

# Northern Jeanne d'Arc Basin Seismic Program Environmental Assessment



# **Northern Jeanne d'Arc Basin Seismic Program Environmental Assessment**

**Prepared by**



**Prepared for**



**Husky Energy Inc.  
707-8th Avenue SW  
Box 6525, Station "D"  
Calgary, AB  
T2P 3G7**

**14 March 2005  
Project No. SA836**

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**Prepared by**

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# 1.0 Introduction

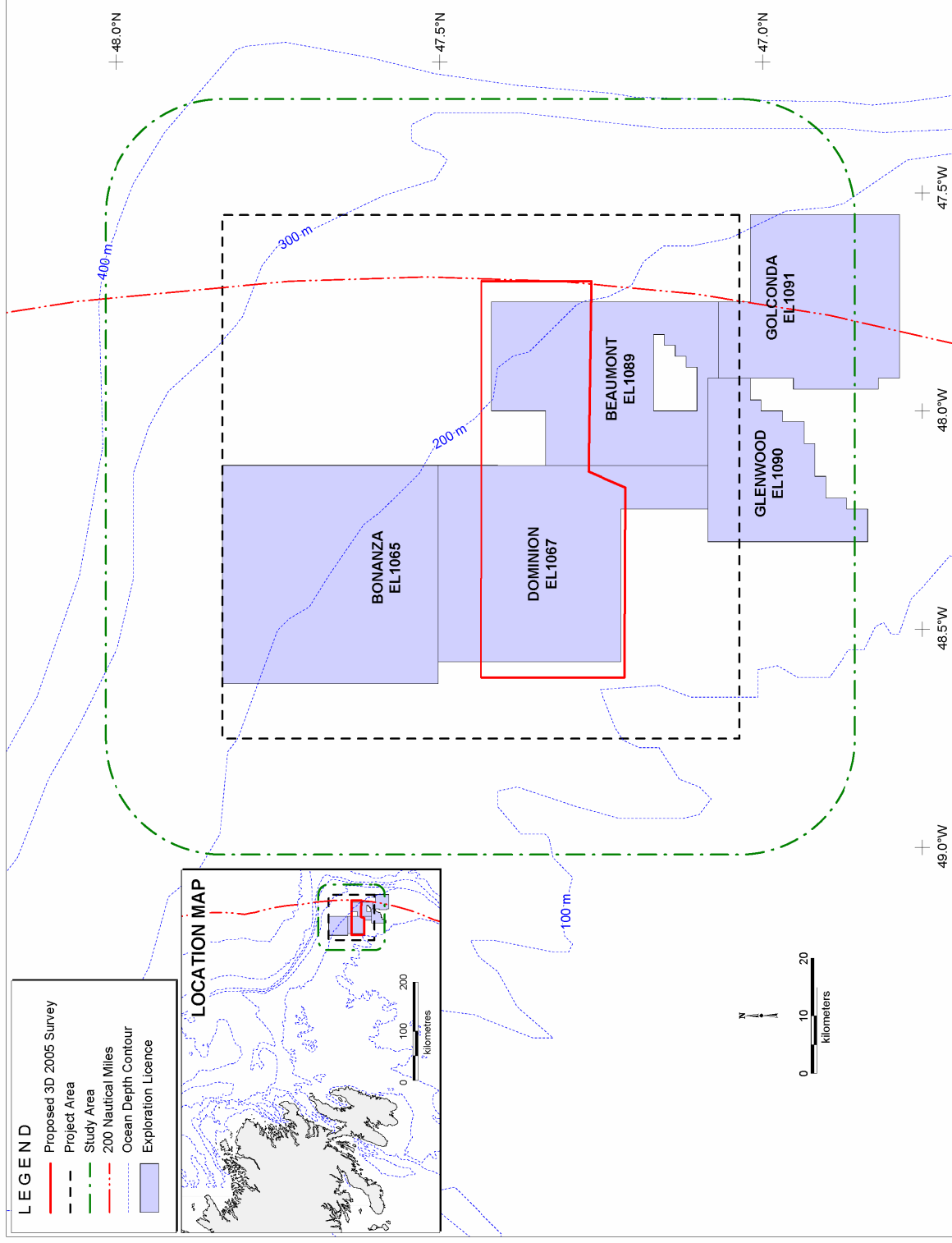
Husky Oil Operations Limited (Husky) proposes to undertake 3-D seismic surveys and follow-up well site geohazard surveys on Husky's exploration acreage in the Northern Jeanne d'Arc Basin (see Figure 1.1). Husky foresees initiating the 3-D seismic survey in the summer of 2005 while other seismic and/or geohazard surveys may occur in 2006 and 2007. The Project would include subsequent geohazard surveys (i.e., well site surveys) only if likely drilling targets are identified.

This document provides a Project Description to allow the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) to fulfill its responsibilities under the *Canadian Environmental Assessment Act* *Federal Coordination Regulations*. This Project Description together with the technical and scope advice received from the C-NOPB and other Federal Agencies through the *Federal Coordination Regulations* and from other stakeholders consulted by Husky will guide the preparation of a Screening Level Environmental Assessment.

## 1.1. Relevant Legislation and Regulatory Approvals

An *Authorization to Conduct a Geophysical Program* will be required from the Canada-Newfoundland Offshore Petroleum Board (C-NOPB or "Board"). The C-NOPB is mandated by the *Atlantic Accord Implementation Acts*. Offshore geophysical surveys (including geohazard surveys) on federal lands are subject to screening under the *Canadian Environmental Assessment Act (CEA Act)*. The Board acts as the federal environmental assessment coordinator or FEAC. Because seismic survey activities have the potential to affect seabirds, marine mammals, and fish and fisheries, the Fisheries and Oceans and Environment Canada are the primarily interested agencies. Legislation that is relevant to the environmental aspects of this Project includes:

- *Canada-Newfoundland Atlantic Accord Implementation Acts*
- *Canadian Environmental Assessment Act*
- *Oceans Act*
- *Fisheries Act*
- *Navigable Waters Act*
- *Canada Shipping Act*
- *Migratory Bird Act*
- *Species at Risk Act*



**Figure 1.1. Location of Project Area.**

## 1.2. Canada Newfoundland Benefits

Husky Energy is committed to bringing maximum benefits associated with East Coast operations to Canada, and in particular Newfoundland and Labrador, where commercially achievable in accordance with our operating philosophy and legislative requirements. In the spirit of the Atlantic Accord, Husky actively seeks to enhance the participation of Canadian, and Newfoundland and Labrador, individuals and organizations in offshore oil and gas activity on the East Coast. Husky's commitment to delivering benefits to the Province and to Canada is outlined in the White Rose Development Application Volume One: Canada-Newfoundland Benefits Plan.

Husky manages East Coast operations from its St. John's office. Canadian, and in particular Newfoundland Labrador, individuals and organizations are provided with *full and fair opportunity* to participate in Husky's activities on the East Coast. Husky also supports the principle that *first consideration* be given to personnel, support and other services that can be provided by Newfoundland and Labrador, and to goods manufactured in Newfoundland and Labrador, where such goods and services are competitive in terms of fair market price, quality and delivery. Contractors and Subcontractors working for Husky on its East Coast operations must also subscribe to and apply these principles in their own operations.

## **2.0 Contacts**

### **2.1. Executive Contact Information**

- Mr. Rood Zoon, General Manager, Husky East Coast Operations  
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### **2.2. Geophysical Contact**

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### **2.3. Environmental Contact**

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## 3.0 Proposed Project

### 3.1. Name and Location

The Northern Jeanne d'Arc Seismic Program Project Area includes the exploration licenses (ELs) 1065, 1067 and 1089 in their entirety and northern portions of EL 1090 and 1091 (Figure 1.1). The x,y coordinates of the Project Area in NAD 83 Zone 22 coordinates are:

Top Left (NW) Corner - Lat 47° 50' Long 48° 45'

Bottom (SE) Right Corner - Lat 47° 33' Long 47° 02'

Husky's intention is to acquire a 3-D seismic survey on EL 1067 and 1089 (Phase 1). The maximum area under consideration for this survey (Year 1) is indicated on Figure 1.1. The coordinates for this proposed 3-D survey in NAD 83 Zone 22 are:

Lat 47° 12' 40" Long 48° 36' 36"

Lat 47° 12' 35" Long 48° 10' 29"

Lat 47° 16' 02" Long 48° 08' 17"

Lat 47° 15' 47" Long 47° 42' 07"

Lat 47° 25' 57" Long 47° 42' 05"

Lat 47° 25' 59" Long 48° 36' 36"

At present, it is estimated that a 9 km turning radius is desirable and the defined Project Area includes enough area around the ELs to easily accommodate seismic vessel turning radii and holding areas during 3-D seismic surveys.

If likely drilling targets are identified, the Project will also include subsequent geohazard surveys (i.e., well site surveys). These may be conducted anywhere on Husky's ELs within the Project Area boundaries (Figure 1.1), depending on the final geophysical interpretation using the acquired 3-D survey and the existing 2D seismic in the application area.

#### 3.1.1. The Operator

Headquartered in Calgary, Alberta, Husky Oil Operations Limited (the Operator) is a Canadian-based integrated energy company serving global customers, committed to maximizing returns to its shareholders in an ethical and socially responsible way, through the dedicated effort of its people. It is involved in:

- Exploration and development of crude oil and natural gas,
- Production, purchase, transportation, refining and marketing of crude oil, natural gas and natural gas liquids and sulfur, and

- Transportation and marketing of refined products.

The Operator is the management and operating company for the Operator's six Significant Discovery Areas (SDA) and ten Exploration Licenses, offshore Newfoundland. The White Rose field, the largest of the Operator's SDA's, is estimated to contain approximately 230-250 million barrels of recoverable reserves.

## **3.2. Project Overview**

The proposed Project is a shipborne geophysical program consisting of approximately 1,500 km<sup>2</sup> of 3-D survey (Year 1) and a yet-to-be-determined area of 3-D and/or geohazard surveys in Years 2 and 3. Surveys will be within Husky ELs 1065 (Bonanza), 1067 (Dominion), and 1089 (Beaumont), and possibly northern portions of EL 1090 (Glenwood) and EL 1091 (Golconda). Some adjacent lands are also included as part of the overall Project Area in order to ensure inclusion of N. Dana, ship turning and holding areas (Figure 1.1).

The surveys will be conducted by a charter seismic vessel or vessels that will be operating in Newfoundland and Labrador waters during 2005-2007. These vessels have previously been assessed as part of other operators' seismic programs and will be assessed again for the coming seasons. The vessels will be approved for operation in Canadian waters and are typical of the worldwide fleet.

The 3-D seismic survey ship will tow a sound source (airgun array) and streamer (s) composed of receiving hydrophones. Survey lines may run north-south or east-west and be spaced between 200 and 400 m apart. The geohazard surveys will be conducted over a much shorter time frame using a smaller vessel and a combination of smaller scale seismic equipment, sonars, and boomers.

Mitigation procedures will include dedicated marine mammal observer (MMO) (s) and "soft-starts" or "ramp-ups" of the 3-D array in order to avoid disturbance to marine life, particularly marine mammals, and a fisheries liaison officer (FLO) and communication procedures to avoid conflicts with the fishery.

### **3.2.1. Alternatives to Project, Alternatives within Project**

The existing 2-D seismic data on EL 1067 and EL 1089 indicate two structures that may contain significant volumes of producible hydrocarbons. The existing data are insufficient to determine exact structural size and internal complexity. Acquisition of new 3-D seismic is required to determine if exploration drilling is warranted.

Husky has exploration commitments on the ELs. The 3-D seismic survey is now a standard precursor to offshore exploratory drilling. It lessens the chances of expending resources "drilling dry holes" and increases safety margins. As such, there is no alternative to the 3-D Project other than to incur financial penalties, lose existing licenses, and explore for oil and gas elsewhere.

Geohazard surveys are a legislated requirement and a standard safety procedure prior to drilling and there is no alternative to them other than to not drill.

Viable alternatives within the Project are the choices between different contractors' ships and survey equipment which are evaluated through the bid evaluation process. In addition, lines can be run north-south (preferred) or east-west.

### **3.2.2. Project Phases**

The Project can be considered as three phases: (1) Year 1 (3-D survey of area defined in Figure 1.1), (2) Year 2 (3-D survey of any other areas that may be identified through additional analyses of existing 2-D data, and geohazard surveys in preparation for a potential drilling program), and (3) Year 3 (additional 3-D and/or geohazard data collection in anticipation of a potential drilling program).

### **3.2.3. Project Scheduling**

The surveys may occur between 1 April and 31 October of any given year. Most likely time window for the 2005 3-D survey is 1 June to 31 October 2005. The duration of the Year 1 3-D survey is estimated at 83-95 days of actual data acquisition and the duration of a geohazard survey in support of a potential drilling program is about 4 days.

### **3.2.4. Site Plans**

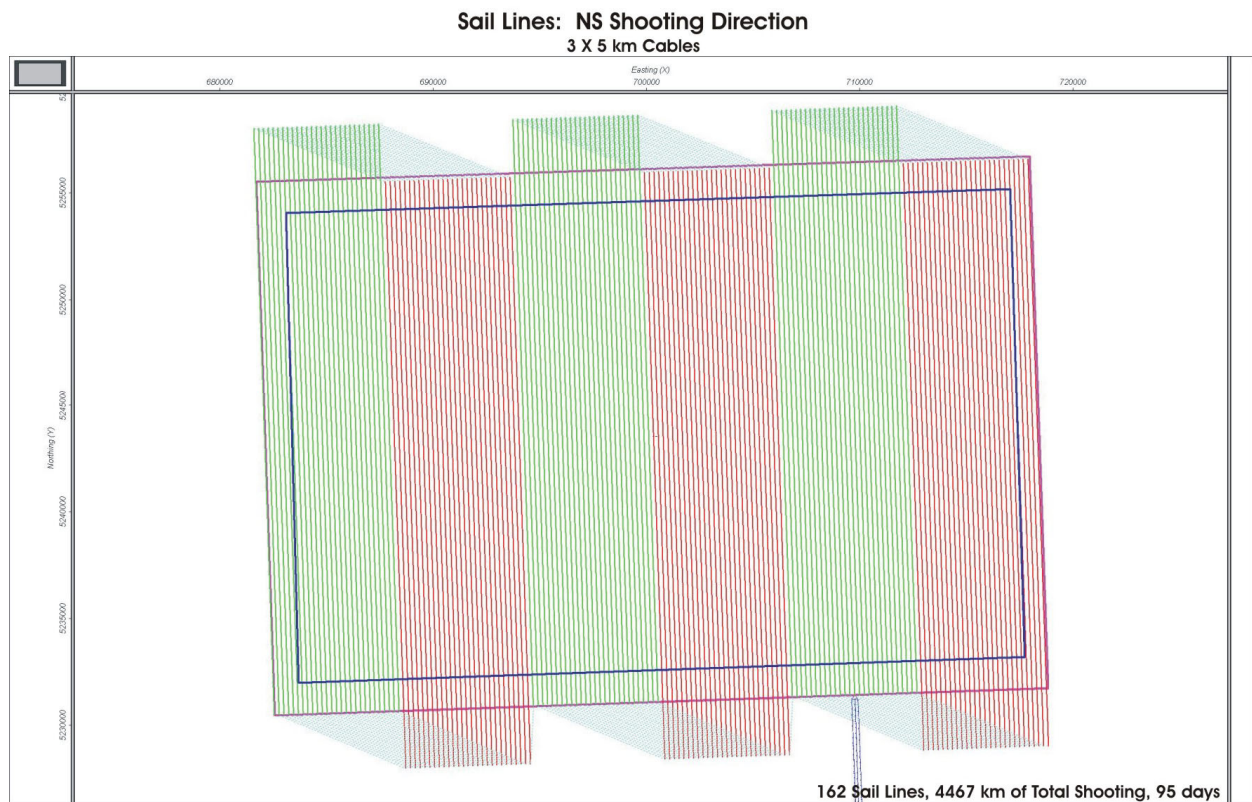
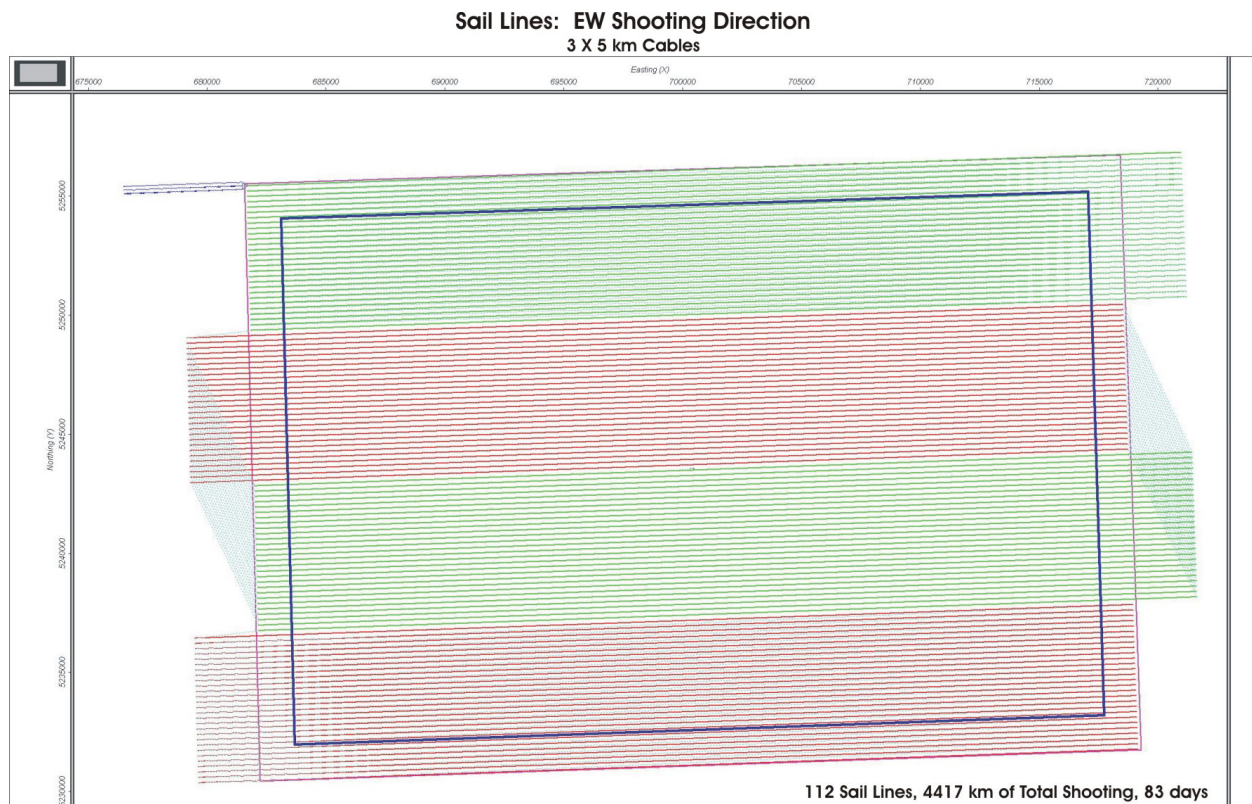
Site maps showing the Project Area and proposed survey area and lines for Year 1 are provided in Figures 1.1 and 3.1. If the 2005 survey starts in June, there will be sufficient time for the lines to be run north-south (preferred); if the survey starts later, lines will be run east-west (see Figure 3.1).

### **3.2.5. Personnel**

The largest seismic vessels in use offshore could potentially accommodate up to 140 personnel. Personnel on seismic vessels typically include individuals from the Operator (i.e., Husky), the vessel owner/operator (ship's officers and crew), and the various technical and scientific personnel from a variety of contractors and subcontractors.

### **3.2.6. Seismic Vessels**

Vessels presently approved and operating on the East Coast on other programs will be utilized. The *GSI Admiral* has been selected to conduct the 2005 3-D seismic survey. Vessel specifics for subsequent years will be provided once the contractors are selected. Most, if not all likely survey vessels have diesel-electric propulsion systems (main and thrusters) and operate on marine diesel or marine gas-oil.



**Figure 3.1. Proposed Sail Lines for East West or North-South Orientation.**

### 3.2.7. 3-D Seismic

As described above, Husky will utilize a seismic vessel already operational in East Coast waters. The 3-D survey sound source will consist of two airgun arrays, 3,000 to 5,000 cubic inches (in<sup>3</sup>) in total volume spaced 50 m apart, and towed at depths about six to seven metres. The airguns will be operated with compressed air at pressures of 2,000 to 2,500 psi, and producing peak-to-peak pressures on the order of 140 bar m or less. There will be three to eight towed streamers (strings of hydrophone sound receivers), 5,000 to 6,000 m in length that will be towed behind the vessel at depths about four to eight metres. Sail lines will run north-south or east-west with spacing dependent upon the number of streamers, probably between 200 and 400 m. Streamer flotation will be either solid or liquid (Isopar) depending upon availability from specific contractors. GSI, the 2005 contractor, presently uses liquid-filled streamers.

#### 3.2.7.1. 2005 3-D Program

The 2005 program will be conducted by the *GSI Admiral*. Detailed specifications for the 2005 3-D Seismic Program are shown below.

- Duration of seismic program – 150 days
- Duration of data acquisition – about 90 days
- Expected dates of operation – June 1, 2005 – October 31, 2005
- Water depth of 2005 program area – 100 – 200 meters
- Area proposed to be surveyed in 2005 – 800 to 1,500 km<sup>2</sup>
- Number of seismic lines – (see Figure 3.1)
- Distance from source arrays to vessel – 90 metres

#### 3.2.7.2. 3-D Survey Equipment

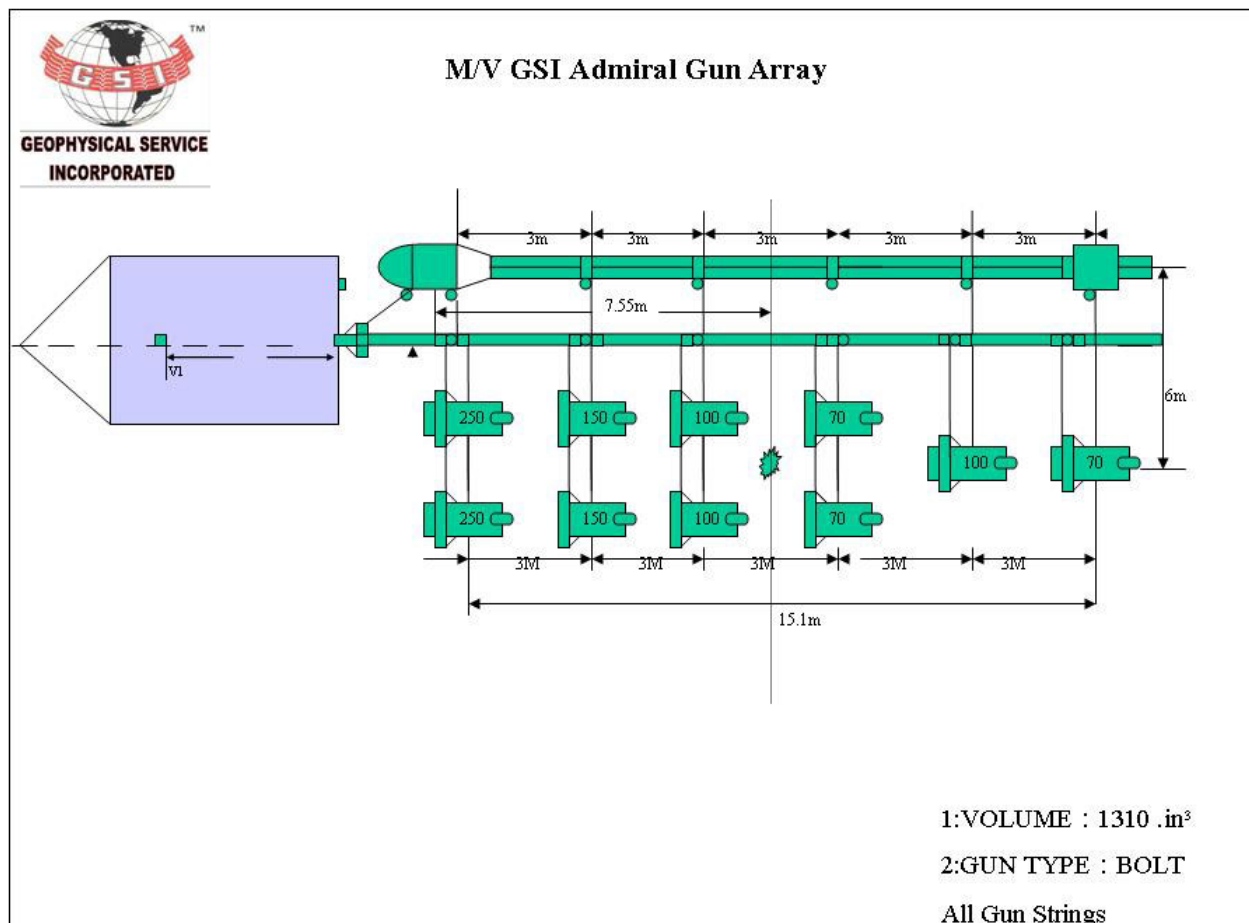
- Volume of each source array – 1,310 cu in [Will use two arrays (run “flip flop”), each with two strings per the attached at 10 meter lateral separation, initiated alternately at 25 meter interval.]
- Schematic of source array – see Figure 3.2.
- Depth of source array – 6 meters
- Source level of array – 85 bar meters
- Source air pressure – 2,000 psi
- Source interval – 25 meters flip-flop or alternating two arrays
- Length of streamers – 6,000 metres
- Length of each streamer section – 100 metres
- Amount of Isopar per section – approx 55 US gals (0.21 m<sup>3</sup>)  
(Isopar in separate hydrophone pocket – no)

### 3.2.7.3. 3-D Vessel

In 2005, the *GSI Admiral* will be the survey vessel. Vessel details are shown below and additional descriptive material is appended (Appendix II).

Crew capacity of vessel – 36 people  
Environmental observers – 1-2  
Number of streamers – 3  
Length – 90 metres  
Propulsion (4,800 BHP; thrusters)  
Fuel – marine gas-oil  
Crew – 36  
Echosounder – Odom, CTS200/12 – 9/24, 12 khz

The *Admiral's* 3-D array is shown in Figure 3.2. Two such arrays, firing alternately, would be employed.



**Figure 3.2. Source Array for 2005 3-D Seismic Program.**

### 3.2.8. Well Site/Geohazard

Once a potential drilling site is located it is standard offshore industry procedure, and a requirement of the C-NOPB, that a well site/geohazard survey be conducted. The purpose of the survey is to identify, and thus avoid, any potential drilling hazards such as steep and/or unstable substrates or pockets of “shallow gas”. It involves acquisition of high resolution seismic, side scan sonar, sub-bottom profile, and bathymetric data over the proposed drilling area (s). Typically the seismic data for well site surveys is collected over closer lines (250 m), using smaller equipment and lower pressures, over a shorter time period (e.g., several days) compared to 3-D seismic programs.

Surficial data are collected using a broad band (e.g., 500 Hz to 6 kHz) sparker or boomer as a sound source which provides data as deep as 100 m into the substrate. A single or multi-beam echo sounder is used for bathymetry and a dual frequency side scan sonar system is used to obtain seabed imagery. Seabed video and/or grab samples are used to provide ground truthing information on the character of the seabed and sediments.

The program will acquire high resolution seismic, side scan sonar, sub-bottom profiler and bathymetric data over the proposed area (s). Survey speed will be on the order of four to five knots. From an operational perspective, the following summarizes the systems to be used during online surveying.

The program, as presently discussed, would see the acquisition of data from a regular survey grid over defined area (s). Geophysical data will be acquired from a series of short survey transects, mostly at 50 m spacing, centred on one or more potential drill locations.

Detailed specifications for the Fugro-Jacques vessel *MV Anticosti* are provided below as a “typical” geohazard survey vessel.

#### 3.2.8.1. Survey Equipment

The geohazard survey work will likely be conducted from the *M.V. Anticosti*, a 54 m long offshore research vessel/tug owned by Cape Harrison Marine, of St. John’s. This is the same vessel and equipment utilized by Fugro-Jacques Geosciences (FJG) within eastern Canada over the past few years, and for recent (2004) Petro-Canada, Chevron Canada and Geological Survey of Canada survey programs. Safety policies and programs are in place, and are on file with the C-NOPB (see list below).

- Bridging Document between Fugro and vessel operator (Cape Harrison Marine)
- HSE plan
- Vessel Safety case
- Fugro safe working procedures for Geophysical work

Differential GPS corrections will be provided via satellite transmission and also via Coast Guard MF beacons (as back-up). Survey speed will average four to five knots during the program.

### **3.2.8.2. Multichannel Seismic Data**

High-resolution multichannel seismic data will be acquired with a suite of four sleeveguns (160 cubic inch (in<sup>3</sup>) total capacity), a 96-channel streamer (6.25 m group and shot interval, 600 m active length), and a TTS 2+ digital recording system. Data will be acquired to two seconds depth, sampled at one millisecond.

The multi-channel seismic source will be comprised of four or more separate sleeveguns, each of 40 in<sup>3</sup> capacity. These are driven by controlled bursts of compressed air to produce an acoustic pulse. They will be deployed within a ladder array, approximately 30 m off the stern of the vessel, and at a depth of 3 m. The compressed air is provided by a diesel-powered compressor on deck. The maximum output from this array has a peak to peak value of 17.0 Bar-metres. This equates with decibel notation of 244.6 dB (peak to peak)//1μPa@1m, or 238 dB (zero to peak)//1μPa@1m.

The CEAA identifies an output level of 275.79 kPa at a distance of one metre from the seismic energy source, as a criterion for inclusion in the list of activities requiring an EA. This is equivalent to a value of 228.69 dB//1μPa@1m. As such, the present acoustic source exceeds the defined threshold level (if considering instantaneous levels).

Rise time for the pulse is approximately four milliseconds, based on a chart provided by the equipment manufacturer. Operating pressure of the guns is a maximum of 2,000 pounds per square inch (psi). The guns can be ramped up in output prior to start of line to meet guidelines in place.

The streamer will be towed from the port quarter of the vessel. A tail buoy will be used, equipped with a radar reflector and strobe light. Streamer depth will be approximately three metres. Total streamer length will be approximately 650 m.

### **3.2.8.3. Surficial Data**

Fugro-Jacques utilizes a Hunttec Deep Tow System (DTS), deployed from the stern of the survey vessel, through an “A” Frame. This system has been proven to be the most effective at providing high resolution sub-bottom profiles from the Grand Banks. The system is towed within the water column, at an altitude of between 20 and 40 m off the seabed. The system will be approximately 150 m behind the survey vessel (dependent on cable deployed, water depth and vessel speed).

The Hunttec DTS uses a “broad band” boomer acoustic source, with frequency bandwidth from 500 Hz to 6 kHz. Power output is typically 500 Joules, but may be increased to 1 kJ if necessary. Rise time of the pulse is less than 0.1 millisecond. The boomer derived pulse is primarily restricted to a 60-degree cone. Maximum peak to peak amplitude is 221 dB relative to 1 μPa at 1 metre. The system utilizes an



internal and external hydrophone to record the return signal. Vertical resolution is approximately 10 cm, with penetration of 40 m in sands, and 100 m in soft sediment. The option exists to use a sparker source, instead of the boomer, if seabed conditions and data quality warrant it. This unit will provide similar output power, albeit at a lower frequency, and in a more omni-directional manner.

Seabed imagery, for the clearance survey, will be acquired with a digital, dual frequency side scan sonar system. Data will be logged to tape and printed in hard copy for on-board assessment. Geo-referenced data will be utilized to create a digital side scan sonar mosaic for inclusion in survey reports. Output power of this system is extremely low, equivalent to an echo sounder in magnitude.

A dual frequency single beam echo sounder or Reson 8101 multi-beam echo sounder will be deployed, if desired. Power output levels of either option are similar to a typical echo sounder commonly used on the Grand Banks. The systems operate at a frequency of 240 kHz.

In the event that potential debris is identified by the side scan or multi-beam systems, a proton magnetometer will be deployed. This system is towed behind the vessel, five to 10 m above the seabed, and emits a low power electromagnetic field.

### **3.2.9. Logistics/Support**

#### **3.2.9.1. Vessels**

As noted above, primary support will be provided by chartered seismic survey vessel (s). In order to mitigate any potentially adverse effects on marine animals, the fisheries, and other vessel traffic, a mitigation plan will be developed as part of the Project. A “guard” or “picket” vessel may be used as a mitigation procedure during some surveys and times. This vessel would be used as an additional method of obtaining information on fishing activity in the area and in warning off other vessels in order to avoid gear losses for all parties.

#### **3.2.9.2. Helicopters**

The larger seismic vessels are usually equipped with a helicopter platform and helicopters are often used for crew changes and light re-supply. In some cases, survey contractors (e.g., *GSI Admiral*) may prefer to come to shore for crew changes and re-supply.

#### **3.2.9.3. Shore Base**

Husky and contractors maintain offices and shore facilities in St. John's. However, some seismic contractors may prefer to crew change or re-supply in other existing Newfoundland ports, presumably on the Avalon Peninsula because of proximity to the Project Area. No new shore base facilities will be established as part of this Project.

### **3.2.10. Waste Management**

Waste management aboard the seismic vessel will be implemented in a manner consistent with Husky's East Coast Waste Management Plan and the contracted vessels policies and procedures that will be reviewed against the Husky Plan to ensure consistency. Husky's East Coast Waste Management Plan is currently on file with the C-NOPB.

## **3.3. Project Site Information**

Project location is on the northern Grand Banks, just north of existing projects such as Hibernia, Terra Nova and White Rose (the closest).

### **3.3.1. Environmental Features**

The physical and biological environment of the northeastern Grand Banks has been described in previous large scale EAs such as the Hibernia EIS (Mobil 1985), Terra Nova EA (Petro-Canada 1996), the White Rose Comprehensive Study and associated documents (Husky 2000, 2001), the Jeanne d'Arc Basin Screening EA for Drilling (Husky 2002), the Orphan Basin Strategic Environmental Assessment (LGL 2003a), and the Orphan Basin 3-D Seismic EA (Buchanan et al. 2004).

### **3.3.2. Physical Environment and Effects on the Project**

The physical environment of the northeastern Grand Banks has been described in previous large scale EAs. The physical environmental conditions that will be encountered within the Project Area will be within the range of conditions as described in those EAs. A summary of expected conditions is contained in the EA (to follow). Effects of the physical environment on the Project are described in following sections and include those caused by wind, ice, waves, and currents.

### **3.3.3. Fish and Fish Habitat**

The fish species that inhabit the Project Area and the other species and habitats that support them are expected to be typical of the Grand Banks for equivalent depths, substrates, and physical oceanographic conditions. These components of the ecosystem have been described in the previous EAs and information concerning them is updated and summarized in the EA sections to follow.

### **3.3.4. Species at Risk**

The Project Area is not known to contain any sensitive areas for species listed on Schedule 1 of the *Species at Risk Act* (SARA) but several listed species (notably blue whale, leatherback turtle, and wolffish) may occur there occasionally; this issue is examined in the EA to follow.

## **3.4. Other Users**

### **3.4.1. Fisheries**

The area of the Grand Banks that contains the Project Area supports a variety of commercial fisheries to be described in the following EA based on latest available DFO data. The most important fisheries, in terms of landed value, in and adjacent to the Project Area, are northern shrimp (mobile trawl fishery) and snow crab (fixed gear fishery).

A mitigation plan will be developed to avoid or at least lessen any potential effects on the commercial fishery. The plan will include such as elements as good communications (e.g., fishery broadcast notifications, FLO (Fisheries Liaison Officer)), avoidance of areas and times of heavy fixed gear use and a fishing gear compensation program. Consultations with the fishing industry will be undertaken through the established ONE OCEAN committee and directly with relevant fishing interests as necessary.

There are no recreational or aboriginal fisheries in or adjacent to the Project Area.

### **3.4.2. Navigable Waters**

Other users of the navigable waters on the Grand Banks in addition to fishery vessels, include other oil industry-related vessels, transport and military vessels and the occasional private yacht.

### **3.4.3. Consultations**

In order to assist in scoping the effects assessment and mitigation plan and to aid in addressing any issues of concern, Husky and consultants contacted the following interested parties:

- Fisheries and Oceans
- Environment Canada
- ONE OCEAN/ Fish, Food and Allied Workers (FFAW)
- Newfoundland and Labrador Natural History Society
- Fishery Products International (FPI)
- Association of Seafood Producers
- Clearwater Seafood's Limited Partnership
- Icewater Harvesting

#### **3.4.4. Spatial Boundaries**

The regional scale study area boundaries take into consideration those established for previous project assessments, for example, Hibernia, Terra Nova and White Rose Developments and Husky's Jeanne d'Arc 2002 exploration program. The Study Area, Project Area, and Year 1 activities boundaries are shown in Figure 1.1.

#### **3.4.5. Temporal Boundaries**

The temporal boundaries for the Project are 2005 to 2007 inclusive, with timing of activities between 1 April and 31 October within any particular year. The most likely timing for the 2005 3-D survey activities is 1 June to 31 October.

#### **3.4.6. Environmental Monitoring**

An environmental observer (s) will be on board the vessels to properly identify marine mammal species for mitigation purposes and to collect opportunistic data on marine mammal behaviour and distribution with and without airguns operating.

## **4.0 Physical Environment**

### **4.1. Bathymetry**

Water depths in the Project Area range from <100 m on the shelf to 300-400 m on the upper continental slope.

### **4.2. Geology**

Geology of the area has been described in the Hibernia EIS and the White Rose Comprehensive Study and thus is not repeated here.

### **4.3. Climatology**

The climatology presented in this report has been prepared from two data sources:

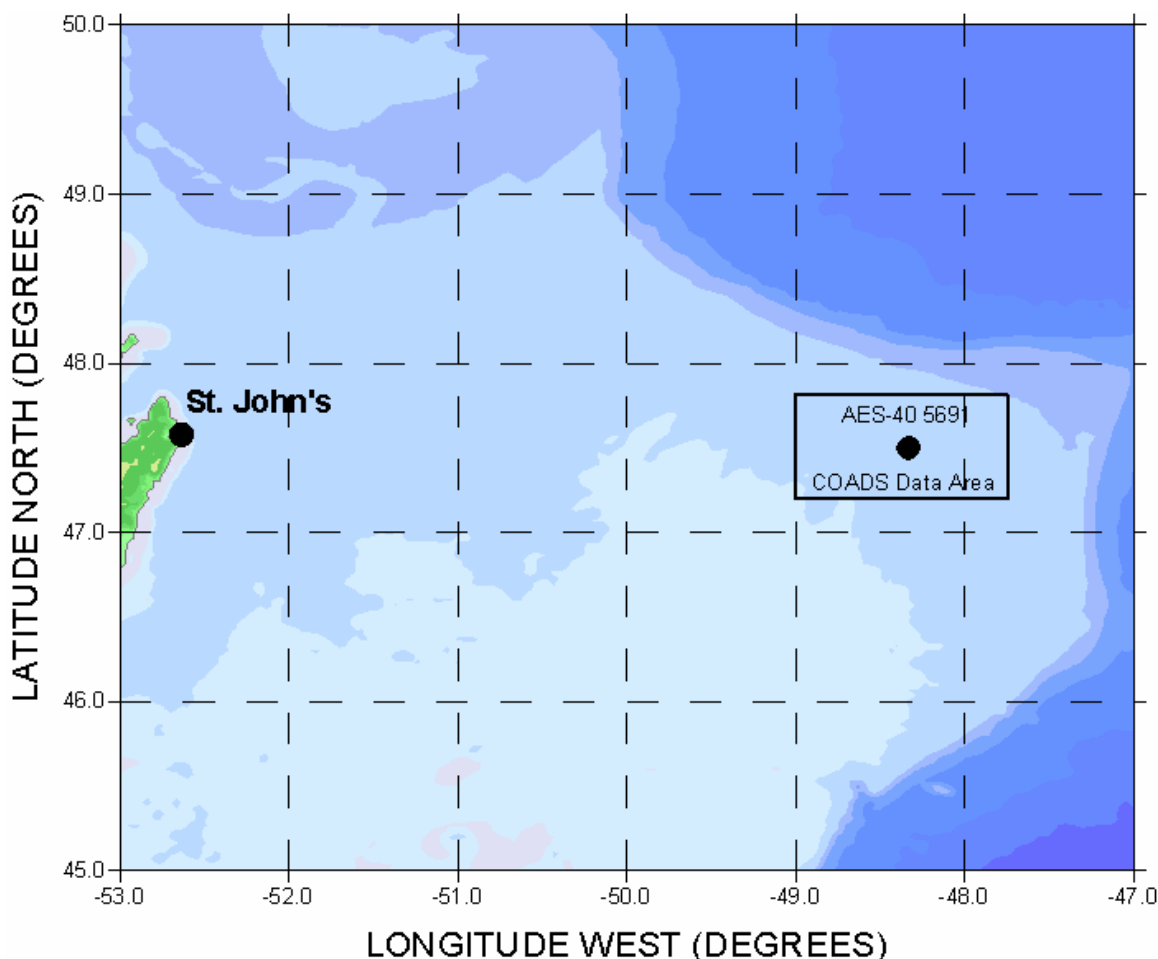
1. AES-40 wind and wave hindcast dataset covering the North Atlantic Ocean that was developed by Oceanweather Inc. of Cos Cob, Connecticut under contract to the Meteorological Service of Canada (MSC); and,
2. Comprehensive Ocean-Atmosphere Data Set (COADS) Long Marine Report (LMR) dataset consisting of marine weather and sea state observations from vessels and platforms at sea; these data were obtained from MSC.

In its earlier versions, the AES-40 data set consists of 40, then 42, continuous years of hindcast wind and wave data. The results of the NCAR/NCEP (U.S. National Centers for Environmental Prediction) global re-analysis for 1958-97 wind fields was used as input to a third generation deep water wave model (Berek et al. 2000). The winds were first modified by adding measured winds from buoys and platforms. Tropical cyclone wind fields were generated and added to the background winds. The wind fields were then refined using Oceanweather's Interactive Objective Kinematic Analysis System. The model grid spacing was 0.625° latitude by 0.833° longitude.

Currently, the AES-40 hindcast dataset provides wind velocity and sea state parameter data at 6-hour intervals for the 49-year period from July 01, 1954 through June 30, 2003. The wind and wave statistics presented in this report are based on the hindcast data for AES-40 grid point 5691, at locations 47.5°N, 48.3°W. Data were extracted from the dataset using Oceanweather's OSMOSIS software. Some of the statistics presented were output directly by OSMOSIS, others were computed using in-house developed software. No quality control of this dataset was necessary.

The temperature and visibility statistics presented in this report were developed from the COADS LMR observational dataset for the period 1950 through 1995. Reports from the area bounded by latitudes 47.2°N and 47.8°N and longitudes 47.75°W and 49.0°W were incorporated in the statistics. The COADS dataset is noisy and contains observation and position errors, as well as coding mistakes. For this work, positions were assumed to be correct. Otherwise, software filters were used to quality control the data in an effort to reduce the number of erroneous reports. The software to select COADS LMR observations, carry out the quality control, and prepare the statistics was developed in-house at OCEANS Ltd.

Figure 4.1 is a location map showing the position of AES-40 grid point 5691 and the COADS data area.



**Figure 4.1. Location Map.**

### 4.3.1. Wind Climatology

The wind climatology for AES-40 grid point 5691 and vicinity is summarized below in a series of tables and plots. Table 4.1 provides basic descriptive statistics for winds at a 10 m level above the surface on a monthly basis and for the full 49-year period. The table shows that the mean or most frequent wind direction is from the west to west-southwest during the winter season, while southwesterly winds prevail during the summer months. Monthly wind speeds are lowest during the months of June, July, and August as expected. Average wind speeds are notably higher during the winter months, with maximum monthly winds having exceeded 31 m/s in December and March. Standard deviations, a measure of the variability about the monthly means, are smallest during the summer and larger in the cold season, as is typical.

**Table 4.1. Monthly 10 m Wind Direction and Speed Statistics.**

Monthly and Annual 10 m Wind Statistics at AES-40 Grid Point 5691						
	Wind Direction (degrees True)	Wind Speed (metres / second)				
	Mean	Min	Max	Mean	Std Dev.	Median
<b>January</b>	261	1.0	27.5	11.0	4.3	10.7
<b>February</b>	265	1.1	29.3	10.9	4.3	10.6
<b>March</b>	266	0.7	31.3	9.8	4.1	9.6
<b>April</b>	250	0.9	25.2	8.3	3.7	7.9
<b>May</b>	239	0.4	23.0	7.1	3.3	6.8
<b>June</b>	230	0.4	21.8	6.6	3.0	6.3
<b>July</b>	222	0.3	20.1	6.2	2.7	6.1
<b>August</b>	229	0.4	21.5	6.5	2.9	6.2
<b>September</b>	251	0.5	24.2	7.6	3.4	7.2
<b>October</b>	260	0.5	26.2	8.8	3.7	8.5
<b>November</b>	255	0.9	26.2	9.6	4.0	9.3
<b>December</b>	260	1.0	31.4	10.6	4.3	10.3
<b>Annual</b>	247	0.3	31.4	8.6	4.0	8.1

Source: AES-40 wind and wave hindcast dataset (July 1954 through June 2003)

Table 4.2 presents maximum wind speeds (at 10 m above sea level) by direction for each month and for the full 49-year period. Evidently, the highest winds are from the southwest through northern sectors. High wind speeds during the late summer months may be caused by tropical cyclones or their remnants, or by energetic extra-tropical low pressure systems.

**Table 4.2. Monthly 10 m Wind Speed Statistics by Direction.**

Month	Monthly and Annual Maximum 10 m Wind Speed									
	(metres / second)									
	True Wind Direction (center of 45 degree sector)								All Directions	
	NE 45	E 90	SE 135	S 180	SW 225	W 270	NW 315	N 360		
January	19.0	23.6	22.2	24.1	26.7	27.5	25.4	22.8	19.0	27.5
February	27.2	21.9	21.6	25.9	29.1	29.3	25.4	29.1	21.6	29.3
March	20.8	19.3	23.3	20.9	23.6	25.1	31.3	26.3	19.3	31.3
April	21.3	21.5	21.3	25.2	23.6	21.1	24.1	24.2	21.1	25.2
May	18.5	15.3	18.1	18.7	21.0	19.0	23.0	19.7	15.3	23.0
June	17.8	20.4	16.1	16.4	16.5	20.8	21.8	13.9	13.9	21.8
July	14.4	14.6	14.2	18.0	20.1	16.4	15.6	14.5	14.2	20.1
August	16.4	17.6	18.9	17.0	16.8	17.0	18.2	21.5	16.4	21.5
September	16.5	19.4	17.2	19.2	24.2	22.9	22.6	18.0	16.5	24.2
October	20.6	17.9	18.7	26.0	26.1	26.2	23.3	24.4	17.9	26.2
November	21.6	20.4	20.1	23.2	23.2	24.6	24.1	26.2	20.1	26.2
December	19.6	21.3	23.2	21.7	24.2	31.4	29.1	28.6	19.6	31.4
Annual	27.2	23.6	23.3	26.0	29.1	31.4	31.3	29.1	21.6	31.4

Source: AES-40 wind and wave hindcast dataset (July 1954 through June 2003)

#### 4.3.1.1. Wind Rose Plots

Table 4.3 shows the percent frequency of occurrence of wind speed by 45-degree direction sector for all months and years. Again, this shows the prevalence of southwest and west winds with the highest winds from the southwest and northwest quadrants. Figure 4.2 is a graphic representation of these data in the form of a wind rose plot.

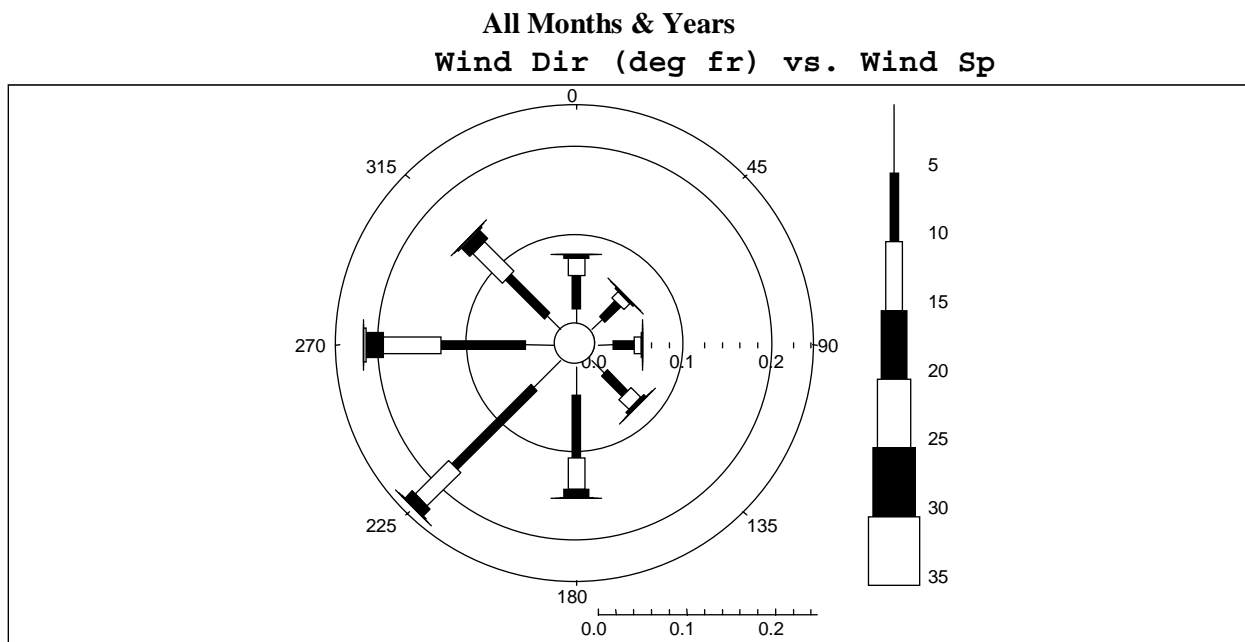
Monthly tables of the percent frequency of wind speed by direction and corresponding wind rose diagrams are available, if required.

**Table 4.3. Percentage Occurrence of Wind Speed by Direction for all Months and All Years.**

All months and all Years										
Wind Speed Range (m/s)		Centre of 45 Degree Direction Bins								Totals
		045	090	135	180	225	270	315	360	
0.0	- < 5.0	1.63	1.65	1.97	3.22	4.30	3.29	2.18	1.62	19.86
5.0	- < 10.0	2.52	2.37	3.32	7.10	12.63	9.51	6.24	3.78	47.47
10.0	- < 15.0	0.98	0.81	1.55	3.49	5.35	6.51	4.72	1.91	25.32
15.0	- < 20.0	0.21	0.16	0.39	0.96	1.13	1.92	1.33	0.39	6.50
20.0	- < 25.0	0.02	0.01	0.03	0.08	0.11	0.28	0.18	0.07	0.79
25.0	- < 30.0	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.06
30.0	- < 35.0	0.00	0.00	0.00	0.00	0.00	< 0.01	< 0.01	0.00	< 0.01
Totals		5.36	5.01	7.26	14.86	23.54	21.54	14.65	7.78	100.00

Source: Grid point 5691, AES-40 wind and wave hindcast data set (July 01, 1954 through June 30, 2003)





**Figure 4.2. Wind Rose for All Months and Years, July 1954 through June 2003.**

#### **4.3.1.2. Monthly Percent Exceedance of the 10 m Wind Speed**

Table 4.4 shows the percentage exceedance of the 10 m wind speed for each month of the year computed from the entire 49-year dataset. The values are plotted in Figures 4.3 and 4.4.

Figure 4.3, which shows curves for the months of January through to July, illustrates the progression from winter conditions to the more benign summer conditions. Figure 4.4 shows the monthly progression from the summer (July) through to the winter season as conditions become more boisterous. The winds are gale force when they read 34 knots (17.5 m/s) and storm force when they read 48 knots (24.7 m/s).

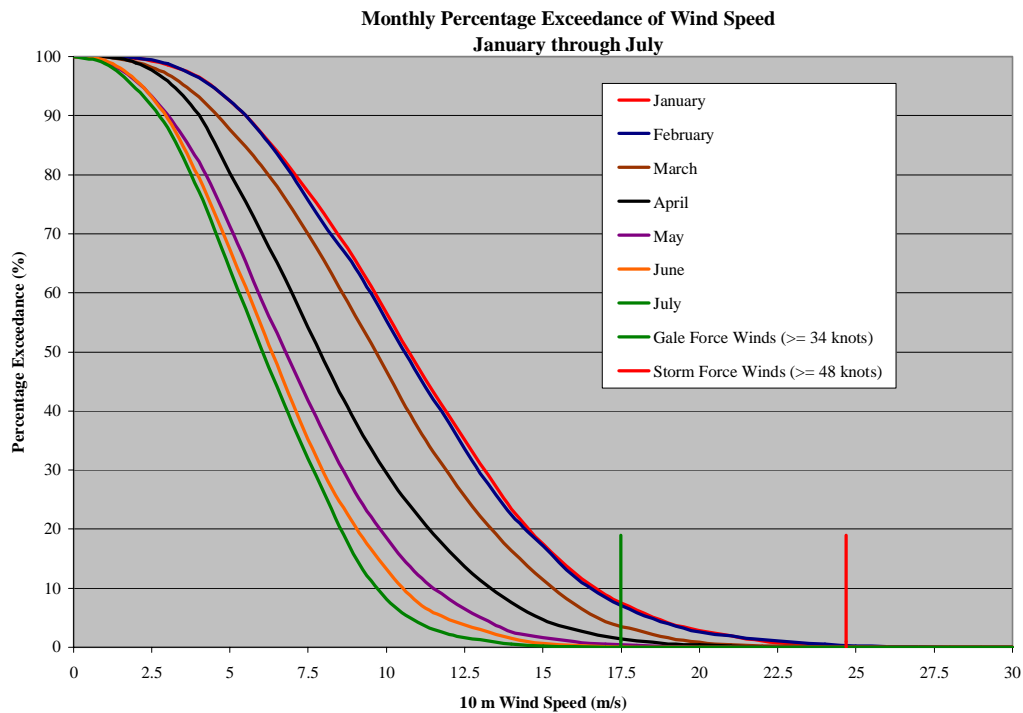
#### **4.3.2. Wave Climate**

The wave climate in the exploration area is dominated by extra-tropical storms primarily during October through March. Occasionally, severe storms may occur outside these months. Storms of tropical origin occur most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the Grand Banks, but occasionally these storms still retain hurricane force winds and hence produce high waves.

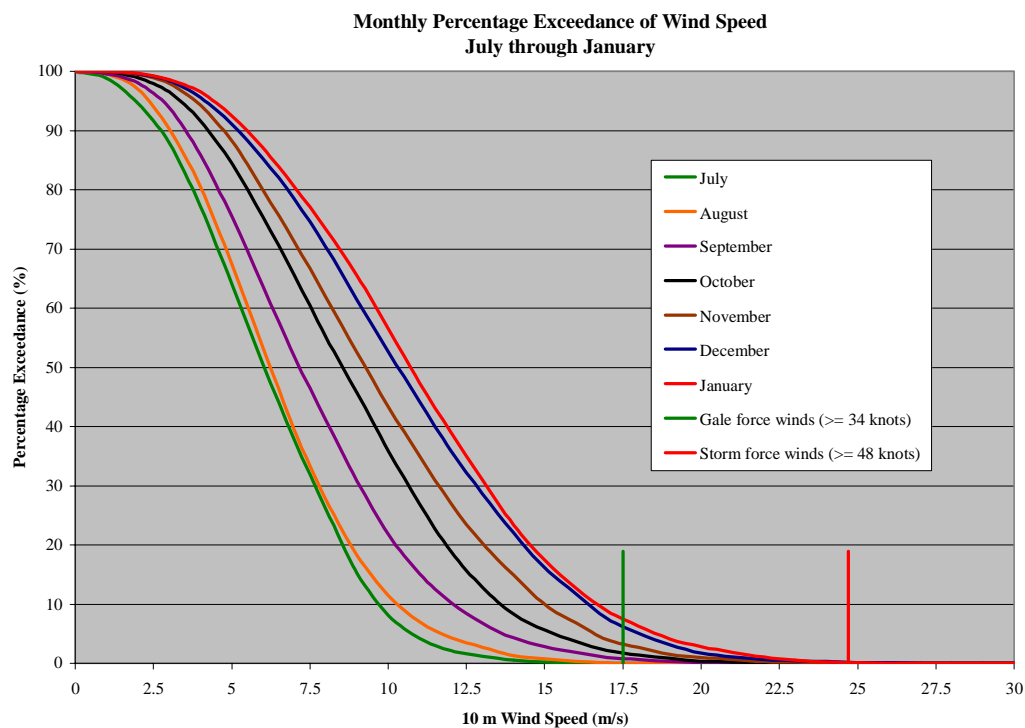
**Table 4.4. Percentage Exceedances of 10 m Wind Speed.**

Wind Speed (m/s)	Percentage Exceedance of Wind Speed (%)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	100.0	100.0	100.0	100.0	99.2	99.3	98.9	99.6	99.6	99.9	99.9	100.0
2	99.7	99.8	99.0	99.0	95.9	96.0	94.6	97.1	98.0	98.9	99.5	99.6
3	98.6	98.8	97.0	95.8	90.1	89.5	87.9	90.3	93.9	96.5	98.0	98.4
4	96.5	96.4	93.2	90.1	82.2	79.5	77.2	80.5	85.9	91.6	94.3	95.6
5	92.5	92.5	87.7	80.3	71.3	67.4	64.1	67.4	75.5	84.4	88.3	91.1
6	87.1	87.0	81.6	70.4	59.0	54.5	50.6	53.5	63.8	75.5	80.1	85.4
7	80.6	79.8	74.1	59.8	47.5	41.4	37.9	39.5	52.0	65.6	71.3	78.5
8	73.4	71.6	65.6	48.6	36.3	29.5	26.2	27.8	41.2	55.3	62.0	70.5
9	65.5	64.3	56.2	38.2	26.3	20.5	15.3	18.3	30.9	45.7	52.6	61.5
10	56.6	55.3	46.7	29.4	18.5	13.2	8.2	11.5	21.8	35.9	43.4	52.7
11	47.4	46.2	37.2	22.3	12.3	7.6	4.2	7.1	15.2	27.0	35.1	44.3
12	39.1	37.9	29.2	16.3	8.1	4.7	2.2	4.4	10.3	19.0	27.1	35.9
13	31.1	29.5	22.2	11.3	5.1	3.0	1.3	2.8	6.8	12.9	20.4	28.8
14	23.5	22.4	16.3	7.6	2.6	1.5	0.6	1.3	4.3	8.4	15.0	22.1
15	17.4	17.2	11.4	4.7	1.7	0.7	0.2	0.8	2.8	5.6	10.0	16.2
16	12.7	12.0	7.4	3.0	1.0	0.4	0.1	0.4	1.9	3.7	6.8	11.8
17	8.9	8.5	4.4	1.9	0.6	0.2	0.0	0.1	1.0	2.2	4.0	7.6
18	6.3	5.9	2.9	1.1	0.3	0.1	0.0	0.1	0.7	1.4	2.7	5.1
19	4.2	4.0	1.6	0.6	0.2	0.1	0.0	0.0	0.4	0.9	1.5	3.1
20	2.8	2.6	0.9	0.4	0.1	0.1	0.0	0.0	0.1	0.4	1.0	1.7
21	1.9	1.9	0.5	0.3	0.1	0.0	0.0	0.0	0.1	0.2	0.7	1.2
22	1.1	1.3	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.7
23	0.6	0.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5
24	0.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3
25	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
26	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
27	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
28	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Grid point 5691, AES-40 wind and wave hindcast data set (July 01, 1954 through June 30, 2003)



**Figure 4.3. Monthly Percentage Exceedances of 10 m Wind Speed - January through July.**



**Figure 4.4. Monthly Percentage Exceedance of 10 m Wind Speed - January through July.**

Sea state conditions at AES-40 grid point 5691 in the Husky exploration area are described in terms of significant wave height and spectral peak period statistics. Table 4.5 contains basic descriptive statistics for significant wave height on a monthly basis. The lowest monthly mean significant wave height occurs in July (1.7 m), while the highest average occurs in January (4.1 m). Standard deviations are smaller in the summer months than during the winter months. Monthly maximum values of significant wave height have ranged from near 6 m in July and August to near 14 m in some winter months. Table 4.6 provides basic statistics for spectral peak period. The spectral peak period is the wave period of monthly maximum energy.

**Table 4.5. Monthly Statistics of Significant Wave.**

Monthly Statistics of Significant Wave Height					
Month	Significant Wave Height (metres / second)				
	Min	Max	Mean	Std Dev.	Median
January	0.9	12.9	4.1	1.6	3.8
February	0.8	13.7	3.9	1.7	3.6
March	0.7	11.2	3.5	1.4	3.2
April	0.8	10.7	2.8	1.1	2.7
May	0.5	10.6	2.2	0.9	2.0
June	0.6	8.9	1.9	0.7	1.7
July	0.5	5.9	1.7	0.6	1.6
August	0.5	5.9	1.8	0.7	1.6
September	0.8	10.4	2.3	1.0	2.1
October	0.9	11.5	2.9	1.2	2.7
November	0.7	11.3	3.3	1.4	3.1
December	1.1	13.4	3.9	1.5	3.6

Source: Grid point 5691, AES-40 wind and wave hindcast dataset (July 01, 1954 to June 30, 2003)

**Table 4.6. Monthly Statistics of Spectral Peak Period.**

Monthly Statistics of Spectral Peak Period					
Month	Peak Period (seconds)				
	Min	Max	Mean	Std Dev.	Median
January	4.8	16.0	10.5	1.9	10.6
February	3.9	17.0	10.3	2.0	10.4
March	4.2	17.0	10.1	2.0	10.1
April	4.1	15.7	9.6	1.8	9.6
May	3.4	15.6	8.5	1.7	8.4
June	4.1	17.4	8.0	1.6	7.9
July	3.8	18.7	7.7	1.6	7.4
August	3.8	17.1	7.8	1.7	7.5
September	4.2	15.9	8.8	2.0	8.5
October	4.2	15.6	9.3	1.9	9.1
November	4.0	15.9	9.8	1.9	9.7
December	4.4	16.7	10.4	1.9	10.4

Source: Grid point 5691, AES-40 wind and wave hindcast dataset (July 01, 1954 to June 30, 2003)

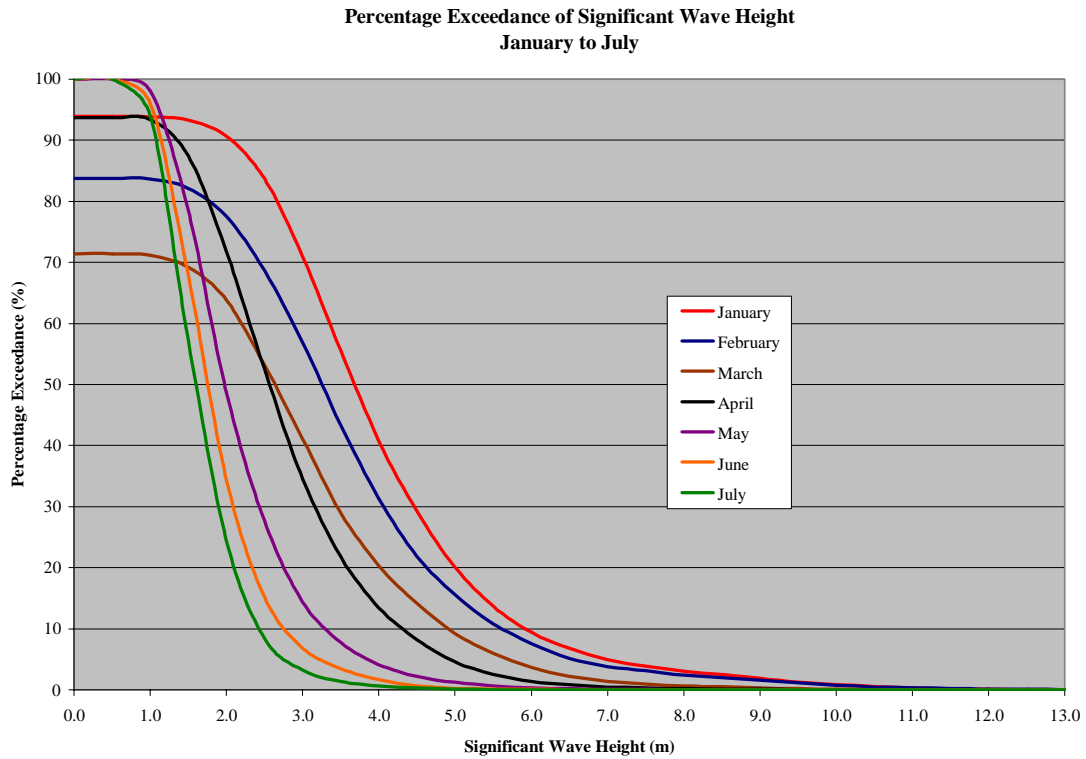
### 4.3.2.1. Monthly Percentage Exceedance of Significant Wave Height

Table 4.7 shows the percentage exceedance of significant wave height for each month of the year. Figures 4.5 and 4.6 are exceedance plots of the data for January to July and for July to January, respectively, showing the progression through the seasons. During the winter and spring months, sea ice incursion at grid point 5601 is indicated in the dataset by zero values for significant wave height. This gives the exceedance values of less than 100 percent for zero significant wave height in the months of January through May. Table 4.8 shows the percent frequency of occurrence of ice in each month for the 49-year period from the AES-40 dataset.

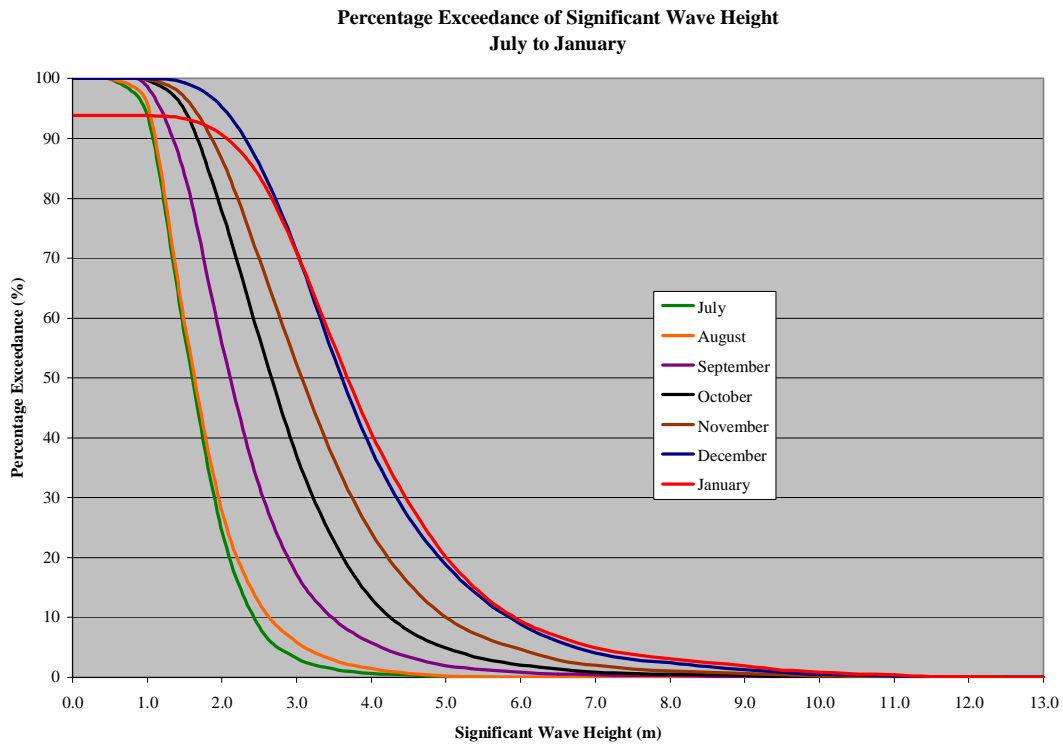
**Table 4.7. Monthly Percentage Exceedance of Significant Wave Height.**

Hs (m)	Percentage Exceedance of Significant Wave Height (%)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.0	93.88	83.72	71.40	93.67	99.95	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.5	93.88	83.72	71.40	93.67	99.93	100.00	99.98	99.92	100.00	100.00	100.00	100.00
1.0	93.84	83.67	71.10	93.37	98.03	96.00	94.01	95.75	98.69	99.75	99.85	100.00
1.5	93.30	82.08	69.21	87.43	78.44	67.84	57.11	59.05	83.83	94.72	96.87	99.33
2.0	90.64	77.51	63.81	71.79	48.70	34.37	24.44	27.78	55.77	77.86	86.55	95.28
2.5	83.69	68.64	53.18	52.45	27.65	15.20	8.46	12.46	31.90	56.76	69.88	85.71
3.0	70.93	56.90	41.13	34.54	14.42	6.84	3.21	5.91	17.21	37.00	52.30	71.10
3.5	55.51	43.32	28.97	21.77	7.75	3.49	1.35	2.86	9.69	22.68	36.38	53.44
4.0	40.77	31.32	20.33	13.45	4.13	1.65	0.64	1.45	5.75	13.12	24.13	38.02
4.5	29.18	21.84	14.12	8.20	2.21	0.65	0.36	0.66	3.40	7.78	15.70	26.71
5.0	20.11	15.64	9.27	4.57	1.22	0.27	0.15	0.25	1.97	4.92	10.03	18.80
5.5	13.69	10.86	5.97	2.55	0.69	0.14	0.03	0.07	1.28	3.08	6.68	12.99
6.0	9.40	7.60	3.74	1.36	0.33	0.09	0.00	0.00	0.80	2.07	4.64	8.87
6.5	6.83	5.18	2.25	0.82	0.16	0.05	0.00	0.00	0.54	1.37	2.89	5.96
7.0	4.92	3.81	1.43	0.49	0.10	0.05	0.00	0.00	0.39	0.81	2.01	4.03
7.5	3.87	3.11	0.92	0.34	0.07	0.05	0.00	0.00	0.31	0.63	1.38	2.96
8.0	3.09	2.42	0.66	0.22	0.05	0.03	0.00	0.00	0.26	0.54	1.04	2.45
8.5	2.49	2.01	0.53	0.15	0.05	0.03	0.00	0.00	0.20	0.40	0.82	1.81
9.0	1.89	1.57	0.33	0.09	0.05	0.00	0.00	0.00	0.10	0.30	0.60	1.28
9.5	1.22	1.16	0.16	0.05	0.02	0.00	0.00	0.00	0.07	0.15	0.39	0.87
10.0	0.84	0.78	0.10	0.05	0.02	0.00	0.00	0.00	0.02	0.08	0.20	0.51
10.5	0.59	0.47	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.02	0.15	0.36
11.0	0.38	0.38	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.18
11.5	0.15	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
12.0	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
12.5	0.05	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
13.0	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
13.5	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Grid point 5691, AES-40 wind and wave hindcast dataset (July 01, 1954 through June 30, 2003)



**Figure 4.5. Monthly Percent Exceedance of Significant Wave Height - January to July.**



**Figure 4.6. Monthly Percent Exceedance of Significant Wave Height - July to January.**

**Table 4.8. Percentage Frequency of Occurrence of Sea Ice at Grid Point 5691.**

Percentage Occurrence of Sea Ice*	
Month	(%)
January	6.12
February	16.28
March	28.60
April	6.33
May	0.05

\*Source: Grid point 5691, AES-40 wind and wave hindcast dataset  
(July 01, 1954 through June 30, 2003)

#### 4.3.2.2. Monthly Percentage Occurrence of Spectral Peak Period

Table 4.9 provides percent frequency of occurrence of spectral peak periods for each month of the year. Again, the percent frequency for zero peak period indicates the occurrence of sea ice at the grid point location. During the warm season, the most frequent peak period is in the 7 to 8 second range; during the winter the peak periods of the higher sea states are more frequent in the 9 to 12 second range.

