Environmental Assessment of Chevron's North Grand Banks Regional Seismic Program, 2011-2017

Prepared by

LGL LIMITED
environmental research associates

for

Chevron

March 2011
Project No. SA1119

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Table of Contents

Page

List of Figures

List of Tables

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1.0 Introduction

This document is a screening level environmental assessment (EA) as defined by the *Canadian Environmental Assessment Act* (*CEAA*) for a 2-D and 3-D seismic program (2011-2017) proposed for the north Grand Banks region by Chevron Canada Limited (CCL; the Proponent). CCL proposes to conduct an initial 2-D and/or 3-D seismic survey in 2011. CCL may also conduct 2-D and/or 3-D seismic surveys and geohazard surveys in 2012 to 2017.

The temporal scope of the Project is a seven year period (2011 to 2017) with seismic operations occurring between May and November in any given year. The present document focuses primarily on the proposed 2-D/3-D seismic program which is anticipated to occur in 2011. It is currently uncertain how many and in which years CCL will undertake seismic and geohazard surveys in the north Grand Banks region during 2012 to 2017, as future surveys will depend on results of the initial surveys and other factors. The geographic scope of the Project is the Project Area (Figure 1.1), which extends from the northern Grand Banks to the Orphan Knoll. The proposed operations in 2011 are expected to occur over a broad area within the Project Area.

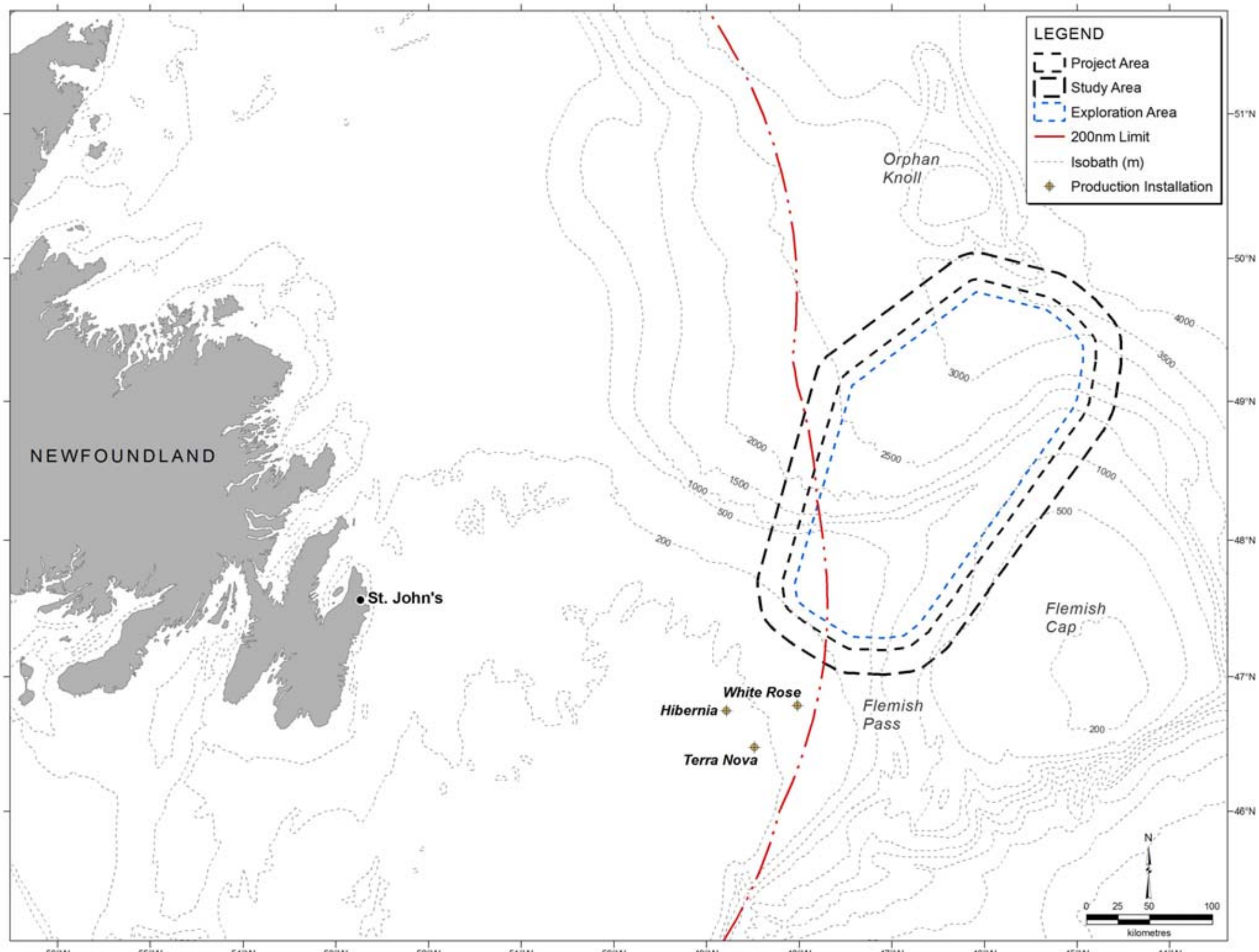

Figure 1.1. Locations of the Exploration, Project, and Study areas for CCL's potential seismic program(s) in 2011 to 2017.

1.1 Relevant Legislation and Regulatory Approvals

An *Authorization to Conduct a Geophysical Program* will be required from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). The C-NLOPB is mandated by the *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*. Offshore geophysical surveys (including geohazard surveys) on federal lands are subject to screening under the *CEAA.* In addition, the *CEAA* specifies that a marine seismic survey with an output level of 275.79 kPa at a distance of one metre from the seismic energy source (i.e., ~228.69 dB/1 µPa@1 m) requires an EA. The seismic survey activities described as part of the Project typically exceed the defined threshold level (if considering instantaneous levels). The C-NLOPB is the lead Responsible Authority (RA) for the EA and acts as the federal environmental assessment coordinator or FEAC. Because seismic survey activities have the potential to affect marine mammals, sea turtles, fish, fisheries, and seabirds, Fisheries and Oceans Canada (DFO) and Environment Canada (EC) are the agencies that have most involvement in the EA process. Legislation that is relevant to the environmental aspects of the Project includes:

- *Canada-Newfoundland Atlantic Accord Implementation Act*
- *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*
- *Canadian Environmental Assessment Act*
- *Oceans Act*
- *Fisheries Act*
- *Navigable Waters Act*
- *Canada Shipping Act*
- *Migratory Birds Convention Act*
- *Species at Risk Act*

One of the specific guidelines issued by the C-NLOPB, the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (May 2008), is directly relevant to this undertaking. It outlines mitigation and monitoring requirements for marine mammals and sea turtles for the program. As indicated in the Guidelines, the Project will follow DFO's *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment.*

1.1.1 Environmental Assessment Validation Process

The issuance of a geophysical/geotechnical work authorization under the *Atlantic Accord Implementation Act* requires a screening level EA pursuant to the *CEAA*.

