including the Atlantic Puffin and Common Murre, had similar reproductive success as in previous years when capelin arrival was "on time" while offshore surface feeders like the Leach's Storm-Petrel had high breeding success (Regehr and Rodway 1999). Inshore surface feeders may be particularly sensitive to changes in prey availability because their foraging strategy makes them more vulnerable to oceanographic changes in temperature, depth of the thermocline, and upwelling and less able to exploit alternative prey species (Regehr and Rodway 1999).

Similarly, the breeding success of Common and Thick-billed Murres in the Gannet Islands, Labrador, was unchanged despite the reduced availability of capelin. These pursuit divers fed their chicks primarily shanny in the mid-1990s versus capelin in the early 1980s (Bryant et al. 1999).

Gull predation on seabird adults, chicks and eggs has increased in recent years and probably varies with the availability of inshore spawning capelin (Rodway et al. 1996; Stenhouse and Montevecchi 1999b). Montevecchi and Myers (1997) noted a shift in the diet of Northern Gannets off the northeast coast of Newfoundland that was related to changes in sea surface temperature on the Newfoundland Shelf. They observed a shift in the 1990s from a diet that consisted of predominantly migratory warm-water pelagic fish (for example, mackerel) and squid, to one of mostly regional cold-water pelagic fish (for example, capelin).

3.2.4.4 Geographic and Seasonal Distribution

The pelagic seabird distributional data for the Grand Banks and offshore presented in the Hibernia EIS (Mobil 1985) and summarized in Table 3.14 generally remain unchanged. Seasonal and annual variations in seabird distribution within the Orphan Basin Study Area are poorly known. Observation programs at both the Hibernia and Terra Nova sites provide additional information on the occurrence of seabirds south of the Orphan Basin Study Area. Also, an offshore bird survey conducted for Husky Oil from supply vessels travelling between St. John's and the White Rose site provides a limited amount of useful data (Wiese and Montevecchi 1999).

Table 3.14 Summary of Seabird Distributions in and Near the Orphan Basin Study Area.

Area	Subarea	Birds Commonly Observed
Flemish Cap		Northern Fulmar, Shearwaters, Black-legged Kittiwake, storm-petrels and Dovekie.
Coastal waters of Newfoundland		Summer: Large numbers of Northern Gannet, Herring Gull, Black-legged Kittiwake, Common Murre and Atlantic Puffin. Small numbers of Northern Fulmar, Great Black-backed Gull, terns, Thick-billed Murre, Razorbill and Black Guillemot. Large numbers of Leach's Storm-Petrel are present, but rarely observed.
		Winter: Large numbers of ducks (primarily Common Eiders), shorebirds, gulls, murres and Dovekie.
Grand Banks	Southeast Shoal	Summer: Northern Fulmar, Greater Shearwater, Sooty Shearwater, storm-petrels, jaegers and skuas.
		Winter: Northern Fulmar and Black-legged Kittiwake.
	"Tail of the Bank"	Spring and Summer: Northern Fulmar and shearwaters common; storm-petrels, jaegers, Black-legged Kittiwake and murres also present.
		Winter: Large numbers of Black-legged Kittiwake, murres and Dovekie.
	Shelf Edge	Spring and Summer: Northern Fulmar, shearwaters, storm-petrels, jaegers and Black-legged Kittiwake common; phalaropes also present.
		Winter: Large numbers of Northern Fulmar, Black-legged Kittiwake, Glaucous Gull, Iceland Gull, skuas and Dovekie.

Source: from Mobil (1985).

Seasonal distribution and numbers of offshore pelagic seabirds (all species combined) within the Study Area are presented in Figure 3.26 (Lock et al. 1994). Seabird numbers within the Orphan Basin Study Area are relatively low during the fall/winter months from October to March. Numbers begin to increase in the spring (April-May) until the annual peak during summer/early fall (June-September).

Periodic seabird sightings were made at the Hibernia site (just south of the Orphan Basin Study Area) from November 1997 to August 1998. The data collected from this site are not presented in detail here because there were only 23 observation periods and these data had unknown observer effort (that is, duration of observation period). However, the data agree in pattern with previous seasonal occurrence observations of seabirds on the Grand Banks; large numbers of Dovekies were sighted in winter and Shearwaters and Storm-petrels were abundant in summer.

The seabird monitoring program employed at the Terra Nova site was more structured than the monitoring at Hibernia, and therefore, produced better sighting data. Data were collected from May to September 1999 aboard dredging vessels. Vessel personnel were trained to identify seabirds and collect various types of data (species, number of birds, behaviour) by an experienced seabird biologist prior to conducting observations. A trained crewmember usually conducted three 20-min watches per day (weather permitting). The data provide information on time of occurrence and relative species abundance near the Terra Nova site, as well as providing information on standardized observations per

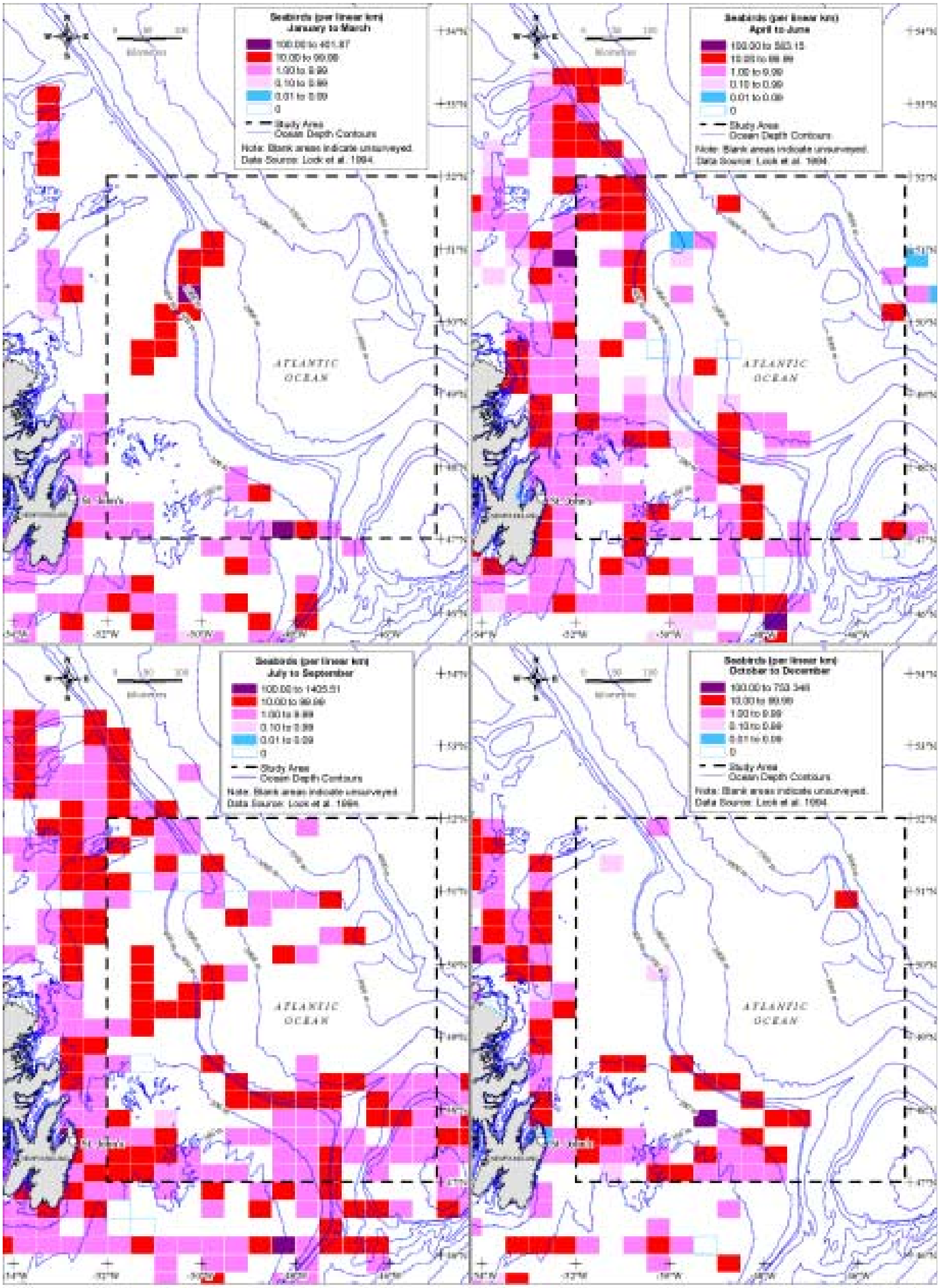


Figure 3.26 Geographical and Seasonal Distributions of Seabirds in the Orphan Basin Study Area.

unit effort (Table 3.15). As expected, large numbers of shearwaters (mostly Greater) were sighted, beginning in June; over 67 percent of seabirds sighted were shearwaters. *Larus* gulls were first sighted in July and accounted for 16.5 percent of the sightings. Smaller numbers of Black-legged Kittiwakes (10.8 percent) were sighted mostly in June. Storm-petrels, fulmars, and skuas were also sighted, along with a few alcids.

Seabird data collected from offshore supply vessels travelling to and from the White Rose area (just south of the Orphan Basin Study Area) during August and September 1999 (Wiese and Montevecchi 1999) have the potential to provide updated information on seabird distribution within the Study Area. The basic count data from these surveys reveal that approximately 73 percent of all seabirds sighted were Greater Shearwaters. Leach's Storm-Petrels, Atlantic Puffins, and Northern Fulmars comprised most of the remaining sightings (Appendix 4 *in* Wiese and Montevecchi 1999).

The Offshore Labrador Biological Studies (OLABS) program conducted by LGL Limited (McLaren et al. 1983) entailed monthly aerial bird surveys (April 1981-April 1982) just to the northwest of the Study Area. Relevant offshore transects included those running from southern Labrador to Notre Dame Bay (northeast Newfoundland) (50°N-53°N) and those in the vicinity of the Funk Island (49°N-50°N).

Table 3.15 Number of Seabirds Sighted from Dredging Vessels at the Terra Nova Site from May to September 1999.

Species	May	June	July	August	September	Total	% of Total
Northern Fulmar		25	14	33	6	78	1.6
Greater Shearwater	16	444	589	379	200	1,628	33.8
Manx Shearwater				1		1	0.0
Shearwater spp.	4	4	402	832	364	1,606	33.4
Storm-petrel spp.		1	112	17	24	154	3.2
Northern Gannet				2	1	3	0.1
Unidentified Duck				2		2	0.0
Larus Gulls			26	65	701	792	16.5
Black-legged Kittiwake	39	439	14	4	26	522	10.8
Great Skua			8	2	3	13	0.3
Dovekie			1	4		5	0.1
Common Murre		4				4	0.1
Murre spp.	2		1			3	0.1
Albatross	1					1	0.0
Total	**62**	**917**	**1,167**	**1,341**	**1,325**	**4,812**	**100.0**
Total Observation Time (min)	1,035	1,535	1,823	1,285	920	6,598	

Data from U. Williams (Petro-Canada). Unidentified seabirds are not included.

In the Funk Island area Northern Fulmars were reported to be common and widespread around Funk Island during the April to December ice-free period (0.38 birds/km^2) (McLaren et al. 1983). Densities were lowest during February and most of those observed occurred along the pack ice edge (0.06

birds/km^2). Storm-petrels were common in May (0.90 birds/km^2) with numbers peaking in mid-July (2.18 birds/km^2), decreasing in September (1.38 birds/km^2) until none were observed after early October. Most storm-petrels were observed on survey lines greater than 45-km from the Islands and in water depths ranging from 100 to 400-m. Northern Gannets arrived in mid-April (0.08 birds/km^2) with numbers rising to a peak in late July (0.40 birds/km^2); most were gone from the area by late October.

Densities of Northern Gannets were highest southwest of Funk Island and were most common within 15-km of the colony. Alcids (mostly Common Murres) were present in large numbers by mid-April (1.17 birds/km^2) with densities peaking in mid-July (2.48 birds/km^2). Most alcids were observed within 15-km of the colonies during the peak of nesting season (mid-July) and within 30-km of the colonies following the appearance of alcid chicks (mid August). Alcids were also present in low densities throughout the winter months (0.13-0.84 birds/km^2). Herring Gulls, Glaucous Gulls, Great Black-backed Gulls, and Black-legged Kittiwakes were recorded within the Funk Island region in low densities throughout the year. Greater and Sooty Shearwaters, which occur as migrants from the southern hemisphere, were present from mid-June to early November with the highest densities occurring in mid-July.

During the OLABS study, major seabird populations in northeastern Newfoundland were predominantly encountered in the Wadham and Penguin Islands area (McLaren et al. 1983). These colonies are important nesting sites for Leach's Storm-Petrels, Common and Arctic Terns, and Atlantic Puffins. Pelagic species such as Greater Shearwaters, storm-petrels, and alcids were uncommon. Most alcids were encountered in mid-May 1981 (0.48 birds/km^2) and mid-March 1982 (0.33 birds/km^2) with the lowest densities (0-0.02 birds/km^2) occurring from June to August when birds were at nesting colonies.

Northern Gannets were not abundant but were regularly seen from late April to early October (0.08-0.45 birds/km^2). Herring Gulls and Great Black-backed Gulls were present in Notre Dame Bay in small numbers during the winter with influxes of both species occurring in March (0.26-0.63 birds/km^2) and peak numbers occurring in late June and early July (0.92-6.6 birds/km^2). Black-legged Kittiwakes were encountered in low densities throughout the year with numbers peaking in early October (3.59 birds/km^2). Iceland and Glaucous Gulls occurred primarily in winter and early spring with numbers peaking in March and April (0.16-0.94 birds/km^2). Common and Arctic Terns were recorded from mid-June to early October, although numbers never exceeded 200 birds per survey in Notre Dame Bay.

3.2.4.5 Summary of Important Areas, Times and Species

The northeastern coast and shelf of Newfoundland and the Grand Banks area are very important for many species of seabirds (see Figure 3.26). Critical areas, times of year and species are outlined below. Most of this information was obtained from Lock et al. (1994). Seasonal distribution numbers of offshore pelagic seabirds (all species combined) within the Study Area are presented in Figure 3.26 (Lock et al. 1994).

Seabird numbers within the Orphan Basin Study Area are relatively low during the fall/winter months from October to March. Numbers begin to increase in the spring (April-May) until the seasonal summer/early fall (June-September) annual peak.

3.2.4.5.1 Summer Concentrations

Most of the world population of Greater Shearwaters, estimated at five million birds, smaller numbers of Sooty Shearwaters and large numbers of Wilson's Storm-Petrels spend the summer on the Grand Banks, wintering from their nesting grounds in the South Atlantic Ocean (Lock et al. 1994). Most of these birds concentrate on the Southeast Shoal of the Grand Banks, where they moult and forage.

3.2.4.5.2 Winter Concentrations

Almost four million Thick-billed Murres winter on the Grand Banks. Those represent over half of the five to six million that breed in western Greenland and the eastern Canadian Arctic. The Grand Banks is also the chief wintering area for the approximately 14 million Dovekies that nest along northwest Greenland. Thousands of waterfowl concentrate near the Cape St. Mary's area, with substantial concentrations also near Argentia and Jude Island, Placentia Bay and Mistaken Point area (southeastern Avalon Peninsula). However, the locations of these winter concentration areas vary within a season and from year to year (Lock et al. 1994).

3.2.4.6 Planning Implications

The existing database for the Study Area is insufficient to identify specific areas and times of key importance to these groups, which contain a number of species that are of international importance and at least that one may become *SARA*-listed. For seabirds it can be deduced that edges of currents and shelf breaks, particularly those within 'commuting' distance of major colonies are key areas. This concerns primarily the southwestern portion of the Study Area. However, such generalities are of little use for decision-making and planning purposes other than to note that most parcels are probably not associated with such areas. Seabird surveys will have to be conducted as part of marine mammal surveys during exploration activity.

3.2.5 Marine Mammals

Twenty species of marine mammal are known to occur in the Orphan Basin Study Area including 15 species of cetaceans (whales and dolphins) and five species of phocids (seals). Additional marine mammal species occur rarely and are therefore not considered important components of the Study Area ecosystem. Most marine mammals are seasonal inhabitants, the waters of the Grand Banks and surrounding areas being important feeding grounds for many of them (Table 3.16).

Table 3.16 Marine Mammals Known to Occur within the Orphan Basin Study Area.

Species Common Name (Scientific Name)	COSEWIC Status[a]	Occurrence Specifics
Baleen Whales (Mysticetes)		
Humpback Whale (*Megaptera novaeangliae*)	SC	Transient and summer resident
Blue Whale (*Balaenoptera musculus*)	E	Late winter, spring, and summer visitor
Fin Whale (*Balaenoptera physalus*)	SC	Transient and summer resident
Sei Whale (*Balaenoptera borealis*)	NC	Late summer visitor
Minke Whale (*Balaenoptera acutorostrata*)	NC	Transient and summer resident
Toothed Whales (Odontocetes)		
Sperm Whale (*Physeter macrocephalus*)	NAR	Transient and summer resident
Northern Bottlenose Whale (*Hyperoodon ampullatus*)[b]	E	Transient
Sowerby's Beaked Whale (*Mesoplodon bidens*)	SC	Transient
Common Bottlenose Dolphin (*Tursiops truncatus*)	NAR	Transient
Killer Whale (*Orcinus orca*)	DD	Year-round resident
Long-finned Pilot Whale (*Globicephala melas*)	NAR	Permanent resident
Short-beaked Dolphin (*Delphinus delphis*)	NAR	Summer resident
Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)	NAR	Summer resident
White-beaked Dolphin (*Lagenorhynchus albirostris*)	NAR	Transient and summer resident
Harbour Porpoise (*Phocoena phocoena*)	SC	Summer resident
True Seals (Phocids)		
Harp Seal (*Phoca groenlandica*)	NC	Winter visitor
Hooded Seal (*Cystophora cristata*)	NAR	Winter visitor
Grey Seal (*Halichoerus grypus*)	NAR	Year-round resident
Ringed Seal (*Phoca hispida*)	NAR	Occasional winter visitor
Bearded Seal (*Erignathus barbatus*)	NAR	Occasional winter visitor

[a] Based on COSEWIC (2003).
E: endangered; SC: special concern; NC: not considered; DD: data deficient; NAR: not at risk
[b] Refers to the Scotian Shelf population. There is uncertainty about which population of this species occurs in Study Area.

The marine mammal community within the southern portion of the Study Area was described in the Hibernia EIS in 1985 (Mobil 1985) and updated in 1995 for the Terra Nova EIS (Petro-Canada 1996). Most of the description on distribution in these reports was based on marine mammal surveys conducted for the Hibernia EIS (Parsons and Brownlie 1981). Although over 20 years have elapsed, the Parsons and Brownlie surveys remain the most comprehensive data available on the spatial and temporal occurrence of marine mammals in or near the Study Area. The information from these surveys and other biological information presented in both EISs are not repeated in this report and the reader is referred to Mobil (1985) and Petro-Canada (1996). Population estimates and feeding information of many of the marine mammal species that occur within the Orphan Basin Study Area are indicated in Tables 3.17 and 3.18.

Table 3.17 Population Estimates of Marine Mammals that Occur in the Orphan Basin Study Area.

Species	Northwest Atlantic (NW) Population Size	Population Occurring in the Study Area		
	Estimated Number	Stock	Estimated Number	Source of Updated Information
Baleen Whales				
Humpback Whale	5,505	NF/Labrador	1,700-3,200	Katona and Beard (1990); Whitehead (1982)
Blue Whale	308 [a]	NW Atlantic	Unknown	Waring et al. (1999)
Fin Whale	2,200 [b]	Can. E. Coast	Unknown	Waring et al. (1999)
Sei Whale	Unknown	Nova Scotia	Unknown	Waring et al. (1999)
Minke Whale	2,790 [b]	Can. E. Coast	Unknown	Waring et al. (1999)
Toothed Whales				
Sperm Whale	Unknown	North Atlantic	Unknown	Reeves and Whitehead (1997)
Northern Bottlenose Whale	Tens of thousands?	North Atlantic	Unknown	Reeves et al. (1993)
Sowerby's Beaked Whale	Unknown			Katona et al. (1993)
Common Bottlenose Dolphin	22,215	NW Atlantic	Unknown	Waring et al. (1999)
Killer Whale	Unavailable		Unknown	Lien et al. (1988)
Long-finned Pilot Whale	4,000-12,000	NW Atlantic	Abundant	Nelson and Lien (1996)
Short-beaked Dolphin	Unavailable			Katona et al. (1993)
Atlantic White-sided Dolphin	27,200	NW Atlantic	Unknown	Palka et al. (1997)
White-beaked Dolphin	Unknown	NW Atlantic	Unknown	Waring et al. (1999)
Harbour Porpoise	Unknown	Newfoundland	Unknown	Wang et al. (1996)
True Seals				
Harp Seal	4.5-4.8 million	NW Atlantic	Unknown	Shelton et al. (1996)
Hooded Seal	400,000-450,000	NW Atlantic	Unknown	Stenson et al. (1997)
Grey Seal	154,000	E. Canada	Unknown	Mohn and Bowen (1996)
Ringed Seal	Unavailable			Katona et al. (1993)
Bearded Seal	Unavailable			Katona et al. (1993)

[a] Based on surveys from the Gulf of St. Lawrence.
[b] Based on surveys from Virginia to the Gulf of St. Lawrence.
[c] Mostly from the Maine coast (US).

Table 3.18 Prey of Marine Mammals that Occur in the Orphan Basin Study Area.

Species	Prey	Source of Updated Information
Baleen Whales		
Humpback Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Blue Whale	Euphausiids	
Fin Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Sei Whale	Copepods, euphausiids, some fish	
Minke Whale	Fish (predominantly capelin), squid, euphausiids	Piatt et al. (1989)
Toothed Whales		
Sperm Whale	Cephalopods, fish	Reeves and Whitehead (1997)
Northern Bottlenose Whale	Primarily squid, also fish	
Sowerby's Beaked Whale	Squid, some fish	Pitman (2002)
Common Bottlenose Dolphin	Squid, fish (mackerel, butterfish)	Gaskin (1992a)
Killer Whale	Herring, squid, seals, dolphins, other whales	Lien et al. (1988)
Long-finned Pilot Whale	Short-finned squid, northern cod, amphipods	Nelson and Lien (1996)
Short-beaked Dolphin	Squid, fish	Katona et al. (1993)
Atlantic White-sided Dolphin	Schooling fish (sand lance, herring), hake, squid	Palka et al. (1997)
White-beaked Dolphin	Fish (cod, capelin, herring), squid	Hai et al. (1996)
Harbour Porpoise	Schooling fish (capelin, cod, herring, mackerel)	
True Seals		
Harp Seal	Fish (capelin, cod, halibut, sand lance), crustaceans	Lawson and Stenson (1995); Lawson et al. (1998); Wallace and Lawson (1997); Hammill and Stenson (in press).
Hooded Seal	Fish (Greenland halibut, redfish, Arctic and Atlantic cod, herring), squid, shrimp, molluscs	Ross (1993)
Grey Seal	Fish (herring, cod, hake, pollock), squid, shrimp	Benoit and Bowen (1990); Hammill et al. (1995)
Ringed Seal	Fish (polar cod), amphipods, krill, shrimp	Katona et al. (1993)
Bearded Seal	Fish (polar cod, sculpins, rough dabs, eelblennies), crabs, shrimp, molluscs, cephalopods, polychaetes, amphipods	Kovacs (2002)

Source: Mobil (1985) with updates where indicated.

3.2.5.1 Offshore Labrador Biological Studies (OLABS) Surveys

As part of the Offshore Labrador Biological Studies (OLABS) programme designed to collect biological data in support of hydrocarbon exploration and production activities in the Labrador Sea and along the Labrador coast, an aerial survey programme was conducted by LGL Ltd. to provide quantitative information on the year-round distribution and movements of marine animals in the Labrador Sea. During the April 1981 to April 1982 period, LGL Ltd. conducted systematic surveys in the Labrador Sea south of 56ºN. The surveys were designed to concentrate specifically on pelagic seabirds; however, marine mammals were routinely recorded during all surveys. The survey area extended between 56ºN and 49º15'N, and as far east as 52ºW, the western limit of the Study Area. Intervals between surveys ranged from one week to one month. The survey routes nearest the Study Area were located around Funk Island and extended eastward close to longitude 52ºW. Surveys were conducted in areas where water depths ranged between inshore shallows to >2,200-m (McLaren et al. 1982).

Ten species of cetaceans were recorded during the surveys in the southern Labrador Sea. They included the minke whale, fin whale, humpback whale, sperm whale, white whale (beluga), Atlantic pilot whale, killer whale, white-beaked dolphin, Atlantic white-sided dolphin, and harbour porpoise. An eleventh species, the northern bottlenose whale, was tentatively identified. The sei whale and blue whale, two species expected to occur in the area, were not seen during the surveys (McLaren et al. 1982).

The OLABS baleen whale sightings by McLaren et al. (1982) included:

- Almost 600 humpback whales were observed throughout the OLABS study area, mostly between May and September. All humpback whale sightings, 77% of which were offshore, occurred in areas with water depths <400-m.