**Table 4.9. Monthly Percent Frequency of Occurrence of Spectral Peak Periods.**

Monthly Percent Frequency of Occurrence of Spectral Peak Period (Tp)												
Tp (s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	6.1	16.3	28.6	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
> 0.0 - < 1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0 - < 2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0 - < 3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0 - < 4.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
4.0 - < 5.0	0.0	0.1	0.4	0.2	0.6	1.0	0.8	1.0	0.4	0.3	0.1	0.0
5.0 - < 6.0	0.5	1.2	0.9	1.5	5.1	8.3	9.6	10.3	4.3	2.1	1.6	0.5
6.0 - < 7.0	2.7	3.7	3.3	5.6	12.4	18.6	24.8	24.1	14.4	7.8	5.8	3.3
7.0 - < 8.0	6.2	6.3	6.5	10.1	21.0	25.8	29.1	28.1	20.4	15.0	10.4	6.9
8.0 - < 9.0	11.4	11.7	9.5	18.2	26.1	24.7	19.2	18.6	21.5	22.7	18.1	13.0
9.0 - < 10.0	16.4	14.6	14.0	21.5	18.0	13.0	9.4	8.1	14.9	19.5	21.2	19.1
10.0 - < 11.0	17.9	15.4	14.6	18.1	9.3	5.0	3.6	4.9	10.7	14.3	19.0	21.9
11.0 - < 12.0	17.0	14.9	11.1	10.9	4.8	1.8	1.2	2.2	6.5	9.7	12.3	16.8
12.0 - < 13.0	12.4	8.2	6.5	3.9	1.5	0.8	0.8	1.3	3.6	4.4	6.0	10.4
13.0 - < 14.0	6.3	4.9	2.6	2.6	0.8	0.4	0.4	0.4	2.4	2.7	3.8	5.1
14.0 - < 15.0	2.6	2.1	1.4	1.1	0.2	0.5	0.4	0.5	0.7	1.2	1.5	2.5
15.0 - < 16.0	0.5	0.6	0.4	0.1	0.0	0.1	0.3	0.2	0.2	0.3	0.3	0.5
16.0 - < 17.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
17.0 - < 18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
18.0 - < 19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Grid point 5691, AES-40 wind and wave hindcast dataset (July 01, 1954 through June 30, 2003)

### 4.3.2.3. Percent Frequency of Significant Wave Height and Spectral Peak Period

Table 4.10 presents the percent frequency of the joint occurrence of significant wave height and spectral peak period for the full 49-year period of the hindcast dataset. Ice is seen to be present at the location 4.73 percent of the time during this period.

**Table 4.10. Percent Frequency of the Joint Occurrence of Significant Wave Height and Spectral Peak Period.**

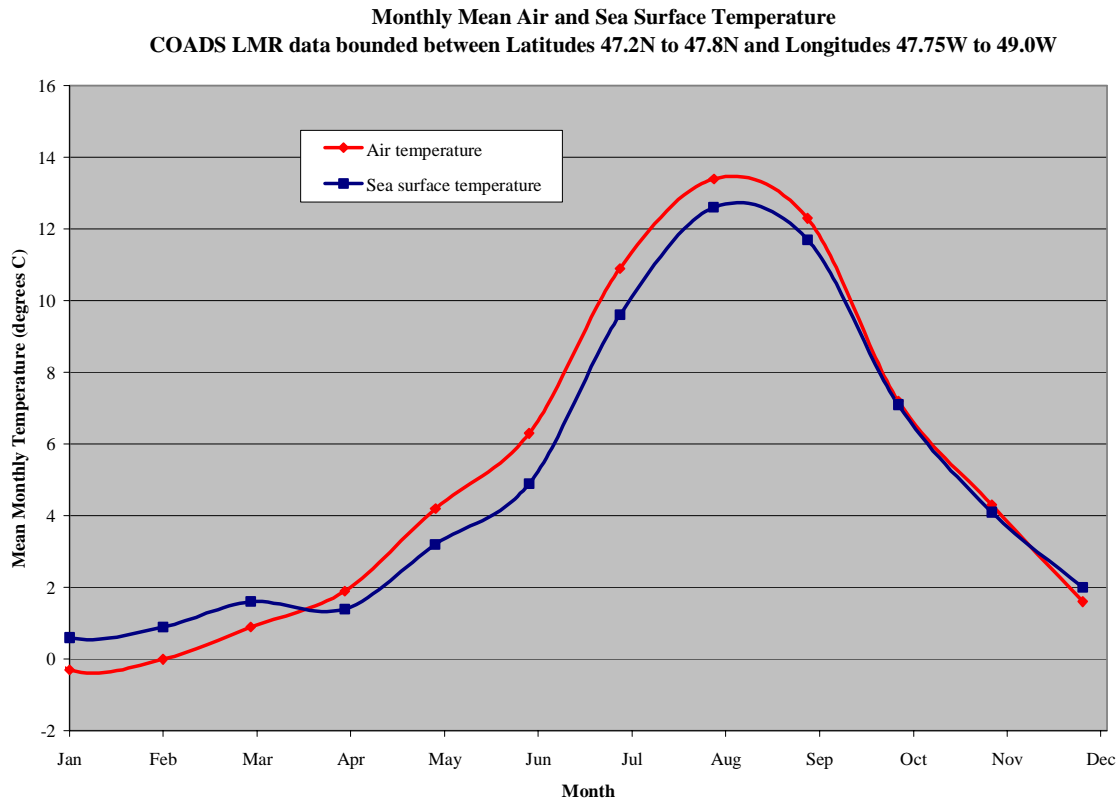
Percent Frequency of Joint Occurrence of Significant Wave Height and Spectral Peak Period															
Spectral Peak Period (s)	Ice 0	Significant Wave Height (m)													
		> 0.0 to < 1.0	1 to < 2.0	2 to < 3.0	3 to < 4.0	4 to < 5.0	5 to < 6.0	6 to < 7.0	7 to < 8.0	8 to < 9.0	9 to < 10.0	10 to < 11.0	11 to < 12.0	12 to < 13.0	13 to < 14.0
0	4.73														
> 0.0 to < 1.0															4.73
1.0 to < 2.0															0.00
2.0 to < 3.0															0.00
3.0 to < 4.0		0.01	0.01												0.02
4.0 to < 5.0		0.04	0.36	0.01											0.41
5.0 to < 6.0		0.20	3.19	0.45	0.01										3.85
6.0 to < 7.0		0.59	5.67	4.06	0.27										10.59
7.0 to < 8.0		0.48	7.23	5.42	2.27	0.13									15.53
8.0 to < 9.0		0.07	7.58	4.53	4.26	1.40	0.08								17.92
9.0 to < 10.0		0.09	3.92	5.57	2.88	2.54	0.75	0.06							15.81
10.0 to < 11.0		0.04	1.57	4.88	2.96	1.57	1.32	0.48	0.05						12.87
11.0 to < 12.0		0.03	0.73	2.21	3.02	1.35	0.77	0.61	0.23	0.09	0.01				9.05
12.0 to < 13.0		0.01	0.33	0.80	1.48	1.01	0.51	0.26	0.19	0.20	0.17	0.02			4.98
13.0 to < 14.0			0.17	0.41	0.59	0.60	0.36	0.20	0.09	0.06	0.10	0.09	0.03		2.70
14.0 to < 15.0			0.12	0.19	0.24	0.26	0.17	0.10	0.04	0.02	0.02	0.02	0.03	0.01	1.22
15.0 to < 16.0			0.04	0.04	0.05	0.06	0.05	0.03	0.01	0.01			0.01	0.01	0.31
16.0 to < 17.0			0.01		0.01	0.01									0.03
17.0 to < 18.0					0.01										0.01
18.0 to < 19.0															0.00
Sums	4.73	1.56	30.93	28.58	18.04	8.93	4.01	1.74	0.61	0.38	0.30	0.13	0.07	0.02	0.00
															100.0

Source: Grid point 5691, AES-40 wind and wave hindcast dataset (July 01, 1954 through June 30, 2003)

### 4.3.3. Air and Sea Surface Temperature

Air and surface temperature data for the Husky exploration area were extracted from the COADS LMR dataset as summarized in the previous section. Monthly mean values were computed and these statistics are presented in Figure 4.7. In the winter season, average sea surface temperatures are warmer than the mean air temperatures; the opposite is the case during the summer season. Because of this, the lower portion of the atmosphere is generally unstable during the winter months and stable in the spring and summer months. Average air temperatures are evidently near zero Celsius at the coldest time of the year and just above 13°C in the warmest month (August). The range of sea surface temperatures is smaller than that for air temperatures, an artifact of the higher heat capacity of the ocean.





**Figure 4.7. Monthly Average Air and Sea Surface Temperature.**

#### 4.3.4. Visibility and Causes of Restricted Visibility

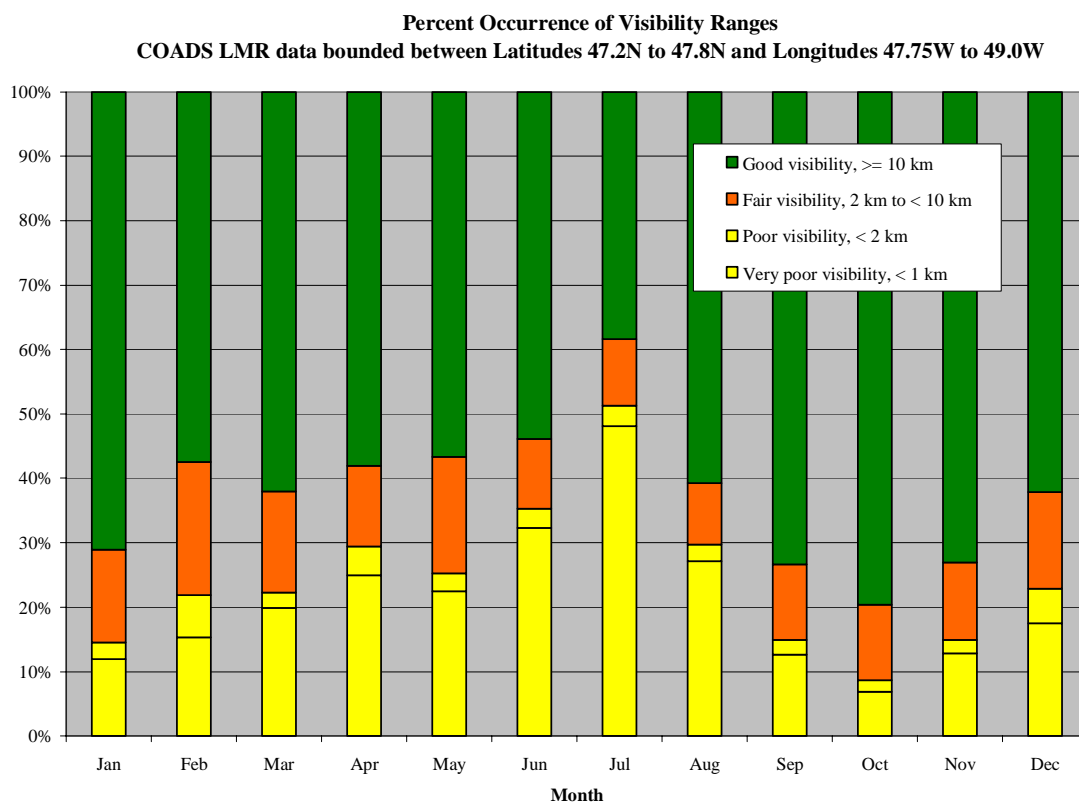
Visibility data were extracted from the COADS observational dataset for this review and presented in Table 4.11. The data were combined to correspond with visibility criteria used in marine weather forecasts, with the ranges expressed in kilometers. Figure 4.8 illustrates these statistics in the form of a bar chart with one additional range; it includes the percent occurrence of visibility reports of less than 1 km, the significant criteria for fog. During the warmer months visibility is restricted by mist and fog; in the winter season snow or snow showers also cause reduced visibility.

**Table 4.11. Percentage Frequency of Occurrence of Visibility Reports.**

		Percent Frequency of Occurrence of Visibility Reports											
Visibility		Month											
Classification	Range	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Poor	< 2 km	14.5	21.8	22.3	29.4	25.3	35.3	51.2	29.7	14.9	8.6	14.9	22.8
Fair	2 km to < 10 km	14.5	20.7	15.7	12.5	18.0	10.8	10.4	9.6	11.8	11.8	12.0	15.1
Good	>= 10 km	71.1	57.5	62.0	58.1	56.7	53.9	38.4	60.7	73.3	79.6	73.0	62.1

Source: COADS LMR marine weather data for area bounded between latitudes 47.2N to 47.8N and longitudes 47.75W to 49.0W (1950 to 1995)

The lowest visibility conditions occur in July with poor visibility being reported in 51% of reports. This is largely due to fog as indicated the Figure 4.8. Primarily, the type of fog is advection fog, which is formed as relatively warm, moist air is advected over the colder water surface. The reports for July indicate that visibility was reduced in either fog or mist for 61.6 % of the observations. Good visibility (no restriction) was reported in only 38.4 % of the observations. October has the highest percentage of good visibility reports with a value of 79.6%.



**Figure 4.8. Percent Frequency of Visibility Ranges.**

## 4.4. Physical Oceanography

### 4.4.1. Water Masses

Temperature and salinity data from historical measurements was extracted from the Bedford Institute of Oceanography (BIO) archive. This archive in addition to maintaining the data collected by BIO and the Department of Fisheries and Oceans (DFO), also contains data collected by Marine Environmental Data Service in Ottawa, the National Oceanographic Center (NODC) in Washington, universities, consulting firms, and other groups. The geographic limits for the database are from 35° to 90°N and 40° to 90°W, thus incorporating the region for this study (Petrie et al. 1999). The geographic limits used for this study

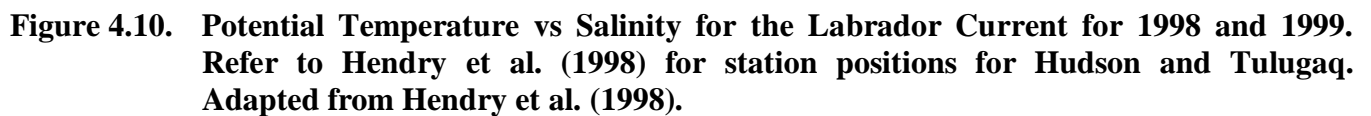
are 47°N to 47.80°N, and 49.25°W to 47.65°W. There is considerable temperature and salinity data available for the Project Area since it includes the long-term Flemish Cap transect sampled by the DFO. The data was bin averaged from 0 to 50 m, in steps of 10 +5 m; 50 to 200 m in steps of 25 +5 m and; 200 to 400 m in steps of 50 +10 m.

#### **4.4.1.1. Historical Data**

There are two major water masses on the eastern Newfoundland Shelf; the cold intermediate layer water (CIL) and the Labrador Current Water (LCW) (Figure 4.9).

Of the two water masses, the CIL is a fresher, colder layer. The CIL water occurs on the Shelf during late spring to the fall with temperatures ranging from 0°C to -1.84°C and salinities ranging from 32 to 33.5 ‰ (Petrie et al. 1988; Colbourne 2004). It can extend from shore to over 200 km, and to a depth of 200 m with inter-annually variations (Colbourne 2004). The CIL forms in the winter through heat loss at the surface and salt releases during ice formation. On the Slope the water is warmer and more saline. The CIL remains isolated between the seasonally heated upper layer of the shelf and the warmer Slope water near the bottom. The CIL water is separated from the warmer saltier water of the continental Slope by a frontal region denoted by a strong horizontal temperature and salinity gradient near the edge of the Shelf (Colbourne and Fitzpatrick 2002).

Also present on the Shelf is the Labrador Current water (LCW) (Figure 4.9). The Labrador Current is the dominant current in the Project Area. It originates from the Hudson Strait at 60°N and flows southward over the Labrador and Newfoundland Shelf and Slope to the tail end of the Grand Banks at 43°N (Lazier and Wright 1993). The Labrador Current becomes two branches on the southern Labrador Shelf; an inshore branch with approximately 15% of the transport and a main slope branch with approximately 85% of the transport (Lazier and Wright 1993). The offshore Labrador Current typically flows along the continental slope between 300 and 1,500 m (Lazier and Wright 1993). The LCW does have seasonal and vertical variability giving it a fairly large range of properties (Figure 4.10). Lazier (1982) demonstrated that the temperature and salinity of the water mass of the Labrador Shelf undergoes seasonal modification, with its properties mirroring the cycle of heating and cooling, ice formation and melt. Hinrichsen and Tomczak (1993) give a general value for the LCW properties of -0.28°C (potential temperature) and 33.33 ‰ (potential salinity). Lazier (1982) gives a range for the inshore (over the shelf) properties of -1.0 to 2.0°C and 32 to 33.5 ‰, and for the offshore branch (over the Slope) a range of 3 to 4°C and 34 to 35 ‰. Therefore, over the Slope the LCW is generally warmer and saltier than the shelf waters. Hendry et al. (1998) plotted the LCW T-S curve for June and July (Figure 4.10) and reveals the extent of the variability with a minimum temperature of approximately -1.44°C and a corresponding salinity near 32.9 ‰ and maximum temperatures and salinities near 7°C and 35 ‰, respectively.



#### **4.4.1.2. Summary of Water Masses**

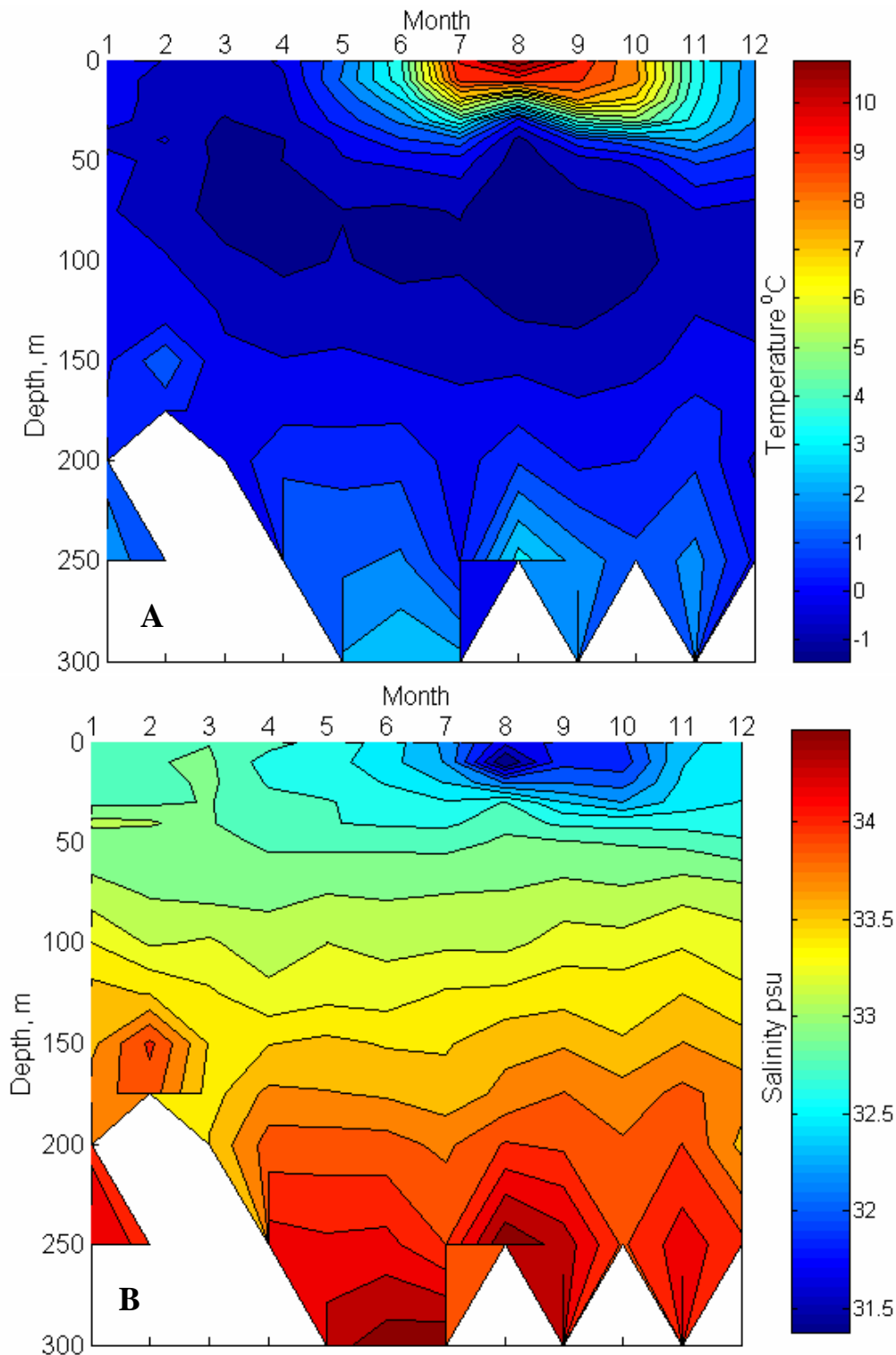
The temperature and salinity contour plots and T-S curves for the region is shown in Figures 4.11 and 4.12, and a comparison with different water masses is shown in Figure 4.13. The upper 50 m temperature and salinity is highly variable. Figure 4.11 shows the presence of the colder, fresher CIL from March to April to a depth of about 125 m. At a depth of 200 m and over, there are large gaps of missing data, primarily in winter. However, it is evident that the temperature and salinity increase underneath the CIL. At 300 m depth where there is data available, between the months of May and July, the salinity is at its highest and the temperature increases slightly indicating the influence of the offshore LCW and the warmer more saline waters of the Slope. The T-S diagram (Figure 4.12) shows the inshore and offshore LCW and CIL according to the given ranges from Lazier (1982) and Petrie et al. (1988), respectively (Figure 4.12). From 30 m to just over 125 m the Shelf water average T-S curve is within the range of the LCW properties, and from 50 m to just over 125 m it is also in the range of the CIL properties (Figure 4.12). From 75 m to 300 m the average T-S curve steadily increases but is not within the range of the offshore LCW. However, certain points at 250 m and over are within the range of the offshore LCW.

Figure 4.13 compares the average T-S curve for the study area; the average T-S curve from the BIO database from 1900-2004 for the Slope region just north on the Orphan Basin Slope; the average for Labrador waters from International Ice Patrol for 1948-1958 (Mamayev 1975) and; the stations from the IV cruise of the R.V. Mikhail Lomonsov (Mamayev 1975). The T-S curve for station 290 on the Newfoundland Shelf is very similar to the curve for this region. The remainder of the T-S curves are not similar except in the region deeper than 200 m in which the Slope water and Labrador Water curves are similar. The North Atlantic T-S curve is warmer and saltier than the all other curves. By comparing the average T-S curve for the Project Area to the T-S diagram in Figure 4.9 the Project Area curve is found to be in the range of the Labrador Current, as expected.

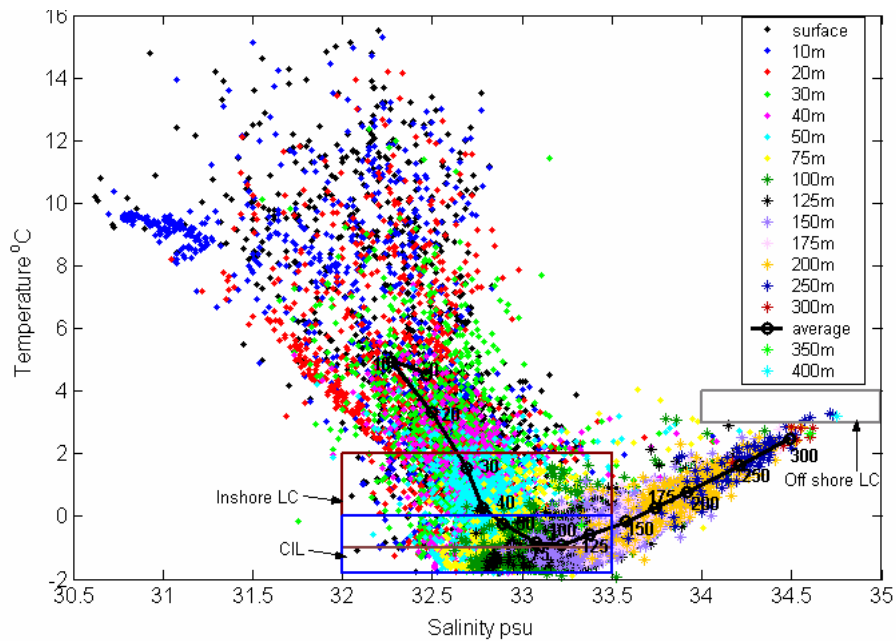
#### **4.4.2. Currents**

##### **4.4.2.1. General Discussion**

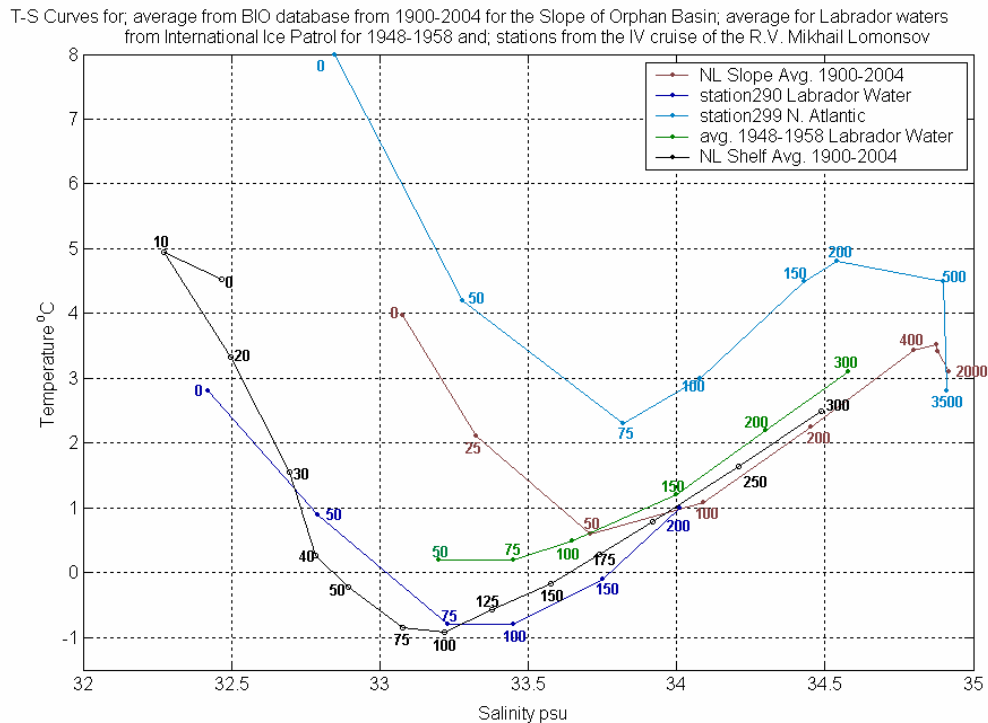
The large scale ocean circulation off Atlantic Canada is dominated by well established currents that flow along the margins of the continental shelf. The main circulatory feature in the Project Area is the Labrador Current, which transports sub-polar water to lower latitudes along the continental shelf of eastern Canada (Figure 4.14). Oceanographic studies show a strong western boundary current following the shelf break with relative low current variability compared to the mean flow. Over the Grand Banks a weaker current system is observed where the magnitude of the variability often exceeds that of the mean flow (Colbourne 2000).



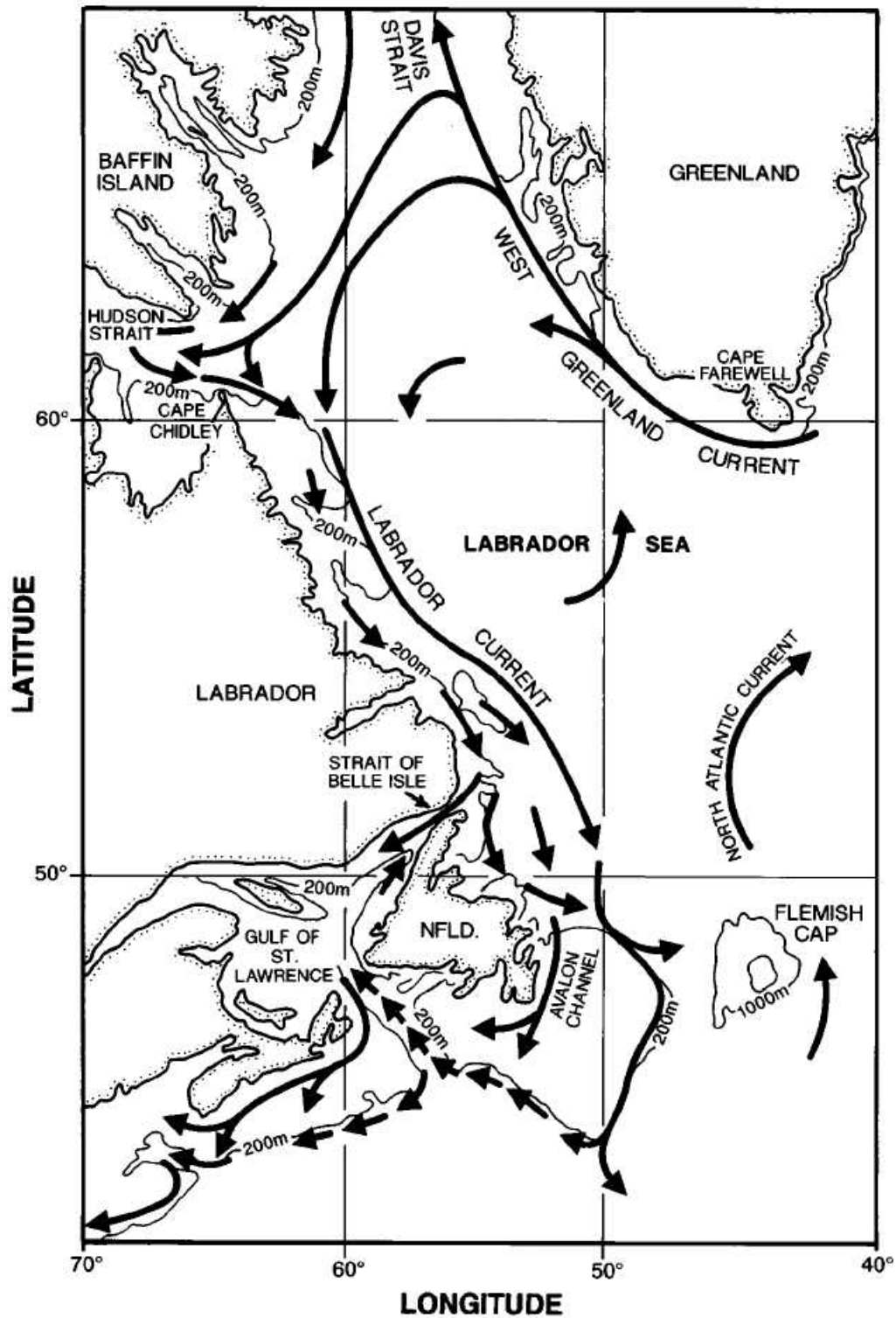
**Figure 4.11. Monthly Mean A) Temperature and B) Salinity from BIO database, 1900-2004 from the Surface to 300 m for the Region on the Newfoundland Shelf Defined by; 47°N to 47.80°N, and 49.25°W to 47.65°W. White areas are missing data.**



**Figure 4.12. T-S Curve from BIO Database, 1900-2004 for the Region on the Newfoundland Shelf Defined by; 47°N to 47.80°N, and 49.25°W to 47.65°W.** Each coloured point depicts a different depth and the line is the average. Points at 350 and 400 m are not included in the average since only one measurement was available. The boxes are the ranges of different water masses, LC water ranges are from Lazier (1982) and the CIL water from Petrie et al. (1988).



**Figure 4.13. T-S Curves for the Newfoundland Shelf (47°N to 47.80°N, and 49.25°W to 47.65°W), Orphan Basin Slope, Labrador Sea and North Atlantic.** The Slope and Shelf average is from the BIO database from 1900-2004 (brown and black line). The average for the Labrador waters is from International Ice Patrol for 1948-1958 (Mamayev 1975) (Green line). The station data is from the IV cruise of the R.V. Mikhail Lomonsov (Mamayev 1975) (blue lines).



**Figure 4.14. Major Ocean Circulation Features in the Northwest Atlantic.**  
(From Colbourne et al. 1997)



The Labrador Current consists of two major branches. The inner branch is located on the inner half of the Shelf and its core is steered by the local underwater topography. The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope and has a tendency to turn to the southeast just north of the study area. Characteristic current speeds are in the order of 25 cm/sec to 40 cm/sec, while those of the inner branch and on the shallow waters of the Grand Banks are generally much lower.

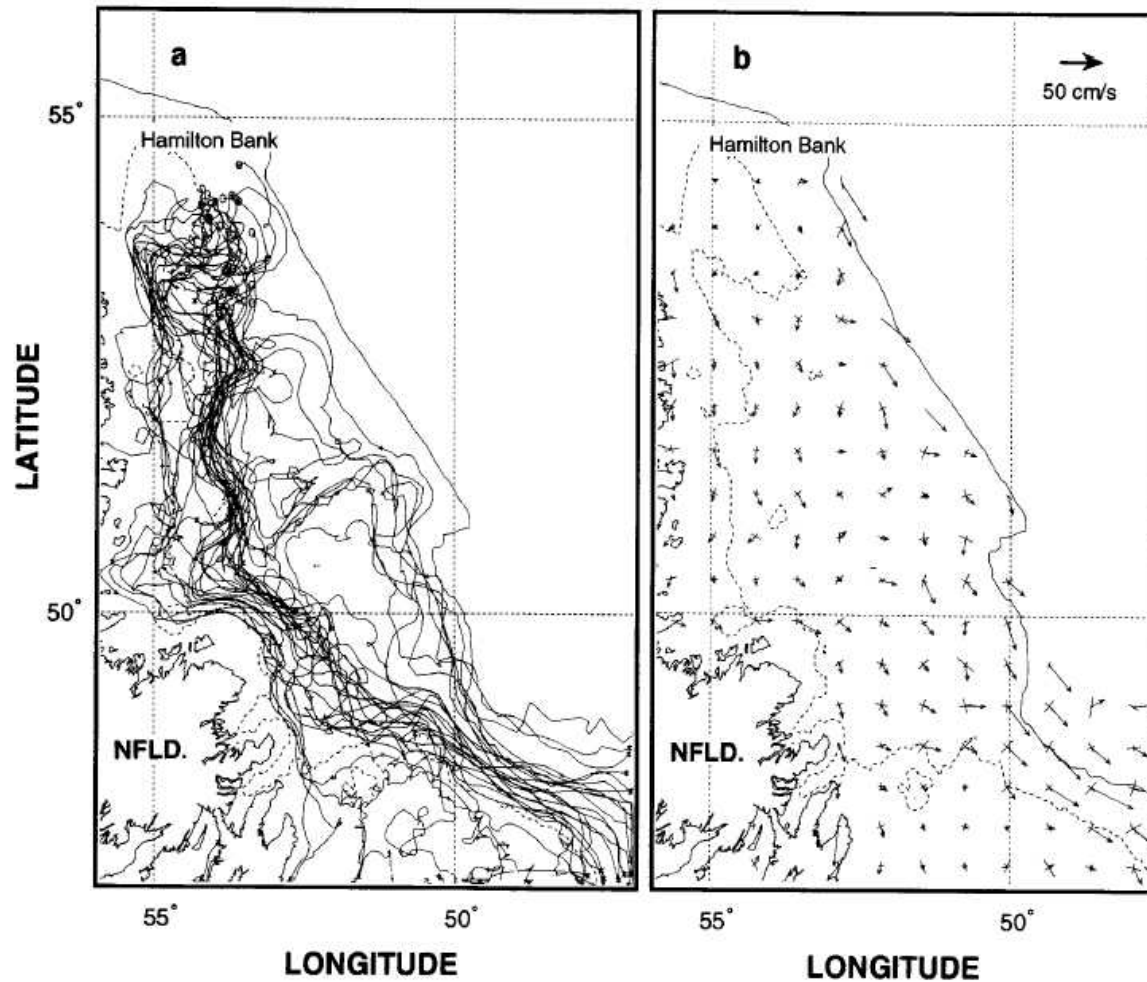
The outer branch of the Labrador Current exhibits a distinct seasonal variation in speeds (Lazier and Wright 1993), in which the mean flows from September to October are nearly twice as large as the mean flows in March and April.

Figure 4.15 shows a summarized analysis of the existing data from drifter buoys carried out by Colbourne et al. (1997). This figure illustrates the general pattern of the spatial distribution of the surface currents to the northeast of the Newfoundland shelf. The intensified flow near the study area can be seen in the form of relatively large vectors and convergence of the paths of the drifter buoys.

The oceanic properties of the Labrador Current water over the Newfoundland Continental Shelf are primarily determined by meteorological wind forcing and solar heat exchange of the Northwest Atlantic including the arctic regions (Colbourne et al. 1997). Wind stress is an important driving force for the currents on the Continental Shelf, with a distinct annual cycle of comparatively strong winds in winter and weaker, more variable winds in summer.

The sector corresponding to the Exploration Licenses EL 1065, EL 1066, EL 1067 and EL 1089 is located near the northeastern edge of the Continental Shelf, north of the Terra Nova and Hibernia fields (Figure 4.16), thus corresponding to an area of transition between the strong offshore branch of the Labrador Current and the weaker, less organized flow characteristic of the shallow waters of the Grand Banks. The sea floor, 100 to 300 m deep in this area, forms part of the upper slope of the Continental Shelf.

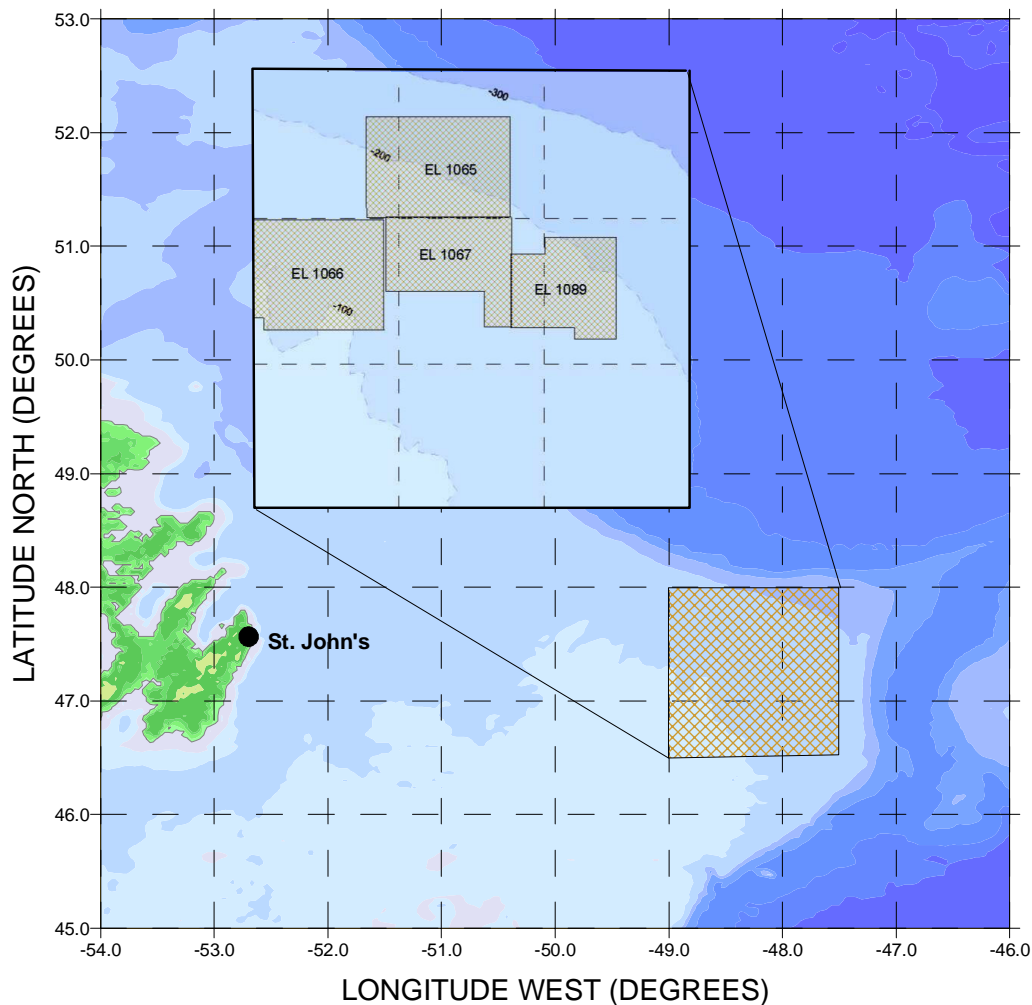
In this area, the wind is not a dominant factor in the general circulation picture. Currents over the shelf edge are generated by mechanisms other than direct wind forcing. De Tracey et al. (1996) suggest that currents at the edge of the Grand Banks are the result of the interaction between factors like meandering and eddy formation in the Labrador Current and the propagation of Continental Shelf waves generated up-stream by distant storms.



**Figure 4.15. Currents on the Northeast Newfoundland Shelf as Inferred from 149 Drifting Buoys by Colbourne et al. (1997).**

(a) Low-pass-filtered drifting buoy tracks. Drop locations are indicated by circles and terminal positions by asterisks.

(b) Mean surface currents derived from spatial averages of all drifting buoy tracks. The principal axes of variation are indicated by crosses.



**Figure 4.16. General Location of the Project Area.**

#### **4.4.2.2. Current Meter Data**

In order to assess the characteristics of the ocean currents in the immediate vicinity of the Project Area, the data collected by five sets of current meters were analyzed. The depth at which the instruments were deployed varied, but they were in general grouped within certain depth intervals. For that reason, and to simplify the presentation of the results, the current data was divided into three groups. In the first group the sampling depths vary between 20 m and 35 m. The second group comprises observations made between 70 m and 98 m. In the third group, the observations are between 135 m and 185 m. These three depth intervals will be referred to as subsurface, mid-water and near bottom depths.

Table 4.12 shows the spatial and temporal coverage of the data. The geographic location of the different data sets is shown in Figure 4.17. The information contained in the data sets was used to obtain overall and monthly rose plots and progressive vector diagrams. Some information on the tidal currents was determined by carrying out a harmonic tidal analysis.

**Table 4.12. Current Meter Data Sets. Their depths, time coverage and geographic location.**

Period Covered	Sampling Depths	Geographic Coordinates
October – December, 1980	35 m, 95 m, 150 m	47.1 N; 47.9 W
May – September, 1982	20 m, 98 m, 179 m	47.5 N; 48.1 W
October – December, 1982	20 m, 98 m, 179 m	47.5 N; 48.1 W
November – February, 1985	21 m, 70 m, 119 m	47.1 N; 48.2 W
December, 1991 – May, 1992	83 m, 143 m	47.8 N; 48.0 W
	141 m, 167 m	47.4 N; 48.2 W
	21 m, 76 m, 136 m	47.2 N; 48.4 W
	75 m, 135 m, 185 m	47.7 N; 48.5 W

#### **4.4.2.2.1. Histograms of Speed and Direction and Progressive Vector Diagrams**

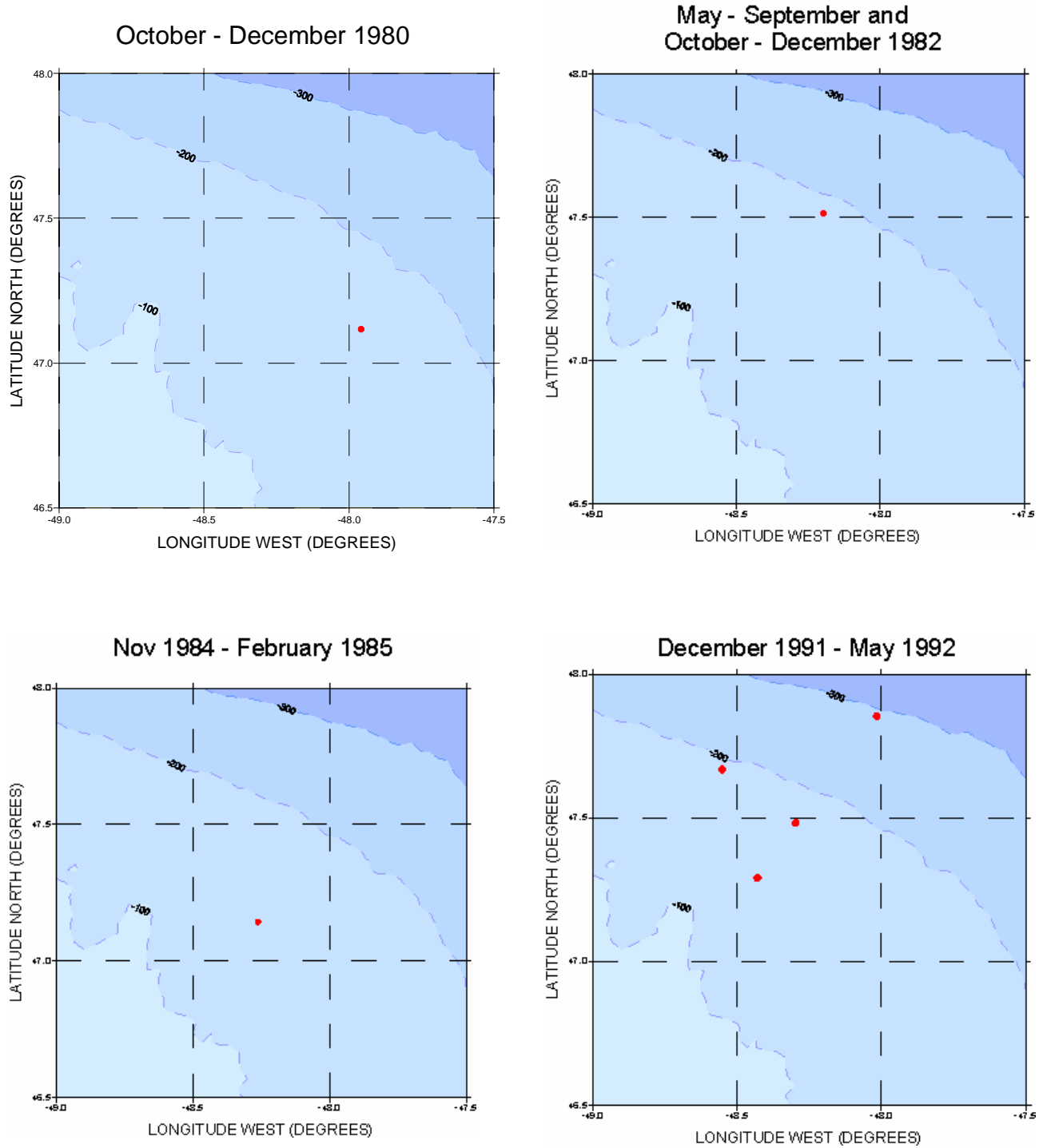
Rose plots are a graphic representation of the bivariate histograms of speed and direction, which give the number of samples that have speed ranges in specified direction intervals. They are useful in indicating the most probable direction the current will follow according to a given data set. Speed histograms give a distribution of the occurrence of speed values divided into selected intervals.

Progressive vector diagrams show the distance and direction a particle of water would travel if the flow was spatially uniform. They are helpful in determining the mean velocity of the currents over the sampling period. The mean velocity is not to be confused with the mean speed, which is a mere average of the speed values, regardless of the direction. Progressive vector diagrams are available, if required.

The predominant direction of the currents in the study area is in the east and southeast directions. This is consistent with the direction of the offshore branch of the Labrador Current usually situated slightly to the north of the Project Area.

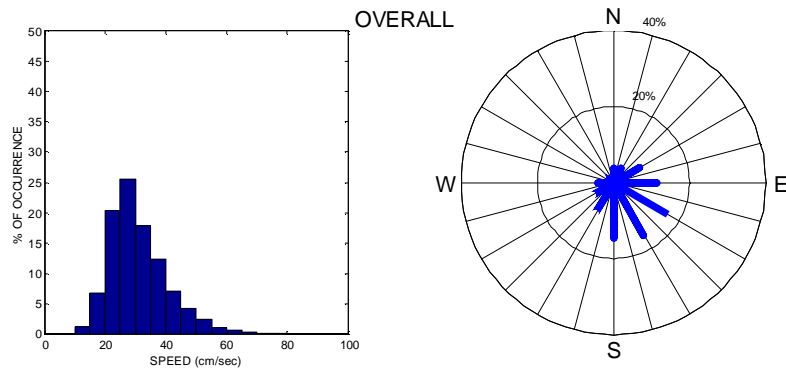
#### **4.4.2.2.2. Subsurface Currents**

At the subsurface levels (Figure 4.18) there was one current series when the overall direction of the dominant currents was not between the east and the southeast. This occurred in the dataset for November 1984 to February 1985. The rest of the plots consistently show dominant currents towards the east or southeast. The statistical summary in Table 4.13 shows that the average speeds are higher during the months of November and December (25 cm/sec – 32 cm/sec). The lowest average speeds are observed during April and May (9 cm/sec– 11 cm/sec).

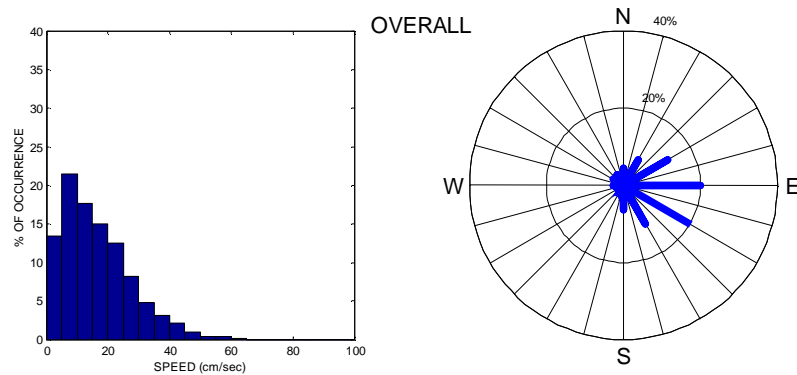


**Figure 4.17. Geographic Position of the Data Sets Used in the Analysis.**

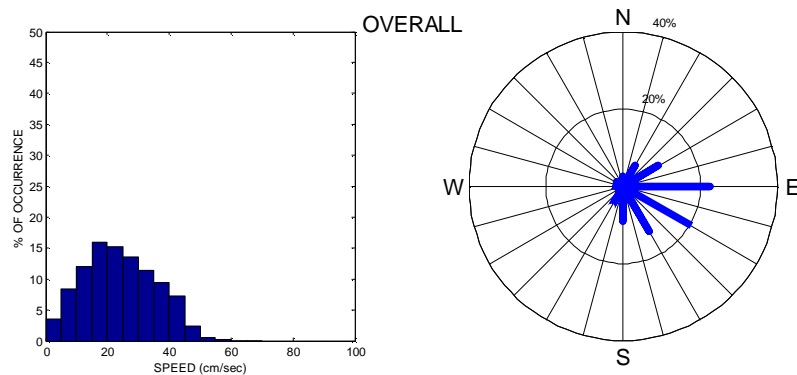
### 35 m October – December 1980



### 20 m May – September 1982

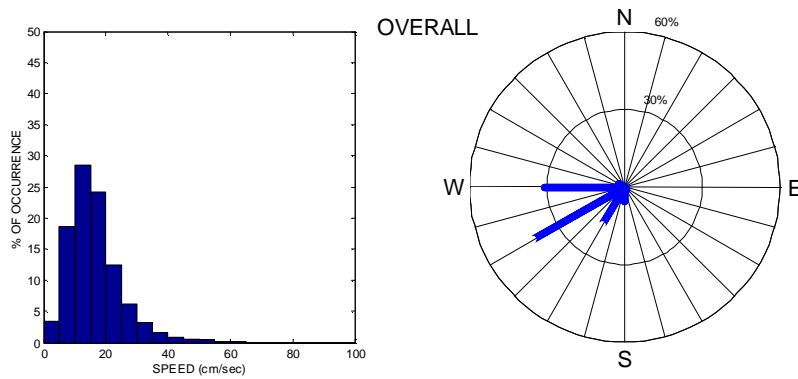


### 20m October – December 1982

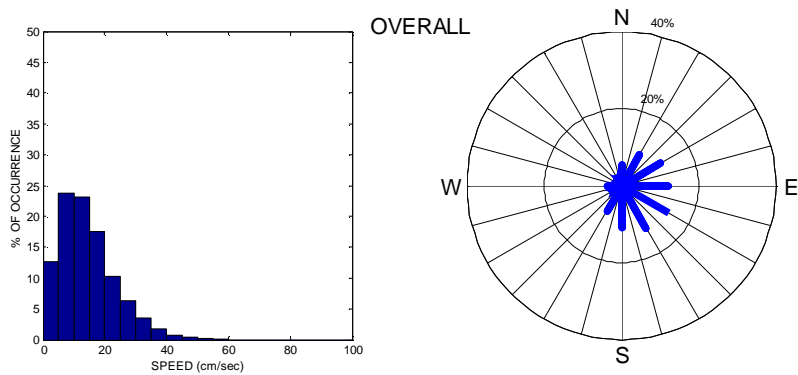


**Figure 4.18. Histograms of Speed and Direction for the Subsurface Observation Depths.**

### 21 m November 1984 – February 1985



### 21 m December 1991 – May 1992



**Figure 4.18 (cont'd). Histograms of Speed and Direction for the Subsurface Observation Depths.**

**Table 4.13. Statistical Summary for the Data Collected at the Near-Surface Depth.**

Sampling Period	Depth	Parameter	Mean	St. Dev	Min.	Max.
October - December 1980	35 m	Speed	30.58	9.62	11.00	77.00
May - September 1982	20 m	Speed	15.99	11.10	0.00	67.13
October - December 1982	20 m	Speed	24.01	11.59	0.15	68.30
November 1984 - February 1985	21 m	Speed	15.77	8.33	1.00	60.00
December 1991 - May 1992		Speed	14.22	8.97	0.00	55.70

The progressive vector diagrams corroborate the general trend of southeastern currents shown by the rose plots, with net displacements to the east-southeast or the southeast in all the cases with the exception of the period between November 1984 and February 1985, when the progressive vector diagram displays a net movement of the water to the southwest. The mean velocity of the water varied between 5.9 cm/sec and 15.2 cm/sec.

#### **4.4.2.2.3. Mid-water Levels**

Figure 4.19 shows also a dominance of southeastern and eastern flows, with the only exception being the period between November 1984 and February 1985, when the currents at a depth of 70 m had a dominant northeast direction.

A seasonal cycle in the current speed is not as evident at mid-depth as in the upper levels, according to the data. As seen in Table 4.14, the mean speeds varied between 10 cm/sec and 16 cm/sec. There is a 1.6 cm/sec mean speed at 83 m during December 1991 to May 1992, which looks suspiciously low for this area and depth.

The progressive vector diagrams show a net displacement of the water parcels to the east and southeast for all the analyzed data sets with the exceptions of the data sets for November 1984 to February 1985 (70 m), and for December 1991 to May 1992 (83 m). In these cases the currents were to the northeast and east-northeast, respectively.

The currents at mid-depth showed mean velocities between 3.2 cm/sec and 11.7 cm/sec.

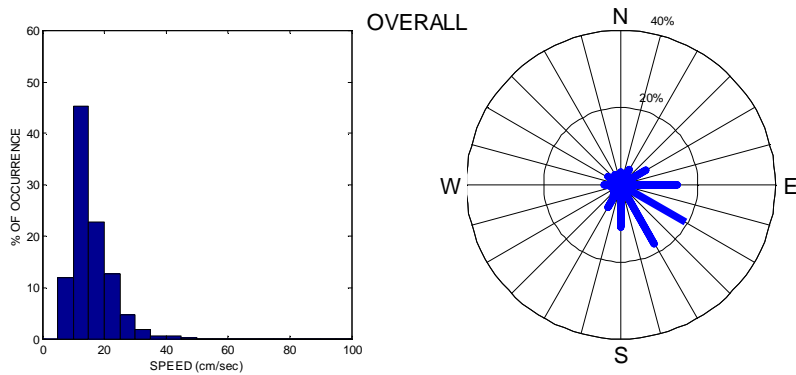
#### **4.4.2.2.4. Near Bottom Currents**

The general pattern of current variability is shown in Figure 4.20. The only exception to the general trend of eastern and southeastern flows is for December 1991 to May 1992 at 141 m, where the dominant current is to the southwest.

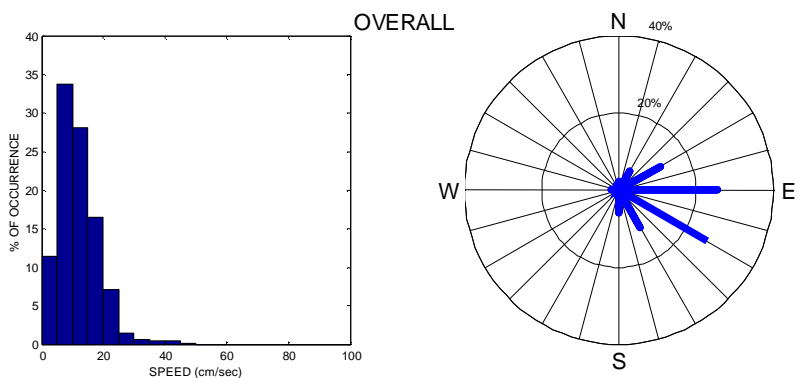
The mean velocities were higher than at the mid-water depths and reached between 3.7 cm/sec and 24.5 cm/sec as shown by the progressive vector diagrams. The maximum mean velocity of 24.3 cm/sec was recorded by the mooring located at the deepest location, where the influence of the outer branch of the Labrador Current was stronger than at any other of the locations where current meters were located (Table 4.15).



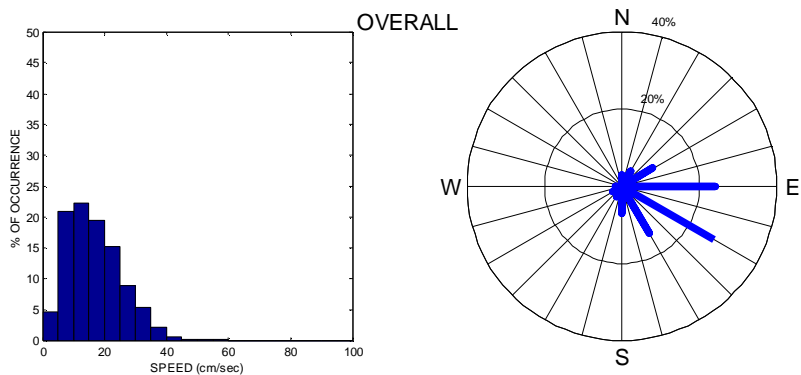
**95 m. October – December 1980**



**98 m May – September 1982**

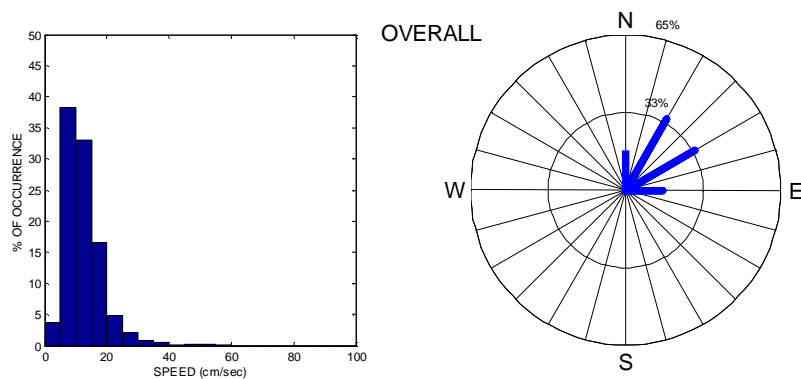


**98 m. October – December 1982**

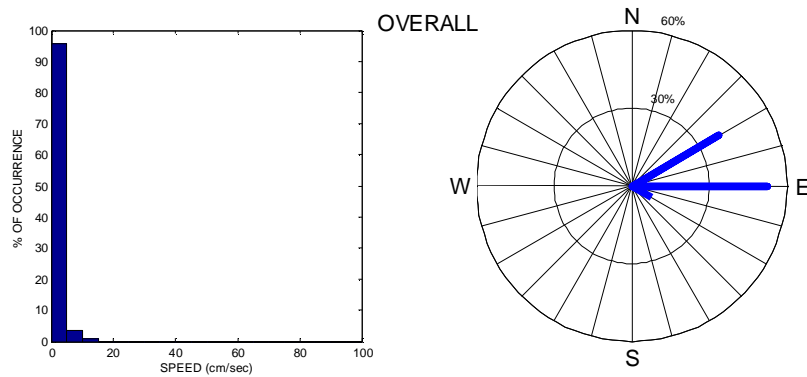


**Figure 4.19. Histograms of Speed and Direction for the Mid-water Observation Depths.**

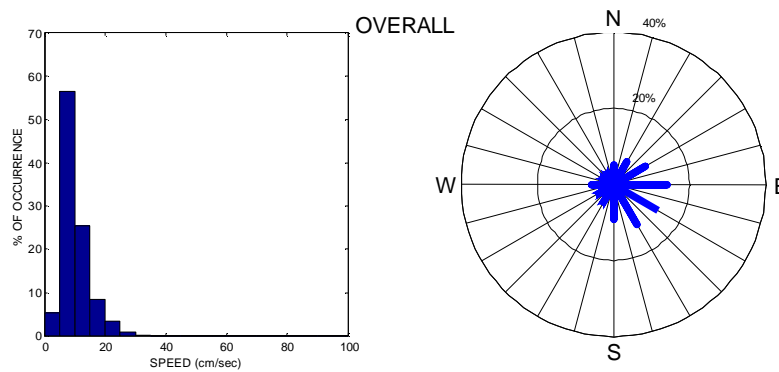
**70 m. November 1984 – February 1985**



**83 m. December 1991 – May 1992**

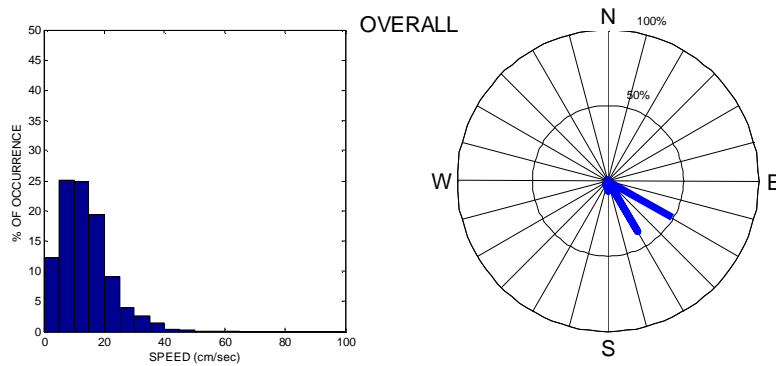


**76 m. December 1991 – May 1992**



**Figure 4.19 (cont'd). Histograms of Speed and Direction for the Mid-water Observation Depths.**

### 75 m. December 1991 – May 1992

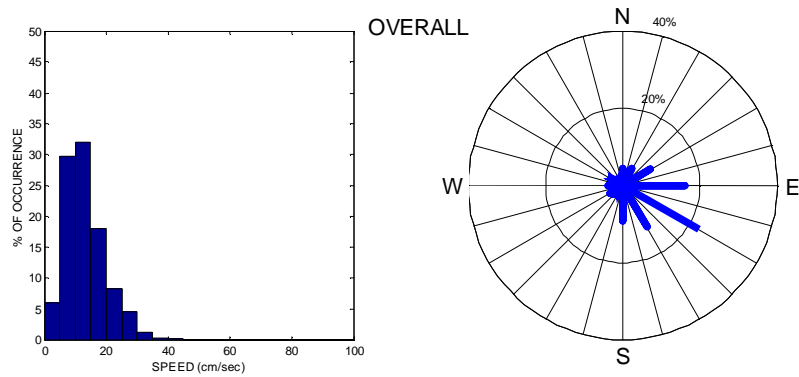


**Figure 4.19 (cont'd). Histograms of Speed and Direction for the Mid-water Observation Depths.**

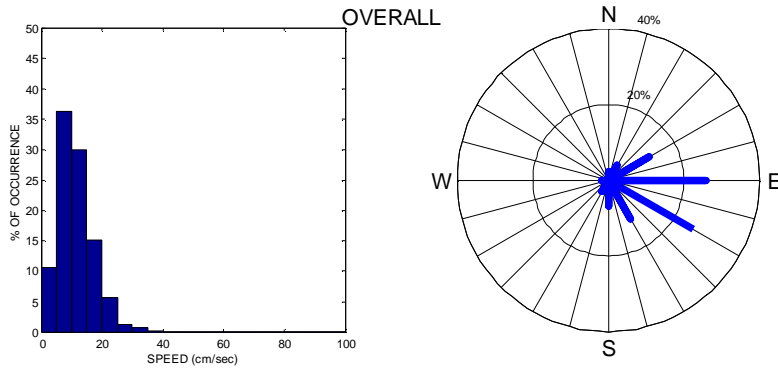
**Table 4.14. Statistical Summary for the Data Collected at Mid-depth.**

Sampling Period	Depth	Parameter	Mean	St. Dev	Min.	Max.
October - December 1980	95 m	Speed	15.09	6.16	4.00	47.00
May - September 1982	98 m	Speed	11.40	6.62	1.00	49.00
October - December 1982	98 m	Speed	16.30	8.77	2.00	59.00
November 1984 - February 1985	70 m	Speed	12.29	6.13	1.50	55.95
December 1991 - May 1992 (northeast location)	83 m	Speed	1.60	1.06	1.10	14.44
December 1991 - May 1992 (south location)	76 m	Speed	10.07	4.62	1.10	37.78
December 1991 - May 1992 (northwest location)	75 m	Speed	13.43	8.38	1.10	61.62

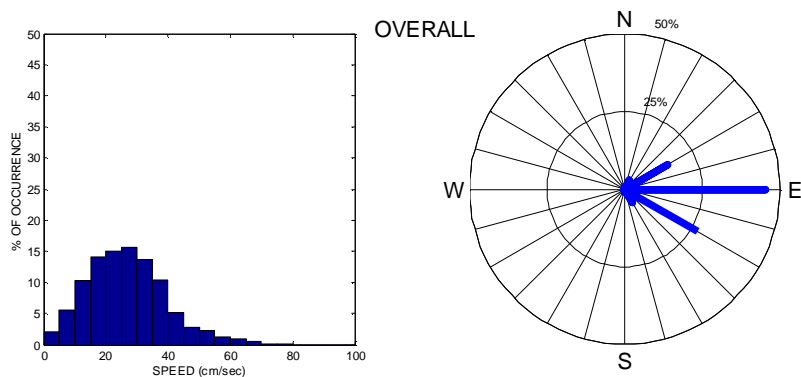
### 150 m. October – December 1980



### 179 m. May – September 1982

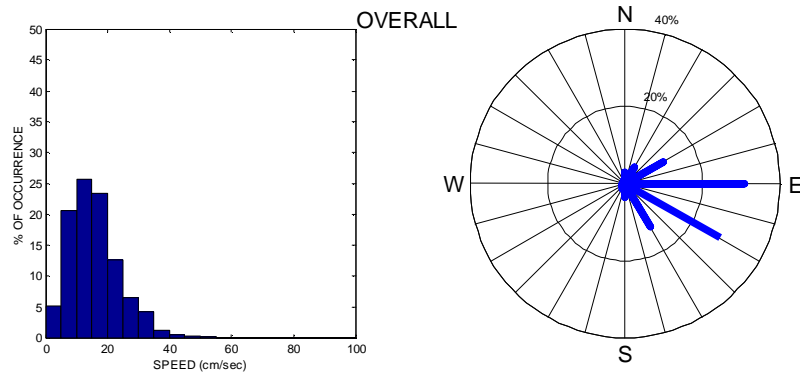


### 179 m. October – December 1982

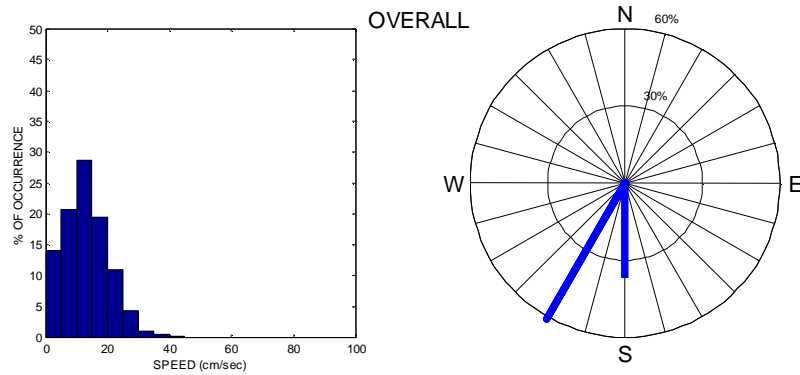


**Figure 4.20. Histograms of Speed and Direction for the Near-Bottom Observation Depths.**

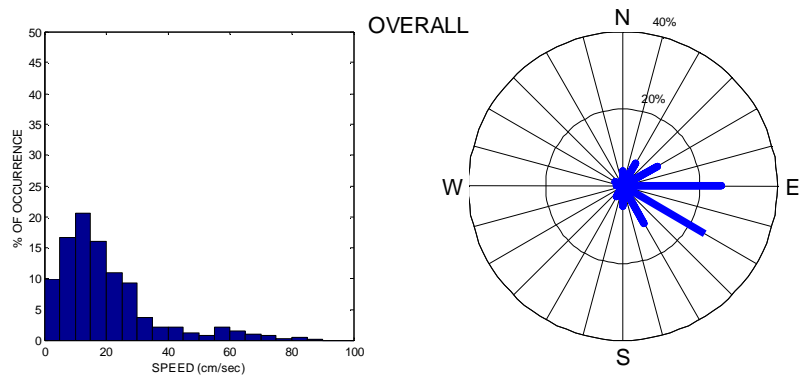
### 142 m. December 1991 – May 1992



### 141 m. December 1991 – May 1992

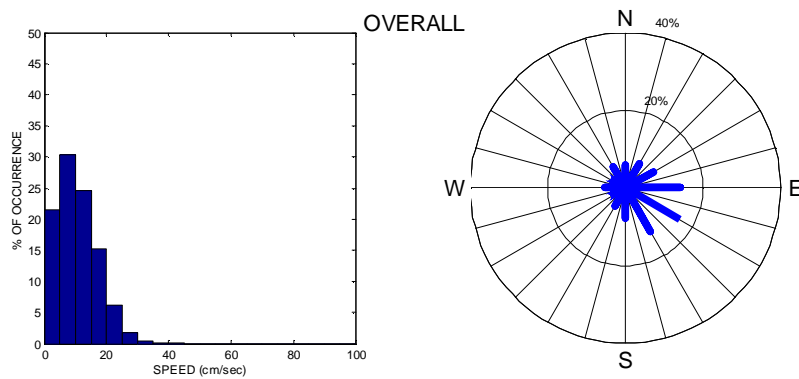


### 167 m. December 1991 – May 1992

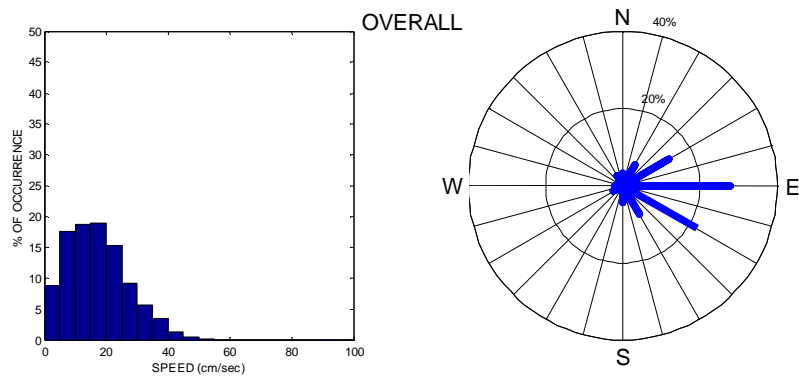


**Figure 4.20 (cont'd) Histograms of Speed and Direction for the Near-Bottom Observation Depths.**

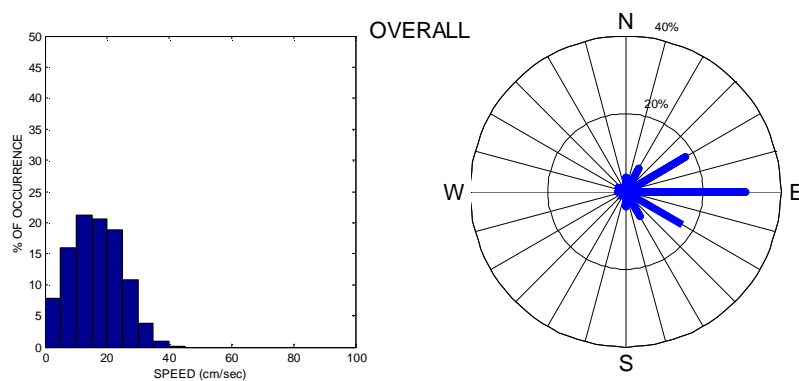
### 136 m. December 1991 – May 1992



### 135 m. December 1991 – May 1992



### 185 m. December 1991 – May 1992



**Figure 4.20 (cont'd) Histograms of Speed and Direction for the Currents Near the Bottom.**

**Table 4.15. Statistical Summary for the Data Collected at the Near-Bottom Depths.**

<b>Sampling Period</b>	<b>Depth</b>	<b>Parameter</b>	<b>Mean</b>	<b>St. Dev</b>	<b>Min.</b>	<b>Max.</b>
October - December 1980	150 m	Speed	12.58	6.53	2.00	45.00
May - September 1982	179 m	Speed	10.80	5.68	2.00	36.00
October - December 1982	179 m	Speed	15.39	8.08	2.00	55.00
December 1991 - May 1992 (northeast location)	143 m	Speed	26.85	12.71	1.10	77.48
December 1991 - May 1992 (central location)	141 m	Speed	12.27	7.57	1.10	43.93
December 1991 - May 1992 (central location)	167 m	Speed	19.86	16.30	1.10	103.95
December 1991 - May 1992 (south location)	136 m	Speed	10.59	6.25	1.10	42.57
December 1991 - May 1992 (northwest location)	135 m	Speed	17.17	9.85	1.10	63.62
December 1991 - May 1992 (northwest location)	185 m	Speed	16.40	8.10	1.10	43.20

#### **4.4.2.2.5. Harmonic Analysis of the Tidal Currents**

With the help of tidal harmonic analysis it is possible to study the variability of the astronomically determined components of the currents. Tidal ellipses represent the orientation and magnitude of the major and minor axes of variability of the tidal currents. Tidal constituent M2, the semidiurnal lunar constituent, with a frequency of two cycles per lunar day is by far the most important tidal components in the area in terms of the variability it brings into the current systems.