The seismic and geohazard survey activities described in this EA may be undertaken at various times over the coming seven years. This EA has been developed taking into account the expected period of time during which these project activities will occur.

Authorizations issued under the *Atlantic Accord Implementation Act* for the kinds of activities described in this assessment may be valid for one to five years at the discretion of the C-NLOPB. Therefore, notwithstanding the fact that this EA has been written to cover a period of seven years based on the best available knowledge at this time, CCL recognizes that should any authorizations need to be renewed during that time period that there will be a regulatory requirement to ensure that the EA is still current and valid to support the renewal of any applicable authorizations. To that end, CCL will, during the first quarter of each year that work is planned in 2012–2017, submit documentation to the C-NLOPB to attest that:

- the scope and nature of activities planned and addressed under this EA have not changed;
- the nature of the species at risk in the Project and Study Areas have been validated and have not changed;
- the nature and extent of the fishing activities being undertaken in the Project Area have been validated and have not changed such that project activities pose any potential effects not previously assessed; and,
- the mitigation measures defined and committed to in the EA are still valid and will continue to be implemented.

Should CCL determine that changes to the project activities or the environmental aspects noted above have taken place it will consult with the C-NLOPB to determine the need for submission of an amendment to the EA.

As part of their ongoing consultation processes, CCL will consult with stakeholders each year in the context of preparing the above-noted submission to the C-NLOPB. These meetings will outline CCL's planned activities for the upcoming year and discuss issues of mutual interest and concern.

1.2 The Proponent

The Proponent is Chevron Canada Limited (CCL), which is headquartered in Calgary, Alberta, and has an office in St. John's, Newfoundland and Labrador (NL).

CCL is a wholly owned subsidiary of Chevron Corporation and one of Canada's leading energy companies. Since 1938, CCL has been actively engaged in exploring, developing, producing and marketing crude oil, natural gas and natural gas liquids in Canada. In offshore NL, CCL has non-operated joint venture interests in Hibernia, Hibernia Southern Extension, Hebron and Terra Nova. CCL also has exploration licenses in Orphan Basin (offshore Newfoundland) and in the Labrador offshore.

Chevron Corporation (NYSE: CVX), one of the world's largest integrated energy companies, is involved in every aspect of the energy industry, from oil and gas exploration and production to transportation, refining and retail marketing, as well as chemicals manufacturing and sales and power production.

1.3 Canada-Newfoundland and Labrador Benefits

Consistent with the requirements of the *Canada–Newfoundland Atlantic Accord Implementation Act*, and the *Canada–Newfoundland Atlantic Accord Implementation (Newfoundland) Act* (the Accord

Acts), CCL is committed to enhancing the opportunities for Canadian and, in particular, Newfoundland and Labrador, participation.

CCL maintains an office in St. John's, NL and manages most aspects of its East Coast Canada business from St. John's. CCL provides full and fair opportunity to Canadian individuals and organizations and in particular those from NL, to participate in CCL's activities in NL. CCL supports the principle that first consideration be given to personnel, support and other services that can be provided within NL, and to goods manufactured in NL, where such goods and services can be delivered at a high standard of Health, Safety and Environmental competency, be of high quality and are competitive in terms of fair market price. Contractors and sub-contractors working for CCL in NL must also apply these principles in their operations.

1.4 Contacts

Relevant contacts at CCL for the proposed seismic program are provided below.

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2.0 Project Description

In 2011, CCL is proposing to conduct a 2-D and/or 3-D seismic survey in an area extending from the northern Grand Banks to Orphan Knoll (see Exploration Area in Figure 1.1), starting as early as 1 May and concluding as late as 30 November. The survey in 2011 is located 340 km to 620 km northeast of St. John's, NL. The timing of the survey is subject to the Proponent's priorities and circumstances, weather and ice conditions, contractor availability and regulatory approvals. Any potential seismic and geohazard surveys conducted during subsequent seasons in 2012 to 2017 will also occur during the same temporal window of 1 May to 30 November. It is anticipated that there may be additional 2D and/or 3D seismic surveys and two geohazard surveys in any one year. The geographic extent of project activities includes the Exploration Area and an additional 10 km buffer around this area for vessel turns. The official name of the Project is the "North Grand Banks Regional Seismic Program, 2011–2017".

2.1 Spatial and Temporal Boundaries

In terms of spatial boundaries, the Project Area (Figure 1.1) includes the area where seismic data will be acquired (Exploration Area) plus a 10 km buffer area to accommodate the ships' turning radii. The Study Area includes the Project Area plus a 20 km buffer area around the Project Area (Figure 1.1) to account for the propagation of seismic survey sound that could potentially affect marine biota. The exact dimensions of the proposed 2011 seismic survey area will be determined in early 2011 as a function of geophysical priorities, vessel availability, and financial considerations.

The temporal boundaries of the proposed Project encompass the 1 May to 30 November period in each year from 2011 to 2017. In 2011, the duration of the proposed 2-D and/or 3-D seismic survey is estimated at 30 to 90 days. In 2012 to 2017, it is estimated that seismic surveys may occur for 30 to 120 days and that geohazard survey data may be collected during a two-week period.

2.2 Project Overview

The proposed Project is a ship-based seismic program commencing with a 30 to 90 day 2-D and/or 3-D survey in 2011. Additional 2-D or 3-D surveys may occur in 2012 to 2017. In addition, geohazard surveys may be conducted over potential drilling targets within the Project Area in 2012 to 2017.

In 2011, CCL is proposing to acquire approximately 6400 linear km of multi-streamer seismic survey data within the Project Area. In addition, the acquisition of about 1500 km^2 of 3-D seismic is under consideration for 2011. Additional seismic surveys may be conducted within the Project Area in 2012 to 2017. The seismic survey ship will tow a sound source (airgun array) and streamer(s) composed of receiving hydrophones. 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 a boomer.

WesternGeco has been selected as the seismic contractor for the proposed 2011 seismic program. No geohazard surveys are planned for 2011. Any seismic vessel operated in 2011 to 2017 will be approved for operation in Canadian waters and be typical of the worldwide seismic fleet. A brief description of the seismic vessel and seismic equipment proposed for use in 2011 is provided below.

Proposed mitigation procedures will follow those recommended by the C-NLOPB in Appendix 2 of *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2008), including ramp-up (i.e., soft start) of the airgun arrays, the use of dedicated Marine Mammal Observer(s) (MMOs) to monitor marine mammals and turtles and implement shut downs of the surveys when appropriate, and the use of a Fisheries Liaison Officer (FLO) and communication procedures to aid in coordination with fishing activities. The need for dedicated MMOs and/or FLOs for the more limited temporal and geographically scoped geohazard surveys in areas of limited fishing activity will be evaluated prior to any potential geohazard surveys.