- Most of the 173 fin whales were observed between July and November, primarily in offshore waters between 55ºN and 51ºN. None were seen in waters deeper than 400-m.

- Twenty-one minke whales were observed between April and December. Minkes observed in the Funk Island survey area were seen primarily before July. These whales were observed in both inshore and offshore areas with water depths were <300-m. Inshore sightings occurred mainly between April and July while the offshore sightings were reported between September and December.

The OLABS toothed whale sightings by McLaren et al. (1982) included:

- The five identified sperm whales were seen over the slope of the Labrador Shelf, north of the Orphan Basin Study Area. All sightings occurred between June and October.

- One northern bottlenose whale was tentatively observed southeast of Funk Island in November. This location is immediately west of the western limit of the Orphan Basin Study Area. The northern bottlenose whale is a priority species under *SARA* (2003) due to the COSEWIC 'endangered' status of the Scotian Shelf population.

- Seventeen killer whales were observed between June and September. Eight of these were just northwest of Funk Island.

- Of the 515 pilot whales observed, 437 were seen in August and September. They were distributed throughout the survey area.

- A total of 628 dolphins were recorded during the aerial surveys in the OLABS study area. Of these, 201 were confirmed white-beaked dolphins, 300 were confirmed white-sided dolphins and the remainder were not identified to species. Both species were observed throughout the OLABS study area. White-beaked dolphins were observed between April and January in both the offshore and inshore areas. White-sided dolphins were recorded between June and December, primarily in the offshore.

- Fourteen harbour porpoises were observed between August and October, primarily in the southern portion of the OLABS study area nearest the Orphan Basin Study Area. These porpoises were seen in both offshore and inshore areas.

- The lone open water sighting of a beluga occurred in May, north of the Orphan Basin Study Area.

3.2.5.2 DFO Cetacean Sighting Database

The Department of Fisheries and Oceans in St. John's (J. Lawson, DFO Marine Mammal Research Biologist, 2003, pers. comm.) is compiling a database of cetacean sightings in waters around Newfoundland and Labrador. These data provide some indication of what species can be expected to occur in the area but they cannot, at this point in the development of the database, provide any fine-scale quantitative information. Table 3.19 contains the coarse summary data pertaining to sightings within and close to the Study Area. Caveats associated with the DFO data are presented with Table 3.19.

All the reliable sightings in NAFO Division 3K occurred inshore of the EEZ. Humpback whales, minke whales, pilot whales and fin whales accounted for the most sightings in 3K between 1979 and 1999. In terms of the number of individual animals, dolphins, pilot whales and humpback whales were the most abundant animals reported. The lone sighting of a group of six northern bottlenose whales occurred at a location in the western portion of the Study Area in 1986. Water depth at this location is between 300 and 400-m.

Most of the reliable sightings of cetaceans in Division 3L occurred shoreward of the EEZ. As was the case with 3K, humpback whales, minke whales, pilot whales and fin whales accounted for most sightings between 1979 and 2000, both inside and outside the EEZ in 3L. These four species also accounted for the most individual animals seen during that period.

Humpback and pilot whales were the most commonly sighted cetacean species in Division 3M between 1958 and 1999.

Table 3.19 Cetacean Sightings Near or Within the Orphan Basin Study Area, 1958-2002.

Species	Number of sighting events (Number of individual animals)			
	Division 3K	**Division 3L (inside EEZ)**	**Division 3L (outside EEZ)**	**Division 3M**
Atlantic white-sided dolphin	1 (160)	1 (2)		1 (12)
Common dolphin	1 (200)	1 (5)	1 (7)	
Dolphin (sp.)			1 (3)	1 (20)
Fin whale	9 (23)	47 (108)	2 (3)	
Harbour porpoise		4 (10)		
Humpback whale	28 (93)	259 (942)	10 (14)	9 (13)
Killer whale	1 (5)	4 (15)		
Minke whale	12 (13)	110 (246)	4 (6)	
Northern bottlenose whale	1 (6)			
Pilot whale	12 (134)	57 (1,169)	4 (79)	6 (336)
Sei whale	1 (1)	7 (14)	1 (1)	
Sperm whale	5 (15)	1 (1)	1 (1)	2 (4)
White-beaked whale	2 (107)	1 (2)		

Source: DFO (2003e).

*Note the following caveats associated with the tabulated data

(1) The sighting data have not yet been completely error-checked.
(2) The quality of some of the sighting data is unknown.
(3) Most data have been gathered from platforms of opportunity that were vessel-based. The inherent problems with negative or positive reactions by cetaceans to the approach of such vessels have not yet been factored into the data.
(4) Sighting effort has not been quantified (i.e., the numbers cannot be used to estimate true species density or areal abundance).
(5) Both older and some more recent survey data have yet to be entered into this database. These other data will represent only a very small portion of the total data.
(6) Numbers sighted have not been verified (especially in light of the significant differences in detectability among species).
(7) For completeness, these data represent an amalgamation of sightings from a variety of years (e.g., since 1979) and seasons. Hence, they may obscure temporal or areal patterns in distribution (e.g., the number of pilot whales sighted in nearshore Newfoundland appears to have declined since the 1980s but the total number sighted in the database included here suggest they are relatively common).

3.2.5.3 Species Profiles

3.2.5.3.1 Baleen Whales (Mysticetes)

The five species of baleen whales that occur in the Study Area include the humpback whale, the blue whale, the fin whale, the sei whale, and the minke whale (see Table 3.16). Although nearly all of these species experienced depletion due to whaling, it is likely that many are experiencing some recovery (Best 1993). The blue whale is considered a priority species under *SARA* based on its 'endangered' designation by COSEWIC. COSEWIC has also designated the humpback whale and the fin whale as species of 'special concern'.

3.2.5.3.2 *Humpback Whale*

The humpback whale has a cosmopolitan distribution. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). It is by far the most common baleen whale in Newfoundland waters. About 900 humpbacks are thought to use the Southeast Shoal of the Grand Banks as a summer feeding area, where their primary prey is capelin (Whitehead and Glass 1985). Thirteen humpbacks were sighted offshore during the offshore supply vessel survey in 1999; most of these sightings were in September (Wiese and Montevecchi 1999).

Recent research on humpbacks suggests genetic as well as spatial segregation between feeding areas within the North Atlantic (Valsecchi et al. 1997). The entire North Atlantic population is estimated at approximately 10,600 individuals (Smith et al. 1999), the northwest Atlantic population at 5,505 individuals (Katona and Beard 1990) and the Newfoundland/Labrador population at 1,700 to 3,200 (Whitehead 1982).

Humpback whales occur relatively commonly within the Orphan Basin Study Area, in both the shallower (<400-m) and deeper (>400-m) areas. In terms of the number of sighting events recorded in the DFO database (DFO 2003e), humpback whales ranked first in Divisions 3K, 3L (inside and outside the EEZ) and 3M, particularly in the portion of Division 3L inside of the EEZ.

The western North Atlantic and North Pacific populations of humpback whale were singly designated by COSEWIC as 'threatened' in April 1982. In April 1985, they were split into separate populations, at which time the western North Atlantic population was designated as 'special concern'. In May 2003, this population was re-examined and subsequently de-listed (i.e., considered 'not at risk').

3.2.5.3.3 *Blue Whale*

The blue whale, which has likely always been rare in Canadian waters (Mansfield 1985), probably numbers in the few hundreds in the northwest Atlantic (Waring et al. 1999). It is rarely sighted on the Grand Banks, and is probably relatively uncommon within the Orphan Basin Study Area. Nothing is known about trends in blue whale abundance in the northwest Atlantic, but the population that summers around Iceland has been increasing at approximately five percent/yr (Sigurjónsson and Gunnlaugsson 1990).

3.2.5.3.4 *Fin Whale*

The fin whale is commonly found on the Grand Banks during summer months (Piatt et al. 1989). Eight fin whales, including two calves, were sighted on the Grand Banks in August 1999, during an offshore supply vessel survey (Wiese and Montevecchi 1999). This species is associated with the presence of capelin, their predominant prey item in these waters (Piatt et al. 1989; Whitehead and Carscadden 1985).

Recent genetic studies indicate that fin whale populations that summer in Nova Scotia, Newfoundland, and Iceland may be genetically distinct from each other (Arnason 1995). The number of fin whales in the northwest Atlantic was recently estimated at approximately 2,200 (Waring et al. 1999). This is lower than estimates from previous reports, but supports the idea that fin whale numbers are decreasing off Newfoundland (Whitehead and Carscadden 1985).

According to the DFO cetacean sightings database, these common visitors to the Study Area have been sighted most often inside the EEZ in both Divisions 3K and 3L, particularly 3L. Fin whale sightings have occurred in both the shallower (<400-m) and deeper (>400-m) areas of the Study Area.

3.2.5.3.5 Sei Whale

The sei whale has a cosmopolitan distribution, and prefers temperate oceanic waters (Gambell 1985). Sei whales are known for their high mobility and unpredictable appearances (Reeves et al. 1998). Incursions into nearshore waters of the Gulf of Maine, associated with high copepod densities, are well documented (Payne et al. 1990; Schilling et al. 1992).

No reliable population estimates are available for sei whales. A 1970s estimate for the Nova Scotia stock suggested a minimum population of 870 individuals (Mitchell and Chapman 1977). This population is thought to range as far as the Grand Banks.

Current knowledge suggests that sei whales are uncommon visitors to the Orphan Basin Study Area compared to more commonly sighted cetacean species. Based on the DFO cetacean sightings database (DFO 2003e), no sei whale sightings have been reported in the Study Area since 1980. The Atlantic population of the sei whale is considered by COSEWIC as ‘data deficient’.

3.2.5.3.6 Minke Whale

Another baleen whale commonly found on the Grand Banks in summer is the minke whale (Piatt et al. 1989). Eight individuals were sighted along the near-shore half of an offshore supply vessel survey in August and September 1999 (Wiese and Montevecchi 1999). Like the fin whale, the minke whale is associated with the presence of capelin, their predominant prey item in these waters (Piatt et al. 1989; Whitehead and Carscadden 1985). The size of the northwest Atlantic population of minke whales is not well known, but the best available estimate is 2,790 individuals (Waring et al. 1999).

Minke whales commonly occur within the Orphan Basin Study Area. Most of the reported Study Area sightings in the DFO database (DFO 2003e) have occurred in Divisions 3K and 3L, inside the EEZ in areas with water depths <400-m.

3.2.5.4 Toothed Whales (Odontocetes)

Ten species of toothed whales are found in the Study Area (see Table 3.16). These species range from the largest living toothed whale, the sperm whale (at approximately 18-m for an adult male (Reeves and Whitehead 1997)) to one of the smallest whales, the harbour porpoise (at approximately 1.6-m for an average adult (Gaskin 1992b)). Most of these marine mammals occur seasonally in the Study Area and little is known regarding their distribution and population size in these waters. The northern bottlenose whale is a priority species under *SARA* due to the COSEWIC 'endangered' designation of the Scotian Shelf population.

3.2.5.4.1 Sperm Whale

Sperm whales have an extensive worldwide distribution (Rice 1989). This species routinely dives to depths of hundreds of metres and may occasionally dive to more than 3,000-m. They apparently are capable of remaining submerged for longer than two hours, but most dives probably last a half-hour or less (Rice 1989). The diet of sperm whales is dominated by mesopelagic and benthic squids and fishes (Reeves and Whitehead 1997).

The number of sperm whales in the North Atlantic and in the Orphan Basin Study Area is unknown. Reeves and Whitehead (1997) caution that previous population estimates for this species are suspect given their long-distance movements and lack of any clear stock structure. There is evidence that stock delineation in this species may be dependent on the time scale of the measure used, further complicating reliable population estimation (Dufault et al. 1999).

It is not known how common sperm whales are within the Orphan Basin Study Area. The few sightings of sperm whales reported in the DFO cetacean sightings database (DFO 2003e) occurred in Division 3K, beyond the 400-m isobath. Sperm whales are known to feed in deep water and it is possible that they occur regularly beyond the continental shelf within the Study Area.

3.2.5.4.2 Northern Bottlenose Whale

Northern bottlenose whales are found only in the North Atlantic, with a total population that may be in the tens of thousands (Reeves et al. 1993). Only a few individuals have been sighted on the Grand Banks. Like sperm whales, bottlenose whales can dive for periods well in excess of one hour, and their dives can reach depths of more than 1,000-m. They live primarily in deep canyon and slope areas, where they prey on squid and deep-sea fishes.

The Orphan Basin Study Area is within the known range of the northern bottlenose whale. This whale's life history is poorly known and most records from Newfoundland are based on carcasses washed ashore. Since nearly half the Study Area has water depths ranging from 1,000-4,000-m, the possibility of northern bottlenose whale occurrence should be considered. The lone tentative sighting record of this cetacean in the Study Area (DFO 2003e) was reported in 3K beyond the 1,000-m isobath. Few bottlenose whales are expected to occur on the relatively shallow Grand Banks.

3.2.5.4.3 Sowerby's Beaked Whale

This beaked whale is also known as the North Sea beaked whale because its distribution appears to be centered there, based on numbers of strandings. In the 1980s, two mass strandings were recorded on the northeast coast of Newfoundland. One involved three animals and the other involved six (Katona et al. 1993).

The Orphan Basin Study Area lies within the known range of the Sowerby's beaked whale. This beaked whale is also a deep-sea diver that occurs mainly in areas where water depth is 1,000-m or more. As is the case with the northern bottlenose whale, the life history of the Sowerby's beaked whale is not well understood and most Newfoundland records of it involve carcasses washed ashore. Since much of the Study Area has water depths ranging from 1,000-4,000-m, the possibility of occurrence of Sowerby's beaked whales should be considered.

3.2.5.4.4 Common Bottlenose Dolphin

A north-south migration has been assumed to occur along the east coast of North America, with common dolphins moving into higher-latitude areas in summer and fall, then moving farther south (or possibly just offshore) for the winter (Selzer and Payne 1988; Gowans and Whitehead 1995). The northern limit of this species range in the summer is likely the Flemish Cap (Gaskin 1992a). Areas with steep subsurface relief, generally in a broad band paralleling the continental slope (100 to 200-m depth contour), tend to have relatively high densities of short-beaked common dolphins in US waters (Selzer and Payne 1988).

The common dolphin in the northwest Atlantic probably numbers in the low tens of thousands (Waring et al. 1999). It is likely most common in the southern portion of the Study Area although the estimated number that does occur in the Study Area is unknown. This dolphin is most common in areas where water depth <400-m.

3.2.5.4.5 Killer Whale

The killer whale is a year-round resident that is thought to occur in relatively small numbers in the Orphan Basin Study Area (Lien et al. 1988). Three killer whales were sighted within 20-km of the

White Rose area on August 24, 1999 (Wiese and Montevecchi 1999). On a global basis, killer whales are not endangered. There are no population estimates for the northwest Atlantic.

3.2.5.4.6 Long-finned Pilot Whale

The most common toothed whale in the Study Area and also one of the only year-round residents is the long-finned pilot whale (also known as the Atlantic pilot whale). This species is considered abundant in the Grand Banks area from July through December. However, none were sighted during a recent offshore supply vessel survey (Wiese and Montevecchi 1999). The northwest Atlantic population probably numbers between 4,000 and 12,000 individuals (Nelson and Lien 1996).

It is a common belief that long-finned pilot whales in the northwest Atlantic prey mainly on short-finned squid in summer. However, this statement is based largely on evidence from inshore waters of Newfoundland (Sergeant 1962), and other evidence suggests that they also prey on a variety of fish species, as well as additional species of cephalopods (especially long-finned squid, *Loligo pealei*) at other times and in other areas (Waring et al. 1990; Overholtz and Waring 1991; Desportes and Mouritsen 1993; Nelson and Lien 1996; Gannon et al. 1997).

Most of the Orphan Basin Study Area pilot whale sightings found in the DFO database (DFO 2003e) (3K, 3L and 3M) were reported in areas where water depth <400-m.

3.2.5.4.7 Short-beaked (Common) Dolphin

The short-beaked dolphin's western North Atlantic range extends from Venezuela and the Gulf of Mexico to Newfoundland. These dolphins occur rather commonly at sea off Newfoundland, usually in groups ranging from 50 to 200 individuals. Most of the population in US waters is located south of Georges Bank in areas where water depth ranges between 100 and 200-m although they do occur out the 2,000 isobath. Short-beaked dolphins eat a variety of fishes and squids (Katona et al. 1993).

Considering the water depth ranges in areas where this cetacean has been sighted in US waters, short-beaked dolphins could potentially occur throughout most of the Orphan Basin Study Area.

3.2.5.4.8 Atlantic White-Sided Dolphin

There are three stocks of Atlantic white-sided dolphins in the northwest Atlantic; Gulf of Maine, Gulf of St. Lawrence and Labrador Sea. The combined northwest Atlantic population probably numbers 27,000 individuals (Palka et al. 1997). The number of white-sided dolphins in the Study Area is unknown. There were seven sightings of 250 individuals on the Grand Banks in August to September 1999, including several sightings within approximately 30-km of the White Rose site, during an offshore supply vessel surveys (Wiese and Montevecchi 1999). The most easterly recorded sighting for individuals from the northwest Atlantic population occurred on the Flemish Cap (Gaskin 1992c).

Few sightings of this dolphin within the Orphan Basin Study Area are recorded in the DFO cetacean sightings database (DFO 2003e). The sightings that are recorded occurred both inside and outside the 400-m isobath.

3.2.5.4.9 White-beaked Dolphin

The white-beaked dolphin tends to be a coastal, cool-water species (Reeves et al. 1999). This species seems to remain at relatively high latitudes throughout the fall and winter (Lien et al. 1997), but the nature of their seasonal movements is uncertain. During the summer, approximately 3,500 white-beaked dolphins have been estimated to occur off southern Labrador (Alling and Whitehead 1987). This species was regularly sighted during the 1980-81 Hibernia surveys, primarily during summer (Mobil 1985). There is no reliable population estimate for the northwest Atlantic. The total North Atlantic population may range from high tens of thousands to low hundreds of thousands (Reeves et al. 1999). Ice entrapment is not uncommon in the bays of southern Newfoundland in years when pack ice is heavy (Hai et al. 1996).

White-beaked dolphin occurrence in the Orphan Basin Study Area is most likely in the inshore regions where water depths are relatively shallow.

3.2.5.4.10 Harbour Porpoise

The harbour porpoise is widely distributed throughout temperate waters, but its population size in Newfoundland waters is unknown (Gaskin 1992b). Harbour porpoises that occur in Newfoundland waters are believed to belong to a separate stock from those in the Gulf of St. Lawrence and Bay of Fundy/Gulf of Maine regions. This is supported by differences in organochlorine contaminant levels, which are lower in Newfoundland animals (Westgate and Tolley 1999), and by differences in mitochondrial DNA haplotype frequencies (Wang et al. 1996).

Harbour porpoises are most likely to occur in the Orphan Basin Study Area in inshore areas where water depths are relatively shallow.

The northwest Atlantic population of harbour porpoise was designated by COSEWIC as ‘threatened’ in April 1990 but in May 2003, it was downlisted to ‘special concern’.

3.2.5.5 Whale Species Included in the COSEWIC Species Assessment Listing

The western North Atlantic and North Pacific populations of humpback whale were singly designated by COSEWIC as ‘threatened’ in April 1982. In April 1985, they were split into separate populations, at which time the western North Atlantic population was designated as ‘special concern’. In May 2003, this population was re-examined and subsequently de-listed (i.e., ‘not at risk’).

The northwest Atlantic population of harbour porpoise was designated by COSEWIC as ‘threatened’ in April 1990 but in May 2003, it was downlisted to ‘special concern’.

The Atlantic population of the sei whale is considered by COSEWIC as ‘data deficient’.

3.2.5.6 True Seals (Phocids)

Five species of true seals are known to occur in the waters of the Orphan Basin Study Area (see Table 3.16). Populations of harp, hooded, and grey seals in Canada are thought to be increasing (Waring et al. 1999). Because of their potential to interact with commercial fisheries, reasonable population estimates for the northwest Atlantic are now available for most seal species. The main diet of seals consists of fish (including capelin, cod, halibut and sand lance) and invertebrates such as squid and shrimp (see Table 3.18), with considerable seasonal, geographic and interannual variation in diet (Hammill et al. 1995; Lawson and Stenson 1995; Wallace and Lawson 1997).

During the OLABS surveys in 1981 and 1982, bearded seals, harbour seals, harp seals, and hooded seals were observed. Grey seals and ringed seals, known to occur in the OLABS study area, were not identified during the surveys. Six harbour seals were seen between August and September, primarily in the inshore. Thirty-three bearded seals were observed primarily in the offshore and north of Orphan Basin Study Area between March and May. An estimated 60,000 harp seals were seen during April to June and January to April periods. Most harp seals were hauled out on pack ice. One hundred and forty-seven hooded seals were observed in the offshore, north of the Orphan Basin Study Area, between February and April (McLaren et al. 1982).

3.2.5.6.1 Harp Seal

Harp seals whelp in the spring in the Gulf of St. Lawrence and in an area known as the 'Front' off southern Labrador and northeastern Newfoundland (Sergeant 1991; DFO 2000b). The main whelping patch for the northwest Atlantic breeding stock of harp seal is close to the northeast corner of the Orphan Basin Study Area. In heavy ice years, it is likely harp seal whelping herds extend into the Study Area. Individuals from these two areas spend the summer in the Arctic and then migrate south in the autumn. Surveys conducted during the early 1990s suggested that offshore waters on the northern edge of the Grand Banks in NAFO fishing area 3L were an important over-wintering area for these animals during those years (Stenson and Kavanagh 1994). Sighting effort from these surveys within the Study Area was low, but harp seals were present in low numbers in the Study Area. Similarly, data from satellite transmitters deployed on harp seals suggest that the Grand Banks is an important wintering area for some seals (Stenson and Sjare 1997). It is possible that more harp seals are occurring south of this area in recent years because there has been an apparent change in their distribution. There has been a documented increase in the extralimital occurrences (south of normal range) of harp seals in the northern Gulf of Maine (McAlpine et al. 1999), which may also be occurring in the Grand Banks area. This southward expansion may be related to the increase in the harp seal population or the recent changes in ocean ecology that may be affecting their foraging success (McAlpine et al. 1999). In 1994, the total population estimate of harp seals in the northwest Atlantic was 4.5 million to 4.8 million, with a suggested growth rate of approximately five percent/yr since 1990 (Shelton et al. 1996).

The diet of harp seals foraging off Newfoundland and Labrador appears to vary considerably with age, season, year and location. On the Grand Banks and Labrador Shelf, capelin predominates, followed by sand lance, Greenland halibut and other pleuronectids (Wallace and Lawson 1997; Lawson et al. 1998). Recent "historical" data on the diet of harp seals greater than a year old from northeast Newfoundland, indicates that there was a shift in prey from capelin in 1982 to Arctic cod in 1986 and beyond, while Atlantic cod remained relatively unimportant throughout this period. Harp seals collected from nearshore waters forage intensively on a variety of fish and invertebrate species, although most of the biomass is derived from relatively few species, particularly Arctic cod, capelin, Atlantic cod, Atlantic herring and some decapod crustaceans. A recent consumption model estimates that harp seals consume less Atlantic cod than once believed as seals apparently spend more time offshore than previously thought (Hammill and Stenson, in press).

3.2.5.6.2 Hooded Seal

Like the harp seal, the hooded seal is a North Atlantic endemic species that reproduces on the spring pack ice of the Gulf of St. Lawrence and along the Labrador coast, and then migrates northward to the sub-Arctic and Arctic to feed during the summer (Lydersen and Kovacs 1999). Data collected from satellite transmitters deployed on hooded seals in the Gulf of St. Lawrence indicate that some females feed near the Flemish Cap after breeding while migrating to Greenland waters (G.B. Stenson, unpubl. data). Tagged males migrating to Greenland in early summer were recorded along the Grand Banks shelf edge near the Flemish Pass. It appears that males spend little time foraging in this area (G.B. Stenson, unpubl. data.). Little is known regarding their winter distribution, although it is believed that the majority of seals remain offshore; they have been seen feeding off the Grand Banks in February. Surveys in the early 1990s suggested that, as was the case for harp seals, the offshore waters on the northern edge of the Grand Banks also might be an important over-wintering area for hooded seals (Stenson and Kavanagh 1994). Hooded seal sightings in the Study Area during these surveys were less frequent than harp seal sightings. The number of visitors to the Study Area is unknown. However, these numbers may be increasing as hooded seals are apparently expanding their southern range of occurrence (McAlpine et al. 1999).

The most recent estimate of pup production at "the Front" off Labrador, made in 1990, was approximately 83,000 (Stenson et al. 1997), suggesting a current total population of hooded seals in the northwest Atlantic of 500,000 (Whitehead et al. 1998).

Hooded seals consume a variety of prey. In nearshore areas of Newfoundland, prey (in decreasing order of total wet weight) includes: Greenland halibut, redfish, Arctic cod, Atlantic herring and capelin. Relatively small amounts of squid (*Gonatus* spp.) and Atlantic cod were also found (Ross 1993). Data from offshore areas are limited, but suggest that similar prey species are consumed (J.W. Lawson and G.B. Stenson, unpubl. data).