#### **4.4.2.3. General Discussion**

According to the analyzed data, the currents in the area of interest generally flow in a southeast direction. The mean current speeds for the area vary in the range of 14 cm/sec to 30 cm/sec in the subsurface layer (20 m – 35 m), between 10 cm/sec and 16 cm/sec in the mid-water layer (70 m – 98 m), and between 10 cm/sec and 26 cm/sec in the deeper water (135 m – 185 m). Maximum speeds reached 77 cm/sec in the upper layer, 56 cm/sec in the middle layer and 104 cm/sec in the near bottom layer.

Due to the specific location of these exploration acreages near the edge of the Grand Banks, the area may be subject to changes in the predominant currents due to displacements of the core of the Labrador

Current. Since the main body of the Labrador Current is situated along the Continental Slope where the water depth is between 300 m and 1,500 m, the northern boundary of the study area may be affected by episodes of increased current, due to the proximity and the shifting of the core of the Labrador Current (like in the case of December 1991 – May 1992 at 167 m, when the maximum currents reached over 100 cm/sec).

## **4.5. Ice and Icebergs**

The following is a description of the ice environment within the proposed 3-D seismic exploration area located to the north of the White Rose field. This description uses as its base, information and data published in the White Rose Development Environmental Impact Assessment (2000). Those data have been updated to include subsequent data and reports from 2000 and 2001. Apart from some small numerical adjustments most data and associated descriptions remain unchanged.

The Project Area lies on the eastern slope of the continental shelf making it susceptible to seasonal incursions of ice. Two different forms of floating ice: sea ice and icebergs are present in this marine environment. Sea ice is produced when the ocean's surface layer freezes. In the area of these locations, sea ice when present is usually loosely packed and pressure-free. Floes are small and generally in advanced stages of deterioration.

Icebergs are freshwater ice made from snow compacted in a glacier. When the leading edge of a glacier reaches the sea, slabs of ice fall off it, creating icebergs. Grand Banks icebergs originate mainly from the glaciers of West Greenland. Ice management efforts focus on icebergs because they pose a hazard to offshore production facilities.

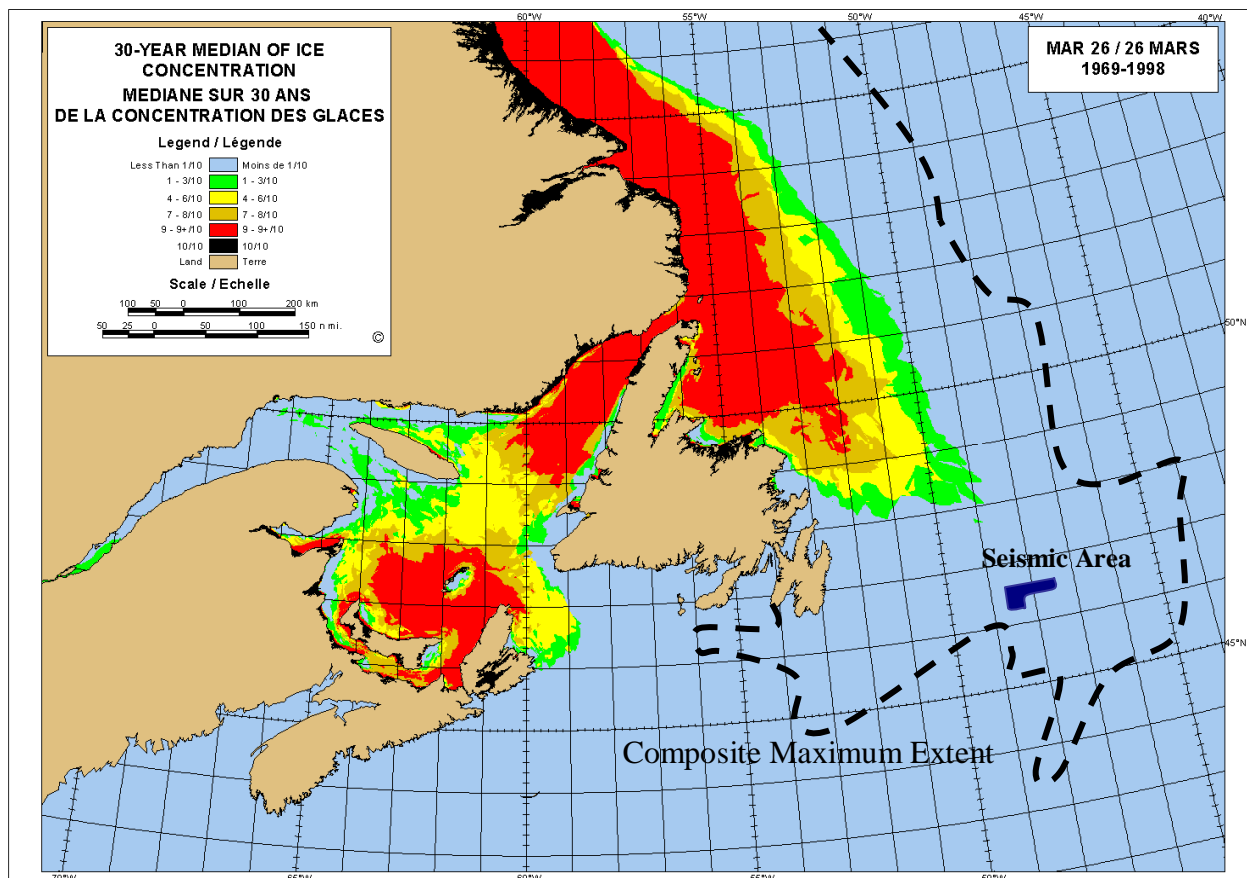
### **4.5.1. Sea Ice**

The proposed sites lie close to the extreme southern limit of the regional ice pack. In typical years, the ice edge reaches the Grand Banks in mid-February (Navoc 1986). The pack ice generally reaches annual peak coverage in March, just before water temperatures rise above the freezing level.

#### **4.5.1.1. Sea Ice Duration**

The median ice edge position shown in Figure 4.21 represents the ice edge for a hypothetically typical year; half the time the ice is farther south and half the time farther north than the median line. The maximum ice positions shown are composites of the most advanced ice-edge positions recorded. Sea ice cover is present at the proposed operations area 40 percent of the record or approximately one year in every three. The duration of these incursions varies from a low of one week to a high of 11 weeks and an average duration was four weeks (Table 4.16).





**Figure 4.21. Mean and Composite Maximum Sea Ice Distribution.**

Source: Canadian Ice Services

**Table 4.16. Sea Ice Duration for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>	<i>Minimum</i>
4 weeks	7 weeks	11 weeks	0
Source: CIS Weekly Ice Charts 1969 - 1998			

#### 4.5.1.2. Sea Ice Concentrations

The Project Area can be affected by the seasonal ice tongue (created when sea ice is swept around the edge of the Grand Banks by the Labrador Current), ice concentrations in the tongue are usually at the lower end of ice coverage – 2/10ths to 6/10ths. However, in extreme years this area has experienced short periods of 9/10ths + coverage. Table 4.17 provides the mean, maximum, and extreme sea ice cover for the area.

**Table 4.17. Sea Ice Concentrations for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
50 percent	90 percent	100 percent
Source: CIS Weekly Ice Charts 1970 - 2000		

#### **4.5.1.3. Sea Ice Floe Size**

AES composite ice chart data for 1964 to 1998 indicate that floes larger than 100 m are present only 10 percent of the time. Estimates made in an earlier study (Dobrocky Seatech 1985) indicate that mean floe diameters in offshore areas south of 49°N are less than 30 m. Only a few floes with diameters larger than 60 m were observed. Table 4.18 provides the mean, maximum and extreme floe sizes for the Grand Banks.

**Table 4.18. Sea Ice Floe Size for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
<30 meters	60 meters	>100 meters
Source: Dobrocky Seatec (1985)		

#### **4.5.1.4. Sea Ice Thickness**

Most of the ice coverage across the Grand Banks ranges from 30 cm to 100 cm in thickness. These data were derived subjectively from CIS ice chart data for periods of ice coverage 1985 to 2001 that exceeded 4 weeks in duration. Table 4.19 provides the mean, maximum, and extreme sea ice thickness for un-deformed ice.

**Table 4.19. Sea Ice Thickness (un-deformed) for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
70 cm	100 cm	200 cm
Source: CIS Weekly Ice Charts 1970 - 2000		

#### **4.5.1.5. Sea Ice Drift Speeds**

When present, the pack ice at the proposed seismic program area is made up of non-continuous, mobile pack. Because of the loose concentrations and the lack of restraint, pack ice is not subject to pressure.

Pack ice drift rates on the Grand Banks virtually mirror the surface currents. Between 1984 and 1987, Petro-Canada conducted a series of studies using satellite tracked ice drifters. The resulting ice drift patterns and velocities are characteristic of currents on the slope region of the Grand Banks.

Eighty percent of the measured drift speeds were less than 0.6 m/sec with a preferred direction towards the southeast. Mean drift speeds were shown to be 0.25 m/sec and extremes of 0.75 – 1.0 m/sec. These measurements confirm observations made by mariners experienced with operating in ice on the Grand Banks. Table 4.20 indicates the mean, maximum and extreme pack ice drift speeds.

**Table 4.20. Sea Ice Drift Speeds for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
0.25 m/sec	0.6 m/sec	1.0 m/sec
Source: Husky Energy (2000)		

#### **4.5.1.6. Sea Ice Timing**

The timing of any sea ice incursion over the proposed seismic survey area is highly variable and historically has occurred from mid-January through to the end of April. The peak period is covered in the period mid-February through to mid-April with the peak probability centered around the last week in February and again the first week in April.

### **4.5.2. Icebergs**

Glacial ice is formed from the accumulation of snow, which gradually changes form as it is compressed into a solid mass of large granular ice. This process produces a structure quite different from pack ice. The principal origins of the icebergs that reach these prospects are the 100 tidewater glaciers of West Greenland, which account for 85% of the icebergs that reach the Grand Banks.

#### **4.5.2.1. Iceberg Distribution**

According to the International Ice Patrol (IIP), the number of icebergs reaching the Grand Banks each year varied from a low of 0 in 1966 to a high of 2,202 in 1984, with the average over the last ten years being around 900 icebergs. Of these only a small proportion will pass through the area of proposed operations which spans approximately two blocks of data. Over the last ten years the average yearly number of icebergs sighted in the proposed seismic area has been 88.

At 48°N, on the approaches to the proposed sites, long-term averages of data compiled by PAL from 1989 to 2001 show that regardless of how many icebergs arrive, the numbers peak in May but are at high levels from March through to June. While the major iceberg flux falls into the March to June period, iceberg sightings on the Grand Banks have been made at least once in each month – January through December - and in 1993 about 20 percent of the icebergs crossed 48°N in February while in 2004 almost 80% crossed in June. It should be noted that over the recent history, two years have been completely iceberg-free and over the long-term record iceberg-free conditions account for approximately five percent of all seasons.

A plot (Figure 4.22) of annual iceberg distribution for 1° grids (7,000 km<sup>2</sup>) between 46°N and 50°N using 1989-2004 PAL data shows the regional iceberg distribution. The upper and lower numbers in each rectangle denote, respectively, the maximum and the mean numbers of icebergs observed each year. The maximum numbers provide a worst-case representation of local annual iceberg severities.

Table 4.21 shows the maximum and mean numbers of icebergs observed crossing the operations area and is based on averaging the sightings over the two adjacent blocks.

**Table 4.21. Iceberg Distributions.**

<i>For the Seismic Operations Area</i>			
Source	Maximum	Minimum	Mean
PAL	311	0	88
Source: Provincial Airlines (2004)			

#### 4.5.2.2. Iceberg Size Distribution

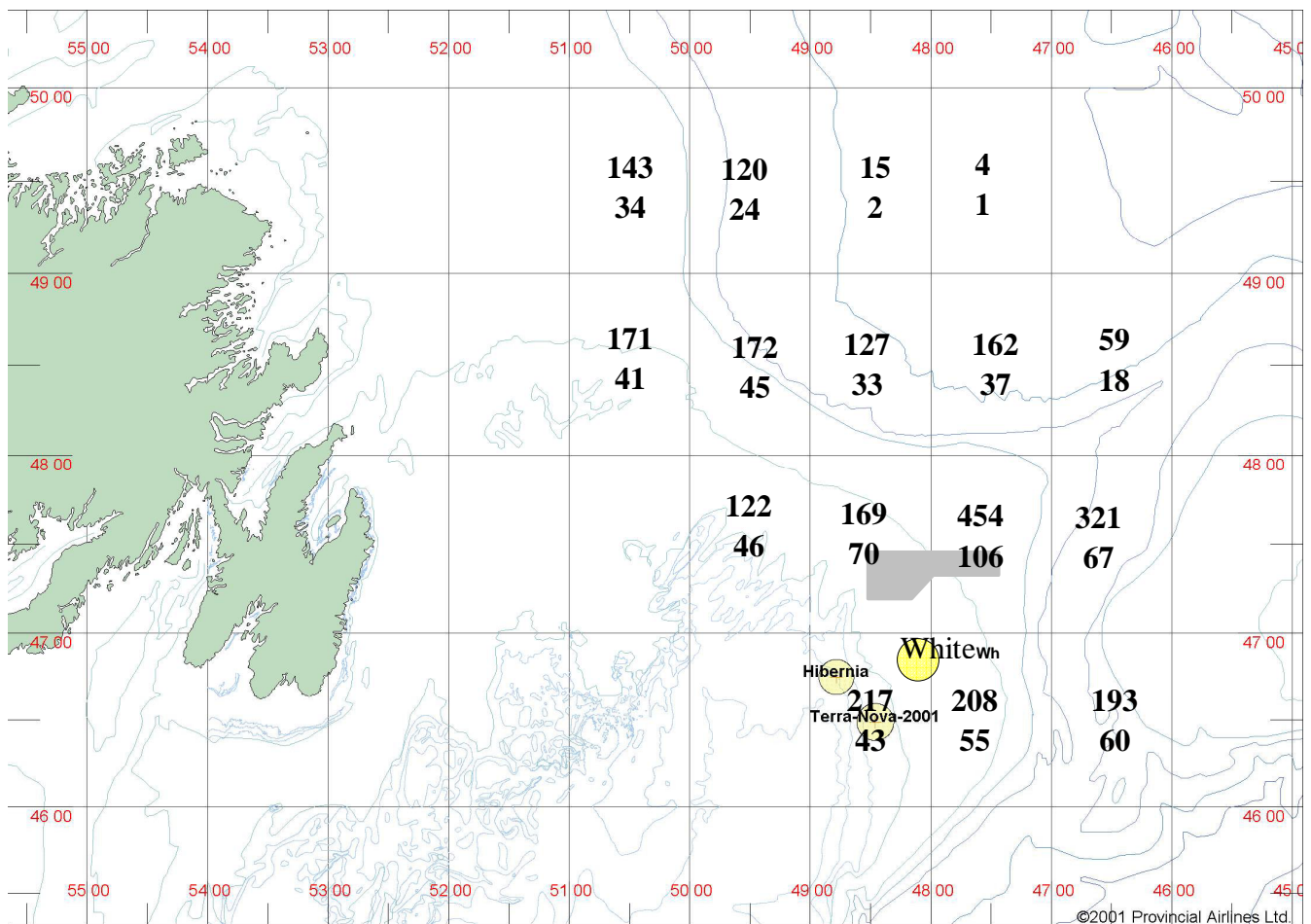
Two recent PERD studies: A Compilation of Iceberg Shape and Geometry Data for the Grand Banks Region (CANATEC 1999), and Grand Banks Iceberg Database (Fleet Technology 2000) lists dimensions for 872 icebergs measured on the Grand Banks and off Labrador. These databases provide extensive measurement data (both above- and below- water) on icebergs. From this database measurement sets were extracted for icebergs within a 100 km radius. Additional data obtained over the 2000 ice-season were added using the same criteria. This brought the total number of available measurement sets to 470.

These data show that for the area 64 percent of measured icebergs fall into the small or lower category. While 24 percent were medium and 12 percent were large. The 150-200 m meters water depth will place a limit on the extreme iceberg size. However, the extreme would likely still be at the upper end of the large range.

Table 4.22 provides the expected iceberg sizes found within the operations area. It should be noted that in recent seasons several ice island fragments have been observed crossing the proposed operations area. Ice islands are defined by their very large surface area reaching 250,000 m<sup>2</sup> but with shallow drafts usually less than 70 m. These events are still quite rare and because of their very large size detection is not an issue.

**Table 4.22. Iceberg Size Distribution for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
Small	Large	Very Large
Source: Fleet Technology (2000)		



**Figure 4.22. Maximum and Mean Annual Numbers of Icebergs Observed.**

Source: PAL Iceberg Sighting Database 1989 – 2001

#### 4.5.2.3. Iceberg Draft

In off-shelf areas, icebergs can have drafts larger than 150 m while in on-shelf areas, iceberg drafts are in the 20-m to 100-m range. Mean on-shelf and off-shelf draft are 60 m and 70 m, respectively.

#### 4.5.2.4. Iceberg Mass

A review of 224 icebergs measured within 100 km from the PERD (1999) database shows similar results. For water depths greater than 100 m the mean iceberg mass was 300,000 tonnes with nearly 10 percent in excess of one million tonnes and 31 percent below 10,000 tonnes.

Table 4.23 shown the mean, maximum, and extreme iceberg masses that could cross the proposed operations area. It should be noted that the Maximum is based on normal icebergs that frequent this area and that the extreme mass is based on recent ice island events and reflects the upper limit of the ice islands documented in this area.

**Table 4.23. Iceberg Mass Distribution for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
300,000 tonnes	2.2 Million tonnes	9 Million tonnes
Source: (CANATEC 1999)		

#### **4.5.2.5. Iceberg Drift Speeds**

Iceberg drift speeds in this area show a correlation with the sub-surface currents. Iceberg drift speeds measured from various drilling operations on the Grand Banks show iceberg drift speeds ranging from a low of 0 to a high of 1.3 m/sec and the mean at 0.3 m/sec (Table 4.24).

A study conducted by Seaconsult (1988) showed that 65 percent of measured iceberg drift speeds were less than 0.4 m/sec regardless of water depth. Over the 2000 ice season, 1,370 measurements of iceberg drift were recorded. Speeds ranged from 0 to 1.3 m/sec and again the mean drift speed was 0.3 m/sec.

Both of these observations agree with other studies conducted over the 1980s, which had established a mean iceberg drift speed of 0.26 m/sec.

Using the extreme sub-surface currents for the proposed operation area as a base, and assuming the same relationship between iceberg and current speed, it would appear that the extreme iceberg drift speeds could peak at 1.8 m/sec.

**Table 4.24. Iceberg Drift Speeds for the Seismic Operations Area.**

<i>Mean</i>	<i>Maximum</i>	<i>Extreme</i>
0.3 m/sec	1.3 m/sec	1.8 m/sec
Source: Husky Energy. (2000)		

#### **4.5.2.6. Iceberg Scour**

Icebergs whose drafts exceed their water depths scrape along the sea floor, creating continuous or interrupted gouges and pits and may eventually become grounded on the seabed. These phenomena are known as 'iceberg scours'.

Recent reports (Croasdale 2000) have quantified over 3,887 individual iceberg scours from the Grand Banks Scour Catalogue produced by Canadian Seabed Research Ltd. Data for this area show the mean scour depth to be 0.1m in depth and just under 600 m in length (Table 4.25).

**Table 4.25. Iceberg Scour Data for the Seismic Operations Area.**

	<i>Mean</i>	<i>Maximum</i>
Depth (m)	0.1	3.5
Width (m)	27	185
Length (m)	599	6,400
Source: Croasdale, K.R. and Associates. (2000)		

## **5.0 Biological Environment**

### **5.1. Ecosystem**

The marine ecosystem of the proposed Project Area is part of the northwest Atlantic. Generally, phytoplankton (e.g., diatoms) photosynthesize carbon (primary production) using nutrients and light, thereby fueling herbivorous zooplankton (e.g., copepods) which in turn, directly and indirectly, feed predators such as other zooplankton (e.g., fish larvae), fish, seabirds, and marine mammals. To complete the cycles, degradation processes (e.g., bacterial) break matter down into particulate and dissolved organic matter that is subsequently utilized by plankton and benthos.

The 3-D seismic and geohazard surveys (the Project) have no potential to cause effects at the ecosystem level and thus the discussion in the following sections is limited to only those key parts of the ecosystem that could be affected, albeit in very minor ways.

### **5.2. Plankton**

In the northwest Atlantic, there is generally a spring plankton bloom that is often followed by a smaller bloom in the fall. The Project Area falls within this general pattern (see below). Given that part of the Project Area occurs over the upper continental slope region, there may be areas of enhanced production similar to other slope areas that have been studied.

Continuous Plankton Recorder (CPR) data collected between 1991 and 2000 along the Z-line running between Iceland and Newfoundland, showed that after 1991, densities of phytoplankton increased, and zooplankton decreased in the region west of 45°W (Sameoto 2004a,b). There have been suggestions that these changes are linked to changes in the Labrador Current. These data are at least generally applicable to the Project Area. Since 1991, phytoplankton in the general vicinity of the Project Area has been densest during the April to June period, followed by the October to December period. Total euphausiid abundance (zooplankton) during the same 1991-2000 period has generally been greatest during the July to September period, followed by the April to June period.

The proposed Project has minimal potential to affect phytoplankton and/or zooplankton to any meaningful degree. For this reason, they will not be discussed further. However, there is some potential for sound energy to affect fish/invertebrate eggs and larvae (ichthyoplankton). These potential effects, particularly as they apply to commercial fish and invertebrate species, are discussed in following sections.

### **5.3. Benthos**

Benthos includes a wide variety of bottom-dwelling animals such as bryozoans, soft and hard corals, anemones, hydroids, sea cucumbers, sea squirts, urchins, sea stars, polychaete worms, clams, crab,



lobster, bottom-associated fish (e.g., flounder), and others. While there has not been intensive sampling of the benthos in the Project Area, it is likely that a diversity of species from all of the above-named groups occurs in the area.

Snow crab (*Chionoecetes opilio*) is an important crab species known to occur within the Project Area. Another noteworthy invertebrate that occurs within the Project Area is the northern shrimp (*Pandalus borealis*). While northern shrimp migrate vertically between the bottom and the upper water column, the species is considered benthic for the purposes of this EA. Spatial and temporal specifics regarding the occurrence and reproduction of snow crab and northern shrimp are presented in a later section that profiles important commercial fishery species.

Historically, other than for some commercial species of fish and crab, there has been little or no concern expressed by stakeholders or the scientific community about either surface-operated seismic or geohazard surveys on bottom communities, particularly in deep water areas.

## **5.4. Invertebrates and Fish**

### **5.4.1. Marine Habitats**

Based on physical habitat characteristics, both the Project Area and the 2005 Survey Area can be divided into two primary areas: (1) the Shelf (<100 m to 200 m), and (2) the Slope (200 m to >300 m).

As is the case at the nearby White Rose site to the south, the surficial geology of the Project Area Shelf region is, presumably, a thin veneer of fine to medium grained sand over a coarser substrate consisting of gravel and gravelly sand (Husky 2000). The Slope region in the Project Area has variable depths ranging primarily between 200 and between 300 and 400 m. Bottom temperatures in the Slope region tend to be slightly higher than those of the Shelf (Colbourne et al. 2004).

### **5.4.2. Profiles of Commercially-Important Species**

Commercial fishery landings data related to harvesting in the proposed Project Area, specific fish and invertebrate species have been selected and described in the following sections based on the latest available DFO data. The selected commercial species accounted for essentially 100% of the April to October Project Area catches landed at Newfoundland ports during 2002 to 2004.

#### **5.4.2.1. Snow Crab**

Snow crab (*Chionoecetes opilio*) are decapod crustaceans that occur over a broad depth range (20 to 700 m) in the Northwest Atlantic. The distribution of this decapod in waters off Newfoundland and southern Labrador is widespread but the stock structure remains unclear. Snow crabs have a tendency to prefer water temperatures ranging between -1 and 4°C. Large snow crabs (≥95-mm carapace width or

CW) occur primarily on soft bottoms (mud or mud-sand) (DFO 2004a), particularly in water depths of 70 to 280 m. Small snow crab appear to be most common on harder substrates (DFO 2004a). Mating generally occurs during the early spring and the females subsequently carry the fertilized eggs for about two years. The larvae hatch in late spring or early summer, and then remain in the water column for 12 to 15 weeks before settling on the bottom (DFO 2004a). Snow crab feed on fish, clams, polychaete worms, brittle stars, shrimp and crustaceans, including smaller snow crab.

Based on the DFO multi-species bottom trawl survey conducted in the fall 2003 as well as fishery logbook data and observer sampling data, there are indications of decline in both exploitable biomass and recruitment in NAFO Divisions 2J3KL. There has also been an apparent contraction of resource within these divisions in recent years (DFO 2004a).

#### **5.4.2.2. 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 6°C. 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 this shrimp. Northern shrimp 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 2003a).

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 downward through the water column and metamorphose to adulthood (DFO 1993).

Since fall of 2002, fall and spring research surveys in NAFO Divisions 3LNO indicated the greatest concentrations of northern shrimp occur along the 3L slope region between 185 m and 550 m. Results from fall 2002, spring 2003 and fall 2003 were quite similar but the distribution map for the spring 2004 research survey indicated slightly smaller catches in this region. During recent years, 90.5 to 99.9% of the total Divisions 3LNO northern shrimp biomass has been found within 3L. Between 2000 and 2003, 21% of the fall biomass and 26% of the spring biomass was found outside the 200 nautical miles limit (Orr et al. 2004).

#### **5.4.2.3. Greenland Halibut**

The Greenland halibut (turbot) is a deepwater flatfish species that occurs in water temperatures ranging between -0.5 to 6.0°C but appears to have a preference for temperatures of 0 to 4.5°C. In the northwest Atlantic off northeastern Newfoundland and southern Labrador, these fish are normally caught at depths

exceeding 450 m. Reported depths of capture range from 90 to 1,600 m. The larger individuals tend to occur in the deeper parts of its vertical distribution. Unlike many flatfishes, the Greenland halibut spends considerable time in the pelagic zone (Scott and Scott 1988).

These halibut are believed to spawn in Davis Strait during the winter and early spring at depths ranging from 650 to 1,000 m. They are also thought to spawn in the Laurentian Channel and the Gulf of St. Lawrence during the winter. The large fertilized eggs of this species (4 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; Kulka et al. 2003). 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 Division 3L, surveys conducted between 1996 and 2001 extended to at least 730 m in the spring and to 1,500 m in the fall using the Campelen 1800 shrimp trawl (Bowering 2002). Division 3K is surveyed only in the fall to depths of 1,500 m. 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).

### **5.4.3. Profiles of SARA-Listed Species**

The four fish species relevant to SARA as of 24 February, 2005 include northern wolffish (*Anarhichas denticulatus*) (Schedule 1-threatened), spotted wolffish (*A. minor*) (Schedule 1-threatened), Atlantic

wolffish (*A. lupus*) (Schedule 1-special concern), and Atlantic cod (*Gadus morhua*) (Newfoundland and Labrador population) (Schedule 3-special concern). [DFO is presently conducting public consultations in regard to the potential inclusion of porbeagle shark (*Lamna nasus*) on a SARA list.] Only those species listed as threatened or endangered on Schedule I have special legal protection under SARA in terms of recovery strategies, penalties to be incurred for harming or killing individuals of the species or destroying critical habitat.

#### **5.4.3.1. Wolffishes**

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

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

Atlantic or striped wolffish (*Anarhichas lupus*) are typically found further south than either northern or spotted wolffish. They have been found at depths of up to 350 m (Scott and Scott 1988). As was indicated for spotted wolffish, Atlantic wolffish are more abundant along the Project Area slope in the fall than in the spring (Kulka et al. 2003). This analysis also indicated that spotted wolffish are slightly more abundant than Atlantic wolffish along the Project Area slope. There is no evidence that Atlantic wolffish migrate long distances, or form schools in Newfoundland waters (DFO 2004b). In the Northwest Atlantic, Atlantic wolffish feed primarily on benthic invertebrates such as echinoderms, molluscs and crustaceans, as well as small amounts of fish. No predators of adult Atlantic wolffish have been identified, but juveniles have been found in the stomachs of Atlantic cod (Scott and Scott 1988).

It is not known with certainty if any of these three wolffish species spawn in the Project Area, although it is probable given the limited migration of the species. If spawning does occur in the Project Area, it would most likely take place along the slope. During the late fall fertilized eggs are deposited on either a hard bottom or underwater ledge (Scott and Scott 1988), producing larvae which are large (2-cm long upon hatching) and semipelagic (DFO 2004b). 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, 2003).

The spotted wolffish and striped wolffish are regarded as commercial species in Newfoundland waters while the northern wolffish is not (Simpson and Kulka 2002, 2003).

While the decline in abundance and biomass estimates of all three species has occurred throughout 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, 2003).

DFO is presently preparing a 'Wolffish Recovery Plan' but this document has not yet been published (J. Simms, DFO biologist, pers. comm.).

#### **5.4.3.2. Atlantic Cod (Newfoundland and Labrador Population)**

Atlantic cod 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. Atlantic cod fertilized eggs, larvae and early juvenile stages remain in the plankton for 10 to 12 weeks. 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). Adult cod are commonly prey for seals and toothed whales, while juvenile cod are commonly preyed upon by squid, Pollock and adult cod (Scott and Scott 1988).

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 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).

Historically, many of the northern cod migrated between overwintering areas in deep water near the shelf break and feeding areas in the shallower waters both on the plateau of Grand Bank and along the coasts of Labrador and eastern Newfoundland. Some cod remained in the inshore deep water during the winter. For centuries, several nations harvested cod while they were in the shallower inshore waters,

first with hook and line and later with nets that eventually evolved into the highly effective Newfoundland cod trap. The deep waters, both inshore and offshore, remained refugia until the 1950s when longliners and bottom trawlers joined the fishery. European bottom trawlers initially exploited the outerbanks cod in summer and autumn but eventually extended the fishing to winter and early spring when the cod were highly aggregated. At the same time as offshore cod landings increased dramatically, the longliners fishing deep inshore waters introduced synthetic gillnets to the fishery.

The number and individual size of the fish declined through the 1960s and 1970s. Fishing effort by the expanding Canadian trawler fleet increased dramatically following Canada's extension of jurisdiction to 200 miles in 1977. The total allowable catch doubled between 1978 and 1984 due to an overestimation of stock size during this period. The stock was finally closed to Canadian fishing in July 1992 due to its decline (Lilly et al. 2001).

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') (Rose 1993). Ollerhead et al. (2004) indicated that between 1998 and 2002, the largest number of spawning cod along the northeast shelf edge of the Grand Banks occurred in June. Data from 1972 to 1997 indicated the highest number of spawning fish on the northeast shelf edge in April to June, peaking in May (Ollerhead et al. 2004).

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.

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 28,000 mt 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).

The most recent assessment of the status of the northern (2J3KL) cod stock was conducted in February 2003. The 2003 research bottom-trawl surveys during both spring and fall indicated that the biomass of cod in the offshore remains extremely low (1% of the average during the 1980s) (DFO 2004c).

At approximately 49-50°N on the outer shelf and upper slope is where the last substantial offshore concentrations of cod were seen as the stock collapsed. This is also one of few offshore areas where a very modest increase in cod density has been seen in recent years. In addition, a substantial portion of the cod stock used to overwinter on the northeastern slope of Grand Bank and the Nose of the Bank

prior to the collapse of the stock. There have not been any recent winter surveys in these areas so occurring cod concentrations are unknown. Nonetheless, these could be critical areas in the recovery of the offshore northern cod. Most cod are found shallower than the 900-m depth (G. Lilly, DFO, pers. comm.). Kulka et al. (2003) mapped the distributions of Atlantic cod on the Grand Banks based on spring and fall DFO research survey data collected between 1972 and 2002.

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. The FRCC recommended that these areas be protected from all forms of commercial fishery (except snow crab trapping) and other invasive activity such as seismic exploration ([www.frcc-ccrh.ca](http://www.frcc-ccrh.ca)).

#### **5.4.4. Fish and Invertebrate Spawning**

Ollerhead et al. (2004) mapped the spawning times and locations for ten commercially important fish and invertebrate species found on the Grand Banks. Mapping was based on data collected on DFO research surveys between 1965 and 2003. Of the species profiles above, Ollerhead et al. (2004) identified spawning within the Project Area by Atlantic cod (April to June with peak in May) and northern shrimp which mate and extrude during summer/early fall. Other species identified as spawners in the Project Area include American plaice (May and June), redfish (June) and witch flounder (May and August)). Redfish spawning within the Project Area were very minimal and located in the extreme northeast. Given the high occurrence of snow crab within portions of the Project Area, it is logical to speculate that this crab species also spawns within the Project Area, likely in spring/early summer.

#### **5.4.5. Sensitive/Special Areas**

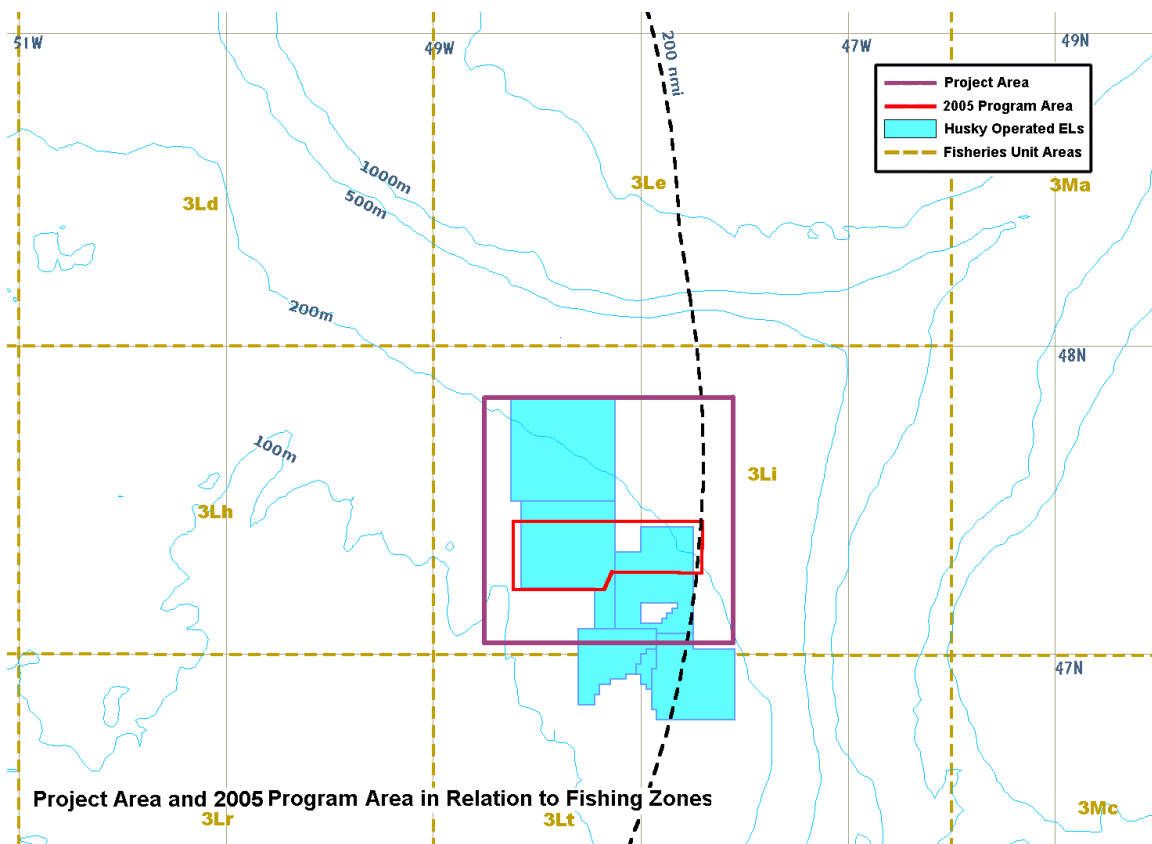
Although there are probably important feeding areas for fish, seabirds, sea turtles and marine mammals, particularly in localized upwelling areas that may be associated with slopes, there are no designated marine protected areas (MPAs) in, or immediately adjacent to, the Project Area. Special/sensitive areas are discussed further in the following relevant sections.

In April 2003, R.G. Thibault, then 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 (“cod box”) within the Bonavista Corridor that will be closed to otter trawling ([www.dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca)). This cod box is about 149 km north of the Project Area and about 189 km north of the proposed 2005 seismic survey area.

## 5.5. Commercial Fisheries

This section describes the anticipated commercial fisheries in the general area of the proposed survey, focusing on the Project Area and on the 2005 Survey Area in particular. Section 6.7 describes mitigations related to the fisheries, and Section 5.4 of this EA describes the biological characteristics and status of the main commercial and other marine species.

The Project Area is within North Atlantic Fisheries Organization (NAFO) management Division 3L, and wholly within Unit Area 3Li, a sub unit of the Division (Figure 5.1). Although a portion of the Project area (~15%) falls east of Canada's 200-mile EEZ, the 2005 Program Area is almost entirely within this Zone. Thus, while some foreign fishing might be encountered outside 200 miles in the eastern Project Area, the Survey Area fisheries would be expected to be primarily domestic.



**Figure 5.1 Project Area and 2005 Survey Area in Relation to Fisheries Management Areas and the 200-Mile EEZ.**

### 5.5.1. Data Sources

The fisheries analysis in this section is based in part on data derived from the Department of Fisheries and Ocean's (DFO) Newfoundland Region (Newfoundland and Labrador) and Maritimes Region (Nova



Scotia) catch and effort datasets (DFO 1985-2004).<sup>1</sup> Maritimes Region data are included because a small portion of the harvest (mainly shrimp) in 3L is landed by Nova Scotia-based vessels. Foreign catches landed outside these areas are not included in these data.

DFO Datasets for 1985 to 2004 are used for the historical overview, while the detailed analysis of fishing activity in the Project area focuses on DFO data in recent years, primarily for 2002 - 2004, since fishing activities in the area have changed significantly in the last decade.<sup>2</sup> For the overview, datasets (1992 – 2001) from the Northwest Atlantic Fisheries Organization (NAFO) are used to quantify 3L shrimp harvesting by foreign and domestic fishers. Shrimp is the principal Project Area species, and is managed in conjunction with NAFO. The NAFO datasets capture harvest by Canadian fishers and non-Canadian NAFO states.

Because the catch data in this area are georeferenced, past harvesting locations can be plotted in relation to the Project Area and the 2005 Survey Area, shown in the accompanying fisheries maps. The data used in the report represent all catch landed within DFO Maritimes Region and for all Newfoundland and Labrador landed catch.

The location given in the datasets is that recorded in the vessel's fishing log, and is reported in the database by degree and minute of latitude and longitude; thus the position is accurate within approximately .5 nautical mile of the reported co-ordinates. It should be noted that for some gear, such as mobile gear towed over an extensive area, or for extended gear, such as longlines, the reference point does not represent the full distribution of the gear or activity on the water. However, over many data entries, the reported locations create a fairly accurate indication of where such fishing activities occur and these kinds of database locations have been groundtruthed by Canning & Pitt Inc. with fishers in Nova Scotia, Newfoundland and Labrador and elsewhere over many years.

Fisheries consultations and contacts for this assessment included representatives of relevant agencies, industry representatives and other interest groups. The consultations were undertaken to inform stakeholders about the survey, to gather information about 2005 fishing activities, and to determine any issues or concerns.

Those consulted are listed in Appendix I. Fisheries-related information provided is reported under the discussions of the commercial fisheries below, and the issues raised during the consultations are discussed in Section 6.1.1.

Other sources consulted for this section include fisheries management plans, quota reports and other DFO documents. These are listed in Appendix I.

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<sup>1</sup> The DFO data used in the report represent all catch landed within DFO Maritimes Region and for all Newfoundland and Labrador landed catch. Foreign catches landed outside these areas are not included in the DFO data sets, but most are captured in the NAFO data.

<sup>2</sup> The data for all three years are still classified by DFO as preliminary, though the species data used in this report are not likely to change to any significant extent when the data are finalized. The most recent Maritimes Region data were accessed in January 2005 the most recent Newfoundland Region data in February 2005.

## 5.5.2. Regional and Historical Overview

Until the early 1990s, the fisheries in Unit Area 3Li were dominated by groundfish harvesting by stern otter trawls. Primarily Atlantic cod as well as American plaice and a few other species were harvested. In 1992, with the acknowledgement of the collapse of several groundfish stocks, a harvesting moratorium was declared and directed fisheries for cod virtually vanished in this area. Today, SARA lists the Atlantic cod (Newfoundland and Labrador population) as a species of special concern under Schedule 3. Since the collapse of the groundfish fisheries in the area, formerly underutilized species – mainly northern shrimp and snow crab – have come to replace them as the principal harvest in eastern 3L, as they have in many other areas. Figure 5.2 indicates these changes in harvesting in 3Li over the last two decades.

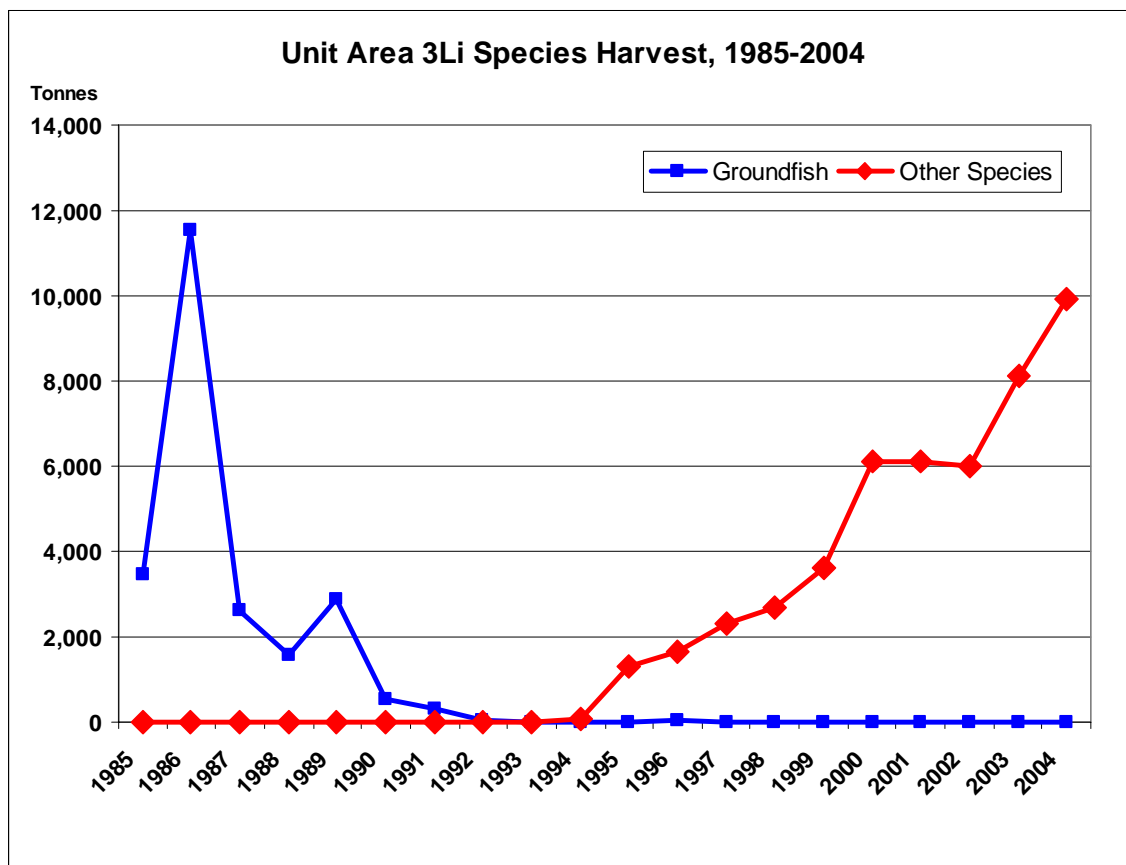
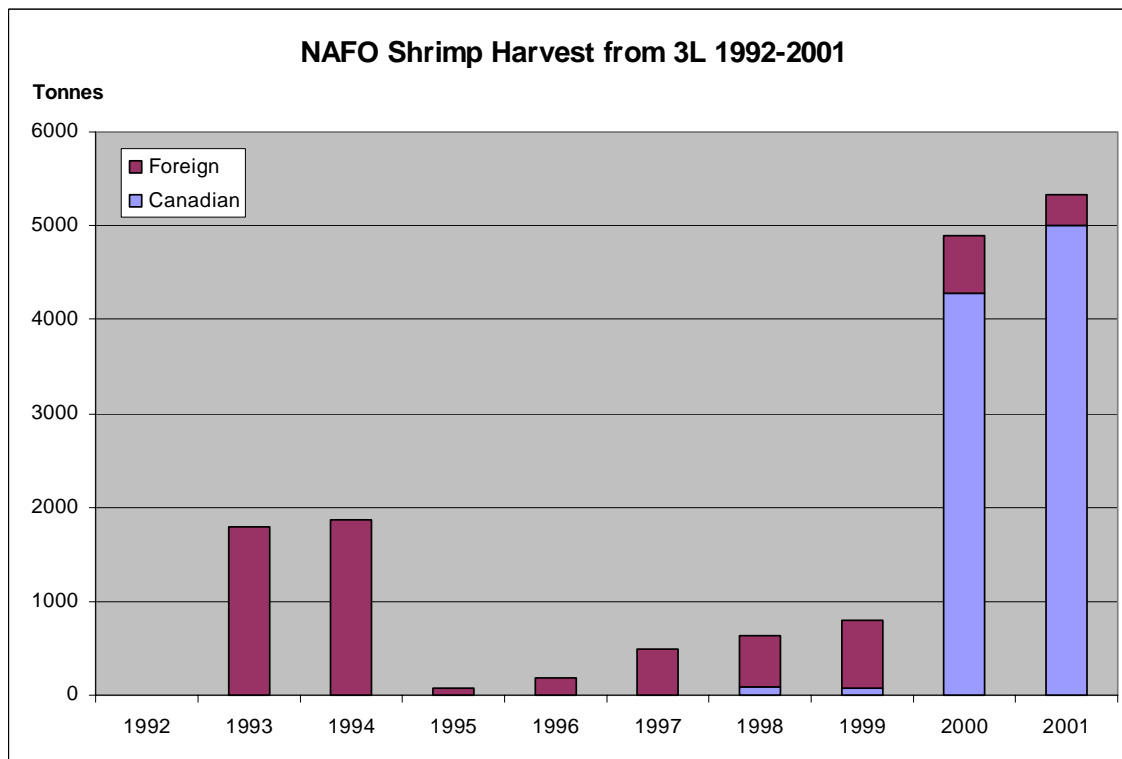


Figure 5.2. Groundfish and Other Species Harvesting in 3Li, 1985 – 2004.

The harvest for shrimp for the period 1992-2001, foreign and domestic, is presented in Figure 5.3, based on NAFO data.



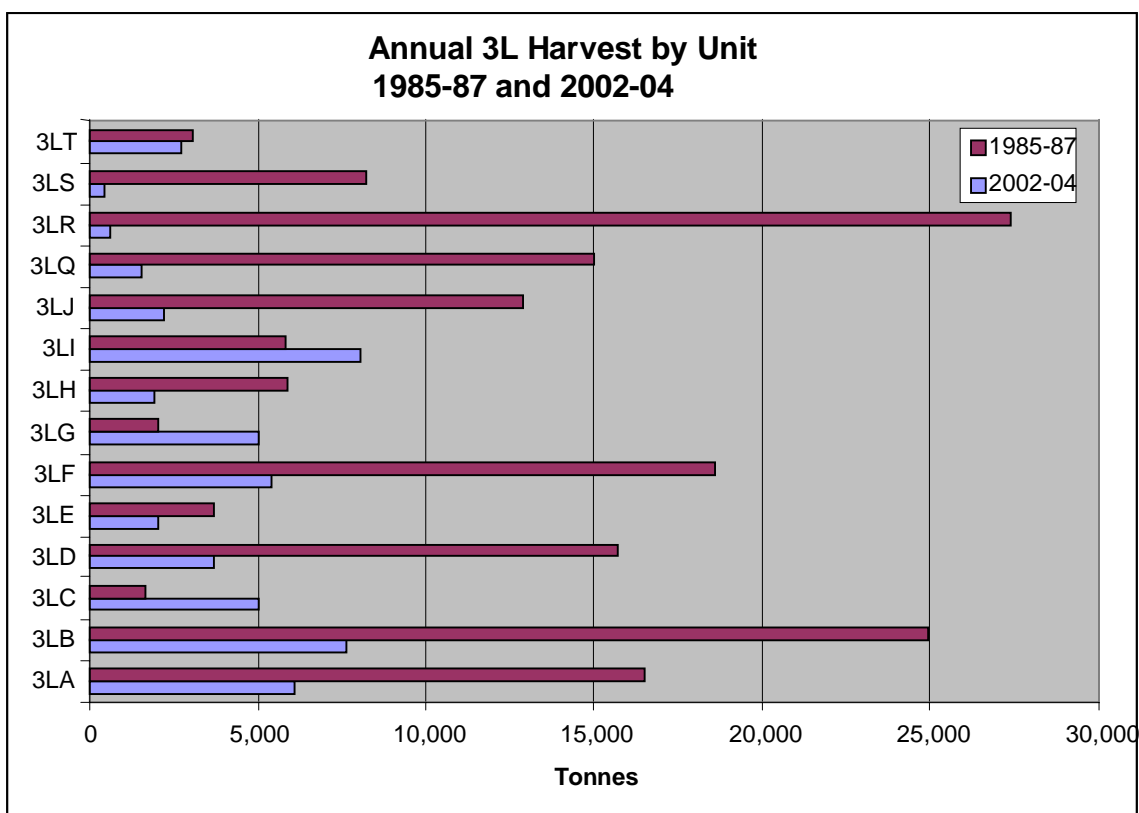
**Figure 5.3. 3L Shrimp Harvest, 1992-2001, Foreign and Domestic.**

Historically, Unit Area 3Li was not one of the more important areas (based on total landings) within Division 3L, but since the groundfish closures it has become quite important because of its snow crab and shrimp resources. See Figure 5.4.

### 5.5.3. Project Area and 2005 Survey Area Fisheries

Table 5.1 and Table 5.2 show the quantity of the harvest recorded within the Project Area and the 2005 Survey Area during 2002 - 2004. The final shows the percent of the total harvest that the species represented that year, for the proposed 2005 survey window (June - October).

Commercial fisheries in the Project Area are almost exclusively for northern shrimp and snow crab (Tables 5.1 and 5.2). These two species made up >99% of the domestic harvest in the area over the past three years during the survey window.



**Figure 5.4 Annual 3L Harvest, Representative Years, Before and After Moratorium.**

**Table 5.1. Harvest by Species, Project Area, June-October, 2002-2004.**

Species	Quantity (tonnes)	% of Total
2002		
Plaice	0.1	0.0%
Shrimp	353.4	39.5%
Snow Crab	542.2	60.5%
Total	895.7	100.0%
2003		
Plaice	0.2	0.0%
Shrimp	2,161.0	73.9%
Snow Crab	761.5	26.1%
Total	2,922.7	100.0%
2004		
Shrimp	2,445.7	74.2%
Snow Crab	852.5	25.8%
Total	3,298.2	100.0%

**Table 5.2. Harvest by Species, 2005 Survey Area, June-October, 2002-2004.**

Year	Species	Quantity (tonnes)
2002	Snow Crab	119.7
2003	Snow Crab	188.6
2004	Snow Crab	248.2

Within the 2005 Survey Area during the 2002-2004 period, the catch has been entirely snow crab, but the harvest in this area represents a small subset of the Project Area harvest, i.e. less than 8% during the last 3 years.

Shrimp catches within the Project Area between 2002 and 2004 occurred primarily in its northeastern region. Reported Greenland halibut catches within the Project area during the 2002-2004 period were few and scattered.

The snow crab fisheries use fixed gear crab pots, while the shrimp harvesters in this area use mobile shrimp trawls. These are described below. Because shrimp trawls are towed behind the fishing vessel, they pose less risk of conflict since the activity can be more easily observed at sea, while fixed gear must be located, identified and carefully avoided by the survey vessel and its survey equipment.

Further information on the snow crab and shrimp fisheries, including seasonality and the gears employed are provided in following sections.

#### **5.5.3.1. Harvesting Locations**

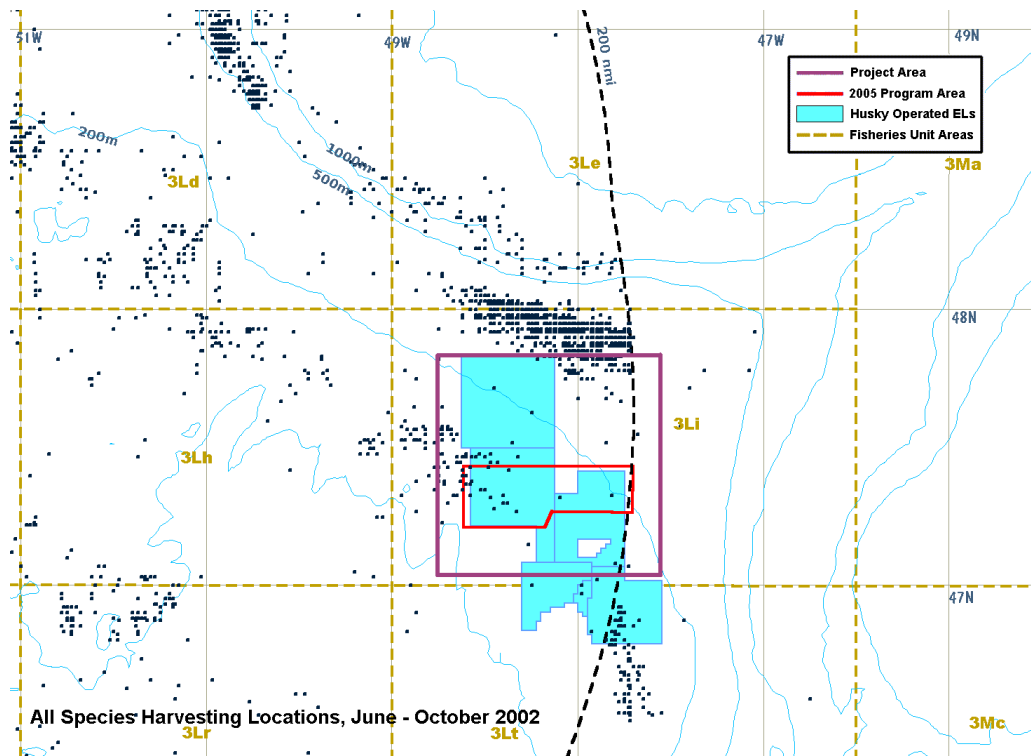
Figures 5.5 to 5.7 indicate domestic fishing locations in relation to the Project Area and 2005 Survey Area for June to October (aggregated) for 2002, 2003 and 2004. As these maps indicate, most of the domestic fish harvesting in the general area of the project is concentrated between the 100 m and 200 m contours of the eastern Grand Bank, both inside and outside the 200-mile EEZ (mainly snow crab), and in depths between 200 m and 1,000 m (shrimp).

They also illustrate that the harvesting locations tend to be generally consistent from year to year.

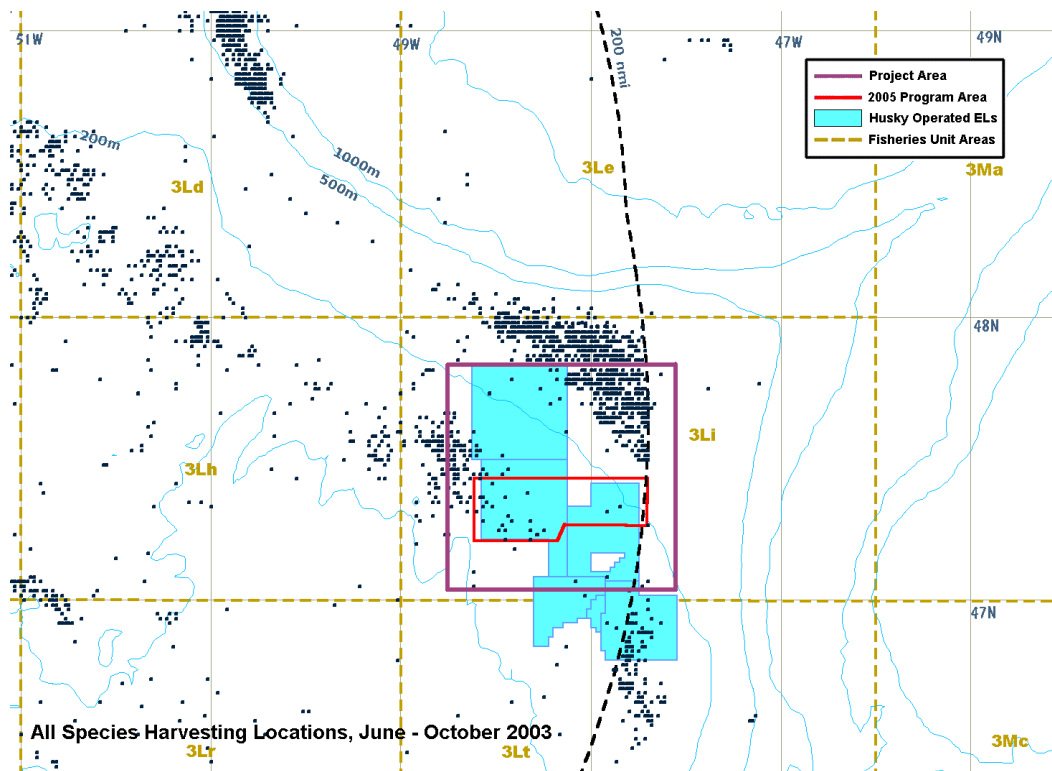
#### **5.5.3.2. Seasonal Distribution**

Harvesting times may change, depending on seasons and regulations set by DFO, the harvesting strategies of fishing enterprises, or on the availability of the resource itself. Figures 5.8 and 5.9 show the 2002 - 2004 catch by month in the Project Area and the 2005 Survey Area, respectively.

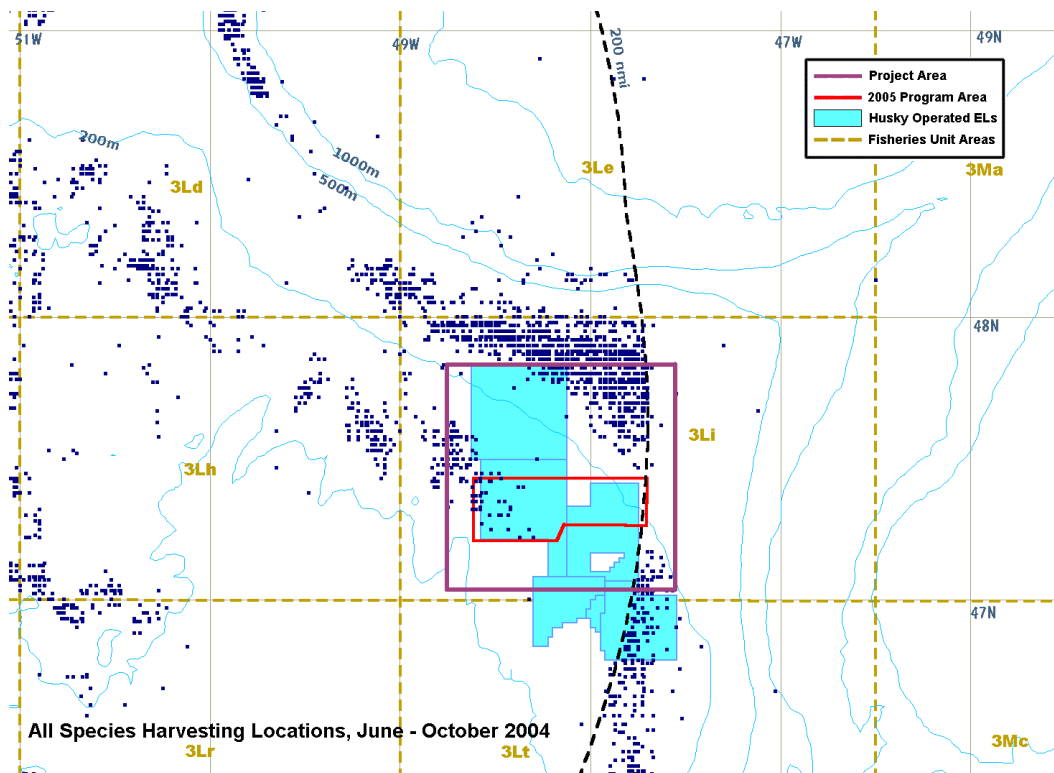
As the graphs indicate, the spring and summer months were generally the most productive, in terms of quantity of harvest, during the three-year period in both areas, though the 2005 Survey Area harvest was much more focused in May and June.



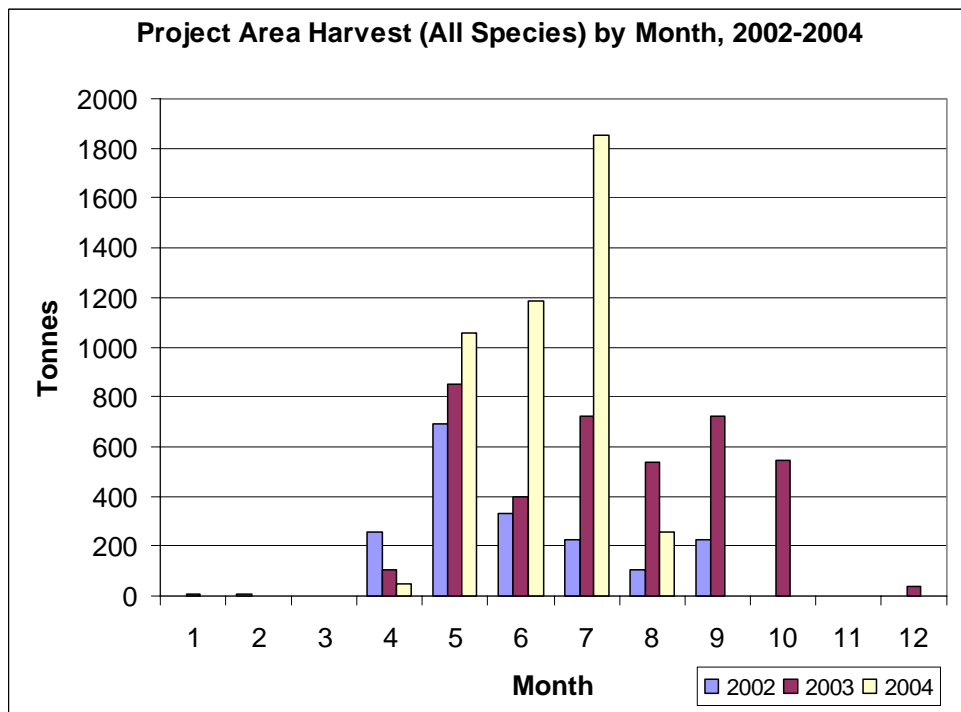
**Figure 5.5 All Species Harvesting Locations, June - October 2002.**



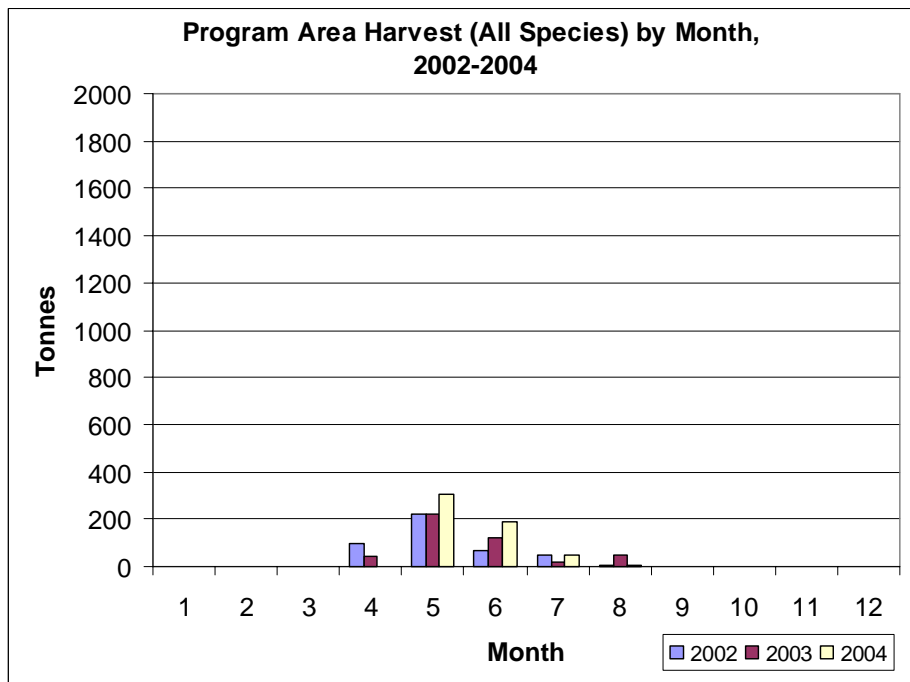
**Figure 5.6. All Species Harvesting Locations, June-October 2003.**



**Figure 5.7. All Species Harvesting Locations, June - October 2004.**

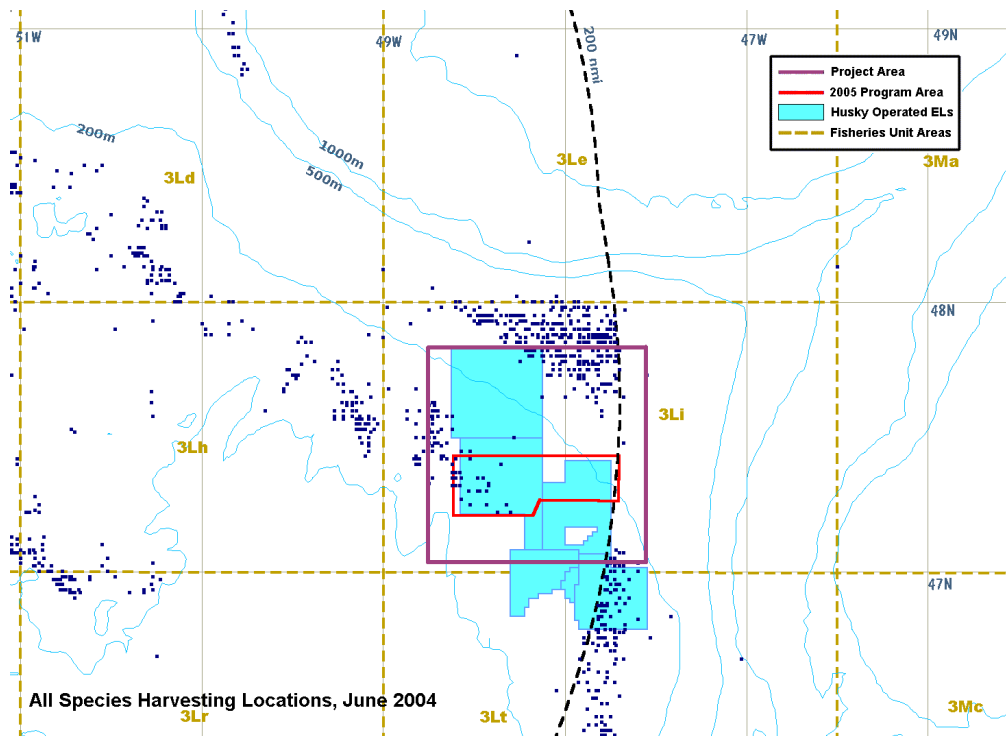


**Figure 5.8. Project Area Harvest by Month, All Species, 2002-2004.**



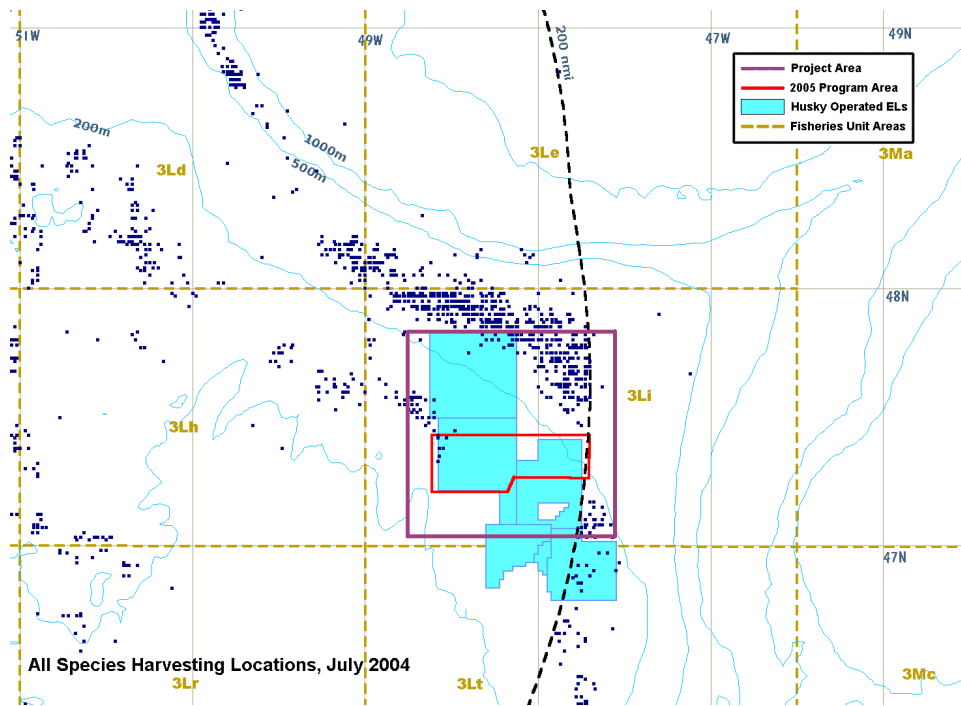
**Figure 5.9. Program Area Harvest by Month, All Species, 2002-2004.**

The following maps (Figures 5.10 to 5.14) show the reported domestic harvesting locations of all species combined, by month for June to October 2004, in relation to the Project Area and 2005 Survey Area.