2.2.1 Objectives and Rationale

The objectives of the Project are to determine the presence and likely locations of geological structures that might contain hydrocarbon deposits. In general, 2-D surveys are used to determine areas where precise and detailed 3-D surveys should be done. The 3-D data are needed to provide higher resolution and quality images than are available from 2-D surveys which use more widely spaced seismic lines and typically only one streamer. Results of 3-D surveys are then used to find potential locations for exploration drilling.

Once a potential drilling site is located it is standard offshore industry procedure, and a requirement of the C-NLOPB, that a well site/geohazard survey be conducted or suitable pre-existing survey data be used to identify, and thus avoid, any potential shallow drilling hazards. Drilling hazards could include steep and/or unstable substrates or pockets of “shallow gas” and seabed obstructions (man-made or natural), including boulders and shallow hydrates. It should be noted that not all well locations, particularly those in deep water areas, will require a geohazard survey because existing 3-D seismic data can be reprocessed to achieve the same objectives.

2.2.2 Alternatives to the Project, Alternatives within the Project

The existing 2-D seismic data for the Exploration Area and surrounding areas indicate structures that may contain volumes of producible hydrocarbons. Acquisition of new 2-D and 3-D seismic data is required to determine if exploration drilling is warranted.

Seismic surveys (2-D and 3-D) are standard precursors to offshore exploratory drilling. They help to define the target subsurface geological formations believed to contain hydrocarbon resources, lessen the chances of expending resources “drilling dry holes” and increase the overall safety of the drilling activity. Accordingly, there is no viable alternative to the proposed seismic survey programs other than to explore for oil and gas elsewhere.

Geohazard surveys are a regulatory requirement of the C-NLOPB and a safety requirement for drilling operations. As noted above, not all well locations, particularly those in deep water areas, will require a geohazard survey because existing 3-D seismic data can sometimes be reprocessed to achieve the same objectives.

Viable alternatives within the seismic and geohazard programs are essentially the choices between different contractor's ships and survey equipment that will be evaluated though the bid evaluation process.

2.2.3 Project Scheduling

In 2011, it is anticipated that the seismic survey will be about 30-90 days in duration and the survey may occur during May to November. In 2012 to 2017, seismic surveys may occur between 1 May and 30 November and program duration is estimated at 30 to 120 days. Geohazard surveys are not planned for 2011. One to two geohazard surveys per year may occur in 2012 to 2017, with each survey lasting about two weeks.

2.2.4 Site Plans

In 2011, the proposed 2-D and/or 3-D survey will be conducted in the Project Area shown in Figure 1.1. Water depth in the Project Area ranges from <200 m to >3500 m. In 2011, seismic data will be acquired along ~70 lines that are primarily oriented southwest/northeast and northwest/southeast. Spacing between seismic lines will be variable.

Geohazard surveys may be conducted at exploratory drill sites, which will be identified in future years. If these surveys are required, CCL will likely use the survey grid approach recommended in the "*Geophysical, Geological, Environmental and Geotechnical Program Guidelines*" (C-NLOPB 2008).

2.2.5 Personnel

A typical seismic vessel can accommodate approximately 50 to 100 personnel. Personnel on seismic vessels typically include individuals from the Proponent (i.e., CCL), the vessel owner/operator (ship's officers and marine crew), and technical and scientific personnel from the main seismic contractor. The seismic vessel will have a FLO and a MMO(s) on board, as well as a CCL representative(s) who serves as Client Quality Control and Processing Quality Control. All project personnel will have all of the required certifications as specified by relevant Canadian legislation and the C-NLOPB. Total crew on board a geohazard vessel will be on the order of 12 (ship's crew), and 12 (technical), and perhaps a MMO and FLO[1] for a total of 24 to 26 individuals.

2.2.6 Seismic Vessel

In 2011, WesternGeco will conduct the proposed seismic survey on behalf of CCL and the M/V *WG Tasman* will serve as the seismic source vessel. The *WG Tasman* has a length of ~90 m, width of 19 m, and an average draft of 6 m. Like most seismic vessels, it is equipped with a helideck, operates an echosounder, will deploy a workboat to repair streamers when necessary, and will carry a Fast Rescue Craft. The *WG Tasman*, like most other seismic vessels, operates diesel-electric propulsion systems (main and thrusters).

[1] If space availability aboard the geohazard vessel is limited, one of the ship's crew trained in marine mammal monitoring and mitigation protocols will perform the duties of MMO. The ship's marine crew would communicate with fishing vessels in the area.

2.2.7 Seismic Energy Source Parameters

The seismic energy source will be comprised of individual airguns arranged in an array. In 2011, CCL is proposing to operate airgun arrays, each 5085 in^3 in total volume. In subsequent survey years (2012–2017), CCL expects to also use two airgun arrays, 3000 in^3 to 6000 in^3 in total volume. The two airgun arrays will be activated alternately (flip-flop arrangement) along the survey lines, typically every 9 to 12 seconds. Survey speed is around 4.5 knots (8.3 km/h). The arrays will be towed at depths of 6 m to 15 m. Airguns will be operated at 2000 to 2500 psi and the source level (at 1 m) of the array may range from 100 to 150 bar-m (~254 to 257.5 dB re 1 μPa zero to peak). The airguns in the array are strategically arranged to direct most of the energy vertically downward rather than sideways (see Appendix C in LGL (2007) for a review of airgun sound characteristics).

2.2.8 Seismic Streamers

The proposed 2-D and/or 3-D seismic survey in 2011 will use a maximum of 10 streamers, each 8000 m long, each separated by 100 m, and deployed at a depth of 12 m. In subsequent survey years (2012–2017), CCL expects to use 6 to 12 towed streamers to a maximum of 20 with an approximate length of up to 8000 m and deployed at depths ranging from 5 to 25 m. For 2011, solid streamers will be deployed.

If fluid-filled streamers are used in subsequent surveys, the fluid used to control buoyancy is called Isopar-M. Isopar-M predominantly consists of isoparaffinic hydrocarbons (C12-C15). In a typical Isopar-filled streamer, each 100 m hydrophone section contains 11.7 L of Isopar divided amongst 78 hydrophone pockets. Each hydrophone pocket contains 150 mL of Isopar and is isolated and completely sealed from other pockets. This isolation of pockets greatly reduces the chances of releasing large amounts of fluid even in the event of a major streamer accident.

2.2.9 Geohazard Vessel and Equipment

If geohazard surveys are required, surveys will be conducted from a vessel similar to those used to conduct geohazard surveys offshore of Newfoundland in recent years (e.g., MV *Anticosti*). Vessels presently approved and operating on the East Coast on other offshore programs will be utilized. Vessel specifics 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.