3.2.5.6.3 Grey Seal

Grey seals in the Orphan Basin Study Area are migrants from the Sable Island and Gulf of St. Lawrence breeding populations. This species occurs in the Study Area year-round, but most commonly in July and August (Stenson 1994). In the past, grey seals were regularly observed hauled out at Miquelon during the summer (Renouf et al. 1983). At present, it is unknown how many grey seals use this site (J.W. Lawson, pers. comm.). The Sable Island and Gulf of St. Lawrence breeding areas account for essentially all of the pup production in the northwest Atlantic, which increased exponentially between 1977 and 1989 (Stobo and Zwanenburg 1990). The eastern Canadian population of grey seals was estimated at 154,000 in 1994 (Mohn and Bowen 1996). The number that migrates into the Study Area is unknown, but is believed to be low.

Grey seals are less tied to coastal and island rookeries than are harbour seals. They travel long distances, one individual having been tracked over a distance of 2,100-km (McConnell et al. 1999). The food of grey seals in the western North Atlantic includes at least 40 species, some of which are commercially important (for example, Atlantic cod, herring, and capelin) (Benoit and Bowen 1990; Hammill et al. 1995).

3.2.5.6.4 Ringed Seal

The ringed seal is the most common Arctic seal and its distribution is circumpolar, encompassing all of the European and Canadian Arctic and extending southward to areas that include Labrador, and occasionally northeast Newfoundland and the Gulf of St. Lawrence. They dive to depths of at least 100-m to feed on polar cod, amphipods, krill and other shrimplike crustaceans (Katona et al. 1993). Compared to harp and hooded seals, ringed seals do not commonly occur in the Orphan Basin Study Area.

3.2.5.6.5 Bearded Seal

The bearded seal has a patchy distribution throughout much of the Arctic and sub-Arctic. This seal's preferred habitat is drifting pack ice in areas over shallow water shelves and, therefore, they are often found in coastal areas. While some of these animals are resident throughout the year in certain locations within their distribution, others follow the retraction of the pack ice northward during the summer and the advance southward once again in the late fall and winter (Kovacs 2002). Bearded seals typically occur north of the Orphan Basin Study Area but small numbers of bearded seals could stray from Labrador waters to the Study Area.

This seal species is primarily a benthic feeder. They do not tend to dive any deeper than 100-m although there are exceptions to as deep as 500-m. Prey include polar cod, sculpins, rough dabs, eelblennies, crabs, shrimps, molluscs, cephalopods, polychaetes and amphipods (Kovacs 2002).

3.2.5.7 Planning Implications

The existing database for the Study Area is insufficient to identify specific areas and times of key importance to marine mammals, which contain a number of species that are of international concern and are *SARA*-listed. For seals, it can be deduced that the late winter ice front is a key area for seals and edges of currents and shelf breaks are key areas for cetaceans. However, the location of the 'front' is variable from year-to-year. Such generalities are of little use for decision-making and planning purposes other than to note that most parcels are probably not associated with such areas. Marine mammal surveys will have to be conducted during exploration activities.

3.2.6 Sea Turtles

Sea turtles may not be common in the area but are important to consider because of their threatened or endangered status, both nationally and internationally (see 3.2.7 Species at Risk, below).

Three species of sea turtles are known to occur in the Orphan Basin Study Area: (1) the leatherback, (2) the loggerhead, and (3) the Kemp's ridley (Ernst et al. 1994). However, little can be said to qualify, much less quantify, the degrees of occurrence of these three sea turtle species within the Study Area due to lack of information. The leatherback turtle is listed as endangered by COSEWIC (2003) and by the United States National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS) (Plotkin 1995). Due to its risk designation by COSEWIC, the leatherback turtle is considered a priority species under *SARA* (2003). The Kemp's ridley is also listed as endangered and the loggerhead turtle is listed as threatened by NMFS and FWS (Plotkin 1995).

3.2.6.1 Leatherback

The leatherback is the largest living turtle (2.2-m in length and over 900-kg (Morgan 1989) and it also may be the most widely distributed reptile, as it ranges throughout the Atlantic, Pacific, and Indian oceans and into the Mediterranean Sea (Ernst et al. 1994). Adults engage in routine migrations between temperate and tropical waters, presumably to optimize both foraging and nesting opportunities. Leatherbacks are less genetically diverse than other sea turtle species and may have less-rigid homing instincts (Dutton et al. 1999).

The worldwide population of leatherbacks is currently estimated at between 26,000 and 43,000 (Dutton et al. 1999). The current population is thought to be declining as major nesting colonies have declined in the last 20 years, although an increase in leatherbacks nesting in Florida has been reported in the last few years (Dutton et al. 1999). Despite its patchy worldwide distribution and in contrast to other sea turtles, adult leatherbacks are regularly sighted in the waters off Nova Scotia and Newfoundland from June to October (with peak abundance in August), where they likely come to feed on jellyfish, their primary prey (Bleakney 1965; Cook 1981; 1984). The scattered nature of the data make estimating the number of turtles in the Canadian Atlantic difficult. However, the North Atlantic Leatherback Turtle Working Group (NALTWG), created in 1997, is currently conducting research on the distribution and abundance of the leatherback. Apparently, more leatherbacks visit waters near the Study Area than was once believed (M. James, pers. comm.). An adult male that was satellite-tagged in waters near Cape Breton Island, Nova Scotia in early September 1999, travelled to Placentia Bay, Newfoundland by the end of the month before migrating south to warmer waters. Data from the US pelagic longline fishery observer program have also 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.

The apparent common northerly occurrence of this species compared to other sea turtles may be attributed to an ability to maintain body temperatures of 25ºC in sea water as much as 18ºC cooler. An adult was even observed by fishermen in Trinity Bay, Newfoundland swimming amongst ice (Goff and Lien 1988). Twenty leatherbacks were reported off Newfoundland between 1976 to 1985, 14 were entangled in fishing gear (Goff and Lien 1988).

Little is known about the biology of the leatherback. It nests from April through November in the tropics along sandy beaches. Females deposit an average of five to seven nests per year, with clutch size averages varying geographically (Plotkin 1995). Nothing is known about the behaviour or survivorship of post-hatchlings. Loss of nesting habitat due to development and erosion, predation by animals, and poaching of adults and eggs for consumption inhibit the recovery of this species. Ingestion of plastic materials, which leatherbacks presumably mistake for jellyfish is common and can be fatal. The loss of individuals (primarily through net entanglement) in the Canadian Atlantic is not known to critically contribute to population decline (Cook 1981).

3.2.6.2 Loggerhead Turtle

This species is the most abundant sea turtle in North American waters (Ernst et al. 1994; Plotkin 1995). The loggerhead turtle winters in the south, but some individuals migrate north into the Canadian Atlantic with the Gulf Stream in summer (Cook 1984). An estimate of the population size in the Study Area is unavailable; however, loggerheads are thought to occur in these waters during summer and fall. Loggerheads found in Canadian waters are generally smaller than those found in coastal US waters, indicating that they are younger animals (Witzell 1999).

Loggerhead turtles apparently dwell in both coastal and offshore waters but generally associate with convergence zones, drift lines and downwellings (Carr 1986). Continental shelf waters are believed to be important because they contain known loggerhead prey like crabs, molluscs, sea pens and various gelatinous organisms (Payne et al. 1984). Loggerheads also eat algae and vascular plants (Ernst et al. 1994). Data from the US 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 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.

There is no worldwide population estimate for this species, but numbers of loggerheads outside of the US are declining (Plotkin 1995). The North American population, which is also thought to be declining, has been estimated to number between 9,000 and 50,000 adults (Ernst et al. 1994). It has been estimated that 5,000 to 50,000 loggerheads are killed annually by offshore shrimp trawls in the southeastern U. and the Gulf of Mexico (Magnuson et al. 1990).

The loggerhead turtle may achieve sexual maturity at an age of 30 to 50 years and one of the largest breeding aggregations is found on the central Atlantic coast of Florida (Magnuson et al. 1990). In fact, 90 percent of females nesting in the Atlantic do so in the southeastern US in what appear to be demographically independent groups (based on mitochondrial DNA haplotype distributions) (Encalada et al. 1998). Most females nest from three to five times in a season and average clutch sizes are between 95 to 150 eggs per nest (LeBuff 1990).

3.2.6.3 Kemp's Ridley Turtle

Kemp's ridleys are the smallest (40 to 50-kg) and rarest of all sea turtles within the Newfoundland area (Cook 1984). These turtles apparently prefer shallow water and while adults rarely range beyond the Gulf of Mexico, juveniles have been sighted along the southeast coast of Newfoundland near St. Mary's Bay and along southern Nova Scotia (Ernst et al. 1994). However, the number of Kemp's ridley turtles that may visit the Study Area is unknown. They apparently prefer shallow water and feed primarily on crabs, but occasionally they eat molluscs, fish, shrimp and vegetation (Shaver 1991).

This species has a very restricted nesting range, with 95 percent of nests laid along a 60-km stretch of beach in Rancho Nuevo, Mexico. The number of females nesting there declined from as many as 40,000 over 50 years ago to approximately 700 in the late 1980s, but saw a steady increase in the 1990s as a result of conservation measures (Marquez et al. 1999). It is unknown how long this species lives or at what age it reaches sexual maturity. More than half of the adult females nest every year between April and August (NRC 1990). They lay an average of 3.1 clutches per season, with an average of 103 eggs per clutch (Rostal 1991). After a 48 to 65 day incubation period, eggs hatch and hatchlings head for the sea (Mager 1985). Both eggs and hatchlings are very vulnerable to predators like ghost crabs, coyotes and hawks (Plotkin 1995). Of greater concern is the incidental capture of turtles in shrimp trawls, despite efforts to deter turtles from areas where trawls are in use.

3.2.6.4 Planning Implications

The existing database for the Study Area is insufficient to identify specific areas and times of key importance to sea turtles, which contain a number of species that are of international concern and are listed by various organizations as threatened or endangered.

There are few reports of sea turtles in the Study Area but few if any directed surveys have been done. It is safe to conclude that they warrant consideration because of their endangered status but that both turtles and data are so scarce for the Study Area, it is unlikely that they would be featured in any strategic plan in the near future. However, sea turtle sightings should be recorded during the required monitoring surveys for seabirds or marine mammals.

3.2.7 Species at Risk

Special consideration must be given to species included under the *Species at Risk Act* (SARA) that was promulgated by the Canadian government on 5 June 2003. As discussed previously, 'Species at Risk' are those species defined as threatened or endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Study Area likely contains some species of threatened or endangered fish, sea turtles and marine mammals. Potential species include

- Blue whale (*Balaenoptera musculus*)
- North Atlantic right whale (*Eubalaena glacialis*)
- Northern bottlenose whale (*Hyperodon ampullatus*)
- Leatherback sea turtle (*Dermochelys coriacea*)
- Atlantic cod (*Gadus morhua*)
- Northern wolffish (*Anarhichas denticulatus*)
- Spotted wolffish (*Anarhichas minor*)
- Cusk (*Brosme brosme*)

The Ivory gull (*Pagophila eburnea*) is presently under consideration as threatened or endangered by COSEWIC (B. Mactavish, LGL Limited, pers. comm.).

3.2.8 Special Areas

Special areas are rare or unique habitats that may contain concentrations of VECs and/or sensitive life stages of VECs. Known or suspected special areas near and adjacent to the Study Area include: the IBAs (eight just to the west of the Study Area, Figure 3.25), Eastport, Bonavista Bay (being considered by DFO as a Marine Protected Area or MPA under the *Oceans Act*), the shelf breaks and the outer edge of the Labrador Current, the Bonavista Corridor or 'Box', important fisheries areas (see Section 3.2.8.2 below), and potentially some areas of abyssal waters including perhaps Orphan Knoll itself.

3.2.8.1 Notable Reports/Projects

There is presently an Environmental Studies Research Fund (ESRF) study being conducted by DFO that will develop maps of spawning areas on the Grand Banks of Newfoundland. Data used to create these maps originate from DFO research vessel surveys. Species that will be included in this atlas include Atlantic cod, haddock, redfish, lumpfish, American plaice, Greenland halibut, witch flounder, yellowtail flounder, Icelandic scallops, northern shrimp, sea scallops and surf clams (S. Kuehnemund, DFO Habitat Evaluation Biologist, pers. comm.).

Another relevant DFO document that was just completed is entitled "Spatial analysis of 18 demersal species in relation to petroleum license areas on the Grand Bank (1980-2000)" (Kulka et al. 2003). The report contains maps that show the distributions and abundances of 18 demersal species in the southern portion of the Study Area (note that the technical report's study area only extends as far north as 49ºN).

3.2.8.2 Potential Fishery 'Hot Spots'

This section lists areas of concentrated fisheries and potential spawning areas and times.

3.2.8.2.1 Commercial Fishery Data

Inner 3L (<200-m) – This is an important area for snow crab harvesting. Snow crab rank first overwhelmingly in Newfoundland landings value in the Study Area between 1998 and 2002.

Inner 3L (200 to 1,000-m) – This is an important commercial fishing area, particularly for Greenland halibut and roughhead grenadier. Between 1998 and 2002, there were also areas of relatively concentrated fishing effort for northern shrimp (200 to 400-m), American plaice (towards 400-m isobath) and redfish (towards 400-m isobath).

Bonavista Corridor (straddling southwestern 3K and northwestern 3L; approximately 49ºN to 50ºN, 49.5 ºW to 51.5ºW; depth ranges from ~ 200-m to ~ 1,000-m) – This area has been identified by DFO as a spawning and migration area for 'northern' cod, and may potentially be closed to trawling in the near future. It is also known as one of the two 'cod boxes', the other being in Hawke Channel to the north in NAFO Division 2J. Commercial species that showed concentrated catches in this area between 1998 and 2002 included northern shrimp and Greenland halibut. Bycatch species that were taken in this area during the same period included Atlantic cod and wolffish.

Outer 3L (Flemish Pass) and 3M (Flemish Cap) – These are important commercial fishing areas for northern shrimp, Greenland halibut, roughhead grenadier and redfish. Most of the recent catches of these species reported in the NAFO Fishery Statistics were landed somewhere other than Newfoundland and, therefore, were most probably caught near and outside the EEZ. Considering that northern shrimp and Greenland halibut rank second and third in Newfoundland landings value in the Study Area over the 1998 to 2002 period, the areas where the non-Newfoundland landed catches are made are likely important to foreign fishing interests.

Inner 3K (~ 200-m to ~ 400-m) – This area is most important in a commercial fishing sense to the harvest of snow crab and northern shrimp.

Intermediate 3K (~ 400-m to ~ 1,000-m) – Based on Newfoundland commercial landings data, this slope region is habitat for Greenland halibut, American plaice, witch flounder, redfish, roughhead grenadier, wolffish, and skate.

Outer 3K (~ 1,000-m to >4,000-m) – This region is essentially one large data gap in terms of commercial fish and invertebrates. Large pelagic fish (tunas and swordfish) are caught in the most offshore areas of NAFO Division 3K but most of the reported catch positions are outside of the Study Area.

3.2.8.2.2 Important Fish Spawning Areas and Times

Important Fish Spawning Areas and Times as defined by Fitzpatrick and Miller (1979) are provided below.

Inner 3L (<200-m) – American plaice (April and May), witch flounder

Inner 3L (200 to 1,000-m) – American plaice (May), redfish (May and June), witch flounder

Bonavista Corridor (straddling southwestern 3K and northwestern 3L; approximately 49ºN to 50ºN, 49.5ºW to 51.5ºW; depth ranges from ~ 200-m to ~ 1,000-m) – Atlantic cod (spring), American plaice (May), redfish (May)

Outer 3L (Flemish Pass) and 3M (Flemish Cap) – American plaice (April to July), redfish (April to June)

Inner 3K (~ 200-m to ~ 400-m) – Atlantic cod (March to May), American plaice (May to June), redfish (May), witch flounder

Intermediate 3K (~ 400-m to ~ 1,000-m) – Atlantic cod (March to May), American plaice (May to June), redfish (May to June), witch flounder

Outer 3K (~ 1,000-m to >4,000-m) – This region is essentially one large data gap in terms of spawning by invertebrates and finfish.

3.2.9 Data Gaps

3.2.9.1 Plankton

There are important data gaps on plankton concerning their distribution in time and space, particularly in the northern and eastern portions of the Study Area. The key data gap is where the areas of enhanced production and/or concentrated biomass coincides with important feeding areas for fish, seabirds and marine mammals.

3.2.9.2 Benthos

The key data gap is that there have been few, if any, benthic community studies in the Study Area. As a result, there is no information on where sensitive species or habitats occur. In exploration drilling programs where there has been no previous activity, the operators have been required to collect benthic data prior to the commencement of drilling activities. Depending on the nature of drilling activities, operators may be required to collect benthic invertebrate data in the Orphan Basin Study Area.

3.2.9.3 Fish and Fisheries

There are key data gaps on sensitive areas and times such as any concentrated areas of spawning and/or migration. The ongoing DFO ESRF study may address this gap to some extent.

3.2.9.4 Seabirds, Marine Mammals and Turtles

Other than listings of occurrence of seabird, marine mammal and sea turtle species, relatively few quantitative data exist for these animals in the Orphan Basin Study Area. Most available data (e.g., OLABS) are over 20 years old. While designed surveys are occasionally conducted to assess some seal populations in these waters, most of the other available data for marine mammals and sea turtles in the

Study Area are incidental in nature. The most repetitive data collection at present is probably that being conducted by observers from drilling rigs operating in the Newfoundland and Labrador offshore area.

For most exploration, delineation and production drilling operations, the Board has required that seabird and whale monitoring from drilling rigs be undertaken by the operator during the drilling program. For seismic programs, it has been a requirement in recent years to conduct marine mammal monitoring for all seismic programs in the Newfoundland and Labrador offshore area. Therefore, it is not unforeseen to anticipate that the Board will make seabird and marine mammal monitoring a requirement of exploration drilling programs in the Orphan Basin area, in addition to marine mammal monitoring for seismic programs.

4.0 Environmental Effects of Exploration Activities

4.1 Scoping

Scoping for this SEA was conducted in the following manner.

- Previous EAs (e.g., Hibernia, Terra Nova, and White Rose) and associated regulator/public comments were reviewed.
- Previous SEAs (e.g., Laurentian Sub-Basin, Scotia Shelf) were reviewed.
- Draft Scoping Document was prepared and submitted in April 2003 for review by regulators.
- Scoping meeting was held in June 2003 with regulators (C-NOPB, Department of Fisheries and Oceans, Environment Canada) and stakeholders (Natural History Society, Canadian Parks and Wilderness Society, Newfoundland and Labrador Department of Fisheries and Aquaculture, Newfoundland and Labrador Department of Mines and Energy).

Some general issues in regard to offshore oil and gas development in Newfoundland and Labrador waters include

- 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 nine specific issues are relevant for the Orphan Basin Study Area:

1. **Marine mammals and noise.** Parts of the Study Area are likely to be important feeding areas for cetaceans (e.g., areas of upwelling).
2. **Effects on finfish and fisheries from noise disturbance (e.g., Bonavista Corridor).**
3. **Disturbance of harp seal pupping and whelping areas**. The 'front' may occur in part of the Study Area.
4. **Effects on shrimp and snow crab fisheries.** The southern part of the Study Area is an important area for the crab fishery, which is the most lucrative fishery in the province. Shrimp are also an important species in the area, including significant catches in international waters.
5. **Effects of seabirds.** The southwestern part of the Study Area is likely an important feeding area for some of the world's largest bird colonies (e.g., Funk Island).

6. **Ecosystem effects.** There will be an increased attention to ecosystem effects because of the likely presence of upwelling areas.
7. **Deep sea fauna.** A large part of the Study Area is in very deep water (as deep as 4000+ m). Relatively little is known about the communities at these great depths. In some offshore areas of the world, deep sea corals are of great concern; in other areas, highly specialized communities (e.g., chemosynthetic ones) are of great concern.
8. ***Species at Risk Act (SARA).*** Special consideration must be given to threatened and endangered species, such as Atlantic cod.
9. **Data gaps.** With the possible exception of fishery statistics, there is a general paucity of data for much of the Study Area, particularly in regard to marine mammals and 'underexploited' fishery species (e.g., in very deep water).

Offshore oil and gas activity has been ongoing at least since the 1940s and thus most environmental effects are reasonably well known, either through direct study or deductive reasoning. Focus should be on such sources as noise, drilling fluids and cuttings, attraction of animals, discharges, and accidental events.

Important potential interactions have been identified in the following sections. Potential effects of seismic surveys and exploration drilling are presented and discussed. Potential mitigations are discussed as appropriate.

4.2 Seismic Surveys

The offshore oil and gas industry uses seismic exploration techniques to evaluate the geology that underlies the sea. These techniques involve beaming powerful sounds into the ocean bottom and monitoring the return patterns. Incidentally, large amounts of energy (noise) enter the water column where marine animals live. There is a concern that these animals may be negatively affected by this energy.

4.2.1 Typical Equipment and Activities

4.2.1.1 2D and 3D Seismic Surveys

A 2D seismic survey typically covers a much larger area than a 3D seismic survey. Survey lines in a 2D seismic survey tend to be much further apart (rarely closer than 1-km), and often are laid out in a number of different directions. The information that can be extracted from a 2D seismic dataset is much more limited than that available from a 3D seismic survey. However, the 2D seismic is appropriate for exploring large areas relatively inexpensively with the intent of identifying areas that warrant further exploration, perhaps the drilling of an exploration well or acquisition of a 3D survey.

The major difference between 2D and 3D seismic surveys is one of sampling. The 3D dataset provides information about the sub-surface on a very tight grid, usually 25-m in each direction, while 2D data provides information every 25-m in one direction but rarely less than every 1-km in the other, leaving it entirely speculative as to what lies between adjacent survey lines. Figure 4.1 illustrates this concept. The true sub-surface structure is shown in Panel A. The sub-surface structure that might be interpreted from a 2D survey with adjacent line separation of 800-m is represented in Panel B by the dashed line. The small geological feature in the centre is missed entirely. Panels C through G show how the interpretation of the sub-surface structure changes when the spacing between survey lines is decreased from 400-m to 25-m, the latter being what is typically realised with a 3D survey. Clearly, the subtleties of the structure are better imaged with decreased distance between adjacent survey lines. This has important ramifications for planning the development of an oil and/or gas field.

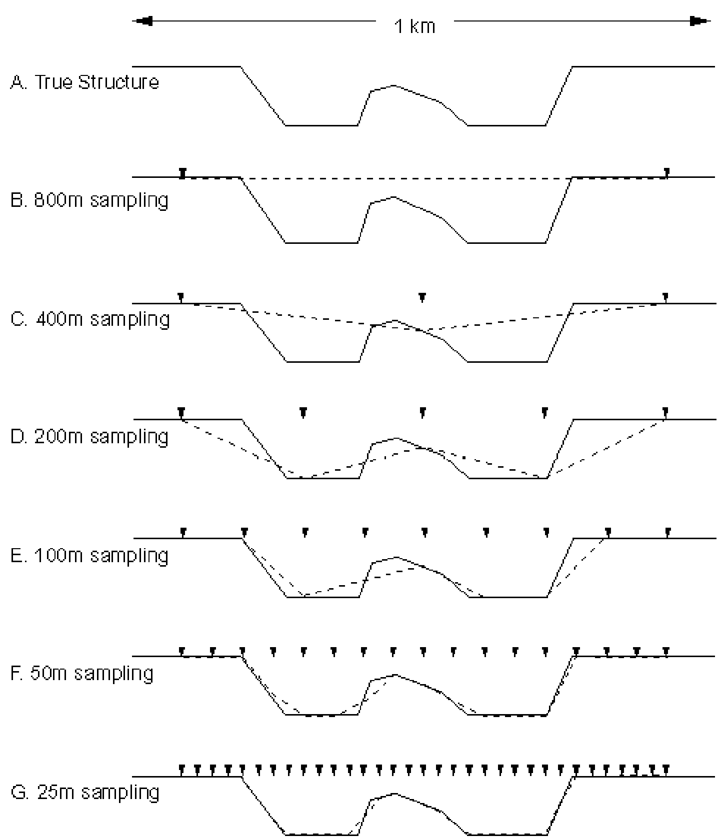


Figure 4.1 Schematic Showing the Increased Precision Resulting from Closer Spacing of Seismic Survey Lines Associated with 3D Surveys (from Davis et al. 1998).

In addition to the simple issue of sampling, much more sophisticated data processing can be applied to 3D datasets than can be applied to data collected from 2D seismic surveys. The more sophisticated data processing provides better resolution and, consequently, gives geoscientists and engineers a clearer insight into the distribution of a reservoir.

In areas where hydrocarbons are known to exist in economic quantities, it is usually cost-effective to acquire a 3D seismic survey prior to the design and construction of production facilities. A 3D seismic survey provides a detailed 'picture' of the sub-surface, allowing the geoscientists and engineers to make realistic estimates of the amount and distribution of hydrocarbons within the reservoir. This knowledge allows for better planning of the locations and numbers of production wells and platforms.