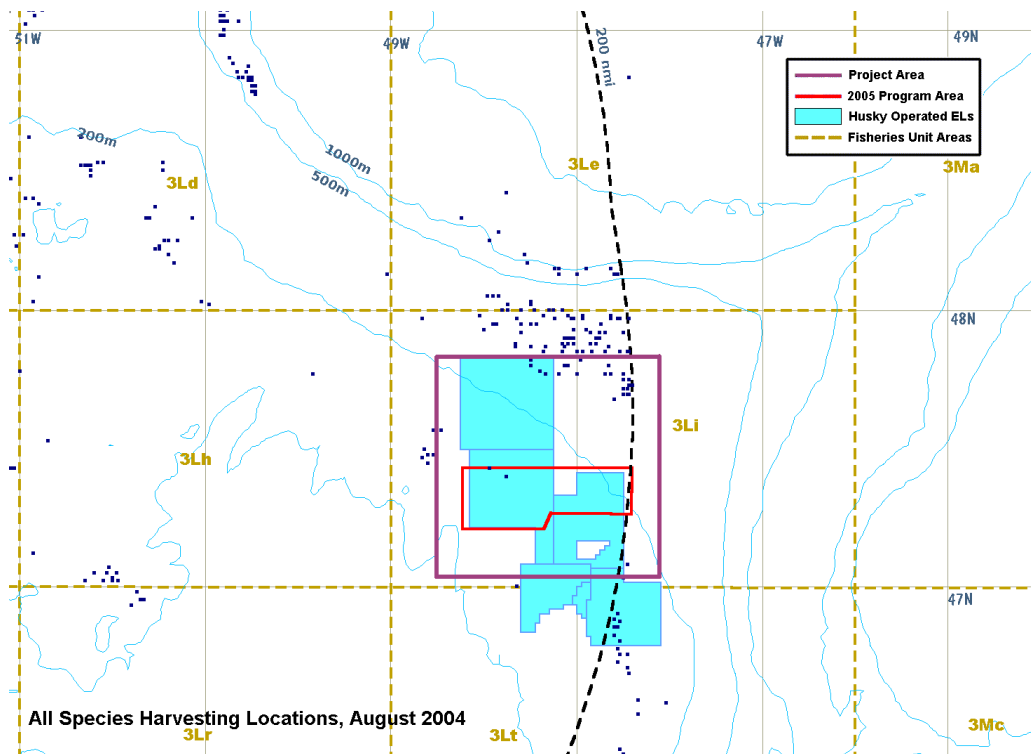


**Figure 5.10. Harvesting Locations, June 2004.**

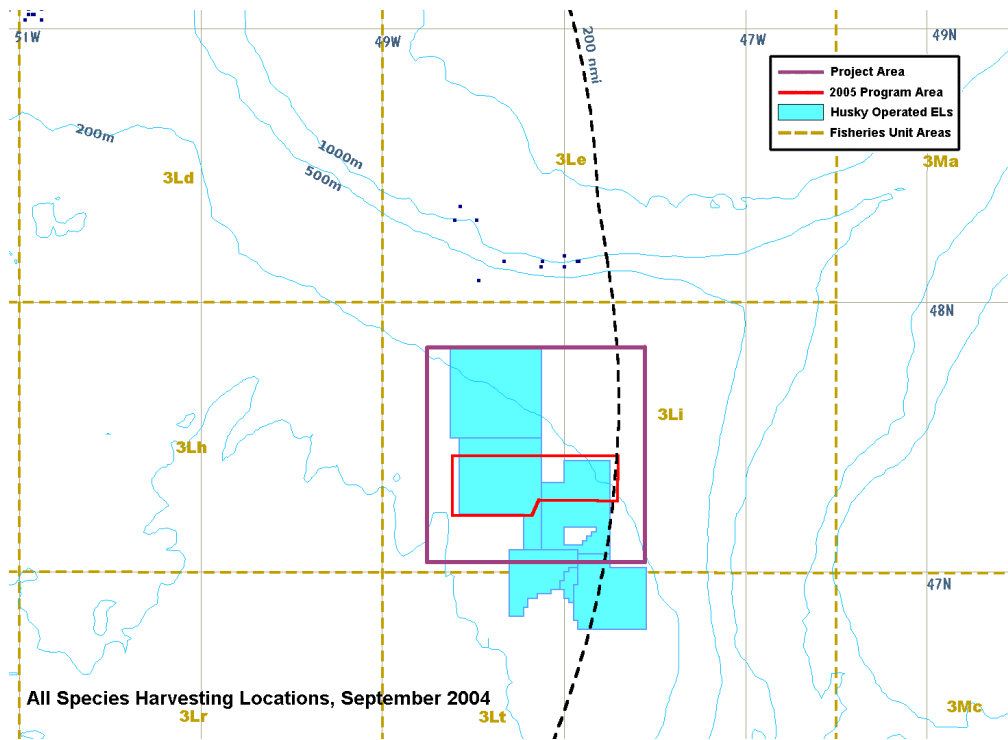




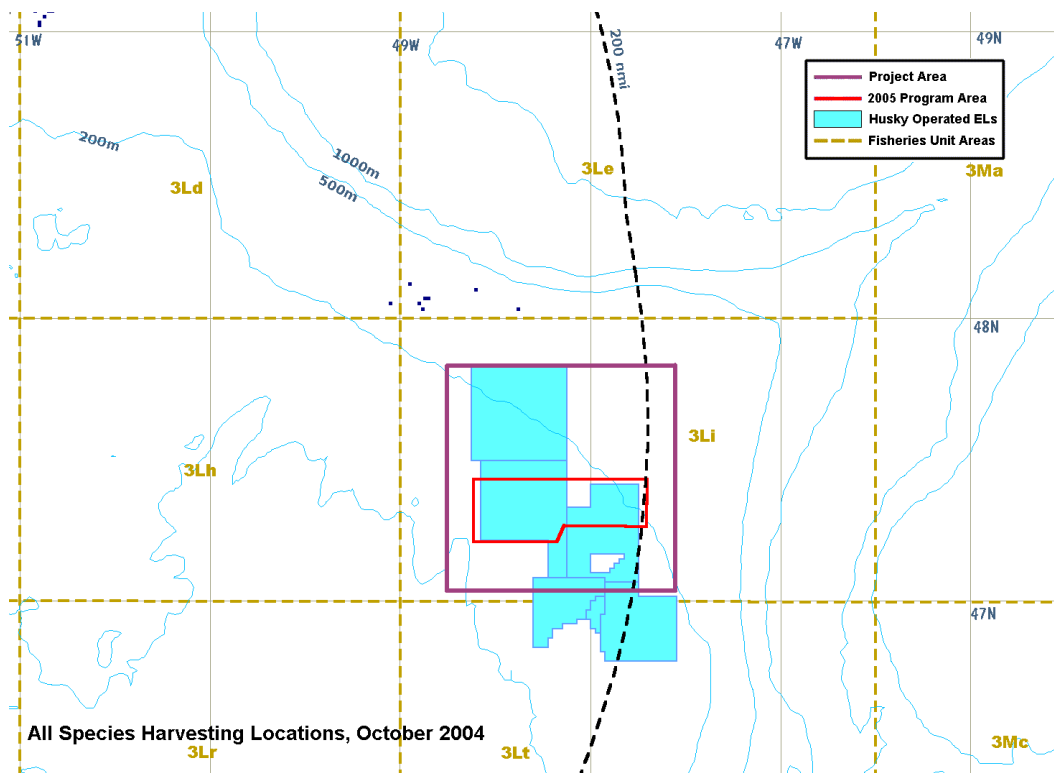
**Figure 5.11. Harvesting Locations, July 2004.**



**Figure 5.12. Harvesting Locations, August 2003.**



**Figure 5.13. Harvesting Locations, September 2003.**



**Figure 5.14. Harvesting Locations, October 2003.**

## 5.5.4. Principal Species Fisheries

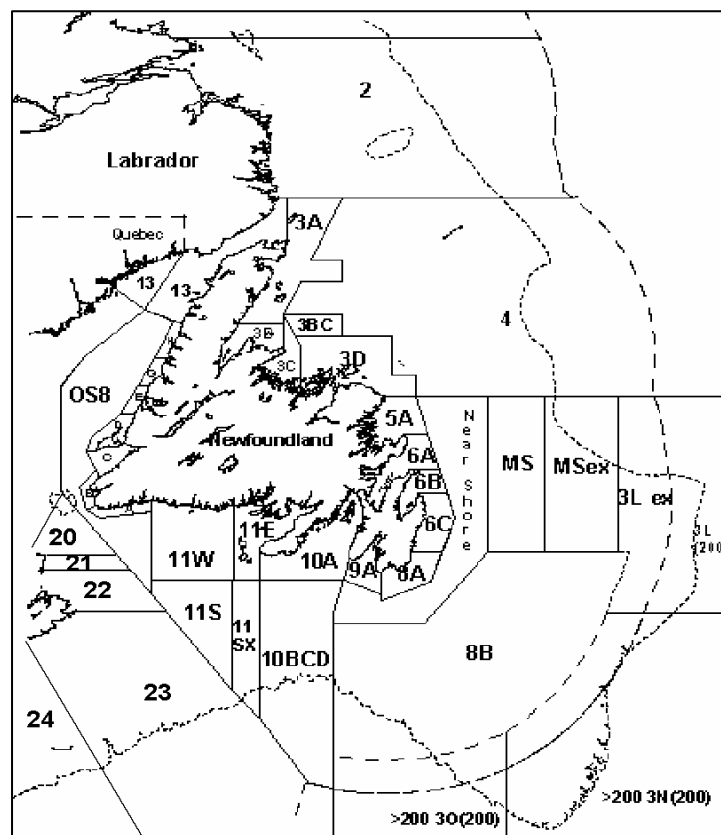
As indicated in the preceding tables, the catch within the Project Area during recent years is almost exclusively comprised of snow crab and shrimp. This is the case year round, as well as within the 2005 survey window. This section describes these two fisheries and expected 2005 activities.

In general, fisheries participants and DFO managers consulted confirm that they expect the main 2005 fisheries in the project Area will be similar to those of the past year or so, and do not expect any major changes in fishing patterns or new fisheries in the area.

### 5.5.4.1. Snow Crab

Snow crab was one of the two principal catches in the Project Area and the only species recorded during the June – October period for 2002 – 2004. As Figure 5.15 shows, the Project Area overlaps crab fishing areas 3Lex (from 170 miles to 200 miles) and 3L200 (beyond 200 miles). Quotas for these areas have not yet been set for 2005, but the 2004 quotas for these areas are shown in Table 5.3.

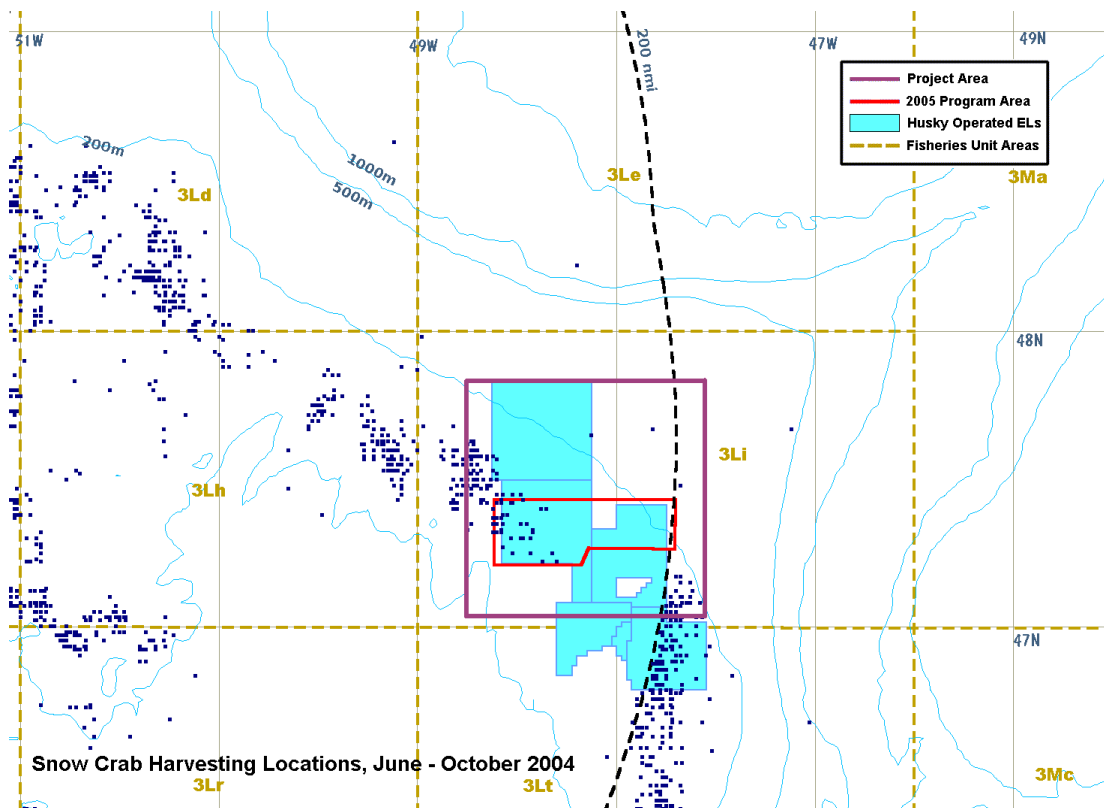
Figure 5.16 shows 2004 harvesting locations during June-October.



**Figure 5.15. Newfoundland Snow Crab Fishing Area.**

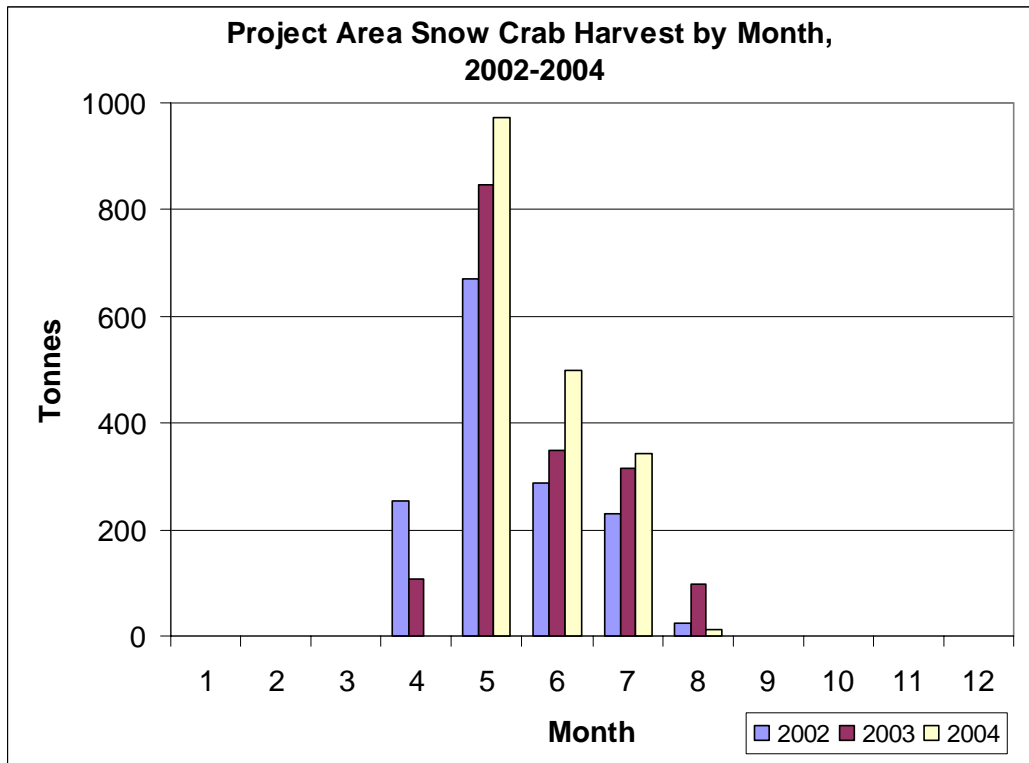
**Table 5.3. 3Lex and 3L200 Snow Crab Quotas, 2004.**

Licence Category	Area	Quota (tonnes)
Full Time	3Lex	1,110
	3L200	950
Supplementary, Large	3Lex	1,585
	3L200	1,990
Total		5,635



**Figure 5.16. Snow Crab Harvesting Locations, June-October 2004.**

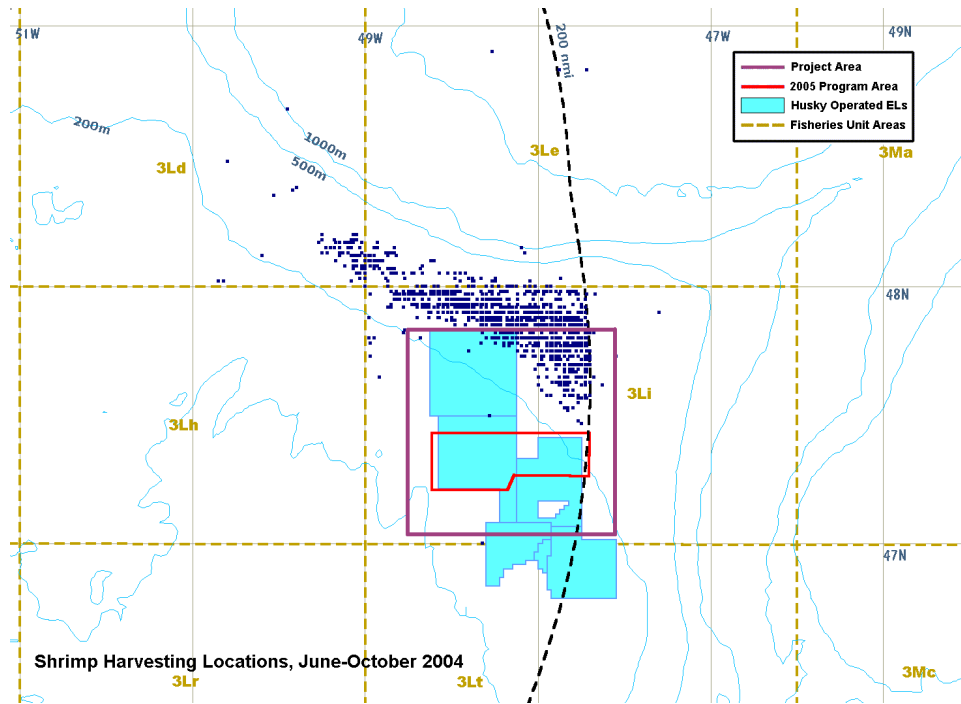
Figure 5.17 shows that the snow crab fishery in the Project Area for the last three years has occurred predominantly in the May - July period peaking in May all three years. This peak period falls outside the project timeframe for 2005. The snow crab harvest within the 2005 Survey Area is the same as that shown in Figure 5.9, since snow crab was the only species recorded as being harvested there.



**Figure 5.17. Snow Crab Harvest by Month.**

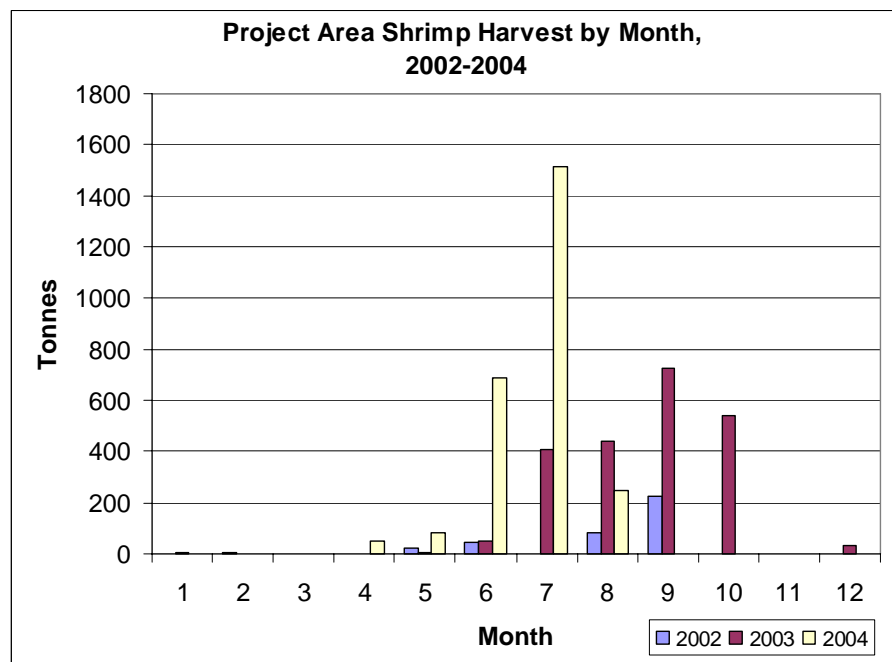
#### **5.5.4.2. Northern Shrimp**

Although there was no shrimp harvested within the 2005 Survey Area in 2002-2004, it was the most significant species harvested within the Project Area, in terms of quantity of harvest. Figure 5.18 shows 2004 domestic harvesting locations for the June-October period. As this map illustrates, this fishery is quite concentrated in a defined zone in the Project Area's northeast quadrant.

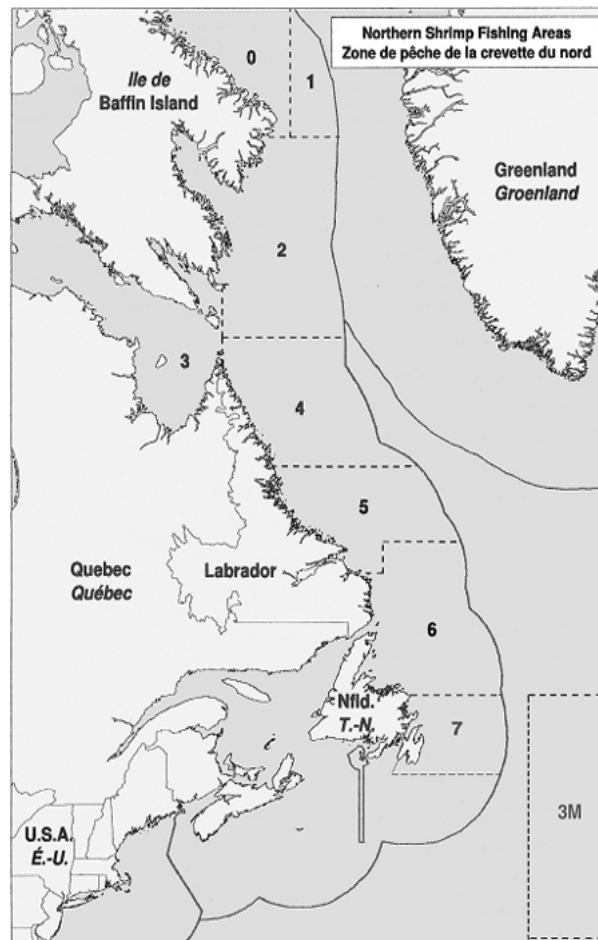


**Figure 5.18 Domestic Shrimp Harvesting Locations, June-October 2004**

Figure 5.19 shows the Project Area shrimp harvest by month for 2002 – 2004. As Figure 5.20 indicates, the Project Area is within Shrimp Fishing Area (SFA) 7. Table 5.4 shows the 2004 quotas for relevant areas, as the 2005 quotas have not yet been set.



**Figure 5.19. Shrimp Harvest by Month.**



**Figure 5.20. Northern Shrimp Fishing Areas.**

**Table 5.4. SFA 6 Shrimp quotas.**

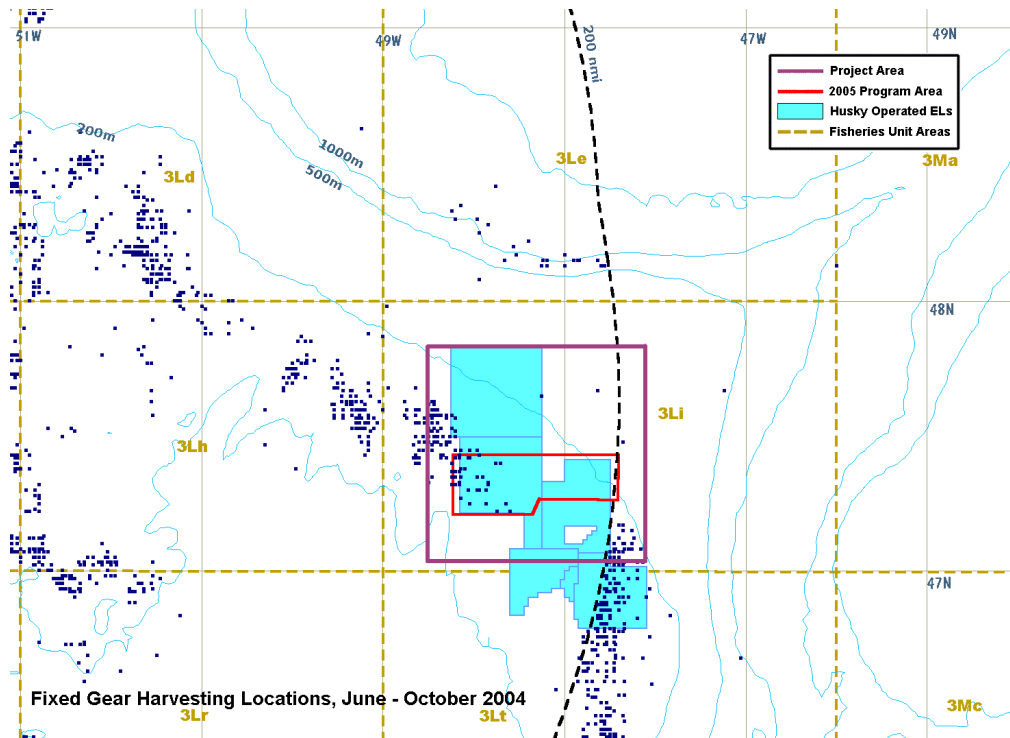
Licence Category	Quota (tonnes)
Offshore >100'	3,517
3L Fishers <65'	5,566
3K Fishers South of 50 30N, <65'	1,000
Total	10,083

### 5.5.5. Fishing Gear

Fisheries within the Project Area are conducted using both fixed (crab pots for shrimp) and mobile gear (shrimp trawls for northern shrimp). In general, fixed gear poses a much greater potential for conflicts with towed survey gear since it is often hard to detect when there is no fishing vessel near by, and it may

be set out over long distances in the water. Because mobile fishing gears are towed behind a vessel, they pose less risk of conflict because the activity can be more easily observed and located on the water. Survey ships and the fishing vessels can communicate with each other and exchange information about their operating areas and activities.

The following map (Figure 5.21) shows the location of fixed gear fishing in 2004 during the June - October period.



**Figure 5.21. Fixed Gear Locations 2004.**

#### **5.5.5.1. Crab Pots**

Because it is a fixed gear, crab pots pose a significant potential for conflict if the survey vessel encounters them. The amount of gear fishers are permitted to use varies by licence category, and also by the area in which a licence holder may be fishing.

Crab pots are set on the seabed in strings buoyed at the surface. Crab gear generally has a highflyer (radar reflector) at one end and a large buoy at the other. Some fishers use highflyers at both ends. Depending on weather, they may be left unattended for several days at a time.

Fishers typically try to leave about 20 fathoms (120 feet) on the seabed between each pot. Thus, allowing slack for the anchor ropes on either end of the string to extend upwards at an angle, the distance between the typical highflyer and end-buoy of, for example, a 50-60 pot string of crab gear would be 6,000 feet to 7,500 feet, or approximately 1.8 km to 2.3 km.



### 5.5.5.2. Shrimp Trawls

The traditional shrimp gear in Newfoundland and Labrador is shrimp trawl, a modified stern otter trawl, for both inshore and offshore vessels, though some use beam trawls. Fishers are licenced to fish only one gear type (DFO 2003b).

Since 1997, it has been mandatory to use a device called a Nordmore grate in shrimp trawls to reduce by-catch of other species. The Nordmore grate is now required in shrimp trawls in all SFAs at all times (DFO 2003b).

Consultations with the Canadian Association of Prawn Producers have indicated that, for the larger ships off Newfoundland and Labrador, tows are typically about 3 hours at speeds of 3-4 kts, but the length of the tow will depend on the rate of the on-board processing plant. In general, the aim is to catch just enough at a time to keep the ship's factory supplied.

### 5.5.6. DFO Science Surveys

Consultations with DFO indicate that there is some potential for overlap with DFO research vessel (RV) surveys during their 3L surveys. Although the 2005 schedule has not yet been finalized, it is expected to be similar to the 2004 schedule, provided below in Table 5.5 (B. McCallum, pers. comm. February 2005).

As has been agreed for past surveys, DFO and the survey operators will exchange locational information as was done successfully in past surveys. Specifically, the exact planned RV survey locations have been supplied and plotted by the survey ship, and the locations of planned locations and vessel positions were provided to DFO. A temporal and spatial separation plan was then agreed upon with DFO and implemented by the seismic vessel to ensure no overlap and an adequate "quiet time" before the RV came to the location.

**Table 5.5. Newfoundland and Labrador DFO Science Survey Schedule (2004).**

Survey	Approx. Location (NAFO Division)	Approx. Timing	Lead Scientist
Multispecies survey	3Ps	Apr 4 - May 3	B. Brodie
Multispecies survey*	3L, 3N, 3O	May 7 - Jun 27	B. Brodie
Groundfish RV survey	4R, 4S, 4T, 3Pn	Aug 1 - 30	D. Archambault
Multispecies survey*	2H, 2J, 3K, 3L, 3M, 3N, 3O	Sep 10 - Nov 28	B. Brodie
Multispecies survey*	Grand Banks	Oct 3 - Dec 12	B. Brodie

\* Potential overlap with Project Area

## 5.6. Seabirds

The highly productive Grand Banks supports large numbers seabirds at all seasons. Seabirds are not spread evenly over the ocean but tend to be concentrated over anomalies such as shelf edges and along currents. Here mixing in the water column creates a productive environment for zooplankton. The Project Area is located on the edge of the Grand Banks where it begins to slope into the deep waters beyond the continental shelf. A branch of the Labrador Current flows south along the shelf edge off eastern Newfoundland including the Grand Banks (see Figure 4.14). The combination of shelf edge and Labrador Current are prime conditions for productivity of zooplankton, which is the base of marine food chains.

The Grand Banks, and the edges, have been identified as areas rich in abundance and diversity of seabirds (Brown 1986; Lock et al. 1994). Table 5.6 lists the species and months of occurrence and abundance expected in the Project Area. Seabird observations from this area are few but significantly more than areas beyond the Continental Shelf (Lock et al. 1994). Most of the information available has been collected by the Canadian Wildlife Service (CWS) through PIROP (Programme intégré de recherches sur les oiseaux pélagiques). This data has been published for 1969-1983 (Brown 1986) and up to the early 1990s (Lock et al. 1994) and is summarized for eastern Newfoundland in Figure 5.22. Additional seabird observations have been collected on the northeast Grand Banks by the offshore oil and gas industry. These data have been analyzed for the period 1999-2002 (Ballie et al. 2005).

There is a pattern of increased bird numbers along the Continental Shelf edge on the northern and northeastern Grand Banks in the July to September period (Brown 1986; Lock et al. 1994) (Figure 5.22). During this period, birds are at their peak numbers on the Grand Banks. Data from other seasons are incomplete but the shelf edge is probably important during all seasons.

The enormous numbers of nesting seabirds on the Avalon Peninsula illustrates the richness of the Grand Banks for seabirds. The seabird breeding colonies on Baccalieu Island, the Witless Bay Islands and Cape St. Mary's are among the largest in Atlantic Canada. More than 4.6 million pairs nest at these three locations alone (Table 5.7 and Figure 5.23). This includes the largest Atlantic Canada colonies of Leach's Storm-Petrel (3,336,000 pair on Baccalieu Island), Black-legged Kittiwake (43,927 pair on Witless Bay Islands), Thick-billed Murre (1,000 pair at Cape St. Mary's) and Atlantic Puffin (216,000 pair Witless Bay Islands). All these birds feed on the Grand Banks during the nesting season May to September. In addition Funk Island, 150 km northwest of the Grand Banks supports the largest colony of Common Murre in Atlantic Canada. Many of these birds would reach the northern Grand Banks during the breeding season.

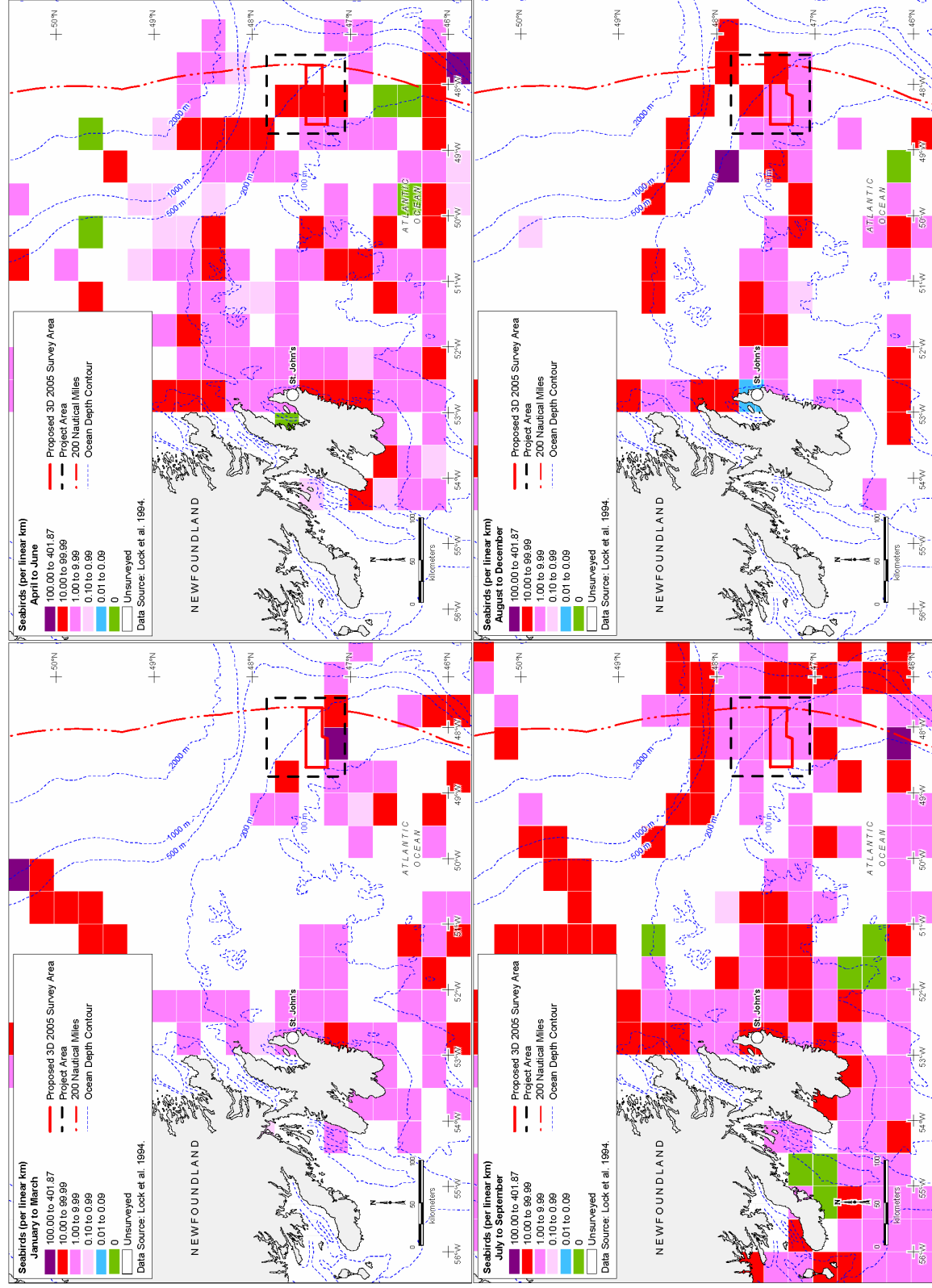
**Table 5.6. Species Occurring in Project Area and Monthly Abundance.**

Common Name	Scientific Name	Monthly Abundance											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b><i>Procellariidae</i></b>													
Northern Fulmar	<i>Fulmarus glacialis</i>	C	C	C	C	C	C	C	C	C	C	C	C
Cory's Shearwater	<i>Calonectris diomedea</i>							R	R	R			
Greater Shearwater	<i>Puffinus gravis</i>					C	C	C	C	C	C	U	
Sooty Shearwater	<b><i>Puffinus griseus</i></b>					S	U	U	U	U	U	S	
Manx Shearwater	<i>Puffinus puffinus</i>					S	S	S	S	S	S		
<b><i>Hydrobatidae</i></b>													
Wilson's Storm-Petrel	<i>Oceanites oceanicus</i>						S	S	S	S			
Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>			C	C	C	C	C	C	C	R		
<b><i>Sulidae</i></b>													
Northern Gannet	<i>Sula bassanus</i>			S	S	S	S	S	S	S			
<b><i>Phalaropodinae</i></b>													
Red Phalarope	<i>Phalaropus fulicaria</i>					S	S	S	S	S	S		
Red-necked Phalarope	<b><i>Phalaropus lobatus</i></b>					S	S	S	S	S			
<b><i>Laridae</i></b>													
Great Skua	<i>Catharacta skua</i>					R	R	R	R	R			
South Polar Skua	<i>Catharacta macconnicki</i>					R	R	R	R	R			
Pomarine Jaeger	<i>Stercorarius pomarinus</i>			S	S	S	S	S	S	S			
Parasitic Jaeger	<i>Stercorarius parasiticus</i>					S	S	S	S	S			
Long-tailed Jaeger	<i>Stercorarius longicaudus</i>					S	S	S	S	S			
Herring Gull	<i>Larus argentatus</i>	S	S	S	S	S	S	S	S	S	S	S	S
Iceland Gull	<i>Larus glaucoides</i>	R	R	R	R						R	R	R
Glaucous Gull	<i>Larus hyperboreus</i>	R	R	R	R						R	R	R
Great Black-backed Gull	<i>Larus marinus</i>	U	U	R	R	R	R	R	U	U	U	U	U
Ivory Gull	<i>Pagophila eburnea</i>		R	R									
Black-legged Kittiwake	<i>Rissa tridactyla</i>	C	C	C	C	C	S	S	S	C	C	C	C
Arctic Tern	<i>Sterna paradisaea</i>					S	S	S	S				
<b><i>Alcidae</i></b>													
Dovekie	<i>Alle alle</i>	U	U	U	U	R				U	U	U	U
Common Murre	<i>Uria aalge</i>	S	S	S	S	S	S	S	S	S	S	S	S
Thick-billed Murre	<i>Uria lomvia</i>	U	U	U	U	S				U	U	U	U
Razorbill	<i>Alca torda</i>				U	U	S	S	S	U	U	U	
Atlantic Puffin	<i>Fratercula arctica</i>				S	S	S	S	S	S	S	S	S

Source: Brown (1986); Lock et al. (1994).

C = Common, U = Uncommon, S = Scarce, R = Rare.

Shaded months indicate most likely time for seismic exploration.



**Figure 5.22 Geographic and Seasonal Distribution of Seabirds in Eastern Newfoundland.**  
 Source: Lock et al. (1994)

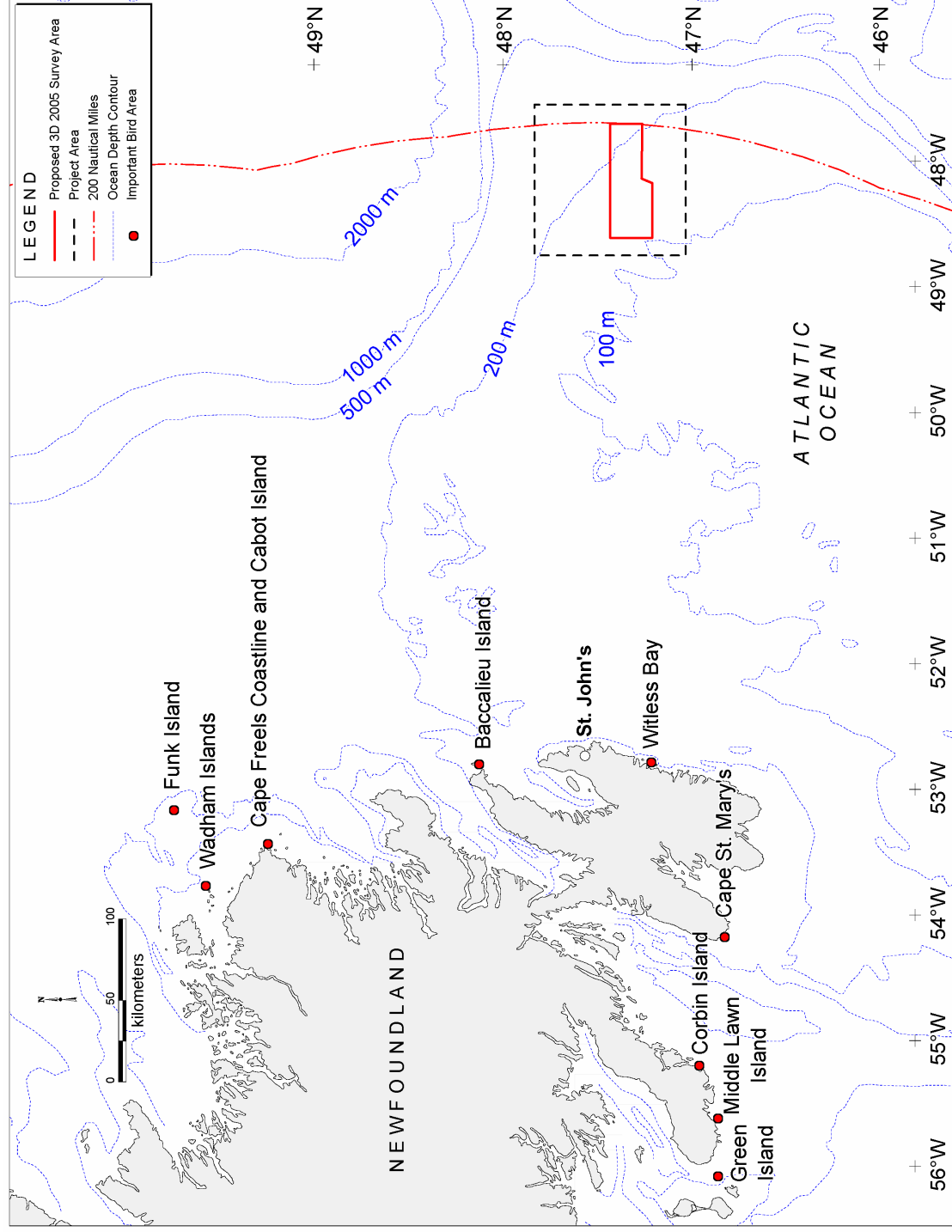
**Table 5.7. Number of Pairs of Seabirds Nesting at Important Bird Sites (IBA) in Eastern Newfoundland.**

Species	Wadham Islands	Funk Island	Cape Freels and Cabot Island	Baccalieu Island	Witless Bay Islands/Tors Cove	Cape St. Mary's	Middle Lawn Island	Corbin Island	Green Island
<i>Procellariidae</i>									
Northern Fulmar		13		20	21	U			
Manx Shearwater					?		100		
<i>Hydrobatidae</i>									
Leach's Storm-Petrel	10,000	?	250	3,336,000	870,020	?	26,313	100,000	72,000
<i>Sulidae</i>									
Northern Gannet		6,075		677	?	5,485			?
<i>Laridae</i>									
Herring Gull		500		U	4,150	U	20	5,000	
Great Black-backed Gull		100		U	163	U	6	25	
Black-legged Kittiwake		810		12,975	43,927	10,000		50	
Arctic and Common Terns	376		250						
<i>Alcidae</i>									
Common Murre		396,461	2,600	4,000	74,687	10,000			
Thick-billed Murre		250		181	600	1,000			
Razorbill	30	200	25	100	230	100			?
Black Guillemot	25	1		100	20+	U			
Atlantic Puffin	15,950	2,000	20	30,000	216,000				
<b>TOTALS</b>	<b>26,332</b>	<b>406,410</b>	<b>3,145</b>	<b>3,384,053</b>	<b>1,209,818</b>	<b>26,585</b>	<b>26,413</b>	<b>105,075</b>	<b>72,000</b>

Source: www.ibacanada.com

'?' indicates possibility of nesting activity

'U' indicates definite nesting activity but numbers of nesting pairs unknown



**Figure 5.23. Locations of Important Bird Areas (IBA) in Eastern Newfoundland Seabirds Containing Significant Seabird Breeding Colonies.**

There are nine seabird nesting sites on the southeast coast of Newfoundland from Cape Freels to the Burin Peninsula meeting the criteria for an Important Bird Area (IBA) (Figure 5.23, Table 5.7). A grand total of 5.2 million pairs of birds breed at these sites. The Project Area is well beyond the foraging range of breeding birds during the breeding season, approximately May to August. At Witless Bay Common Murres forage up to 200 km from the breeding site but usually only 50-100 km (Cairns et al. 1990, in Gaston and Jones 1998). However, during post breeding dispersal the Study Area is within range of all seabirds breeding in eastern Newfoundland and Labrador. In addition Grates Point, Mistaken Point and Placentia Bay qualify as IBAs because of significant wintering populations of Common Eider. An IBA is a site that provides essential habitat for one or more species of breeding or non-breeding birds.

In addition to local breeding birds there are many non-breeding seabirds on the Grand Banks during the summer months. Most of the world's population of Greater Shearwater is thought to migrate to the Grand Banks and eastern Newfoundland to moult and feed during our summer months after completion of nesting in the Southern Hemisphere. All species of seabirds require more than one year to become sexually mature. Many non-breeding sub-adult seabirds, especially Northern Fulmar and Black-legged Kittiwake, are present on the Grand Banks year-round.

Other seabirds (jaegers, terns and phalaropes) migrate north in spring and south in autumn over the Grand Banks between breeding sites in the low Arctic to wintering areas in the more southern latitudes. Large numbers of Arctic breeding Thick-billed Murre, Dovekie, Northern Fulmar and Black-legged Kittiwake migrate to eastern Newfoundland, including the Grand Banks, for the winter.

The only species of eastern offshore seabird that is listed on SARA is Ivory Gull. It is currently listed as a species of concern. It would likely be rare and less than annual occurrence in the Project Area.

### **5.6.1. Seasonal Abundance of Seabirds in the Project Area**

The world range and seasonal occurrence and abundance of seabirds in the Project Area are described. Table 5.6 summarizes the abundance status for each species monthly. Information was derived from Brown (1986), Lock et al. (1994) and Ballie et al. (2005).

#### **5.6.1.1. Procellariidae (fulmars and shearwaters)**

##### **5.6.1.1.1. Northern Fulmar**

Northern Fulmar breeds in the north Atlantic, north Pacific and Arctic Oceans. In Atlantic Ocean it winters south to North Carolina and southern Europe. It is common all year in ice-free waters off eastern Newfoundland (Brown 1986; Lock et al. 1994). Through band recoveries it is known that most individuals in Newfoundland water are from Arctic breeding colonies. Adults and sub-adult birds are present in the winter with sub-adults remaining through the summer. There are fewer than 100 pairs

breeding in eastern Newfoundland (Cairns et al. 1989). Found to be most numerous during spring and autumn on the northeast Grand Banks 1999-2002, based on observations from drill rigs (Ballie et al. 2005).

*Status in Project Area*

Common all year.

**5.6.1.1.2. Cory's Shearwater**

Cory's Shearwater is a subtropical species breeding in the eastern Atlantic Ocean on the Azores Island and Cape Verdes Islands, the Mediterranean and western Indian Ocean. In late summer small numbers reach the waters off southern Nova Scotia. A few occur in southern Newfoundland waters, including the Grand Banks. Cory's Shearwater was recorded from drill platforms on the northeast Grand Banks, but due to similarity in appearance to the abundant Greater Shearwater, the actual numbers observed remains unconfirmed (Ballie et al. 2005).

*Status in Project Area*

Rare, July to September

**5.6.1.1.3. Greater Shearwater**

The Greater Shearwater breeds on the Tristan de Cunha Islands in south Atlantic Ocean. Spends non-breeding season in north Atlantic. Greater Shearwater has a significant presence on the Grand Banks. A considerable portion of the entire population of about five million migrate from Southern Hemisphere breeding sites to feed and moult on the Grand Banks and eastern Newfoundland in June and July (Lock et al. 1994). After moulting birds remain in the area until early November. Greater Shearwater was the most numerous bird observed from drill platforms on the northeast Grand Banks 1999-2002 (Ballie et al. 2005). Numbers increased through the summer to a peak in September then decreased rapidly with stragglers into November. Median flock size was usually <50 but occasionally up to 1,200.

*Status in Project Area*

Common, May to early November.

**5.6.1.1.4. Sooty Shearwater**

Sooty Shearwater breeds in the south Atlantic and south Pacific Oceans. It spends most of the non-breeding season in Northern Hemisphere. Some Sooty Shearwaters follow the same migration pattern as Greater Shearwater by migrating north to Canadian waters in spring. Sooty Shearwater is usually outnumbered by Greater Shearwater in eastern Canada (Brown 1986). Numbers peaked at 2.5 birds/day at one drill platform on the northeast Grand Banks 2000 and 2001 (Ballie et al. 2005).



*Status in Project Area*

Uncommon, May to October.

**5.6.1.1.5. Manx Shearwater**

Manx Shearwater breeds in northeast Atlantic Ocean. It is uncommon in the northwest Atlantic. Manx Shearwater is a recent colonizer of North America. The only known established breeding colony in North America is at Middle Lawn Island off the Burin Peninsula, Newfoundland where <100 pairs breed (Cairns et al 1989). Other nest sites in Newfoundland have not been confirmed. Most observed in North American waters are probably non-breeding sub-adults and post-breeding birds from European breeding colonies. Manx Shearwater winters in middle latitudes of Atlantic Ocean. A total of 39 were observed on drill platforms on the northeast Grand Banks 1999-2002 (Ballie et al. 2005). This <0.1% of all the birds recorded.

*Status in Project Area*

Scarce, May to October.

**5.6.1.2. Hydrobatidae (storm-petrels)**

**5.6.1.2.1. Leach's Storm-Petrel**

Leach's Storm-Petrel breeds in the north Pacific and north Atlantic Oceans. It winters at the middle latitudes and south of equator in both oceans. It is an abundant breeder in eastern Newfoundland with more than four million pairs nesting on islands off the eastern Avalon Peninsula (Table 5.7). The largest breeding colony in the world is at Baccalieu Island on the northeast Avalon Peninsula, where over 3.3 million pairs nest (Lock et al. 1994). They range far from breeding colonies to feed. Many non-breeding sub-adults remain at sea through the breeding season. An average of <1 Leach's Storm-Petrel was recorded per day from the drill platforms on the northeast Grand Banks 1999-2002 (Ballie et al. 2005). The low number may have been a result of the height of observers off the water and the lack of persistent use of binoculars for scanning. Storm-petrels are difficult to see because they are dark and fly very low over the water.

*Status in Project Area*

Common, April to early November.

**5.6.1.2.2. Wilson's Storm-Petrel**

The Wilson's Storm-Petrel breeds in south Atlantic Ocean and Antarctic. In the non-breeding season (May to October) they migrate north to waters off southern Nova Scotia and Newfoundland. It is uncommon in Newfoundland waters June to September (Brown 1986).

*Status in Project Area*

Scarce, June to September.

**5.6.1.3. Sulidae (gannets)**

**5.6.1.3.1. Northern Gannet**

The Northern Gannet breeds in north Atlantic from Canada to Iceland and the British Isles. They winter at sea south of breeding range but north of the equator. About 12,000 pair nest on three colonies in the eastern Newfoundland (Table 5.7). Gannets are common near shore and scarce beyond 100 km from shore. The Project Area is farther off shore than the range of most Northern Gannets.

*Status in Project Area*

Scarce, April to October.

**5.6.1.4. Phalaropodinae (phalaropes)**

There are two species of phalaropes that occur at sea. They are the Red Phalarope and Red-necked Phalarope. Both breed in the Arctic to sub-Arctic of North America and Eurasia. They winter at sea mostly in the Southern Hemisphere. They migrate and feed offshore, including Newfoundland waters in spring and autumn migrations. The two phalaropes are often difficult to distinguish at sea. Red Phalarope usually outnumbers Red-necked Phalarope in Newfoundland waters (Brown 1986). Phalaropes seek out areas of upwelling and convergence where rich sources of zooplankton are found. They are locally common especially along the shelf edges off Newfoundland and Labrador.

*Status in Project Area*

Scarce, May to October.

**5.6.1.5. Laridae (skuas, jaegers, gulls and terns)**

**5.6.1.5.1. Great Skua and South Polar Skua**

The Great Skua breeds in the North Hemisphere in Iceland and northwestern Europe. The South Polar Skua breeds in the Southern Hemisphere and migrates to the Northern Hemisphere for the non-breeding season. Both species occur in Newfoundland waters May to October. Identifying skuas to species is very difficult at sea. Skuas are kleptoparasites usually occurring where other seabirds are numerous particularly along shelf edges. Generally skuas are quite scarce.

*Status in Project Area*

Scarce, May to October.

#### **5.6.1.5.2. Pomarine Jaeger, Parasitic Jaeger and Long-tailed Jaeger**

All three species of jaeger nest in the sub-Arctic to Arctic in North America and Eurasia. They winter at sea in the Pacific Ocean and Atlantic Ocean. Pomarine and Parasitic Jaegers winter mainly south of 35°N and Long-tailed Jaeger mainly south of the equator. The three species of jaeger are relatively easy to identify in adult plumage but very difficult in sub-adult plumages. As a group their habits are very similar so they are lumped here. Adults migrate through Newfoundland waters in spring and fall. Sub-adults often migrate only part way to the breeding grounds and are often present in Newfoundland waters all summer. Like skuas they are kleptoparasites preying chiefly on Black-legged Kittiwakes and Arctic Terns. Densities of jaegers, like most predators, are relatively low. Peak numbers occur during migration in May to early June and September to October.

##### *Status in Project Area*

Scarce, May to October.

#### **5.6.1.5.3. Herring, Great Black-backed, Iceland, and Glaucous Gull**

Herring Gull breeds in northern North America, Europe and northeast Russia. It winters in southern part of breeding range. Great Black-backed Gull is restricted to north Atlantic breeding and winters in coastal Canada and Europe. Iceland Gull breeds in northeast Canadian Arctic and Greenland and winters on open coastal waters south to New England States. Glaucous Gull breeds in sub-Arctic and Arctic in North America, Greenland and Eurasia and winters within breeding range and south. The large gulls are generally rare to scarce far from shore on the Grand Banks. The exception is Great Black-backed Gull.

On drill platforms on the northeast Grand Banks 1999-2002, Great Black-backed Gull was common September to February and nearly absent March to August (Ballie et al. 2005). Herring Gulls were present in consistent numbers throughout the year but in lower numbers than Great Black-backed Gulls.

##### *Status in Project Area*

Herring Gull, scarce throughout year.

Great Black-backed Gull, uncommon September to February and rare March to August.

Glaucous Gull, rare November to April.

Iceland Gull, rare November to April.

#### **5.6.1.5.4. Black-legged Kittiwake**

The Black-legged Kittiwake has a circumpolar breeding range. In Canada it breeds from the Arctic south to Nova Scotia. It winters at sea in northern Pacific Ocean and northern Atlantic Ocean. Black-legged Kittiwake is an abundant seabird off the Newfoundland coast. Breeding colonies on the Avalon Peninsula and north east coast of Newfoundland total 77,398 pairs (Cairns et al. 1989). Many of the four million pairs that breed in the North Atlantic Ocean spend some time off the east coast of

Newfoundland (Brown 1986; Lock et al. 1994). Black-legged Kittiwake is present in all months of the year on the Grand Banks. Observations from the drill platforms on the northeast Grand Banks 1999-2002 showed Black-legged Kittiwakes were present October to May but were most prevalent November to December (Ballie et al. 2005).

*Status in Project Area*

Common, October to May and scarce, June to September.

**5.6.1.5.5. Ivory Gull**

Ivory Gull breeds in high Arctic Canada, Greenland and northern Eurasian. It winters among the sea ice within breeding range and slightly farther south. Extends farthest south on the northwestern Atlantic.

Ivory Gull may occur in the small numbers in the Project Area when pack ice reaches the northern Grand Banks in late winter. The thirty-year median of ice concentration shows ice extending into the northern edge of the Grand Banks east to 48°W in late February to late March. More information on Ivory Gull can be found in the Species at Risk section.

Ivory Gull probably rarely reaches the Project Area. In unusually heavy ice years, ice may be more prevalent within the Project Area at which time a few Ivory Gulls could be present in February to April. A total of 21 Ivory Gulls reported from drill platforms on the northeast Grand Banks 1999-2002 seems too high and most were reported when there was no ice.

*Status in Project Area*

Rare, less than annual, January to March.

**5.6.1.5.6. Arctic Tern**

Arctic Tern breeds in sub-Arctic to Arctic of North America and Eurasian. In western Atlantic breeds south to Nova Scotia. It winters at sea in the Southern Hemisphere. Arctic Terns migrant at sea through Newfoundland and Labrador waters in spring and autumn.

*Status in Project Area*

Scarce, May to September.

**5.6.1.6. Alcidae (Dovekie, murre, Black Guillemot, Razorbill and Atlantic Puffin)**

**5.6.1.6.1. Dovekie**

Dovekie breeds in the North Atlantic mainly in Greenland and east Nova Zemlya, Jan Mayen and Franz Josef Land in northern Russia. It winters at sea south to 35°N. Dovekie is a very abundant bird with a world population estimated at 30 million (Brown 1986). A large percentage of the Greenland breeding

Dovekies winter in the western Atlantic, mainly off Newfoundland (Brown 1986). The low numbers of Dovekies observed from the drill platforms on the northeast Grand Banks 1999-2002 was attributed to the difficulty in seeing the small birds from the observation posts (Ballie et al. 2005).

*Status in Project Area*

Uncommon, October to April.

**5.6.1.6.2. Common Murre**

Common Murre breeds in north Pacific Ocean and north Atlantic Ocean. In the western Atlantic, it winters southern Newfoundland to Massachusetts. It is an abundant breeder in eastern Newfoundland with nearly half a million pairs, with 80% of those on Funk Island (Table 5.7). During breeding season the Project Area is probably too far from breeding sites to be used regularly for foraging. In the non-breeding season August to March, Common Murre are likely to be found on the northern Grand Banks. Due to low density and high difficulty in detecting murres at sea, surveys generally underestimate or miss them.

*Status in Project Area*

Scarce, throughout the year.

**5.6.1.6.3. Thick-billed Murre**

Thick-billed Murres breeds in sub-Arctic to Arctic in North America and Eurasia. In Atlantic Canada breeds as far south as Newfoundland. Winters in open water within breeding range and in western Atlantic south to New Jersey.

Thick-billed Murre is the winter murre in eastern Newfoundland. Many of the more than two million Arctic Canada and Greenland breeders winter in Newfoundland and Labrador waters. The Grand Banks has been identified as an important wintering area for Thick-billed Murres (Brown 1986 and Lock et al. 1994). Relatively small numbers (~2,000) breed in eastern Newfoundland (Table 5.7). In eastern Newfoundland waters and the Study Area it is common from October to May and scarce June to September.

*Status in Project Area*

Uncommon, October to April.

**5.6.1.6.4. Razorbill**

Razorbill breeds in the north Atlantic Ocean from Maine, eastern Canada Greenland Iceland to Great Britain. It winters south to North Carolina and France. Razorbills are relatively scarce compared to the murres. Most of the 20,000 pairs of breeding in Atlantic Canada are in south east Labrador (Brown 1986). About 710 pairs breed in eastern Newfoundland adjacent to the Regional Area (Table 5.7).

Razorbills for the most part winter south of Newfoundland from Nova Scotia south to North Carolina. It is probably rare or uncommon on the northeastern Grand Banks as a migrant. Observations of Razorbill at sea are often obscured because of the difficulty in distinguishing from the murre.

*Status in Project Area*

Rare, April to November.

#### **5.6.1.6.5. Atlantic Puffin**

Atlantic Puffin breeds in the north Atlantic in Maine, Nova Scotia, Newfoundland and Labrador, Greenland, Iceland and northwest Europe. Atlantic Puffin is abundant in the North Atlantic with about 12 million pairs (Brown 1986). About 320,000 pairs nest in Atlantic Canada of which most nest in south east Newfoundland (Brown 1986). In North America it is thought to winter southern Newfoundland to southern Nova Scotia.

The Project Area is probably too far east of the breeding sites to be used as foraging areas in the summer. Migrants and post-breeders may use the northern Grand Banks in late summer and early autumn. Only one was observed from the drill platforms on the northeast Grand Banks 1999-2002 (Ballie et al. 2005). This was at least partly due difficulty in detectability at sea. Puffins winter on the southern Grand Banks to Georges Bank, Nova Scotia (Brown 1986).

*Status in Project Area*

Scarce, April to November.

#### **5.6.2. Prey and Foraging Habits**

Marine birds in the Regional Area consume a variety of prey ranging from small fish to zooplankton. Different methods for capturing food range from plunge diving from a height of 30 m into the water, feeding on the surface and sitting on the water then diving. Table 5.8 summarizes the feeding habits of birds expected to occur in the Project Area.

##### **5.6.2.1. Procellariidae (fulmar and shearwaters)**

Northern Fulmar and the four species of shearwaters that are expected to occur in the area feed on a variety of invertebrates, fish and zooplankton at or very near the surface. Caplin are an important food source for shearwaters. They secure their prey by swimming on the surface and picking at items on the surface, or dipping head under the water. Shearwaters are also capable of diving a short distance under the surface, probably no more than a meter on average. They may do this flying low over the water and then plunging into the water with enough force to get them below the surface for a few seconds or dive from a sitting position.

**Table 5.8. Foraging Strategy and Prey of Seabirds in the Project Area.**

Species	Prey	Foraging Strategy	Time with Head Under Water	Depth
<b><i>Procellariidae</i></b>				
Northern Fulmar	Fish, cephalopods, crustaceans, zooplankton, offal	Surface feeding.	Brief	<1 m
Cory's Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	<1 m
Greater Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	<1 m
Sooty Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	<1 m
Manx Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	<1 m
<b><i>Hydrobatidae</i></b>				
Wilson's Storm-Petrel	Crustaceans, zooplankton	Surface feeding	Brief	<0.5 m
Leach's Storm-Petrel	Crustaceans, zooplankton	Surface feeding	Brief	<0.5 m
<b><i>Sulidae</i></b>				
Northern Gannet	Fish, cephalopods	Deep plunge diving	Brief	10 m
<b><i>Phalaropodinae</i></b>				
Red Phalarope	Zooplankton, crustaceans	Surface feeding	Brief	0 m
Red-necked Phalarope	Zooplankton, crustaceans	Surface feeding	Brief	0 m
<b><i>Laridae</i></b>				
Great Skua	Fish, cephalopods, offal	Kleptoparasitism	Brief	<0.5 m
South Polar Skua	Fish, cephalopods, offal	Kleptoparasitism	Brief	<0.5 m
Pomarine Jaeger	Fish	Kleptoparasitism	Brief	<0.5 m
Parasitic Jaeger	Fish	Kleptoparasitism	Brief	<0.5 m
Long-tailed Jaeger	Fish, crustaceans	Kleptoparasitism, surface feeding	Brief	<0.5 m
Herring Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5 m
Iceland Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5 m
Glaucous Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5 m
Great Black-backed Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5 m
Ivory Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5 m

Species	Prey	Foraging Strategy	Time with Head Under Water	Depth
Black-legged Kittiwake	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5 m
Arctic Tern	Fish, crustaceans, zooplankton	Surface feeding, shallow plunging	Brief	<0.5 m
<b><i>Alcidae</i></b>				
Dovekie	Crustaceans, zooplankton, fish	Pursuit diving	Prolonged	Max 30 m, average is <30 m
Common Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100 m, average 20-50 m
Thick-billed Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100 m, average 20-60 m
Razorbill	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 120 m, average 25 m
Atlantic Puffin	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 60 m, average <60 m

Sources: Cramp and Simmons (1983), Gaston and Jones (1998), Nettleship and Birkhead (1985) and Lock et al. (1994).



#### **5.6.2.2. Hydrobatidae (storm-petrels)**

Leach's and Wilson's Storm-Petrel feed on small crustaceans, various small invertebrates and zooplankton. These storm-petrels usually feed while on the wing picking small food items from the surface of the water.

#### **5.6.2.3. Sulidae (Northern Gannet)**

Northern Gannet feeds on cephalopods and small fish such as caplin, mackerel, herring and Atlantic saury. They secure prey in spectacular fashion by plunging from a height of up to 30 m into the water reaching depths of 10 m. They pop back to the surface within a few seconds of entering the water.

#### **5.6.2.4. Phalaropodinae (phalaropes)**

Red-necked and Red Phalaropes eat zooplankton at the surface of the water. They secure food by swimming and rapidly picking at the surface of the water. Head probably rarely goes beneath surface.

#### **5.6.2.5. Laridae (skuas, jaegers, gulls, terns)**

Skuas and jaegers feed by chasing other species of birds until they drop food they are carrying or disgorge the contents of their stomachs. This method of securing food is called kleptoparasitism. Long-tailed Jaeger, the smallest member of this group, also feeds on small invertebrates and fish, which are caught by dipping to the surface of the water while remaining on the wing.

The large gulls, Herring, Great Black-backed, Glaucous and Iceland Gull, are opportunists eating a variety of food items from small fish at the surface, to carrion, and refuse and offal from fishing and other ships at sea. They find this food at the surface and may plunge their head under water to grab food just below the surface but rarely is the entire body submerged.

Ivory Gull often feed from the wing over water, dip feeding for small fish and invertebrates on the surface. They occasionally plunge dive so that the entire body may be submerged momentarily. They also swim and pick at the surface of the water and walk on ice to scavenge animal remains.

Black-legged Kittiwakes feed on a variety of invertebrates and small fish. Caplin is an important part of their diet when available. They feed by spotting prey from the wing then dropping to water surface and plunge diving. The body may be submerged very briefly. They also swim and pick at small invertebrates near the surface.

Arctic Tern feed on small fish and invertebrate that they catch from the wing with a shallow plunge dive. The entire bird rarely goes beneath the surface. They rarely rest on the water.

#### **5.6.2.6. Alcidae (Dovekie, murre, Razorbill and Atlantic Puffin)**

This group of birds is different than the other seabirds of the Project Area. They spend considerable time resting on the water and dive deep into the water column for food. Dovekie feeds on zooplankton including larval fish. They can dive down to 30 m and remain under water up to 41 seconds, but average dives are somewhat shallower and shorter in duration (Gaston and Jones 1998). Common Murre and Thick-billed Murre have been recorded diving to 100 m but 20-60 m is thought to be average. Dives have been timed up to 202 seconds but 60 seconds is closer to average (Gaston and Jones 1998). Razorbill has been recorded diving to 120 m but 25 m is thought to be more typical with time under water about 35 seconds (Gaston and Jones 1998). Black Guillemot usually feeds in water <30 m in depth but in deep water has been recording diving to 50 m with a maximum 147 seconds under water. Average depth and duration of dives expected to be less (Gaston and Jones 1998). Atlantic Puffin will dive to 60 m but 10-45 m is thought to be more typical. Maximum length of time recorded under water is 115 seconds but a more typical dive would be about 30 seconds.

#### **5.6.3. Species of Special Concern**

Ivory Gull is considered of special concern under SARA (<http://www.speciesatrisk.gc.ca/>). The global breeding range is Arctic Canada, northern Greenland, Spitsbergen, Norway and northern Russia (Godfrey 1986). The breeding population in eastern Canadian Arctic is estimated to be 2,400 (Thomas and MacDonald 1987 in Haney and MacDonald 1995) and 35,000 globally ([www.speciesatrisk.gc.ca/](http://www.speciesatrisk.gc.ca/)).

Ivory Gulls winter among pack ice and drift ice in the Arctic and sub-Arctic regions, avoiding ice-free waters and showing a marked preference for ice edges and open leads (Cramp and Simmons 1983; Haney and MacDonald 1995). Winter ranges extends south in pack ice to the northeast coast of Newfoundland (Brown 1986; McLaren et al. 1983). In 1981 aerial seabird survey route centred around Funk Island (N49° 45' W53°11') resulted in several Ivory Gull sightings. There were four sightings ranging from 1-5 individuals on the February survey and four sightings ranging from 1-5 individuals on the March survey (McLaren et al. 1983).

The McLaren et al. (1983) observations of Ivory Gull around Funk Island are 400 km northwest of the Project Area. There have been very few winter surveys for seabirds in the Project Area, especially in the presence of pack ice. It is possible that Ivory Gulls could be in the Project Area late winter during heavy ice years when ice reaches its annual southern limit. There is not enough information from the eastern edge of the ice pack in Newfoundland to estimate the density of Ivory Gulls that might occur. Ivory Gull are unlikely to occur in the Project Area during the seismic or geohazard survey season.

Ivory Gulls feed by hovering, contact-dipping, surface-plunging, wading in shallow water and surface seizing (Cramp and Simmons 1983). Birds may submerge deep enough so that only wing tips project above the water surface (Cramp and Simmons 1983). They feed on various small fish, including lanternfish (Myctophidae) and juvenile Arctic cod (*Boreogadus saida*), and invertebrates (Cramp and Simmons 1983; Haney and MacDonald 1995). Ivory Gulls also feeds on carrion when available (Cramp and Simmons 1983; Haney and MacDonald 1995).

## 5.7. Marine Mammals and Sea Turtles

### 5.7.1. Marine Mammals

At least 22 species of marine mammal are known or expected to occur in and near the Project Area including 17 species of cetaceans (whales and dolphins) and five species of phocids (seals). Additional marine mammal species may occur rarely. Most marine mammals are seasonal inhabitants, the waters of the Grand Banks and surrounding areas being important feeding grounds for many of them (Table 5.9).

**Table 5.9. Marine Mammals Known or Expected to Occur Within the Project Area.**

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

<sup>a</sup> Based on COSEWIC (2004a,b).

E: endangered; SC: special concern; NC: not considered; DD: data deficient; NAR: not at risk

<sup>b</sup> Refers to the Scotian Shelf population.

<sup>c</sup> Refers to the Davis Strait population. There is uncertainty about which population (Scotian Shelf vs. Davis Strait) of this species occurs in the Project Area.

The marine mammal community within and near the Project Area was described in the Hibernia EIS in 1985 (Mobil 1985), updated in 1995 for the Terra Nova EIS (Petro-Canada 1996), and updated again in 2000 for the White Rose EIS (Husky 2000). 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 Project 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), Petro-Canada (1996), and Husky (2000). Population estimates and feeding information of many of the marine mammal species that occur within the Project Area are indicated in Tables 5.10 and 5.11, respectively.

#### **5.7.1.1. DFO Cetacean Sighting Database**

The Department of Fisheries and Oceans in St. John's (J. Lawson, DFO Marine Mammal Research Scientist, 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 5.12 contains the coarse summary data pertaining to sightings within and close to the Project Area (NAFO Division 3L). Caveats associated with the DFO data are presented with Table 5.12.

Most of the reliable sightings of cetaceans in Division 3L occurred shoreward of the EEZ. 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.

#### **5.7.1.2. Species Profiles**

##### **5.7.1.2.1. Baleen Whales (Mysticetes)**

The five species of baleen whales that occur in the regional area include the humpback whale, blue whale, fin whale, sei whale, and minke whale (see Table 5.9). Although nearly all of these species experienced depletion due to whaling, it is likely that many are experiencing some recovery (Best 1993).

**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 Montevicchi 1999).

**Table 5.10. Population Estimates of Marine Mammals that Occur in and near the Project Area.**

Species	Northwest Atlantic (NW) Population Size	Population Occurring in the Project Area		
	Estimated Number	Stock	Estimated Number	Source of Updated Information
<b>Baleen Whales</b>				
Blue Whale	308 <sup>a</sup>	NW Atlantic	Unknown	Waring et al. (2004: Appendix III)
Fin Whale	2,814 <sup>b</sup>	Can. E. Coast	Unknown	Waring et al. (2004)
Sei Whale	Unknown	Nova Scotia	Unknown	COSEWIC (2003a); Waring et al. (2004)
Humpback Whale	5,505 (11,570 in North Atlantic)	NF/Labrador	1,700-3,200	Whitehead (1982); Katona and Beard (1990); Baird (2003)
Minke Whale	4,018 <sup>c</sup>	Can. E. Coast	Unknown	Waring et al. (2004)
<b>Toothed Whales</b>				
Sperm Whale	4,702 <sup>d</sup>	North Atlantic	Unknown	Reeves and Whitehead (1997); Waring et al. (2004)
Northern Bottlenose Whale	Tens of thousands?	North Atlantic	Unknown	Reeves et al. (1993); Waring et al. (2004)
Sowerby's Beaked Whale	Unknown			Katona et al. (1993)
Common Bottlenose Dolphin (offshore stock)	29,774	NW Atlantic	Unknown	Waring et al. (2004)
Risso's Dolphin	30,000	US East Coast	Unknown	Reeves et al. (2002)
Killer Whale	Unavailable		Unknown	Lien et al. (1988); Waring et al. (2004)
Long-finned Pilot Whale	14,524	NW Atlantic	Abundant	Nelson and Lien (1996); Waring et al. (2004)
Short-beaked Common Dolphin	30,768	NW Atlantic	Unknown	Katona et al. (1993); Waring et al. (2004)
Atlantic White-sided Dolphin	51,640 <sup>e</sup>	NW Atlantic	Unknown	Palka et al. (1997); Waring et al. (2004)
White-beaked Dolphin	Unknown	NW Atlantic	Unknown	Waring et al. (2004)
Risso's Dolphin	29,110	NW Atlantic	Unknown	Waring et al. (2004: Appendix III)
Striped Dolphin	61,546	NW Atlantic	Unknown	Waring et al. (2004: Appendix III)
Harbour Porpoise	Unknown	Newfoundland	Unknown	Wang et al. (1996); COSEWIC (2003b); Waring et al. (2004)
<b>True Seals</b>				
Harp Seal	5.2 (±1.2) million	NW Atlantic	Unknown	DFO (2000)
Hooded Seal	500,000	NW Atlantic	Unknown	Whitehead et al. (1998)
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)

<sup>a</sup> Based on surveys from the Gulf of St. Lawrence. This estimate deemed unsuitable for abundance estimation.

<sup>b</sup> Based on surveys from George's Bank to the mouth of the Gulf of St. Lawrence.

<sup>c</sup> Based on surveys from George's Bank to the mouth of the Gulf of St. Lawrence plus a survey in the Gulf of St. Lawrence.

<sup>d</sup> Based on surveys from Florida to the Gulf of St. Lawrence.

<sup>e</sup> Gulf of Maine Stock.