The wellsite geohazard program, if required, will acquire high resolution seismic, side scan sonar, sub-bottom profiler and bathymetric data over the proposed area. Survey speed will be on the order of four to five knots. The geohazard equipment is anticipated to be similar to that used in recent years for site survey work offshore Newfoundland for various operators. From an operational perspective, the following text summarizes the typical acoustic sources to be used during surveying. However, it should be noted that equipment may vary depending on contractor selection. If equipment specifics differ from those included below, details will be provided once the contractors are selected.

2.2.10 Geohazard Seismic Data

High-resolution multi-channel seismic data will be acquired with a small airgun array. The seismic source is typically comprised of four airguns, each of 40 in^3 capacity. The compressed air for the airguns is provided by a diesel-powered compressor on deck. The maximum output from this typical array has a peak to peak value of 17.0 bar-m. This equates to a source level (at 1 m) of ~238 dB re 1µPa (zero to peak). A single streamer is typically towed from the port quarter of the vessel. A tail buoy will be used, equipped with a radar reflector and strobe light. Total streamer length is typically ~ 650 m.

2.2.10.1 Surficial Data

Huntec Deep Tow System

The Huntec Deep Tow System (DTS) 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 a distance of between 20 and 40 m off the seabed. The Huntec DTS uses a "broadband" 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 60º cone. Maximum peak to peak amplitude is 221 dB re 1 µPa at 1 m.

Side Scan Sonar

Seabed imagery, for the clearance survey, is typically acquired with a digital, dual frequency (105 kHz and 390 kHz) side scan sonar system. The sonar source level for 390 kHz is 216 dB re 1 µPa at 1 m (zero to peak) and for 105 kHz is 221 dB re 1 µPa at 1 m (zero to peak). The activation rate of the side scan sonar is 3.3 times per second at 200 m range. The beamwidth is: horizontal, 1.2º and 0.5º for the 105 kHz and 390 kHz frequencies, respectively. A 50º arc is swept perpendicular to the survey transect.

Echo Sounders

A Reson 8101 multi-beam is an echo sounder typically used to acquire bathymetric data. Power output levels are similar to the types of echo sounders commonly used on the Grand Banks. The system operates at a frequency of 240 kHz and the source level is 207 dB re 1 uPa at 1 m (zero to peak) and its sounding rate may be ~4 to 6 times per second. The multibeam echo sounder covers 1.5º per beam and 101 beams cover a 150º arc perpendicular to the survey transect.

A single-beam echosounder is usually operated to provide quality control of the data acquired from the multi-beam echosounder. The single-beam echosounder operates at 24 kHz and 200 kHz (dual frequency capable) and the source levels are 213 dB re 1 uPa at 1 m (zero to peak) and 209 dB re 1 uPa at 1 m (zero to peak) for 24 kHz and 200 kHz frequencies, respectively. The sounding rate of this source will be typically two times per second. The single-beam echosounder derived pulse is primarily restricted to a 9º (200 Hz) and a 24º (24 kHz) conical beam.

Magnetometer

In the event that potential debris is identified by the side scan or multi-beam systems, a proton magnetometer is typically utilized. This system is towed behind the vessel, 5 to 10 m above the seabed, and emits a low power electromagnetic field.

Camera and Sediment Sampler

A camera system and sediment sampler is typically deployed at a number of locations across the site, for the purposes of groundtruthing the geophysical data. Surficial sediment samples (of approximately 0.7 L in size) are described on board by a geologist, and stored in sample bags for subsequent processing. The camera is usually lowered to an elevation of 1 m or more above the seabed as the vessel drifts across the intended sites.

2.2.10.2 Logistics and Support

Offshore seismic operations will be supported by a picket and supply vessel and potentially a helicopter. No new shorebase facilities will be required for the Project. Crew changes, if required, will be based out of St. John’s, NL.

2.2.10.3 Picket Vessel

The seismic ship will be accompanied by a picket vessel with responsibilities for communications with other vessels (primarily fishing vessels) that may be operating in the area and for scouting ahead to look for hazards. The geohazard vessel will not likely require or be accompanied by a picket vessel.

2.2.10.4 Supply Vessel

Heavy re-supply (including water, food, parts and fuel) to the seismic vessel will be conducted by offshore supply vessel throughout the duration of the program. Supply vessels may be typical of those that regularly service Hibernia, Terra Nova and White Rose. A typical supply vessel is crewed by about 6 to 12 marine qualified personnel. Given the short duration of a typical geohazard survey (i.e., two weeks), re-supply is not anticipated for these programs.

2.2.10.5 Helicopter

If required, aircraft support will be provided by twin-engine helicopters. Helicopters may be used to ferry personnel and lightweight supplies to and from the seismic vessel. In addition, helicopter emergency response support will be available to the seismic vessel. Helicopters will be based out of St. John’s, NL. Once determined, this information will be provided to the C-NLOPB.

2.2.11 Waste Management

Wastes produced from the seismic, geohazard, supply and picket vessels, including grey and black water, bilge water, deck drainage, discharges from machinery spaces and hazardous and non-hazardous waste material will be managed in accordance with MARPOL and with the seismic contractor's waste management plan. A licensed waste contractor will be used for any waste returned to shore.

2.2.12 Air Emissions

Air emissions will be those associated with standard operations for marine vessels in general, including the seismic vessel, picket vessel, geohazard and supply vessel. There are no anticipated implications for the health and safety of workers on these vessels.

2.2.13 Accidental Events

In the unlikely event of the accidental release of hydrocarbons during the Project, CCL's seismic and geohazard survey contractor will implement the measures outlined in the contractor's oil spill response plan. In addition, CCL has emergency management plans in place which will be bridged with the seismic (and geohazard) contractor's response plans prior to commencement of the seismic program.

2.3 Mitigation

Mitigation measures are detailed throughout the EA. The measures are reviewed and summarized in Section 5.9.

3.0 Physical Environment

The Scoping Document required that the EA include a review of the meterological and oceanographic characteristics, including extreme conditions, to provide the basis for assessing the effects of the environment on the Project. A detailed description of met-ocean conditions in the Study and Project areas, and methodologies used, are contained in the report by Oceans (2011) that is appended to this document (Appendix D). A summary of the most relevant climatology (Section 3.1), physical oceanography (Section 3.2), and ice/iceberg (Section 3.3) information is provided below.

3.1 Climatology

Every marine seismic survey program is influenced by weather conditions both from routine operational and environmental safety perspectives. During routine activities, data quality and hence, survey time on site can be affected by weather, particularly wind and wave conditions. This section provides a very general overview of climatic conditions in the Study Area with a more detailed description of extreme events.

3.1.1 Weather Systems

The area between the northern Grand Banks and the Orphan Knoll experiences weather conditions typical of a marine environment with the surrounding waters having a moderating effect on temperature. In general, marine climates experience cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Furthermore, a marine climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and receives significant amounts of precipitation.