Modern vessels conducting 3D marine seismic surveys using the streamer method are 80 to 95-m in length and have a crew of about 40 people. The vessels are capable of traveling at about 14 knots (26-km/h) while in transit with no equipment deployed. When surveying equipment is in the water, vessel speed must be no less than 3.5 knots (6.5-km/h) and no more than 5.5-knots (10-km/h) in order to avoid damage to the towed equipment.

Seismic vessels towing streamers have very limited manoeuvrability when the equipment is deployed. They require a minimum of 45 minutes to safely execute a 180° turn, and cannot change course faster than 5° per minute. Deployment and retrieval of the equipment is a very time consuming process, one that cannot be accomplished safely when wave heights exceed 3-m. Retrieval of the equipment in good weather conditions can be accomplished in about 12 hours, but more often requires a minimum of 24 hours. Deployment of the equipment takes a minimum of 24 hours, and sometimes several days. If sea conditions are expected to reach and remain above Sea State 6 (Beaufort Force 9 winds) for more than 24 hours, it is likely that the in-sea equipment will be retrieved.

Seismic surveys can only identify potential hydrocarbon bearing formations. The formation can contain, oil, gas, water or hydrocarbons in less than commercial quantities. Once a potential formation is identified, exploration drilling is used to determine the nature of the formation. If the formation appears to be a good prospect, then delineation drilling and 3D seismic is used to determine the extent of the formation.

Seismic is sometimes conducted in areas where it has been done before. In some cases, a 3D survey may be needed in an area where a 2D survey was conducted. In other cases, data collected using old analogue equipment (mechanical pen on graph paper) needs to be redone using high- resolution digital acquisition and processing equipment.

Vertical Seismic Profiles (VSPs) are typically acquired during drilling using a cluster of medium-sized airguns with a total volume of 450-1500-cu in. The depth of penetration required for a VSP is similar to that required for conventional 2D and 3D surveys, however, during a VSP, the detectors are deployed in the well-bore (relatively quiet environment) and the seismic sound waves must travel in only one direction through the earth before being recorded. These two factors allow sufficient data quality to be achieved with a significantly smaller source than is required for 2D and 3D seismic survey operations.

4.2.1.2 Equipment

Marine seismic surveys are carried out using high-pressure "airguns" for the sound source. The airguns are grouped in subarrays that contain 4 to 8 airguns, usually operating at 2,000 psi (Davis et al. 1998; Caldwell et al. 2000; IEG 2001). Airguns can range from 30 to 800-in^3 in size (Caldwell et al. 2000). Arrays can total 8,000-in^3 (Caldwell and Dragoset 2000). Typical arrays are about 2,000 to 4,000-in^3 and contain 12 to 48 airguns (Davis et al. 1998; Caldwell and Dragoset 2000) (Figures 4.2 and 4.3).

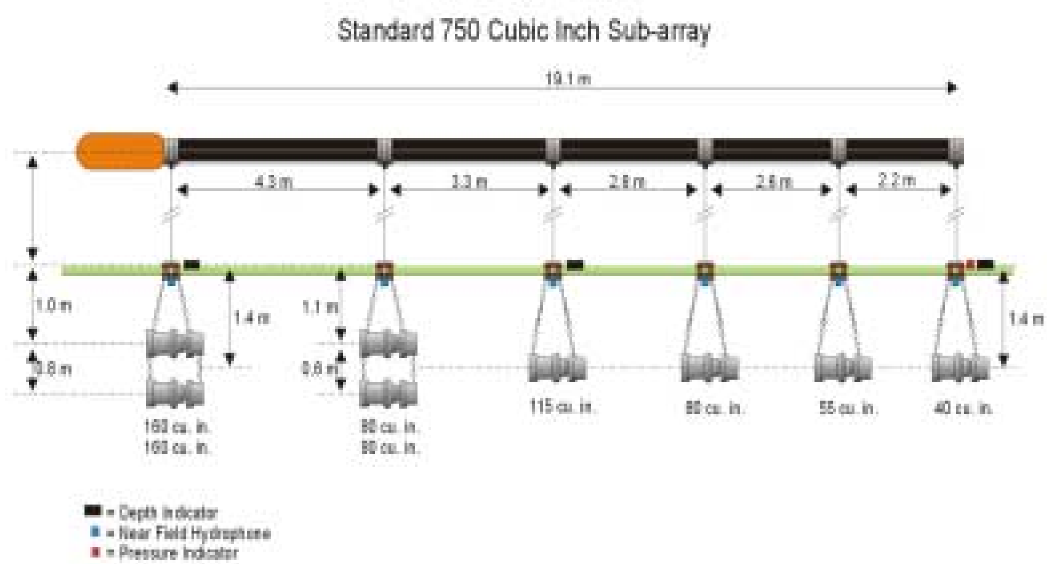


Figure 4.2 Layout of Airguns in 750-in^3 Sub-array Proposed for Use in the Canadian Beaufort Sea During Summer 2001/2002 (from IEG 2001).

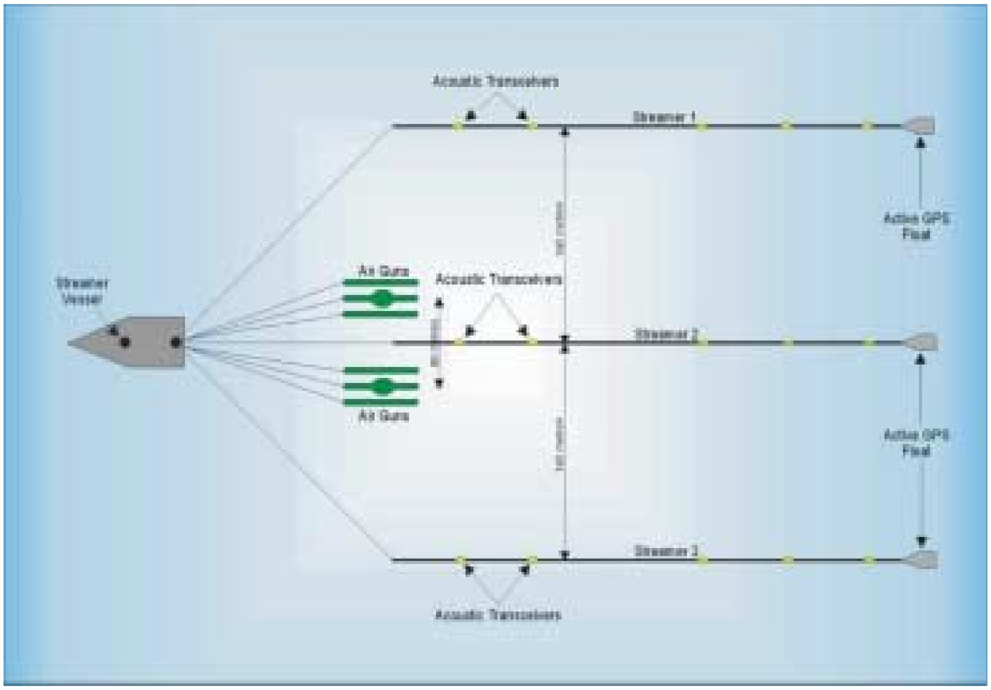


Figure 4.3 Configuration of the 2250-in^3 Array and Streamers Proposed for Use in the Canadian Beaufort Sea During Summer 2001 (from Western Geco 2001).

During a 3D survey, the returning signals (echoes) are recorded, during typical streamer surveys, by almost 3,000 hydrophones (microphones) that are towed behind the survey vessel. For typical operations, the seismic vessel tows 8 streamers. Each streamer is 4 to 6-km long with several hundred hydrophones spaced 10 or so metres apart. The streamers are towed at a water depth of 7 or 8-m, and they are about 100-m apart; thus, the swath of towed equipment can be ~700-m wide.

The location of the hydrophones at any time can be determined using sophisticated positioning equipment (which includes magnetic compasses, acoustic pingers and GPS units), but cannot be controlled. The position and shape of the streamers behind the seismic vessel is strongly dependent upon currents, and at times, the farthest hydrophone may be more than 1.5-km to the side of the vessel track.

During 2D marine seismic surveys, the survey vessel tows a single streamer of between 4,500 and 6,000-m in length. Recovery and deployment of the 2D seismic equipment can normally be accomplished in 12 hours or less. Specific site survey operations require that the survey vessel tow a single streamer of 300-1,200-m at about 3-m depth.

For vertical seismic profile (VSP) operations, no streamer is deployed.

4.2.1.3 Characteristics of Seismic Noise Sources

An airgun array is towed behind the boat at a depth of 6-m. Airguns typically are fired every 25-m, or about once every 10-sec. For 3D seismic programs, the zero-to-peak overall source level of the array is about 64 bar-m (256 dB re 1 µPa $_{0\text{-}p}$ at 1-m) or 128 bar-m peak-to-peak (262 dB re 1 µPa -$m_{p\text{-}p}$) in the downward direction. This is approximately equivalent to an overall broadband rms source level of 246 dB re 1 µPa and a sound exposure level (SEL) of 236 dB re 1 µPa (see following sections for discussion of different forms of sound level presentation). Because the array is configured to focus sound toward the bottom, effective source levels for propagation in the horizontal direction are lower than those straight down from the array.

4.2.1.4 Vertical Seismic Profiles

Vertical Seismic Profiles (VSPs) are typically acquired using a cluster of medium sized airguns with a total volume of 450-1500-cu-in and a peak pressure output of ~240-250 dB re 1µPa at 1-m. The depth of penetration required for a VSP is similar to that required for conventional 2D and 3D surveys.

The degree of complexity for VSPs can vary significantly, with the total number of shots taken ranging from a few hundred to tens of thousands. Thus, the time taken to acquire a VSP can range from 24 hours to more than a week. The airgun cluster may be deployed from the drilling platform itself and remain in one place while the VSP is acquired, but in other cases, the source may be deployed from a vessel and fired in a pattern all around the drilling platform but rarely more than 500-m away.

4.2.1.5 Underwater Sound and its Propagation

Noise levels produced by human activities in air and underwater are determined by their acoustic power output and by the sound transmission characteristics of the local area. A given noise source operating in different areas, or in the same area at different times, may be detectable for greatly varying distances, depending on regional and temporal changes in sound propagation conditions among other considerations. Similarly, a moderate-level source transmitting over an efficient path may produce the same received level at a given range as a higher-level source transmitting through an area where sound is attenuated rapidly.

The following discussions of sound characteristics and propagation deal primarily with underwater sound sources.

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

Most treatments of the effects of underwater noise 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 typically decreases with increasing distance from the source. The ***receiver*** of these sounds is generally 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 noise in the sea around the receiver.

Underwater ambient noise, if sufficiently loud, may prevent a marine mammal from detecting another sound through a process known as masking. Masking can occur as a result of either natural sounds (e.g., during periods of strong winds or near surf zones) or anthropogenic sounds (e.g., shipping noise). The sea is a naturally noisy environment that can "drown out" or mask weak signals from distant sources, even in the absence of anthropogenic sounds.

4.2.1.6 Acoustic Concepts and Terminology

Humans and other animals hear sounds with a complicated non-linear type of response. To a first approximation, the ear responds logarithmically rather than linearly to received sound. Hence, 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), defined as follows:

$$\textit{Sound Pressure Level (SPL)} = 20 \log (P/P_o)$$

where P_o is a reference level, usually 1 μPa. The reference level needs to 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 source. A source level is generally expressed as the SPL 1-m from the source. If the source is large (i.e., not a point source), as is the case 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 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). The peak positive pressure, usually called the peak or zero-to-peak pressure (0-p), is approximately half the peak-to-peak pressure. Therefore, the difference between the two is approximately 6 dB. The average pressure recorded during the pressure pulse can be expressed as the root mean square (rms) or average pressure. The rms pressure is usually determined by "averaging" over the duration of the pulse, and 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; Greene et al. 2000). To compare pulses of various types, sound pressure can be integrated over a standard unit of time, usually 1 second, to obtain the Sound Exposure Level (SEL). The SEL is typically 20 to 25 dB below the zero-to-peak pressure and 10 to 15 dB below the rms pressure (Figure 4.4).

An understanding of these different methods of expressing sound pressure is necessary because one needs to compare different measures of sound pressure reported in the literature and understand the different kinds of effects related to different aspects of a sound pressure wave. Severity of physical damage is often related to peak pressure. Much of the literature relating to the potential effects of sound on fisheries expresses sound levels as peak pressures. However, some criteria for marine mammal impacts are expressed on an energy basis or as Sound Exposure Levels (SEL), which are equivalent (e.g., Lazauski et al. 1999). Most reports on the effects of sound on marine mammals express sound as average (rms) pressures (Richardson et al. 1995).

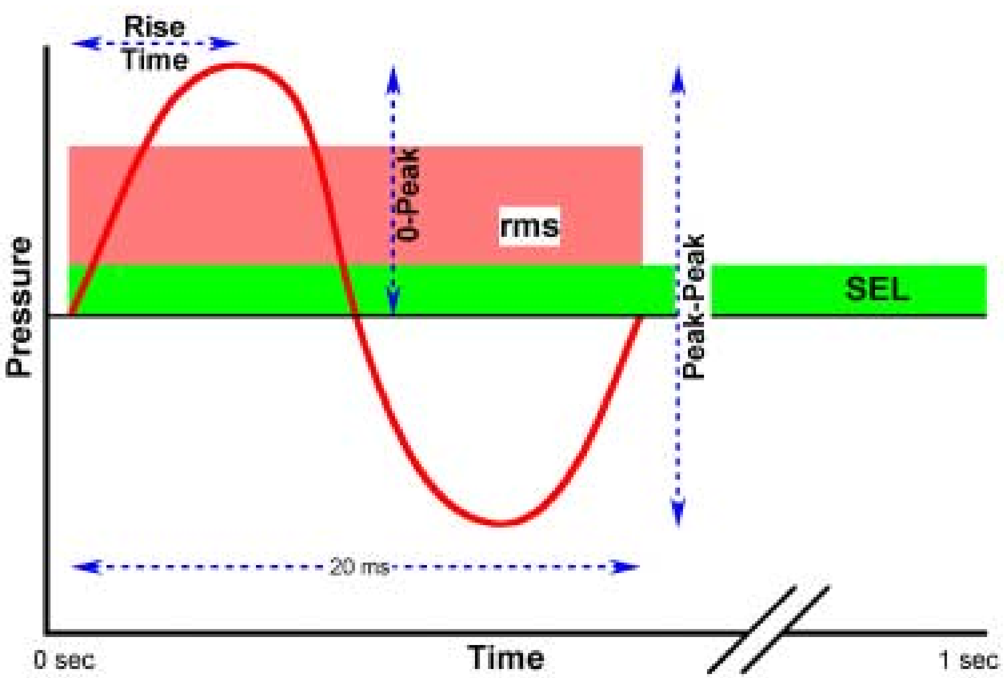


Figure 4.4 Terminology Used to Describe Sound Pressure Levels in an Acoustic Impulse.

Peak pressures should only be compared among similar sources. Physical damage is due to both the peak pressure and the rise time. The rise time is the amount of time required for a sound pulse to reach peak pressure from the zero (baseline) pressure. For example, a human diver can easily sustain an overall change of five atmospheres (515,000 Pa, 234 dB re 1 µPa) during a slow descent, but this is likely not the case for a similar pressure change during a much shorter period.

Sound measurements are often expressed on a broadband basis (i.e., 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 of sound 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, known as a sound spectrum. 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).

4.2.1.7 Propagation Path

The pressure of a sound pulse diminishes with increasing distance from the source (R). Most of the loss in pressure is due to spreading (Figure 4.5). The diminishment of pressure with increasing distance from the source is spherical to a distance that is approximately equivalent to the water depth. The loss in sound pressure resulting from spherical spreading is expressed as follows:

$$20 \log R \text{ dB}$$

When spherical spreading is occurring, the transmission loss is 6 dB with each doubling of the distance. That is to say, pressure decreases by one half with each doubling of the distance. In shallow water at horizontal distances much greater than bottom depth (D), sound propagates through a channel bounded by the bottom and the surface. For hard-bottom regions spreading is approximately cylindrical, with loss in dB expressed as

$$10 \log R/D \text{ dB}$$

When spreading is cylindrical, the spreading loss is 3 dB with each doubling of the distance, or one half that of spherical spreading. 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 15 log R dB, 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.

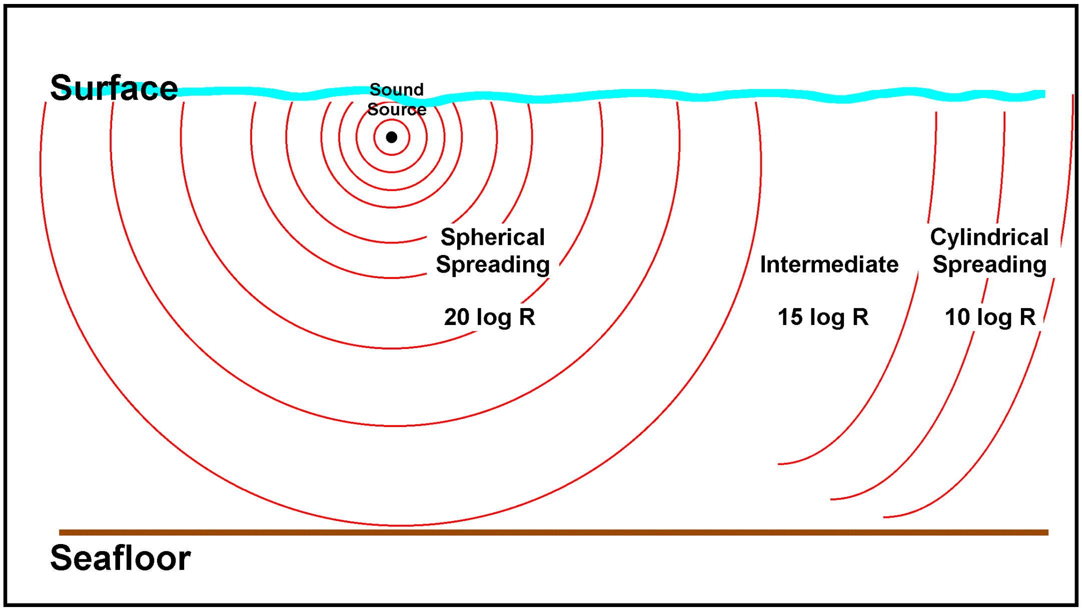


Figure 4.5 Schematic Representation of Acoustic Spreading Loss From a Sound Source as a Function of Distance and Interaction with the Seafloor.

In many cases, recorded and modelled spreading losses do not agree well with a simple spherical/cylindrical spreading model. The estimation of spreading is complicated by many factors. These include reflections from the surface and bottom and sub-bottom layers, absorption in the bottom and (at high frequencies) in the water itself, and differences in propagation for different sound frequencies. 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 (Richardson et al. 1995). In deep (and in arctic) water, sound speed often varies with depth in a way that causes sound waves to be channelled within the water mass, resulting in low propagation loss and propagation over long distances. Sound propagation characteristics may change as sound travels from a source in shallow water to a receiver in deeper water. 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 (Urick 1983; Richardson et al. 1995). These and other factors complicate the estimation of transmission loss and necessitate the use of sophisticated models.

Once source levels and propagation loss have been evaluated, the next step is to assess the effects of this noise 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 noise in the waters in which it is swimming. If background noise is high, then a source of anthropogenic noise will not be detectable as far away as would be possible under quieter conditions. Wind, thermal noise, precipitation, ship traffic and biological sources are all major contributors to ambient noise. However, ambient noise 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 noise source.

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

1. ambient noise 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 noise influence of generally decreasing size. The zone within which the received level from a particular source of anthropogenic noise 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 noise is the distance beyond which its received level falls substantially below the ambient noise level or the hearing threshold in all frequency bands. Once the noise falls substantially below ambient or below the hearing threshold, marine animals will not be able to detect sound from the anthropogenic sound source. Ambient noise 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 noise 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 noise. The latter is the zone, generally much smaller, within which the received sound level is higher and the animal might be detrimentally affected.

4.2.2 Interactions and Potential Effects

4.2.2.1 Fish and Invertebrates

Exposure to seismic pulses sometimes elicits behavioural reactions by some fish and invertebrate species but there is limited information in the literature on the effect of noise-induced behavioural changes on the overall well being of fish. Most of the existing information indicates that effects of noise on fish and invertebrate behaviour are transitory and inconsequential biologically. There is evidence indicating that seismic pulses emitted from airguns can damage the hearing organs of juvenile and adult fish as well as kill or harm eggs and larvae that are very near the seismic source. However, it is generally accepted that most juvenile and adult fish will demonstrate avoidance behaviour when exposed to seismic activity. One fish species of concern is the Atlantic cod, particularly the 'northern' cod stock that occurs in the Study Area. The 'northern' cod is now designated as 'endangered' by COSEWIC (2003) and is therefore a priority species under *SARA* (2003). The juveniles and adults of this species are not as susceptible to hearing damage compared to "hearing specialists", as its swim bladder is not connected to the inner ear (e.g., as in herring).

4.2.2.1.1 Behavioural Effects

Underwater noise fluctuation can alter the behaviour of some fish. Sudden changes in the ambient noise level can cause fish to alter swimming speed and direction. Various factors including the time of year, state of stomach fullness, and the nature of the sound, all may contribute to the nature of the reaction of fish to underwater noise.

Short, sharp sounds can startle herring. In one study, herring changed direction and moved away from the source, but schooling behaviour was not affected (Blaxter et al. 1981). The fish reacted to received sounds of 144 dB re 1 µPa at 80 or 92 Hz. However, when the sound level was increased gradually (ramped up), sounds needed to be 5 dB higher to elicit the same response. Schwarz and Greer (1984) studied the responses of penned herring to various sounds and noted three kinds of responses including a startle response and avoidance. Twenty five percent of the fish groups habituated to the sound of a large vessel and 75% of the responsive fish groups habituated to the sound of a small boat. Chapman and Hawkins (1969) also noted that fish adjust rapidly to high sound levels. Fish enclosed in a cage and exposed to seismic pulses swam faster and in tighter formation as the airgun source approached (McCauley et al. 2000). These reactions were observed at received sound levels above approximately 156-161 dB re 1 µPa (rms). Fish exposed a second time to the airgun source exhibited little or no behavioural response, which suggests either that there was some hearing damage or that fish habituated to the noise.

In the open sea, fish that are to the side of a boat will avoid the sound of a moving boat by swimming away from it or trying to outrun it (Misund et al. 1996; Misund 1997). Most schools of fish will not show avoidance if they are not in the path of the vessel. When the vessel passes over fish, some species, in some cases, show sudden escape responses that include lateral avoidance and/or downward compression of the school (Misund 1997). Avoidance reactions are quite variable and depend on species, life history stage, behaviour, time of day, whether the fish have fed recently, and sound propagation characteristics of the water (Misund 1997).

Squid (*Sepioteuthis australis*) exposed to airgun pulses quickly changed direction away from the source of the disturbance and, in many cases, fired their ink sacs (McCauley et al. 2000). Firing of ink sacs was not evident if the array was ramped up rather than starting at full volume. Squid showed an increase in alarm responses above 156 dB re 1 µPa (rms). McCauley et al. (2000a) also carried out pilot scale studies on lobster and crab but only recorded visual reactions to the sound source; no strenuous analysis or experimental design was implemented in these studies.

Based on the above review, there could be behavioural effects on some fish within and near an area of seismic activity. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. Based on available literature, a 160 dB re 1 µPa (rms) sound level is used to assess disturbance effects. This is a conservative criterion; fish are unlikely to be displaced from this 160 dB zone. Based on the acoustic modelling results provided in the recent Marathon seismic EA (LGL et al. 2003), it is estimated that this sound level could occur at distances ranging from 3.3-12.4-km from the array. An area of 34 to 483-km^2 around the array would be ensonified by levels exceeding 160 dB re 1 µPa (rms) depending on location and season.

As mentioned, certain populations of Atlantic cod have been designated as endangered by COSEWIC, including the ‘northern’ cod that occur in the Orphan Basin Study Area. Within the western part of Study Area is the ‘Cod Box’ known as the Bonavista Corridor. Rose (1993) reported both spring and fall migratory behaviour and spring spawning behaviour by Atlantic cod in this ‘Cod Box’. Considering the current state of this particular Atlantic cod stock, the Bonavista Corridor could be critical habitat for this stock.

There have been anecdotal reports in Newfoundland that northern shrimp react to seismic surveys by immediately moving away from the sound source. Depending on the depth of water and the location of the shrimp school in the water column, this sonar-detected movement is either downwards or across the water column (H. Thorne, commercial fisherman, pers. comm.).

As part of a 2002 ESRF study of the effects of seismic energy on snow crabs, a short biotelemetry program was conducted to investigate the effects of seismic airgun noise on snow crab activity. The intention was to monitor the crab activity at an appropriate scale to determine decreased activity as well as movement out of an area. However, the only determination from the telemetry program was that most of the tagged animals did not leave the area immediately in response to seismic energy. The received sound levels (0-p) on bottom were approximately 170 to 180 dB re 1 µPa (Christian et al. in press).