**Table 5.11. Prey of Marine Mammals that Occur in the Project Area.**

Species	Prey	Source of Updated Information
<b>Baleen Whales</b>		
Blue Whale	Euphausiids	
Fin Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Sei Whale	Copepods, euphausiids, some fish	
Humpback Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Minke Whale	Fish (predominantly capelin), squid, euphausiids	Piatt et al. (1989)
<b>Toothed Whales</b>		
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)
Risso's Dolphin	Squid	Reeves et al. (2002)
Striped Dolphin	Cephalopods, shoaling fish	Reeves et al. (2002)
Harbour Porpoise	Schooling fish (capelin, cod, herring, mackerel)	
<b>True Seals</b>		
Harp Seal	Fish (capelin, cod, halibut, sand lance), crustaceans	Lawson and Stenson (1995); Lawson et al. (1998); Wallace and Lawson (1997); Hammill and Stenson (2000).
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.

**Table 5.12. Cetacean Sightings Near or Within the Project Area, 1958-2002.**

Species	Number of sighting events (Number of individual animals)	
	Division 3L (inside EEZ)	Division 3L (outside EEZ)
Fin Whale	47 (108)	2 (3)
Sei Whale	7 (14)	1 (1)
Humpback Whale	259 (942)	10 (14)
Minke Whale	110 (246)	4 (6)
Sperm Whale	1 (1)	1 (1)
Killer Whale	4 (15)	
Pilot Whale	57 (1,169)	4 (79)
Common Dolphin	1 (5)	1 (7)
Atlantic White-sided Dolphin	1 (2)	
White-beaked Dolphin	1 (2)	
Dolphin (sp.)		1 (3)
Harbour Porpoise	4 (10)	

Source: DFO (2003d).

\*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).

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 11,570 individuals (Baird 2003), 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 and near the Project 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 2003d), humpback whales ranked first in Division 3L (inside and outside the EEZ).

The western North Atlantic and North Pacific populations of humpback whale were singly designated by the Committee on Species of Endangered Wildlife in Canada (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’; COSEWIC 2003a). [COSEWIC designations are relevant because they are a potential precursor to designation under SARA.]

**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. 2004). It is rarely sighted on the Grand Banks, and is probably relatively uncommon within the Project 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). The blue whale is considered ‘endangered’ by COSEWIC.

One blue whale was sighted northwest of the Project Area during DFO surveys in spring 2004 (J. Lawson, DFO, pers. comm.).

**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 (Whitehead and Carscadden 1985; Piatt et al. 1989).

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 2,800 (Waring et al. 2004).

According to the DFO cetacean sightings database, these common visitors to the Project Area have been sighted most often inside the EEZ in Division 3L.

The fin whale is designated by COSEWIC as a species of ‘special concern.’

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

**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 ~4,000 individuals (Waring et al. 2004).



Minke whales commonly occur within and near the Project Area. Most of the reported Project Area sightings in the DFO database (DFO 2003d) have occurred in Division 3L, inside the EEZ in areas with water depths <400 m.

#### **5.7.1.2.2. Toothed Whales (Odontocetes)**

Twelve species of toothed whales may occur in the Project Area (see Table 5.9). Most of these marine mammals occur seasonally in and near the Project 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.

**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).

Population numbers of sperm whales are not known for the NW Atlantic. Likewise, it is not known how commonly sperm whales might occur within the Project Area. 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). There are two sightings of sperm whales reported in the DFO cetacean sightings database (DFO 2003d) that occurred in Division 3L. Sperm whales are known to feed in deep water and it is possible that they occur regularly beyond the continental shelf within the Slope waters near the Project Area.

Sperm whales have previously been reported to be associated with areas of high plankton productivity and upwelling, presumably because the squid upon which they feed are in turn feeding on the zooplankton (Cushing 1969 in Griffin 1999). If sperm whale occur in or near the Project Area, it is likely that they would be males because females usually do not venture north of 40 degrees latitude (Griffin 1999; Whitehead 2003). Another relevant point is that they may not be highly concentrated as males tend to be more dispersed than females (S. Dufault, LGL, pers. comm.) and it is likely they will occur in deeper waters of the Project Area. On the East Coast to the south of Newfoundland, warm-core rings and Gulf Stream fronts have been identified as areas of concentration for sperm whales (Griffin 1999).

Sperm whales are considered ‘not at risk’ by COSEWIC.

**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. The Scotian Shelf population of northern bottlenose whales seem to prefer waters between 800-1,500 m deep (Wimmer and Whitehead 2004). This species lives primarily in deep canyon and slope areas, where they prey on squid and deep-sea fishes.

The Project 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. There have been several sightings of this species in deep waters north and southeast of the Project Area (Wimmer and Whitehead 2004; Moulton et al. 2005). Since most of the Project Area has water depths <400 m, the possibility of northern bottlenose whale occurrence should be considered low.

The northern bottlenose whale that inhabits the Scotian Shelf is considered as 'endangered' whereas the Davis Strait population is considered 'not at risk.' It is uncertain which population individuals sighted off eastern Newfoundland would belong.

**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 Project 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 Project Area has water depths <400 m, the possibility of occurrence of Sowerby's beaked whales should be considered low. They are considered of 'special concern' by COSEWIC.

**Killer Whale.**—The killer whale is a year-round resident that is thought to occur in relatively small numbers in the Project 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.

**Long-finned Pilot Whale.**—The most common toothed whale in the Project 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. There was one sighting of 16 pilot whales southeast of the Project Area in June 2004 during the CCGS *Hudson* research expedition (Lang and Moulton 2004). However, none were sighted during a recent offshore supply vessel survey (Wiese and Montevecchi 1999). The northwest Atlantic population is estimated at ~14,500 individuals (Waring et al. 2004).

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 Project Area pilot whale sightings found in the DFO database (DFO 2003d) (3L) were reported in areas where water depth <400 m. This species is considered 'not at risk' by COSEWIC.

***Common (Short-beaked) 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 at the 2000 m 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 Project Area.

***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 Gulf of Maine population is estimated at ~51,600 individuals (Waring et al. 2004). The number of white-sided dolphins in the Project 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 Project Area are recorded in the DFO cetacean sightings database (DFO 2003d).

***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 Project Area is most likely limited to areas where water depths are relatively shallow.

**Common Bottlenose Dolphin.**—A north-south migration has been assumed to occur along the east coast of North America, with bottlenose 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). It is considered ‘not at risk’ by COSEWIC.

**Risso’s Dolphin.**—Risso’s dolphin is widely distributed in tropical and warm temperate oceans (Reeves et al. 2002). It is usually found over deep water (>300 m) where they feed almost exclusively on squid. They are abundant worldwide but are probably rare in the Project Area (Reeves et al. 2002).

**Striped Dolphin.**—This species’ preferred habitat seems to be deep water along the edge and seaward of the continental shelf, particularly in areas with warm currents (Baird et al. 1993). Offshore waters of Newfoundland are thought to be at the northern limit of its range. Stock distinctions are unknown and the Northwest Atlantic population is estimated at 61,546 (Whitehead et al. 1998; Waring et al. 2004: Appendix III), but COSEWIC does not consider the species to be at risk (COSEWIC 2004a,b).

**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). 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’.

Harbour porpoise occurrence in the Project Area is most likely limited to areas where water depths are relatively shallow.

#### **5.7.1.2.3. True Seals (Phocids)**

Five species of true seals are known to occur in the waters of the Project Area (see Table 5.9). 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 5.10), with considerable seasonal, geographic and interannual variation in diet (Hammill et al. 1995; Lawson and Stenson 1995; Wallace and Lawson 1997).

**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 2000). The main whelping patch for the northwest Atlantic breeding stock of harp seal is north of the Project 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). 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; Lacoste and Stenson 2000), 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). The total population in 2000 was estimated at 5.2 million (DFO 2000).

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. Harp seals consume less Atlantic cod than once believed as seals apparently spend more time offshore than previously thought (Hammill and Stenson 2000).

**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). The number of visitors to the Project Area is unknown. However, these numbers may be increasing as hooded seals are apparently expanding their southern range of occurrence (McAlpine et al. 1999; Harris et al. 2001a; Mignucci-Giannoni and Odell 2001).

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 400,000-450,000.

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).

**Grey Seal.**—Grey seals in the Project Area are migrants from the Sable Island and Gulf of St. Lawrence breeding populations. This species may occur in the Project 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 Project 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).

**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 Project Area.

**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 Project Area but small numbers of bearded seals could stray from Labrador waters to the Project 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 includes polar cod, sculpins, rough dabs, eelblennies, crabs, shrimps, molluscs, cephalopods, polychaetes and amphipods (Kovacs 2002).

## **5.7.2. Sea Turtles**

Sea turtles are probably not common in the Project Area but are important to consider because of their threatened or endangered status, both nationally and internationally.

Three species of sea turtles may occur in the Project Area: (1) the leatherback, (2) the loggerhead, and (3) the Kemp's ridley sea turtle (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 Project Area due to lack of information. The leatherback turtle is listed as endangered by COSEWIC (2004a,b) and by the United States National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS) (Plotkin 1995). The leatherback sea turtle is listed as endangered under Schedule 1 of SARA. The Kemp's ridley is also listed as endangered and the loggerhead turtle is listed as threatened by NMFS and FWS (Plotkin 1995).

### **5.7.2.1. 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. Recent satellite-telemetry data show that leatherbacks, including adult males, adult females, and juveniles undergo annual round trip migrations from nesting areas in the Caribbean and South America to waters off Nova Scotia and Newfoundland (James et al. 2005). Adult leatherbacks are regularly sighted in the waters off Nova Scotia and Newfoundland from June to October (James et al. 2005), where they likely come to feed on jellyfish, their primary prey (Bleakney 1965; Cook 1981; 1984). Indeed, feeding areas in Atlantic Canada are considered significant for this species (James et al. 2005). Leatherbacks do not migrate along specific routes but utilize broad areas of the Atlantic. They exhibit foraging site fidelity to shelf and slope waters off Canada and the northeastern United States. Leatherbacks equipped with satellite tags did not occur in the Project Area but some did migrate through the Grand Banks south of Newfoundland (James et al. 2005).

Leatherbacks nest from April through November in the tropics along sandy beaches, preferring areas with little vegetation (Nordmoe et al. 2004). Females deposit an average of five to seven nests per year, with clutch size averages varying geographically (Plotkin 1995). Leatherbacks do not nest annually; inter-nesting intervals are 2-3 years. Little is known about the behaviour or survivorship of post-hatchlings. Leatherbacks are specialized predators of gelatinous zooplankton, feeding on scyphozoan jellyfish, pyrosomes, and siphonophores (Davenport 1998 in Hays et al. 2004). They exhibit diel dive patterns, spending much of the night diving, typically to modest depths, but around sunrise, dives become progressively deeper. The deepest dive profile recorded for a leatherback (and indeed any reptile) was a 54-minute dive to 626 m. (Some dives might be deeper—Eckert et al. (1989).) However, dives are typically much shallower (<200 m) and shorter (<40 minutes) (Hays et al. 2004).

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 25°C in sea water as much as 18°C cooler. (An adult was even observed by fishermen in Trinity Bay, Newfoundland swimming amongst ice in waters as cold as 0°C (Goff and Lien 1988).) Leatherbacks likely use many means to maintain body temperatures including: high physical activity, insulating oily layer, and counter-current heat exchange (James and Mrosovsky 2004).

The population size for leatherbacks is poorly known, but likely exceeds several hundred thousand animals in the Atlantic (DFO 2004d). There is no estimate of what fraction of the population may migrate into Canadian waters. 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 (James 2001). Ingestion of plastic materials, which leatherbacks presumably mistake for jellyfish is common and can be fatal. Entanglement in fishing gear is also an issue. Of the twenty leatherbacks reported off Newfoundland between 1976 to 1985, 14 were entangled in fishing gear (Goff and Lien 1988). James et al. (2005) collected 83 records of leatherbacks interacting with fixed gear from 1997-2003 in shelf waters off eastern Canada. Of these 83 incidents, 18% involved dead turtles. The authors note that these voluntarily reported interactions likely represent a small fraction of the leatherback-fixed gear interactions occurring in Atlantic Canada. The leatherback sea turtle is considered endangered by COSEWIC (2001) and it is listed as endangered under Schedule 1 of SARA. A recovery plan for this species is in preparation for Atlantic Canada.

#### **5.7.2.2. 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 Project Area is unavailable; however, loggerheads may 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 concentrate prey species for both the turtles and the swordfish and tuna that are the targets of the longline fishers.

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).

### **5.7.2.3. 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 Project 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).

## 6.0 Effects Assessment

This effects assessment considers both the effects of the Project on the environment (methods described in the following section) and also the effects of the environment on the Project.

### 6.1. Methodology

#### 6.1.1. Scoping

Scoping for the effects assessment was conducted by reviewing the Orphan Basin 3-D Seismic EA (Buchanan et al. 2004), the White Rose Comprehensive Study and Supplement (Husky 2000, 2001), relevant seismic EAs (e.g., Davis et al 1998; Moulton et al. 2003), and Husky VSP and geohazard survey EAs (e.g., LGL 2003b, 2004). The C-NOPB also provided a scoping document for the Project. In addition, various stakeholders were contacted for input (see below). Reviews of present state of knowledge were also conducted.

Consultations for the proposed Husky Energy 3-D survey included the following agencies and stakeholders. (A list of all persons consulted is provided in Appendix I.)

- Fisheries and Oceans
- Environment Canada
- One Ocean/FFAWU
- Natural History Society
- Association of Seafood Producers
- Fishery Products International
- Clearwater Seafood's Limited Partnership
- Icewater Harvesting

Comments and concerns noted by each of these groups are discussed below.

*Agencies.* Relevant managers with Fisheries and Oceans (DFO) and Environment Canada (EC) indicated that they had already provided written comments to C-NOPB on the proposed survey.

*One Ocean/FFAWU/Natural History Society.* One Ocean representatives, the FFAWU's biologist and representatives of the Natural History Society did not have any specific comments or concerns about the proposed survey.

*Association of Seafood Producers (ASP).* ASP representatives did not have any specific comments or concerns about the proposed survey.

*Fishery Products International (FPI).* Proposed survey activities in the general vicinity of the Northern Jeanne d'Arc Basin area were discussed and reviewed with FPI managers in light of the firm's 2005 harvesting plans within Unit Area 3Li, and other Grand Bank's fishing areas.

Company managers noted that one of their vessels recently (late January) completed its 2005 3L shrimp fishery on grounds to the north and west of the study area and will not be returning to these shrimp grounds again during 2005.

FPI vessels will also be conducting their usual turbot fishing activities on grounds for this species fishing in the northwest portion of 3Li. This species will be taken with otter trawls, and FPI vessels will be operating in water depths between 300-400 fathoms (545 m - 725 m); however managers noted that most of this turbot catch is usually taken in water depths of 300 fathoms (545 m) or less.

These turbot fisheries are due to commence in April-May, 2005, but this will depend on what may be happening in the firm's yellowtail fisheries on other offshore grounds well away from the study area. (Managers noted that FPI vessels usually continue to pursue yellowtail until catch rates decline; once this occurs, the vessels will switch to turbot.)

In 2004, FPI's turbot fisheries in 3Li commenced in May and continued until the first week of September. Though, as noted above, FPI's 2005 turbot harvest will depend on what transpires in its yellowtail activities, company managers indicated that they expect to start fishing turbot somewhat earlier than last year, i.e. possibly in March-April, and that this fishery may go on longer than last year. However, this would depend on catch rates – as noted below, as well as the use of these turbot grounds by smaller (< 65') vessels using gillnets. (Heavy concentrations of fixed gear usually make it difficult for larger FPI vessels using mobile gear, i.e. otter trawls.) It is also possible, managers noted, that FPI vessels may return to turbot grounds in 3L later in the year.

In previous (CCR-FPI meeting, Sept. 2004) consultations, FPI managers noted that their vessels usually continue to fish turbot grounds within 3L1 as long as catch rates are relatively high, and that catch rates are generally higher earlier in the season. Last year, catch rates decreased towards the end of the summer and the vessels then moved to more northerly turbot grounds. (It was also noted that, in 2004, a Nova Scotia-based vessel also fished turbot on the same study area grounds on which FPI was operating, and that some foreign vessels, e.g. from Portugal, would probably be fishing turbot in these areas this year as well, as has been their practice in the past.)

*Icewater Harvesting.* Company representatives indicated that their vessel the *Cape Fortune* expects to be harvesting turbot in 3L as well this year, and expects to be fishing from May to the end of June. However, managers indicated that these turbot harvesting operations would be primarily within 3Ld and 3Ka, and thus well to the northwest of proposed survey activities.

*Clearwater Seafood's Limited Partnership.* Clearwater managers received information about the proposed 3-D survey, but to date have not provided any comments.

### 6.1.2. Valued Ecosystem Components

The valued ecosystem components (VEC) approach was used to provide focus for this EA because it is neither feasible nor advisable to consider every species of the thousands that occur on the Grand Banks. This approach is more or less standard practice for Canadian EA. It is recognized by the authors that this approach does not capture every conceivable situation for every species but it does consider potentially important effects on those species or groups of species that are of most interest commercially, socially, culturally and aesthetically to society.

VEC selection was based upon project scoping (see ‘Scoping’ above) with the following foremost considerations:

- commercial, social, cultural and aesthetic importance to society
- at least some potential sensitivity to project activities, and
- potential for interaction with project activities

The following VECs were selected:

- **Commercial fish** (including fish habitat considerations) with emphasis on the three primary species: (1) shrimp, (2) snow crab, and (3) Greenland halibut (turbot), and *SARA* species (e.g., Atlantic cod and wolffish). It is recognized that there are many other fish species, commercial or prey species, that could be considered but it is our professional opinion that this suite of species captures all of the relevant issues concerning the potential effects of seismic surveys on important invertebrate and fish populations of the Project Area.
- **Commercial fisheries** are directly linked to the fish VEC above but all fisheries (trawling, gillnetting, longlines, pots, etc.) are considered where relevant. This includes those listed above plus some potential pelagic fisheries (e.g., tuna) that could occur in the Project Area.
- **Seabirds** with emphasis on those species most sensitive to seismic activities (e.g., deep divers such as murres) or vessel stranding (e.g., petrels), and *SARA* species (e.g., Ivory Gull)
- **Marine Mammals** with emphasis on those species potentially most sensitive to low frequency sound (e.g., baleen whales such as humpback whale) or *SARA* species (e.g., blue whale).
- **Sea Turtles**, although probably very rare, are mostly threatened and endangered and thus are *SARA* species and VECs.
- **Species at Risk**, as noted above.

## 6.2. Boundaries

For the purposes of this EA, the following boundaries are defined.

**Temporal**—the temporal boundaries of the Project are June to October 2005 (Phase 1), possibly 1 April to 31 October in subsequent years.

**Project Area**—the ‘Project Area’ is defined as the area of the ELs plus an additional areas around the outer perimeter of these parcels to accommodate the ships’ turning radii and some acquisition outside the perimeter necessary to achieve seismic imaging objectives within the perimeter, and holding areas (see Figure 1.1).

**Affected Area**—the ‘Affected Area’ varies according to the specific vertical and horizontal distributions and sensitivities of the VECs of interest and is defined as that area within which effects (physical or important behavioural ones) have been reported to occur. It is likely that in the present case virtually all potential effects will be confined within the Project Area.

**Study Area**—an area around the Project Area large enough to encompass effects reported in the literature.

**Regional Area**—the regional boundary is the boundary as defined in previous EAs such as Hibernia, Terra Nova and White Rose and is retained here for consistency.

## 6.3. Effects Assessment Procedures

The systematic assessment of the potential effects of the Project phase involved three major steps:

1. preparation of interaction (between Project activities and the environment) matrices;
2. identification and evaluation of potential effects including description of mitigation measures and residual effects, and
3. preparation of residual effects summary tables, including evaluation of cumulative effects.

### 6.3.1. Identification and Evaluation of Effects

Interaction matrices were prepared that identify all possible Project activities that could interact with any of the VECs. The matrices include times and places where interactions could occur. The interaction matrices are used only to identify potential interactions; they make no assumptions about the potential effects of the interactions.

Interactions were then evaluated for their potential to cause effects. In instances where the potential for an effect of an interaction was deemed impossible or extremely remote, these interactions were not

considered further. In this way, the assessment could focus on key issues and the more substantive environmental effects.

An interaction was considered to be a potential effect if it could change the abundance or distribution of VECs, or change the prey species or habitats used by VECs. The potential for an effect was assessed by considering:

- the location and timing of the interaction;
- the literature on similar interactions and associated effects (seismic and geohazard EAs for Offshore Nova Scotia and Newfoundland and Labrador);
- when necessary, consultation with other experts; and
- results of similar effects assessments and especially, monitoring studies done in other areas.

When data were insufficient to allow certain or precise effects evaluations, predictions were made based on professional judgement. In such cases, the uncertainty is documented in the EA. Effects were evaluated for the proposed geophysical surveys, which include mitigation measures that are mandatory or have become standard operating procedure in the industry.

### **6.3.2. Classifying Anticipated Environmental Effects**

The concept of classifying environmental effects simply means determining whether they are negative or positive. The following includes some of the key factors that are considered for determining negative environmental effects, as per the CEA Agency guidelines (CEAA 1994):

- negative effects on the health of biota;
- loss of rare or endangered species;
- reductions in biological diversity;
- loss or avoidance of productive habitat;
- fragmentation of habitat or interruption of movement corridors and migration routes;
- transformation of natural landscapes;
- discharge of persistent and/or toxic chemicals;
- toxicity effects on human health;
- loss of, or detrimental change in, current use of lands and resources for traditional purposes;
- foreclosure of future resource use or production; and
- negative effects on human health or well-being.

### **6.3.3. Mitigation**

Mitigation measures appropriate for each effect predicted in the matrix were identified and the effects of various Project activities were then evaluated assuming that appropriate mitigation measures are applied. Residual effects predictions were made taking into consideration both standard and project-specific mitigations.

### 6.3.4. Evaluation Criteria for Assessing Environmental Effects

Several criteria were taken into account when evaluating the nature and extent of environmental effects. These criteria include (CEAA 1994):

- magnitude;
- geographic extent;
- duration and frequency;
- reversibility; and
- ecological, socio-cultural and economic context.

Magnitude describes the nature and extent of the environmental effect for each activity. Geographic extent refers to the specific area (km<sup>2</sup>) affected by the Project activity, which may vary depending on the activity and the relevant VEC. Duration and frequency describe how long and how often a project activity and/or environmental effect will occur. Reversibility refers to the ability of a VEC to return to an equal, or improved condition, at the end of the Project. The ecological, socio-cultural and economic context describes the current status of the area affected by the Project in terms of existing environmental effects. Two tables are provided for each group of VECs, indicating the results of the effects analysis and the significance of those effects.

Magnitude was defined as:

Negligible	An interaction that may create a measureable effect on individuals but would never approach the 10% value of the 'low' rating. Rating = 0.
Low	Affects 0 to 10 percent of individuals in the affected area (e.g., geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 1.
Medium	Affects 10 to 25 percent of individuals in the affected area (see geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 2.
High	Affects more than 25 percent of individuals in the affected area (e.g., geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 3.

Definitions of magnitude used in this EA have been used previously in numerous offshore oil-related environmental assessments under CEAA. These include assessments of exploratory (including Husky 2000, 2001, 2002; LGL 2003b, 2004; Buchanan et al. 2004, and others).

Durations are defined as:

1	=	<1 month
2	=	1 – 12 month
3	=	13 – 36 month
4	=	37 – 72 month
5	=	>72 month

Short duration can be considered 12 months or less and medium duration can be defined as 13 to 36 months.

### **6.3.5. Cumulative Effects**

Projects and activities considered in the cumulative effects assessment included other human activities in Newfoundland and Labrador offshore waters, with emphasis on the Regional Area of the Grand Banks.

- Survey program within-project cumulative impacts. For the most part, and unless otherwise indicated, within-project cumulative effects are fully integrated within this assessment;
- Other offshore oil exploration activity (particularly seismic surveys and exploratory drilling). In the Newfoundland and Labrador offshore for 2005, activity may include three other seismic programs and two exploratory/delineation drilling programs (C-NOPB web site). Existing and developing production projects include Hibernia (GBS platform), Terra Nova FPSO, and White Rose FPSO installation;
- Commercial fisheries;
- Marine transportation (tankers, cargo ships, supply vessels, naval vessels, fishing vessel transits, etc.); and
- Hunting activities (marine birds and seals).

### **6.3.6. Integrated Residual Environmental Effects**

Upon completion of the evaluation of environmental effects, the residual environmental effects (effects after project-specific mitigation measures are imposed) are assigned a rating of significance for:

- each project activity or accident scenario;
- the cumulative effects of project activities within the Project; and
- the cumulative effects of combined projects on the Grand Banks.

These ratings are presented in summary tables of residual environmental effects. The last of these points considers all residual environmental effects, including project and other-project cumulative environmental effects. As such, this represents an integrated residual environmental effects evaluation.



The analysis and prediction of the significance of environmental effects, including cumulative environmental effects, encompasses the following:

- determination of the significance of residual environmental effects;
- establishment of the level of confidence for prediction; and
- evaluation of the scientific certainty and probability of occurrence of the residual impact prediction.

Ratings for level of confidence, probability of occurrence, and determination of scientific certainty associated with each prediction are presented in the table of residual environmental effects. The guidelines used to assess these ratings are discussed in detail in the sections below.

### **6.3.7. Significance Rating**

Significant environmental effects are those that are considered to be of sufficient magnitude, duration, frequency, geographic extent, and/or reversibility to cause a change in the VEC that will alter its status or integrity beyond an acceptable level. Establishment of the criteria is based on professional judgment, but is transparent and repeatable. In this EA, a *significant* effect is defined as:

*Having a high magnitude or medium magnitude for a duration of greater than one year and over a geographic extent greater than 10 km<sup>2</sup>*

An effect can be considered *significant*, *not significant*, or *positive*.

### **6.3.8. Level of Confidence**

The significance of the residual environmental effects is based on a review of relevant literature, consultation with experts, and professional judgment. In some instances, making predictions of potential residual environmental effects is difficult due to the limitations of available data (for example, technical boundaries). Ratings are therefore provided to indicate, qualitatively, the level of confidence for each prediction.

### **6.3.9. Determination of Whether Predicted Environmental Effects are Likely to Occur**

As per Husky (2000), the following criteria for the evaluation the likelihood of any predicted significant effects are used.

- probability of occurrence; and
- scientific certainty.

### **6.3.10. Follow-up Monitoring**

Because any effects of the Project on the environment will be relatively short-term and transitory, there is no need to conduct follow-up monitoring. However, there will be some level of monitoring during the course of the Project, and if these observations indicate an accidental release of fuel or flotation fluid (Isopar) or some other unforeseen occurrence, then the need for follow up monitoring will be assessed in consultation with the C-NOPB.

## **6.4. Effects of the Environment on the Project**

The physical environment is described in some detail in Section 4.3 Climatology, Section 4.4 Oceanography, and Section 4.5 Ice and the reader is referred to those sections to assist in determining the effects on the Project. Furthermore, safety issues are assessed in some detail during the permitting and program application processes. Nonetheless, effects on the Project are important to consider, at least on a high level, because they may sometimes cause effects on the environment. For example, accidental spills of streamer fluid may be more likely to occur during rough weather.

Given the Project time frame of April (June in 2005) to October and the requirement of a seismic survey to avoid periods and locations of sea ice, sea ice should have no effect on the Project. Icebergs in the spring and early summer may cause some survey delays if tracks have to be altered to avoid them. Most environmental constraints on seismic and geohazard surveys are those imposed by wind and wave. The Project scheduling avoids the most continuous extreme weather conditions and Husky contractors are thoroughly familiar with east coast operating conditions. As a prediction of the effects of the environment on the Project, Husky uses an estimate of 33% weather-related down time for the Project (S. Anfort, Senior Geologist, Husky). This cannot be considered a significant effect on the Project otherwise the Project would not be acceptable to the Proponent. Seismic vessels typically suspend surveys once wind and wave conditions reach certain levels because the ambient noise affects the data. They also do not want to damage towed gear which would cause costly delays.

Effects of the biological environment on the Project are unlikely although there are anecdotal accounts of sharks attacking and damaging streamers.

## **6.5. Effects of the Project on the Environment**

### **6.5.1. Ecosystem**

There will be *no effect* (or *negligible* at most) from the Project on ecosystem components such as water quality, plankton and benthic communities and these are not discussed further except where they represent some life stage of a particular VEC such as snow crab or Atlantic cod (see following sections).

## **6.5.2. Fish and Invertebrates**

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

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

## **6.5.3. Pathological Effects**

In water, acute injury or death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay (Hubbs and Rechnitzer 1952 *in* Wardle et al. 2001). Generally, the higher the received pressure and the less time it takes for the pressure to rise and decay, the greater the chance of acute pathological effects. Considering the peak pressure and rise/decay time characteristics of seismic airgun arrays used today, the pathological zone for fish and invertebrates would be expected to be small, i.e., within a few metres of the seismic source.

### **6.5.3.1. Fish**

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

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

Studies have indicated that exposure to intense noise can affect the auditory thresholds of fish. Temporary threshold shift (TTS) can occur in fish under certain conditions, followed by complete recovery within 24 hours. Amoser and Ladich (2003) exposed two hearing specialist fish, the nonvocal goldfish (*Carassius auratus*) and the vocalizing catfish (*Pimelodus pictus*) to intense white noise (158 dB re 1  $\mu$ Pa; unspecified measure type) for periods of 12 and 24 hours and then tested their post-exposure hearing sensitivities using auditory brainstem response (ABR) immediately following exposure as well as at 3, 7 and 14 days after exposure. Hearing sensitivities were also measured prior to exposure to the intense sound. Both species exhibited loss of hearing sensitivity (maximum of 26 to 32 dB) immediately after exposure, the greatest loss occurring at the most sensitive frequencies. The catfish exhibited the highest maximum loss of hearing sensitivity. While the goldfish hearing sensitivity returned to normal within three days of exposure, the catfish hearing sensitivity took 14 days to return to normal. Smith et al. (2004) found that goldfish had significant threshold shift after only 10 minutes of exposure to white noise (160-170 dB re 1  $\mu$ Pa; unspecified measure type) and that these shifts increased linearly up to approximately 28 dB after 24 hours of exposure to the noise. Threshold shifts did not increase beyond the 24-hour exposure time. After 21 days of exposure to the noise, the goldfish hearing sensitivity required 14 days to recover to normal levels. It should be noted that TTS may seldom (or never) occur in the wild unless fish are prevented from fleeing the irritant.

Some studies have also provided some information on the effects of seismic exposure on fish eggs and larvae (Kostyuchenko 1973; Dalen and Knudsen 1987; Holliday et al. 1987; Matishov 1992; Booman et al. 1996; Dalen et al. 1996). Overall, effects appeared to be minimal and any mortality effect was generally not significantly different from the experimental controls. Generally, any observed larval mortality occurred after exposures within 0.5 to 3 m of the airgun source. Matishov (1992) reported some retinal tissue damage in cod larvae exposed at 1 m from the airgun source. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae and concluded that mortality rates caused by exposure to seismic are so low compared to the natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

#### **6.5.3.2. Invertebrates**

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

In 2001 and 2003, there were two incidents of multiple strandings of the giant squid (*Architeuthis dux*) on the north coast of Spain. The strandings occurred at about the same time as geophysical seismic

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

McCauley et al. (2000a) reported results from the exposure of caged cephalopods (50 squid and two cuttlefish) to noise from a single 20 in<sup>3</sup> airgun. The cephalopods were exposed to both stationary and mobile sound sources. The two-run total exposure times of the three trials ranged from 69 to 119 minutes at a firing rate of once every 10 to 15 seconds. Maximum zero-to-peak exposure levels were greater than 200 dB re 1 µPa.

Statocysts were removed and preserved but at the time of the study report publication, results of the statocyst analyses were not available. Some of the squid fired their ink sacs apparently in response to the first shot of one of the trials and then moved quickly away from the airgun. However, the ink sac firing was not observed for similar or greater received levels if the signal was ramped up. In addition to the above-described startle responses, some squid also moved towards the water surface as the airgun approached. Sound shadows, areas of lower sound pressure levels, are known to occur there (Richardson et al. 1995). An increase in swimming speed was also exhibited by some of the squid. No squid or cuttlefish mortalities were reported as a result of these exposures.

Pearson et al. (1994) exposed Stage II larvae of the Dungeness crab to single discharges from a seven-airgun seismic array and compared their mortality and development rates with those of unexposed larvae. For immediate and long-term survival and time to molt, this field experiment did not reveal any statistically significant differences between the exposed and unexposed larvae, even those exposed within 1 m of the seismic source.

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

### **6.5.3.3. Summary of Pathological Effects**

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

#### 6.5.4. Physiological Effects

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

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

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

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

1. The seismic survey did not cause any acute or chronic (5 months) mortality of the crab, or any changes to the feeding activity of the treated crabs being held in the laboratory.
2. Neither the survival of embryos being carried by the female crabs during exposure nor the locomotion of the larvae after hatch appeared to be affected.
3. There was acute soiling of gills, antennules and statocysts of the crabs at the exposure site but after 5 months, all structures had returned to their clean state.

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

Lagardère (1982) presented results from laboratory experimentation that suggested that behavioural and physiological reactions of brown shrimp (*Crangon crangon*) were modified by exposure to increased background noise in tanks. Shrimp were kept in two environments for about three months, one noisier than the other. The mean difference in sound level in the 80 to 400 Hz range was 30 to 40 dB (unspecified measure type). There was a significant difference in growth rate and reproduction rate

between the two groups. Those shrimp in the noisier environment had lower rates of each compared to those in the quieter environment. Increased noise levels also appeared to increase aggression (cannibalism) and mortality rate, and decrease food uptake. It is unclear how tank experiments with sound relate to conditions in the wild.

#### **6.5.4.1. Summary of Physiological Effects**

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

#### **6.5.5. Behavioural Effects**

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

##### **6.5.5.1. Fish and Invertebrate Acoustic Detection and Production**

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

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

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

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

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

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

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

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



#### **6.5.5.2. Behavioural Effects of Seismic**

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

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

Christian et al. (2004) conducted an experimental commercial fishery for snow crab before and after the area was exposed to seismic shooting. No drastic decrease in catch rate was observed after seismic shooting commenced. Another behavioural investigation by Christian et al. (2004) involved caging snow crabs, positioning the cage 50 m below a seven-gun array, and observing the immediate responses of the crabs to the onset of seismic shooting by remote underwater camera. No obvious startle behaviours were observed

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

Studies on the effects of sound on fish behaviour have also been conducted using caged or confined fish. Such experiments were conducted in Australia using fish, squid and cuttlefish as subjects (McCauley et al. (2000a,b). Common observations of fish behaviour included startle response, faster swimming, movement to the part of the cage furthest from the seismic source (i.e., avoidance), and eventual habituation. Fish behaviour appeared to return pre-seismic state 15 to 30 minutes after cessation of seismic. Squid exhibited strong startle responses to the onset of proximate airgun firing by releasing ink and/or jetting away from the source. The squid consistently made use of the 'sound shadow' at surface

where the sound intensity was less than at 3-m depth. These Australian experiments provided more evidence that fish and invertebrate behaviour will be modified at some received sound level. Again, these behavioural changes seem to be temporary.

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

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

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

#### **6.5.5.3. Behavioural Effects of Ultrasound**

As mentioned in a previous section, a number of clupeid species can detect and respond to ultrasonic sounds of frequencies up to 180 kHz. Behavioural studies of responses of American shad (*Alosa sapidissima*) to ultrasound demonstrated that these fish show a graded series of responses depending on the received SPL, and to a lesser degree, the frequency of the source sound (Plachta and Popper 2002 in Popper et al. 2004). The American shad exhibited negligible response to sounds below 160 dB re 1  $\mu$ Pa at any frequency. Received SPLs of 175 dB re 1  $\mu$ Pa at 30 to 120 kHz with stimuli of at least one second duration, the shad showed mild reactions to the onset of the sound. Between 175 and 184 dB re 1  $\mu$ Pa at stimulus frequencies ranging between 70 and 110 kHz, the fish showed rapid and directional responses directly away from the sound source. At received SPLs above 185 dB re 1  $\mu$ Pa, the shad

exhibited very rapid and random patterns of behaviours that resulted in some animals attempting to jump from the experimental tank. A field study by Wilson and Dill (2002) showed that Pacific herring (*Clupea pallasii*) reacted in a manner similar to that of the shad in the tank experiment. There is speculation that these responses to ultrasound evolved to help these fish, particularly shallow-water species, detect and avoid echolating cetacean predators.

#### **6.5.5.4. Summary of Behavioural Effects**

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

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

#### **6.5.6. Effects Assessment Summary - Fish VEC**

The best approach when assessing the effects of the proposed seismic program on the fish VEC is to use species that best represent the variability associated with crucial criteria considered during the assessment. It would also be most effective to assess the effects of seismic on species that have been studied after exposure to seismic. Snow crab and Atlantic cod are two species that appropriately serve just that purpose.

The criteria worth consideration in the assessment include (1) distance between the seismic source and animal under normal conditions (post-larval snow crabs remain on bottom, post-larval cod occur in the water column, and larvae of both snow crab and cod are planktonic in upper water column), (2) motility of the animal (post-larval snow crabs much less motile than post-larval cod, and larvae of both are essentially passive drifters), (3) absence or presence of a swim bladder (i.e., auditory sensitivity) (snow crabs without swimbladder and cod with swimbladder), (4) reproductive strategy (snow crabs carry fertilized eggs at the bottom until larval hatch and cod eggs are planktonic), and (5) residency in the Project Area (i.e., year-round vs. seasonal) (snow crab are essentially permanent residents and cod are more temporary residents).

Potential impacts on other marine invertebrate and fish species must be inferred from the assessment using snow crab and Atlantic cod.

Potential interactions between the Project in 2005 and the fish VEC are shown in Table 6.1.

**Table 6.1. Potential Interactions between the Project and Fish VEC.**

Valued Environmental Component: Fish						
	Feeding		Reproduction		Adult Stage	
	Plankton	Benthos	Eggs/Larvae	Juveniles <sup>a</sup>	Pelagic Fish	Groundfish
<b>Project Activities</b>						
Vessel Lights	x		x		x	
Sanitary/Domestic Waste	x		x		x	
Air Emissions	x		x		x	
Garbage <sup>b</sup>						
Noise						
Vessel			x	x	x	x
Seismic Array	x	x	x	x	x	x
Boomer	x	x	x	x	x	x
Echo Sounder	x	x	x	x	x	x
Side Scan Sonar	x	x	x	x	x	x
Helicopters						
Shore Facilities <sup>c</sup>						
Accidental Spills	x		x		x	
<b>OTHER PROJECTS AND ACTIVITIES</b>						
Grand Banks	x	x	x	x	x	x
Scotian Shelf	x	x	x	x	x	x
Exploration	x	x	x	x	x	x
Fisheries	x	x	x	x	x	x
Marine Transportation	x		x		x	x
<sup>a</sup> Juveniles are young fish that have left the plankton and are often found closely associated with substrates. <sup>b</sup> Not applicable as garbage will be brought ashore. <sup>c</sup> There will not be any new onshore facilities. Existing infrastructure will be used.						

#### 6.5.6.1. Physical Effects (Pathological and Physiological)

As indicated in the preceding discussion of the effects of seismic on fish and invertebrates, there is a relative lack of knowledge about the potential physical (pathological and physiological) effects of seismic energy on these marine animals. Available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range. Considering the typical source levels associated with commercial seismic arrays, close proximity to the source would result in exposure to very high sound pressure levels. While egg and larval stages are not able to actively escape such an exposure scenario, juvenile and adult cod would most likely avoid it. Juvenile and adult snow crab are benthic and generally far enough from the source so that the received sound pressure levels are well below the levels that may have had impact during experimentation. In the case of eggs and larvae, it is likely that the numbers negatively affected by such exposure would not be that different from those succumbing to natural mortality. Limited data

regarding physiological impacts on fish and invertebrates indicate that these impacts are short-term and are also most apparent after exposure at close range. Table 6.2 provides the details of the physical effects assessment.

The proposed Project for 2005 is predicted to have *negligible to low* physical effects on the various life stages of the commercial fish VEC over a duration of *1-12 months* in an area  $<1 \text{ km}^2$ . Therefore, physical effects of the proposed program on the fish VEC would be *not significant*.

#### **6.5.6.2. Disturbance Effects (Behavioural)**

Based on the review of the effects of seismic on fish and invertebrates in a preceding section, there is limited data to support any conclusive statements regarding the behavioural effects on these animals as a result of exposure to seismic energy. The available information indicates that behavioural changes in response to noise are short-term. However, there is no available information on what constitutes critical durations of change to the various behaviours. There appears to be a great deal of inter- and intra-specific variability. In the case of finfish, three general types of behavioural responses have been identified: (1) startle, (2) alarm, and (3) avoidance. The type of behavioural reaction appears to depend on many factors, including the type of normal behaviour being exhibited at time of exposure, and proximity and energy level of sound source. The behaviours of most concern would include those associated with reproduction and migration. Behavioural effects on fish and invertebrates appear to occur at greater distances from the seismic source than physical effects. As discussed earlier, certain clupeid fish also exhibit avoidance behaviours when exposed to ultrasound of sufficient amplitude and within a specific frequency range. These responses are temporary in nature. Table 6.2 provides the details of the disturbance effects assessment.

The proposed Project for 2005 is predicted to have *negligible to low* behavioural effects on the various life stages of the fish VEC over a duration of *1-12 months* in an area *11-100* or *101-1,000 km<sup>2</sup>*. Therefore, disturbance effects of the Project on the fish VEC would be *not significant*.

#### **6.5.7. Effects on Commercial Fisheries**

The chief sources for potential impacts of the Project on the commercial fisheries are related to (1) changes in catch rates resulting from noise-induced behavioural changes (scaring) of fish, (2) interference with fishing activities - particularly fixed gear - owing to gear or vessel conflicts, or (3) as a result of effects on stock assessments and DFO research, which is used, among other purposes, for setting fishing quotas or exploring new fisheries. Each of these issues has been raised during consultations and issues scoping for various oil and gas surveys. [Impacts related to physical effects on fish and invertebrates are not discussed here as they were assessed in previous sections, and predicted to be *not significant*.]

**Table 6.2. Effects Assessment on Fish VEC, Including Fish Habitat Considerations.**

Valued Environmental Component: Fish								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/Socio-Cultural and Economic Context
<b>Project Activities</b>								
<b>Vessel Lights</b>	Attraction (N)	-	0	1	2	2	R	1
<b>Sanitary/Domestic Waste</b>	Increased Food (N /P)	-	0	1	1	2	R	1
<b>Air Emissions</b>	Surface Contaminants (N)	-	0	1	1	2	R	1
<b>Garbage<sup>a</sup></b>	Surface Contaminants (N)	-	-	-	-	-	-	-
<b>Noise</b>								
Vessel	Disturbance (N)							
Seismic Array	Physical Effects (N)	Ramp-up Delay Start	0-1	1	1	2	R	1
Seismic Array	Disturbance (N)	Ramp-up Delay Start	0-1	3-4	1	2	R	1
Boomer	Physical Effects (N)		0-1	1	1	2	R	1
Boomer	Disturbance (N)		0-1	3-4	1	2	R	1
Echo Sounder	Disturbance (N)		0-1	3	1	2	R	1
Side Scan Sonar	Disturbance (N)		0-1	3	1	2	R	1
<b>Helicopters</b>	-	-	-	-	-	-	-	-
<b>Shore Facilities<sup>b</sup></b>	-	-	-	-	-	-	-	-
<b>Accidental Spills</b>	Injury/Mortality (N)	Spill Response	1	2	1	1	R	1
<p><b>Key</b></p> <p><b>Magnitude:</b>  0 = Negligible, (essentially no effect)  1 = Low  2 = Medium  3 = High</p> <p><b>Frequency:</b>  1 = &lt; 11 events/yr  2 = 11-50 events/yr  3 = 51-100 events/yr  4 = 101-200 events/yr  5 = &gt; 200 events/yr  6 = continuous</p> <p><b>Reversibility:</b>  R = Reversible  I = Irreversible (refers to population)</p> <p><b>Duration:</b>  1 = &lt;1 month  2 = 1-12 months  3 = 13-36 months  4 = 37-72 months  5 = &gt;72 months</p> <p><b>Geographic Extent:</b>  1 = &lt;1 km<sup>2</sup>  2 = 1-10 km<sup>2</sup>  3 = 11-100 km<sup>2</sup>  4 = 101-1,000 km<sup>2</sup>  5 = 1,001-10,000 km<sup>2</sup>  6 = &gt;10,000 km<sup>2</sup></p> <p><b>Ecological/Socio-cultural and Economic Context:</b>  1 = Relatively pristine area or area not affected by human activity  2 = Evidence of existing effects</p> <p><sup>a</sup> Not applicable as garbage will be brought ashore.  <sup>b</sup> There will not be any new onshore facilities required. Existing infrastructure will be used.</p>								

Although impacts on DFO assessment/research surveys could occur either as a result of behavioural responses or fishing interference (i.e. through the same pathways as impacts on commercial fishing), they are discussed and assessed separately.

As described in the Commercial Fisheries sections (Section 5.5), the 2005 Survey Area has relatively little fishing activity compared with the Project Area as a whole, but the fishery within the 2005 Survey Area, for snow crab, uses fixed gear and thus poses a risk for gear conflict.

The spatial relationship between fish harvesting locations and the survey area is important because the chief means of mitigating any potential impacts on the commercial fisheries surveys (catch effects or gear conflicts) is to avoid fishing areas, particularly fixed gear areas, when they are occupied by harvesters. Operationally, this will require a good knowledge of the 2005 fisheries, excellent at-sea communications, the active involvement of the Fisheries Liaison Officer (FLO) on board (described below), and shore-based support from the Single Point of Contact (SPOC) (see below). Gear damage compensation, in case a conflict does occur, provides a means of final mitigation of impacts.

The potential seismic and geohazard survey interactions between the Project and the fisheries are shown in Table 6.3. The effects assessments are shown in Table 6.4 and Table 6.5.

**Table 6.3. Potential Interactions between the Project and Commercial Fisheries VEC.**

<b>Valued Environmental Component: Commercial Fisheries</b>			
	<b>For Finfish and Mobile Invertebrates (mobile trawls)</b>	<b>For Sedentary Benthic Invertebrates (fixed crab pots)</b>	<b>Research Surveys</b>
<b>Project Activities</b>			
<b>Vessel Lights</b>			
<b>Sanitary/Domestic Waste</b>	x		x
<b>Air Emissions</b>			
<b>Garbage</b>	x		x
<b>Noise</b>			
Seismic Array	x	x	x
Boomer	x	x	x
Side Scan Sonar	x	x	x
Echo Sounder	x	x	x
<b>Vessel Activities</b>			x
Streamer, Ship, geohazard survey equipment	x	x	x
<b>Accidental Spills</b>	x		x
<b>Other Projects and Activities</b>			
<b>Exploration</b>	x	x	x
<b>Marine Transportation</b>	x	x	x

The C-NOPB April 2004 Guidelines (C-NOPB 2004) provide guidance aimed at minimizing any impacts of petroleum industry surveys on commercial fish harvesting. These Guidelines were developed based on best practices during previous years' surveys in Atlantic Canada, and on guidelines from other national jurisdictions. The relevant Guidelines state (Appendix 2, Environmental Mitigative Measures):

- 1.a) The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained.
- 1.c) The operator should publish a Canadian Coast Guard "Notice to Mariners" and a "Notice to Fishers" via the CBC Radio program Fisheries Broadcast.
- 1.d) Operators should implement a gear and/or vessel damage compensation program, to promptly settle claims for loss and/or damage that may be caused by survey operations. The scope of the compensation program should include replacement costs for lost or damaged gear and any additional financial loss that is demonstrated to be associated with the incident. The operator should report on the details of any compensation awarded under such a program.
- 1.e) Procedures must be in place on the survey vessel(s) to ensure that any incidents of contact with fishing gear are clearly detected and documented (e.g., time, location of contact, loss of contact, and description of any identifying markings observed on affected gear). As per Section 4.2 of these Guidelines, any incident should be reported immediately to the 24-hour answering service at (709) 778-1400 or to the duty officer at (709) 682 4426.
- 2.b) Surveys should be scheduled, to the extent possible, to reduce potential for impact or interference with Department of Fisheries and Oceans (DFO) science surveys. Spatial and temporal logistics should be determined with DFO to reduce overlap of seismic operations with research survey areas, and to allow an adequate temporal buffer between seismic survey operations and DFO research activities.
- 2.c) Seismic activities should be scheduled to avoid heavy fished areas, to the extent possible. The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained. The use of a 'Fisheries Liaison Officer' (FLO) on-board the seismic vessel would be considered an acceptable approach.
- 2.d) Where more than one survey operation is active in a region, the operator(s) should arrange for a 'Single Point of Contact' for marine users that may be used to facilitate communication.



The following sections describe how the proposed Husky surveys will meet each of these mitigative guidelines, as well as other measures that will be applied.

### **6.5.8. Impacts on Catch Rates (Fishing Success)**

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

The discussion of the behavioural effects on fish and invertebrates in Section 6.5.2 presents the results of studies on the effects of seismic noise on catch rates. While most - though not all - of these studies report some decrease in catch rates near seismic arrays, there is less agreement on the duration and geographical extent of the effect, ranging from a quick return to several days, and from very localized effects to decreased catch rates as far as 15-km to 20-km away.

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

In general, seismic survey activities avoid active fishing areas because of the risk of gear or vessel conflicts. The parts of the 2005 work area that do have some concentrations of snow crab harvesting will need to be avoided when they are being actively fished. The mitigation measures described below described how this will be implemented.

With these mitigation measures in place, the proposed seismic program is predicted to have low disturbance effects on the fishery (Table 6-4). Therefore, disturbance effects of the Project on this component of the commercial fisheries VEC would be *not significant*.

#### **6.5.8.1. Mitigations**

**Avoidance.** Potential impacts on fishing (catch success as well as gear conflicts) will be mitigated by avoiding heavily fished areas when these fisheries are active (specifically the snow crab areas) to the greatest extent possible. As described in this report, most of the fishing is concentrated in fairly well defined areas within the 2005 Survey and Project areas. The location of activities in these areas especially will be monitored closely by the ship and the FLO (see below) and plotted by Project vessels, and fishing boats will be contacted by radio. Survey personnel (through the SPOC (described below) will also continue to be updated about fisheries near the survey. The mapping of activities contained in this EA report will also be an important source of fisheries information for the survey operators.

**Table 6.4. Effects Assessment on Commercial Fisheries.**

Valued Environmental Component: Commercial Fisheries								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/Socio-Cultural and Economic Context
<b>Project Activities</b>								
<b>Sanitary/Domestic Waste</b>	Increased Food (N/P)	Waste treatment (non-chemical)	0	1	1	2	R	1
<b>Garbage</b>	Surface Contaminants (N)	No at-sea disposal	0	0	0	0	R	1
<b>Noise</b>								
Seismic Array Boomer, Side Scan Sonar, Echo Sounder	Behavioural Response (N/P)	Avoidance, Communications, FLO on board	1	2-3	2	1	R	1
<b>Vessel Activities</b>								
Streamer, ship, geohazard equipment	Gear conflict and damage (N)	Avoidance, FLO, SPOC, Compensation plan	0 <sup>a</sup>	1-2	1	1	R	1
<b>Accidental Spills</b>	Injury/Mortality (N)	Spill Response	1	2	1	1	R	1
<p>Key:</p> <p>Magnitude:  0 = Negligible, essentially no effect  1 = Low  2 = Medium  3 = High</p> <p>Frequency:  1 = &lt; 11 events/yr  2 = 11-50 events/yr  3 = 51-100 events/yr  4 = 101-200 events/yr  5 = &gt; 200 events/yr  6 = continuous</p> <p>Reversibility:  R = Reversible  I = Irreversible (refers to population)</p> <p>Duration:  1 = &lt; 1 month  2 = 1-12 months  3 = 13-36 months  4 = 37-72 months  5 = &gt; 72 months</p> <p>Geographic Extent:  1 = &lt; 1-km<sup>2</sup>  2 = 1-10-km<sup>2</sup>  3 = 11-100-km<sup>2</sup>  4 = 101-1000-km<sup>2</sup>  5 = 1001-10,000-km<sup>2</sup>  6 = &gt; 10,000-km<sup>2</sup></p> <p>Ecological/Socio-cultural and Economic Context:  1 = Relatively pristine area or area not affected by human activity  2 = Evidence of existing effects</p> <p>*N/A = Not Applicable</p>								
<sup>a</sup> This is considered negligible since, if a conflict occurs, compensation will eliminate any economic impact.								

The sequencing of work areas will consider fishing locations, and will be aimed at minimizing any interference with fishing.

**Communications.** During the fisheries consultations for this and other surveys, fisheries representatives noted that good communications is one of the best ways to minimize interference with fishing activities. Communication will be maintained (directly at sea, and through the survey Single Point of Contact) to facilitate information exchange with fisheries participants. This includes such groups as DFO managers, independent fishers, representatives of fisheries organizations such as the FFAWU, and managers of other key corporate fisheries in the area.

Relevant information about the survey operations will also be publicized using established communications mechanisms, such as the *Notices to Shipping* (Continuous Marine Broadcast and NavTex) and CBC (Newfoundland) Radio's *Fisheries Broadcast*, as well as direct communications between the survey vessel and fishing vessels via marine radio at sea.

**Fisheries Liaison Officer.** As a specific means of facilitating at-sea communications, and informing the survey vessel operators about local fisheries, Husky will have an FLO as a "fisheries representative". The FLO will be hired through, and on the advice of, the FFAWU. Experienced FLOs for this survey, knowledgeable about the area's fisheries, have been identified by the Union. The FLO will remain on the relevant survey vessel for the entire program. This will provide a dedicated marine radio contact for all fishing vessels in the vicinity of operations to discuss interactions and resolve any problems that may arise at sea. This person will assist the vessel's bridge personnel to become informed about established fishing activities.

Since 2002 FLOs have been utilized in Newfoundland and Labrador waters and have proven highly effective in communicating with fishers at sea and avoiding gear and fishing conflicts in this Sector.

### **6.5.9. Fishing - Conflict with Fishing Gear**

In previous surveys, concerns have been raised about the seismic vessel or streamer fouling fishing gear, most specifically fixed gear (crab pots in the Project and 2005 Survey areas) if it is concurrent and co-locational with survey operations. In the past, such gear conflicts have occurred in other areas, typically –two or three times a year throughout Atlantic Canada, though in 2003 and 2004 there were no reported cases caused by a survey. (One incident, in Nova Scotia, was the result of a rig transit.) All incidents have involved fixed gear (typically crab or lobster pots, gill nets or large pelagic longlines). When these events have occurred, they have been assessed and compensation paid for losses.

Proposed mitigation plans to avoid active fishing areas are described above. With precautions and compensation plans in place (described below), the economic impacts on fishers would be *negligible*, and thus *not significant*.

### 6.5.9.1. Mitigations

**Avoidance.** As discussed above, potential impacts on fishing gear will be mitigated by avoiding active fixed gear fishing areas. In the past, the diligence of the FLO, good at-sea communications and mapping of fishing locations have usually proven effective at preventing such conflicts.

**Fisheries Liaison Officer.** As described above, the on-board fisheries industry FLO will provide a dedicated marine radio contact for all fishing vessels near project operations to help identify gear locations, assess potential interactions and provide guidance to the Bridge.

**Single Point of Contact.** This has become a standard and effective mitigation for all seismic surveys operating in this sector. The survey will use the firm of Canning & Pitt Associates, Inc. as the survey's SPOC with the fisheries industry, as described in the C-NOPB Guidelines. In addition, as part of their SPOC role, Canning & Pitt Associates, Inc. have provided these services in the Newfoundland and Labrador offshore each year since 1997. They will endeavor to update vessel personnel (e.g. the FLO) about known fishing activities in the area, and will relay relevant information from DFO and fishing companies.

**Fishing Gear Compensation.** In case of accidental damage to fishing gear or vessels, Husky Energy will implement gear damage compensation contingency plans to provide appropriate and timely compensation to any affected fisheries participants. The Notices to Shipping filed by the vessel will also inform fishers that they may contact the SPOC (Canning & Pitt Associates, Inc., toll free at 877-884-3474), if they believe that they have sustained survey-related gear damage.

Husky will follow the procedures (which have been employed successfully in the past) for documenting any incidents; an incident reporting form that will be used, and which meets the requirements of the C-NOPB Guidelines.

Husky is familiar with programs developed jointly by the fisheries industry and offshore petroleum operators (e.g. by the Canadian Association of Petroleum Producers and other Operators) as alternatives to claims through the courts or the C-NOPB, to address all aspects of compensation for attributable gear and vessel damage. These programs include provisions for paying compensation for lost or damaged gear, and any additional financial loss, which is demonstrated to be associated with the incident. The programs include mechanisms for claim payments and dispute resolution. The operator will implement similar procedures to settle claims promptly for any loss or damage that may be caused by survey operations, including the replacement costs for lost or damaged gear, and any additional financial loss that is demonstrated to be associated with the damage, as specified under the 2004 Guidelines, Appendix 2 (1d).

Husky will provide the C-NOPB with details of any compensation to be paid.

### **6.5.10. DFO Research Surveys**

Since these research surveys are conducted by "fishing" for species, the issues related to potential interference with DFO research surveys are essentially the same as for commercial fish harvesting, i.e. potential effects on catch rates, and potential conflicts with the fisheries research operations.

As previously noted, there is some potential for overlap with DFO research surveys of 3L, although the 2005 schedule has not yet been finalized. Last year, surveys in some part of 3L occurred in May and June, and September – December. It will be necessary to obtain more specific information on survey timing and locations for 2005 as it becomes available. This information will be forwarded to the survey operators. It has also been acknowledged, during past surveys, that the best way to prevent overlap between the surveys is to exchange detailed locational information and establish a temporal and spatial separation plan, as was implemented with DFO Newfoundland in the fall of 2002 for other surveys. This is discussed in more detail in the Mitigations section, below.

As discussed below, any DFO survey taking place in the vicinity of the proposed Project surveys will need to be monitored and avoided by the vessel. Given this, the impact on DFO science surveys will be *negligible* and *not significant* (Table 6.5).

#### **6.5.10.1. Mitigations**

The mitigations described above to avoid fisheries disturbance and gear conflicts will apply generally to DFO science cruises.

As in past surveys, the survey vessel and DFO will need to exchange detailed locational information. In 2002 when the plan was implemented in the eastern Newfoundland Region, the exact planned RV survey locations were provided and plotted by the survey ship, and the locations of planned survey lines and daily vessel location reports were provided to DFO. A temporal and spatial separation plan was then agreed with DFO and implemented by the seismic vessel to ensure that their work did not overlap spatially and temporally, and to ensure an adequate "quiet time" before the RV came to the location.

### **6.5.11. Effects on Seabirds**

Interactions between the Project and seabirds are shown in Table 6.6. There are three main potential types of hazards to seabirds from offshore seismic exploration: (1) underwater sound from seismic airguns, boomer, echo sounder and side scan sonar, (2) leakage of petroleum product from streamers, and (3) attraction to ship lights at night.

**Table 6.5. Effects Assessment on Research Surveys.**

Valued Environmental Component: Research Surveys								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/Socio-Cultural and Economic Context
<b>Project Activities</b>								
<b>Sanitary/Domestic Waste</b>	Increased Food (N/P)	Waste treatment (non-chemical)	0	1	1	2	R	1
<b>Garbage</b>	Surface Contaminants (N)	No at-sea disposal	0	0	0	0	R	1
<b>Noise</b>								
Seismic Array Boomer, Side Scan Sonar, Echo Sounder	Behavioural Response (N/P)	Separation plan, Avoidance, Communications	0	2-3	1	1	R	1
<b>Vessel Activities</b>								
Streamer, ship geohazard survey equipment	Gear conflict and damage (N)	Separation plan, Avoidance	0	1-2	1	1	R	1
<b>Accidental Spills</b>	Injury/Mortality (N)	Spill Response	1	2	1	1	R	1
<p>Key:</p> <p>Magnitude:  0 = Negligible, essentially no effect  1 = Low  2 = Medium  3 = High</p> <p>Frequency:  1 = &lt; 11 events/yr  2 = 11-50 events/yr  3 = 51-100 events/yr  4 = 101-200 events/yr  5 = &gt; 200 events/yr  6 = continuous</p> <p>Reversibility:  R = Reversible  I = Irreversible  (refers to population)</p> <p>Duration:  1 = &lt; 1 month  2 = 1-12 months  3 = 13-36 months  4 = 37-72 months  5 = &gt; 72 months</p> <p>Geographic Extent:  1 = &lt; 1-km<sup>2</sup>  2 = 1-10-km<sup>2</sup>  3 = 11-100-km<sup>2</sup>  4 = 101-1000-km<sup>2</sup>  5 = 1001-10,000-km<sup>2</sup>  6 = &gt; 10,000-km<sup>2</sup></p> <p>Ecological/Socio-cultural and Economic Context:  1 = Relatively pristine area or area not affected by human activity  2 = Evidence of existing effects</p> <p>*N/A = Not Applicable</p>								

**Table 6.6. Potential Interactions Between the Project and Marine Birds.**

Valued Environmental Component: Marine Birds	
Project Activities	
Vessel Lights	x
Sanitary/Domestic Waste	x
Air Emissions	x
Garbage*	
Noise	x
Vessel	x
Seismic Array	x
Boomer	x
Sparker	x
Echo Sounder	x
Side Scan Sonar	x
Helicopters	x
Shore Facilities (N/A)	
Accidental Spills	x
OTHER PROJECTS AND ACTIVITIES	
Exploration	x
Fisheries	x
Marine Transportation	x
* Not applicable as garbage will be brought ashore or burned.	

#### 6.5.11.1. Sound Effects Assessment on Seabirds

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

Most species of seabirds that are expected to occur in the Project Area feed at the surface or at less than one metre below the surface of the ocean (see Table 5.8). This includes *Procellariidae* (Northern Fulmar, Greater Shearwater, Sooty Shearwater and Manx Shearwater), *Hydrobatidae* (Wilson's Storm-Petrel and Leach's Storm-Petrel), *Phalaropodinae* (Red Phalarope and Red-necked Phalarope), *Laridae* (Great Skua, South Polar Skua, Pomarine Jaeger, Parasitic Jaeger, Long-tailed Jaeger, Herring Gull, Iceland Gull, Glaucous Gull, Great Black-backed Gull, Ivory Gull, Black-legged Kittiwake and Arctic Tern). Northern Gannet plunge dive to a depth of 10 metres. These species are under the surface for a few seconds during each dive so would have minimal opportunity to receive underwater sound.

There is only one group of seabirds occurring regularly in the Project Area that require considerable time under water to secure food. They are the *Alcidae* (Dovekie, Common Murre, Thick-billed Murre, Razorbill and Atlantic Puffin). From a resting position on the water they dive under the surface in

search of small fish and invertebrates. Alcids use their wings to propel their bodies rapidly through the water. All are capable of reaching great depths and spending considerable time under water (Gaston and Jones 1998). An average duration of dive times for the five species of *Alcidae* is 25-40 seconds reaching an average depth of 20-60 m, but murre are capable of diving to 120 m and have been recorded underwater for up to 202 seconds (Gaston and Jones 1998).

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

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

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

While supporting data on effects (or lack thereof) are few, it is predicted that there will be *no significant effect* on seabirds from the sound because the magnitude of the effect (if it occurs) will be low, the geographic extent will be small (probably <1 km<sup>2</sup>), and duration will be <1 year (Table 6.7).

#### **6.5.11.2. Petroleum Leakage from Streamers**

Seismic streamers may be solid-filled, semi-solid, or contain a paraffinic hydrocarbon called Isopar M for flotation. The precise effects of Isopar M on birds is not known. However, all petroleum products have detrimental effects on the insulating attributes of seabird's feathers. It is a kerosene-like product that can leave a relatively thin-layered slick on the surface of water under calm conditions. It evaporates readily. The break-down process is speeded up by sunlight, wind, wave and ship's propellor action. The streamers are constructed of self-contained units 100 m in length. Therefore, a single leak in a steamer should result in a maximum loss from one 100 m section of no more than 208 litres.

All seabirds expected to occur in the Project Area, except Arctic Tern, spend considerable time resting on the water. Birds that spend most of their time on water, such as the murre, Atlantic Puffins and Dovekies, would be most likely species to suffer harmful effects from an Isopar M slick. Northern Fulmar, the shearwaters and storm-petrels are attracted to slicks but would not likely confuse it with a natural oceanic slick comprised of zooplankton or offal. However, flocks of seabirds resting on the water would not necessarily get out of the water if they drifted into an Isopar M slick.



**Table 6.7. Effects Assessment on Marine Birds.**

Valued Environmental Component: Seabirds								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/Socio-Cultural and Economic Context
<b>Project Activities</b>								
<b>Vessel Lights</b>	Attraction (N)	Turn off non-essential exterior lighting	1	2	6	2	R	2
<b>Sanitary/Domestic Waste</b>	Increased Food (N/P)	-	1	1	6	2	R	1
<b>Air Emissions</b>	Surface Contaminants (N)	-	0	1	6	2	R	1
<b>Garbage</b>	Surface Contaminants (N)	-	-	-	-	-	-	-
<b>Noise</b>								
Vessel	Disturbance (N)	-	0	-	1	2	R	1
Seismic Array	Physical Effects (N)	-	0-1	1	1	2	R	1
Seismic Array	Disturbance (N)	-	0-1	1	1	2	R	1
Boomer	Physical Effects (N)	-	0-1	1	1	1	R	1
Boomer	Disturbance (N)	-	0-1	1	1	1	R	1
Echo Sounder	Disturbance (N)	-	0-1	1	1	1	R	1
Side Scan Sonar	Disturbance (N)	-	0-1	1	1	1	R	1
<b>Helicopters</b>	Disturbance (N)	-	-	-	-	-	-	-
<b>Shore Facilities (N/A)<sup>b</sup></b>	-	-	-	-	-	-	-	-
<b>Accidental Spills</b>	Injury/Mortality (N)	Spill Response	1	1	1	2	R	1
<p><b>Key:</b></p> <p><b>Magnitude:</b>  0 = Negligible, (essentially no effect)  1 = Low  2 = Medium  3 = High</p> <p><b>Frequency:</b>  1 = &lt;11 events/yr  2 = 11-50 events/yr  3 = 51-100 events/yr  4 = 101-200 events/yr  5 = &gt;200 events/yr  6 = continuous</p> <p><b>Reversibility:</b>  R = Reversible  I = Irreversible (refers to population)</p> <p><b>Duration:</b>  1 = &lt;1 month  2 = 1-12 months  3 = 13-36 months  4 = 37-72 months  5 = &gt;72 months</p> <p><b>Geographic Extent:</b>  1 = &lt; 1 km<sup>2</sup>  2 = 1-10 km<sup>2</sup>  3 = 11-100 km<sup>2</sup>  4 = 101-1,000 km<sup>2</sup>  5 = 1,001-10,000 km<sup>2</sup>  6 = &gt;10,000 km<sup>2</sup></p> <p><b>Ecological/Socio-cultural and Economic Context:</b>  1 = Relatively pristine area or area not affected by human activity  2 = Evidence of existing effects</p> <p>*N/A = Not Applicable</p>								

An exposure to a surface slick of a kerosene-like substance under very calm conditions may harm or kill individual birds. However, because spills will likely be small, and evaporation and dispersion rapid, the magnitude, and geographic extent of any spills will be insufficient to cause significant effects on the populations of the area and therefore any effects will be *not significant* (see Table 6.7).

#### **6.5.11.3. Attraction to Lights on Ship**

Storm-Petrels, mainly Leach's Storm-Petrels, are often attracted to lights at night. This includes lights at coastal lighthouses and ships at sea. Montevecchi et al. (1999) describes the problem of lights and flares on offshore platforms and support vessels. Lights on foggy nights may attract more birds than on clear nights. The birds may become injured by flying directly into the source of light or the ship infrastructure. Storm-Petrels may land on ships at night and become 'stranded'. Storm-Petrels have short weak legs and have trouble becoming airborne from a solid flat surface. Procedures developed by Canadian Wildlife Service (CWS) and Petro-Canada will be used to handle the birds and gently release them. It is recognized by Husky that a CWS *Bird Handling Permit* will likely be required. Bird handling mitigations will reduce any effects to *negligible* and thus *not significant*.

### **6.5.12. Marine Mammals and Sea Turtles**

#### **6.5.12.1. Effects of Seismic and Geohazards Sounds**

Airguns used during marine seismic operations introduce strong sound impulses into the water. The seismic pulses produced by the airguns are directed downward toward the seafloor, insofar as possible; however, energy will propagate outward from the source through the water. The airguns could have several types of effects on marine mammals and sea turtles and are the principal concern associated with the proposed seismic survey. Sounds from the geohazards equipment are of less concern given their relatively lower source levels, emittance in a narrow beam, short duration of the geohazards program, and that some equipment operates at frequencies outside the range of marine mammal and sea turtle hearing abilities. There is relatively little information available for the responses of marine mammals and sea turtles to sonar sounds that would be produced during the geohazards survey. Sounds from the geohazards equipment are very short pulses, 1-4 times every sec, depending on water depth and are emitted in a narrow beam.

To assess the potential effects of the proposed seismic and geohazards survey on the marine mammals and turtles of the Jeanne d'Arc Basin, this section provides the following: (A) a summary of the types of noise effects on marine mammals and sea turtles; (B) a description of the hearing abilities of marine mammals and sea turtles, (C) a discussion of the potential for masking by seismic (and geohazards) surveys, (D) disturbance effects of seismic (and geohazards) surveys, (E) the possibility of hearing impairment by seismic surveys, (F) the possibility of strandings and mortality, and (G) non-auditory physiological effects.

#### **6.5.12.1.1. (A) Categories of Noise Effects**

The effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioural response;
3. The noise may elicit reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviours (detectable only by statistical analysis) to active avoidance reactions;
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any man-made noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, the intermittent airgun pulses that will be broadcast during the proposed survey could cause masking for only a small proportion of the time at close distances, given the short duration of airgun pulses relative to the inter-pulse intervals;
6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

#### **6.5.12.1.2. (B) Hearing Abilities of Marine Mammals and Sea Turtles**

The hearing abilities of marine mammals (and other animals including sea turtles) are functions of the following (Richardson et al. 1995; Au et al. 2000):

1. Absolute hearing threshold (the level of sound barely audible in the absence of ambient noise);
2. Critical ratio (the signal-to-noise ratio required to detect a sound at a specific frequency in the presence of background noise around that frequency);

3. The ability to localize sound direction at the frequencies under consideration; and
4. The ability to discriminate among sounds of different frequencies and intensities.

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many man-made sounds including sounds made during seismic exploration.

### **Toothed Whales**

Hearing abilities of some toothed whales (odontocetes) have been studied in detail, as reviewed in Chapter 8 of Richardson et al. (1995) and in Au et al. (2000). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kilohertz (kHz), but extremely good sensitivity at, and above, several kHz. There are at present no specific data on the absolute hearing thresholds of the larger, deep-diving toothed whales, such as the sperm and beaked whales.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes remain above the hearing thresholds of odontocetes such that the pulse could be heard at distances out to several tens of kilometers (Richardson and Würsig 1997). However, there is no evidence that odontocetes react to airgun pulses at such long distances, or even at intermediate distances where sound levels are well above the ambient noise level (see below).

The Huntec boomer operated from the *MV Anticosti* emits pulsed sounds with frequency bandwidth from 500 Hz to 6 kHz. That frequency is within the hearing range of many odontocetes. The side-scan sonar emits pulsed sounds at dual frequencies of 100 kHz and 398 kHz. The 100 kHz channel can likely be heard by some odontocetes. The multibeam echosounder operates at frequencies of 240 kHz. Thus, sound pulses from the boomer and sidescan sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam. However, the multibeam echosounder operates at frequencies (240 kHz) that are likely too high to be detected by odontocetes.

### **Baleen Whales**

The hearing abilities of baleen whales have not been studied directly. Behavioural and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centered at 4 kHz (see Richardson et al. 1995 for a review). Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpbacks, to >15 kHz (Au et al. 2001). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds

(Ketten 2000). The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies. Ambient noise energy is higher at low frequencies than at mid frequencies. At frequencies below 1 kHz, natural ambient levels tend to increase with decreasing frequency.

The hearing systems of baleen whales are almost certainly more sensitive to low-frequency sounds than are the ears of the small toothed whales. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales. However, baleen whales have commonly been seen well within the distances where seismic sounds would be detectable and yet show no overt reaction to those sounds. Behavioural responses by baleen whales to seismic pulses have been documented, but received levels of pulsed sounds necessary to elicit behavioural reactions are typically well above the minimum detectable levels (Malme et al. 1984, 1988; Richardson et al. 1986, 1995, 1999; McCauley et al. 2000a; Johnson 2002).

Sound pulses from the Hunttec boomer operated from the *MV Anticosti* will likely be readily audible to baleen whales. However, the multibeam echosounder and side-scan sonar operate at frequencies that are likely too high to be detected by baleen whales.