The climate of the Project Area is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence is considerably stronger in the winter months than during the summer months, due to an increase in the south to north temperature gradient. [Meteorological convention defines seasons by quarters; e.g., winter is December, January, February, etc.]

At any given time, the upper level flow is a wave-like pattern of large and small amplitude ridges and troughs. These ridges and troughs tend to act as a steering mechanism for surface features and therefore, their positions in the upper atmosphere determine the weather at the earth's surface. Upper ridges tend to support areas of high pressure at the surface, while upper troughs lend support to low pressure developments. The amplitude of the upper flow pattern tends to be higher in winter than summer, which is conducive to the development of more intense storm systems.

During the winter months, an upper level trough tends to lie over Central Canada and an upper ridge over the North Atlantic resulting in three main storm tracks affecting the region: one from the Great Lakes Basin, one from Cape Hatteras, North Carolina and one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area.

Frequently, intense low pressure systems become 'captured' and slow down or stall off the coast of NL. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity and size of the system, from the relatively benign to heavy weather conditions. Rapidly deepening storms are a problem south of Newfoundland in the vicinity of the warm water of the Gulf Stream. Sometimes these explosively deepening oceanic cyclones develop into a "weather bomb"; defined as a storm that undergoes central pressure declines greater than 24 mb over 24 hours. Hurricane force winds near the center, the outbreak of convective clouds to the north and east of the center during the explosive stage, and the presence of a clear area near the center in its mature stage (Rogers and Bosart 1986) are typical of weather bombs. After development, these systems will either move across Newfoundland or near the southeast coast producing gale to storm force winds from the southwest to south over the area.

There is a general warming of the atmosphere during spring due to increasing heat from the sun. This spring warming results in a decrease in the north-south temperature gradient. Due to this weaker temperature gradient during the summer, storms tend to be weaker and not as frequent. Furthermore, the weaker tropical-to-polar temperature gradient in the summer results in the storm tracks moving further north. With the low pressure systems passing to the north of the region, the prevailing wind direction during the summer months is from the southwest to south. As a result, the incidences of gale or storm force winds are relatively infrequent over Newfoundland during the summer.

3.1.2 Extreme Analysis

An analysis of extreme wind and waves was performed using the MSC50 data set. This data set was determined to be the most representative of the available data sets, as it provides a continuous 52-year period of 1 hourly data for the Project Area. The extreme value analysis for wind speeds was carried out using the peak-over-threshold method. For the extreme wave analysis, two methods were used; the peak-over-threshold method and the joint probability method (see Appendix D).

After considering four different distributions, the Gumbel distribution was chosen to be the most representative for the peak-over-threshold method as it provided the best fit to the data. Since extreme values can vary, depending on how well the data fits the distribution, a sensitivity analysis was carried out to determine how many storms to use in the analysis.

The number of storms determined to provide the best fit annually and monthly for the grid points 13428 and 14697 (see Figure 3.1) are presented in Table 3.1.

3.1.2.1 Extreme Value Estimates for Winds from the Gumbel Distribution

The extreme value estimates for wind were calculated using Oceanweather's Osmosis software program for the return periods of 1-year, 10-years, 25-years, 50-years and 100-years. The calculated annual and monthly values for 1-hour, 10-minutes and 1-minute are presented in Tables 3.2 to 3.4. The analysis used hourly wind values for the reference height of 10 m above sea level. These values were converted to 10-minute and 1-minute wind values using a constant ration of 1.06 and 1.22, respectively (U.S. Geological Survey 1979). The annual 100-year extreme 1-hour wind speed was determined to be 33.2 m/s at Grid Point 13428 and 33.4 m/s at Grid Point 14697. Monthly, the highest extreme winds occur during February

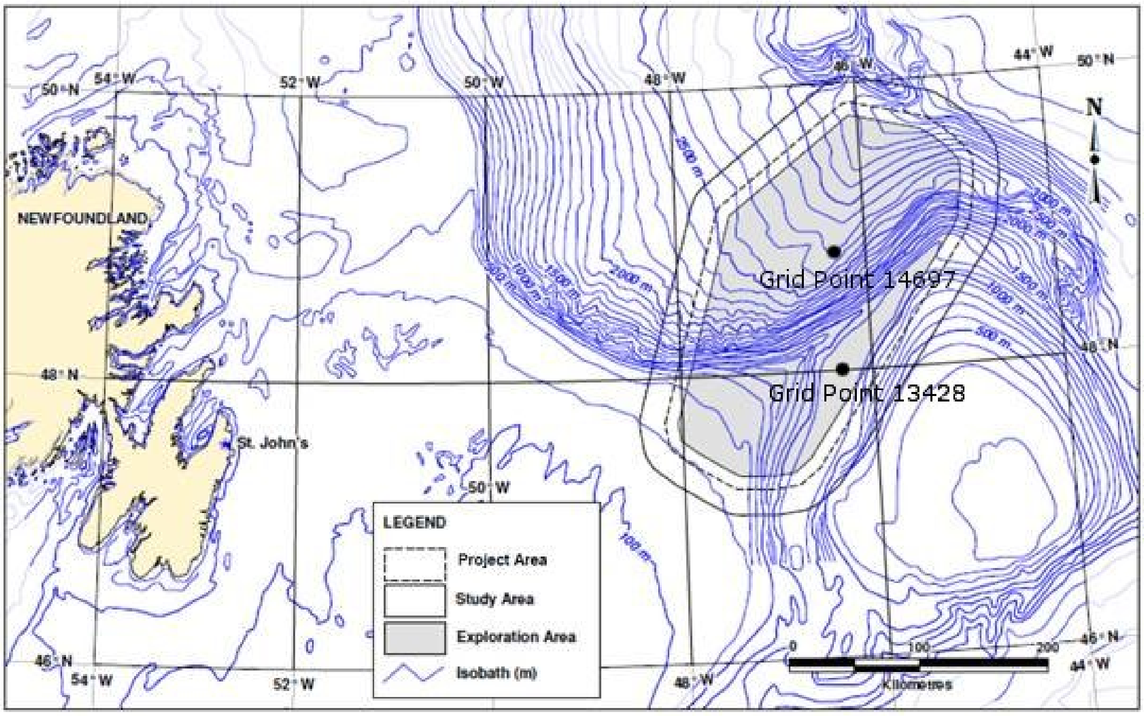


Figure 3.1. Location of the grid points (13428 and 14697) used in meteorlogical analyses relative to the Project and Study areas.

Table 3.1. Number of storms providing best fit for extreme value analysis of winds and waves.

Grid Point #		Annually	Monthly
13428	Wind	284	66
	Wave	227	55
14697	Wind	265	62
	Wave	247	60

at Grid Point 13428 with extreme wind estimates of 32.7 m/s. For Grid Point 14697, December has the highest 1-hour extreme wind estimates of 32.8 m/s.