4.2.2.1.2 Physical Effects

Juveniles and Adults

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that unlike the explosives formerly used, airguns do not generally kill fish. Various experimental studies showed that airgun discharges cause minimal fish kill and any injurious effects were generally limited to within a metre or so of the seismic source.

In a review of the subject, Turnpenny and Nedwell (1994) summarized the physical effects of seismic noise on fish as follows:

Effect	**dB re 1 µPa$_{0\text{-}P}$**
Transient stunning	192
Internal Injuries	220
Egg/larval damage	220
Fish mortality	230-240

Exposure to continuous sounds of 180 dB re 1 µPa rms for 1 to 5 hours at an individual frequency between 20 and 400 Hz can cause damage to the sensory hair cells that are the fundamental sound receptors in fish (Enger 1981; Hastings et al. 1996). Hastings et al. (1996) found that continuous exposure to 300 Hz sounds at this received level caused damage to the sensory hairs. There was no damage to the lateral line or to other hearing structures. Exposure to sounds at 60 Hz or to pulsed sounds (20% duty cycle) of 180 dB re 1 µPa for 1 h did not have this effect. The effects of continuous noise on hearing are much stronger than are effects of short pulses such as seismic pulses. Data on the effects of continuous noise are not comparable to results based on pulsive sounds, such as seismic exploration. A typical airgun array produces a 20-ms pulse every 12 seconds (0.2% duty cycle). During a seismic program, the airgun array operates for an average of about 30 to 40% of the time. The array is towed at a speed of 6.5 to 10-km/h. Thus, a stationary fish would be exposed to high intensity sounds for only a few minutes during the execution of a particular seismic line assuming that it did not take evasive action as the array approached.

McCauley et al. (2003) found damage to fish hearing organs after exposure to seismic pulses (every 10 -seconds) from a single 20-in^3 airgun with a source level of 203 dB re 1 µPa (rms). Pink snapper (*Pagrus auratus*) held in cages were exposed to an airgun towed towards and away from the cage, mimicking the stimulus from a passing seismic vessel. Results showed extensive damage to the ears weeks after exposure (McCauley et al. 2003). Received seismic sounds ranged from approximately 140 to 182 dB re 1 µPa (rms). It is uncertain at what threshold level damage was incurred. Damage included “blebbing” on the epithelium suggesting mechanical damage or dying sensory hair cells and deep holes in the saccular epithelium in areas where sensory hair cells would be located. It was recognized that free-ranging fishes might swim away from seismic sound and hence, may not incur the same level of physical damage (McCauley et al. 2003). Any injurious effects on fish would likely be limited to short distances. Also, many of the fish that might otherwise be within the injury-radius are likely to be displaced from this region prior to the approach of the airguns through avoidance reactions to the passing seismic vessel or to the airgun sounds as received at distances beyond the injury radius.

No statistically significant higher levels of stress (cortisol hormone levels) were measured in fish exposed to seismic (McCauley et al. 2000). Santulli et al. (1999) did demonstrate that European sea bass (*Dicentrarchus labrax* L.) exhibited a biochemical stress response after exposure to seismic pulses from an 8-airgun, 2500-in^3 array. Biochemical parameters returned within normal levels within 72 h after exposure and no mortality was observed.

Damage to fish hearing is not likely to be an issue for mobile fish that avoid the array. Fish that are stationary by habit and territorial fish that do not avoid the array, such as some benthic species, will only be subject to high exposure levels during one or two passes of the seismic array and for only a brief period of time.

Given that fish probably avoid seismic noise, fish will likely not be exposed to levels of sound from the airgun array high enough to cause hearing damage. A received level exceeding 180 dB re 1 μPa (rms) is used as the criterion for assessing physical effects on fish (hearing damage). This is a conservative estimate considering that most literature indicates physical effects occur at much higher received sound levels. The mitigative measure of ramping up the airgun array should permit fish close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing damage. Therefore, there is little potential for fish being close enough to an array to experience significant hearing damage.

Eggs and Larvae

Falk and Lawrence (1973), Kostyuchenko (1973), Weinhold and Weaver (1982), Dalen and Knutsen (1986, 1987), and Holliday et al. (1987) all conducted studies in which fish eggs and larvae were exposed to pressure waves from an airgun. The resultant lethal received levels for eggs and larvae ranged between 226 and 234 dB re 1 μPa (0.6 to 3.0-m from source) (Turnpenny and Nedwell 1994; Vekilov et al. 1995; Gausland 2000). Larvae were damaged by airgun pulses (received level of 216 dB re 1 μPa rms) emitted within 5-m of the larvae (Kostyuchenko 1973).

Lethal effects of seismic on fish eggs and larvae remain a concern considering that they are unable to actively avoid the seismic source (Thomson et al. 2001). In a worst-case risk analysis, Sætre and Ona (1996) estimated total mortality from a 3D seismic survey on a typical larval population in Norway to be only 0.45% (0.1 to 0.5%) of the fish larvae (0.18% of the total population per day). However, natural mortality was estimated to be 5-15% per day for eggs and larvae, or 1-3% for fish fry and 0-age group. Therefore, the effects of seismic exploration on fish larvae were small, and impossible to differentiate from natural mortality (Sætre and Ona 1996; Thomson et al. 2001). Dalen et al. (1996), based on a review of the literature on seismic and fisheries, concluded that seismic operations may be safely conducted in larval drift areas.

The eggs and larvae of 'northern' cod, listed by COSEWIC as endangered and, therefore, a priority species under *SARA* occur in the 'Bonavista Corridor'. Based on available literature, the percentage of ichthyoplankton and benthic invertebrate larvae that would be affected by seismic would probably be well within natural mortality levels.

4.2.2.2 Fisheries

There is concern that seismic sound may displace commercial fish/invertebrate species away from fishing areas or that fish/invertebrate behaviour may change in such a way as to decrease their catchability. The results of experiments described below suggest that there could be reduced catchability for some commercial species during periods of seismic exploration.

Chapman and Hawkins (1969) tested the reactions of whiting (hake) in the wild to an airgun emitting low-frequency, high-amplitude pulses (220 dB re 1 µPa.m$_{0\text{-}P}$). The research vessel was anchored and the school of whiting was monitored with an echosounder. The airgun fired intermittently. Before the airgun was fired, the fish were at 25 to 55-m depth. In response to the sound pulses, the fish dove and formed a compact layer below 55-m water depth. By the end of an hour of exposure to the sound pulses, the fish had habituated; they rose in the water despite the continued presence of the sound pulses. The airgun was switched off and, when it resumed firing, the fish began to descend again. The habituation seems to have been of short duration. Assuming spherical spreading from the single airgun, received levels would have been 192 dB re 1 µPa at 25-m and 185 dB at 55-m.

Pearson et al. (1992) conducted a controlled experiment to determine the effects of airgun noise pulses on several species of rockfish off the California coast. The authors used an airgun with a source level of 223 dB re 1 µPa $_{0\text{-}p}$. They noted the following:

- Startle responses at received levels of 200-205 dB re 1 µPa and above for two sensitive species, but not for two other species exposed to levels up to 207 dB;
- Alarm responses at 177-180 dB for the two sensitive species, and at 186 to 199 dB for the other two species;
- An overall threshold for the above behavioural response at about 180 dB$_{0\text{-}P}$;
- An extrapolated threshold of about 161 dB for subtle changes in the behaviour of rockfish; and
- A return to pre-exposure behaviours within the 20-60-min exposure period.

The startle response was as noted above, but in some cases, fish also shuddered with each pulse.

In a concurrent experiment, Skalski et al. (1992) used a 100-in^3 airgun with a source level of 223 dB$_{0\text{-}P}$ re 1 µPa at 1-m to examine effects on catch per unit effort (CPUE) of rockfish. The ship with the airgun traversed the trial fishing area and then stood off while the fishing vessel deployed a set line, did three echosounder transects, and then deployed two more set lines, each for 20-min. Each fishing experiment lasted 1 h 25 min. Received levels at the base of the rockfish aggregations were 186 to 191 dB re 1 µPa $_{0\text{-}P}$. Skalski et al. noted that the catch per unit effort (CPUE) of rockfish declined by an average of 52.4% when airgun pulses were emitted. They believed that the reduction in catch resulted from a change in behaviour of the fish. The fish schools descended to near the bottom when the airgun was firing, and the fish changed their swimming and schooling behaviour. The fish did not disperse, but the authors hypothesized that dispersal could have occurred at a different location with a different bottom type.

Skalski et al. (1992) did not continue fishing after airgun firing ceased. They speculated that CPUE would return to normal quickly in their experimental area because fish behaviour returned to normal minutes after the sounds ceased. However, in an area where sound had caused the fish to disperse, a lowered CPUE might persist.

Rockfish generally remain in one place for a period of time and were not displaced by seismic sounds. Territorial rock reef fish off the coast of the UK did not leave their established territories despite being exposed to high received levels of seismic sounds (Wardle et al. 2001). Invertebrates also did not show any signs of moving away from the reef. Wardle et al. concluded that sounds from the seismic airguns had little effect on "…the day-to-day behaviour of the resident fish and invertebrates". Effects on catchability were not investigated. La Bella et al. (1996) used an 8-airgun, 2500-in^3 array to investigate the effects of seismic on main fishery resources of the Adriatic Sea. They concluded that "…no relevant effects are induced on fishery resources by seismic airgun shooting".

Løkkeborg (1991), Løkkeborg and Soldal (1993), and Dalen and Knutsen (1986) examined effects of seismic on catch of demersal fish such as cod and haddock. In general, there was a reduction of catch of some species within the survey area. Turnpenny and Nedwell (1994) examined results of these studies and the results of the studies on rockfish. They roughly estimated received sound levels at catch locations and estimated that catchability is reduced when received sound levels exceed 160-180 dB re 1 $\mu Pa_{0\text{-}P}$ and that reaction thresholds of fish without swim bladders, such as flatfish, would be about 20 dB higher. Given the variability in transmission loss in different areas, the sound levels that were actually received by the fish observed in these studies are not known.

The most comprehensive experiments on the effects of seismic on abundance and catch of cod and haddock were conducted in the Barents Sea by Engås et al. (1993, 1996). The exploration area was 3 x 10 nautical mile (n.mi.). in size at the centre of a 40 x 40 n. mi. (74 X 74-km) study area over water depths of 250-280-m. Airguns were fired for five days. Fish abundance was measured with longlines, trawls and echosounders for seven days prior to treatment, during the five days of treatment, and for five days after airgun noise ceased. Acoustic density of cod and haddock combined decreased over the entire study area by 45% during the experiment and 64% during the five-day period after airguns ceased. More than 90% of the trawl catch was cod. During shooting, catch in the experimental area decreased by 60%, and catch in the other areas (up to 18-km from the exploration area) decreased by 45 to 50%. Catch rates did not recover during the five-day period after the airguns stopped. For haddock, the trawl catch in the exploration area declined by 68% and that in other areas by 56 to 71%. The longline catch for cod declined by 45% in the exploration area, but the decline was smaller with increasing distance from the exploration area, with no reduction in catch at distances of 16 to 18 n. mi. from it. Catches increased after cessation of airgun releases. Declines in the longline catches of haddock were greatest in the exploration area and less so outside of the exploration area. The observed decrease in catch occurred immediately after shooting began. The change in fish distribution was so rapid that it was not observed in the overall catch data. No outward movement of large numbers of fish was detected. Engås et al. (1996) believed that there was no evident diminution of effect with increasing distance because the study area was too small. The results from this study are unique. There has not been other documentation of such major displacements of fish populations in relation to seismic exploration. It is not clear whether the study might have corresponded with a naturally occurring migratory movement of fish out of the study area.

Engås et al. (1996) did not measure received sound levels within their study area. Assuming simple spherical spreading to a distance equivalent to the depth and then cylindrical spreading and a factor for transmission loss, received levels at 18-km could have been about 167 dB re 1 µPa. However, given the kind of variability in spreading loss from area to area, it is not possible to estimate the actual received levels.

Turnpenny and Nedwell (1994) reported on the effects of seismic on inshore bass fisheries in shallow UK waters (5-30-m). They used tagged fish and catch records. There was no reduction in bass catch on days when seismic took place. Results of the tagging study showed no migration out of the area. The airgun array had a peak output of 250 dB re 1 µPa at 1m. Received levels in the fishing areas were estimated to have been 163-191 dB re 1 μPa_{0-P}. Turnpenny and Nedwell (1994) conclude that effects on fisheries would be smaller in shallow nearshore waters than in deep water because attenuation of sound is more rapid in shallow water than in deep water.

Only the study conducted by Chapman and Hawkins (1969) addressed habituation. They found that fish habituated to seismic sounds quickly over the short term. The other studies did not address long-term habituation. Only Chapman and Hawkins (1969) and Skalski et al. (1992) followed the behaviour of individual schools of fish. With the exception of the California studies of rockfish, investigators did not measure received noise levels. Thus, it is not possible to say, with any certainty, what sound levels could cause reduction in catchability of cod and haddock.

Anecdotal information from Newfoundland fishermen has indicated that there are perceived decreases in snow crab catch rates immediately following exposure to seismic survey activity (G. Chidley, commercial fisherman, pers. comm.) Another component of the 2002 Newfoundland study of the effects of seismic energy on snow crab attempted to focus on the effects of seismic on the catchability of snow crab using standard commercial fishery techniques (i.e., fleet of baited crab pots). Catch rate variability was high during each of the two fishing periods and no differences between pre-seismic and post-seismic catch rates were detected. The received sound levels (0-p) on bottom were approximately 170 to 180 dB re 1 µPa (Christian et al. in press).

4.2.2.3 Marine Mammals

Marine mammals rely heavily on the use of underwater sounds to communicate and gain information about their environment. Three types of effects are considered here: (1) masking, (2) disturbance (behavioural), and (3) potential hearing impairment and other physical effects. The reactions of marine mammals to noise can be variable and depend on the species involved, and the activity of the animal at the time of exposure to noise. Because underwater noise sometimes propagates for long distances, the radius of audibility can be large for strong noise. 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.

4.2.2.3.1 Masking Effects

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 amidst noise is important in communication, predator and prey detection, and in the case of toothed whales, echolocation. Marine mammals are adapted to cope with momentary 'masking' by natural sounds such as surf noise. Masking effects of seismic noise 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-sec. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 2000). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a recent study reports that sperm whales continued calling in the presence of seismic pulses (Madsen et al. in press). 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 strongest spectrum levels below 200 Hz and considerably lower spectrum levels above 1000 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.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, and even shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999; reviewed in Richardson et al. 1995b:233ff, 364ff). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, so it is not known whether these types of responses ever occur upon exposure to seismic sounds. If so, these adaptations, along with directional hearing and preadaptation to tolerate some masking by natural sounds, would all reduce the importance of masking.

4.2.2.3.2 Behavioural Effects

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 relative to potential impacts on marine mammals. For many species and situations, there is no detailed information about reactions to noise, including seismic pulses. 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 significant 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 significant.

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, bowhead whales and ringed seals. Data from less intensive studies are available for sperm whales and some other species of baleen and small toothed whales.

Baleen Whales

Migrating humpback, grey, and bowhead whales reacted to noise 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, 2000; Miller et al. 1999). Fin and blue whales have also displayed some behavioural reactions to airgun noise (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 become evident at somewhat lower received levels. Recent studies have shown that some species of baleen whales 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, 2000) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-gun 2678-cu in array, and to a single 20-in^3 airgun with source level 227 dB re 1 µPa-m (p-p). They found that the overall distribution of migrating humpbacks through their study 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 5-8-km from the array and those reactions kept most pods about 3-4-km 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. Mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1µPa 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, i.e. 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 5-8-km from the airgun array and 2-km from the single gun. However, some individual humpback whales, especially males, approached within distances 100 to 400-m, where the maximum received level was 179 dB re 1µPa 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. concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1µPa effective pulse pressure level.

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 kilometers. 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.

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.

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.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises 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 about reactions of toothed whales to noise 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.

Dolphins

Seismic operators sometimes see species of toothed whales near operating airgun arrays (e.g., Duncan 1985; Arnold 1996; Stone 1997, 1998, 2000, 2001). 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 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).

Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis*, of 2D seismic surveys in the Irish Sea. 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).

Observers stationed on seismic vessels operating off the UK in recent years have provided data on the occurrence and behaviour of various toothed whales exposed to seismic pulses (Stone 1997, 1998, 2000, 2001). Results were variable among species and years. However, dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Pilot whales have shown conflicting results. There have been no consistent trends in sighting rates from year to year during periods of seismic vs. non-seismic periods (Stone 2000). There is some evidence that pilot whales increase their swim speed, alter their course away from the seismic vessel, and tail slap during periods of seismic shooting (Stone 2000).

Observations of toothed whale responses to noise 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 noise 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 noise 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.

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. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001a). However, these vessels were not emitting airgun pulses.

Much attention has been given to a recent (September 2002) stranding of Cuvier’s beaked whales in the Gulf of California (Mexico) while a seismic survey was underway 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 noise thought to be in the best hearing range of toothed whales like the Cuvier’s beaked whale.

Sperm whales

All three species of 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 noise 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). Also, sperm whales in the Gulf of Mexico may have moved away from a seismic vessel (Mate et al. 1994).

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 2000, 2001). 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. However, the UK results do seem to show considerable tolerance of seismic surveys by at least some sperm whales. Also, a recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa p-p (Madsen et al., in press). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behaviour of sperm whales (McCall Howard 1999). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico is presently underway (Caldwell 2002).

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, show localized (~1-km) avoidance. In contrast, 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 noise from mid-frequency sonars. Whether they ever do so in response to low frequency seismic survey noise is unknown.

Pinnipeds

Few studies of the reactions of pinnipeds to noise 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 noise have also been observed during recent seismic surveys along the US west coast. Some limited data are available on physiological responses of seals exposed to seismic sound, as studied with the aid of radio telemetry. 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 exposed to noise 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 noise 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 and grey seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbour seals were exposed to seismic pulses from a 90-in^3 array (3 x 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 seismic 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 swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appear 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 individual 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 avoid 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 indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and 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 noise 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.

4.2.2.3.3 Physical Effects

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 Temporary Threshold Shift (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 US 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).

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater-pulsed 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.

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to days. The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals. TTS commonly occurs in mammals, including humans.

Toothed Whales

Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single one-second pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 μPa rms at 3, 10, 20, and 75 kHz. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited 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.

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 to 13 milliseconds (ms) in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received SPL (sound pressure levels) of 221 dB re 1 µPa produced no more than a slight and temporary reduction in hearing.

A similar study was conducted by Finneran et al. (2002) using an 80-in^3 water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses contain proportionally more energy at higher frequencies than do airgun pulses (Hutchinson and Detrick 1984). "Masked TTS" (MTTS) was observed in a beluga after exposure to a single impulse with peak-to-peak pressure of 226 dB re 1 µPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 µPa^2·s. Thresholds returned to within 2 dB of pre-exposure value approximately four minutes after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1 µPa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1 µPa^2·s (Finneran et al. 2000, 2002). In this study, TTS was defined as occurring when there was a 6-dB or larger increase in post-exposure thresholds; the reference to masking (MTTS) refers to the fact that these measurements were obtained under conditions with substantial background noise. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10-13-ms.

The data quoted above all concern exposure of small odontocetes to single pulses of duration 1-s or shorter, 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 studies 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 (approx. 221-226 dB p-p) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200-205 dB (rms) might result in 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.

Baleen Whales

There are no data on levels or properties of sound that are required to induce TTS in any baleen whale.

Seals

TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) have not been measured. For sounds of relatively long duration (20-22 minutes), Kastak et al. (1999) reported that they could induce mild TTS in California sea lions, harbor seals, and northern elephant seals by exposing them to underwater octave-band noise at frequencies in the 100-2000 Hz range. Mild TTS became evident when the received levels were 60-75 dB above the respective hearing thresholds, i.e., at received levels of about 135-150 dB. Three of the five subjects 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 TTS thresholds 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 TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999; cf. Au et al. 2000).

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are not as strong or consistent as those of cetaceans (see above). Pinnipeds occasionally seem to be attracted to operating seismic vessels. As previously noted, there are no data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. It is not known whether pinnipeds near operating seismic vessels, and especially those individuals that linger nearby, incur significant TTS.

4.2.2.3.4 *Non-auditory Physiological Effects*

Potential non-auditory physiological effects of seismic noise on marine mammals 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 marine mammals exposed to sound from airgun arrays. However, there have been no direct studies of the potential for airgun pulses to elicit any of these effects. If any such effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods.

Very little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances from the noise 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.

4.2.2.4 Sea Turtles

There are few studies on the effects of airgun pulses on marine turtles.

4.2.2.4.1 Behavioural Effects

Loggerhead and green turtles showed behavioural avoidance to received sound levels of 166 dB re µPa rms[1] generated by an airgun (McCauley et al. 2000). The behaviour of the animals became more erratic at received sound levels of 175 dB re µPa rms (McCauley et al. 2000). It is likely that sea turtles will exhibit behavioural reactions or avoidance within an area of unknown size around a seismic vessel (Moulton and Richardson 2000).

Leatherback sea turtles, listed as 'endangered' by COSEWIC, are expected to feed primarily on jellyfish. It is unknown how jellyfish react to seismic noise, if these invertebrates react at all. Leatherbacks are also known to feed on sea urchins, tunicates, squid, crustaceans, fish, blue-green algae, and floating seaweed. It is possible that some prey species may exhibit localized avoidance of the seismic array but this is unlikely to impact sea turtles, which are also likely to avoid the seismic vessel and are known to search for aggregations of prey.

4.2.2.4.2 Physical Effects

Moein et al. (1994) observed apparent TTS in captive loggerhead turtles after exposing the animals to a few hundred airgun pulses at distances of no more than 65-m. The hearing capabilities of the tested animals returned to normal two weeks later. These researchers did not report the size of the airgun used or the received sound levels. Thus, the sound levels that caused the TTS in the turtles are not known.

Desert tortoises (*Gopherus agassizii*) exhibit TTS after being exposed to repeated high intensity sonic booms (Bowles et al. 1999). Recovery from TTS for these turtles usually occurred in less than one hour (Bowles et al. 1999). Bowles et al. (1999) suggested that tortoises could tolerate exposures to these sounds without permanent injury.

Based on available data, sea turtles might exhibit temporary hearing loss if the turtles are close to the airguns (Moulton and Richardson 2000). However, there is not enough information on sea turtle temporary hearing loss and no data at all on permanent hearing loss to reach any definitive conclusions about received sound levels that trigger TTS. The mitigation measure of ramping up the airgun array over a 20 to 30-min period should permit sea turtles close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Therefore, there is likely little potential for sea turtles to be close enough to an array to experience hearing impairment. If some turtles did experience TTS, the effects would likely be quite "temporary".

4.2.2.5 Seabirds

There have been virtually no studies of the effects of airgun-based seismic exploration on seabirds. Stemp (1985) made observations on the reactions of seabirds to seismic exploration programs in southern Davis Strait over three summer periods. No mortality or effects on distribution were detected in 1982, the only year when an airgun-based program was conducted. John Parsons (*in* Stemp 1985) reported that shearwaters off Sable Island did not respond to underwater explosive charges 30-m away, even though the birds' heads were underwater. Evans et al. (1993:8) made observations from operating seismic vessels in the Irish Sea. They noted when seabirds were near the seismic boats, "there was no observable difference in their behaviour, birds neither being attracted nor repelled by seismic testing". Recent observations (August 2001) from a seismic vessel in the nearshore waters of the Alaskan Beaufort Sea revealed that over a hundred long-tailed ducks were sighted between 100 and 225-m of the airgun array (LGL Ltd., unpubl. data). These ducks showed no clear avoidance pattern of the seismic vessel during periods with and without seismic activity. The lack of an overt response may be at least partly related to the fact that received levels of underwater sound from airguns are typically greatly reduced at and immediately below the surface as compared with levels deeper in the water (Greene and Richardson 1988).

Diving seabirds are more likely to be affected than are birds that remain at or near the surface of the water. The deep diving seabirds that occur in the Study Area include various alcids (Dovekies, Common Murres, Thick-billed Murres, Razorbills and Atlantic Puffins). Other marine birds in the Study Area that plunge below the ocean's surface in pursuit of food include various shearwater species, Northern Gannets and Arctic Terns. While on the surface, they likely would not be affected by seismic pulses. However, some species will dive several metres to feed on bottom-dwelling or pelagic organisms. Some species, like the Common Murre will dive more than 100-m to forage (Gaston and Jones 1998). Some of these birds may avoid the area around an operating airgun array. Fish-eating species may be displaced if the fish on which they feed avoid an area around airgun arrays.

The auditory systems of birds, unlike mammals, have some capability to recover even from exposure to sounds that are strong enough to cause direct auditory injury (Corwin and Cotanche 1988). Most species of seabirds that occur in the Study Area would spend most of their time surface or plunge feeding in the first few meters of the water column or simply resting on top of the water. Deeper-diving alcids do occur within the Study Area throughout the year. Some of these birds might exhibit temporary threshold shift (TTS) if they dive too close to a firing airgun array. The mitigative measure of ramping up the airgun array would allow time for seabirds close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Birds can avoid the ensonified area by remaining at the surface or by flying away. Therefore, there is likely little potential for birds being close enough to an array to experience hearing damage.