## **Pinnipeds**

Underwater audiograms have been obtained using behavioural methods for three species of phocinid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995:211ff; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). In comparison with odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, higher auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid (hair) seals have better sensitivity at low frequencies ( $\leq 1$  kHz) than do odontocetes. Below 30–50 kHz, the hearing threshold of most species tested are essentially flat down to about 1 kHz, and ranges between 60 and 85 dB re 1  $\mu$ Pa. Recent measurements for a harbor seal indicate that, below 1 kHz, its thresholds deteriorate gradually to ~97 dB re 1  $\mu$ Pa at 100 Hz (Kastak and Schusterman 1998). The northern elephant seal (not an Atlantic species) appears to have better underwater sensitivity than the harbor seal, at least at low frequencies (Kastak and Schusterman 1998, 1999).

Sound pulses from the Hunttec boomer operated from the *MV Anticosti* will likely be readily audible to phocids. However, the multibeam echosounder and side-scan sonar operate at frequencies that are likely too high to be detected by phocids.

## **Sea Turtles**

The limited available data indicate that the frequency range of best hearing sensitivity by sea turtles extends from roughly 250–300 Hz to 500–700 Hz (Ridgway et al. 1969; Bartol et al. 1999), which

overlaps with the frequencies of airgun sound pulses and the Hunttec boomer. Sensitivity deteriorates as one moves away from this range to either lower or higher frequencies. However, there is some sensitivity to frequencies as low as 60 Hz, and probably as low as 30 Hz. Thus, there is substantial overlap in the frequencies that sea turtles detect vs. the frequencies in airgun pulses. Given that, plus the high levels of airgun pulses, sea turtles undoubtedly hear airgun sounds. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. Given the high source levels of airgun pulses and the substantial levels even at distances many kilometers away from the source, sea turtles probably can hear distant seismic vessels. However, in the absence of relevant absolute threshold data, one cannot estimate how far away an airgun array might be audible. It is likely sea turtles can hear sounds from the Hunttec boomer but unlikely that they can hear the side-scan sonar and echosounder.

#### **6.5.12.1.3. (C) Masking Effects of Seismic Surveys**

Masking is the obscuring of sounds of interest by interfering sounds, usually at similar frequencies. Marine mammals are highly dependent on sound and their ability to recognize sound signals amidst noise is important in communicating, detecting predators, locating prey, and in toothed whales, echolocation. Marine mammals are adapted to cope with some degree of “masking” by natural sounds like surf noise. 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 1,000 Hz (e.g., Tolstoy et al. 2004). These frequencies are mainly used by mysticetes. Seismic sounds are short pulses occurring every 10-20 sec. Pulse duration is short, e.g., 20 ms, when the pulse is received near the source, but tends to become longer during propagation and may be 0.25 s to 0.5 s, or longer, when received at a distance of several kilometers. Even then, the gaps between pulses are much longer than the pulses themselves. Some baleen whales are known to continue calling in the presence of seismic pulses. Bowhead whale calls (Richardson et al. 1986; Greene et al. 2000) and blue whale calls (McDonald et al. 1995; Niekirk et al. 2004) calls can be heard between the seismic pulses. The discontinuous nature of seismic pulses makes significant masking effects unlikely even for mysticetes whose calls may be at the same frequencies as the dominant energy in airgun pulses. Masking effects of seismic (and sonar) pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or possibly to shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; reviewed in Richardson et al. 1995: 233ff, 364ff). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, and 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.

It has been suggested (Eckert 2000) that sea turtles use passive reception of acoustic signals to detect the hunting sonar of killer whales; however, the echolocation calls of killer whales are at frequencies that are probably too high for sea turtles to detect. Hearing may play a role in sea turtle navigation. However, recent studies suggest that visual, wave, and magnetic cues are the main navigational cues used by sea turtles, at least by hatchlings and juveniles (Lohmann et al. 1997, 2001; Lohmann and Lohmann 1998). Therefore, masking is probably not relevant to sea turtles. Even if acoustic signals were important to sea turtles, their hearing is best at frequencies slightly higher (250 to 700 Hz) than frequencies where most airgun sounds are produced (<200 Hz), although their hearing extends down to the airgun frequencies. If sea turtles do rely on acoustical cues from the environment, the wide spacing between seismic (and sonar) pulses would permit them to receive these cues, even in the presence of seismic activities.

Thus, masking is unlikely to be a significant issue for either marine mammals or sea turtles exposed to the pulsed sounds from seismic and geohazards surveys.

#### **6.5.12.1.4. (D) Disturbance by Seismic Surveys**

Disturbance includes a variety of effects, including subtle changes in behaviour, more conspicuous dramatic changes in activities, and displacement. Disturbance is one of the main concerns in this project. For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic pulses. Behavioural reactions of marine mammals to sound are difficult to predict. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. 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 let alone 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.

The sound criteria often used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioural observations during studies of several species. However, information is lacking for many species. Detailed, systematic studies have been done on humpback, gray and bowhead whales, and on sperm whales. Less detailed data are available (primarily from monitoring studies from seismic ships) for some other species of baleen whales, sperm whales, and small toothed whales. There is little information available for sea turtle response to seismic surveys.

#### **Baleen Whales**

Humpback, gray, 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, 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a; Miller et al. 1999). Fin and blue whales also show

some behavioural reactions to airgun noise (McDonald et al. 1995; Stone 1997, 1998, 2000). Prior to the late 1990s, it was thought that bowhead whales, gray 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  $\mu$ Pa (rms), but that 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  $\mu$ Pa (rms). The observed avoidance reactions involved 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 or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors. The results of systematic studies for humpback, gray, and bowhead whales are provided below. Results of seismic monitoring studies pertaining to these and other species are provided below.

*Humpback Whales:* McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-gun 2,678 in<sup>3</sup> array, and to a single 20 in<sup>3</sup> airgun with source level 227 dB re 1  $\mu$ Pa·m (p-p). They found that the overall distribution of humpbacks migrating through their study area was unaffected 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 1  $\mu$ Pa (rms); this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. 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 100–400 m, where the maximum received level was 179 dB re 1  $\mu$ Pa (rms).

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64 L (100 in<sup>3</sup>) airgun (Malme et al. 1985). Some humpbacks seemed “startled” at received levels of 150–169 dB re 1  $\mu$ Pa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1  $\mu$ Pa (rms).

*Bowhead Whales:* Bowhead whales on their summering grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6 to 99 km and received sound levels of 107–158 dB (rms) (Richardson et al. 1986); their general activities were indistinguishable from those of a control group. Bowheads usually did show strong avoidance responses when seismic vessels



approached within a few kilometers (~3-7 km) and when received levels of airgun sounds were 152-178 dB (Richardson et al. 1986, 1995). In one case, bowheads engaged in near-bottom feeding began to turn away from a 30-gun array with a source level of 248 dB at a distance of 7.5 km, and swam away when it came within about 2 km. Some whales continued feeding until the vessel was 3 km away. The results of a seismic monitoring program conducted in the nearshore waters of the Canadian Beaufort Sea in the summers of 2001 and 2002 (Miller and Davis 2002; Miller and Moulton 2003; Miller et al. 2005) supports the findings of the aforementioned study. Lower sighting rates and greater sighting distances during periods of seismic operations vs. periods when no guns were operating suggests that bowheads did avoid close approach to the area of seismic operations. However, the still substantial number of sightings during seismic periods and the relatively small (600 m) but significant difference in sighting distances suggests that the avoidance was localized and relatively small in nature. Feeding bowhead whales tend to tolerate higher sound levels than migrating whales before showing an overt change in behaviour. The feeding whales may be affected by the sounds, but the need to feed may reduce the tendency to move away.

Migrating bowhead whales in the Alaskan Beaufort Sea seem more responsive to noise pulses from a distant seismic vessel than are summering bowheads. In 1996-98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20-30 km, and that few bowheads approached within 20 km. Received sound levels at those distances were only 116-135 dB re 1  $\mu$ Pa (rms). Some whales apparently began to deflect their migration path when still as much as 35 km away from the airguns. At times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area of seismic operations did not persist beyond 12-24 h after seismic shooting stopped. These and other data suggest that migrating bowhead whales are more responsive to seismic pulses than were summering bowheads.

*Gray Whales:* Malme et al. (1986, 1988) studied the responses of feeding gray whales to pulses from a single 100 in<sup>3</sup> airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1  $\mu$ Pa (rms), and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Malme et al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6 to 2.8 km from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. These findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1  $\mu$ Pa (rms) and higher. The 50% probability of avoidance was estimated to occur at a distance of 2.5 km from a 4,000 in<sup>3</sup> array operating off central California. This would occur at an average received sound level of about 170 dB (rms). Some slight behavioural changes were noted at received sound levels of 140 to 160 dB (rms).

There was no indication that Western gray whales exposed to seismic noise were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001, but there were indications of subtle behavioural effects and (in 2001) localized avoidance by some individuals (Johnson 2002; Weller et al. 2002). An intensive monitoring program involving vessel- and shore-based observations, aerial surveys, and acoustic measurements was implemented in 2001 to provide information on gray whale reactions to seismic noise, and to facilitate implementation of a mitigation program (Johnson 2002). (The 1997 study was less detailed.) The seismic array used in 2001 had a total volume of 1,640 in<sup>3</sup> during operations adjacent to the primary gray whale feeding area. Results of the monitoring program are outlined below:

- Aerial surveys, combined with shore- and vessel-based observations, showed that gray whales remained in the general region where the seismic survey was conducted, but some individual whales were displaced locally.
- Aerial survey results and corresponding multivariate statistical analyses did not indicate that the frequency of gray whale feeding behaviour in the overall region was influenced by seismic surveys even though the surveys apparently caused some local avoidance.
- Observations from shore adjacent to the area where whales fed and where the seismic program occurred showed no direct connection between local gray whale abundance and seismic surveys. Some behavioural parameters were correlated with seismic survey activity, but the behavioural effects were short-term and within the natural range of variation.
- Acoustic monitoring revealed that gray whales located in primary feeding habitat were not exposed to received levels of seismic sound exceeding 163 dB re 1 µPa (rms).
- Gray whales continued to feed in the same general areas in 2001 as in 1999 and 2000 when there were no seismic surveys in the immediate area, but the seismic survey apparently caused some local relocation of certain individual gray whales (Johnson 2002).

#### *Monitoring Studies and Baleen Whales:*

Several monitoring programs designed to monitor the influences of seismic operations on marine mammals (and sea turtles) are available, including:

- Joint Nature Conservation Committee's (JNCC) monitoring program in United Kingdom (Stone 2003)
- Marathon's 2003 monitoring program in Scotian Slope (Moulton and Miller 2004, 2005)
- Lamont-Doherty Earth Observatory's (L-DEO) monitoring programs (Smultea and Holst 2003; Haley and Koski 2004; Holst 2004; MacLean and Haley 2004; Smultea et al. 2004)

With the exception of the JNCC program, details concerning dates of operation, the types of airgun arrays (including source level), used in each seismic program and the marine mammal monitoring effort are provided in Table 6.8. The results of each monitoring program are summarized in Table 6.9 and described in more detail below for baleen whales.

**Table 6.8. Recent Seismic Programs and Corresponding Marine Mammal Monitoring Programs.**

			Airgun Source			Hours of Visual Observation	
Location	Water Depth (m)	Dates	No./Type of Guns	Total Volume (in <sup>3</sup> )	Source Level @ 1 m (dB re 1µPa)	Seismic	Non-seismic
Scotian Slope	200-4800	21 May-17 Oct 2003	28 Sleeve guns	3090	228 (rms)	552	431.4
NW Atlantic	2468-5372	16 Jul-15 Aug 2004	Single GI	75	230 (0-pk)	243	45
SE Caribbean <sup>a</sup>	15-6000	18 Apr-3 Jun 2004	20 Bolt	6947	255 (0-pk)	438	479
Mid-Atlantic Ridge	1500-4500	25 Oct-9 Nov 2003	20 1,500C Bolt	8760	255 (0-pk)	20.4	22.2
Norwegian Sea	<100-5000	29 Aug-26 Sep 2003	2 GI, 6 1,500C Bolt 10 1,500C	210, 1350	237 (0-pk), 243 (0-pk)	265.8	71.3
E. Pacific	2000-3400	12-23 Jul 2003	Bolt, 12 1500C Bolt	3050, 3660	248 (0-pk), 250 (0-pk)	99.1	41.3
<sup>a</sup> There was also 846 h (800 h during seismic and 46 h during non-seismic periods) of passive acoustic monitoring for marine mammals (via SeaMap system).							

**Table 6.9. Marine Mammal Sighting and Effects of Seismic Programs During Recent Monitoring Programs.**

Location	Species Observed			Seismic Effects <sup>a,b</sup>
	Dolphins	Baleen Whale	Other Toothed Whale	
Scotia Slope	LF Pilot Whale, Atl. White-sided, Spotted, SB Common, Risso's, Striped Dolphin	Blue, Fin, Humpback, Minke	Sperm, Northern Bottlenose Whale	<b>Dolphin</b> sighting rates higher during seismic periods (not significant); CPA significant farther away during seismic periods; behaviours similar during seismic & non-seismic periods. <b>Baleen whale</b> sighting rates lower during seismic periods (not significant); similar CPA; more likely to 'swim away' during seismic periods. <b>Toothed whale</b> (caution: small sample size) sighting rates lower during seismic periods; CPA farther away during seismic periods (not significant); perhaps more likely to 'swim away' during seismic periods.
NW Atlantic	LF Pilot Whale, Atl. Spotted, SB Common, Bottlenose Dolphin	Fin, Humpback	Sperm, Northern Bottlenose Whale	<b>Cetacean</b> density lower during seismic periods; CPA closer during seismic periods.
SE Caribbean	SF Pilot Whale, Atl. Spotted, LB Common, Bottlenose, Pantropical Spotted, Spinner, Striped Dolphin	Bryde's, Fin	Sperm Whale	<b>Cetacean</b> density lower during seismic periods; CPA farther away during seismic periods; more acoustic detections during seismic periods.
Mid-Atlantic Ridge	-	-	-	Too few sightings.
Norwegian Sea	LF Pilot Whale	Fin, Minke	Unident. Beaked Whale	All sightings during seismic periods. Therefore, no comparisons between seismic and non-seismic periods possible.
E. Pacific	-	-	Unident. Beaked Whale	Too few sightings.
<sup>a</sup> 'Significance' refers to statistically significant results.				
<sup>b</sup> CPA refers to closest point of approach to the seismic ship.				

**JNCC 1997-2000.**—Over 44,000 h of observations were collected by MMOs aboard seismic ships during 1997-2000 in UK waters (Stone 2003). Details concerning the types of airgun arrays (specific volumes and source levels) are not provided. Typically, full-scale seismic surveys used arrays  $>3,000 \text{ in}^3$  and site surveys used arrays of  $<180 \text{ in}^3$ . Blue, sei, fin, and minke whales have occasionally been reported in areas ensounded by airgun pulses. Sightings by observers on seismic vessels off the U.K. from 1997–2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly farther from the airguns during shooting compared with periods without shooting (Stone 2003). Baleen whale pods sighted from the ship were found to be at a median distance of about 1.6 km from the array during shooting and 1.0 km during periods without shooting (Stone 2003). Baleen whales, as a group, made more frequent alterations of course (usually away from the vessel) during shooting compared with periods of no shooting (Stone 2003). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003).

**Scotian Slope Monitoring Program, 2003.**—In late May to mid-October 2003, a marine mammal monitoring program (from the MV *Ramform Viking*) was conducted during Marathon's 3-D seismic program on the Scotian Slope in EL 2410 and 2411 (Moulton and Miller 2004, 2005). Water depths ranged from 200-4,800 m. The acoustic sources were two  $3,090 \text{ in}^3$  arrays consisting of 28 airguns which fired alternatively. Based on available data from ship-based monitoring, there is some evidence that indicates baleen whales exhibited localized avoidance of seismic operations. Baleen whale sighting rates were lower during seismic vs. non-seismic periods. The lower sighting rates recorded during seismic operations suggest that some baleen whales avoided the seismic operations by larger distances and thereby stayed out of visual range of the marine mammal monitors on the *Viking*. However, the radial distances at which baleen whales were initially sighted were, on average, similar during periods of No Guns (mean = 1,303 m) vs. periods of Array Seismic (mean = 1,311 m) and All Seismic (mean = 1,324 m). There was some indication that the likelihood for a baleen whale to “swim away” was higher during seismic operations vs. non-seismic periods, insofar as could be determined by behavioural observations from the seismic vessel. Baleen whales at the average sighting distance (1,324 m) during seismic operations would have been exposed to sound levels (via direct path) of about 169 dB re  $1 \mu\text{Pa}$  (rms) (back-calculated from field measurements using RAM Model) (Moulton and Miller 2005).

**Lamont-Doherty Earth Observatory's Monitoring Programs, 2003-2004.**—Baleen whales were sighted during three of the five Lamont-Doherty Earth Observatory's (L-DEO) monitoring programs (Table 6.9). Given the small sample sizes, the L-DEO report authors pooled baleen whale and toothed whale sightings in one category—“cetaceans” when examining the influences of seismic.

In July and August 2004, a marine mammal monitoring program was conducted during L-DEO seismic program in the Northwest Atlantic at a site 537-796 km southeast of Newfoundland in waters ranging from 2,468-5,372 m (Haley and Koski 2004). The seismic source was a single  $75 \text{ in}^3$  GI airgun (Table 6.8). Considering all cetaceans together (there were too few sightings to analyze data on a species level), observed cetacean density determined from visual observations were lower during seismic vs.

non-seismic periods. Comparisons of the closest point of approach (CPA) showed that cetaceans (especially delphinids) tended to be closer during seismic (mean = 1,184 m) vs. non-seismic (mean = 1,365 m) periods. All six baleen whale sightings during the NW Atlantic cruise occurred during non-seismic periods (one sighting of four fin whales, two sightings of individual humpback whales and three sightings consisting of 10 unidentified baleen whales).

In April to June 2004, a marine mammal monitoring program (visual plus passive acoustic monitoring) was conducted during L-DEO seismic program in the Southeast Caribbean in waters ranging from 15-6,000 m (Smultea et al. 2004). The seismic source was comprised of 20 Bolt airguns with a total volume of 6,947 in<sup>3</sup> (Table 6.8). There were only three visual sightings of baleen whales (two Bryde's whale and one unidentified baleen whale) from the seismic ship and no acoustic detections. When considering all cetaceans combined, the results of the monitoring program indicate that seismic sounds displaced or deterred cetaceans from approaching the seismic ship, and/or affected their behaviour. Apparent densities of cetaceans during seismic periods were 35-55% of those during non-seismic periods. Also, comparisons of the closest point of approach (CPA) showed that cetaceans tended to be closer during non-seismic (mean = 352 m) vs. seismic (mean = 1,376 m) periods.

In late August to September 2003, a marine mammal monitoring program was conducted during L-DEO seismic program in the Norwegian Sea in waters ranging from <100-5,000 m (MacLean and Haley 2004). Two seismic sources were used: two GI airguns (each 105 in<sup>3</sup>) and six 1,500C Bolt airguns with a total volume of ~1,350 in<sup>3</sup> (Table 6.8). All marine mammals, including one fin whale and five minke whale sightings, were sighted during seismic periods (265.8 h of daylight observations), despite 71.2 h of (daylight) observations when the airguns were inactive. The baleen whales exhibited variable behaviour, three individuals or groups 'swam away' and three either 'swam towards' or 'swam parallel' to the seismic ship.

*Discussion and Conclusions:* Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, recent studies of humpback and especially bowhead whales show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased.

Some baleen whales do not exhibit any indications of disturbance by 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 reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and 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 many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km from the source. 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. Gray whales continue to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were 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 gray whales mentioned above. Numerous seismic monitoring programs around the world provide information on toothed whale, primarily delphinids, responses to seismic programs.

***Delphinids:*** Seismic operators sometimes see species of toothed whales near operating airgun arrays (e.g., Duncan 1985; Arnold 1996; Stone 2003). When a 3,959 in<sup>3</sup>, 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 regardless of whether the guns were firing. However, in Puget Sound, Dall's porpoises observed when a 6,000 in<sup>3</sup>, 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 2-D 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 (as part of the JNCC program) operating off the United Kingdom in 1997–2000 have provided data on the occurrence and behaviour of various toothed whales exposed to

seismic pulses (Stone 2003). Dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods of shooting. Except for pilot whales, all of the small odontocete species tested, including killer whales, were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales showed few reactions to seismic activity. The displacement of the median distance from the array was ~0.5 km or more for most species groups. Killer whales also appear to be more tolerant of seismic shooting in deeper waters. For all small odontocete species, except pilot whales, that were sighted during seismic surveys off the United Kingdom from in 1997–2000, the numbers of positive interactions with the survey vessel (e.g., bow-riding, approaching the vessel, etc.) were significantly fewer during periods of shooting. All small odontocetes combined showed more negative interactions (e.g., avoidance) during periods of shooting. Small odontocetes, including *Lagenorhynchus* spp. and other dolphin spp., showed a tendency to swim faster during periods with seismic shooting; *Lagenorhynchus* spp. were also observed to swim more slowly during periods without shooting. Significantly fewer white-beaked dolphins, *Lagenorhynchus* spp., harbor porpoises, and pilot whales traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting.

During Marathon’s 3-D seismic program on the Scotian Slope (Moulton and Miller 2004, 2005; see Tables 6.9), dolphins were consistently observed from the seismic ship during periods when the airguns were active, and quite often approached the ship during seismic operations. There was no indication that the likelihood for a dolphin to “swim away” was higher during seismic operations vs. non-seismic periods insofar as could be determined by visual observations from the seismic ship (Moulton and Miller 2004). Dolphin sighting rates (Table 6.9) were higher during seismic vs. non-seismic periods; although the differences were not statistically significant. Despite the higher sighting rates during seismic periods and the seemingly “positive” behavioural reactions by some dolphins, the radial distances at which dolphins were initially sighted were, on average, significantly smaller during periods of No Guns (mean = 854 m) than during periods of Array Seismic (mean = 985 m) and All Seismic (mean = 1,073 m). These findings suggest that some dolphins exhibited localized avoidance of the seismic operations. Dolphins at the average sighting distance (1,073 m) during seismic operations would have been exposed to sound levels (via direct path) of about 169 dB re 1  $\mu$ Pa (rms). Some dolphins, especially long-finned pilot whales, approached the seismic ship within 300 m (and on two occasions within 150 m of the airguns) and hence, may have been exposed to sound levels exceeding 190 dB re 1  $\mu$ Pa (rms) (Austin et al. 2004).

Dolphins were detected during three of the five L-DEO monitoring programs (Table 6.9). As already mentioned, the L-DEO report authors pooled toothed and baleen whale sightings in one category—“cetaceans” when examining the influences of seismic. Cetacean densities were lower during seismic vs. non-seismic periods. During the SE Caribbean monitoring program (Smultea et al. 2004), in contrast to visual results, acoustic detection rates were considerably higher during seismic vs. non-seismic periods. The authors speculate that delphinids called more frequently while the airguns were active or that calls may have increased in response to, or to “compensate for”, the airgun sounds. Another

possibility is that more delphinids were in the area during seismic operations but that they were not readily detectable visually.

Captive bottlenose dolphins and beluga whales exhibit changes in behaviour when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). Finneran et al. (2002) exposed a captive bottlenose dolphin and white whale to impulses from a watergun (80 in<sup>3</sup>). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited a reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviours were exhibited by captive bottlenose dolphins and a white whale exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviours in captive, trained marine mammals exposed to single sound pulses may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound (pk-pk level >200 dB re 1 µPa) before exhibiting the aversive behaviours mentioned above.

***Large Toothed Whales:*** Based on available data from ship-based monitoring during Marathon's 3-D seismic program in the Scotian Slope (see Table 6.9), there is some evidence that indicates toothed whales (most sightings were of sperm whales) exhibited avoidance of seismic operations. Toothed whale sighting rates were lower during seismic vs. non-seismic periods (Table 6.9) but the sample size was too small to conduct statistical tests. The radial distances at which toothed whales were initially sighted were, on average, smaller during periods of No Guns (mean = 762 m) than during periods of Array Seismic (mean = 1,378 m) and All Seismic (mean = 1,014 m; Moulton and Miller 2004), but the difference was not statistically significant. There was some indication that the likelihood for a toothed whale to "swim away" was higher during seismic operations vs. non-seismic periods insofar as could be determined by visual observations from the seismic vessel. These results suggest that some toothed whales may have exhibited localized avoidance from the immediate area around the seismic ship. However, results should be treated cautiously given the small sample size. Toothed whales (i.e., sperm whales) at the average sighting distance during seismic operations would have been exposed to sound levels of about 168 dB re 1 µPa (rms) (Moulton and Miller 2005).

***Beaked whales.***— There are no detailed 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. 2001). However, those vessels were not emitting airgun pulses. Northern bottlenose whales were observed in the Gully during Marathon's 2003 seismic program, when the seismic ship was ~55 km away and the airguns were active (Moulton and Miller 2004). The whales were observed from an acoustic monitoring vessel and sometimes approached to within 5 m. It is



estimated that received sound levels from the airgun pulses were ~132.6 dB re 1  $\mu$ Pa (rms) (as measured at 77 m water depth and 126.5 dB re 1  $\mu$ Pa (rms) at 180 m water depth; Moulton and Miller 2004). It appears that exposure to received sound levels did not displace these northern bottlenose whales from their known concentration area in the Gully. During Chevron's 2004 monitoring program in the Orphan Basin, there was one sighting of five northern bottlenose whales when the airgun arrays were being ramped up (Moulton et al. 2005). These whales were initially sighted 830 m from the seismic ship and swam towards the ship to a distance of 638 m and were not resighted. It is uncertain what sound levels these whales would have been exposed to. During L-DEO's monitoring program in the Norwegian Sea (MacLean and Haley 2004), there was one sighting of two unidentified beaked whales. These whales were sighted ~2 km from the seismic ship and were 'swimming away'. Another unidentified beaked whale was sighted from the L-DEO seismic ship in the Eastern Pacific during seismic operations (Smultea and Holst 2003; Table 6.8). The whale was sighted at a distance of ~1 km from the ship and was observed breaching and orienting away from the seismic ship.

There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operation, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. There has been a recent (Sept. 2002) coincident stranding of Cuvier's beaked whales in the Gulf of California (Mexico) when the scientific research vessel *Maurice Ewing* was conducting a research seismic survey in the general area (e.g., Malakoff 2002). It is quite unlikely that an earlier stranding of Cuvier's beaked whales in the Galapagos, during April 2000, was associated with a then-ongoing seismic survey as "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry 2002). The evidence with respect to seismic surveys and beaked whale strandings is inconclusive, and NMFS has not established a link between the Gulf of California stranding and the seismic activities (Hogarth 2002).

**Sperm whales.**— Reported responses of sperm whales to the sounds of seismic surveying have been variable, and the picture is far from clear. Some investigators have reported dramatic responses, while others have reported no measurable responses at all. One reported response was for sperm whales to fall silent in the presence of seismic noise. A seismic survey vessel operating along the Kerguelen Plateau was heard by investigators involved in the marine mammal monitoring portion of the Heard Island Feasibility Test (Bowles et al. 1994). During baseline nighttime acoustic monitoring, sperm whales were heard during 15% of the 409 minutes of acoustic recordings made while the seismic vessel was not operating. In contrast, sperm whales were never heard during the 380 minutes of baseline acoustic recording when the seismic vessel was audible. Those investigators recorded seismic pulses from that survey vessel when it was 687 km away and when it was 1,070.5 km away. The pulses they recorded from that very distant survey vessel exceeded background noise levels by only 10 to 15 dB.

In another study, seismic activity appeared to have no effect on the population of male sperm whales inhabiting the submarine canyon known as the Gully off the Nova Scotian continental shelf (McCall Howard 1999). In fact, that study found that sperm whales were heard more often during the summer of 1998, when a seismic survey was being conducted nearby (whales heard during 65% of acoustic monitoring periods), than they were during a three-year period (1988 to 1990) about a decade earlier in which no seismic surveying was conducted (whales heard during 42% of acoustic monitoring periods). The author of that report calculated that whales in the Gully could have been subjected to noise levels of 130 and 150 dB re 1  $\mu$ Pa during those seismic surveys.

Other investigators have reported displacement of sperm whales in relation to seismic activity. During vessel surveys for sperm whales in the Gulf of Mexico in June 1993, reported by Mate et al. (1994) in abstract form, sperm whales were routinely sighted 100 km southeast of the Mississippi River on four of five survey days at a density of 0.092 whales/km prior to seismic surveys in the area. Within the area of the seismic survey, they reported a significant ( $p < 0.001$ ) drop in sperm whale density to 0.038 whales/km during the first two days of the seismic survey and then to 0.0 whales/km for the following five days. During the last five days (920 km of survey effort), they reported seeing only a single group of sperm whales 61 km southwest of the seismic survey area, which happened to also be 56 km northeast of another seismic survey area. Those researchers suggested that further investigation was warranted to ensure that sperm whales were not displaced from important habitat. Received sound levels were not reported and few details were given in this abstract presentation.

Another survey for cetaceans in the northern Gulf of Mexico, GulfCet, conducted from 1992–1997, used acoustic and visual methods to detect cetaceans over a vast area consisting of 14 north–south transects ranging from the 100- to the 2,000-m isobaths (Rankin and Evans 1998). Those investigators reported that large-scale sperm whale distribution was affected by seismic surveying and they also speculated that there was a possibility that communication and orientation behaviour of sperm whales may have been negatively impacted by seismic exploration. However, no details of the effects were given in that abstract presentation. Furthermore, in the technical report of the GulfCet II Program (Davis et al. 2000), the same investigators further analyzed the data and concluded that there were no differences in sighting frequencies of sperm whales among three different signal-to-noise categories (low [no seismic], moderate [0–12 dB above ambient noise levels], and high [>12 dB above ambient noise levels]) when sightings were analyzed by hydrographic feature.

In July 2002, Madsen et al. (2002a) recorded the sounds of sperm whales off Andenes, Norway, before, during, and after their exposure to seismic survey pulses. Those investigators estimated the sound pressure levels (peak-to-peak) received by the whales to be 136 to 146 dB re 1  $\mu$ Pa, with a frequency range of 110 to 260 Hz and a peak frequency of 200 Hz. Sperm whales in that study produced patterns of usual clicks and creaks during exposure to the seismic sound, and no significant difference was observed in the click rate of a single sperm whale 10 seconds before and after the first airgun pulse. Hence, the sperm whales in that study did not appear to cease clicking in response to seismic surveying nor did they alter their usual acoustic behaviour during feeding. Madsen et al. (2002a) also reported that sperm whales were sighted in the canyon on all but one of the 13 days of the seismic survey. Hence,

those researchers reported that seismic surveys neither resulted in the cessation of click emissions nor the displacement of those animals.

Attempts to link sperm whale strandings to seismic surveys have failed. Goold et al. (2002), in an analysis of sperm whale strandings along the coasts of the British Isles and eastern Canada from 1988 to 1997, found no evidence to link the strandings to seismic surveys. They reported a seasonal mismatch between strandings, which occurred mostly in the fall and winter, and seismic surveys, which took place mostly during the summer in both the British Isles and eastern Canada. Simmonds and Mayer (1997), on the other hand, speculated that a series of sperm whale strandings in the North Sea in 1994 to 1995 could have been related to seismic surveys. They proposed that the sperm whales normal southward migration to the west of the British Isles could have been deflected by seismic surveying west of the Shetland Islands, stranding some individuals around Scotland and forcing others into the North Sea, an area thought to be outside their normal range. Those investigators speculated that lesions found on the bodies of sperm whales stranded on the Belgian and Dutch coasts could have resulted from stress and secondary infections experienced by the animals after becoming trapped in the North Sea. Simmonds and Mayer (1997) also speculated that the outer ear lesions that they found, if they extended into the middle and inner ears, could have interfered with the animals' abilities to echolocate and communicate and, thus, could have been responsible for the strandings. The conclusions of that study are speculative and no direct link between seismic surveying and the observed phenomena could be established.

The effects of seismic surveys on vessel-based visual sightings of sperm whales off the UK were investigated by Stone (2003). There were 123 sightings representing 191 sperm whales during the three years of that study. The sighting rates of sperm whales were found to be not significantly different during matched pairs ( $n = 23$ ) of "shooting" versus "not shooting" periods from the same day during surveys with large airgun arrays. The total volume of the airgun array used in those surveys often exceeded 3,000 in<sup>3</sup>. In addition, the median closest distance of approach to the airguns was found to be not significantly different between "shooting" and "not shooting" periods. There was a significant difference in the sighting rate of sperm whales among years but no clear trend in this rate, with the highest rate in 1998, the lowest rate in 1999, and an intermediate rate in 2000. When Stone (2003) further investigated behaviours of sperm whales in relation to seismic surveying, she found their direction of travel relative to the survey vessel to be not significantly different between "shooting" and "not shooting" periods ( $n = 104$ ). However, they were seen less often crossing the path of the ship (7.50% versus 18.75%) and more often traveling parallel to the ship in the same direction (25.00% versus 15.63%) during "shooting" versus "not shooting" periods, respectively. The percentages of sperm whale encounters during which slow swimming, diving, or logging was observed were also not significantly different between "shooting" and "not shooting" periods. In spite of this apparent lack of effects, on one occasion the investigators observed what they believed could be described as a startle response by a sperm whale during a soft-start (ramp up) procedure at a distance of 2 km from the airguns. Prior to the soft-start, the observers reported that the whale had been swimming slowly and had dived. It resurfaced as the soft-start procedure began and was described by the observers as swimming rapidly at the surface. The direction of travel of that animal relative to the airguns was not reported.

The Sperm Whale Seismic Study (SWSS) was initiated in April 2002 to assess the effects of seismic surveys on the sperm whales in the northern Gulf of Mexico. The SWSS consists of three years of field research primarily in the offshore waters of the northern Gulf of Mexico beyond the 200-m isobath between Galveston in the west and the DeSoto Canyon in the east. The final report of the first year of the SWSS has been released (Jochens and Biggs 2003). The data from that study are, as yet, preliminary, and it is not possible to draw firm conclusions from the results so far. However, there are a few points worth noting. Using passive acoustic techniques, investigators heard airguns at 52% of their monitoring stations and they heard sperm whales *and* airguns at 16% of their monitoring stations during the 2002 field season (Jochens and Biggs 2003). Thus, seismic surveys apparently did not result in a cessation of click emission by sperm whales. The use of passive acoustic techniques to detect locations of sperm whales and seismic surveying provided no indication that the sperm whales moved away from the seismic sources.

Finally, the SWSS is making use of one of the most sophisticated pieces of technology currently available to researchers for assessing reactions of deep-diving whales. Developed by researchers at the Wood's Hole Oceanographic Institute (Johnson and Tyack 2003), the digital acoustic recording tag, or D-tag, provides simultaneous readings of a whale's orientation in three dimensions, its depth, and its swimming speed and also records the sounds made and heard by the animal with sufficient sensitivity to detect individual fluke strokes. Data from the D-tag are combined with passive acoustic techniques to track tagged whales and with visual observations of whales at the surface to further assess behaviour. The D-tag is attached to a whale's back by two or three suction cups, with a pump to maintain a vacuum in the cups and an active release controlled by a timer in the D-tag. It is deployed using a 12-m long cantilevered pole to minimize the impact of tagging on the animal. The maximum attachment time on sperm whales has been 10 hours, although early releases from whales have resulted from social interactions between animals and breaching (Johnson and Tyack 2003). Responses of sperm whales to the tagging process and to the tag have not been reported (Jochens and Biggs 2003; Johnson and Tyack 2003; Zimmer et al. 2003). However, in another study, investigators using a suction-cup tag deployed by a crossbow reported a mild short-term reaction (turned, spy hopped, and dove) of a sperm whale to the tag hitting the body. When the whale returned to the surface, it exhibited normal behaviours not different from those of other group members (Amano and Yoshioka 2003).

Researchers involved in the 2002 phase of SWSS were able to conduct two controlled exposure experiments (CEEs) to study the responses of tagged sperm whales to airguns (Jochens and Biggs 2003). In the first experiment, a single tagged sperm whale was logged by the tag as being exposed to seismic pulses with a received sound level of 143 dB at 600 m depth and 10 nautical miles from the airgun array. At 600 m depth, the seismic pulses were recorded to have most of their energy at frequencies below 1 kHz. Pulses from the same airgun array measured at a depth of 20 m had much stronger high-frequency components. In that first experiment, researchers measured creak rates of the sperm whale before, during, and after exposure to seismic pulses as an indication of feeding success. Creak rates were 10.6, 16.4, and 13.7 creaks/hour for the three periods, respectively, suggesting that feeding success, as measured by creak rate, was not adversely affected for that individual during that time. In the second CEE, investigators tagged three sperm whales in the same group. Those whales were exposed to a

maximum received level of 148 dB when the seismic vessel was 4.5 nautical miles away. There was no indication that the whales showed horizontal avoidance of the seismic vessel nor was there any indication of a change in creak rate. However, those three whales cannot be considered as independent samples, and results from the 2002 phase of this study represent a very small sample size. An additional four CEEs were conducted during the 2003 phase of SWSS (Miller et al. 2003). Detailed results of these experiments are not yet available.

*Conclusions:* Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, show localized avoidance. In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications. There are no detailed data on responses of beaked whales to seismic surveys, but available data suggest beaked whales exhibit avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars. Whether they ever do so in response to seismic survey noise is unknown. Seismic sound is quite different in characteristics from sonar noise in terms of frequencies, pulse durations, strength, beam width and so forth.

Most of the proposed seismic program will occur in waters <300 m deep, so the chances of encountering deep-water species, like beaked whales are reduced. Nonetheless, the ramp-ups that are planned at the start of each period of airgun operation will encourage beaked whales (and other species) to move away before the sound level becomes high. This mitigation measure is planned on the assumption that a short (few hours) period of displacement from the originally-occupied location is preferable to sudden exposure to high sound levels if there was a sudden onset of full-power airgun operations.

## **Pinnipeds**

Few quantitative 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 surveys have also been observed during recent seismic surveys along the U.S. 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, gray 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 United Kingdom, a radio-telemetry study has demonstrated short-term changes in the behaviour of harbor (=common) seals and gray seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbor seals were exposed to seismic pulses from a 90 in<sup>3</sup> array (3 x 30-in<sup>3</sup> airguns), and behavioural responses differed among individuals. One harbor seal avoided the array at distances up to 2.5 km from the source and only resumed foraging dives after seismic stopped. Another harbor seal exposed to the same small airgun array showed no detectable behavioural response, even when the array was within 500 m. All gray seals exposed to a single 10-in<sup>3</sup> 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 gray 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.

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behaviour modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array." (Arnold 1996). In Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmeck 1998).

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. 2001b; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1,500 in<sup>3</sup>. 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 avoidance movements were relatively small, on the order of 100 m to, at most, a few hundreds of meters, and many seals remained within 100–200 m of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997.

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 meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioural reactions may be stronger than evident to date from visual studies.

## Sea Turtles

There have been far fewer studies of the effects of airgun noise (or indeed any type of noise) on sea turtles than on marine mammals and fish. Three such studies have focused on short-term behavioural responses of sea turtles in enclosures to single airguns. Comparisons of results among studies are difficult, because experimental designs and reporting procedures have varied greatly, and only one of the studies provided specific information about the levels of the airgun pulses received by the turtles. We are not aware of any studies on responses of free-ranging sea turtles to seismic sounds or on the long-term effects of seismic or other sounds on sea turtles. Results from some recent seismic monitoring programs provide some data.

The most recent of the studies of caged sea turtles exposed to airgun pulses was a study by McCauley et al. (2000b) off Western Australia. This is apparently the only such study in which received sound levels were estimated carefully. McCauley et al. (2000b) exposed caged green and loggerhead sea turtles (one of each) to pulses from an approaching and then receding 20 in<sup>3</sup> airgun operating at 1,500 psi and 5 m gun-depth. The single airgun fired every 10 s. There were two trials separated by two days; the first trial involved ~2 h of airgun exposure and the second ~1 h. The results from the two trials showed that, above a received level of 166 dB re 1 µPa (rms), the turtles noticeably increased their speed of swimming relative to periods when no airguns were operating. The behaviour of the sea turtles became more erratic when received levels exceeded 175 dB re 1 µPa (rms). The authors suggested that the erratic behaviour exhibited by the caged sea turtles would likely, in unrestrained turtles, be expressed as an avoidance response (McCauley et al. 2000b).

O'Hara and Wilcox (1990) tested the reactions to airguns of loggerhead sea turtles held in a 300 × 45 m area of a canal 10 m deep in Florida. Nine turtles were tested at different times. The sound source consisted of one 10 in<sup>3</sup> airgun plus two 0.8 in<sup>3</sup> "poppers" operating at 2,000 psi<sup>3</sup> and gun-depth 2 m for prolonged periods: 20–36 hours in duration. The turtles maintained a standoff range of about 30 m when exposed to airgun pulses every 15 sec or every 7.5 sec. It was also possible that some turtles remained on the bottom of the enclosure when exposed to airgun pulses. O'Hara and Wilcox (1990) did not measure the received airgun sound levels. McCauley et al. (2000b) estimated that "the level at which O'Hara saw avoidance was around 175–176 dB re 1 µPa (rms)". The levels received by the turtles in the Florida study probably were actually a few dB less than 175–176 dB because the calculations by McCauley et al. (2000b) apparently did not allow for the shallow 2 m gun depth in the

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<sup>3</sup> There was no significant reaction by five turtles during an initial series of tests with the airguns operating at the unusually low pressure of 1,000-psi. The source and received levels of airgun sounds would have been substantially lower when the air pressure was only 1,000-psi than when it was at the more typical operating pressure of 2,000-psi.

Florida study. The effective source level of airguns is less when they are near 2 m depth than at 5 m (Greene and Burgess 2000).

Moein et al. (1994) investigated the avoidance behaviour and physiological responses of loggerhead turtles exposed to an operating airgun, as well as the effects on their hearing. The turtles were held in a netted enclosure about 18 m by 61 m by 3.6 m deep, with an airgun of unspecified size at each end. Only one airgun was operated at any one time; firing rate was one shot every 5–6 sec. Ten turtles were tested individually, and seven of these were retested several days later. The airgun was initially discharged when the turtles were near the center of the enclosure and the subsequent movements of the turtles were documented. The turtles exhibited avoidance during the first presentation of airgun sounds at a mean range of 24 m, but the avoidance response waned quickly. Additional trials conducted on the same turtles several days later did not show statistically significant avoidance reactions, although there was an indication of slight initial avoidance followed by rapid waning of the avoidance response. The authors described the rapid waning of the avoidance response as “habituation”. Their auditory study indicated that exposure to the airgun pulses may have resulted in temporary hearing impairment (TTS, see later section). Reduced hearing sensitivity may also have contributed to the waning response upon continued exposure. There was some evidence from the physiological measurements of increased stress in the sea turtles, but this stress could also have been a result of handling of the turtles.

Inconsistencies in reporting procedures and experimental design prevent direct comparison of Moein’s study with either McCauley et al. (2000b) or O’Hara and Wilcox (1990). Moein et al. (1994) stated, without further details, that “three different decibel levels (175, 177, 179) were utilized” during each test. These figures probably are received levels in dB re 1  $\mu$ Pa, and probably relate to the initial exposure distance (mean 24 m), but these details were not specified. Also, it was not specified whether these values were measured or estimated, or whether they are expressed in peak-peak, peak, rms, SEL, or some other units. Given the shallow water in the enclosure (3.6 m), any estimates based on simple assumptions about propagation would be suspect.

Despite the problems in comparing these three studies, there is a consistent trend showing that, at some received level, sea turtles show avoidance of an operating airgun. McCauley et al. (2000b) found evidence of behavioural responses when the received level from a single small airgun was 166 dB re 1  $\mu$ Pa *rms*, and avoidance responses at 175 dB re 1  $\mu$ Pa (rms). Based on these data, McCauley et al. (2000b) estimated that, for a typical airgun array (2,678 in<sup>3</sup>, 12-elements) operating in 100–120 m water depth, sea turtles may exhibit behavioural changes at ~2 km and avoidance around 1 km. These estimates are subject to great variation, depending on the seismic source and local propagation conditions.

There have been no specific studies of free-ranging sea turtles exposed to seismic pulses, and potential long-term behavioural effects of seismic exposure have not been investigated. Sea turtle sightings have been made during L-DEO seismic monitoring programs (Table 6.8). During the L-DEO seismic monitoring program in the Eastern Pacific, six sea turtle sightings (two green, two leatherback, and two Olive Ridley sea turtles) were made (Smultea and Holst 2003). Five of these sightings occurred during



airgun operations (all within 100 m of the seismic ship), and one turtle appeared to react to the airguns. This turtle was initially sighted ~100 m from the bow, floated by the ship to within 10 m of the airgun array, and then swam away. During the L-DEO seismic monitoring program in the Northwest Atlantic, 26 sea turtle sightings (25 unidentified and one leatherback sea turtle) were made (Haley and Koski 2004). Nine of the 25 sea turtles seen during seismic periods (one 75 in3 airgun) were actively moving away from the vessel. The 16 other sea turtles did not exhibit avoidance response. Sea turtles were also observed during seismic operations in the SE Caribbean by L-DEO (Smultea et al. 2004). Two sea turtles (hawksbill and unidentified sea turtle) were seen between 10-20 m from the 20-airgun array. Both turtles swam vigorously away from the seismic vessel.

The paucity of data precludes specific predictions as to how free-ranging sea turtles respond to seismic sounds. The possible responses could include one or more of the following: (1) avoid the entire seismic survey area to the extent that the turtles move to less preferred habitat; (2) avoid only the immediate area around the active seismic vessel, i.e., local avoidance of the source vessel but remain in the general area; and/or (3) exhibit no appreciable avoidance, although short-term behavioural reactions are likely.

The potential alteration of a migration route might have negative impacts. However, it is not known whether the alteration would ever be on a sufficient geographic scale, or be sufficiently prolonged, to prevent turtles from reaching an important destination. Again, this is not a likely possibility in the circumstances of the present project.

Avoidance of a preferred foraging area because of seismic survey noise may prevent sea turtles from obtaining preferred prey species and hence could impact their nutritional status. However, it is highly unlikely that sea turtles would completely avoid a large area along a migration route. Available evidence suggests that the zone of avoidance around seismic sources is not likely to exceed a few kilometers (McCauley et al. 2000b). Avoidance reactions on that scale could prevent sea turtles from using an important coastal area or bay if there was a prolonged seismic operation in the area. Sea turtles might be excluded from the area for the duration of the seismic operation, or they might remain but exhibit abnormal behavioural patterns (e.g., lingering at the surface where received sound levels are lower). Whether those that were displaced would return quickly after the seismic operation ended is generally unknown. Again, this is not a likely possibility in the circumstances of the present project, since operations will be in offshore areas that are not known or expected to be preferred foraging habitat.

The results of experiments and monitoring studies on responses of marine mammals and fish to seismic surveys show that behavioural responses are possible, depending on species, time of year, activity of the animal, and other unknown factors. The same species may show different kinds of responses at different times of year or even on different days (Richardson et al. 1995). It is reasonable to expect similar variability in the case of sea turtles exposed to airgun sounds. For example, sea turtles of different ages have very different sizes, behaviour, feeding habits, and preferred water depths. Nothing specific is known about the ways in which these factors may be related to airgun sound effects on sea turtles. However, it is reasonable to expect lesser effects in young turtles concentrated near the surface (where levels of airgun sounds are attenuated) as compared with older turtles that spend more time at depth where airgun sounds are generally stronger.

In summary, most studies have been conducted in shallow water, enclosed areas and thus are not directly applicable to the Project Area. The limited available data indicate that sea turtles will hear airgun sounds. Based on available data, it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. Seismic operations in or near areas where turtles concentrate are likely to have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Jeanne d'Arc Basin, including the Project Area, is not a breeding area for sea turtles and it is not known or thought to be an important feeding area, and thus high concentrations of sea turtles are unlikely.

#### **6.5.12.1.5. (E) Hearing Impairment and 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 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 National Marine Fisheries Service (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  $\mu$ Pa (rms), respectively (NMFS 2000). [Note that NMFS is considering alternative criteria—see Federal Register/Vol. 70(7): 1871-1875.] Those criteria have been used in establishing the safety (=power-down) zones for seismic surveys in some parts of Canada. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause TTS in marine mammals. As discussed below, the 180 dB criterion for cetaceans is probably quite conservative (i.e., lower than necessary to avoid auditory injury), at least for delphinids.

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the possibility of hearing impairment.

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 might (in theory) 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 strong pulsed sounds.

#### **Temporary Threshold Shift (TTS)**

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 (in cases of strong TTS) 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.

*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  $\mu$ Pa (rms) at 3, 10, 20, and 75 kHz, with no strong relationship between frequency and onset of TTS across this range of frequencies. 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; 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 level) of 221 dB re 1  $\mu$ Pa 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<sup>3</sup> water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses were expected to contain proportionally more energy at higher frequencies than 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  $\mu$ Pa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1  $\mu$ Pa<sup>2</sup> · s. Thresholds returned to within 2 dB of pre-exposure value ~4-min after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1  $\mu$ Pa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1  $\mu$ Pa<sup>2</sup> · 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 (but controlled) 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 sec or shorter, generally at frequencies higher than the predominant frequencies in airgun pulses. With single short pulses, the TTS threshold appears to be (to a first approximation) a function of the energy content of the pulse (Finneran et al. 2002). 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 with variable received levels. Given the results of the aforementioned studies and a seismic pulse duration (as received at close range) of ~20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1  $\mu$ Pa (rms) (approx. 221–226 dB pk-pk) 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, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale.

*Pinnipeds:* TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) have not been measured. For sounds of relatively long duration (20–22 min), 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 100–2,000 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 ~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 min than for 20–22 min, 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; Ketten et al. 2001; cf. Au et al. 2000).

*Sea Turtles:* There have been few studies that have directly investigated hearing or noise-induced hearing loss in sea turtles.

Moein et al. (1994) used an evoked potential method to test the hearing of loggerhead sea turtles exposed to a few hundred pulses from a single airgun. Turtle hearing was tested before, within 24 h after, and two weeks after exposure to pulses of airgun sound. Levels of airgun sounds to which the turtles were exposed were not specifically reported. The authors concluded that five turtles (of ~11 tested) exhibited some change in their hearing sensitivity when tested within 24 h after exposure to airgun sound relative to pre-exposure sensitivity, and that hearing had reverted to normal when tested two weeks after exposure. These results are consistent with the occurrence of TTS upon exposure of the turtles to airgun pulses. The report did not state the size of the airgun used, or the received sound levels at various distances. The distances of the turtles from the airgun were also variable during the tests; the turtle was about 30 m from the airgun at the start of each trial, but it could then either approach the airgun or move away to a maximum of about 65 m during subsequent airgun pulses. Thus, the levels of airgun sounds that apparently elicited TTS are not known. Nonetheless, it is noteworthy that there was evidence of TTS from exposure to pulses from a single airgun. However, it may be relevant that these turtles were confined and unable to move more than about 65 m away. Turtles in the open sea might move away, and even if they did not move away, turtles near the seismic line would receive only a few pulses at near-maximum level as the seismic vessel went by.

Studies with terrestrial reptiles have also demonstrated that exposure to impulse noise can cause hearing loss. Desert tortoises (*Gopherus agassizii*) exhibit TTS after exposure to repeated high intensity sonic booms (Bowles et al. 1999). Recovery from these temporary hearing losses was usually rapid (<1 h), which suggested that tortoises can tolerate these exposures without permanent injury (Bowles et al. 1999).

The apparent occurrence of Temporary Threshold Shift in loggerhead turtles exposed to many pulses from a single airgun  $\leq 65$  m away suggests that sounds from an airgun array could cause at least temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs. There is also the possibility of permanent hearing damage to turtles close to the airguns. However, there are few data on temporary hearing loss and no data on permanent hearing loss in sea turtles exposed to airgun pulses.

*Likelihood of Incurring TTS:* A marine mammal within a radius of  $\leq 100$  m around a typical array of operating airguns might be exposed to a few seismic pulses with levels of  $\geq 205$  dB, and possibly more pulses if the mammal moved with the seismic vessel.

As shown above, most cetaceans show some degree of avoidance of seismic vessels operating an airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. However, TTS would be more likely in any odontocetes that bow-ride or otherwise linger near the airguns. While bow-riding, odontocetes would be at or above the surface, and thus not exposed to strong sound pulses given the pressure-release effect at the surface. However, bow-riding animals generally dive below the surface intermittently. If they did so while bow-riding near airguns, they would be exposed to strong sound pulses, possibly repeatedly.

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.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1  $\mu$ Pa (rms). The corresponding limit for pinnipeds has been set at 190 dB. These sound levels are *not* considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS, before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As discussed above, TTS data that have subsequently become available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to seismic pulses stronger than 180 dB re 1  $\mu$ Pa (rms).

It has been shown that most whales tend to avoid ships and associated seismic operations. In addition, ramping up airgun arrays, which has become standard operational protocol for many seismic operators, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. [Three species of baleen whales that have been exposed to pulses from single airguns showed avoidance (Malme et al. 1984-86, 1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b). This strongly suggests that baleen whales will begin to move away during the

initial stages of a ramp-up, when a single airgun is fired.] Thus, whales will likely not be exposed to high levels of airgun sounds. Likewise, any whales close to the trackline could move away before the sounds from the approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for whales to be close enough to an airgun array to experience TTS. Furthermore, in the event that a few individual cetaceans did incur TTS through exposure to airgun sounds, this is a temporary and reversible phenomenon.

### **Permanent Threshold Shift (PTS)**

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times (time required for sound pulse to reach peak pressure from the baseline pressure). Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal. However, given the evidence that mammals close to an airgun array might incur TTS, there has been speculation about the possibility that some individuals occurring very close to airguns might incur PTS (Richardson et al. 1995, p. 372ff).

Single or occasional occurrences of mild TTS do not cause permanent auditory damage in terrestrial mammals, and presumably do not do so in marine mammals. The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during recent controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995). For impulse sounds with very rapid rise times (e.g., those associated with explosions or gunfire), a received level not greatly in excess of the TTS threshold may start to elicit PTS. Rise times for airgun pulses are rapid, but less rapid than for explosions.

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. Some factors that contribute to onset of PTS are as follows:

- exposure to single very intense noises,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) has reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rapid rise time.

Sound impulse duration, peak amplitude, rise time, and number of pulses are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1994) 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.

## **Marine Mammals**

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. If we assume that the TTS threshold for exposure to a series of seismic pulses may be on the order of 220 dB re 1  $\mu$ Pa (pk-pk) in odontocetes, then the PTS threshold might be about 240 dB re 1  $\mu$ Pa (pk-pk). In the units used by geophysicists, this is 10 bar m. Such levels are found only in the immediate vicinity of the largest airguns (Richardson et al. 1995:137; Caldwell and Dragoset 2000). It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of baleen whales and pinnipeds may be lower, and thus may extend to a somewhat greater distance. However, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. Some pinnipeds do not show strong avoidance of operating airguns.

Although it is unlikely that the planned airgun operations could cause PTS in any marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. The planned monitoring and mitigation measures, including ramp-ups, visual monitoring (and the use of an observer before and during startups and when possible at other times), and power-down of the airguns when endangered baleen whales are seen within the "safety radii", will minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

## **Sea Turtles**

The study by Moein et al. (1994) indicates that sea turtles can experience TTS when exposed to moderately strong airgun sounds. However, there are no data to indicate whether or not there are any plausible situations in which exposure to repeated airgun pulses at close range could cause permanent hearing impairment in sea turtles.

Behavioural avoidance and hearing damage are related. If sea turtles exhibit little or no behavioural avoidance, or if they acclimate to seismic noise to the extent that avoidance reactions cease, sea turtles might sustain hearing loss if they are close enough to seismic sources.

Turtles in the area of seismic operations prior to start-up may not have time to move out of the area even if standard ramp-up (=soft-start) procedures are in effect. It has been proposed that sea turtles require a longer ramp-up period because of their relatively slow swimming speeds (Eckert 2000). However, it is unclear at what distance from a seismic source sea turtles might sustain temporary hearing impairment, and whether there would ever be a possibility of exposure to sufficiently high levels for a sufficiently long period to cause irreversible hearing damage (PTS).

In theory, a reduction in hearing sensitivity, either temporary or permanent, may be harmful for sea turtles. However, very little is known about the role of sound perception in the sea turtle's normal activities. Hence, it is not possible to estimate how much of a problem it would be for a turtle to have either temporary or permanent hearing impairment. It is noted above that sea turtles are unlikely to use passive reception of acoustic signals to detect the hunting sonar of killer whales, because the echolocation signals of killer whales are likely inaudible to sea turtles. Hearing is also unlikely to play a major role in their navigation. However, hearing impairment, either temporary or permanent, might inhibit a turtle's ability to avoid injury from vessels, because they may not hear them in time to move out of their way. In any event, sea turtles are unlikely to be at great risk of hearing impairment.

#### **6.5.12.1.6. (F) Strandings and Mortality**

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval sonar exercises has raised the possibility that beaked whales may be susceptible to injury and/or stranding when exposed to strong pulsed sounds of certain frequencies.

In March 2000, several beaked whales that had been exposed to repeated pulses from high intensity, mid-frequency military sonars stranded and died in the Providence Channels of the Bahamas Islands, and were subsequently found to have incurred cranial and ear damage (NOAA and USN 2001). Based on post-mortem analyses, it was concluded that an acoustic event caused hemorrhages in and near the auditory region of some beaked whales. These hemorrhages occurred before death. They would not necessarily have caused death or permanent hearing damage, but could have compromised hearing and navigational ability (NOAA and USN 2001). The researchers concluded that acoustic exposure caused this damage and triggered stranding, which resulted in overheating, cardiovascular collapse, and physiological shock that ultimately led to the death of the stranded beaked whales. During the event, five naval vessels used their AN/SQS-53C or -56 hull-mounted active sonars for a period of 16 h. The sonars produced narrow (<100 Hz) bandwidth signals at center frequencies of 2.6 and 3.3 kHz (-53C), and 6.8 to 8.2 kHz (-56). The respective source levels were usually 235 and 223 dB re 1  $\mu$  Pa, but the -53C briefly operated at an



unstated but substantially higher source level. The unusual bathymetry and constricted channel where the strandings occurred were conducive to channeling sound. This, and the extended operations by multiple sonars, apparently prevented escape of the animals to the open sea. In addition to the strandings, there are reports that beaked whales were no longer present in the Providence Channel region after the event, suggesting that other beaked whales either abandoned the area or (perhaps) died at sea (Balcomb and Claridge 2001). Other strandings of beaked whales associated with operation of military sonars have also been reported (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998). In these cases, it was not determined whether there were noise-induced injuries to the ears or other organs. Another stranding of beaked whales (15 whales) happened on 24–25 September 2002 in the Canary Islands, where naval maneuvers were taking place.

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to hearing damage and, indirectly, mortality suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

As discussed earlier, there has been a recent (Sept. 2002) coincident stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) when a research seismic survey by the L-DEO/NSF vessel *Maurice Ewing* was underway in the general area (Malakoff 2002). However, 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 (Hogarth 2002; Yoder 2002).

Adult humpback whales off the Bahia and Espirito Santo state coasts of Brazil have been reported to strand in relatively higher numbers during a year (2002) when a 3-D seismic program was underway than in other years (1975-2001, 2003—Engel et al. 2004). [Total numbers of stranded humpbacks, adults and immature whales, were similar in 2001 (14), 2002 (20), and 2003 (20).] The authors note, however, that the apparent increase in stranding rates for adult humpbacks in 2002 did not allow for increased search effort and the probable increase in population size of the humpbacks. No detailed necropsies were performed on the stranded whales found in 2002, but there was no evidence of entanglement, collision with a boat, or auditory injury (Engel et al. 2004). The study did not document how closely the operating seismic vessel approached the humpbacks, nor the sound levels to which the whales were exposed. No causal link between seismic surveys and the strandings was established.

In a response to this publication, the International Association of Geophysical Contractors (IAGC 2004) examined the stranding data in more detail relative to the locations of the seismic ships and estimated received sound levels. IAGC (2004) reported that adult humpback stranding sites were 90-560 km (mean = 344 km) from the nearest operating seismic vessel. The authors conclude that it is not

reasonable to assume that animals were exposed to sound pressure levels even as high as those detailed in previous studies where no significant reactions were observed.

The monitoring and mitigation measures built into the planned work reduce the risk to beaked whales (and other species of cetaceans) that might otherwise exist. Use of ramp-up procedures, in conjunction with the (presumed) natural tendency of beaked whales to avoid an approaching vessel, will reduce exposure.

#### **6.5.12.1.7. (G) Non-auditory Physiological Effects**

Possible types of non-auditory physiological effects or injuries that might occur in marine mammals or sea turtles exposed to strong underwater sound might, in theory, include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals or sea turtles exposed to sound from airgun arrays. Preliminary results of investigations to measure blood chemistry markers indicative of nervous system activation or immune function in a bottlenose dolphin and a beluga whale before and after exposure to seismic pulses suggest little to no change in those measures (Romano et al. 2001). If any non-auditory physiological effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods. This is unlikely to occur in a deep-water open-ocean situation where there is no nearby land or shoals to confine the movements of the animals. Long-term exposure to anthropogenic noise may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). However, there is essentially no information about the occurrence of noise-induced stress in marine mammals. Also, it is doubtful that any single marine mammal or sea turtle would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at this frequency, the ensuing resonance could cause damage to the animal. Diving marine mammals are not subject to the bends or air embolism because, unlike a human SCUBA diver, they only breath air at sea level pressure and have protective adaptations against getting the bends. There may be a possibility that high sound levels could cause bubble formation in the blood of diving mammals that in turn could cause an air embolism, tissue separation, and high, localized pressure in nervous tissue (Gisiner [ed.] 1999; Houser et al. 2001). A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Among other reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry [ed.] 2002).

Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area. Jepson et al. (2003) necropsied eight Cuvier's beaked whales, one Blainville's beaked whale, and one Gervais' beaked whale that were part of a group of 14 beaked whales that stranded in the Canary Islands close to the site of an international naval exercise in September 2002. Those researchers found gas-bubble lesions in those animals and they concluded that the symptoms were consistent with acute trauma due to in vivo bubble formation as a result of rapid decompression. That interpretation is controversial (Fernández et al. 2004; Piantadosi and Thalmann 2004). In support of the theory that whales can get gas-bubble lesions, sperm whale skeletons were examined for bone surface morphology and it was revealed that specimens exhibited possible chronic effects of nitrogen emboli (Moore and Early 2004). The authors suggest that sperm whales may be susceptible to the effects of deep diving and that other cetacea may be open to acute embolic injury if forced to surface rapidly.

In summary, very little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals or sea turtles. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals or sea turtles 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.

#### **6.5.12.2. Effects of Helicopter Overflights**

There are no helicopter flights planned for 2005. In subsequent years, it is anticipated that helicopter flights to the seismic ship from St. John's will occur every three weeks. Helicopters will maintain a regulated flight altitude above sea level unless it is necessary to fly lower for safety reasons.

##### **6.5.12.2.1. Marine Mammals**

**Baleen Whales.**—Baleen whale responses to aircraft (pre-1995 studies) are summarized in Richardson et al. (1995), p. 249-252. Those observations showed that whales often react to aircraft overflights by hasty dives, turns, or other changes in behaviour. Responsiveness depends on the activities and situations of the whales (e.g., gray whales; Moore and Clarke 2002). Whales actively feeding or socializing often seem rather non-responsive. Whales in confined waters or with calves sometimes seem more responsive. In a more recent study, opportunistic observations of bowhead whale responses to a Bell 212 helicopter (and Twin Otter fixed-wing aircraft) were acquired during four spring migration periods in the Alaskan Beaufort Sea (Patenaude et al. 2002). The helicopter was found to have numerous prominent tones at frequencies up to approximately 340 Hz, with the most prominent peak at 22 Hz. Sound levels between the peaks were 10-15 dB above ambient noise levels. Helicopter overflights elicited detectable responses in 14% of 63 bowhead groups. Most observed reactions (abrupt dives, breaching, tail slapping, and brief surfacings) by bowheads (63%) to the helicopter occurred when

it was at altitudes  $\leq 150$  m and lateral distances  $\leq 250$  m. In this and other studies, there was no indication that single or occasional aircraft overflights cause more than brief behavioural responses.

**Toothed Whales.**—Toothed whale responses to aircraft (pre-1995 studies) are summarized in Richardson et al. (1995), p. 247-248. Odontocetes reacting to aircraft may dive, slap the water with flippers or flukes, or swim away. The activity of a toothed whale sometimes appears to influence whether or not there is a behavioural response. In more recent studies, Richter et al. (2003) reported that male sperm whales off Kaikoura, New Zealand, spent more time at the surface and showed more frequent heading changes in the presence of aircraft (small fixed-wing planes and helicopters) involved in whalewatching activities. The responses of beluga whales in the Alaskan Beaufort Sea to the noise of a Bell 212 helicopter (and Twin Otter fixed-wing aircraft) were assessed by Patenaude et al. (2002). Beluga whales reacted to the helicopter on 15 of 40 occasions. These reactions included immediate dives, changes in heading, changes in behavioural state, and apparent displacements. Reactions occurred more often when the helicopter passed at altitudes  $\leq 150$  m than when it passed at altitudes  $> 150$  m and significantly ( $p = 0.004$ ) more often when the helicopter's lateral distance from the whales was  $\leq 250$  m versus 250–500 m. Beluga whales reacted 50% of the time when the helicopter was stationary on the ice with the engines running. In this and other studies, there was no indication that single or occasional aircraft overflights cause more than brief behavioural responses in toothed whales.

**Seals.**—Pinniped response to aircraft (pre-1995 studies) are summarized in Richardson et al. (1995), p. 243-247. Pinnipeds hauled out on land or ice seem to be more responsive to overflights than pinnipeds in the water. Born et al. (1999) assessed the responses of ringed seals hauled out on the ice to overflights by fixed-wing twin-engine aircraft (Partenavia PN68 Observer) and a helicopter (Bell 206 III). Both aircrafts flew over seals at an altitude of 150 m. Overall, 6% of the seals (total = 5,040) escaped (left the ice) as a reaction to the fixed-wing aircraft and 49% of the seals (total = 227) escaped as a response to the helicopter. Some seals seem to habituate to frequent overflights. Perry et al. (2002) assessed the effect of sonic booms from a Concorde supersonic jet on gray (*Halichoerus grypus*) and harbor seals (*Phoca vitulina*) on Sable Island, Nova Scotia, Canada. There was no significant difference in the behaviour or beach counts of gray and harbor seals before vs. after booms, but harbor seals were more vigilant. The heart rate of gray seal mother and pups did not change significantly after exposure to booms, however, harbor seals showed a tendency (non-significant) toward an elevated heart rate. Overall, exposure to sonic booms did not substantially affect the breeding behaviour of gray and harbor seals. In this and other studies, there was no indication that single or occasional aircraft overflights cause more than brief behavioural responses in pinnipeds.

**Sea Turtles.**—To the best of our knowledge, there are no systematic data on sea turtle reactions to helicopter overflights. Given the hearing sensitivities of sea turtles, they can likely hear helicopters, at least when the helicopters are at lower altitudes and the turtles are in relatively shallow waters. It is unknown how sea turtles would respond, but single or occasional overflights by helicopters would likely only elicit a brief behavioural response.

### 6.5.12.3. Effects of Presence of Vessels

During the proposed seismic program, there will be one seismic ship at all times and a picket vessel on site during most of the 150-day program. It is anticipated that a supply ship will also be on site occasionally. Marine mammal responses to ships are presumably responses to noise, but visual or other cues are also likely involved. Marine mammal response (or lack thereof) to ships and boats (pre-1995 studies) are summarized in Richardson et al. (1995), p. 252-274. More recent studies are summarized below.

***Baleen Whales.***—The responses of North Atlantic right whales in the Bay of Fundy to ships, sounds from conspecifics, and a signal designed to alert the whales were monitored using multi-sensor acoustic recording tags (Nowacek et al. 2004). The whales reacted overtly to a signal designed to alert the whales to avoid ship strikes; they swam strongly to the surface, likely increasing rather than decreasing the risk of collision with ships. The whales reacted mildly to controlled exposure to sounds of conspecifics, but showed no response to controlled sound exposure to ships as well as actual ships (Nowacek et al. 2004). It is thought that right whales, particularly in the Bay of Fundy, may be susceptible to collisions with ships as they may have difficulty in locating the direction of the ship because of echos off the sea bottom and surface (Terhune and Verboom (1999). Right whales may swim into the acoustic shadow (quietest location usually ahead of the ship at the surface; Blue et al. 2001) of an on-coming ship, thus making them more susceptible to collisions (Terhune and Verboom 1999).

Marine mammal monitoring was undertaken from a high-speed, catamaran car ferry transiting the Bay of Fundy during the summers of 1998-2002 (Dufault and Davis 2003). The ferry had no propellers but used four water jets for power and sailed at speeds of 40 kts. The majority of baleen whales (including fin, humpback and minke whales) sighted from the ferry appeared to exhibit avoidance behaviour including heading away, changing heading, or diving (Dufault and Davis 2003). Avoidance responses were greater for humpback whales than for the other species of baleen whales that were seen.

Au and Green (1997, 2000) concluded that it was unlikely that the sound levels from whale-watching vessels would have serious effects on humpback whales in Hawaiian waters. They found that whale-watching vessels had source levels only 8 to 10 dB stronger than the level of background humpback whale sounds produced at the peak of the whale season (Au and Green 2000).

The vocal activity of humpback whales may change in response to approaches by motor boats. Two humpback whales sang shorter versions of their songs when exposed to engine noise and three humpbacks interrupted their songs after the motor boat switched gears but resumed singing when the motor was in neutral (Sousa-Lima et al. 2002). Sample size was small in this study.

The response of humpback whales to whale-watching vessels in Hervey Bay, Australia was monitored in 1994 in an attempt to develop design criteria for vessels to minimize disturbance to whales (McCauley and Cato 2001). It was found that rapid increases in vessel noise produced more responses

by humpbacks. The behaviour of southward migrating humpback whales in Hervey Bay in response to whale-watching vessels was monitored in 1988 and 1989 (Corkeron 1995). Whale pods, both with and without calves, were more likely to dive rather than slip beneath the water surface when vessels were within 300 m of the vessels. Corkeron indicates that it is uncertain whether short-term behavioural changes would be accompanied by longer-term avoidance. This study provides no information on the types of whale-watching vessels and their sound levels.

The influence of whale-watching vessels on the behaviour of migrating (southbound and northbound) gray whales in Baja California, Mexico during the winters of 1998 and 1999 (Heckel et al. 2001). The presence of vessels did appear to affect whale swim direction (whale headings were more variable) and velocity (became more variable) but results were inconsistent for whales migrating north vs. south. Also, a head-on approach by whale-watching boats significantly affected whale swimming direction and velocity vs. approaches towards the rear or flanks of the whale. This study provides no information on the types of whale-watching vessels and their sound levels. The authors also identify a small sample size, especially for the northbound migrating gray whales, as a potential issue.

Increased vessel traffic (primarily fishing vessels) at two known calving sites for gray whales in the Gulf of California, Mexico has been attributed to the absence of whales in recent years (Findley and Vidal 2002). Semi-continuous dredging to clear and deepen the channel leading into the bays also likely contributed to the abandonment of the area.

Based on a study of fin whale response to a small (4.5 m long) inflatable boat powered by a 25-hp outboard engine, Jahoda et al. (2003) recommend that exposure of fin whales (in the Ligurian Sea) to vessel traffic, including whale-watching vessels, be carefully monitored. The study monitored 25 fin whales in their feeding ground during approaches by the inflatable boat within 5-10 m, moving with sudden speed (0-26 km/h) and directional changes for an hour. Whales were also monitored before and after the sudden approach from distances >200 m and at low speeds (5 km/h). Fin whales responded to the close approach of the boat by apparently ceasing feeding, beginning to travel at increased speed, and reducing the amount of time spent on the surface. One hour after close approach, the fin whales had not resumed to pre-disturbance behaviours. The authors note fin whale response may be, entirely or in part, a response to biopsy sampling, which was occurring as well. No source or received sound levels from the inflatable boat were provided.

**Toothed Whales.**—Reports of sperm whales' reactions to boat noises vary to both extremes, with most studies showing little evidence of disturbance. André et al. (1997) were unable to elicit any reaction from sperm whales off the Canary Islands in response to playbacks of engine noise (source level of 180 dB re 1  $\mu$ Pa/Hz, generated from the engine of a 15 m, 19-gross-ton ship traveling at 25 knots) at a distance of 100 m from the animals during their investigations to discover a noise that could potentially deter sperm whales from ferry routes. Those investigators speculated that the sperm whales they were investigating in the Canary Islands may have lost hearing sensitivity to the low frequencies generated by ships' engines and propellers because of the heavy marine traffic in the area. As mentioned above, those investigators were successful at eliciting reactions in response to a higher frequency 10-kHz pulse.

André et al. (2001) presented, in abstract form, the results of an examination of the ears of two sperm whales killed after collisions with ferries in the Grand Canary Islands. They found the ears of both animals to have reduced auditory nerve volumes (not specified further). In addition, in one animal, the inner ear had patches of dense tissue. Those researchers suggested that these results, as confirmed by histological analyses, were consistent with auditory nerve degeneration and fibrous growth in response to long-term exposure to low-frequency sounds from shipping. These whales are resident in an area of heavy marine traffic. Details of this investigation have not been published.