A comparison of these values, with actual values measured by platforms in the Project Area was not possible. Logarithmic profiles for adjusting wind speeds from anemometer height to the surface are valid only in neutral or unstable conditions. Observations from platforms on the Grand Banks over the past ten years frequently show stable conditions in which the surface layer wind speed profiles are not valid. Using a logarithmic profile to adjust wind speeds between the 10-m and anemometer level would therefore introduce an unnecessary source of error in the results.

The annual and monthly extreme value estimates for significant wave height for return periods of 1-year, 10-years, 25-years, 50-years and 100-years are given in Table 3.5. The annual 100-year extreme significant wave height for Grid Point 13428 and Grid Point 14697 is 16.3 m and 16.4 m, respectively. Monthly, the highest extreme significant wave height occurs during the winter months with an extreme height of 16.2 m in February at Grid Point 13428 and 15.9 m in December at Grid Point 14697.

Table 3.2. 1-hr extreme wind speed estimates (m/s) for return periods of 1, 10, 25, 50 and 100 years.

	Grid Point #13428					Grid Point #14697				
Period	1 yr	10 yr	25 yr	50 yr	100 yr	1 yr	10 yr	25 yr	50 yr	100 yr
January	23.1	27.0	28.2	29.2	30.1	23.2	26.8	27.9	28.8	29.6
February	22.8	28.3	30.0	31.4	32.7	23.0	28.3	30.0	31.2	32.5
March	20.7	25.8	27.4	28.6	29.9	20.8	26.4	28.1	29.4	30.7
April	18.7	22.8	24.2	25.2	26.2	18.9	22.9	24.2	25.1	26.1
May	16.4	21.2	22.7	23.9	25.0	16.5	21.3	22.8	23.9	25.1
June	14.8	18.8	20.0	21.0	21.9	15.1	18.9	20.0	20.9	21.7
July	13.5	16.7	17.8	18.5	19.3	13.4	17.1	18.3	19.1	20.0
August	13.7	20.5	22.7	24.4	26.0	13.7	20.2	22.2	23.7	25.2
September	17.5	23.6	25.6	27.1	28.5	17.8	23.0	24.6	25.8	27.0
October	18.8	24.3	26.0	27.3	28.6	18.9	24.8	26.8	28.2	29.6
November	20.4	25.2	26.7	27.8	29.0	20.7	25.3	26.7	27.7	28.7
December	22.5	27.9	29.7	31.0	32.3	22.3	28.3	30.1	31.5	32.8
Annual	26.0	29.7	31.1	32.2	33.2	26.2	29.9	31.3	32.3	33.4

Table 3.3. 10-minute extreme wind speed (m/s) estimates for return periods of 1, 10, 25, 50 and 100 years.

	Grid Point #13428					Grid Point #14697				
Period	1 yr	10 yr	25 yr	50 yr	100 yr	1 yr	10 yr	25 yr	50 yr	100 yr
January	24.5	28.6	29.9	30.9	31.9	24.6	28.4	29.6	30.5	31.4
February	24.2	30.0	31.8	33.2	34.6	24.3	30.0	31.8	33.1	34.4
March	21.9	27.3	29.1	30.4	31.6	22.0	28.0	29.8	31.2	32.5
April	19.8	24.2	25.6	26.7	27.7	20.0	24.3	25.6	26.6	27.7
May	17.4	22.4	24.1	25.3	26.5	17.5	22.6	24.2	25.4	26.6
June	15.7	19.9	21.2	22.2	23.2	16.0	20.0	21.2	22.1	23.0
July	14.4	17.7	18.8	19.6	20.4	14.2	18.1	19.3	20.3	21.1
August	14.5	21.8	24.1	25.8	27.5	14.5	21.4	23.5	25.1	26.7
September	18.5	25.0	27.1	28.7	30.2	18.8	24.4	26.1	27.3	28.6
October	19.9	25.7	27.6	29.0	30.3	20.1	26.3	28.4	29.9	31.4
November	21.6	26.7	28.3	29.5	30.7	22.0	26.8	28.2	29.4	30.5
December	23.8	29.6	31.4	32.8	34.2	23.6	29.9	31.9	33.3	34.8
Annual	27.5	31.4	32.9	34.1	35.2	27.7	31.6	33.1	34.3	35.4

3.1.2.2 Extreme Value Estimates for Waves from a Gumbel Distribution

A significant wave height of 13.6 m was measured by a buoy located at the Mizzen L-11 field on 8 March 2003. This height is slightly higher than the 50-year annual significant wave height for both Grid points.

The maximum individual wave heights were calculated within Oceanweather's OSMOSIS software by evaluating the Borgman integral (Borgman 1973), which was derived from a Raleigh distribution function. The maximum individual wave heights and extreme associated peak periods are presented Table 3.6 and Table 3.7, respectively. Maximum individual wave heights and the extreme associated peak periods peak during the month of February for both points.

Table 3.4. 1-minute extreme wind speed (m/s) estimates for return periods of 1, 10, 25, 50 and 100 years.

	Grid Point #13428					Grid Point #14697				
Period	1 yr	10 yr	25 yr	50 yr	100 yr	1 yr	10 yr	25 yr	50 yr	100 yr
January	28.2	32.9	34.4	35.6	36.7	28.3	32.7	34.1	35.1	36.1
February	27.8	34.5	36.6	38.2	39.8	28.0	34.6	36.6	38.1	39.6
March	25.2	31.5	33.5	34.9	36.4	25.3	32.2	34.3	35.9	37.4
April	22.8	27.9	29.5	30.7	31.9	23.0	27.9	29.5	30.7	31.8
May	20.0	25.8	27.7	29.1	30.5	20.1	26.0	27.9	29.2	30.6
June	18.1	22.9	24.4	25.6	26.7	18.5	23.0	24.4	25.5	26.5
July	16.5	20.4	21.7	22.6	23.5	16.4	20.9	22.3	23.3	24.3
August	16.7	25.0	27.7	29.7	31.7	16.7	24.6	27.1	28.9	30.8
September	21.3	28.8	31.2	33.0	34.8	21.7	28.0	30.0	31.5	32.9
October	22.9	29.6	31.7	33.3	34.9	23.1	30.3	32.6	34.4	36.1
November	24.8	30.7	32.6	34.0	35.3	25.3	30.8	32.5	33.8	35.1
December	27.4	34.0	36.2	37.8	39.4	27.2	34.5	36.7	38.4	40.0
Annual	31.7	36.2	37.9	39.2	40.5	31.9	36.4	38.1	39.5	40.8

Table 3.5. Extreme significant wave height estimates for return periods of 1, 10, 25, 50 and 100 years.