It is unlikely that prey species for birds would be impacted by seismic activities to a degree that inhibits the foraging success of birds. If prey species exhibit avoidance of the seismic ship, it will likely be transitory in nature and over a small portion of a bird's foraging range within the seismic area.

4.2.3 Mitigations and Planning

There are four major areas of mitigation for seismic surveys, as discussed below.

4.2.3.1 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 (Canning and Pitt 2002; C-NOPB and C-NSOPB 2003; LGL et al. 2003).

4.2.3.2 Observers

The placement of trained observers should be aboard the seismic vessel to monitor the immediate area for presence of marine mammals, sea turtles and seabirds. Shutdowns of the airgun array could be implemented if deemed necessary due to the proximity of species of concern. Shutdown 'triggers' may vary by location and species. Fishery liaison observers are used to communicate and mitigate potential conflicts with fishing vessels (see below).

4.2.3.3 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.

4.2.3.4 Guard Vessels

Guard vessels, preferably crewed by commercial fishermen, typically 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.

4.2.3.5 Other Mitigations

The Laurentian Subbasin SEA (C-NOPB and C-NSOPB 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
- Compensation for gear and vessel damage
- Compliance with all applicable regulations concerning discharges

4.2.3.6 Planning Implications

More specific planning measures other than the mitigations listed above associated with seismic surveys will be dealt with in project-specific EAs.

4.2.4 Data Gaps

With respect to data gaps specific to seismic exploration, there is a lack of noise measurement and modeling in the Orphan Basin Study Area. The Board would most likely require this information as it pertains to specific project sites.

Data gaps specific to the marine fauna groups potentially affected by seismic exploration are wide and numerous. Relevant gaps would have to be dealt with on a project-specific basis. 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.

Of the marine fauna groups discussed in the previous sections, cetaceans are best understood in terms of the effects of seismic noise. However, in absolute terms, little is known about the effects of seismic activity on whales. That being said, it is apparent that the subject of how seismic exploration activities affect physical and behavioural aspects of marine animals in general represents a large data gap. A paucity of biota occurrence data in the large deepwater portion of the Orphan Basin Study Area magnifies the extent of the data gap.

4.3 Exploratory and Delineation Drilling

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 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.

4.3.1 Typical Equipment and Activities

Typical drilling equipment, procedures and associated activities are described in detail in the Terra Nova and White Rose EISs, the generic exploratory drilling EA for the Scotian Shelf (LGL et al. 2000), CAPP (2001a,b), the Husky Lewis Hill exploratory drilling EA (Husky 2003), and Laurentian Sub-Basin Draft SEA (C-NOPB and C-NSOPB 2003). Those aspects relevant to an Orphan Basin SEA are briefly summarized below.

4.3.1.1 Drill Rigs

There are two likely rig types suitable for drilling in the Study Area: (1) the semi-submersible, and the (2) drill ship. In water depths up to about 1,000-m (1,800-m possible) they are likely to be anchored by eight or more lines; in deeper depths, dynamically-positioned semi-submersibles or drill ships would be used (CAPP 2001a). Dynamic positioning is a computerized system of global positioning, acoustic devices, and drive units that work together to enable a ship to maintain a precise position without anchoring.

Both drill platform types perform similar functions and contain both living and working facilities. Quantities and qualities of emissions and effluents are similar with both types of rig. The primary difference from an environmental perspective is that drill ships are noisier than semi-submersibles and that dynamically positioned ones are nosier than anchored platforms (Richardson et al 1995).

Drill rigs in Canadian waters are protected by a ship exclusion zone of 500-m radius from the rig or 50-m out from the anchors whichever is greater (CAPP 2001c). To date, Grand Banks rigs have been serviced by two or more St. John's-based offshore supply vessels, one of which stands by the rig at all times for safety purposes. Rigs on the Grand Banks are also normally serviced by helicopters (Super Puma or equivalent) operating from St. John's Airport. Given the extra distances in reaching most of the Orphan Basin parcels, it is likely that special arrangements will have to be made for re-fueling helicopters offshore.

4.3.1.2 Exploratory Drilling Procedures

Wells are drilled using a drill bit on the end of sections of drill stem. Lubrication and removal of drill cuttings, and exclusion of any formation fluids are facilitated by drilling fluids or muds. Sections of steel casing pipe are installed in the borehole behind the drilling. Wells are drilled, and conductor casing cemented in place, in stages of gradually decreasing hole diameters (Figure 4.6). For example, a typical well may be drilled at 36" diameter for about the first 220-m or so (conductor setting depth, subject to C-NOPB approval) when the conductor casing is installed; the next casing depth may be about 1,200-m (surface casing depth) (CAPP 2001b; Husky 2003). After the surface casing is drilled, the Blowout Preventor (BOP) and riser are installed. Once the riser is in place the drill cuttings are brought to the surface for recycling and treatment, prior to discharge. Prior to this point, cuttings and associated mud are discharged to the sea floor. After the surface casing, a production casing is installed. The total well depth may be on the order of 3,600-m.

Drilling of a single well may range from 30 to 120 days, depending on the depth of the well. A 'typical' well on the shelf (e.g., Parcels 1 or 2) might take 45 days to drill and 20 days to test, if hydrocarbons are found. Wells in deeper water would likely take more time.

4.3.1.3 Drill Muds and Cuttings

Exploratory drilling in Newfoundland and Labrador waters is conducted using either water-based drilling muds (WBM) or synthetic-based muds (SBM). Exploratory wells on the Grand Banks typically drill mostly with WBMs; however, SMBs might be used in difficult or special situations. Typically in offshore Newfoundland, SBMs are used in high-angle deviated wells, which are usually not seen during exploration, in well sections where problematic formations (e.g., certain shales) are expected, or in deep water wells, where they are usually required for the prevention of gas hydrates. All drilling fluids are handled and treated in accordance with C-NOPB policies and the Offshore Waste Treatment Guidelines (OWTG) (NEB et al. 2002).

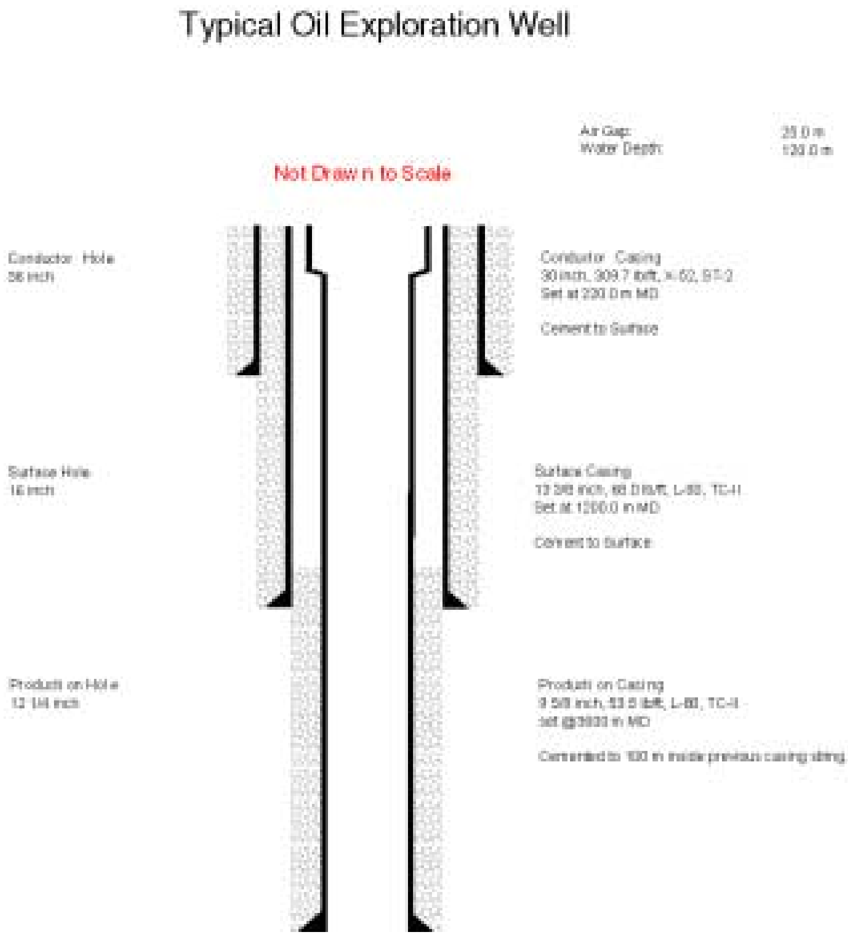


Figure 4.6 Typical Oil Exploration Well.

Source: Husky (2002).

A ‘typical’ exploratory well on the Grand Banks could yield on the order of a 1,000-m^3 of mud and cuttings to the sea floor during pre-riser drilling. After the riser is installed, cuttings are brought to the surface for separation and treatment in the solids control system. Some of the mud is reconditioned and re-used; treated cuttings with some mud still remaining are discharged in accordance with the OWTG. About another 1,000-m^3 of treated cuttings and mud may be discharged near the surface (Husky 2003). There also may be additional inputs of mud in special circumstances such as bulk discharges of water-based mud (WBM) during a switchover to synthetic based mud (SBM), if it occurs. 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 SBM tends to clump together and fall closer to the rig than WBM.

Specifics on mud formulations per specific hole sections and their respective toxicities is provided in the permit applications for ‘authority to drill a well’ (ADW) that must be approved by C-NOPB for each well.

4.3.1.4 Vertical Seismic Profiles

Vertical seismic profiles (VSP) are now required by the C-NOPB. 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-NOPB.

4.3.1.5 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-NOPB.

4.3.1.6 Waste Management

The main discharges associated with exploration drilling are mud and cuttings (see preceding sections). Other typical operational discharges, which must be treated in accordance with the OWTG, prior to discharge include:

> **Produced water.** This is a waste product only if hydrocarbons are found and tested. Most likely it would be sampled and burned through the rig’s flare or packaged and disposed on land in an approved site. The limit for production facilities is 30-mg/L oil (30-day weighted average).

Grey water. This is galley and wash water that is discharged on the order of 40-m^3 per day (Husky 2003). Particle size must be 6-mm or less.

Black water. Sewage or 'black water' from rig personnel (85-120 personnel) would be approximately 19-m^3 per day. It must be ground to 6-mm particle size.

Machinery Space Discharges, Bilge Water, Deck Drainage. These must be treated to 15-mg/L oil or less as per OWTG.

Ballast Water. Tanks on supply boats and rigs approved for the East Coast offshore are segregated and should not contain oily water. If oil is present, it must be treated to 15-mg/L or less.

Cooling Water. Top drives and draw-works on rigs are cooled by pumping water through a set of heat exchangers; the water is then discharged overboard in accordance with OWTG. Other equipment is cooled through a closed loop system which may use chlorine as a biocide. Water from closed systems is tested prior to discharge and should comply with the OWTG. Any use of biocide other than chlorine must be approved by the C-NOPB.

Chemicals. Chemicals for use offshore in Newfoundland waters are typically selected according to the Offshore Chemical Guidelines that specify the lowest toxicity formulations and alternatives. Chemical waste and containers are usually returned to shore for disposal. In some cases chemicals may be neutralized and disposed offshore under C-NOPB approvals. By regulation, operators must test the BOP which results in the release of 1.0-m^3 of test fluid (glycol/water).

Trash and Garbage. Most rigs now have recycling programs. Trash is brought to shore by an approved waste handler and hazardous waste is containerized. Garbage may be macerated to 6-mm or brought to shore. Some rigs may have approved incinerators.

A drilling operator in Newfoundland and Labrador waters must submit a Waste Management Plan to the C-NOPB for approval. In addition, all discharges, effluents and emissions would be reviewed during the environmental assessment process or specific drilling programs. For the most part, these waste streams are now routinely mitigated to very low environmental effects, if any, to the offshore environment. Thus, for the most part, this SEA focuses on actual drilling waste (i.e., mud and cuttings), noise, and accidental releases.

4.3.1.7 Air Emissions

Offshore rigs and supply boats runs primarily on diesel or diesel/electric; helicopters operate on jet fuel. These machines create air emissions. There are also fugitive emissions from fuel and slops tanks and so forth. In general, the environmental effect on the offshore environment of exhaust emissions has been less an issue than on land due to the lack of sensitive receptors such as human presence, terrestrial vegetation, or freshwater environments combined with a windy dynamic environment. However, with increasing attention on greenhouse gases, the oil industry is starting to select new equipment on the basis of fuel efficiency and low emissions.

4.3.1.8 Ice Management

Each drilling rig operator is required to submit an Ice Management Plan to the C-NOPB for approval. 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 Orphan Basin 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).

4.3.2 Interactions and Potential Effects

Routine drilling operations have the potential to interact with most components of the offshore ecosystem from plankton to whales. In numerous East Coast EAs most of these interactions have been deemed to result in low magnitude, short duration, and small area effects (if not negligible effects), and certainly not significant effects. However, as discussed above, experience with previous offshore EAs has demonstrated that there are several key interactions that are the most important from both a technical-scientific and public perception point of view:

- Effects on benthos (including effects on little known sensitive deep sea fauna such as deepwater corals)
- Attraction of birds to rigs
- Noise disturbance of marine animals, primarily whales

4.3.2.1 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). Modeling of the fate of drill mud and cuttings discharges was conducted for the White Rose EA and for the Lewis Hill exploratory drilling EA (Husky 2003). 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 several wells in Orphan Basin over a period of several years. 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 (2001d) 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 (e.g., review presentation of Buchanan et al. 2003). The salient points are briefly summarized in the two following sections.

4.3.2.1.1 Water-Based Muds

Composition of a typical WBM formulation includes the primary components of water, barite and bentonite; calcium carbonate, caustic, fluid loss agent, inhibitor, potassium chloride, lime, glycol inhibitor, soda ash, viscosifier, and biocide are added for control purposes (Husky 2003).

The following points are relevant to an assessment of the discharge of WBM and cuttings in the Orphan Basin Study Area.

- WBM are essentially non-toxic. The main component of WBM is seawater in which the primary additives are bentonite (clay), barite and potassium chloride. Much previous literature (e.g., the North Sea) on the effects of mud/cuttings deals with field where oil-based muds (OBM) were used for a number of years. The OBM literature is not very relevant to WBM or SBM usage. Bedford Institute of Oceanography researchers have reported decreased growth in scallops in shallow Nova Scotia waters but these results are not applicable to the Study Area because of the scarcity of scallops and the different depths and substrates (see Husky 2000, 2001).

- Chemicals such as caustic soda, soda ash, viscosifiers, and shale inhibitors are added to control mud properties. All constituents are screened using the Offshore Chemical Selection Guidelines (NEB et al. 1999).

- Discharge of WBM and associated cuttings is regulated by C-NOPB. Spent and excess WBM and cuttings can be discharged without treatment but operators are encouraged to reduce discharges as much as possible (NEB et al. 2002).

- The discharge of WBM may increase metals in sediments such as barium, arsenic, cadmium, copper, mercury, lead, and zinc, generally to 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 2001d).

- The primary effect of WBM will be smothering of benthos in a small area near the hole. The exact area of effect cannot be predicted because animals' reactions will 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). Exploratory drilling in the Orphan Basin 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 for the shallower areas) after the drilling ceased, based upon the published literature (Husky 2000, 2001, 2003; MMS 2000; CAPP 2001d). Very deep sites may take longer to recover.

Results of mud deposition modeling for the Study Area may be roughly similar to areas of the Grand Banks that have been modeled. For the Lewis Hill EA (Husky 2003), a modeling exercise was conducted for the fate of drilling mud and cuttings released in the centre of the Lewis Hill 'box' (Lorax 2002 *in* Husky 2003). The exercise is described below. Water depths in the 'box' generally range from about 100-m (excluding a knoll of about 10-m depth) to 150-m, with a depth of approximately 100-m at the proposed drill site in the centre of the box. The oil concentration in the cuttings and muds was assumed to be zero.

Historical ocean data obtained from the Bedford Institute of Oceanography were used to prescribe currents in the area, and particle sizes for cuttings were based on estimates from the Hibernia K-18 well. Four particle size classes ranging from 0.1-mm to 7-mm in diameter were used to specify the cuttings. The bottom section of the well, with diameters of 12¼" (31.1-cm), produces both mud and cuttings that would be discharged from the drilling unit. These solids would be returned to the surface, processed through the mud recovery system and then discharged into the sea at a nominal depth of 5-m. The estimated solids volumes for this section of the well were 834-m^3 of mud and 201-m^3 of cleaned cuttings. Approximately 634-m^3 of mud would be discharged as the 12 ¼" hole is drilled; the balance of 200-m^3 would be dumped upon completion of drilling to 3,600-m.

The 12¼" section was represented by four activities that were distinguished by their particle size distributions and mud content. Two separate simulations were performed: the first modeled the drilling schedule for a specific period of interest from March 25 through April 5, 2003. The second simulation estimated the statistical properties of the deposition by combining the results from forty separate model runs over the period from March through August, 2003.

The deposition pattern resulting from the March – April simulation was roughly elliptical in shape with the area covered by cuttings of at least 0.001-mm having dimensions of approximately two by four kilometres (Lorax 2002 *in* Husky 2003). The coarse material was deposited within a much smaller area approximately 500-m in diameter centred on the well location. The maximum thickness of approximately 10-mm occurred within a 25-m radius of the well (Lorax 2002 *in* Husky 2003). It is unlikely that any biological effect would occur until thickness was about 10-mm (1-cm) or greater (see Bakke et al. 1989), all of which would occur well within a radius of 500-m of the well.

The mean deposition pattern for the March – August period had a similar orientation and elliptical shape to the March – April simulation, but with dimensions of three by four kilometres (Lorax 2002 *in* Husky 2003). The distribution of material was also similar with most of the material being deposited within a 250-m radius of the well site. The maximum mean thickness is less than 1-cm within a very small radius of the well.

Sediment transport of parent sand and mud/cuttings in the benthic boundary layer is not expected at Lewis Hill on a regular basis, but could occur sporadically and infrequently (e.g., during winter storms). However, such infrequent episodes of sediment transport would not likely alter the predicted deposition pattern to a significant extent (Lorax 2002 *in* Husky 2003; D. Hodgins, Lorax, pers. comm.).

Effects of WBM drilling mud and cuttings discharge on fish or fish habitat (including benthos) at Lewis Hill were predicted to be very localized, short term and *not significant*. In general, these results are applicable to the Orphan Basin Study Area.

4.3.2.1.2 Synthetic-based Muds

Synthetic muds were developed to replace oil-based muds which were considered toxic to varying degrees and which appeared responsible for the longevity of cuttings piles. In general, SBM is essentially non-toxic, has the potential to biodegrade relatively rapidly, and less mud is required than for WBM for the same distance drilled. SBM tend to ‘clump’ cuttings together more than WBM thus cuttings tend to disperse less and fall closer to the rig.

The following points concerning SBM are relevant to an exploration drilling program EA in the Orphan Basin Study Area.

- 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.

- 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 250-500-m from the drilling platform (Husky 2000, 2001, 2003; MMS 2000; CAPP 2001d). The White Rose EA concluded a total area of impact of less than 1-km^2 from multi-well drill centres 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 will be treated prior to discharge as per the OWTG.

In previous EAs, effects of synthetic drilling mud and associated cuttings discharge, if they occur, on the marine environment, including the benthos, were predicted to be small in geographic extent, short term and *not significant* (Petro-Canada 1996; Husky 2000, 2001; Buchanan et al. 2003; Husky 2003). It is likely that similar determinations could be made for the Study Area.

4.3.2.1.3 Deep Sea Benthos

At present, benthic data are insufficient to map any potentially sensitive areas of species such as deep sea corals that may be disturbed on a small scale by the anchors or the drilling and associated discharges. On the other hand, it is likely that the deep water wells will be drilled using dynamic positioning so that in many cases, anchor effects will not be an issue. [Nine of the 14 parcels are mostly below the 2,000-m contour.] C-NOPB may require the operator to expand a typical well site survey to determine the presence of corals in the area. Avoidance of sensitive concentrations constitutes a key mitigation for any effects.

4.3.2.2 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 or collided with the rig. This issue is presently being addressed on the Grand Banks by:

- Proposed ESRF study on this issue

- Requirement by C-NOPB for operators to implement a seabird and marine mammal monitoring program

- Seabird surveys conducted from supply boats (ESRF, Petro-Canada, Husky) to provide some data on densities approaching the rigs

- ESRF study on seabird and marine mammal monitoring protocols.

- ESRF study on remote technologies for monitoring bird movements relative to the flare boom

- Programs to gently capture, hold and release petrels that become stranded on offshore vessels or rigs. [Petro-Canada has recorded no bird mortalities since instituting this program at Terra Nova several years ago (U. Williams, pers. comm.).]

4.3.2.3 Effects of Underwater Noise (Other than Seismic) on Marine Mammals

Noise produced during exploration drilling emanates from the drill rig, supply vessels, and associated aircraft. Seismic guns may also be discharged periodically from the rig or supply boat (vertical seismic profiling or VSP) in order to get more detailed information on the hole or reservoir (this aspect is covered under seismic noise—see Section 4.2). The effects of underwater noise 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 noise must be used to estimate possible reactions of marine mammals to the kinds of sounds being considered in this assessment.

Toothed whales (odonocetes) appear to exhibit a greater variety of reactions to manmade underwater noise 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, true seals (pinnipeds) seem more tolerant of, or at least habituate more quickly to, potentially-disturbing underwater noise than whales.

Offshore oil development and production activities produce sounds that can be classified into two or 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 classed 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 noise.

4.3.2.3.1 Pulsed Sounds

One of the sound sources that could operate some oil and gas development sites is a large pile driver. This is probably not directly relevant to the Orphan Basin but given the lack of information on reactions of marine mammals to various types of sound it is included here. Only limited data are available on reactions of marine mammals to pile-driving sounds although it is likely cetaceans and seals can hear pulsed sounds.

With the exception of a study of Indo-Pacific hump-backed dolphins (*Sousa chinensis*) near a pile driver, most of the work that has been done on the responses of whales and seals to pulsed sounds has been in relation to marine seismic exploration. Marine mammal reaction to seismic noise is discussed in Section 4.2.2.

Toothed Whales

Experimental results (e.g., Würsig et al. 2000; Akamatsu et al. 1993) show that responses to impulsive noise sources are highly variable among toothed whales. In a single study of pile driving (with an in-air hammer operation), dolphins changed their swimming speed and were less abundant nearby after the operation. Under some circumstances, some species will avoid such noises 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.

Mysticete Whales

Research on pulsed sound and baleen whales has been conducted by Watkins (1986), Lien et al. (1992) and Maybaum (1993).

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 (Figure 4.7). 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 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 will avoid such noises 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).

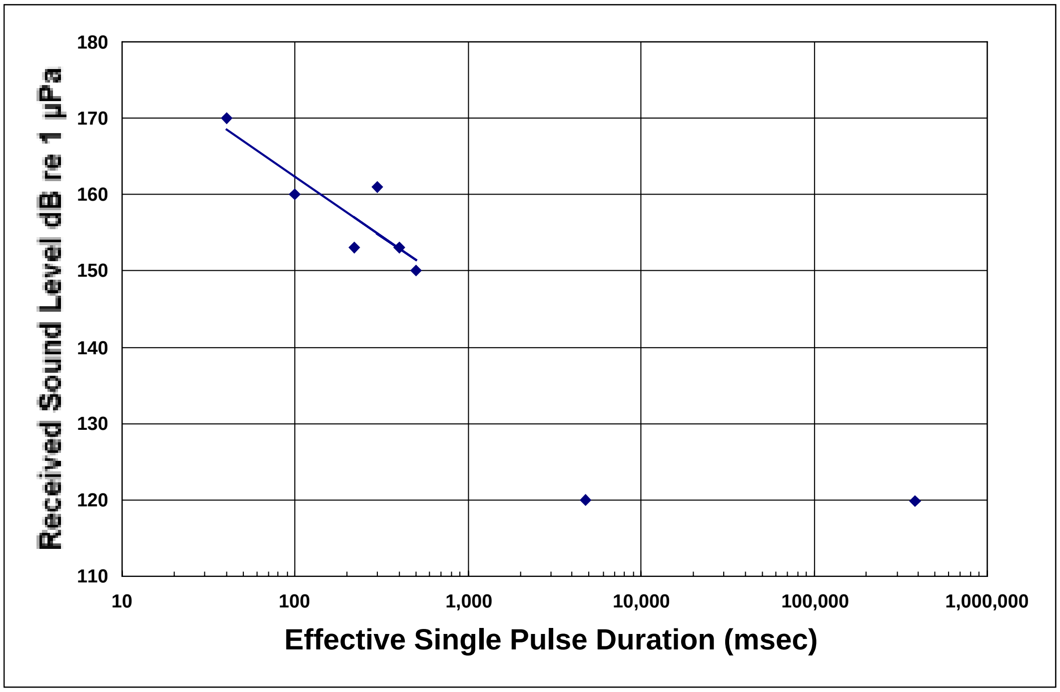


Figure 4.7 Estimated Behavioural Avoidance Thresholds, in dB re 1 µPa rms[1] (using a 50% avoidance criterion), for Baleen Whales Exposed to Airgun Sounds (dB re 1 µPa), Intermittent Helicopter Sounds, and a Continuous Sound Source Simulating Oil Industry Activities. Adapted from Malme (1993).