There were 87 sightings of sperm whales during the 1992–1994 GulfCet shipboard surveys in the north central and western Gulf of Mexico (Würsig et al. 1998). However, sperm whale reactions were only recorded for 15 of those sightings, as the researchers reported that reactions tended to be "non-existent" unless the vessel approached the animals within several hundred meters. Of the 15 sightings of sperm whales during which responses were recorded, on 11 occasions the sperm whales were reported to have exhibited no reaction. During the other four encounters, the sperm whales dove abruptly. All four of those occurred within 200 m of the ship. Sperm whales were never reported to approach the survey vessel. The authors of that report estimated the sound levels of their survey vessels in the 20–1,000 Hz frequency range to be on the order of 120–150 dB re 1  $\mu$ Pa at 200 m and 105–125 dB re 1  $\mu$ Pa at 9–10 km. These estimates were based not on direct measurements, but on comparisons with supply vessels of similar sizes.

A couple of different groups have looked at the effects of whalewatching boats on sperm whales. (1) Richter et al. (2003) reported that male sperm whales off Kaikoura, New Zealand, had shorter mean and median blow intervals in the presence of their research vessel and/or whalewatching boats and that the sperm whales in that study spent more time at the surface and changed heading more frequently in the presence of whalewatching boats. Additionally, the whales exhibited a shorter time to first click in the presence of boats (defined as the time between when a whale was observed to lift its tail flukes from the water to initiate a deep dive and when it was first heard to click during that descent). Resident sperm whales, in general, appeared to show fewer reactions and less-pronounced reactions to whalewatching vessels than did transient animals, suggesting habituation to the disturbance. (2) Sperm whales off the Azores were studied using both land- and boat-based observations to assess the effects of whalewatching boats on those animals, without any clear evidence of disturbance (Magalhães et al. 2002). In that study, there were 64 sightings of sperm whales during land-based observations. No changes in feeding or socializing/resting behaviours were observed during the 39 sightings when whalewatching boats were present. Changes in heading, spatial arrangement, diving patterns, frequencies of aerial displays, and swimming speed at times when a whalewatching boat was present versus absent were not statistically significant. A whalewatching boat was present during 30 of the 40 boat-based observations of sperm whales. Those investigators found significantly higher rates of changes in swimming speed and aerial displays when inappropriate maneuvers (including angle of approach, vessel speed, and minimum distance of approach) were made by the whalewatching boats. The mean breathing interval of groups of mature female and immature whales was significantly longer in the presence of whalewatching boats only when they were accompanied by calves and was not affected for groups without calves or for larger individuals. Finally, Gordon et al. (1998) reported that sperm whale calves often approached whalewatching boats off Dominica.

Short-term effects of boats on coastal bottlenose dolphins have been documented in several studies, but long-term effects are as yet speculative. Janik and Thompson (1996) assessed the surfacing patterns of bottlenose dolphins in response to passing boats in the Moray Firth, Scotland, a heavily trafficked area connecting the Caledonian Canal with the North Sea. They compared the number of dolphin surfacings in the one-minute period prior to a boat passing within 50 m with the number of dolphin surfacings in the one-minute period following the boat's passing. Significantly fewer dolphin surfacings were observed following a boat passing than prior to a boat passing. However, 22 of their 34 boat-dolphin encounters involved the same dolphin-watching boat, which followed the dolphins and tried to stay in their vicinity. When the authors analyzed these separately, they found a significant effect of the dolphin-watching boat on bottlenose dolphin surfacing rate but no significant effect of other boat traffic.

There were 110 sightings of bottlenose dolphins during the shipboard portion of the 1992–1994 GulfCet program (Würsig et al. 1998). Reactions to the survey ship were reported for 88 of those encounters. Most of the reported reactions were positive, with the dolphins bowriding the vessel during 68 of the sightings and merely approaching the vessel on an additional six occasions. For the remaining 14 sightings, the bottlenose dolphins were reported to have displayed no reaction. No avoidance reactions were observed.

Cope et al. (1999) investigated the effects of boat traffic on coastal Atlantic bottlenose dolphins off South Carolina. The results of that study, presented in abstract form, suggest significant disturbance caused by dolphin-watching boats and motorboats, while kayaks, sailboats, ships, and ferries had no apparent effects on dolphin behaviour. Those investigators defined disturbance using four categories: no response, change in behaviour, change in direction of movement, and change in both. They found the level of disturbance to be significantly correlated with the number of boats present and with boat speed. Greater boat speeds resulted in greater numbers of individuals at the surface, while the proportion of dolphins feeding and group size and cohesion were lower. Few details were given in this abstract presentation.

Scarpaci et al. (2000) made behavioural recordings along with simultaneous acoustic recordings of bottlenose dolphins in Port Phillip Bay, Australia, to assess the effects of commercial dolphin-swim boats on those animals. Those investigators found that the dolphins whistled at significantly ( $p = 0.001$ ) higher rates in the presence of boats. They suggested that the dolphins may have increased their level of whistling to maintain group cohesion in the presence of boats. In another study involving the bottlenose dolphins off Port Phillip Bay, Australia, Scarpaci et al. (2001) used focal group observations from land to assess the dolphins' responses to boats. They found the dolphins to feed less when vessels were present (9.5% of observations) than absent (19.7%). They also noted the proportion of observations of social behaviour to be highest when vessels were present.

Allen and Read (2000) examined bottlenose dolphin foraging in relation to boat traffic density in one heavily trafficked and one rather pristine inshore site along the west central coast of Florida. Although boat densities were significantly greater at both sites during the weekend than on weekdays, frequencies of dolphin foraging were not significantly different between the two time periods at either site. Habitat



selection, however, was significantly different between the weekend and weekday periods at the heavily trafficked site, with dolphins preferring dredged channels and spoil islands on weekdays whereas their weekend distribution was random. Those investigators suggested that the dolphins decreased their use of primary foraging habitats when vessel densities were high either to avoid vessels or in response to changes in prey densities that resulted from the high density of vessels.

Nowacek et al. (2001) studied the impact of boats on resident bottlenose dolphins in the inshore and nearshore waters of the Gulf of Mexico in Sarasota Bay, Florida. They used focal animal observations to assess individual responses to experimental boat approaches from a distance of 100 m. Those investigators found that those bottlenose dolphins had significantly ( $p < 0.0001$ ) longer interbreath intervals during boat approaches than during control periods when no boats were within 100 m and that experienced mothers (those with at least one calf  $\geq 3$  years of age) had the longest interbreath intervals during boat approaches. In addition, closer approaches resulted in significantly ( $p < 0.01$ ) longer interbreath intervals, while boat speed and boat type had no effect on interbreath interval. Those researchers also used video recording of the animals from an airship to assess subsurface behaviours during experimental approaches. They found significantly ( $p < 0.0001$ ) more changes in interanimal distance, swimming speed, and heading of bottlenose dolphins during boat approaches than during control situations. These changes, for the most part, involved the animals moving closer together, swimming faster, and moving out of the path of the approaching boat. Changes in headings and interanimal distances were related to water depth, boat type, and boat speed. More changes occurred in heading and interanimal distance during slow approaches than during fast approaches, suggesting duration of exposure impacted the probability of a reaction. Also, more changes in heading and interanimal distance occurred during erratic approaches, suggesting that unpredictability increased the likelihood of a reaction.

In a recent study, the bottlenose dolphins of northern Scotland were found to be more likely to breathe in synchrony when boats were present (Hastie et al. 2003). The authors of that report suggested that this could be related to an antipredator response, if the dolphins perceived the boats as a threat, or that increased synchrony may play a role in social cohesion during times when acoustic communication may be masked.

In the Bay of Islands, New Zealand, Constantine et al. (2004) evaluated the effects of dolphin-watching boats on bottlenose dolphins. In that study, the dolphins' behaviours were found to vary significantly ( $p < 0.0001$ ) with the number of boats present. Resting behaviour seemed to be most affected, decreasing with increasing numbers of boats. Resting behaviour was only observed 0.5% of the time when three or more boats were present.

Ross and Markowitz (2001) studied the reactions of Hawaiian spinner dolphins to boat presence at Midway Atoll National Wildlife Refuge using shore-based observations. They compared aerial and surface behaviours before the arrival of a boat, during the boat presence, and for 15, 30, and 60 minutes after the boat had left at distances of 100, 300, and 500 m. The results of that study, presented in abstract

form, suggest that aerial and surface behaviours increased within 300 m and 100 m of a boat. This immediate increase in the frequencies of these behaviours declined by 60 minutes after the boat had left.

There were 14 sightings of spinner dolphins during the shipboard portion of the 1992–1994 GulfCet program (Würsig et al. 1998). For all 14 of those sightings, the spinner dolphins were reported to have been bowriding the survey vessel. No avoidance reactions were observed. There were 177 sightings of pantropical spotted dolphins during those shipboard surveys. Response to the survey vessel was reported for 165 of those sightings. In general, the responses of spotted dolphins to the survey vessel were positive. During 137 (83%) of those encounters, the dolphins were observed bow riding with the vessel and for an additional 18 sightings, they were observed approaching the ship. On nine occasions, the spotted dolphins did not appear to react to the survey vessel, while there was a single sighting during which they exhibited avoidance behaviour.

Reactions of beluga whales to ships and boats are highly variable depending on the circumstances, ranging from very tolerant to highly responsive (Richardson et al. 1995).

The effect of vessel noise on beluga whales in the St. Lawrence River estuary, Québec, Canada, was assessed by Lesage et al. (1999). They used controlled experiments to record the surface behaviour and vocalizations of beluga whales before, during, and after the passing of two different types of boats—an outboard motorboat moving rapidly and erratically on an unpredictable course, and a ferry moving regularly and slowly through the study area on a predictable route. Noise from the motorboat peaked at a frequency of 6 kHz but was strong up to 16 kHz, with a second peak at 11.5 kHz. The noise from the ferry, on the other hand, had its greatest sound levels below 6 kHz and its engines generated a tone at around 175 Hz. Beluga whales changed their vocalizations in response to both these vessels. Changes included the use of higher-frequency vocalizations, a greater redundancy in vocalizations (more calls emitted in a series), and a lower calling rate. The lower calling rate persisted for longer during exposure to the ferry than to the motorboat.

Investigators attempting to record beluga whale vocalizations off Norway found those whales to be surprisingly silent most of the time. The whales were silent during 72% of the recordings when the whales were known to be in the vicinity. Those researchers suggested that the relative silence of this usually vocal species could be attributed to the presence of the research vessel in an area where whales are not accustomed to boat traffic (Karlsen et al. 2002).

Harbor porpoises, in general, tend to show avoidance behaviour toward boats (see Richardson et al. 1995). Palka (1996) reported that some harbor porpoises showed avoidance reactions at greater than 700 m from a survey vessel in the Gulf of Maine.

**Seals.**—When in the water (vs. hauled out), seals appear less responsive to approaching vessels. Some seals will approach a vessel out of apparent curiosity, including noisy vessels such as those operating airgun arrays (Moulton and Lawson 2002). Suryan and Harvey (1999) reported that Pacific harbor seals (*Phoca vitulina richardsi*), commonly left the shore when powerboat operators approached to observe

them. These seals apparently detected a powerboat at a mean distance of 264 m, and seals left their haul-out sites when boats approached to within 144 m.

**Sea Turtles.**—To the best of our knowledge, there are no systematic data on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound.

#### **6.5.12.4. Effects of Accidental Spills**

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with Husky's policy, and handling and reporting procedures. It is possible that small amounts of Isopar could be leaked from the streamers or that a fuel spill may occur from the seismic ship and/or its support vessels. Any spills would likely be small and quickly dispersed by wind, wave, and ship's propellor action. The effects of hydrocarbon spills on marine mammals and sea turtles were overviewed in Husky Oil (2000) in Section 5.9.1.3 and 5.9.2.3, respectively and are not repeated here. Based on studies, whales and seals do not exhibit large behavioural or physiological responses to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil (St. Aubin 1990; Williams et al. 1994). Sea turtles are thought to be more susceptible to the effects of oiling than marine mammals but any effects are believed to be sublethal (Husky Oil 2000). Effects of an Isopar spill on marine mammals or sea turtles would be *negligible*.

#### **6.5.13. Effects of Other Project Activities**

There is potential for marine mammals and sea turtles to interact with the lights, domestic and sanitary wastes, and air emissions from the seismic ship and its support vessels. As discussed previously, any effects from these interactions are predicted to be *negligible*.

#### **6.5.14. Application of Effects Assessment**

Based on the above review, marine mammals and sea turtles will likely exhibit certain behavioural reactions, including displacement from an area around a seismic acoustic source. There is also a chance of displacement from geohazards sources but the likelihood is much reduced relative to the seismic array given the lower source levels and narrow operating beams of the geohazards equipment. The size of this displacement area will likely vary amongst species, during different times of the year, and even amongst individuals within a given species. There is also a risk that marine mammals (and perhaps sea turtles) that are very close to the seismic array may incur temporary hearing impairment. The assessment of impacts presented here is based upon the best available information, however, there are data gaps that limit the certainty of these impact predictions. Note that we have discussed potential impacts separately for toothed whales, baleen whales, and seals given their different hearing abilities and sensitivities to sound.

Potential interactions between Project activities and marine mammals and sea turtles are shown in Table 6.10.

**Table 6.10. Potential Interactions between the Project and (1) Marine Mammals and (2) Sea Turtles.**

<b>Valued Environmental Components: (1) Marine Mammals and (2) Sea Turtles</b>				
	<b>Toothed Whales</b>	<b>Baleen Whales</b>	<b>Seals</b>	<b>Sea Turtles</b>
<b>PROJECT ACTIVITIES</b>				
<b>Vessel Presence/Lights</b>	x	x	x	x
<b>Sanitary/Domestic Waste</b>	x	x	x	x
<b>Air Emissions</b>	x	x	x	x
<b>Garbage (N/A) <sup>a</sup></b>				
<b>Noise</b>				
Vessel	x	x	x	x
Seismic Array	x	x	x	x
Boomer	x	x	x	x
Echosounder				
Sidescan sonar	x			
<b>Helicopters</b>	x	x	x	x
<b>Shore Facilities <sup>b</sup> (N/A)</b>				
<b>Accidental Spills</b>	x	x	x	x
<b>OTHER PROJECTS AND ACTIVITIES</b>				
<b>Grand Banks</b>				
<b>Scotian Shelf</b>				
<b>Exploration</b>	x	x	x	x
<b>Fisheries</b>	x	x	x	x
<b>Marine Transportation</b>	x	x	x	x
<sup>a</sup> Not applicable as garbage will be brought ashore or burned.				
<sup>b</sup> There will not be any new onshore facilities. Existing infrastructure will be used.				

### 6.5.15. Noise Criteria for Assessing Impacts

Impact zones for marine mammals are commonly defined by the areas within which specific received sound level thresholds are exceeded. The U.S National Marine Fisheries Service (NMFS 1995, 2000) has concluded that whales should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1  $\mu$ Pa (*rms*). The corresponding limit for seals has been set at 190 dB re 1  $\mu$ Pa (*rms*). These sound levels are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS, one cannot be certain that there will be no injurious effects, auditory or otherwise, to marine mammals. An additional criterion that is often used in predicting impacts is 160 dB re 1  $\mu$ Pa; at this received level, some marine mammals exhibit behavioural effects. The 180 and 190 dB re 1  $\mu$ Pa (*rms*) distances for the airgun arrays operated by Husky's proposed seismic contractor are unknown. We assume a 500-m safety zone (or zone around the airgun arrays where marine mammals and sea turtles may experience TTS or physical effects from the sound) based upon the C-NOPB recommendation for a marine mammal safety zone. In the absence of site-specific acoustic modeling, we have used the acoustic modelling results in Moulton et al. (2003) to provide guidance on the ranges one might expect sound levels to be 160 dB (from a 24 airgun 4,450 in<sup>3</sup> array); it was estimated that 160 dB could occur at distances ranging from ~3 to 12 km (varied based on water depth and time of year) from the array. We use the maximum distance of 12 km when estimating disturbance effects on marine

mammals. These three noise criteria (160, 180, and 190 dB re 1  $\mu$ Pa (*rms*)) and the corresponding “estimated” distances at which they occur, have been used in this document when assessing impacts on marine mammals.

#### **6.5.15.1. Marine Mammal VEC**

Marine mammal effects assessment is contained in Table 6.11.

##### **6.5.15.1.1. Toothed Whales**

Despite the relatively poor hearing sensitivity of toothed whales (at least the smaller species that have been studied) at the low frequencies that contribute most of the energy in seismic pulses, sounds are sufficiently strong that they remain above the hearing threshold of odontocetes at tens of kilometers from the source. Also, toothed whales can likely hear the boomer and sidescan sonar. There are no toothed whale species listed as endangered by COSEWIC that regularly occur in the Project Area. The received sound level of 180 dB re 1  $\mu$ Pa (*rms*) criterion is accepted as a level that below which there is no physical effect on toothed whales. It is assumed that disturbance effects for toothed whales may occur at received sound levels at or above 160 dB re 1  $\mu$ Pa (*rms*). However, it is noted that there is no good scientific basis for using this 160-dB criterion for odontocetes.

#### **Hearing Impairment and Physical Effects**

Given that whales typically avoid seismic noise, whales in and near the Project Area will likely not be exposed to levels of sound from the airgun array that are high enough to cause non-auditory physical effects or hearing impairment. It is highly unlikely that toothed whales will experience mortality or strand as a result of the Proponent’s seismic activity. The mitigation measure of ramping up the airgun array will allow any whales close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the airgun array and geohazards sources will not be started if a whale is sighted within the 180 dB safety zone. There is little potential for toothed whales being close enough to the array and geohazards sources to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite “temporary”. The Proponent’s seismic and geohazards program is predicted to have *negligible to low* physical impacts on toothed whales, over a duration of *1-12 months* (approximately 90 days), in an area *<1 km<sup>2</sup>*. Therefore, auditory and physical impacts on toothed whales would be *not significant*.

#### **Disturbance Effects**

Based on the above review, there could be behavioural effects on some species of toothed whales within the Project Area. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. Based on available literature, a 160 dB re 1  $\mu$ Pa (*rms*) sound level is used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. This is likely a conservative criterion since some toothed whale species:

**Table 6.11. Effects Assessment on Marine Mammals.**

<b>Valued Environmental Component: Marine Mammals</b>								
<b>Project Activity</b>	<b>Potential Positive (P) or Adverse (A) Environmental Effect</b>	<b>Mitigation</b>	<b>Evaluation Criteria for Assessing Environmental Effects</b>					
			<b>Magnitude</b>	<b>Geographic Extent</b>	<b>Frequency</b>	<b>Duration</b>	<b>Reversibility</b>	<b>Ecological/ Socio-Cultural and Economic Context</b>
<b>Project Activities</b>								
<b>Vessel Presence/ Lights</b>	Attraction (A)	-	0-1	1	6	2	R	1
<b>Sanitary/Domestic Waste</b>	Increased Food (A/P)	-	0-1	1	6	1	R	1
<b>Air Emissions</b>	Surface Contaminants (A)	-	0	1	6	2	R	1
<b>Garbage</b>	-	-	-	-	-	-	-	-
<b>Noise</b>								
Vessel	Disturbance (A)		0-1	1-2	1	2	R	1
Seismic Array	Physical Effects (A)	Ramp-up <sup>a</sup> Delay Start Shutdown	0-1	1	1	2	R	1
Seismic Array	Disturbance (A)	Ramp-up <sup>a</sup> Delay Start Shutdown	1	3-4	1	2	R	1
Boomer	Physical Effects (A)	Delay Start	0-1	1	1	1	R	1
Boomer	Disturbance (A)	Delay Start	0-1	1	1	1	R	1
Sidescan Sonar	Physical Effects (A)	Delay Start	0-1	1	1	1	R	1
Sidescan Sonar	Disturbance (A)	Delay Start	0-1	1	1	1	R	1
<b>Helicopters</b>	Disturbance (A)	Maintain high altitude	0-1	1-2	1 <sup>c</sup>	1	R	1
<b>Shore Facilities (N/A)<sup>b</sup></b>	-	-	-	-	-	-	-	-
<b>Accidental Spills</b>	Injury/Mortality (A)	Spill Response	1	2	?	1	R	1

Valued Environmental Component: Marine Mammals								
Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
<div>Key:</div> <div>Magnitude: 0 = Negligible, essentially no effect 1 = Low 2 = Medium 3 = High</div> <div>Frequency: 1 = &lt;11 events/yr 2 = 11-50 events/yr 3 = 51-100 events/yr 4 = 101-200 events/yr 5 = &gt;200 events/yr 6 = continuous</div> <div>Reversibility: R = Reversible I= Irreversible (refers to population)</div> <div>Duration: 1 = &lt;1 month 2 = 1-12 months 3 = 13-36 months 4 = 37-72 months 5 = &gt;72 months</div> <div>Geographic Extent: 1 = &lt;1 km<sup>2</sup> 2 = 1-10 km<sup>2</sup> 3 = 11-100 km<sup>2</sup> 4 = 101-1,000 km<sup>2</sup> 5 = 1,001-10,000 km<sup>2</sup> 6 = &gt;10,000 km<sup>2</sup></div> <div>Ecological/Socio-cultural and Economic Context: 1 = Relatively pristine area or area not adversely affected by human activity 2 = Evidence of existing adverse effects</div> <div>*N/A = Not Applicable</div>								
<div><sup>a</sup> For endangered baleen whales, the airgun arrays will be shutdown if a whale is sighted within 500 m of the array.</div> <div><sup>b</sup> There will not be any new onshore facilities required. Existing infrastructure will be used.</div> <div><sup>c</sup> Estimated helicopter trips during 2005.</div>								

- have been observed in other areas relatively close to an active seismic source where received sound levels are greater than 160 dB; and
- individuals which may be temporarily displaced from an area will not be significantly impacted by this displacement.

It is uncertain how many toothed whales may occur in the Project Area (June to October). The Project Area is not known to be an important feeding or breeding areas for toothed whales. Disturbance effects from seismic and geohazards sources on toothed whales would likely be *minor*, over a *1-12 month* period (approximately 90 days), in an area of *11-100* or *101-1,000 km<sup>2</sup>*. Therefore, impacts related to disturbance, are judged to be *not significant* for toothed whales.

## Prey Species

It is unlikely that prey species for toothed whales will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature and over a small portion of a whale's foraging range within the Project Area. Potential impacts of reduced prey availability on toothed whales are predicted to be *negligible*.

#### 6.5.15.1.2. Baleen Whales

Baleen whales are thought to be sensitive to low frequency sounds such as those that contribute most of the energy in seismic pulses. Species of most concern are those that are listed as endangered by COSEWIC and that may occur in and near the Project Area (blue whales) and those listed as special concern by COSEWIC that occur in relatively high numbers when operations will occur (fin whales). As with toothed whales, the 180 dB re 1  $\mu$ Pa (*rms*) criteria is used when estimating the area where hearing impairment may occur for all species of baleen whales (although there are no data to support this criterion for baleen whales). For all baleen whale species, it is assumed that disturbance effects (avoidance) may occur at sound levels greater than 160 dB re 1  $\mu$ Pa (*rms*).

#### Hearing Impairment and Physical Effects

Given that baleen whales typically avoid seismic noise, baleen whales, including blue and fin whales, will likely not be exposed to levels of sound from the airgun array high enough to cause non-auditory physical effects or hearing damage. The mitigation measure of ramping up the airgun array will allow any whales close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the airgun array will not be started if a baleen whale is sighted within the 180 dB safety zone. If a blue whale (or North Atlantic right whale—very unlikely to occur in Project Area) is sighted within 500 m of the seismic array when the airguns are active, the array will be shutdown. Therefore, there is little potential for baleen whales, including blue whales, being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite “temporary”. The Proponent’s seismic program is predicted to have *negligible to low* physical impacts on baleen whales, over a duration of *1-12 months* (approximately 90 days), in an area  $<1 \text{ km}^2$ . Therefore, auditory and physical impacts on baleen whales would be *not significant*.

#### Disturbance Effects

Based on the above review, there could be behavioural effects on some species of baleen whales within and near the Project Area. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. The area where displacement would most likely occur would have a predicted scale of impact at 11-100 or 101-1,000  $\text{km}^2$ . This is likely a conservative estimate given that:

- some baleen whale species in other regions have been observed in areas relatively close to an active seismic source; and
- it is unlikely that displacement from an area, constitutes a significant impact for baleen whales in the Project Area.

It is uncertain how many baleen whales may occur in the Project Area during the period when seismic activity is most likely to occur (June to October). The Project Area is not known to be important feeding or breeding areas for baleen whales and blue whales are not known to concentrate in the area. Disturbance effects on species of baleen whales, including blue whales, would likely be *low*, over a *1-12*



*month period* (approximately 90 days), in an area of *11-100* or *101-1,000-km<sup>2</sup>*. Therefore, impacts related to disturbance, are judged to be *not significant* for baleen whales.

## **Prey Species**

It is unlikely that prey species for baleen whales, particularly euphausiids, will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature and over a small portion of a whale's foraging range within the seismic area. Potential impacts of reduced prey availability on baleen whales, including those species considered at risk by COSEWIC, are predicted to be *negligible*.

### **6.5.15.1.3. Seals**

None of the species of seal that occur within the Project Area are considered at risk by COSEWIC.

## **Hearing Impairment and Physical Effects**

Given that seals typically avoid the immediate area around a seismic array, seals, primarily harp and hooded seals, will likely not be exposed to levels of sound from the airgun array high enough to cause non-auditory physical effects or hearing impairment. The mitigative measure of ramping up the airgun array will allow any seals close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Therefore, there is little potential for seals being close enough to an array to experience hearing impairment. If some seals did experience TTS, the effects would likely be quite "temporary". The Proponent's seismic program is predicted to have *negligible to low* physical impacts on seals, over a duration of *1-12 months* (approximately 90 days), in an area *<1 km<sup>2</sup>*. Therefore, auditory and physical impacts on seals would be *not significant*.

## **Disturbance Effects**

Based on the above review, there could be behavioural effects on seals within and near the Project Area. Known effects include changes in diving behaviour and avoidance of the seismic vessel. It is uncertain how many seals may occur in the Project Area during the period when seismic activity is most likely to occur (June to October). Most harp and hooded seals would be in arctic waters at this time of year. There are no available criteria for assessing the sound level most likely to elicit avoidance reactions in seals. It is noteworthy that seals have been sighted inside the radius thought to cause TTS (190 dB) in other areas. A 160 dB re 1 µPa (*rms*) sound level has been conservatively used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. Therefore, the area where displacement may occur would have a scale of impact at *11-100* or *101-1,000 km<sup>2</sup>*. This estimated area around the seismic vessel would be ensonified at 160 dB for ~90 days; duration of *1-12 months*. The Proponent's proposed seismic program is predicted to have *low* disturbance impacts on seals. Therefore, impacts related to disturbance, are judged to be *not significant* for seals.

## Prey Species

It is unlikely that prey species for seals will be impacted by seismic activities to a degree that inhibits the foraging success of seals. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature and over a small portion of a seal's foraging range within the seismic area. Potential impacts of reduced prey availability are predicted to be *negligible*.

### 6.5.15.2. Sea Turtle VEC

Effects assessment for sea turtles is contained in Table 6.12.

## Hearing Impairment and Physical Effects

Based on available data, it is likely that 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 on permanent hearing loss to reach any definitive conclusions about received sound levels that trigger TTS. Also, it is likely that sea turtles will exhibit behavioural reactions or avoidance within an area of unknown size around a seismic vessel. The mitigation measure of ramping up the airgun array over a 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. [Also, it is unlikely that many sea turtles will occur in the Project Area.] 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". The Proponent's seismic program is predicted to have *negligible to low* physical impacts on sea turtles, over a duration of *1-12 months* (approximately 90 days), in an area  $<1 \text{ km}^2$ . Therefore, auditory and physical impacts on sea turtles would be *not significant*.

## Disturbance Effects

It is possible that sea turtles will occur in the Project Area, although the cooler water temperatures likely preclude some species from occurring there and it is not an area known for sea turtles. If sea turtles did occur near the seismic vessel, it is likely that sea turtles would exhibit avoidance within a localized area around the seismic vessel. Based on observations of green and loggerhead sea turtles, behavioural avoidance may occur at received sound levels of 166 dB re  $\mu\text{Pa rms}$ . The area where displacement would most likely occur would have a scale of impact at 11-100  $\text{km}^2$ . This estimated area around the seismic vessel would be ensonified at 166 dB for ~90 days. The Proponent's seismic program is predicted to have *low* disturbance effects on sea turtles, over a duration of *1-12 months* (approximately 90 days), in an area 11-100  $\text{km}^2$ . Therefore, impacts related to disturbance, are judged to be *not significant* for sea turtles.

**Table 6.12. Effects Assessment on Sea Turtles.**

Valued Environmental Component: Sea Turtles								
Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
<b>Project Activities</b>								
Vessel Presence/ Lights	Attraction (A)	-	0-1	1	6	2	R	1
Sanitary/Domestic Waste	Increased Food (A/P)	-	0-1	1	6	1	R	1
Air Emissions	Surface Contaminants (A)	-	0	1	6	2	R	1
Garbage	Surface Contaminants (A)	-	-	-	-	-	-	-
Noise								
Vessel	Disturbance (A)		0-1	1-2	1	2	R	1
Seismic Array	Physical Effects (A)	Ramp-up Delay Start	0-1	1	1	2	R	1
Seismic Array	Disturbance (A)	Ramp-up Delay Start	0-1	3	1	2	R	1
Boomer	Physical Effects (A)	Delay Start	0-1	1	1	1	R	1
Boomer	Disturbance (A)	Delay Start	0-1	1	1	1	R	1
Helicopters	Disturbance (A)	Maintain high altitude	0	1	1	1	R	1
Shore Facilities (N/A) <sup>a</sup>	-	-	-	-	-	-	-	-
Accidental Spills	Injury/Mortality (A)	Spill Response	1	2	?	1	R	1
<p><b>Key:</b></p> <p>Magnitude:  0 = Negligible, essentially no effect  1 = Low  2 = Medium  3 = High</p> <p>Frequency:  1 = &lt;11 events/yr  2 = 11-50 events/yr  3 = 51-100 events/yr  4 = 101-200 events/yr  5 = &gt;200 events/yr  6 = continuous</p> <p>Reversibility:  R = Reversible  I = Irreversible (refers to population)</p> <p>Duration:  1 = &lt;1 month  2 = 1-12 months  3 = 13-36 months  4 = 37-72 months  5 = &gt;72 months</p> <p>Geographic Extent:  1 = &lt;1 km<sup>2</sup>  2 = 1-10 km<sup>2</sup>  3 = 11-100 km<sup>2</sup>  4 = 101-1,000 km<sup>2</sup>  5 = 1001-10,000 km<sup>2</sup>  6 = &gt;10,000 km<sup>2</sup></p> <p>Ecological/Socio-cultural and Economic Context:  1 = Relatively pristine area or area not adversely affected by human activity  2 = Evidence of existing adverse effects</p> <p>*N/A= Not Applicable</p>								
<sup>a</sup> There will not be any new onshore facilities required. Existing infrastructure will be used.								

## Prey Species

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. Potential impacts of reduced prey availability are predicted to be *negligible*.

### 6.5.16. Effects on Species at Risk

As discussed in previous sections, SARA species of relevance to the Project Area include:

- Wolffish
- Atlantic cod
- Ivory Gull
- Leatherback sea turtle
- Blue whale

As per the detailed effects assessment contained in Section 6.5.6, physical effects of the Project on the various life stages of wolffish and Atlantic cod will range from *negligible* to *low* over a duration of 1-12 months, within an area of <1 km<sup>2</sup>. Behavioural effects may extend out to a larger area but are still predicted to be *not significant*.

The Project will have *no effect* on Ivory Gull because they are unlikely to be in the area during the summer when the surveys are being conducted. Furthermore, they are not known to be sensitive to stranding on vessels or to underwater sound.

Blue whale have and sea turtles have always likely been scarce on the Grand Banks and the chances of encountering them are low. Project mitigations will include ramp-ups, shutdowns of the airgun arrays, and the presence of MMOs. The Project is predicted to have *no significant effect* (physical, or behavioural) on baleen whales, including blue whales, or on sea turtles (see preceding sections).

## 6.6. Cumulative Effects

This EA has assessed cumulative effects within the Project and thus the residual effects described in preceding sections include any potential cumulative effects from the Husky seismic survey and geohazard survey activities in the Basin.

It is also necessary to assess cumulative effects from other activities outside the Project that are planned for the area. These activities may include:

- Commercial fishing [Note that there are no recreational or aboriginal fisheries in Orphan Basin.]
- Vessel traffic (e.g., transportation, defense, yachts)
- Hunting (e.g., seabirds, seals)
- Offshore oil and gas industry

Commercial fishing has been discussed in detail in Section 5.5. Commercial fishing activities, by their nature, cause mortality and disturbance to fish populations and may cause incidental mortalities or disturbance to seabirds, marine mammals, and sea turtles. It is predicted that the seismic surveys will not cause any mortality to these VECs (with the potential exception of small numbers of petrels) and thus there will be no or negligible cumulative effect from mortalities. There is some potential for cumulative effect from disturbance (e.g., fishing vessel noise) but there will be directed attempts by both industries to mitigate effects and to avoid each other's active areas and times. Any gear damage attributable to the Project will be compensated and thus any effects will be *not significant*.

In the summer, the main North Atlantic shipping lanes between Europe and North America lie to the north of the Grand Banks into the Strait of Belle Isle. In the winter, that traffic shifts to the main shipping lanes along the southern Grand Banks into the Gulf of St. Lawrence. Thus, potential for cumulative effects with other shipping is predicted to be *negligible to low*.

The vast majority of hunting of seabirds (mostly murre) in Newfoundland and Labrador waters occurs near shore from small boats and thus, there is little or no potential for cumulative effects on this VEC. Similarly, most, if not all, seal hunting would occur inshore of the Project Area

Offshore oil and gas industry 2005 projects listed on the C-NOPB/CEAA registry ([www.cnopb.nfnet.com](http://www.cnopb.nfnet.com) as viewed 16 February 2005) include:

- Labrador Shelf 2D Seismic Program (TGS-NOPEC or GSI)
- Orphan Basin 3-D Seismic Program (Chevron Canada Resources, ExxonMobil, Shell, and Imperial)
- Jeanne d'Arc Basin Delineation Drilling Program (Husky)
- Laurentian Sub-basin 3-D Seismic Program (ConocoPhillips)

In addition, there are two existing offshore production developments (Hibernia and Terra Nova) and one under construction (White Rose) on the northeastern part of the Grand Banks. The proposed drilling program and the existing developments are at least 35 to 40 km distant from the 2005 Survey Area, are within the range of activities that have occurred on the Grand Banks over the last 10 years. Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to be *not significant*.

There is potential for cumulative effects with the Orphan Basin 3-D Seismic Program, which have the potential to overlap in time and, potentially in space, if animals in both areas receive sound from more than one program at a time. Nonetheless, the two surveys will have to be far enough apart at any given time so as not to interfere with each other's data quality. As discussed in Buchanan et al. (2004), significant negative effects on key sensitive VECs such as marine mammals appear unlikely beyond a localized area from the sound source (it is this zone upon which the mitigation measures are based). In addition, all programs will use mitigation measures such as ramp ups and shutdowns of the airgun arrays. Thus, it seems likely that while some animals may receive sound from one or more seismic programs in 2005, the current scientific prediction is it that *no significant residual effects* will result.

## 6.7. Summary of Mitigations

Project mitigations have been detailed in the various individual sections of the preceding EA and are summarized in the text provided below and in Table 6.13. Husky and contractors will adhere to mitigations detailed in Appendix 2 of the C-NOPB *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (April 2004).

Fishers who may be operating in the area will be notified of the timing and location of planned activities by means of a CCG "Notice to Mariners" and a "Notice to Fishers" on the CBC Radio Fisheries Broadcast. In addition, if necessary, individual fixed gear fishers will be contacted to arrange mutual avoidance. Any contacts with fishing gear, with any identifiable markings, will be reported to the C-NOPB within 24 h of the contact. Any floating debris resulting from contact with fish gear will be retrieved and retained if it is safe to do so in the opinion of the vessel's master. Husky will advise the C-NOPB prior to compensating and settling all valid lost gear/income claims promptly and satisfactorily.

**Table 6.13. List of Mitigations.**

Potential Effects	Primary Mitigations
Interference with fishing vessels	Upfront planning to avoid high concentrations of fishing vessels; SPC; advisories and communications; FLOs; picket vessels
Fishing gear damage	Upfront planning to avoid high concentrations of fishing gear; SPC; advisories and communications; FLOs; picket vessels; compensation program
Interference with shipping	SPC; advisories and communications; FLOs; picket vessels
Interference with DFO research vessels	Communications and scheduling
Temporary or permanent hearing damage to marine animals	Delay start-up if baleen whales (incl. blue whales) or sea turtles are within 500 m; ramp-up of airguns; use of qualified environmental observers
Disturbance to Species at Risk or other key habitats	Geographic and temporal avoidance, if possible
Injury to stranded seabirds	Handling and release protocols
Seabird oiling	Adherence to OWTG; use of solid streamer when feasible

Specific mitigations to minimize potential conflicts and any adverse effects with other vessels; these include:

- Excellent communications (VHF, HF, Satellite, etc.)
- Utilization of fisheries liaison officers (FLOs) for advice and coordination in regard to avoiding fishing vessels and fishing gear
- Environmental Observers (MMOs) onboard
- Picket vessels to alert other vessels of towed gear in water
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast
- Compensation program in the event any project vessels damage fishing gear
- Single Point of Contact (SPC)

Husky will also coordinate with Fisheries and Oceans, St. John's, to avoid any potential conflicts with research vessels that may be operating in the area.

Mitigation measures designed to reduce the likelihood of impacts on marine mammals will include ramp-ups, no initiation of airgun array if a marine mammal is sighted 30 min prior to ramp-up within 500 m safety zone of the energy source, shutdown of the energy source if an endangered whale or sea turtle is observed within the 500 m safety zone. Prior to the onset of the seismic survey, the airgun array will be gradually ramped up. One airgun will be fired first and then the volume of the array will be increased gradually over a recommended 20-40 min period. Two observers aboard the seismic ship will watch for marine mammals and sea turtles 30 min prior to ramp-up. If a marine mammal or sea turtle is sighted within 500 m of the array, then ramp-up will not commence until the animal has moved beyond the 500-m zone or 20 min have elapsed since the last sighting. The observers will watch for marine mammals, sea turtles, and seabirds when the airgun array is active and note the location and behaviour of these animals. The seismic array will be shutdown if an endangered whale or sea turtle is sighted within the safety zone. The planned monitoring and mitigation measures, including ramp-ups, visual monitoring (and the use of two observers before and during startups and when possible at other times), and power-down of the airguns when endangered baleen whales are seen within the "safety radii", will minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce hearing impairment. Any dead or distressed animals will be reported immediately to the C-NOPB. A monitoring report will be submitted to the C-NOPB.

The mitigation measure of ramping up the airgun array will allow any marine mammals or sea turtles close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the airgun array will not be started if a marine mammal or sea turtle is sighted within the 180 dB safety zone (expected to be within the 500 m specified in the C-NOPB *Guidelines*). If an endangered baleen whale or sea turtle is sighted within 500 m of the seismic array when the airguns are active, the array will be shutdown. Therefore, there is little potential for baleen whales, including blue whales, being close enough to the array to experience hearing impairment.

The mitigation measure of ramping up the airgun array over a 20 to 40-min period should also permit sea turtles close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. [Also, it is unlikely that many sea turtles will occur in the Project Area.] Therefore, there is likely little potential for sea turtles to be close enough to an array to experience hearing impairment.

Any seabirds (most likely Leach's Storm-Petrel) that become stranded on the vessel will be released using the mitigation methods consistent with *The Leach's Storm-Petrel: General Information and Handling Instructions* by U. Williams (Petro-Canada) and J. Chardine (CWS) (n.d.). It is understood by Husky that a CWS *Migratory Bird Handling Permit* will likely be required. In the unlikely event that marine birds or mammals are injured or killed by Project equipment or accidental spills of fuel or streamer flotation fluid, a report will immediately be filed with C-NOPB and the need for follow-up monitoring assessed.

Marine mammal and seabird observations will be made during ramp-ups and during data acquisition periods, and at other times on an opportunistic basis. Protocols will be consistent with those developed by LGL in conjunction with DFO and Environment Canada (i.e., the ESRF draft study). A monitoring program will be designed in consultation with DFO and CWS as per the C-NOPB *Guidelines*. Data will be collected by qualified environmental observers (biologists), FLOs and other qualified designates (e.g., qualified crew members) with the latter reporting to the environmental observer. A monitoring report will be submitted to the C-NOPB one year after completion of the surveys.

## **6.8. Summary of Residual Effects**

A summary of the Project's residual effects on the environment, in other words those effects that remain after mitigations have been instituted, are shown in Table 6.14.



**Table 6.14. Significance of Potential Residual Environmental Effects of the Proposed Seismic Program on VECs in the Northern Jeanne d'Arc.**

Valued Environmental Component: Fish, Fisheries, Birds, Turtles, Mammals, SARA				
	Significance Rating	Level of Confidence	Likelihood (Significant Effect Only)	
Project Activity	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Project Activities</b>				
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Garbage (N/A)	-	-	-	-
<b>Underwater Sound</b>				
Array – physical effects	NS	3	-	-
Array – behavioural effects	NS	3	-	-
Boomer - physical effects	NS	3	-	-
Boomer - behavioural effects	NS	3	-	-
Sidescan Sonar – physical effects	NS	3	-	-
Sidescan Sonar – behavioural effects	NS	3	-	-
<b>Helicopters</b>	NS	3	-	-
<b>Shore Facilities (N/A)</b>	-	-	-	-
<b>Accidental Spills</b>	NS	2	-	-
<p>Key:</p> <p>Residual environmental Effect Rating:</p> <p>S = Significant Adverse Environmental Effect</p> <p>NS = Not-significant Adverse Environmental Effect</p> <p>P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> <p>Probability of Occurrence: based on professional judgment:</p> <p>1 = Low Probability of Occurrence</p> <p>2 = Medium Probability of Occurrence</p> <p>3 = High Probability of Occurrence</p> <p>Scientific Certainty: based on scientific information and statistical analysis or professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> <p>N/A = Not Applicable</p> <p><sup>a</sup> Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.</p>				

## 7.0 References Cited

- Allen, M.C. and A.J. Read. 2000. Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. *Mar. Mamm. Sci.* 16(4):815-824.
- Alling, A.K. and H.P. Whitehead. 1987. A preliminary study of the status of White-beaked Dolphins, *Lagenorhynchus albirostris*, and other small cetaceans off the coast of Labrador. *Canadian Field-Naturalist*. 101: 131-135.
- Amano, M. and M. Yoshioka. 2003. Sperm whale diving behavior monitored using a suction-cup-attached TDR tag. *Mar. Ecol. Prog. Ser.* 258:291-295.
- Amoser, S. and F. Ladich. 2003. Diversity in noise-induced temporary hearing loss in otophysine fishes. *J. Acoust. Soc. Am.* 113(4): 2170-2179.
- André, M., E. Degollada and A. Fernández. 2001. Hearing loss in long-term low frequency sounds [sic] exposed sperm whales. Abstract presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, November 28-December 3, 2001, Vancouver, Canada. p. 6-7.
- André, M., M. Terada and Y. Watanabe. 1997. Sperm whale (*Physeter macrocephalus*) behavioural response after the playback of artificial sounds. *Rep. Int. Whal. Comm.* 47:499-504.
- Anonymous. 1975. Phantom killer whales. *S. Afr. Ship. News Fish. Ind. Rev.* 30: 50-53.
- Arnason, A. 1995. Genetic markers and whale stocks in the North Atlantic Ocean: A review. p. 91-103. *In*: A.S. Blix, L. Walloe and O. Ulltang (eds.), *Whales, Seals, Fish and Man. Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic. Developments in Marine Biology* 4.
- Arnold, B.W. 1996. Visual monitoring of marine mammal activity during the Exxon 3-D seismic survey/Santa Ynez Unit, offshore California/9 November to 12 December 1995. Rep. from Impact Sciences Inc., San Diego, CA, for Exxon Co. U.S.A., Thousand Oaks, CA. 25 p.
- Astrup, J. and B. Møhl. 1993. Detection of intense ultrasound by the cod *Gadus morhua*. *J. Exp. Biol.* 182: 71-80.
- Au, W. W. L., A.N. Popper and R.R. Fay. 2000. *Hearing by Whales and Dolphins*. Springer-Verlag, New York, NY. 458 p.
- Au, W., J. Darling and K. Andrews. 2001. High-frequency harmonics and source level of humpback whale songs. *J. Acoust. Soc. Am.* 110(5, Pt. 2):2770.
- Au, W.W.L. 1993. *The sonar of dolphins*. Springer-Verlag, New York, NY. 277 p.
- Au, W.W.L. and M. Green. 2000. Acoustic interaction of humpback whales and whale-watching boats. *Mar. Environ. Res.* 49(5, Jun.), 469-481.
- Au, W.W.L. and M. Green. 1997. Acoustic interaction of humpback whales and whale-watching boats off Maui, Hawaii. *J. Acoust. Soc. Am.* 102(5, Pt. 2), 3177.
- Austin, M.E., A.O. MacGillivray, D.E. Hannay and S.A. Carr. 2004. Acoustic Monitoring of Marathon Canada Petroleum ULC 2003 Cortland/Empire Seismic Program. Marathon Canada Petroleum ULC, by JASCO Research Ltd. 66 p.
- Baird, R.W. 2003. Update COSEWIC status report on the humpback whale *Megaptera novaeangliae* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +25 p.
- Baird, R.W., P J. Stacey and H. Whitehead. 1993. Status of the Striped Dolphin, *Stenella coeruleoalba*, in Canada. *Canadian Field-Naturalist* 107:455-465. 1993.

- Balcomb, K.C., III and D.E. Claridge. 2001. A mass stranding of cetaceans caused by naval sonar in the Bahamas. *Bahamas J. Sci.* 8(2):2-12.
- Ballie, S.M., G.J. Robertson, F.K. Wiese, U.P. Williams and D.G. Taylor. 2005. Seabird data collected by the Grand Banks offshore hydrocarbon industry 1999-2002: results, limitations, and suggestions for improvement. Canadian Wildlife Service Technical Report No. 000 Atlantic Region. xx+pp.
- Bartol, S., J.A. Musick and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). *Copeia* 1999(3):836-840.
- Benoit, D. and W.D. Bowen. 1990. Seasonal and geographic variation in the diet of Grey Seals (*Halichoerus grypus*) in Eastern Canada. p. 215-226. In: W.D. Bowen (ed.), Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Canadian Bulletin on Fisheries and Aquatic Sciences. 222 p.
- Berek, E.P., V.J. Cardone and V.R. Swail. 2000. Comparison of hindcast results and extreme value estimated for wave conditions in the Hibernia Area-Grand Banks of Newfoundland. Sixth Wave Hindcasting and Forecasting Workshop, Monterey, CA, 6-10-Nov, 2000.
- Best, P.B. 1993. Increase rates in severely depleted stocks of baleen whales. *ICES Journal of Marine Science*. 50: 169-186.
- Blaxter, J.H.S., J.A.B. Gray and E.J. Denton. 1981. Sound and startle responses in herring shoals. *J. Mar. Biol. Assoc. U.K.* 61: 851-869.
- Bleakney, J.S. 1965. Reports of marine turtles from New England and Eastern Canada. *Canadian Field-Naturalist* 79: 120-128.
- Blue, J.E., E.R. Gerstein and S.E. Forsythe. 2001. Ship strike acoustics: it is all just shadows and mirrors. *J. Acoust. Soc. Am.* 110(5, Pt. 2):2723.
- Booman, C., J. Dalen, H. Leivestad, A. Levsen, T. van der Meeren and K. Toklum. 1996. Effeter av luftkanonshyting på egg, larver og yngel. *Fisken og Havet* 1996(3):1-83. (Norwegian with English summary).
- Born, E.W., F.F. Riget, R. Dietz and D. Andriashek. 1999. Escape responses of hauled out ringed seals (*Phoca hispida*) to aircraft disturbances. *Polar Biol.* 21(3):171-178.
- Bowering, W.R. 2002. Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Subarea 2 and Divisions 3KLMNO: Stock trends based on Canadian research vessel survey results during 1978-2001. NAFO SCR Doc. 02/24. 40 p.
- Bowles, A.E., M. Smultea, B. Würsig, D.P. DeMaster and D. Palka. 1994. Relative abundance and behaviour of marine mammals exposed to transmissions for the Heard Island feasibility test. *J. Acoust. Soc. Am.* 96: 2469-2484.
- Bowles, A.E., S. Eckert, L. Starke, E. Berg, L. Wolski and J. Matesic. 1999. Effects of flight noise from jet aircraft and sonic booms on hearing, behaviour, heart rate, and oxygen consumption of desert tortoises (*Gopherus agassizi*), Wright-Patterson AFB, Ohio: United States Air Force Research Laboratory. 131 p.
- Brander, K.M. 1994. Patterns of distribution, spawning, and growth in North Atlantic cod: the utility of inter-regional comparisons. *ICES J. Mar. Sci. Symp.* 198: 406-413.
- Brown, R.G.B. 1986. Revised atlas of eastern Canadian seabirds. 1. Shipboard surveys. Canadian Wildlife Service, Ottawa. 111 p.

- Buchanan, R.A., J. Christian, V. Moulton and B. Mactavish. 2004. Orphan 3-D Seismic Program, 2004-2006 environmental assessment. LGL Report No. SA799. Prepared for Chevron Canada Resources and ExxonMobil. 209 p. + App.
- Budelmann, B.U. 1992. Hearing in crustacea. p. 131-139. *In:* (eds.) D.B. Webster, R.R. Fay and A.N. Popper. The Evolutionary Biology of Hearing.
- Cairns, D.K., W.A. Montevecchi and W. Threlfall. 1989. Researcher's guide to Newfoundland seabird colonies. Second edition. Memorial University of Newfoundland Occasional Papers in Biology, No. 14. 43 p.
- Calambokidis, J. and S.D. Osmek. 1998. Marine mammal research and mitigation in conjunction with air gun operation for the USGS 'SHIPS' seismic surveys in 1998. Draft Rep. from Cascadia Research, Olympia, WA, for U.S. Geol. Surv., Nat. Mar. Fish. Serv., and Minerals Management Service Var. pag.
- Caldwell, J. and W. Dragoset. 2000. A brief overview of seismic air-gun arrays. The Leading Edge (Aug): 898-902.
- Canada-Newfoundland Offshore Petroleum Board. Geophysical, Geological, Environmental and Geotechnical Program Guidelines, April 2004.
- Canadian Ice Services. 1960-1999. Composite Ice Charts. Ottawa, ON.
- Carr, A. 1986. Rips, FADS, and Little Loggerheads. BioScience 36: 92-100.
- Cavanagh, R.C. 2000. Criteria and thresholds for adverse effects of underwater noise on marine animals. Rep by Science Applications Intern. Corp., McLean, VA, for Air Force Res. Lab., Wright-Patterson AFB, Ohio. AFRL-HE-WP-TR-2000-0092. Var. pag.
- CEAA. 1994. Environmental Assessment Guidelines Canadian Environmental Assessment Agency, Ottawa.
- Christian, J.R., A. Mathieu, D.H. Thomson, D. White and R.A. Buchanan. 2004. Effect of seismic energy on snow crab (*Chionoecetes opilio*) 7 November 2003. Environmental Studies Research Funds Report No. 144. Calgary. 106 p.
- Colbourne E. 2000. Interannual variations in the stratification and transport of the Labrador Current on the Newfoundland Shelf. International Council for the Explorations of the Sea. CM 2000/L:2.
- Colbourne, E. and C. Fitzpatrick. 2002. Physical oceanographic conditions in NAFO subareas 2 and 3 on the Newfoundland and Labrador Shelves during 2001. NAFO SCR Doc. 02/41, 23p.
- Colbourne E., B. deYoung, S. Narayanan and J. Helbig. 1997. Comparison of hydrography and circulation on the Newfoundland Shelf during 1990-1993 with the long-term mean. Can. J. Fish. Aquat. Sci. Vol. 54(Suppl. 1), 1997
- Colbourne, E. 2004. Decadal Changes in the Ocean Climate in Newfoundland and Labrador Waters from the 1950s to the 1990s. e. J. Northwest Atlantic Fishery Science, V34, No. 4.
- Colbourne, E., C. Fitzpatrick, D. Senciall, P. Stead, W. Bailey, J. Craig and C. Bromley. 2004. An assessment of the physical oceanographic environment on the Newfoundland and Labrador Shelf during 2003. Can. Sci. Advis. Sec. Res. Doc. 2004/022.
- Constantine, R., D.H. Brunton and T. Dennis. 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. Biol. Cons. 117:299-307.
- Cook, F.R. 1981. Status report on the Leatherback Turtle *Dermochelys coriacea* in Canada. Committee on the Status of Endangered Wildlife in Canada. 17 p.

- Cook, F.R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Natural Sciences, National Museums of Canada, Ottawa, ON. 200 p.
- Coombs, S. and J.C. Montgomery. 1999. The enigmatic lateral line system. p. 319-362. *In:* (eds.) R.R. Fay and A.N. Popper. Comparative Hearing: Fish and Amphibians. Springer Handbook of Auditory Research. Springer-Verlag New York Inc.
- Cope, M., D. St. Aubin and J. Thomas. 1999. The effect of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in the nearshore waters of Hilton Head, South Carolina. Presented at the 13th Biennial Conference on the Biology of Marine Mammals, November 28-December 3, 1999, Wailea, Hawaii. p. 37-38.
- Corkeron, P.J. 1995. Humpback whales (*Megaptera novaeangliae*) in Hervey Bay, Queensland: behaviour and responses to whale-watching vessels. *Can. J. Zool.* 73(7):1290-1299.
- Corwin, J.T. 1981. Audition in elasmobranchs. p. 81-102. *In:* W.N. Tavolga, A.N. Popper and R.R. Fay (eds.) Hearing and Sound Communication in Fishes. Springer-Verlag New York Inc.
- COSEWIC. 2001. COSEWIC assessment and update status report on the leatherback turtle *Dermochelys coriacea* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 25 p.
- COSEWIC. 2003a. COSEWIC assessment and status report on the sei whale *Balaenoptera borealis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +27 p.
- COSEWIC. 2003b. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 60 p.
- COSEWIC. 2004a. Canadian Species at Risk, May 2004. Committee on the Status of Endangered Wildlife in Canada. 49 p.
- COSEWIC. 2004b. Canadian Species at Risk, November 2004.
- Cramp, S. and K.E.L. Simmons (eds.). 1983. The Birds of the Western Palearctic, Volume III: Wader to Gulls. Oxford Univ. Press, Oxford. 913 p.
- Croasdale, K.R. and Associates. 2000. Study of Iceberg Scour and Risk on the Grand Banks. PERD/CHC Report 31-26, Panel on Energy Research and Development), Calgary, AB.
- Dahlheim, M.E 1987. Bio-acoustics of the gray whale (*Eschrichtius robustus*). Ph.D. Thesis, Univ. Brit. Columbia, Vancouver, B.C. 315 p.
- Dalen, J. and G.M. Knudsen. 1987. Scaring effects in fish and harmful effects on eggs, larvae and fry by offshore seismic explorations. Symposium on Underwater Acoustics, Halifax, 1986.
- Dalen, J., E. Ona, A.V. Soldal and R. Saetre. 1996. Seismiske undersøkelser til havs: en vurdering av konsekvenser for fisk og fiskerier [Seismic investigations at sea; an evaluation of consequences for fish and fisheries]. *Fisken og Havet* 1996:1-26. (in Norwegian, with an English summary - English translation not yet published).
- Davenport, J. 1998. Sustaining endothermy on a diet of cold jelly: energetics of the leatherback turtles *Dermochelys coriacea*. *British Herpetological Society Bulletin* 62:4-8.
- Davis, R.A., D.H. Thomson and C.I. Malme. 1998. Environmental assessment of seismic exploration on the Scotian Shelf. Report by LGL Ltd. for Mobil Oil Canada Properties Ltd., Shell Canada Ltd., Imperial Oil Ltd., and the CNSOPB.

- Davis, R.W., W.E. Evans and B. Wursig (eds.). 2000. Cetaceans, sea turtles and seabirds in the Northern Gulf of Mexico: distribution, abundance and habitat associations. Vol. II: Technical Report. OCS Study MMS 2000-003.
- Desportes, G. and R. Mouritsen. 1993. Preliminary results on the diet of Long-finned Pilot Whales off the Faroe Islands. Report of the International Whaling Commission (Special Issue 14): 305-324.
- DeTracey, B. M., C.L.Tang and P.C. Smith. 1996. Low-frequency currents at the northern shelf edge of the Grand Banks. Journal of Geophysical Research, Volume 101, Issue C6, p. 14223-14236.
- DeYoung, B. and G.A. Rose. 1993. On recruitment and distribution of Atlantic cod (*Gadus morhua*) off Newfoundland. Can. J. Fish. Aquat. Sci. 50: 2729-2741.
- DFO. 1985-2004. Newfoundland Region and Maritimes Region Catch and Effort Database (digital version). Georeferenced harvest data.
- DFO. 1993. Underwater World: The Northern Shrimp. 6 p.
- DFO. 2000. Northwest Atlantic Harp Seals. DFO Science Stock Status Report E1-01 (2000).
- DFO. 2003a. Northern Shrimp (*Pandalus borealis*): Divisions 0B to 3K. Can. Sci. Advis. Sci. Stock Status Rep. 2003/036.
- DFO. 2003b. Integrated Fisheries Management Plan Northern Shrimp Northeast Newfoundland, Labrador Coast and Davis Strait (Effective 2003).
- DFO. 2003c. Northern (2J+3KL) cod stock status update. DFO Science Stock Status Report A2-01.
- DFO. 2003d. Cetacean sighting database.
- DFO Quota Reports (Newfoundland Region), for 2004. Accessed February 2005. [http://www.nfl.dfo-mpo.gc.ca/publications/reports\\_rapports2.asp](http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports2.asp)
- DFO. 2004a. Newfoundland and Labrador snow crab. Can. Sci. Advis. Sec. Stock Status Report 2004/012.
- DFO. 2004b. Allowable harm assessment for spotted and northern wolffish. DFO Can. Sci. Advis. Sec. Stock Status Report 2004/031.
- DFO. 2004c. Northern (2J + 3KL) Cod. Can. Sci. Advis. Sec. Stock Status Report 2004/011.
- DFO. 2004d. Allowable harm assessment for leatherback turtle in Atlantic Canadian waters. DFO Stock Status report 2004/035. 6 p.
- DFO. 2004e. Potential impacts of seismic energy on snow crab. DFO Can. Sci. Advis. Sec. Habitat Status Report 2004/003.
- Dobrocky Seatech. 1985. Field Data Report: Sea Ice Documentation in the Vicinity of the Hibernia Drilling Area. Report prepared for Mobil Oil Canada Ltd., Calgary, AB.
- Dufault, S. and R.A. Davis. 2003. Whale monitoring aboard The Cat, summer 2002. LGL Rep. 2741. Rep. from LGL Ltd., King City, Ont. for Bay Ferries Ltd., Charlottetown, P.E.I. 33 p. + Appendices.
- Dufault, S., H. Whitehead and M. Dillon. 1999. An examination on the current knowledge on the stock structure of Sperm Whales (*Physeter macrocephalus*) worldwide. Journal of Cetacean Resource Management. 1: 1-10.
- Duncan, P.M. 1985. Seismic sources in a marine environment. p. 56-88. In: Proc. Workshop on Effects of Explosives Use in the Marine Environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin. Envir. Prot. Br., Ottawa, ON. 398 p.
- Dunning, D.J., Q.E. Ross, P. Geoghegan, J. Reichle, J.K. Menezes and J.K. Watson. 1992. Alewives avoid high-frequency sound. N. Am. J. Fish. Manage. 12: 407-416.

- Eckert, S.A. 2000. Letter to M. James, Nova Scotia Leatherback Turtle Working Group, re possible impacts of seismic exploration off Nova Scotia on sea turtles. Hubbs-Sea World Res. Inst., San Diego, CA. 4 p.
- Eckert, S.A., K.L. Eckert, P. Ponganis and G.L. Kooyman. 1989. Diving behavior of leatherback sea turtles (*Dermochelys coriacea*). Can. J. Zool. 67:2834-2840.
- Encalada, S.E., K.A. Bjorndal, A.B. Bolten, J.C. Zurita, B. Schroeder, E. Possardt, C.J. Sears and B.W. Bowen. 1998. Population structure of Loggerhead Turtle (*Caretta caretta*) nesting colonies in the Atlantic and Mediterranean as inferred from mitochondrial DNA control region sequences. Marine Biology 130: 567-575.
- Engås, A, S. Løkkeborg, E. Ona and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*G. morhua*) and haddock (*M. aeglefinus*). Can. J. Fish. Aquat. Sci. 53(10):2238-2249.
- Engel, M.H., M.C.C. Marcondes, C.C.A. Martins, F.O. Luna, R.P. Lima and A. Campos. 2004. Are seismic surveys responsible for cetacean strandings? An unusual mortality of humpback whales in Abrolhos Bank, northeastern coast of Brazil. Report of International Whaling Commission. SC/56/E28. 8 p.
- Enger, P.S. 1981. Frequency discrimination in teleosts-central or peripheral. p. 243-253. In: (eds.) W.N. Tavolga, A.N. Popper and R.R. Fay. Hearing and Sound Communication in Fishes. Springer-Verlag New York.
- Ernst, C.H., R.W. Barbour and J.E. Lovich (eds.). 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, DC. 578 p.
- Falk, M.R. and M.J. Lawrence. 1973. Seismic exploration: its nature and effects on fish. Tech. Rep. Ser. No. Vol. CEN/T-73-9. Resource Management Branch, Fisheries Operations Directorate, Central Region, Winnipeg.
- Fay, R.R. and A.N. Popper. 1999. Hearing in fishes and amphibians: An introduction. p. 1-14. In: (eds.) R.R. Fay and A.N. Popper. Comparative Hearing: Fish and Amphibians. Springer Handbook of Auditory Research. Springer-Verlag New York Inc.
- Fernández, A., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, E. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham and P.D. Jepson. 2004. Pathology: whales, sonar and decompression sickness (reply). Nature 428(6958):716.
- Findley, L.T. and O. Vidal. 2002. Gray whale (*Eschrichtius robustus*) at calving sites in the Gulf of California, Mexico. J. Cetacean Res. Manage. 4(1):27-40.
- Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. J. Acoust. Soc. Am. 108(1):417-431.
- Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. J. Acoust. Soc. Am. 111(6):2929-2940.
- Frantzis, A. 1998. Does acoustic testing strand whales? Nature 392(6671):29.
- Gambell, R. 1985. Sei Whale *Balaenoptera borealis* lesson, 1828. p. 155-170. In: S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Volume 3. Academic Press, London.

- Gannon, D.P., A.J. Read, J.E. Craddock and J.G. Mead. 1997. Stomach contents of Long-finned Pilot Whales (*Globicephala melas*) stranded on the U.S. mid-Atlantic Coast. *Marine Mammal Science* 13: 405-418.
- Gaskin, D.E. 1992a. Status of the Common Dolphin, *Delphinus delphis*, in Canada. *Canadian Field-Naturalist* 106: 55-63.
- Gaskin, D.E. 1992b. Status of the Harbour Porpoise, *Phocoena phocoena*, in Canada. *Canadian Field-Naturalist* 106: 36-54.
- Gaskin, D.E. 1992c. Status of the Atlantic White-sided Dolphin, *Lagenorhynchus acutus*, in Canada. *Canadian Field-Naturalist* 106: 64-72.
- Gaston, A.J. and I.L. Jones. 1998. The Auks. *Bird Families of the World*. Oxford Univ. Press, NY. 349 p.
- Gentry, R. (ed.). 2002. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans, Silver Spring, MD, April 2002. *Nat. Mar. Fish. Serv.* 19 p.  
Available at [www.nmfs.noaa.gov/prot\\_res/PR2/Acoustics\\_Program/acoustics.html](http://www.nmfs.noaa.gov/prot_res/PR2/Acoustics_Program/acoustics.html)
- Gisiner, R.C. (ed.). 1999. Workshop on the effects of anthropogenic noise in the marine environment 10-12 February 1998. *Marine Mammal Science Program, Office of Naval Research, Arlington, VA*. 141 p.
- Godfrey, W.E. 1986. *The Birds of Canada*. National Museums of Canada, Ottawa. 595 p.
- Goff, G.P. and J. Lien. 1988. Atlantic Leatherback Turtle, *Dermochelys coriacea*, in cold water off Newfoundland and Labrador, *Canadian Field-Naturalist* 102: 1-5.
- Goold, J.C. 1996a. Acoustic assessment of common dolphins off the west Wales coast, in conjunction with 16th round seismic surveying. Rep. from School of Ocean Sciences, Univ. Wales, Bangor, Wales, for Chevron UK Ltd, Repsol Explor. (UK) Ltd., and Aran Energy Explor. Ltd. 22 p.
- Goold, J.C. 1996b. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying. *J. Mar. Biol. Assoc. U.K.* 76:811-820.
- Goold, J.C. 1996c. Acoustic cetacean monitoring off the west Wales coast. Rep. from School of Ocean Sciences, Univ. Wales, Bangor, Wales, for Chevron UK Ltd, Repsol Explor. (UK) Ltd, and Aran Energy Explor. Ltd. 20 p.
- Goold, J.C., H. Whitehead and R.J. Reid. 2002. North Atlantic sperm whale, *Physeter macrocephalus*, strandings on the coastlines of the British Isles and eastern Canada. *Can. Field-Naturalist* 116(3):371-388
- Gordon, D., P. Schwinghamer, T.W. Rowell, J. Prena, K. Gilkinson, W.P Vass and D.L. McKeown. 1998. Studies in Eastern Canada on the impact of mobile fishing gear on benthic habitat and communities. In: Dorsey, E.M. and J. Pederson (eds.), *Effects of fishing gear on the sea floor of New England*. Conservation Law Foundation, Boston, Massachusetts.
- Gowans, S. and H. Whitehead. 1995. Distribution and habitat partitioning by small Odontocetes in the Gully, a submarine canyon on the Scotian Shelf. *Canadian Journal of Zoology* 3: 1599-1608.
- Greene, C.R., Jr. and W.C. Burgess, with R. Norman and R.W. Blaylock. 2000. Physical acoustics measurements, 1999. p. 3-1 to 3-45. In: W.J. Richardson (ed.), *Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1999*. LGL Rep. TA2313-4. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 155 p.



- Greene, G.D., F.R. Engelhardt and R.J. Paterson (eds.). 1985. Proceedings of the workshop on effects of explosives use in the marine environment. Canadian Oil and Gas Lands Administration and Environmental Protection Branch Ottawa, Ontario. 398 p.
- Griffin, R.B. 1999. Sperm whale distributions and community ecology associated with a warm-core ring off Georges Bank. *Marine Mammal Science* 15: 33-51.
- Guerra, A., A.F. González and F. Rocha. 2004. A review of the records of giant squid in the north-eastern Atlantic and severe injuries in *Architeuthis dux* stranded after acoustic explorations. ICES CM 2004/CC:29.
- Hai, D.J., J. Lien, D. Nelson and K. Curren. 1996. A contribution to the biology of the White-beaked Dolphin, *Lagenorhynchus albirostris*, in waters off Newfoundland. *Canadian Field-Naturalist* 110: 278-287.
- Haley, B. and W.R. Koski. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's ADWBC seismic program in the Northwest Atlantic Ocean, July-August 2004. LGL Rep. TA2822-27. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.
- Hammill, M.O. and G.B. Stenson. 2000. Estimated prey consumption by harp seals (*Phoca groenlandica*), grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*), and in Atlantic Canada. *Journal of Northwest Fisheries Science* 26: 1-23.
- Hammill, M.O., M.S. Ryg and B. Mohn. 1995. Consumption of cod by the Northwest Atlantic Grey Seal in Eastern Canada. p. 337-349. *In*: A.S. Blix, L. Walloe and O. Ulltang (eds.), Whales, seals, fish and man. Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic. Developments in Marine Biology 4.
- Haney, J.C. and S.D. MacDonald. 1995. Ivory Gull *Pagophila eburnea*. *In*: The birds of North America, No. 175, ed. A. Poole and F. Gill. The Academy of Natural Sciences of Philadelphia and American Ornithologists' Union, Washington, DC. 21 p.
- Harris, D.E., B. Lelli, G. Jakush and G. Early. 2001a. Hooded seal (*Cystophora cristata*) records from the southern Gulf of Maine. *Northeast. Nat.* 8: 427-434.
- Harris, R.E., G.W. Miller and W.J. Richardson. 2001b. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. *Mar. Mamm. Sci.* 17(4):795-812.
- Hassel, A., T. Knutsen, J. Dalen, S. Løkkeborg, K. Skaar, Ø. Østensen, E.K. Haugland, M. Fonn, Å. Høines and O.A. Misund. 2003. Reaction of sandeel to seismic shooting: A field experiment and fishery statistics study. Institute of Marine Research, Bergen, Norway.
- Hayes, R.M., D.G. Mountain and T.C. Welford. 1977. Physical oceanography and the abiotic influence on cod recruitment in the Flemish Cap region. ICNAF Res. Doc., No. 54, Serial No. 5107, 33 p.
- Hays, G.C., J.D.R. Houghton, C. Isaacs, R.S. King, C. Lloyd and P. Lovell. 2004. First records of oceanic dive profiles for leatherback turtles, *Dermochelys coriacea*, indicate behavioural plasticity associated with long-distance migration. *Animal Behaviour* 67:733-743.
- Heckel, G. S.B. Reilly, J.L. Sumich and I Espejel. 2001. The influences of whalewatching on the behaviour of migrating gray whales (*Eschirichtius robustus*) in Todos Santos Bay and surrounding waters, Baja California, Mexico. *J. Cetacean Res. Manage.* 3(3):227-237.
- Hendry, R.M., R.A. Clarke, J.R.N. Lazier and I.M. Yashayaev. 1998. Changes in Labrador Sea properties from 1998 to 1999. Annex H – Area 2b (Labrador Sea) Canadian Report, 6p.

- Hinrichsen, H. H. and M. Tomczak. 1993. Optimum multiparameter analysis of the water mass structure in the western North Atlantic Ocean. *J. Geophys. Res.* 98: 10,155-10,169.
- Hirst, A.G. and P.G. Rodhouse. 2000. Impacts of geophysical seismic surveying on fishing success. *Reviews in Fish Biology and Fisheries.* 10:113-118.
- Hogarth, W.T. 2002. Declaration of William T. Hogarth in opposition to plaintiff's motion for temporary restraining order, 23 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Div.
- Holliday, D.V., R.E. Pieper, M.E. Clarke and C.F. Greenlaw. 1987. The effects of airgun energy releases on the eggs, larvae, and adults of the northern anchovy (*Engraulis mordax*). API Publication 4453. Report by Tracor Applied Sciences for American Petroleum Institute, Washington, DC. 115 p.
- Holst, M. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's TAG seismic study in the mid-Atlantic Ocean, October-November 2003. LGL Rep. TA2822-21. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 42 p.
- Hooker, S.K., R.W. Baird, S. Al-Omari, S. Gowans and H. Whitehead. 2001. Behavioural reactions of northern bottlenose whales (*Hyperoodon ampullatus*) to biopsy darting and tag attachment procedures. *Fish. Bull.* 99: 303-308.
- Houser, D.S., R. Howard and S. Ridgway. 2001. Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals? *J. Theor. Biol.* 213(2):183-195.
- Husky Energy. 2000. Development Application – White Rose Development: Environmental Impact Statement, prepared on behalf of the White Rose Proponents.
- Husky Oil. 2000. Whiterose Oilfield Comprehensive Study
- Husky. 2000. White Rose Comprehensive Study – Part One (Environmental Impact Statement).
- Husky. 2001. White Rose oilfield comprehensive study supplemental report responses to comments from Canada-Newfoundland Offshore Petroleum Board, Department of Fisheries and Oceans, Environment Canada, Natural Resources Canada and Canadian Environmental Assessment Agency. Submitted by Husky Oil Operations Limited (Operator). 265 p. + App.
- Husky. 2002. Husky Jeanne d'Arc Basin exploration drilling program description and environmental assessment. Prepared by LGL Limited in association with Oceans Limited, PAL and S.L. Ross. LGL Limited Report No. SA725 for Husky Oil, St. John's. 188 p.
- Hutchings, J.A. 1996. Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. *Can. J. Fish. Aquat. Sci.* 53: 943-962.
- Hutchings, J.A. and R.A. Myers. 1994. Timing of cod reproduction: interannual variability and the influence of temperature. *Mar. Ecol. Prog. Ser.* 108: 21-31.
- Hutchinson, D.R. and R.S. Detrick. 1984. Water gun vs. air gun: A comparison. *Mar. Geophys. Res.* 6: 295-310.
- IAGC. 2004. Further analysis of 2002 Abrolhos Bank, Brazil humpback whale strandings coincident with seismic surveys. International Association of Geophysical Contractors. Houston, TX. 12 p.
- IMG-Golder Corp. 2002. Behavioural and physical response of riverine fish to airguns. Report prepared for WesternGeco, Calgary, Alberta.