	Grid Point #13428					Grid Point #14697				
Period	1 yr	10 yr	25 yr	50 yr	100 yr	1 yr	10 yr	25 yr	50 yr	100 yr
January	9.8	12.8	13.6	14.2	14.8	10.1	12.8	13.6	14.3	14.9
February	8.7	13.1	14.4	15.3	16.2	9.4	13.0	14.1	14.9	15.7
March	7.3	10.6	11.6	12.2	12.9	7.7	10.8	11.8	12.5	13.1
April	5.9	9.3	10.3	11.0	11.7	6.4	9.3	10.3	10.9	11.6
May	4.6	8.3	9.3	10.1	10.8	4.9	8.4	9.5	10.3	11.1
June	3.5	6.6	7.5	8.1	8.7	3.9	6.5	7.3	7.9	8.5
July	3.3	5.5	6.1	6.5	7.0	3.5	5.5	6.1	6.5	6.9
August	3.5	6.4	7.3	7.9	8.5	3.9	6.1	6.8	7.2	7.7
September	5.2	9.9	11.2	12.2	13.1	5.6	10.2	11.5	12.6	13.6
October	6.6	10.9	12.3	13.4	14.4	6.4	11.1	12.6	13.6	14.7
November	7.6	11.6	12.7	13.5	14.3	8.1	11.8	12.9	13.7	14.5
December	9.4	13.0	14.0	14.8	15.5	9.7	13.3	14.3	15.1	15.9
Annual	11.8	14.1	14.9	15.6	16.3	11.9	14.2	15.1	15.8	16.4

3.1.2.3 Joint Probability of Extreme Wave Heights and Spectral Peak Period

In order to examine the period ranges of storm events, an environmental contour plot was produced showing the probability of the joint occurrence of significant wave heights and the spectral peak periods using the methodology of Winterstein et al. (1993). A contour plot depicting these values for return periods of 1-year, 10-years, 25-years, 50-years and 100-years for both Grid Points are presented in Figures 3.2 and 3.3. The annual values for the significant wave height estimates and the associated spectral peak periods are given in Table 3.8. The extreme wave height for all return periods was higher using the Weibull Distribution when compared to the Gumbel Distribution.

Table 3.6. Extreme maximum wave height estimates for return periods of 1, 10, 25, 50 and 100 years.

	Grid Point #13428					Grid Point #14697				
Period	1 yr	10 yr	25 yr	50 yr	100 yr	1 yr	10 yr	25 yr	50 yr	100 yr
January	18.3	23.6	25.1	26.3	27.4	18.7	24.0	25.6	26.8	28.0
February	16.4	24.3	26.6	28.2	29.9	17.4	24.3	26.4	28.0	29.5
March	13.8	19.7	21.4	22.6	23.9	14.4	20.1	21.9	23.2	24.5
April	11.1	17.1	18.8	20.1	21.3	11.9	17.5	19.3	20.5	21.8
May	8.5	15.9	18.0	19.5	21.1	9.2	16.0	18.1	19.7	21.2
June	6.8	12.2	13.7	14.9	16.0	7.5	12.2	13.6	14.6	15.6
July	6.3	10.1	11.2	12.0	12.8	6.6	10.1	11.2	12.0	12.8
August	6.8	12.2	13.7	14.8	15.9	7.4	11.5	12.8	13.7	14.6
September	9.7	17.8	20.3	22.0	23.7	10.6	18.7	21.1	23.0	24.8
October	12.3	20.2	22.7	24.6	26.5	12.0	20.6	23.2	25.1	27.0
November	14.0	21.3	23.3	24.8	26.3	15.0	21.7	23.7	25.2	26.7
December	17.3	24.0	25.9	27.3	28.6	17.9	24.5	26.4	27.9	29.4
Annual	21.7	26.0	27.7	28.9	30.2	22.0	26.4	28.1	29.3	30.6

Table 3.7. Extreme associated peak period estimates for return periods of 1, 10, 25, 50 and 100 years.

	GridPoint #13428					GridPoint #14697				
Period	1 yr	10 yr	25 yr	50 yr	100 yr	1 yr	10 yr	25 yr	50 yr	100 yr
January	13.2	14.9	15.3	15.6	15.9	13.3	14.9	15.3	15.6	15.9
February	12.3	15.1	15.8	16.3	16.8	12.7	14.8	15.4	15.8	16.3
March	11.9	13.4	13.8	14.1	14.3	11.9	13.4	13.8	14.1	14.4
April	11.2	12.8	13.2	13.4	13.7	11.5	12.9	13.2	13.5	13.7
May	9.7	12.4	13.0	13.4	13.8	10.0	12.4	13.0	13.5	13.9
June	8.3	11.3	12.0	12.5	13.0	9.1	11.0	11.5	11.9	12.2
July	8.4	10.7	11.3	11.7	12.1	8.6	10.5	11.0	11.4	11.7
August	8.7	11.3	11.8	12.2	12.6	9.2	11.0	11.5	11.8	12.1
September	10.8	13.7	14.4	14.8	15.3	10.9	13.6	14.2	14.7	15.1
October	12.0	13.8	14.3	14.7	15.0	11.5	13.8	14.4	14.8	15.2
November	12.1	14.1	14.5	14.9	15.2	12.1	14.1	14.6	15.0	15.4
December	13.0	15.0	15.5	15.8	16.2	13.2	14.8	15.3	15.6	15.9
Annual	14.3	15.5	16.0	16.3	16.6	14.2	15.5	15.9	16.3	16.6

3.2 Physical Oceanography

3.2.1 Major Currents in the Study Area

The Study Area is the southern part of Orphan Basin, the Sackville Spur, the Northeast Newfoundland Slope and northern Flemish Pass. The large scale circulation off the coast of Newfoundland and Labrador is dominated by well established currents that flow along the margins of the Continental Shelf. The two major current systems in the area are the Labrador Current and the North Atlantic Current (Colbourne and Foote 2000). The Labrador Current is the main current in the Study Area and it transports sub-polar water