Seals

Data on the reactions of seals to pulsed sounds are limited, but the few reports (e.g., Richardson et al. 1995; Yurk and Trites 2000; Smultea et al. submitted MS) available 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.

[1] re 1 µPa rms is the standard reference pressure adopted for underwater sound pressure level (SPL) measurements. To facilitate reading of this document, it is usually omitted hereafter.

4.3.2.3.2 Continuous Sounds

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 sensitivity 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.

Drilling

Baleen whales sometimes show behavioural changes in response to received broadband drillship noises of 120 dB or greater. On their summer range in the Beaufort Sea, bowhead whales reacted to drillship noises within 4 to 8-km 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 noise level around 115 dB (Greene 1987a; 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 1-km, at received levels of ~120 dB (Malme et al. 1983, 1984). Humpback whales showed no obvious avoidance response to broadband drillship noises at a received level of 116 dB (Malme et al. 1985).

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 noise efficiently into the water. In contrast, a drilling rig that is standing on steel legs would likely radiate much less noise 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.

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 (*Delphinapterus leucas*) 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 noise were less pronounced than were reactions to motorboats with outboard engines. Captive belugas exposed to playbacks of recorded semi-submersible noise seemed quite tolerant of that sound (Thomas et al. 1990).

4.3.2.3.3 Transient Sounds

Ships and Boats

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 1987a), and were 11 dB higher when bow thrusters were operating than when they were not (Greene 1985, 1987a). The *Robert Lemeur* has nozzles around the thruster propellers. Broadband noise levels from ships lacking nozzles or cowlings around the propellers can be about 10 dB higher than those from ships with the nozzles (Greene 1987a).

Reactions of baleen whales to boat and other noises 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) occasionally approach stationary or slow-moving boats, but more commonly avoid boats. Avoidance is strongest when boats approach directly or when vessel noise 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, Bauer 1986, Dean et al. 1985, 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 response 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). The closely-related bowhead whale typically begins avoiding diesel powered boats at distances of ~4-km; 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.

Some species of small toothed cetaceans avoid boats when they are approached within 0.5-1.5-km, with occasional reports of avoidance at distances as great as 12-km (Richardson et al. 1995). Some toothed whale species appear to be more responsive than others. Beaked whales seem especially responsive.

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). Harbour porpoises tend to avoid boats.

In summary, cetaceans may show little reaction, or slow, inconspicuous avoidance reactions, to ships and boats that are moving slowly on a steady course. If the vessel changes course and/or speed, whales likely will swim rapidly away. Avoidance is strongest when the boat travels directly towards the whale. Dolphins may either approach the vessel (to bow ride) or avoid it.

Ship and boat noise does 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 (*Phoca vitulina concolor*) 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, *Phoca vitulina richardsi*, commonly left the shore when powerboat operators approached to observe the seals. These 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.

Aircraft Overflights

Sound from an elevated source in 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 noise from 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 noise received by animals.

Most species of toothed whales do not appear to react to aircraft overflights, except when the aircraft fly at altitudes below 150-m (Richardson et al. 1995). Beaked whales, pygmy and dwarf sperm whales, 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 will dive hastily, turn, or swim away from the flight path (see below). 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 ASL 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. During earlier surveys with a similar aircraft and methodology, bottlenose dolphins reacted like some other small cetacean species (Mullin et al. 1991). They 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. The reactions were likely to be of short duration. Dall's porpoise and spinner dolphins reacted abruptly to overflights at 215-300-m (Withrow et al. 1985; B. Würsig *in* Richardson et al. 1995).

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 aeroplanes 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). 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). Some sperm whales showed no reaction to helicopters and aeroplanes flying over at altitudes of 150-m, but some dove immediately (Clarke 1956; Mullin et al. 1991).

Minke, bowhead, and right whales sometimes reacted 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 within a slant range of 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. 1995a,b).

Seals hauled out for pupping or moulting have variable sensitivity 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).

Literature on reactions of marine mammals to helicopters flying or hovering at low altitude is limited. However, based on those data, on the high noise level at the surface below the helicopter, and (if landing, taking off, or hovering) the extended duration of exposure (relative to a passing aircraft), behavioural reactions to such low-altitude aircraft are expected to be stronger than to helicopters or fixed-wing aircraft engaged in overflights at higher altitude.

In summary, low overflights and hovering of helicopters are likely to produce stronger behavioural responses by marine mammals than do overflights by fixed-wing aircraft. Most of the responses are likely to be of short duration.

4.3.2.3.4 Masking Effects

Hearing thresholds for marine mammals represent the lowest levels of sound these animals can detect in a quiet environment. However, the sea is usually noisy, even in the absence of man-made sounds. Background ambient noise often interferes with or masks the ability of an animal to detect a sound signal even when that signal is above the absolute hearing threshold. In the Study Area, as elsewhere, natural ambient noise includes contributions from wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal noise resulting from molecular agitation (see Chapter 5 of Richardson et al. 1995). Background noise 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 noise. Conversely, if the background level of underwater noise is high (e.g., on a day with strong wind and high waves), an anthropogenic noise source will not be detectable as far away as would be possible under quieter conditions, and will itself be masked at the longer distances where it could be detected at a “quieter” time. In fact, ambient noise 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 noise 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 noise (Richardson et al. 1995). In general, masking effects are expected to be less severe in the case of transient sounds than with continuous sounds. In the former case, mammals will still be able to hear other sounds of interest in the "gaps" between the transient sounds.

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. Some of these are summarised below.

Structured signals such as echolocation click sequences of small toothed whales may be readily detected even in the presence of strong background noise because their frequency content and temporal features usually differ strongly from those of the background noise (Au and Moore 1988; 1990). It is primarily the components of background noise that are similar in frequency to the sound signal in question that determine the degree of masking of that signal. Low-frequency industrial noise 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 noise.

Most masking studies present the test signal and the masking noise from the same direction. The sound localisation abilities of marine mammals suggest that, if signal and noise 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 noise 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 noises by improving the effective signal-to-noise ratio. In the cases of high-frequency hearing by the bottlenose dolphin, beluga, and killer whale, empirical evidence confirms that masking depends strongly on the relative directions of arrival of sound signals and the masking noise (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 noise. There is evidence that some toothed whales can shift the dominant frequencies of their echolocation signals from a frequency range with much ambient noise toward frequencies with less noise (Au et al. 1974, 1985; Moore and Pawloski 1990; Thomas and Turl 1990; Romanenko and Kitain 1992; Lesage et al. 1999). Some of these studies also showed that source levels of echolocation signals may increase when necessary to counteract noise.

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 noise source has little effect on the degree of masking when the sound frequency is 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 noise generated by anthropogenic activities such as large ships or station-keeping by large vessels with thrusters, and to a lesser extent transient sounds such as piledriving sounds, 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.

4.3.2.3.5 Hearing Impairment

Temporary Threshold Shift (TTS)

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 of hearing sensitivity (Kryter 1985). TTS can last from minutes or hours to days. The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995).

Only a few data on sound levels and durations necessary to elicit mild TTS 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. With the exception of an opportunistic observation by Kastak and Schusterman (1996) of TTS in a captive harbour seal, the first systematic data on TTS in marine mammals were released in 1997 by Ridgway et al. (1997). For bottlenose dolphins exposed to a one-second pulse of underwater sound, the TTS threshold is about 192 dB re 1 µPa across a broad range of frequencies (3 to 75 kHz) (Ridgway et al. 1997). This lack of strong frequency-dependence was consistent with evidence from terrestrial mammals.

During underwater sound playback trials, Au et al. (1999) exposed a captive bottlenose dolphin to 30-50 minutes of octave-band continuous noise in the 5 to 10 kHz band. (Noise levels at the water surface were 3 dB lower.) This dolphin's hearing was not affected when the noise level was 171 dB re 1 µPa, which is equivalent to a total energy flux density of 205 dB re 1 μPa^2-s. Moderately strong TTS (12 to 18 dB reduction in sensitivity) was obtained when the noise level increased to 179 dB with energy flux density of 213 dB re 1 μPa^2-s or 1330-J/m^2. In the latter situation, the fatiguing stimulus was about 96 dB above the animal's pure-tone threshold of 84 dB.

In an expansion of the original Ridgway et al. (1997) study, Schlundt et al. (2000) used a behavioural response paradigm to measure masked underwater hearing thresholds in five bottlenose dolphins and two beluga whales before and immediately after exposure to intense a single 1-sec tone at 0.4, 3, 10, 20, or 75 kHz. The resulting levels of fatiguing stimuli necessary to induce 6 dB or larger masked temporary threshold shifts (MTTSs) were generally between 192 and 201 dB, although there was individual variation. At the conclusion of the study, all thresholds had returned to baseline values so there was no evidence of permanent change in hearing sensitivity (PTS, see below). These data confirmed that these cetacean species are susceptible to TTS and that, after mild TTS, hearing sensitivity returns to pre-exposure values.

Evidence from a captive experiment using two bottlenose dolphins and a beluga whale (Finneran et al. 2000) suggests that a typical broadband impulse with a received level near 221 dB re 1 µPa (pk-pk; equal to 206 dB rms) was not sufficient to cause MTTS; there were indications that the TTS threshold may have been just slightly higher (Finneran et al. 2000). The test sounds during the Finneran et al. (2000) study were short.

Kastak et al. (1999) reported that they could induce mild TTS in common seals, northern elephant seals, and California sea lions by exposing them to lower received levels of underwater octave-band noise at frequencies in the 100 to 2000 Hz range for relatively long durations (20-22 minutes). Mild TTS became evident when the received levels were 60-75 dB above the hearing threshold at the centre frequency of the octave band in question. Given the reported hearing thresholds, these "60-75 dB sensation levels" translated to absolute received levels of about 135-150 dB. All subjects recovered to baseline hearing sensitivity within 24 hr of exposure. When exposure duration was increased from 20-22-min to 40-min, TTS thresholds generally became lower (Schusterman et al. 2000). These 20-40-min exposures to strong sound were longer than those likely to occur when marine mammals pass an oil exploration or production platform, or as large vessels move by.

Studies of TTS in terrestrial mammals have shown that TTSs more pronounced than those discussed above are sometimes fully recoverable, i.e., no permanent hearing impairment (PTS; see next section) and no loss of sensory hair cells in the inner ear (e.g., Ahroon et al. 1996). It is likely that the same recovery faculty is present in marine mammals, but this has not been demonstrated.

For potentially damaging noise exposures to humans, scientists have developed Damage Risk Criteria (DRC; see Ward 1968, 1997) that attempt to determine the parameters of sound exposure that could result in temporary or permanent changes in hearing sensitivity (see below). These have been easier to establish for continuous sounds or single impulsive sounds than for intermittent, impulsive sounds like pile driving or sonar.

Assuming that marine mammals have underwater hearing thresholds of 40 to 70 dB re 1 µPa (see Section 8.2 in Richardson et al. 1995), DRCs for marine mammals underwater could range from 40 to 70 dB higher than the equivalent human aerial DRC values. Before there were any data on TTS in marine mammals, Richardson et al. (1995) estimated preliminary acoustic DRCs for marine mammals underwater for different numbers and types of sound pulses.

Most of the evidence on sound exposure and adverse hearing effects, discussed above, has generally applied to exposure times that last for tens of seconds or minutes, rather than those brief impulses from pile driving, seismic arrays, and sonar. Recent workshops (e.g., HESS 1999) have recommended a precautionary approach be taken and have suggested a 180 dB re 1 µPa (rms) radius safety zone, defined by a transmission loss model, and verified on-site using acoustic measurements. In the United States NMFS now recommends that both baleen whales and toothed whales be limited to an SPL no greater than 180 dB re 1 Pa_{rms} Based on recommendations from NMFS' Acoustic Criteria Workshop in 1998, NMFS indicates that seals should not be exposed to impulse sounds exceeding 190 dB re 1 μPa_{rms}. NMFS is not very specific about what might happen at higher sound levels (see next subsection).

To a significant degree, the 180 dB criterion arose from the HESS "experts" workshop (HESS 1999). There, it was as much the non-auditory physiological effects as hearing impairment that induced participants to settle on 180 dB as the received level above which they were concerned about the possibility that exposure to repetitive impulse sounds could have physically injurious effects.

Permanent Threshold Shift (PTS)

There are no data on noise 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 noise strong enough to elicit TTS, or shorter-term exposure to noise levels well above the TTS threshold, could cause hearing injury. Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies. This permanent increase in the threshold above which the mammal can detect sound is termed Permanent Threshold Shift (PTS). Richardson et al. (1995) hypothesized that permanent hearing impairment caused by prolonged exposure to continuous man-made noise is not likely to occur in marine mammals, at least 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 PTS. Based on existing data, Ketten (1995) has noted that the criteria for differentiating the sound pressure levels that result in 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 threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. At least in terrestrial mammals, the received sound level from a single noise exposure must be far above the TTS threshold for there to be any risk of PTS (Kryter 1985, 1994; Richardson et al. 1995). Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals.

4.4 Mitigations and Planning

4.4.1.1 Routine Emissions and Effluents

Mitigations for routine discharges in the Newfoundland and Labrador offshore area are well established and include:

- Use of environmental criteria in selection of equipment and chemicals for use offshore (e.g., Offshore Chemical Guidelines)
- Adherence to the OWTG for routine discharges
- Development of state-of-the-art Waste Management Plan and use of certified waste handlers and approved landfills

Additional optional mitigations may include:

- Containerization and shipment to shore of all waste with the exception of drilling waste
- Secondary or tertiary treatment of sewage

4.4.1.2 Drill Mud and Cuttings

Regulated mitigations include adherence to the OWTG.

Other mitigations may include:

- Selection of most innocuous formulations

- Collection of baseline data [The Board may require, prior to drilling, collection of data on benthos; also, post-drilling surveys may be required to determine extent of cuttings deposition.]

4.4.1.3 Potential Conflicts with Fisheries

In the past there has been little conflict between the oil and fishing industries in Newfoundland and Labrador waters. Mitigations include good communications and development of compensation programs for gear any loss that can be attributed to the operators. An additional mitigation could include the establishment of a fisheries liaison office.

Compensation programs respecting loss or damage to fishing gear/vessels resulting from seismic or drilling activities are currently required. Fishery Liaison Officers (FLO) are required during the conduct of seismic programs offshore.

4.4.1.4 Bird Attraction

Present mitigations, as discussed above, include surveys, research, and safe release programs for seabirds. The timing and nature of exploration drilling may require the use of bird deterrent equipment.

4.4.1.5 Noise Disturbance

As discussed above, drill ships are noisier than semi-submersibles and dynamically positioned ones are the noisiest. In addition, supply vessels and acoustic devices used during drilling also emit noise. Mitigations may include careful selection of equipment, ramping up (required in the case of seismic equipment), and avoidance of sensitive areas and times. A discussion of sensitive areas and times is contained in Section 3.2.8.

Protocols for explosive wellhead severance are available that include a safety zone and careful charge design and placement. Well termination programs must be approved by C-NOPB.

4.4.1.6 Planning Considerations

With mitigations in place, routine exploratory drilling can probably be conducted in the Orphan Basin Study Area with little environmental disturbance if, as expected, there is a low intensity of activity spread over time and if particularly sensitive areas and times are avoided. The conundrum is that in some cases the sensitive areas may not be well-known due to the lack of basic survey data for the Study Area.

Planning considerations for VSP and wellhead severance include the provision that the Board will require a marine mammal monitoring program and that acoustic or explosive energy is not to be released when marine mammals are within a certain distance from the rig.

4.5 Cumulative Effects – Oil and Gas Activity

This section considers cumulative effects of oil and gas activity. This and other industrial activities are considered further in Section 5.0.

The Orphan Basin Study Area has been relatively intensively surveyed by seismic (see Section 2.0). The number of seismic surveys to be conducted in 2004 will depend on the results of the 2003 Call for Bids. Judging from previous seismic exploration activities on the Grand Banks, it seems reasonable to assume a maximum of several seismic surveys per year for the entire Orphan Basin Study Area. There is some potential for overlap if exploratory rigs were conducting VSP operations simultaneously with a seismic survey ship in the same area. However, in this case it would be probably technically inadvisable as data quality may be affected. In any event, cumulative effects between seismic and other activities will be additive.

In consideration of the size of past exploration licenses and the number of parcels offered in the 2003 Call for Bids, it could be assumed for the purposes of the SEA that there would be a maximum of 14 exploration licenses issued if the 2003 Call is successful. Under the Boards' rights issuance processes for the 2003 Call, licenses must be relinquished if a well is not spudded within the first period of the license (typically 5 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.

The following estimate has been 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 attracted 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.

Recent experience with exploratory drilling offshore Eastern Canada indicates that operators prefer to share the high mobilization costs of drilling units and to drill their respective prospects sequentially rather than simultaneously. Due to the small number of units worldwide that are capable of drilling deep-water prospects in harsh environments, one unit may be dedicated to the deepwater portions of the permit area and another selected for on-shelf portions.

In consideration of the above it is assumed that 4-6 exploration wells will be drilled during the period of the exploration licenses and that one discovery is made that attracts three further delineation wells during the nine-year license period - for a total of 7-9 wells during the period of the licenses. It is further assumed that no more than two drilling units will be active at any given time, and that for a fraction of the drilling time two pairs of wells "overlap".

If the 2003 Call for Bids is successful, it is anticipated that there could be 3-4 seismic programs in the OB area in 2004, two of which may be 3D surveys, and the remaining 2D surveys.

For the purposes of this SEA, it has been assumed that there will be a total of 7-9 wells drilled during the period of the exploration licenses somewhere within the 14 parcels (K. Coady, C-NOPB, pers. comm.). Due to typical rig availability issues, a maximum of two rigs could be drilling at the same time in Orphan Basin: one on the shelf in relatively shallow water and one in deep water off the shelf (K. Coady, C-NOPB, pers. comm.). Any cumulative effects will not be overlapping or synergistic within the Orphan Basin Study Area, unless supply vessels follow the same routes at the same time. Similarly, any drilling in Orphan Basin will not overlap with any drilling on the Grand Banks (see below). Cumulative effects will, however, be additive; this is only a potential issue with migratory species that may be subject to repeated disturbances as they transit the East Coast.

Up to mid-July 2003, there had been 219 exploration, delineation, and production wells drilled offshore Newfoundland and Labrador (C-NOPB web site). As of June 2003, there were a total of 30 current exploration licenses for which no drilling has occurred (C-NOPB web site). Some of these licenses may expire by 2004 unless conditions of the licenses are met. However, these numbers are not indicative of the number of exploration wells likely to be drilled during a typical year on the Grand Banks. The Canadian Association of Petroleum Producers (CAPP) has predicted that there will be between one and four drill rigs per year operating on the Grand Banks over the next 10 years (CAPP 1999). CAPP's scenario for a moderate level of activity predicts two rigs drilling exploration, delineation and production wells on the Grand Banks over the next ten years.

It is reasonable to assume, on average, that there will be one or two exploratory wells drilled per year on the Grand Banks for the foreseeable future (CAPP 1999; D. Burley, pers. comm.). Any cumulative effects on the Grand Banks ecosystem from routine exploratory drilling in Orphan Basin 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 (see Section 4.6).

If cumulative effects are viewed as a potential problem for certain areas of the Study Area, several planning measures could be instituted by the C-NOPB. For example, limits could be imposed on the amount of concurrent seismic and drilling activity that would be allowed, and supply vessel or helicopter routing could be specified to avoid overlaps in time or space.

4.6 Accidental Events

Accidental events with potential for environmental damage offshore may range from small spills of fuels and chemicals, for example during loading or unloading, to medium spills of diesel fuel during a fuel tank rupture, to oil or gas blowouts. This section, based almost verbatim on work done by SL Ross for Husky (2003), addresses diesel fuel and oil blowouts as they are of most concern.

4.6.1 Blowout and Spill Probabilities

4.6.1.1 Blowout and Spill Probabilities

Two types of accidents that could occur during an exploration 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).

4.6.1.2 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 US 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 1300 thousand tonnes per year - see Table 4.1).

The spill record is particularly good for the US Outer Continental Shelf (OCS) where 28,000 wells were drilled and over 10 billion (10^9) barrels[2] of oil and condensate were produced from 1972 to 2000.

[2]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.

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 US OCS waters and the North Sea.

Table 4.1 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 US waters, but is not restricted in international waters. Thus, it was assumed that this practice does not occur frequently in US waters.
2. World-wide numbers of recreational vessels were not available.
3. Insufficient data were available to develop estimates for this class of vessels.

4.6.1.3 Spill Sizes

It is convenient to categorize spill sizes to correspond to statistical databases such as that maintained by the US 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 4.2. 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 4.2 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)

4.6.1.4 Offshore Newfoundland

Spill frequencies for drilling activities off Newfoundland are shown in Table 4.3. Here, both exploration and development wells were used to normalize the spill numbers. It is likely that both forms of drilling are similar with respect to the chances of having small spills.

Table 4.3 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.

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).

4.6.1.5 Summary of Blowout and Spill Frequencies

The oil spill frequencies calculated by SL Ross are summarized in Table 4.4 for Husky's Lewis Hill Project of one well per year (Husky 2003). The highest frequencies are obviously for the smaller, platform-based spills. Spills less than one barrel in size may occur once every two years (roughly one every year for the Orphan Basin scenario of two wells per year), based on recent petroleum development experience off Newfoundland. Spills larger than one barrel but less than 10 barrels may occur once every five years at Lewis Hill (2.5 years for Orphan Basin), and spills in the 1 to 49-bbl range have a 1-in-40 chance (1-in-20 for Orphan Basin) of occurring per year. Oil spills of all types larger than 50 barrels may have about a 1-in-300 chance (1-in-150 chance for Orphan Basin) of occurring every year, based on experience in the US OCS (Husky 2003).

There is about a 1-in-3,600 chance per year (about 1-in-1,800 for the Orphan Basin scenario) of having any sort of deep blowout. Shallow gas blowouts may occur and are three or four times more probable than ones that occur at depth, but these would have virtually no chance of involving an oil spill.

Table 4.4 Predicted Number of Blowouts and Spills for Lewis Hill Project (1 well/yr).

Event	**Historical Frequency (per well drilled)[1]**	**Predicted No. of Events per year**	**Frequency (assumes one well/ year)**
Deep blowout during exploration drilling	2.85×10^{-4}	2.85×10^{-4}	One every 3,600 yrs
Exploration drilling blowout with oil spill >1000-bbl	1.14×10^{-4}	1.14×10^{-4}	One every 8,800 yrs
Exploration drilling blowout with oil spill >10,000-bbl	8.57×10^{-5}	8.57×10^{-5}	One every 11,600 yrs
Exploration drilling blowout with oil spill >150,000-bbl	2.86×10^{-5}	2.86×10^{-5}	One every 35,000 yrs
Platform-based oil spill, 0-1-bbl	0.55	0.55	One every 2yrs
Platform-based oil spill, 1.1-9.9-bbl	0.20	0.20	One every 5 yrs
Platform-based oil spill, 10-49.9-bbl	2.5×10^{-2}	2.5×10^{-2}	One every 40 yrs
Platform-based oil spill, 50-999-bbl	0	See Note[2]	See Note[2]

[1] Blowouts and blowout-spills (first four rows of data) are based on worldwide, US OCS, and North Sea experience; Platform-based oil spills (last three rows of data) are based on Newfoundland experience, 1997 to 2000.

[2] Because there have been no spills of this size in offshore Newfoundland and because the database has a short time frame, detailed predictions are not possible. Nonetheless, the predicted number of events can be expected to be much less than 2.5×10^{-2} and the frequency much less than once every 40 years.

Source: Husky (2003)

The chances of an extremely large (>150,000-bbl), very large (>10,000-bbl), and large (>1,000-bbl) oil well blowout from exploration drilling are very small—about a 1-in-35,000, 1-in-11,600 and 1-in-8,800 chance per year, respectively. This translates into about a 1-in-17,500, 1-in-5,800, and 1-in-4,400 chance for the Orphan Basin scenario. This means that if drilling continued at the rate of one well per year forever, one could expect (for example) an extremely large spill once every 35,000 years (17,500 years for Orphan Basin). These predictions are based on worldwide blowout data and are strongly influenced by blowouts that occurred in parts of the world where drilling regulations may be less rigorous. It might also be reasonable to expect even lower frequencies than those calculated above in view of the fact that no exploration drilling blowout spills larger than 10,000 barrels have occurred anywhere in the world since 1987, suggesting a significant improvement of technology and/or practice over the past 15 years.

In summary, large spills and blowouts are now very rare for offshore US and the North Sea, and the same record can probably be expected for Orphan Basin.

4.6.2 Fate and Behaviour

It is not presently known if the Orphan Basin Study Area contains oil, gas, both or neither in significant quantities. At present, neither the potential properties nor the locations of drilling are known. Furthermore, blowout and spill modeling has not been conducted for the Orphan Basin Study Area. This will be done during the site-specific EA process.