- Jahoda, M., C.L. Lafortuna, N. Biassoni, C. Almirante, A. Azzellino, S. Panigada, M. Zanardelli and G. Notarbartolo Di Sciara. 2003. Mediterranean fin whales (*Balaenoptera physalus*) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. *Mar. Mamm. Sci.* 19(1):96-110.
- James, M.C. 2001. COSEWIC status report on the leatherback turtle *Dermochelys coriacea* in Canada, in COSEWIC assessment and update status report on the leatherback turtle *Dermochelys coriacea* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 25 p.
- James, M.C. and N. Mrosovsky. 2004. Body temperatures of leatherback turtles (*Dermochelys coriacea*) in temperate waters off Nova Scotia, Canada. *Can. J. Zool.* 82:1302-1306.
- James, M.C., C.A. Ottensmeyer and R.A. Myers. 2005. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. *Ecology Letters* 8:195-201.
- Janik, V.M. and P.M. Thompson. 1996. Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Mar. Mamm. Sci.* 12(4):597-602.
- Jepson, P.D., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, F. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham and A. Fernández. 2003. Gas-bubble lesions in stranded cetaceans: was sonar responsible for a spate of whale deaths after an Atlantic military exercise? *Nature* 425:575-576.
- Jochens, A.E. and D.C. Biggs [eds.]. 2003. Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 p.
- Johnson, M.P. and P.L. Tyack. 2003. A digital acoustic recording tag for measuring the response of wild marine mammals to sound. *IEEE. J. Ocean. Eng.* 28(1):3-12.
- Johnson, S.R. 2002. Marine mammal mitigation and monitoring program for the 2001 Odoptu 3-D seismic survey, Sakhalin Island Russia: Executive summary. Rep. from LGL Ltd, Sidney, B.C., for Exxon Neftegas Ltd., Yuzhno-Sakhalinsk, Russia. 49 p. Also available as Working Paper SC/02/WGW/19, Int. Whal. Comm., Western Gray Whale Working Group Meeting, Ulsan, South Korea, 22-25 October 2002. 48 p.
- Karlsen, J.D., A. Bisther, C. Lydersen, T. Haug and K.M. Kovacs. 2002. Summer vocalisations of adult male white whales (*Delphinapterus leucas*) in Svalbard, Norway. *Polar Biol.* 25:808-817.
- Kastak, D. and R.J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise and ecology. *J. Acoust. Soc. Am.* 103(4): 2216-2228.
- Kastak, D. and R.J. Schusterman. 1999. In-air and underwater hearing sensitivity of a northern elephant seal (*Mirounga angustirostris*). *Can. J. Zool.* 77: 1751-1758.
- Kastak, D., R.J. Schusterman, B.L. Southall and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. *J. Acoust. Soc. Am.* 106: 1142-1148.
- Kastelein, R.A., P. Mosterd, B. van Santen, M. Hagedoorn and D. de Haan. 2002. Underwater audiogram of a Pacific walrus (*Odobenus rosmarus divergens*) measured with narrow-band frequency-moldualted signals. *J. Acoust. Soc. Am.* 112(5):2173-2182.
- Kasuya, T. 1986. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.* 37:61-83.

- Katona, S.K. and J.A. Beard. 1990. Population size, migration and feeding aggregation of the Humpback Whale (*Megaptera novaeangliae*) in the Western North Atlantic Ocean. Report of the International Whaling Commission (Special Issue 12): 295-305.
- Katona, S.K., V. Rough and D.T. Richardson. 1993. A Field Guide to Whales, Porpoises and Seals from Cape Cod to Newfoundland. Smithsonian Institution Press, Washington, USA. 316 p.
- Kenyon, T.N., F. Ladich and H.Y. Yan. 1998. A comparative study of hearing ability in fishes: the auditory brainstem response approach. *J. Comp. Physiol. A* 182: 307-318.
- Ketten, D.R. 1994. Functional analysis of whale ears: adaptations for underwater hearing. *IEEE Proc. Underwat. Acoust.* 1:264-270.
- Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. p. 391-407. *In: R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.), Sensory systems of aquatic mammals. De Spil Publ., Woerden, Netherlands.* 588 p.
- Ketten, D.R. 2000. Cetacean ears. p. 43-108. *In: W.W.L. Au, A.N. Popper and R.R. Fay (eds.), Hearing by Whales and Dolphins. Springer-Verlag, New York, NY.* 485 p.
- Ketten, D.R., J. Lien and S. Todd. 1993. Blast injury in humpback whale ears: evidence and implications. *J. Acoust. Soc. Am.* 94(3, Pt. 2):1849-1850.
- Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. *J. Acoust. Soc. Am.* 110(5, Pt. 2):2721.
- Kostyuchenko, L.P. 1973. Effects of elastic waves generated in marine seismic prospecting on fish eggs in the Black Sea. *Hydrobiol. J.* 9:45-48.
- Kovacs, K.M. 2002. Bearded seal (*Erignathus barbatus*). p. 84-87. *In: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, California.*
- Kryter, K.D. 1985. The effects of noise on man, 2nd ed. Academic Press, Orlando, FL. 688 p.
- Kryter, K.D. 1994. The Handbook of Hearing and the Effects of Noise. Academic Press, Inc., Orlando, FL. 673 p.
- Kulka, D.W., N.C. Antle and J.M. Simms. 2003. Spatial analysis of 18 demersal species in relation to petroleum licence areas on the Grand Bank (1980-2000). *Can. Tech. Rep. Fish. Aquat. Sci. No.* 2473. 202 p.
- LaBella, G., C. Frogliia, A. Modica, S. Ratti and G. Rivas. 1996. First assessment of effects of air-gun seismic shooting on marine resources in the central Adriatic Sea. Society of Petroleum Engineers, Inc. International Conference on Health, Safety and Environment, New Orleans, Louisiana, U.S.A., 9-12 June 1996.
- Lacoste, K.N. and G.B. Stenson. 2000. Winter distribution of harp seals (*Phoca groenlandica*) off eastern Newfoundland and southern Labrador. *Polar Biology* 23: 805-811.
- Lacroix, D.L., R.B. Lanctot, J.A. Reed and T.L. McDonald. 2003. Effect of underwater surveys on molting male Long-tailed Ducks in the Beaufort Sea, Alaska. *Can. J. Zool.* 81:1862-1875.
- Lagardère, J.P. 1982. Effects of noise on growth and reproduction of *Crangon crangon* in rearing tanks.
- Lang, A.L. and V.D. Moulton. 2004. Marine mammal and seabird monitoring during the CCGS Hudson research expedition, June—July 2004. LGL Rep. SA818. Rep. from LGL Ltd., King City, ON, and St. John's, NL, for ExxonMobil Canada Ltd., St. John's, NL, and Chevron Canada Resources, Calgary, AB. 22 p.

- Lawson, J.W. and G.B. Stenson. 1995. Historic variation in the diet of Harp Seals (*Phoca groenlandica*) in the Northwest Atlantic. p. 261-269. In: A.S. Blix, L. Walloe and O. Ulltang (eds.), Whales, seals, fish and man. Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic. Developments in Marine Biology 4.
- Lawson, J.W., J.T. Anderson, E.L. Dalley and G.B. Stenson. 1998. Selective foraging by Harp Seals *Phoca groenlandica* in nearshore and offshore waters of Newfoundland, 1993 and 1994. Marine Ecology Progress Series 163: 1-10.
- Lazier, J.R.N. 1982. Seasonal variability of temperature and salinity in the Labrador Current. J. Mar. Res. 40: 341-356.
- Lazier, J.R.N. and D.G. Wright. 1993. Annual Velocity variations in the Labrador Current, Journal of Physical Oceanography, 23, 659-678.
- LeBuff, C.R., Jr. 1990. The Loggerhead Turtle in the Eastern Gulf of Mexico. Caretta Research, Inc., Sanibel, FL. 216 p.
- Lesage, V., C. Barrette, M.C.S. Kingsley and B. Sjare. 1999. The effect of vessel noise on the vocal behaviour of belugas in the St. Lawrence River Estuary, Canada. Mar. Mamm. Sci. 15: 65-84.
- LGL 2003a. Orphan Basin Strategic Environmental Assessment. Report by LGL Limited, St. John's, NL to the Canada-Newfoundland Offshore Petroleum Board, St. John's, NL. LGL Report No. SA767. 229 p.
- LGL 2003b. White Rose Addendum: Vertical Seismic Profiling Project Description and Environmental Assessment. LGL Limited Report No. SA782. Prepared for Husky Oil Operations Limited, St. John's, NL. 17 p.
- LGL 2004. Wellsite Geohazard Survey Environmental Assessment Terra Nova Development. LGL Limited Report No. SA809. Prepared for Petro-Canada, St. John's, NL. 64 p.
- Lien, J., D. Nelson and J.D. Hai. 1997. Status of the White-beaked Dolphin, *Lagenorhynchus albirostris*, in Canada. Report for the Committee on the Status of Endangered Wildlife in Canada.
- Lien, J., G.B. Stenson and P.W. Jones. 1988. Killer Whales (*Orcinus orca*) in waters off Newfoundland and Labrador, 1978-1986. Rit Fiskideildar. 11: 194-201.
- Lilly, G.R., P.A. Shelton, J. Bratney, N.G. Cadigan, B.P. Healey, E.F. Murphy and D.E. Stansbury. 2001. An assessment of the cod stock in NAFO Divisions 2J and 3KL. Canadian Science Advisory Secretariat Research Document 2001/044. 149 p.
- Ljungblad, D.K., B. Würsig, S.L. Swartz and J.M. Keene. 1988. Observations on the behavioural responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41: 183-194.
- Lock, A.R., R.G.B. Brown and S.H. Gerriets. 1994. Gazetteer of marine birds in Atlantic Canada. An atlas of seabird vulnerability to oil pollution. Canadian Wildlife Service, Environmental Conservation Branch, Environment Canada, Atlantic Region. 137 p.
- Lohmann, K.J. and C.M.F. Lohmann. 1998. Migratory guidance mechanisms in marine turtles. J. Avian Biol. 29(4):585-596.
- Lohmann, K.J., B.E. Witherington, C.M.F. Lohmann and M. Salmon. 1997. Orientation, navigation, and natal beach homing in sea turtles. p. 107-135. In: P.L. Lutz and J.A. Musick (eds.), The biology of sea turtles. CRC Press, Boca Raton, FL. 432 p.

- Lohmann, K.J., S.D. Cain, S.A. Dodge and C.M.F. Lohmann. 2001. Regional magnetic fields as navigational markers for sea turtles. *Science* 294(5541):364-366.
- Løkkeborg, S. 1991. Effects of geophysical survey on catching success in longline fishing. ICES CM B:40. 9 p.
- Lomond, T.M., D.C. Schneider and D.A. Methven. 1998. Transition from pelagic to benthic prey for age 0-1 Atlantic cod, *Gadus morhua*. *Fish. Bull.* 96: 908-911.
- Lydersen, C. and K.M. Kovacs. 1999. Behaviour and energetics of ice-breeding, North Atlantic phocid seals during the lactation period. *Marine Ecology Progress Series*. 187: 265-281.
- MacLean, S.A. and B. Haley. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Stfregga Slide area of the Norwegian Sea, August - September 2003. LGL Rep. TA2822-20. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 59 p.
- Madsen, P.T., B. Møhl, B.K. Nielsen and M. Wahlberg. 2002a. Male sperm whale behaviour during exposures to distant seismic survey pulses. *Aquat. Mamm.* 28(3):231-240.
- Magalhães, S., R. Prieto, M.A. Silva, J. Gonçalves, M. Afonso-Dian and R.S. Santos. 2002. Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. *Aquat. Mamm.* 28(3):267-274.
- Mager, A.M., Jr. 1985. Five-year status reviews of sea turtles listed under the Endangered Species Act of 1973. U.S. Dept. Commerce, NOAA, National Marine Fisheries Service, St. Petersburg. FL. 90 p.
- Magnuson, J., K. Bjørndal, W. DuPaul, G. Graham, D. Owens, C. Peterson, P. Pritchard, J. Richardson, G. Saul and C. West. 1990. Decline of Sea Turtles: Causes and Prevention. National Academy Press, Washington, DC.
- Malakoff, D. 2002. Suit ties whale deaths to research cruise. *Science* 298(5594): 722-723.
- Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280. *In*: G.D. Greene, F.R. Engelhardt and R.J. Paterson (eds.), *Proc. Workshop on effects of explosives use in the marine environment*, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.
- Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1986. Behavioral responses of gray whales to industrial noise: feeding observations and predictive modeling. *Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest.*, NOAA, Anchorage, AK 56(1988):393-600. BBN Rep. 6265. 600 p. OCS Study MMS 88-0048; NTIS PB88-249008.
- Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73. *In*: W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (eds.), *Port and ocean engineering under arctic conditions*, vol. II. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111 p.
- Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218377.

- Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Rep. 5851; OCS Study MMS 85-0019. Rep. from BBN Labs Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218385.
- Mamayev, O.I. 1975. Temperature - Salinity Analysis of the World Ocean Waters. Elsevier Scientific, Amsterdam, 374 p.
- Mann, D.A., D.M. Higgs, W.N. Tavalga, M.J. Souza and A.N. Popper. 2001. Ultrasound detection by clupeiform fishes. J. Acoust. Soc. Am. 109: 3048-3054.
- Mansfield, A.W. 1985. Status of the Blue Whale, *Balaenoptera musculus*, in Canada. Canadian Field-Naturalist 99: 417-420.
- Marquez, R., J. Diaz, M. Sanchez, P. Burchfield, A. Leo, M. Carrasco, J. Pena, C. Jimenez and R. Bravo. 1999. Results of the Kemp's ridley nesting beach conservation efforts in Mexico. Marine Turtle Newsletter 85: 2-4.
- Mate, B.R. and J.T. Harvey. 1987. Acoustical deterrents in marine mammal conflicts with fisheries. ORESU-W-86-001. Oregon State Univ., Sea Grant Coll. Progr., Corvallis, OR. 116 p.
- Mate, B.R., K.M. Stafford and D.K. Ljungblad. 1994. A change in sperm whale (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. Journal of the Acoustical Society of Amer. 96: 3268-3269.
- Matishov, G.G. 1992. The reaction of bottom-fish larvae to airgun pulses in the context of the vulnerable Barents Sea ecosystem. Fisheries and Offshore Petroleum Exploitation 2<sup>nd</sup> International Conference, Bergen, Norway, 6-8 April 1992.
- McAlpine, D.F., P.T. Stevick and L.D. Murison. 1999. Increase in extralimital occurrences of ice-breeding seals in the northern Gulf of Maine region: more seals or fewer fish? Marine Mammal Science. 15: 906-911.
- McCall Howard, M.P. 1999. Sperm whales *Physeter macrocephalus* in the Gully, Nova Scotia: Population, distribution, and response to seismic surveying. B.Sc. (Honors) Thesis. Dalhousie Univ., Halifax, N.S.
- McCauley, R.D. and D.H. Cato. 2001. The underwater noise of vessels in the Hervey Bay (Queensland) whale watch fleet and its impact on humpback whales. J. Acoust. Soc. Am. 109(5, Pt. 2):2455.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000a. Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188 p.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, M.-N. Jenner, M.-N., C. Jenner, R.I.T. Prince, A. Adhitya, K. McCabe and J. Murdoch. 2000b. Marine seismic surveys - a study of environmental implications. APPEA (Austral. Petrol. Product. Explor. Assoc. ) Journal 40:692-708.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, M.-N. Jenner, M.-N., C. Jenner, R.I.T. Prince, A. Adhitya, K. McCauley, R.D., J. Fewtrell and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears. J. Acoust. Soc. Am., 113, 1: 638-642.

- McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe and J. Murdoch. 1998. The response of humpback whales (*Megaptera novangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. APPEA (Austral. Petrol. Product. Explor. Assoc.) Journal 38:692-707.
- McConnell, B.J., M.A. Fedak, P. Lovell and P.S. Hammond. 1999. Movements and foraging areas of Grey Seals in the North Sea. Journal of Applied Ecology 36: 573-590.
- McDonald, M.A., J.A. Hildebrand and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. J. Acoust. Soc. Am. 98: 712-721.
- McLaren, P.L., R.E. Harris and I.R. Kirkham. 1983. Distribution of marine birds in the southern Labrador Sea, April 1981-April 1982. Offshore Labrador Biological Studies Program (OLABS). LGL Limited Report for Petro-Canada Exploration Inc., Calgary, Alberta. 252 p + App.
- Mignucci-Giannoni, A.A. and D.K. Odell. 2001. Tropical and subtropical records of hooded seals (*Cystophora cristata*) dispel the myth of Caribbean monk seals (*Monachus tropicalis*). Carib. Bull. Mar. Sci. 68:47-58.
- Miller, G.W. and R.A. Davis (eds.) 2002. Marine mammal and acoustical monitoring of Anderson Exploration Ltd.'s open-water seismic program in the southeastern Beaufort Sea. Final report by LGL Ltd., King City, ON., and JASCO Research Ltd., Victoria, B.C. for Devon Canada Corporation, Calgary, AB. 199 p.
- Miller, G.W. and V.D. Moulton. 2003. Vessel-based marine mammal monitoring of Devon Canada Corporation's 2002 open-water seismic program in the southeastern Beaufort Sea. Report by LGL Ltd., King City, ON., for Devon Canada Corporation, Calgary, AB. 49 p.
- Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109. In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.
- Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001-2002. p. 511-542. In: S.L. Armsworthy, P.J. Cranford and K. Lee (eds.), Offshore oil and gas environmental effects monitoring/Approaches and technologies. Battelle Press, Columbus, OH. 631 p.
- Miller, P., M. Johnson, N. Aguilar, M. Grund, V. Teloni, M. Quero, A. Beier, D. Engelhaupt, A. Thode and J. Diebold. 2003. Cruise report for EW0303. SWSS year two, 2003, Dtag component. Available at: <http://seawater.tamu.edu/swss/doc/dtagrpt03/Dtag2003CruiseReport.pdf>.
- Mobil 1985. Hibernia Development Project, Environmental Impact Statement. Volume IIIa: Biophysical Assessment. Mobil Oil Canada, Ltd. (Operator), Gulf Canada Resources Inc., Petro-Canada Inc., Chevron Canada Resources Ltd., and Columbia Gas Development of Canada Ltd. 258 p.
- Moein, S.E., J.A. Musick, J.A. Keinath, D.E. Barnard, M. Lenhardt and R. George. 1994. Evaluation of seismic sources for repelling sea turtles from hopper dredges. Rep. from Virginia Inst. Mar. Sci., [Gloucester Point], VA, for U.S. Army Corps of Engineers. 33 p.



- Mohn, R. and W.D. Bowen. 1996. Grey Seal predation on the Eastern Scotian Shelf: modelling the impact on Atlantic Cod. *Can. J. Fish. Aquat. Sci.* 53: 2722-2738.
- Montevecchi, W.A., F.K. Wiese, G. Davoren, A.W. Diamond, F. Huettmann and J. Linke. 1999. Seabird attraction to offshore platforms and seabird monitoring from support vessels and other ships: Literature review and monitoring designs. Prepared for Canadian Association of Petroleum Producers by Memorial University of Newfoundland, St. John's, Newfoundland and University of New Brunswick, Saint John. New Brunswick. 35 p.
- Moore, M.J. and G.A. Early. 2004. Cumulative sperm whale bone damage and the bends. *Science* 306 (24 December 2004): 2215.
- Moore, S.E. and J.T. Clarke. 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). *J. Cetac. Res. Manage.* 4(1):19-25.
- Morgan, P.J. 1989. Occurrence of Leatherback Turtles (*Dermochelys coriacea*) in the British Islands in 1988 with reference to a record specimen. p. 119-120. *In: S.A. Eckert, K.L. Eckert, and T.H. Richardson (Compilers), Proceedings of the Ninth Annual Conference on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-232. U.S. Dept. Commerce, Miami FL. 305 p.*
- Moulton, V.D. and G.W. Miller 2004. Marine mammal monitoring of Marathon Canada Petroleum's 3-D seismic program on the Scotian Slope, 2003. LGL Rep. SA759-1. Rep. from LGL Ltd., St. John's, NL, for Marathon Canada Petroleum, Halifax, Nova Scotia. 94 p. + appendices.
- Moulton, V.D. and G.W. Miller. 2005. Marine mammal monitoring of a seismic survey on the Scotian Slope, 2003. *Can. Tech. Rep. Fish. Aquat. Sci.* [in press]
- Moulton, V.D. and J.W. Lawson. 2002. Seals, 2001. p. 3-1 to 3-48. *In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of WesternGeco's open water seismic program in the Alaskan Beaufort Sea, 2001. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for WesternGeco, Houston, TX, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. LGL Rep. TA2564-4.*
- Moulton, V.D. and W.J. Richardson. 2000. A review of sea turtles and seismic noise. Report by LGL Ltd. for British Petroleum, Aberdeen, Scotland.
- Moulton, V.D., R.A. Davis, J.A. Cook, M. Austin, M.L. Reece, S.A. Martin, A. MacGillivray, D. Hannay and M.W. Fitzgerald. 2003. Environmental assessment of Marathon Canada Limited's 3-D seismic program on the Scotian Slope, 2003. LGL Rep. SA744-1. Rep. by LGL Limited, St. John's, Newfoundland, CEF and JASCO Research Ltd. for Marathon Canada Ltd., Halifax, Nova Scotia. 173 p. + Appendices.
- Moulton, V.D., B.D. Mactavish and R.A. Buchanan. 2005. Marine mammal and seabird monitoring of Chevron Canada Limited's 3-D seismic program on the Orphan Basin, 2004. LGL Rep. SA 817-1. Rep. by LGL Limited, St. John's, Newfoundland, for Chevron Canada Limited, Calgary, Alberta.
- Navoc (Naval Ocean Command). 1986. Sea Ice Climate Atlas, Vol. II, Arctic East. Document NAVAIR 50-1C-541. 147p.

- Nedwell, J.R., B. Edwards, A.W.H. Turnpenny and J. Gordon. 2004. Fish and marine mammal audiograms: A summary of available information. Report by Subacoustech Ltd for Chevron Texaco Ltd., TotalFinaElf Exploration UK PLC, DSTL, Department of Trade and Industry, and Shell U.K. Exploration and Production Ltd.
- Nelson, D. and J. Lien. 1996. The status of the Long-finned Pilot Whale, *Globicephala melas*, in Canada. Canadian Field-Naturalist. 110: 511-524.
- Nestler, J.M., G.R. Ploskey, J. Pickens, J. Menezes and C. Schilt. 1992. Responses of blueback herring to high-frequency sound and implications for reducing entrainment at hydropower dams. N. Am. J. Fish. Manage. 12: 667-683.
- Nettleship, D.N. and T.R. Birkhead, 1985. The Atlantic alcaidae. Academic Press, London. 574 p.
- Nieukirk, S.L., K.A. Stafford, D.K. Mellinger, R.P. Dziak and C.G. Fox. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. J. Acoust. Soc. Am. 115(4): 1832-1843.
- NMFS. 1995. Small takes of marine mammals incidental to specified activities; offshore seismic activities in southern California. Fed. Regist. 60(200, 17 Oct.):53753-53760.
- NMFS. 2000. Taking and importing marine mammals; Taking marine mammals incidental to Naval activities/Proposed rule. Fed. Regist. 65(239 12 December): 77546-77553.
- NOAA and USN. 2001. Joint interim report: Bahamas marine mammal stranding event of 14-16 March 2000. U.S. Dep. Commer., Nat. Oceanic Atmos. Admin., Nat. Mar. Fish. Serv., Sec. Navy, Assis. Sec. Navy, Installations and Envir. 61 p.
- Nordmore, E.D., A.E. Sieg, P.R. Sotherland, J.R. Spotila, F.V. Paladino and R.D. Reina. 2004. Nest site fidelity of leatherback turtles at Playa Grande, Costa Rica. Animal Behaviour 68:387-394.
- Nowacek, S.M., R.S. Wells and A.R. Solow. 2001. Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. Mar. Mamm. Sci. 17(4):673-688.
- NRC (National Research Council). 1990. Decline of the Sea Turtles: Causes and Prevention. National Academy Press, Washington, DC. 259 p.
- O'Hara, J. and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, *Caretta caretta*, to low frequency sound. Copeia 1990(2):564-567.
- Olson, P.A. and S. B. Reilly. 2002. Pilot Whales. p. 898-893. In: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, CA. 1414 p.
- Ollerhead, L.M.N., M.J. Morgan, D.A. Scruton and B. Marrie. 2004. Mapping spawning times and locations for 10 commercially important fish species found on the Grand Banks of Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 2522: iv + 45 p.
- Orr, D.C., P.J. Veitch and D.J. Sullivan. 2004. An update on information pertaining to northern shrimp (*Pandalus borealis*, Kroyer) and groundfish in NAFO Divisions 3LNO. NAFO SCR Doc. 04/86.
- Overholtz, W.J. and G.T. Waring. 1991. Diet composition of Pilot Whales *Globicephala spp.* and Common Dolphins *Delphinus delphis* in the mid-Atlantic Bight during spring 1989. U.S. Fisheries Bulletin. 89: 723-728.
- Palka, D. 1996. Evidence of ship avoidance from harbour porpoises during line transect sighting surveys in the Gulf of Maine. Abstract SC/47/SM27. Rep. Int. Whal. Commn 46:675.

- Palka, D., A. Read and C. Potter. 1997. Summary of knowledge of White-sided Dolphins (*Lagenorhynchus acutus*) from US and Canadian Atlantic Waters. Report of the International Whaling Commission 47: 729-734.
- Panel on Energy Research & Development (PERD). A Compilation of Iceberg Shape and Geometry Data for the Grand Banks Region. PERD/CHC Report 20-43. Compiled by: (CANATEC Consultants 1999), Available at: <http://www.chc.nrc.ca/ColdRegionsTechnology/ColdRegions.html>
- Panel on Energy Research & Development (PERD). Grand Banks Iceberg Update, 2000. PERD/CHC Report 20-40. Compiled by: (Fleet Technology, Available at: <http://www.chc.nrc.ca/ColdRegionsTechnology/ColdRegions.html>)
- Parsons. J.L. and J.E. Brownlie. 1981. Distribution and abundance of marine mammals of the Grand Banks, 1980-1981. Grand Banks Wildlife Study, Final Report. Chapter 4. Report by MacLaren Plansearch for Mobil Oil Canada Ltd.
- Patenaude, N.J., W.J. Richardson, M.A. Smultea, W.J. Richardson, W.R. Koski, G.W. Miller, B. Würsig and C.R. Greene, Jr. 2002. Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. Mar. Mamm. Sci. 18(2):309-335.
- Payne, P.M., D.N. Wiley, S.B. Young, S. Pittman, P.J. Clapham and J.W. Jossi. 1990. Recent fluctuations in the abundance of baleen whales in the Southern Gulf of Maine in relation to changes in selected prey. U.S. Fisheries Bulletin. 88: 687-696.
- Payne, P.M., L.A. Selzer and A.R. Knowlton. 1984. Distribution and density of cetaceans, marine turtles and seabirds in the shelf waters of the Northeastern United States, June 1980-December 1983, based on shipboard observations. Final Rep., Contr. NA-81-FA-C-00023. Rep. From Manomet Bird Observ., Manomet, MA, for Nat. Mar. Fish. Serv., Northeast Fish. Cent., Woods Hole, MA. 264 p.
- Pearson, W., J. Skalski, S. Sulkin and C. Malme. 1994. Effects of seismic energy releases on the survival and development of zoeal larvae of Dungeness crab (*Cancer magister*). Mar. Environ. Res., 38: 93-113.
- Pearson, W.H., J.R. Skalski and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on behavior of captive rockfish (*Sebastes spp*). Can. J. Fish. Aquat. Sci. 49: 1343-1356.
- Perry, E.A., D.J. Boness and S.J. Insley. 2002. Effects of sonic booms on breeding gray seals and harbour seals on Sable Island, Canada. Journal of the Acoustical Society of America 111:599-609.
- Petrie, B., P. Yeats and P. Strain. 1999. Nitrate, Silicate and Phosphate Atlas for the Scotian Shelf and the Gulf of Maine. Can. Tech. Rep. Hydrogr. Ocean Sci. 203, vii-96p.
- Petrie, B., S. Akenhead, J. Lazier and J. Loder. 1988. The cold intermediate layer on the Labrador and Northeast Newfoundland Shelves, 1978-1986. NAFO Sci. Counc. Stud. 12: 57-69.
- Petro-Canada. 1996. Development Application Terra Nova Development Environmental Impact Statement. Prepared by Petro-Canada on behalf of Terra Nova Proponents (Petro-Canada, Mobil Oil Canada Properties, Husky Oil Operations Limited, Murphy Oil Company Ltd., and Mosbacher Operating Limited).
- Piantadosi, C.A. and E.D. Thalmann. 2004. Pathology: whales, sonar and decompression sickness. Nature 428(6984):716.

- Piatt, J.F., D.A. Methven, A.E. Burger, R.L. McLagan, V. Mercer and E. Creelman. 1989. Baleen whales and their prey in a coastal environment. *Canadian Journal of Zoology* 67: 1523-1530.
- Pitman, R.L. 2002. Mesoplodont whales (*Mesoplodon spp.*). p. 84-87. In: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), *Encyclopedia of Marine Mammals*. Academic Press, San Diego, California.
- Plotkin, P.T. (ed.). 1995. National Marine Fisheries Service and U.S. Fish and Wildlife Service status reviews for sea turtles listed under the Endangered Species Act of 1973. National Marine Fisheries Service, Silver Spring, Maryland. 139 p.
- Popper, A.N., D.T.T. Plachta, D.A. Mann and D. Higgs. 2004. Response of clupeid fish to ultrasound: a review. *ICES J. Mar. Sci.* 61: 1057-1061.
- Popper, A.N., M. Salmon and K.W. Horch. 2001. Acoustic detection and communication by decapod crustaceans. *J. Comp. Physiol. A* 187: 83-89.
- Provincial Airlines Limited (PAL). Iceberg Sightings Database, 1985-2001. Available at: <http://www.provair.com/icebergnet/home.htm>
- Provincial Airlines Ltd. 1995. Historical Iceberg Sightings 1989-1995. Report prepared for Petro-Canada for the Terra Nova Project by Provincial Airlines Ltd. St. John's, NF. 16 p. + Appendix.
- Rankin, S. and W.E. Evans. 1998. Effect of low frequency seismic exploration sounds on the distribution of cetaceans in the Northern Gulf of Mexico. 16th Intern. Congress on Acoustics and 135th Meeting Acoustical Society of America: the sound of the future, a global view of acoustics in the 21st century. Vol. 2, p. 1407-1408.
- Reeves, R. and H. Whitehead. 1997. Status of the Sperm Whale, *Physeter macrocephalus*, in Canada. *Canadian Field-Naturalist* 111: 293-307.
- Reeves, R., C. Smeenk, C.C. Kinze, R.L. Brownell Jr. and J. Lien. 1999. White-beaked Dolphin *Lagenorhynchus albirostris* Gray, 1846. p. 1-30. In: S.H. Ridgeway and R. Harrison (eds.), *Handbook of Marine Mammals Volume 6, the Second Book of Dolphins and Porpoises*. Academic Press, San Diego, CA. 486 p.
- Reeves, R.R., B.S. Stewart, P.J. Clapham and J.A. Powell (eds). 2002. *National Audubon Society Guide to Marine Mammals of the World*. Alfred A. Knopf, New York. 527 p.
- Reeves, R.R., E. Mitchell and H. Whitehead. 1993. Status of the Northern Bottlenose Whale, *Hyperoodon ampullatus*. *Canadian Field-Naturalist* 107: 491-509.
- Reeves, R.R., G.P. Silber and P.M. Payne. 1998. Draft recovery plan for Fin Whales (*Balaenoptera physalus*) and Sei Whales (*B. borealis*). Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland.
- Reeves, R.R., R.J. Hofman, G.K. Silber and D. Wilkinson. 1996. Acoustic deterrence of harmful marine mammal-fishery interactions: proceedings of a workshop held in Seattle, Washington, 20-22 March 1996. NOAA Tech. Memo NMFS-OPR-10. U.S. Dep. Commerce, Nat. Mar. Fish. Serv. 70 p.
- Renouf, D., J.W. Lawson and L. Gaborko. 1983. Attachment between Harbour Seal mothers and pups. *Journal of Zoology, London*. 199: 179-187.
- Rice, D.W. 1989. Sperm Whale *Physeter macrocephalus* Linnaeus, 1758. p. 177-233. In: S.H. Ridgeway and R. Harrison (eds.), *Handbook of Marine Mammals, Volume 4*. Academic Press, London.

- Richardson, W.J. and B. Würsig. 1997. Influences of man-made noise and other human actions on cetacean behaviour. *Mar. Freshwat. Behav. Physiol.* 29(1-4):183-209.
- Richardson, W.J. and C.I. Malme. 1993. Man-made noise and behavioral responses. p. 631-700. *In*: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), *The bowhead whale*. Spec. Publ. 2, Society for Marine Mammalogy, Lawrence, Kansas. 787 p.
- Richardson, W.J., B.W. Würsig and C.R. Greene Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. *J. Acoust. Soc. Am.* 79: 1117-1128.
- Richardson, W.J., C.R. Greene, Jr., C.I. Malme and D.H. Thomson. 1995. *Marine mammals and noise*. Academic Press, San Diego. 576 p.
- Richardson, W.J., G.W. Miller and C.R. Greene Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. *J. Acoust. Soc. Am.* 106(4, Pt. 2):2281.
- Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. *Arctic* 40(2):93-104.
- Richter, C.F., S.M. Dawson and E. Slooten. 2003. Sperm whale watching off Kaikoura, New Zealand: effects of current activities on surfacing and vocalisation patterns. *Science for Conservation* 219. Department of Conservation, Wellington. 78 p. Available at <http://www.doc.govt.nz/Publications/004~Science-and-Research/Science-for-Conservation/PDF/SFC219.pdf>
- Ridgway, S.H., D.A. Carder, R.R. Smith, T. Kamolnick, C.E. Schlundt and W.R. Elseberry. 1997. Behavioural responses and temporary shift in masked hearing threshold of bottlenose dolphins, *Tursiops truncatus*, to 1-second tones of 141 to 201 dB re 1  $\mu$ Pa. Tech. Rep. 1751, Revision 1. Tech. Rep. to Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E DIV D3503, San Diego, CA. 27 p.
- Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. *Proc. Nat. Acad. Sci. U.S.* 64:884-890.
- Romano, T., M. Keogh, C. Schlundt, J. Finneran and D. Carder. 2001. Approaches to understanding the effects of loud sound on marine mammal health. Abstract presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, November 28-December 3, 2001, Vancouver, Canada. p. 181-182.
- Rose, G.A. 1993. Cod spawning on a migration highway in the northwest Atlantic. *Nature* 366: 458-461.
- Rose, G.A., B. deYoung, D.W. Kulka, S.V. Goddard and G.L. Fletcher. 2000. Distribution shifts and overfishing the northern cod (*Gadus morhua*): a view from the ocean. *Can. J. Fish. Aquat. Sci.* 57: 644-663.
- Ross, G.L. and H. Markowitz. 2001. Behavioral responses of Hawaiian spinner dolphins, *Stenella longirostris*, to vessel presence at midway atoll, National Wildlife Refuge. Abstract presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, November 28-December 3, 2001, Vancouver, Canada. p. 184.

- Ross, S.A. 1993. Food and feeding of the Hooded Seal (*Cystophora cristata*) in Newfoundland. M.Sc. Thesis, Memorial University of Newfoundland, St. John's, NF.
- Rostal, D.C. 1991. The reproductive behaviour and physiology of the Kemp's ridley Sea Turtle, *Lepidochelys kempi* (Garman, 1880). Ph.D. Dissertation, Texas A&M University, College Station, TX.
- SACLANT. 1998. Estimation of cetacean hearing criteria levels. Section II, Chapter 7 In: SACLANTCEN Bioacoustics Panel Summary Record and Report. Report by NATO SACLANT Undersea Research Center. 60 p. Available at <http://enterprise.spawar.navy.mil/spawarpublicsite/>
- Saetre, R. and E. Ona. 1996. Seismike undersøkelser og på fiskeegg og -larver en vurdering av mulige effekter på bestandsniva. [Seismic investigations and damages on fish eggs and larvae; an evaluation of possible effects on stock level] Fisken og Havet 1996:1-17, 1-8. (in Norwegian, with an English summary - full translation not published).
- Sameoto, D. 2004a. Northwest Atlantic plankton trends 1959 to 2000. Can. Sci. Advis. Sec. Res. Doc. 2004/073.
- Sameoto, D. 2004b. The 1990s a unique decade for plankton change in the Northwest Atlantic. Can. Sci. Advis. Sec. Res. Doc. 2004/074.
- Sand, O. 1981. The lateral line and sound reception. p. 459-478. In: W.N. Tavolga, A.N. Popper, and R.R. Fay (eds.) Hearing and Sound Communication in Fishes. Springer-Verlag New York Inc.
- Santulli, A., C. Messina, L. Ceffa, A. Curatolo, G. Rivas, G. Fabi and V. Damelio. 1999. Biochemical responses of european sea bass (*Dicentrarchus labrax*) to the stress induced by offshore experimental seismic prospecting. Mar. Pollut. Bull. 38:1105-1114.
- Scarpaci, C., S.W. Bigger, P.J. Corkeron and D. Nugegoda. 2000. Bottlenose dolphins (*Tursiops truncatus*) increase whistling in the presence of 'swim-with-dolphin' tour operations. J. Cetacean Res. Manage. 2(3):183-185.
- Scarpaci, C., D. Nugegoda and P.J. Corkeron. 2001. Behavioural studies of dolphins and dolphin watchers in Port Phillip Bay, Australia. Abstract presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, November 28-December 3, 2001, Vancouver, Canada. 189 p.
- Schilling, M.R., I. Seipt, M.T. Weinrich, S.E. Frohock, A.E. Kuhlberg and P.J. Clapham. 1992. Behaviour of individually-identified Sei Whales *Balaenoptera borealis* during an episodic influx into the southern Gulf of Maine in 1986. U.S. Fisheries Bulletin 90: 749-755.
- Schlundt, C.E., J.J. Finneran, D.A. Carder and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. J. Acoust. Soc. Am. 107: 3496-3508.
- Schusterman, R., D. Kastak, B. Southall and C. Kastak. 2000. Underwater temporary threshold shifts in pinnipeds: tradeoffs between noise intensity and duration. J. Acoust. Soc. Am. 108: 2515-2516.
- Schwarz, A.L. and G.L. Greer. 1984. Responses of Pacific herring, *Clupea harengus pallasii* to some underwater sounds. Can. J. Fish. Aquat. Sci. 41:1183-1192.
- Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219. 731 p.
- Seaconsult Ltd. 1988. Physical Environmental Data for Production Systems at Terra Nova. Report prepared for Petro-Canada Inc. Calgary, AB.

- Selzer, L.A. and P.M. Payne. 1988. The distribution of White-sided (*Lagenorhynchus acutus*) and Common Dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. *Marine Mammal Science* 4: 141-153.
- Sergeant, D.E. 1962. The biology of the Pilot or Pothead Whale *Globicephala melaena* (Traill) in Newfoundland waters. *Bulletin of the Fisheries Research Board of Canada* 132: 1-84.
- Sergeant, D.E. 1991. Harp Seals, man and ice. *Canadian Special Publications of Fisheries and Aquatic Sciences* 114: 153 p.
- Shaver, D.J. 1991. Feeding ecology of wild and headstarted Kemp's ridley Sea Turtles in south Texas waters. *Journal of Herpetology* 25: 327-334.
- Shin, H.-O., D.-J. Lee and H.-I. Shin. 2003. Behavior of Israeli carp *Cyprinus carpio* traced by long baseline telemetry techniques during dynamite explosion work. *Fish. Sci.* 69: 27-36.
- Sigurjónsson, J. and T.H. Gunnlaugsson. 1990. Recent trends in abundance of Blue (*Balaenoptera musculus*) and Humpback Whales (*Megaptera novaengliae*) of west and southwest Iceland, with a note on occurrence of other cetacean species. *Report of the International Whaling Commission* 40: 537-551.
- Simmonds, M. P. and L.F. Lopez-Jurado. 1991. Whales and the military. *Nature* 351(6326):448.
- Simmonds, M.P. and S.J. Mayer. 1997. An evaluation of environmental and other factors in some recent marine mammal mortalities in Europe: implications for conservation and management. *Environ. Rev.* 5:89-98.
- Simpson, M.R. and D.W. Kulka. 2002. Status of three wolffish species (*Anarhichus lupus*, *A. minor*, and *A. denticulatus*) in Newfoundland waters (NAFO Divisions 2GHJ3KLNOP). *Canadian Science Advisory Secretariat Research Document* 2002/078. 96 p.
- Simpson, M.R. and D.W. Kulka. 2003. Formulation of an incidental harm permit strategy for wolffish species (*Anarhichadidae*). *Can. Sci. Advis. Sec. Res. Doc.* 2003/047.
- Skalski, J.R., W.H. Pearson and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes spp.*). *Can. J. Fish. Aquat. Sci.* 49(7):1357-1365.
- Slotte, A., K. Hansen, J. Dalen and E. Ona. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian coast. *Fish. Res.* 67: 143-150.
- Smith, M.E., A.S. Kane and A.N. Popper. 2004. Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). *J. Exp. Biol.* 207: 427-435.
- Smultea, M.A. and M. Holst. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Hess Deep area of the Eastern Equatorial Tropical Pacific, July 2003. LGL Rep. TA2822-16. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 68 p.
- Smultea, M.A., M. Holst, W.R. Koski and S. Stoltz. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, April-June 2004. LGL Rep. TA2822-26. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 106 p. Available at [http://www.nmfs.noaa.gov/pr/readingrm/mmpa\\_small\\_take/SECarib90d040914.pdf](http://www.nmfs.noaa.gov/pr/readingrm/mmpa_small_take/SECarib90d040914.pdf)

- Sousa-Lima, R.S., M.E. Morete, R.C. Fortes, A.C. Freitas and M.H. Engel. 2002. Impact of boats on the vocal behavior of humpback whales off Brazil. *J. Acoust. Soc. Am.* Vol. 112(5, Pt. 2):2430.
- St. Aubin, D.J. 1990. Physiologic and Toxic Effects on Polar Bears. p. 235-239. *In:* J.R. Geraci and D.J. St. Aubin (eds.), *Sea mammals and oil: confronting the risks*. Academic Press, San Diego. 282 p.
- Stenson, G.B. 1994. The status of pinnipeds in the Newfoundland region. *Northwest Atlantic Fisheries Organization, Scientific Council Studies* 21: 115-119.
- Stenson, G.B. and B. Sjare. 1997. Seasonal distribution of Harp Seals, *Phoca groenlandica*, in the Northwest Atlantic. *ICES. C.M.* 1997/10 p.
- Stenson, G.B. and D.J. Kavanagh. 1994. Distribution of Harp and Hooded Seals in offshore waters of Newfoundland. *Northwest Atlantic Fisheries Organization, Scientific Council Studies* 21: 121-142.
- Stenson, G.B., R.A. Myers, I-H. Ni and W.G. Warren. 1997. Pup production and population growth of Hooded Seals (*Cystophora cristata*) near Newfoundland, Canada. *Can. J. Fish. Aquat. Sci.* 54 (Suppl. 1): 209-216.
- Stobo, W.T. and C.T. Zwanenburg. 1990. Grey Seal (*Halichoerus grypus*) pup production on Sable Island and estimates of recent production in the Northwest Atlantic. p. 171-184. *In:* W.D. Bowen (ed.), *Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts*. *Can. Bull. Fish. Aquat. Sci.* 222 p.
- Stone, C.J. 1997. Cetacean observations during seismic surveys in 1996. *JNCC Report* 228. Joint Nature Conservancy, Aberdeen, Scotland. 41 p. + App.
- Stone, C.J. 1998. Cetacean observations during seismic surveys in 1997. *JNCC Report* 278. Joint Nature Conservancy, Aberdeen, Scotland. 55 p. + App.
- Stone, C.J. 2000. Cetacean observations during seismic surveys in 1998. *JNCC Report* 301. Joint Nature Conservancy, Aberdeen, Scotland. 62 p. + App.
- Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. *JNCC Report* 323. Joint Nature Conservancy, Aberdeen, Scotland. 43 p.
- Suryan, R.M. and J.T. Harvey. 1999. Variability in reactions of Pacific harbor seals, *Phoca vitulina richardsi*, to disturbance. *Fish. Bull.* 97(2):332-339.
- Sverdrup, A., E. Kjellsby, P.G. Krüger, R. Fløysand, F.R. Knudsen, P.S. Enger, G. Serck-Hanssen and K.B. Helle. 1994. Effects of experimental seismic shock on vasoactivity of arteries, integrity of the vascular endothelium and on primary stress hormones of the Atlantic salmon. *J. Fish Biol.* 45: 973-995.
- Terhune, J.M. and W.C. Verboom. 1999. Right whales and ship noises. *Mar. Mamm. Sci.* 15(1): 256-258.
- Thompson, D., M. Sjöberg, E.B. Bryant, P. Lovell and A. Bjørge. 1998. Behavioural and physiological responses of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals to seismic surveys. p. 134. *In:* *World Marine Mammal Science Conf. Abstract volume*, Monaco. 160 p.
- Thomsen, B. 2002. An experiment on how seismic shooting affects caged fish. *Faroese Fisheries Laboratory*, University of Aberdeen, Scotland.
- Tolstoy, M., J.B. Diebold, S.C. Webb, D.R. Bohnenstiehl, E. Chapp, R.C. Holmes and M. Rawson. 2004. Broadband calibration of R/V Ewing seismic sources. *Geophys. Res. Lett.* 31. L14310, doi: 10.1029/2004GL020234.



- Valsecchi, E., P. Palsboll, P. Hale, D. Glockner-Ferrari, M. Ferrari, P. Clapham, F. Larsen, D. Mattila, R. Sears, J. Sigurjonsson, M. Brown, P. Corkeron and B. Amos. 1997. Microsatellite genetic distances between oceanic populations of the Humpback Whale (*Megaptera novaeangliae*). *Molecular Biology Evolution*. 14: 355-362.
- Vázquez, A. 2002. Results from bottom trawl survey on Flemish Cap of July 2001. NAFO SCR Doc. 01/12. 8 p.
- Wallace, S.D. and J.W. Lawson. 1997. A review of stomach contents of Harp Seals (*Phoca groenlandica*) from the Northwest Atlantic: an update. *International Marine Mammal Association* 97-01.
- Wang, J.Y., D.E. Gaskin and B.N. White. 1996. Mitochondrial DNA analysis of Harbour Porpoise, *Phocoena phocoena*, subpopulations in North American waters. *Can. J. Fish. Aquat. Sci.* 53: 1632-1645.
- Wardle, C.S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson and D. Mackie. 2001. Effects of seismic air guns on marine fish. *Cont. Shelf Res.* 21(8-10): 1005-1027.
- Waring, G.T., P. Gerrior, P.M. Payne, B.L. Parry and J.R. Nicolas. 1990. Incidental take of marine mammals in foreign fishery activities off the northeast United States, 1977-1988. *U.S. Fisheries Bulletin* 88: 347-360.
- Waring, G.T., R.M. Pace, J.M. Quintal, C.P. Fairfield and K. Maze-Foley (Eds.). 2004. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments-2003. NOAA Technical Memorandum NMFS-NE-182. United States National Oceanic and Atmospheric Administration (NOAA) Fisheries: National Marine Fisheries Service: Office of Protected Resources. 300 p.
- Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. *Mar. Mamm. Sci.* 2: 251-262.
- Weller, D.W., Y.V. Ivashchenko, G.A. Tsidulko, A.M. Burdin and R.L. Brownell, Jr. 2002. Influence of seismic surveys on western gray whales off Sakhalin Island, Russia in 2001. Working Paper SC/54/BRG14, Int. Whal. Comm., Western Gray Whale Working Group Meeting, Ulsan, South Korea, 22-25 October 2002. 12 p.
- Westgate, A.J. and K.A. Tolley. 1999. Geographical differences in organochlorine contaminants in Harbour Porpoises *Phocoena phocoena* from the western North Atlantic. *Marine Ecology Progress Series* 177: 255-268.
- Whitehead, H. 1982. Populations of Humpback Whales in the Northwest Atlantic. Report of the International Whaling Commission 32: 345-353.
- Whitehead, H. 2003. Sperm Whales: Social Evolution in the Ocean. University of Chicago Press, Chicago, IL. 431 p.
- Whitehead, H. and C. Glass. 1985. The significance of the Southeast Shoal of the Grand Bank to Humpback Whales and other cetacean species. *Canadian Journal of Zoology* 63: 2617-2625.
- Whitehead, H. and J.E. Carscadden. 1985. Predicting inshore whale abundance - whales and capelin off the Newfoundland coast. *Can. J. Fish. Aquat. Sci.* 42: 976-981.
- Whitehead, H., W.D. Bowen, S.K. Hooker and S. Gowans. 1998. Marine mammals. p. 186-221. *In*: W.G. Harrison and D.G. Fenton (eds.), *The Gully: A scientific review of its environment and ecosystem*. Department of Fisheries and Oceans, Ottawa, ON.

- Wiese, F. K. and W.A. Montevecchi. 1999. Marine bird and mammal surveys on the Newfoundland Grand Bank from offshore supply vessels. Contract Report Prepared for Husky Oil. 23 p. + App.
- Williams, T.M., G.A. Antonelis and J. Balke. 1994. Health Evaluation, Rehabilitation, and Release of Oiled Harbor Seal Pups. p. 227-242. *In*: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego. 395 p.
- Wilson, B. and L.M. Dill. 2002. Pacific herring respond to stimulated odontocete echolocation sounds. *Can. J. Fish. Aquat. Sci.* 59: 542-553.
- Wimmer, T. and H. Whitehead. 2004. Movements and distribution of northern bottlenose whales, *Hyperoodon ampullatus*, on the Scotian Slope and in adjacent waters. *Can. J. Zool.* 82(11): 1782-1794.
- Winn, H.E. and N.E. Reichley. 1985. Humpback Whale *Megaptera novaeangliae* (Borowski, 1781). p. 241-273. *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. Volume 3. Academic Press, London.
- Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. *U.S. Fisheries Bulletin* 97: 200-211.
- Würsig, B., S.K. Lynn, T.A. Jefferson and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. *Aquat. Mamm.* 24: 41-50.
- Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L. Bradford, S.A. Blokhin and R.L. Brownell (Jr.). 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Final Report by Texas A&M Univ., College Station, TX, and Kamchatka Inst. Ecol. and Nature Manage., Russian Acad. Sci., Kamchatka, Russia, for Sakhalin Energy Investment Co. Ltd and Exxon Neftegaz Ltd, Yuzhno-Sakhalinsk, Russia. 101 p.
- Yoder, J.A. 2002. Declaration of James A. Yoder in opposition to plaintiff's motion for temporary restraining order, 28 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Division.
- Zelick, R., D.A. Mann and A.N. Popper. 1999. Acoustic communication in fishes and frogs. *In*: (eds.) R.R. Fay and A.N. Popper. Comparative Hearing: Fish and Amphibians. Springer Handbook of Auditory Research. Springer-Verlag New York.
- Zimmer, W.M.X., M.P. Johnson, A. D'Amico and P.L. Tyack. 2003. Combining data from a multisensor tag and passive sonar to determine the diving behavior of a sperm whale (*Physeter macrocephalus*). *IEEE. J. Ocean. Eng.* 28(1):13-28.

## Personal Communication

Dufault, S.	LGL
Lawson, J.	DFO Marine Mammal Research Scientist, 2003
Lilly, G.	DFO
MaCallum, B.	DFO Science Surveys, February 2005
Simms, J.	DFO Biologist

# **Appendix I. Persons Consulted**

## **DFO Newfoundland Region**

James Meade, Senior Regional Habitat Biologist  
Lisa Noble, Senior Regional Habitat Biologist  
Joe Tillman, Section Head, Branch Programs and Planning  
B. MaCallum, DFO Science Surveys.

## **Environment Canada (Environmental Protection Branch)**

Glenn Troke, EA Co-ordinator  
Holly Hogan, Environmental Assessment Biologist

## **Natural History Society**

Dr. Len Zedel, MUN  
Dr. Kim Bell, Independent Fisheries Biologist

## **One Ocean**

Gordon Slade, Executive Director  
Maureen Murphy, Research Assistant

## **FFAWU**

Sherry Glynn, Fisheries Biologist

## **Association of Seafood Producers**

Derek Butler, Executive Director

## **Fishery Products International**

Wilson Fudge, Director, Government Relations and Development  
Sigurdur Jonsson, Director, Fleet Operations  
Derek Fudge, Manager, Fleet Administration and Scheduling

## **Icewater Harvesting**

Michael O'Connor, Fish Harvesting Consultant

## **Nova Scotia**

Christine Penney, Director of Corporate Affairs, Clearwater Seafood's Limited Partnership

## Appendix II. GSI Admiral – Vessel and Equipment

### GSI ADMIRAL

### VESSEL AND EQUIPMENT

#### principal particulars

*The following specification is for information only.*

#### GSI Admiral

Outfitted in 1998 for high quality 3D seismic data acquisition, this vessel is equipped with the latest generation seismic installation and is designed for safe, reliable operation in demanding offshore environments around the world. Capable of deploying up to 4 x 6 kilometres of cable over a range of spreads up to 0.48 kilometres.

Featuring spacious, streamer and source handling decks for safe and efficient working conditions conforming with best industry practice.

#### INSTRUMENT ROOM

- Large (150m<sup>2</sup>) air conditioned instrument room complete with 60 Kva UPS stabilised power supply and fitted instrument racks capable of housing seismic recording, source control, seismic navigation and optional seismic processing facilities.

#### UPPER DECK WORKSHOPS

- 3 air conditioned upperdeck workshops (2 off 20' x 8'. 1 off 10' x 8'). Outfitted as seismic source workshop, mechanical, fitting and welding workshops complete with limited fixed and consumable tools.

Tools and Ship Spares

#### PRINCIPAL PARTICULARS

Vessel fitted with limited machine shop, engineering and fitting tools and machinery spares.

Vessel Type	Seismic Survey Vessel
Port of Registry & Flag	Halifax, N.S. Canada, Canadian flag
Call Sign	VOCC
Registration No.	823 287
IMO No.	7384314
LOA	89.59 m
LBP	82.02 m
BM	17.40 m
B Extreme	19.00 m
DM	9.40 m (Working deck)
DM	6.80 m (Freeboard deck-main)
GRT	3545
NRT	1031
Displacement	4745.55 t
DWT (Summer)	13500

Draft (Summer)	5.85 m
Builder	Stocznia Im Komuny Paryskiej
Year of Build	1976
Major Conversion	1998
Conversion Shipyard	Cammell Laird, Birkenhead, Cheshire, England
Classification	Det Norske Veritas (DNV) D 1A1 Heldk
Main Engine	Zgoda Sulzer ZL40/80
BHP	4800 @ 500 rpm
Gearbox	Renk, Type-AUS 90SD-2, Ratio – 3.11: 1
Propeller	Kamewa Controllable Pitch, 4 Blades
Fuel Consumption (Transit Mode)	13 Tonnes
Fuel	MGO 5Cst @ 40deg C
Electrical Power	1 x 1200 kVA/400v /50 Hz Shaft Alternator Make DKBL 536/06 + DEA 434
Emergency Generator	1 x 190 kVA /400 v / 50 Hz Diesel set Make Skania Type DS14A01LR
Main Generator	1 x 950 kVA @750 rpm H. Cegiejski/Sulzer Model 6 AL 25/30
Seismic Domestic Generator	Caterpillar Model 3412DI-T 320 kVA 440v/60Hz
Seismic Generator Operations x 2	Caterpillar Model 3516 TA 2281 kVA 600v/60 Hz
Additional Propulsion	Azimuth Thruster Type UL 2001/6100 Kamewa Power 1491 kW (Retractable)
Prime Mover	Caterpillar 3516 TA RPM 1800
Vessel speed (Thruster only)	7 Knots
Cruising Speed (Main Engine)	13 Knots
Seismic Compressors	3 x Hamworthy 800E (800 cfm each @ 207 Bar)
	3 x Hamworthy 425E (390 cfm each @ 207 Bar)
Prime Movers	Electric Motors
Fuel Capacity	1400 m <sup>3</sup>
Water Capacity	136 m <sup>3</sup>
Water Making Capacity	24 Tonnes Daily. Rochem Reverse Osmosis Plant
Sewage Treatment Plant	Hamworthy
Steering Gear	Hydroster, Gdansk. Single Semi-Balanced Rudder Two hydraulic Rams, Two Electro-Hydraulic P/P's
Hydraulic Power Pack (Seismic)	Odin, 3 x 63 kW @ 160 L./min each. From Main 1400 Litre Stainless Steel Tank
Deck Mooring	1 x Electric Windlass x 2 Anchors, 1 x Capstan
Stores Cranes	2 x 1 Tonne. 2 x 2.2 Tonne
Liferaft Capacity	6 x 25 Man, 2 x 16 Man, 1 x 4 Man
Fast Rescue Craft	1 x UFAS / Weedo 17, 2 x 60HP
Seismic Workboat	Davit only fitted
<b>Bridge Equipment</b>	
Radar No 1	Decca Bridgemaster Arpa BM 343/12
Radar No 2	Decca Bridgemaster Arpa BM 252/6
Gyro Compass 1	Anschutz
Gyro Compass 2	Seapath
Magnetic Compass	J.R. Krohn 79047
Auto Pilot	Robertson AP9 Mk 3

GPS Receiver x 2	Leica MX 400 DGPS
Echo Sounder	Skipper NaN Jing GDS 101
Speed Indicator	SRD 331 MDV
Anemometer	Walker 2060 Analog
Navtex Receiver	ICS Nav 5
Weather Station	Taiyo TF 721
Satcom	Sperry H2095
SSB Radio Telephone	Sperry RE 2100
Watch Receiver	Delco Electro DC-303
VHF Radio x 3	Sperry RY 6102
Aeronautical VHF	Jotron TR 6102
VHF Handset	Delcom GN 2940
Telex	Sperry RM 2151
Helicopter Beacon	Sencea STR 25
Internal Telephone System	Phontech
EPIRB	1 x Float Free, Jotron 405
SART	2 x Tron 20652 / 20653
Transmitter	Sperry T2130
Receiver	Sperry RE 2100
MF/HF DSC Watchkeeper	Sperry RM2150
Satellite C	Sperry H2095B
Watchkeeper 2182 kHz	Delcom
Doppler Log	Sperry SRD 331
Electronic Chart System	Racal VMS
SSB Radio	Mousson-2, 250 W
VHF Radio (X3)	Sperry RY 6102
Integrated navigation system	Concept Systems Spectra/Sprint/Reflex/Racal Winfrog
Survey Echo Sounder	Echo Trac DF3200 MKII
Primary navigation	Multifix
Doppler log	Sperry SRD 331
<b>Recording Instruments:</b>	
Type	I/O MSX Marine Recording System
Tape format	8015 SEG D, 3590-tape cartridges
Tape recorders	4 X IBM Magstar 3590
Display System	Seis QC, 20" Color Monitor, Versatec 24" Plotter, HP Postscript Laser Printer
<b>Energy Source:</b>	
Energy Source type	Bolt Technologies "LL" Air Guns
Subarrays	6 x 10 guns each, 2 x 10 guns spare
Total Capacity	7860 cubic inches
Synchronizer	Syntron GCS-90
Air Compressors	3 X Hamworthy 800E (800 CFM each) 3 X Hamworthy 425E (390 CFM each)
Working pressure	2000 psi (138 bar)
<b>Streamer:</b>	
Type	I/O MSX, 24 bit Digital

Hydrophone type	I/O Preseis 2517
Streamer length	2D: 1 x 8000 m ; 3D: 4 x 6000 m
Active sections	60 x 100 meter + 30 x 100 spare
Stretch sections	2 x 87.5meter head + 1x 85 meter tail plus 100% spare
Tow Leader	1 x 425 meter (armored/faired) + 2 x 425 meter spare
Cable levellers	DigiCOURSE Model 5011 Compass Birds + spares
Streamer winch capacity	4 x 7500 meter each

### 3. Survey Vessel and Energy Source

The survey will be conducted by the *GSI Admiral*, call sign VOCC, a Canadian-flag research vessel registered in Halifax, which is fully equipped, to conduct the proposed seismic program. The vessel adheres to some of the world's highest safety, quality control and environmental protection standards. The 3,545 GRT ship is 89.6 m long with a 117.4 m beam and a draft (summer) of 5.85 m (Figure 3).



**Figure 3:** *GSI Admiral*



### 3.1 Survey Vessel and Streamer

The vessel has in place a shipboard oil pollution emergency plan (SOPEP) in conformity with the International Maritime Organization (IMO) and approved by the Det Norske Veritas Classification AS on behalf of the Government of Canada. On-board environmental protection equipment includes containment booms, absorbent pads, oil spill dispersant, and other such equipment. The ship has a newly installed DNV approved oily water separator and treatment plant to ensure that traces of oil in bilge water are removed prior to pumping out bilge water which may contain hydrocarbons. The ship is also outfitted with a sewage treatment plant, and GSI's waste disposal practices conform to the strict international standards contained in Marpol 73/78.

Section: Accident Assessment provides more details about the *GSI Admiral* and its safety and environmental protection protocols and equipment.

The proposed survey will use two streamers up to 6,000 m in length, towed at a depth of 8m to 9m.<sup>4</sup> It will be marked at the end by a tail buoy with a Racal RGPS positioning device, a white strobe light and a radar reflector. Distance from the stern of the vessel to the tail buoys will be approximately 6,200 m based on the planned near trace offset, tail stretch and tail rope length. It is expected that the vessel will travel at a speed of about 8 - 9 km/hr while surveying.

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<sup>4</sup> The length of the streamer is determined by the depth being imaged during the survey; the streamer depth is chosen for operational and scientific (technical) reasons.

## 3.2 Source Array

The sound source (array) will be towed at a depth of about 6 meters below the surface. It will consist of a 2,620 cu.in. / 2,000 nominal psi array made up of 12 sources in two sub-arrays. Two such arrays will be utilized in an alternating fashion (flip flop). The array will activate about every 8 seconds, or 25 m. This is to allow enough time for the sound to reach its target and for the echo to return and be recorded by the hydrophones embedded in the streamer.

The array is expected to have a 75.6 barmeter peak-to-peak pressure with a rise time of 12 milliseconds, as shown in Figure 4. Figure 5 shows the portion of the frequency spectrum where most of the array energy is concentrated<sup>5</sup>. Maximum amplitude will be 214.1 dB re 1  $\mu$ Pa/Hz at 1 m.

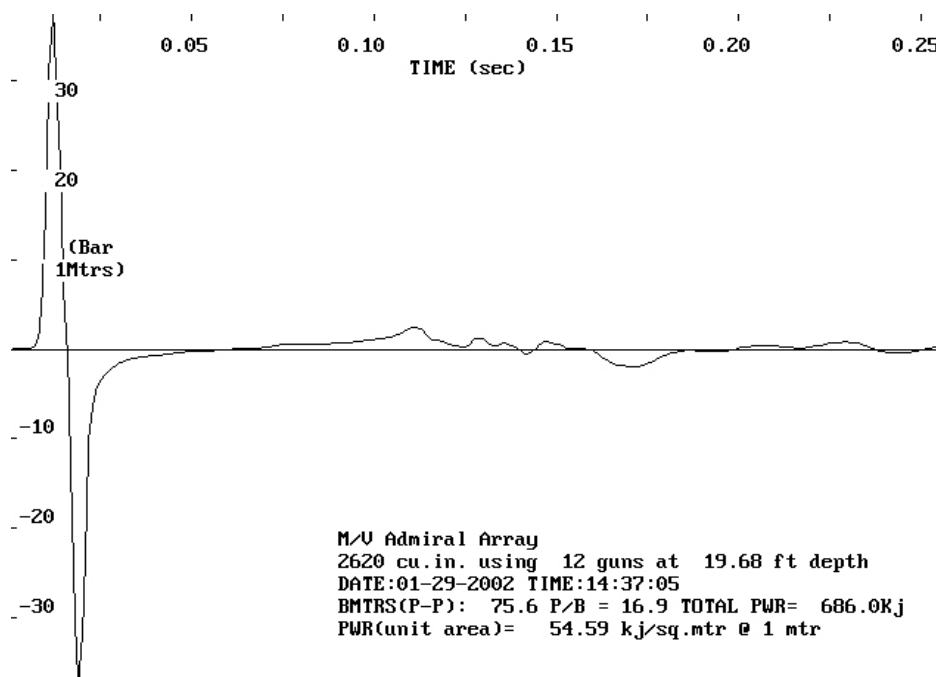
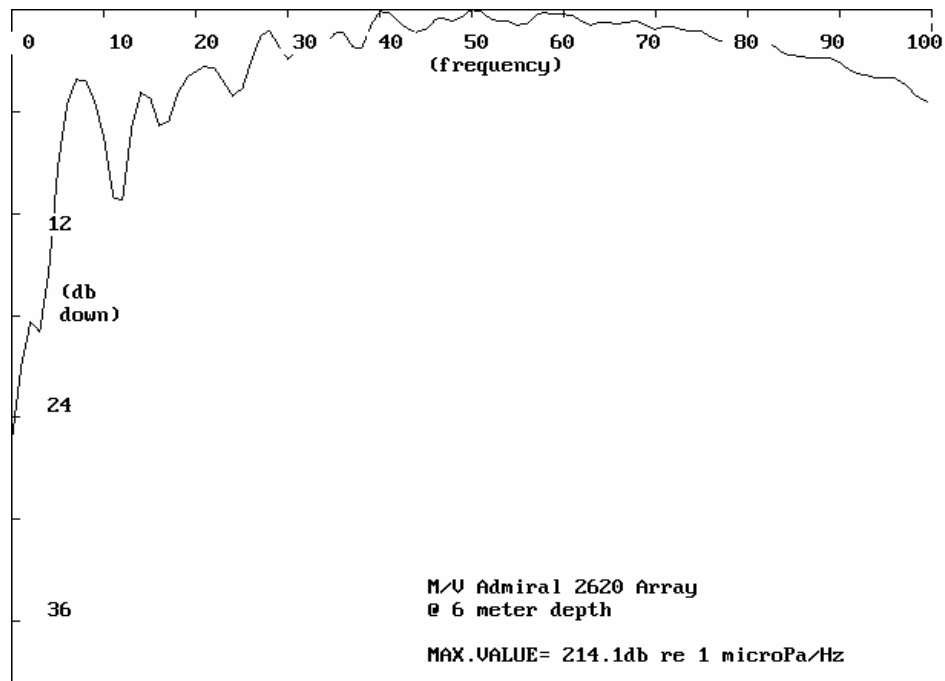


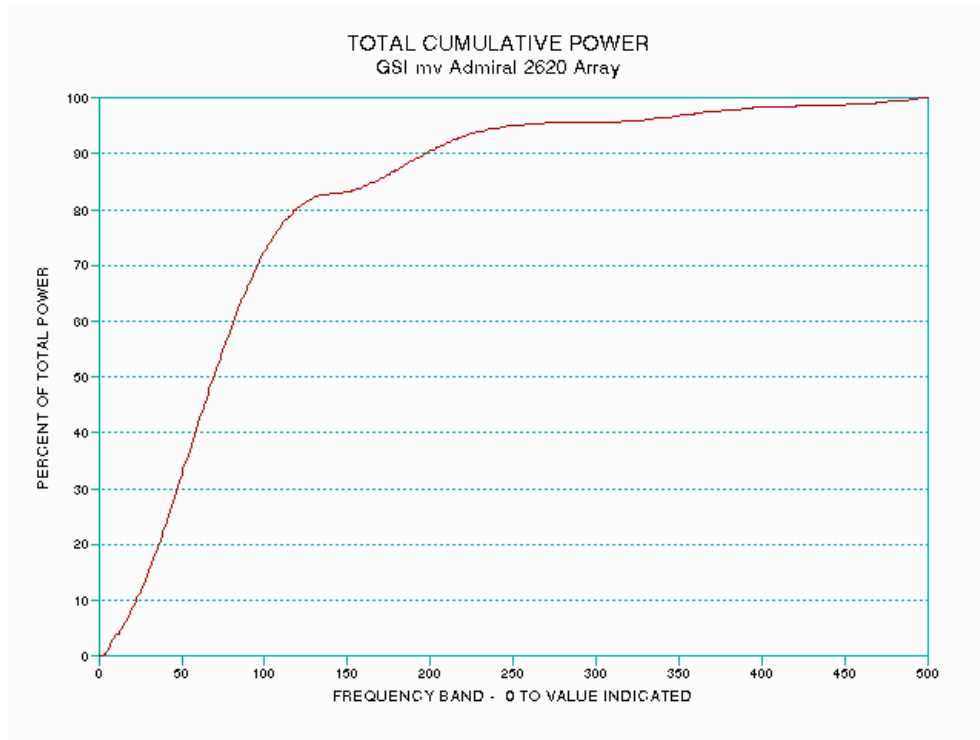
Figure 4: 2620 Array Signature

<sup>5</sup> Axis shows dB down



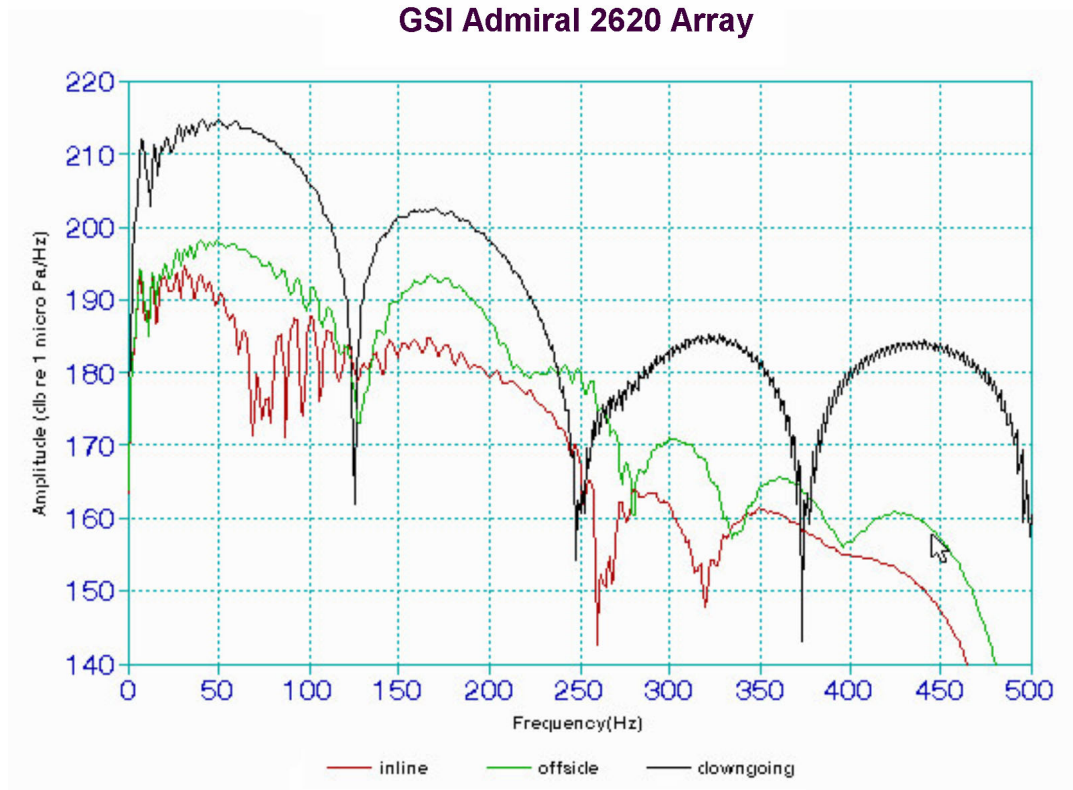
**Figure 5: 2620 Frequency Spectrum at 6 m deployed depth**

Figure 6 shows the percent of the power from the array that is in the band from zero hertz to the value indicated; it illustrates that most of the energy that the array generates (more than 80 %) is in the band below 100 hertz.



**Figure 6: Total Cumulative Power of the Array at Frequency**

Figure 7 shows the amplitude (dB re 1uPa/Hz) of the 2620 array for frequencies between 0 and 500 Hz; the different coloured lines show the amplitude inline (inline with the array), offside (perpendicular to the inline array) and downgoing (immediately beneath the array).



**Figure 7: Frequency - Amplitude Plot of the 2620 Array**

The configuration of the array, including the size of the different sources and their relative position in the array is presented in Figure 8. The numbers next to the symbols are the number of the gun; the numbers inside the symbols are the cu. in. of each element. Note that some are clusters (coalescing) others are individual.