Reviews of the fate and behaviour of Grand Banks oils are contained in Mobil (1985), Petro-Canada (1996), Husky (2000, 2001, 2002, 2003), and off southern Newfoundland (LGL et al. 2000).

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 in the press).

Once on the surface an oil slick in offshore waters will be driven by surface currents that are highly influenced by the wind. All oil spill modeling done to date for the Grand Banks has shown that most spills will be driven to the east by the prevailing westerlies, and spill behaviour in the Orphan Basin would be no exception. However, there may be more of a southeasterly component than on the Grand Banks due to the greater influence of the south-flowing Labrador Current.

Extensive oil spill modeling conducted for Hibernia, Terra Nova, and White Rose demonstrated that most, if not all, offshore spills on the northeastern Grand Banks would not reach the shorelines of Newfoundland, where effects would be greatest. Without pre-judging future modeling exercises, it can be predicted that most spill scenarios for the Orphan Basin and Flemish Pass parcels would show oil flowing mostly to the east with little if any reaching shore. However, the situation for those two parcels on the northeast Newfoundland shelf is more uncertain because the current and wind regime is probably more complex and because they are closer to land than the Basin or Pass parcels. Also, previous analysis and modeling for the Grand Banks used fairly waxy crude and shallow water which puts the fate of most of the oil on or near the surface of the water; very deep water blowouts may have unusual behaviours.

4.6.3 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. The key points of relevance to offshore planning for the Orphan Basin 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, but given the ubiquitous nature of their distribution, and the fact that most oil is expected to rise to the surface, large scale toxic effects will not occur.

- Benthos will 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. Under most reasonable scenarios, it is unlikely that enough eggs and larvae could be affected to be detected at the population level or by the fishery. In other words, any mortalities would be masked by naturally high rates of mortality of these life stages.

- Marine mammals and sea turtles are generally believed to be able to avoid most spills and thus while some negative health effects on individual animals could occur, overall effects on the populations would be small. Sea turtles may be somewhat more sensitive than marine mammals in this regard. Also, a large scale oil spill that coincided with the seal ‘pupping’ front could have population level effects.

- 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 entering 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 (Camphuysen 1989; Wiese 1999). Diving-feeders occurring within the Orphan Basin Study Area include Greater Shearwaters, Sooty Shearwaters, Manx Shearwaters, Northern Gannets, Terns, Dovekies, Common Murres, Thick-billed Murres, Razorbills, Black Guillemots, and Atlantic Puffins.

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 potentially significant biophysical effect from a large offshore oil spill or blowout is with seabirds, and then only 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 the Orphan Basin 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. Effects could be potentially significant if markets are affected although these can be mitigated to a large degree by monetary compensation programs.

4.6.4 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-NOPB. 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 the Eastern Canada Response Corporation (ECRC), or equivalent, to provide spill response capabilities in the event of a spill.

It should be noted that offshore spill response in the case of a major blowout in the Orphan Basin Study Area would probably be of limited value except under the somewhat unusual conditions of calm, ice-free seas. Nonetheless, a rapid response capability such as boom deployment around the source can mitigate a spill to some degree. Response effort would also be directed toward protecting sensitive shorelines.

Effects on the fishery can be mitigated by compensation programs.

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 will be required to submit OSRPs and compensation plans to the Board.

4.6.5 Data Gaps

The effects of different types of petroleum hydrocarbons are fairly well known. The distribution of the fisheries in the Study Area are 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 well known. DFO is presently addressing distribution of fish eggs and larvae, and marine mammals, at least to a limited degree. Seabird and marine monitoring programs that are now required components of seismic and drilling programs will be adding important distributional data as well. These data are important because there are probably large feeding concentrations in the Study Area.

- Fate and behaviour of oil spills. Physical characteristics of hydrocarbons are unknown and potential trajectories are unknown. Oil properties cannot be defined until oil discoveries are made in the Study Area but trajectory analyses will be run as part of the project-specific EA process. Highest priority ‘release points’ for the modeling should be those parcels on the shelf.

5.0 Cumulative Effects

In consideration of the size of past exploration licenses and the number of parcels offered in the 2003 Call for Bids, it could be assumed for the purposes of the SEA that there would be a maximum of 14 exploration licenses issued if the 2003 Call is successful. Under the Boards' rights issuance processes for the 2003 Call, licenses must be relinquished if a well is not spudded within the first period of the license (typically 5 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.

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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 attracted 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.

Recent experience with exploratory drilling offshore Eastern Canada indicates that operators prefer to share the high mobilization costs of drilling units and to drill their respective prospects sequentially rather than simultaneously. Due to the small number of units worldwide that are capable of drilling deep-water prospects in harsh environments, one unit may be dedicated to the deepwater portions of the permit area and another selected for on-shelf portions.

In consideration of the above it is assumed that 4-6 exploration wells will be drilled during the period of the exploration licenses and that one discovery is made that attracts three further delineation wells during the nine-year license period - for a total of 7-9 wells during the period of the licenses. It is further assumed that no more than two drilling units will be active at any given time, and that for a fraction of the drilling time two pairs of wells "overlap".

If the 2003 Call for Bids is successful, it is anticipated that there could be 3-4 seismic programs in the Study Area in 2004, two of which may be 3D surveys, and the remaining 2D surveys.

5.1 Oil and Gas Activities

Potential cumulative effects in the Orphan Basin Study Area from oil and gas activities are those that would originate from two exploration drilling programs: one on the shelf and one in deep water. [This has been determined as the most likely 'worst case' scenario based on predicted availability of specialized rigs. Additionally, there could be one or two geophysical programs (although potentially as many as four the first year) during a typical year based on previous Grand Banks experience.

Baring 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.]

The geophysical programs (2D, 3D, VSP, or other) will certainly 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 outside the mandate of the present study, 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.

5.1.1 Seismic Surveys

The environmental effects of individual seismic programs are not necessarily mutually exclusive of each other. It is possible, albeit slightly, that these effects could accumulate and interact to result in cumulative environmental effects.

As in other potential Eastern Canadian hydrocarbon exploratory areas that have recently undergone environmental assessment, it is anticipated that one or two seismic surveys (as many as four) may be conducted annually within the Orphan Basin Study Area over the next few years (Husky 2000, 2001, 2003). Seismic activities during any particular year would likely not overlap as their acoustic data quality would be poor. If there was some degree of temporal overlap between seismic programs in the Study Area, there would likely be considerable spatial separation.

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 (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, seismic programs will undergo the site-specific EA process and monitoring programs and FLOs will be required.

There is another possible scenario that could result in cumulative effects. This scenario involves highly mobile marine animals (primarily marine mammals and sea turtles) that, through their movements, could be exposed to the noises of the same seismic program multiple times. The potential for cumulative effects on marine mammals and sea turtles will therefore depend on the intensity and spatial distribution of any particular seismic program as well as the movement patterns of the animals. It is most likely that these marine animals would initially avoid the immediate area being exposed to seismic and remain distant from it until cessation of seismic activity.

5.1.2 Fisheries

The Study Area, particularly on the shelf and slopes, undergoes intensive fishing pressure (see Section 3.2.3), 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 slight, but not measureable, additional stress on fish and fisheries. However, it should be noted that the majority of the parcels (Orphan Basin proper) do not receive intensive fishing pressure at present, at least not from Canadian vessels.

5.1.3 Shipping

Parts of the Study Area are subject to potentially heavy vessel traffic (i.e., thousands of transits) from fishing vessels (mostly to and from the shelf and slopes, during summer) and shipping. According to Figure 4.5-1 *in* Mobil (1985), a major shipping lane bisects the Study Area from the northeast to the southwest during May to December. Vessel traffic associated with exploration activity in the Study Area on the order of several supply vessel transits per week will be insignificant compared to normal traffic patterns.

5.1.4 Other Activities

Other activities with some potential for cumulative effects are hunting, military activity (e.g., naval exercises), and research activity (e.g., in the past Texas A&M University has conducted deepsea drilling in the Study Area, Bedford Institute of Oceanography has conducted extensive geological studies at least in the Flemish Pass area, and DFO may also conduct fisheries research trawling in the Study Area.). Hunting is probably not an issue as it involves inshore activity directed at nearshore populations of sea ducks and murres (known locally as 'turres'). At present, there is no specific information available on projected military or research activity in the area but the Orphan Basin is north of typical naval training areas (D. Thomson, LGL, pers. comm.) but it does have a history of physical and geological research cruises.

6.0 Summary and Conclusions

6.1 Potential Issues

Potential issues that are generally applicable to East Coast oil and gas exploration activity include:

- Effects of accidental spills on marine flora and fauna
- Effects of noise on marine mammals, and to a lesser extent on commercial invertebrates and fish
- Disturbance of sensitive benthic communities, particularly little known deep water communities such as deep water corals
- Attraction of seabirds, particularly petrels, to rigs and supply vessels

Potential issues specific to the Orphan Basin Study Area identified during this SEA include:

- All of the above issues in combination with large data gaps on the distribution of VECs within the Study Area, including areas that have been postulated as major areas of enhanced production and feeding such as slope of the northern Grand Banks and fronts associated with the Labrador Current
- Potential sensitivity of the Bonavista Corridor or 'Cod Box' where there may be large congregations of Atlantic cod, a species listed as endangered by COSEWIC and listed under *SARA*.
- Intensive exploitation of fisheries on the shelf and slopes in the Study Area
- Potential conflicts with international fisheries outside the EEZ

6.2 Data Gaps

There is a considerable database on fishery landings in the Study Area and it is clear that the western and southern halves of the area are very important to the fishery, particularly for species such as snow crab, northern shrimp, Greenland halibut, and historically, Atlantic cod. At least the western half of the Study Area is known to be an important feeding area for many species of seabirds and marine mammals but quantitative survey data are very scarce.

Key data gaps identified during this SEA include:

- Distribution of VECs in time and space, specifically fish eggs and larvae, seabirds, marine mammals and sea turtles, particularly for *SARA*-listed species such as Atlantic cod and wolffish, potentially Ivory Gull, leatherback turtle, and northern bottlenose whale

- Locations of enhanced areas of production and/or concentrations of feeding seabirds and marine mammals

- 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 deepwater 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 parcels within the Study Area, with highest priority given to those parcels (#1 and #2) on the shelf

6.3 Addressing the Data Gaps

As previously discussed, most of the data gaps can be addressed in the following manner.

- Additional distributional data (e.g., fish spawning aggregations) on key VECs are presently being collected by DFO. In addition, bird and mammal surveys required as part of exploration activities will add to the distributional database. Areas of concentration and/or critical habitat can be determined from satellite data and directed aerial and boat-based surveys, potentially under the auspices of ESRF or other funding venue. Site-specific EAs will also provide additional analyses and information.

- The C-NOPB may require the collection of benthic and noise data as part of the approval process for exploration activities.

- Physical and chemical properties of oil and gas from Orphan Basin is probably a moot point until significant discoveries are made. The C-NOPB will require the data to be collected prior to approving a development application for production.

- Oil spill trajectory modeling (and potentially drill mud deposition modeling) will be conducted during the site-specific EA process.

- Because the Orphan Basin Study Area is a ‘new area’ with some large data gaps, the Board will require detailed baseline studies as part of any EA in support of an oil production development application.

6.4 Planning Considerations

6.4.1 Potential Zoning Scheme

Planning inevitably implies some type of classification or zoning approach to development. Given the large data gaps, such an exercise can be considered tentative. Based on information presented in the SEA the following ‘zones’ could be assigned to the Orphan Basin Study Area. These zones are based primarily on physical features (as suggested by stakeholders during the scoping meeting) with some consideration to known biological factors and parcel locations (Figure 6.1).

Zone A: ‘top shelf’ with <200-m water depths; benthic conditions may be similar to the Grand Banks but primary production may be higher due to upwelling caused by the Labrador Current confronting the shelf edge; includes southwestern corner of the Study Area and potentially small areas in the extreme northwest and southeast corners of the Study Area It contains only one parcel (#2) (Figure 6.1). May contain high densities of feeding seabirds and humpback whales. The southwestern and northwestern components of this zone have high densities of snow crab as demonstrated by the catch distribution figures (see Figures 3.10 to 3.24).

Zone B: ‘low shelf’ or top of shelf break with 200 to <400-m water depths; covers a relatively broad band along the northeast Newfoundland shelf mostly in the western half of the Study Area, but also northern Flemish Cap (Figure 6.1). Contains the potentially critical Bonavista ‘Cod Box’ that appears important as a migration pathway for Atlantic cod and as spawning habitat for Atlantic cod, American plaice and redfish (see Figure 6.1) May contain high densities of feeding seabirds and humpback whales. This zone contains only two parcels: #1 and #13. The most important commercial fisheries presently being prosecuted in this zone are those for snow crab (western Study Area zonal component) and northern shrimp (both zonal components).

Zone C: ‘deep break’ with 400 to <2,000-m water depths; a band that contains the core of the strong offshore branch of the Labrador Current and any associated areas of frontal enhancement of production due to current shear (Figure 6.2). It includes Flemish Pass and the area north of Flemish Cap where the current turns to the east. May contain feeding concentrations of migrating or overwintering seabirds and deep sea whales. Parcels 3, 6, 7, 10, 11, 12 and 14 are located in this zone. Greenland halibut and

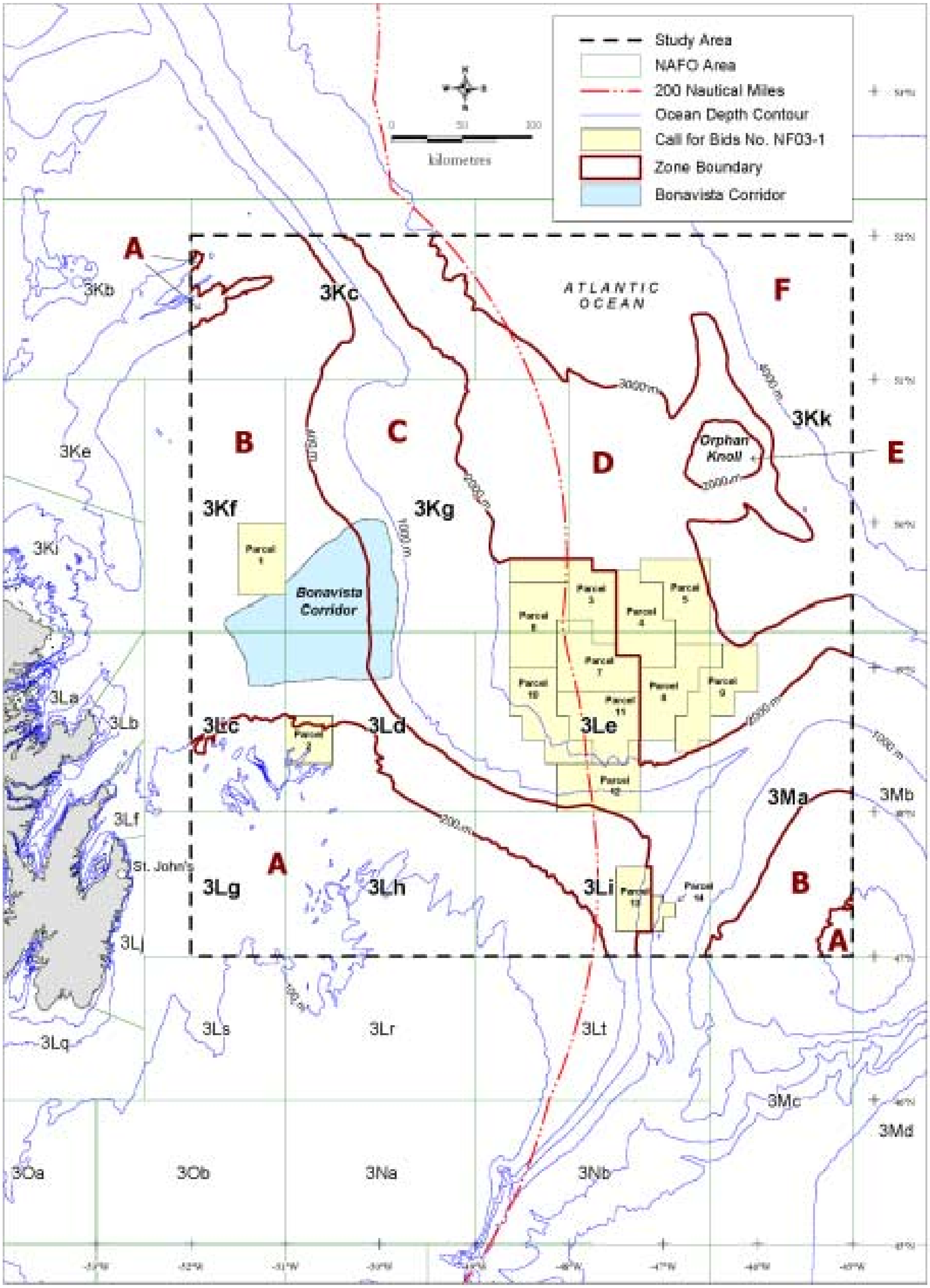

Figure 6.1 Proposed Zonal Scheme for the Study Area.

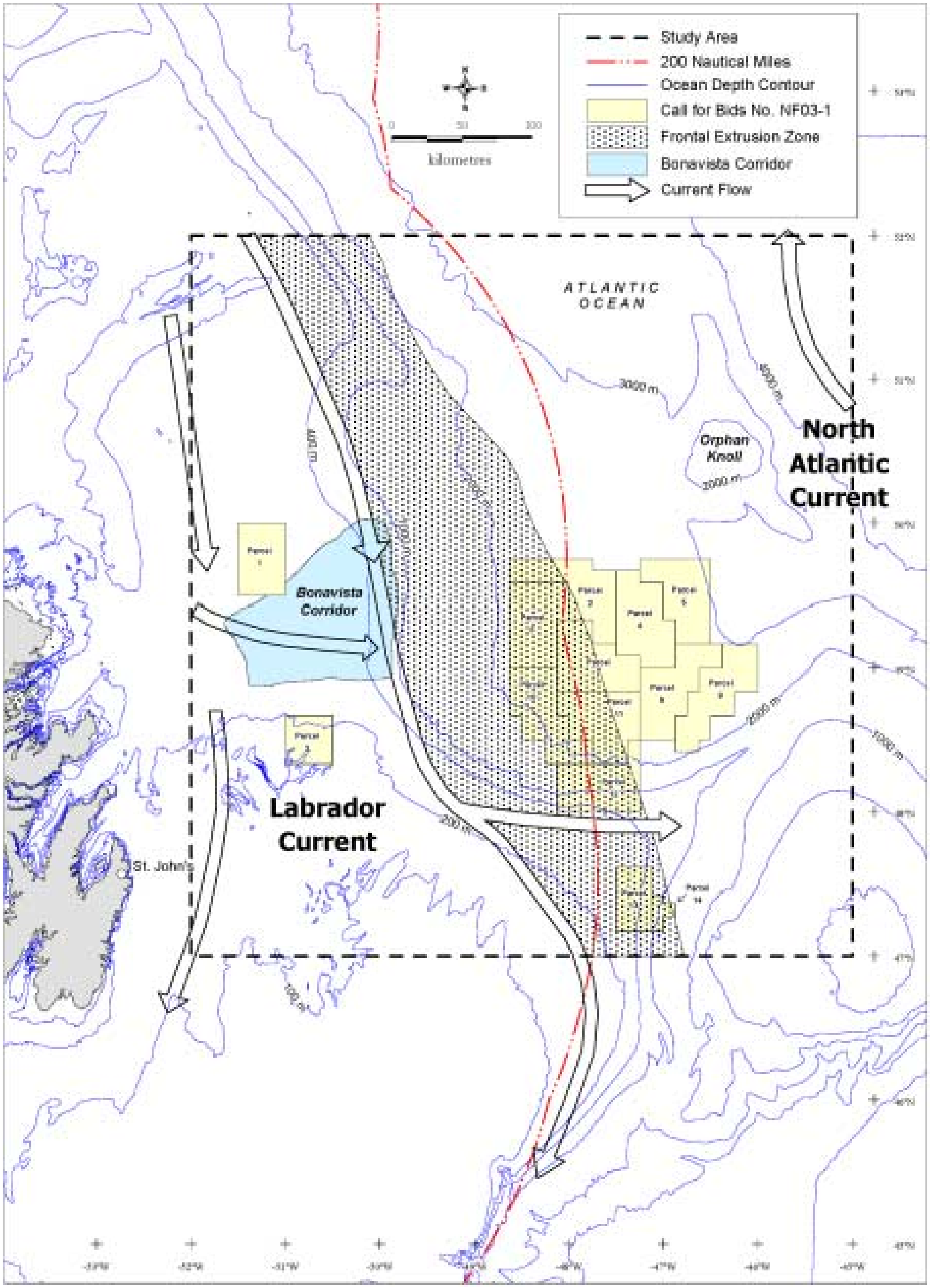

Figure 6.2 General Locations of Major Oceanic Currents and Frontal Extrusion Zone in the Study Area.

northern shrimp are presently the most important commercial species within this zone, particularly in the shallower portion of it. This zone also contains the most diversified group of commercial fisheries, including the harvests of American plaice, witch flounder, redfish, roughhead grenadier, wolffish and skate. Tuna and swordfish catches have also been reported in the northern part of this zone

Zone D: 'deep basin' with water depths 2,000 to 3,000-m; contains parcels 4, 5, 8, and 9. Productivity may be lower than the shallower zones and there is less likelihood of high concentrations of marine life. Bottom communities are probably very uniform and long-lived. There is a lack of commercial fishery data in this zone, probably because Canadian commercial fishery effort in the portion of this zone inside of the EEZ is limited, and most of the zone lies outside of the EEZ where commercial catch data are more tenuous.

Zone E: Orphan Knoll proper; water depths 2,000 to about 1,800-m; assigned its own zone based on the potentially unique biology of a steep-sided rise in a deep sea basin. It contains no parcels at present. There is a lack of commercial fishery information in this zone.

Zone F: 'very deep basin' with water depths 3,000 to 4,000+m; Bottom communities are probably very uniform and long-lived; productivity and concentrations of marine life probably relatively low. It contains no parcels at present and is also generally devoid of biological data. There is a lack of commercial fishery information in this zone.

The C-NOPB, in consultation with other regulators, and as more information becomes available, may use a zoning approach similar to the concept presented above. The Board may specify special mitigations by zones. For example, certain areas such as the Bonavista 'Cod Box' may have to be avoided entirely. Zones A and B on the shelf may require more detailed spill modeling than zones off the shelf. Deep water zones C or D may require more baseline benthic data to be collected than the more well-known shallow areas would require.

6.4.2 Available Mitigations

Mitigations have been discussed in Sections 4.2.3, 4.4 and 4.6.4.

For seismic exploration (including vertical seismic profiling or VSP), available mitigations include

1. Ramping up ('soft start') of airguns at the start of survey,

2. Placement of marine mammal observers to collect data on marine mammals, seabirds and sea turtles,

3. Communication with the fishing industry,

4. Notice to mariners,

5. Use of fisheries guard vessels and observers (FLOs) to help avoid conflicts with fishing vessels and gear,

6. Compensation for gear losses attributable to seismic survey activity,

7. Selection of equipment to minimize source levels,

8. Avoidance of sensitive areas and/or times (e.g., the Bonavista 'Corridor' or 'Cod Box'), and

9. Shutdowns if certain sensitive species of marine mammals are within a pre-determined safety zone.

Mitigations 1 to 6 are now standard practice in 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-NOPB,

- Use of environmental criteria (to minimize emissions) in selection of any new equipment to be installed,

- Well abandonment procedures to be approved by C-NOPB (mechanical procedures are much preferred over explosive means; if explosives are used, restrictions on safety zones, timing, type, placement and shape of charges will be imposed),

- Selection of supply vessel and aircraft routing to avoid sensitive areas and/or times, in so far as safety issues allow,

- Communication with fishing industry and other mariners in regard to vessel routing and safety zone, and other issues that may arise,

- Placement of seabird observers (also to record marine mammals and sea turtles) on supply vessels, and

- Implementation of a fishing gear compensation program in the event that gear is damaged by an operator.

All of the above mitigations are now standard practice on the East Coast.

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-NOPB,

- Participation in the East Coast Response Corporation,

- 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.

All of the above mitigations are now standard practice on the East Coast.

6.5 Conclusion

This SEA has been intended to aid the C-NOPB in their decision-making in regard to potential restrictions on seismic surveys and exploratory drilling in the Orphan Basin area in general and the parcels out for bids in particular. At present, the major constraint is the lack of distributional data on seabirds and marine mammals and baseline data on sensitive benthic communities (e.g., particularly deepwater benthos, including corals). It is anticipated that these data gaps will be at least partially filled during the required site-specific EA process and monitoring programs conducted during exploration activities. In the event that commercial discoveries of oil or gas are made, major baseline surveys will be required prior to approval of a Development Plan Application for production.

In conclusion, other than the Bonavista 'Cod Box', and the data constraint mentioned above, there were no issues discovered during this SEA that would *a priori* preclude oil exploration activity conducted using C-NOPB-approved vessels, rigs and procedures. Nonetheless, the SEA will be reviewed in five years time and periodically thereafter.

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