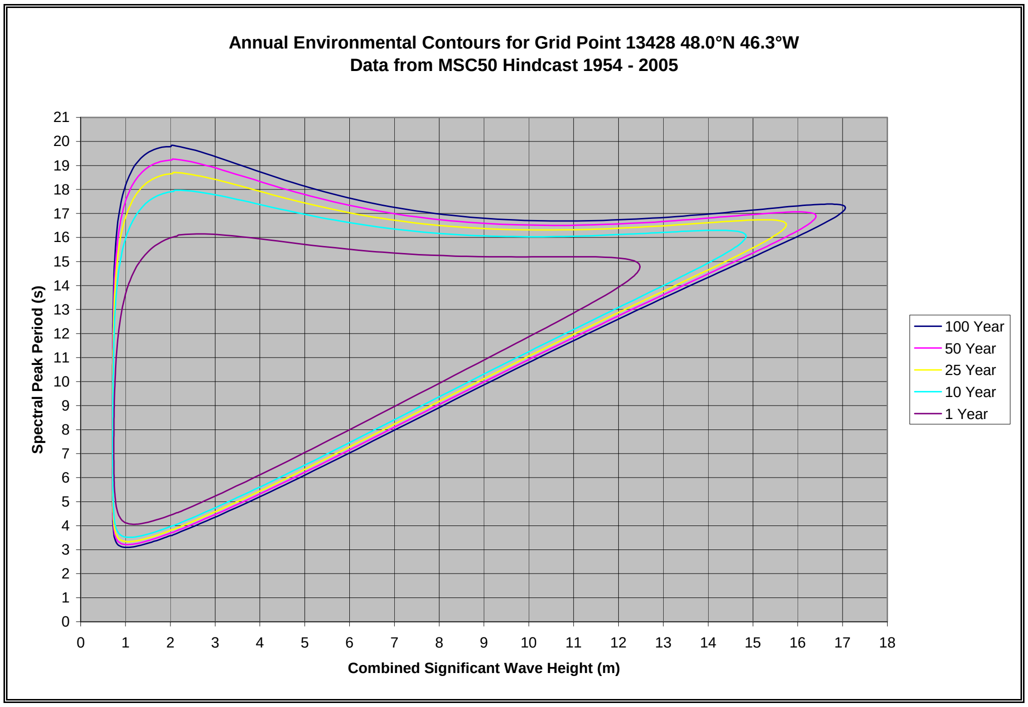


Figure 3.2. Environmental contour plot for grid point 13428 located near 48.0°N, 46.3°W.

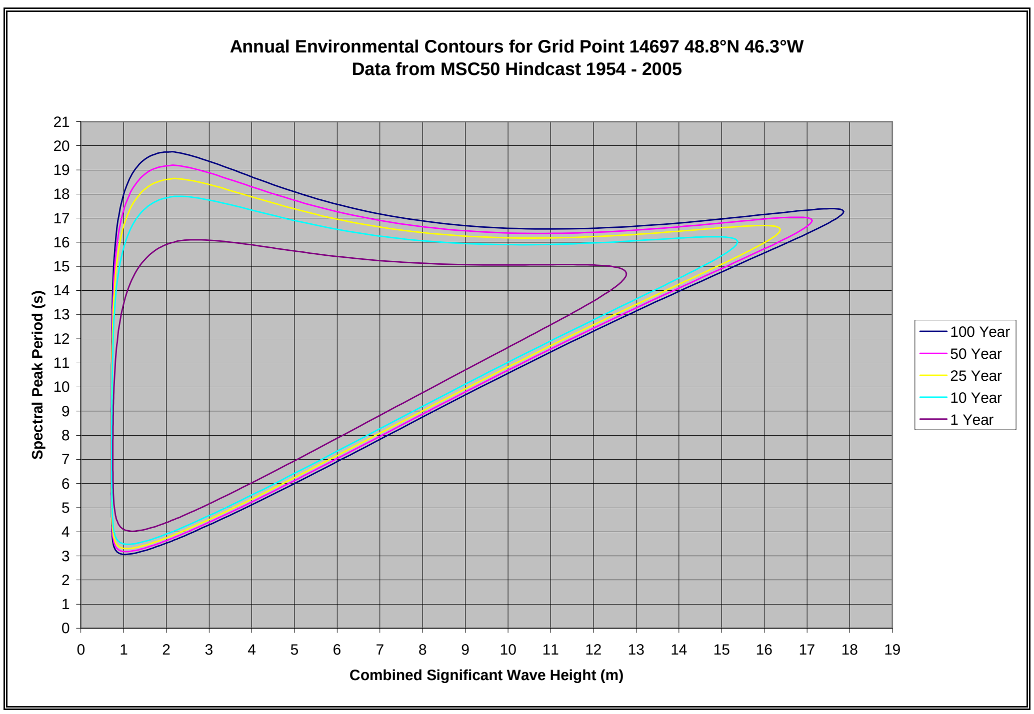


Figure 3.3. Environmental contour plot for grid point 14697 located near 48.8°N, 46.3°W.

to lower latitudes along the Continental Shelf of eastern Canada. Oceanographic studies show that this strong western boundary current follows the shelf break with relatively low variability compared to the mean flow. Over the Grand Banks a weaker current system is observed where the variability often exceeds that of the mean flow.

Table 3.8. Annual extreme significant wave estimates and spectral peak periods for return periods of 1, 10, 25, 50 and 100 years.

	Combined Significant Wave Height (m)		Spectral Peak Period Median Value (s)	
Return Period	**Grid Point 13428**	**Grid Point 14697**	**Grid Point 13428**	**Grid Point 14697**
1 yr	12.5	12.8	14.8	14.7
10 yr	14.8	15.4	16.1	16.0
25 yr	15.7	16.4	16.5	16.5
50 yr	16.4	17.1	16.9	16.9
100 yr	17.1	17.9	17.2	17.3

The Labrador Current consists of two major branches. The inshore branch of the Labrador Current is approximately 100 km wide (Stein 2007) and is steered by the local underwater topography through the Avalon Channel. The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope. The offshore branch passes between the 400 m and 1200 m isobaths (Lazier and Wright 1993). This branch of the Labrador Current divides east of 48°W, resulting in part of the branch flowing to the east around Flemish Cap and the other flowing south around the eastern edge of the Grand Banks and through Flemish Pass. Within Flemish Pass the width of the Labrador Current is reduced to 50 km with speeds of about 30 cm/s (Stein 2007). This flow transports cold, relatively low salinity Labrador Slope water into the region. To the southeast of the Flemish Cap the North Atlantic Current transports warmer, high salinity water to the northeast along the southeast slope of Grand Bank and the Flemish Cap (Figure 3.4).

The volume transport of the Labrador Current is variable from year to year. Han et al. (2010) found that the transport decreased by 6.3 Sv from the early to late 1990's and increased by 3.2 Sv from the late 1990's to the early 2000's. They found that the multi-year changes in the Labrador Current transport appeared to be primarily barotopic and positively correlated with the North Atlantic Oscillation at zero lag implying a fast response of the regional circulation to the atmospheric forcing variability.

The outer branch of the Labrador Current exhibits a distinct seasonal variation in flow speeds (Lazier and Wright 1993), in which mean flows are a maximum in October and a minimum in March and April. This annual cycle is reported to be the result of the large annual variation in the steric height over the continental shelf in relation to the much less variable internal density characteristic of the adjoining deep waters. The additional freshwater in spring and summer is largely confined to the waters over the shelf. In summer, the difference in sea level between the shelf and open ocean is 0.09 m greater than in winter (Lazier and Wright 1993). This difference produces a greater horizontal surface pressure gradient and hence stronger mean flows.

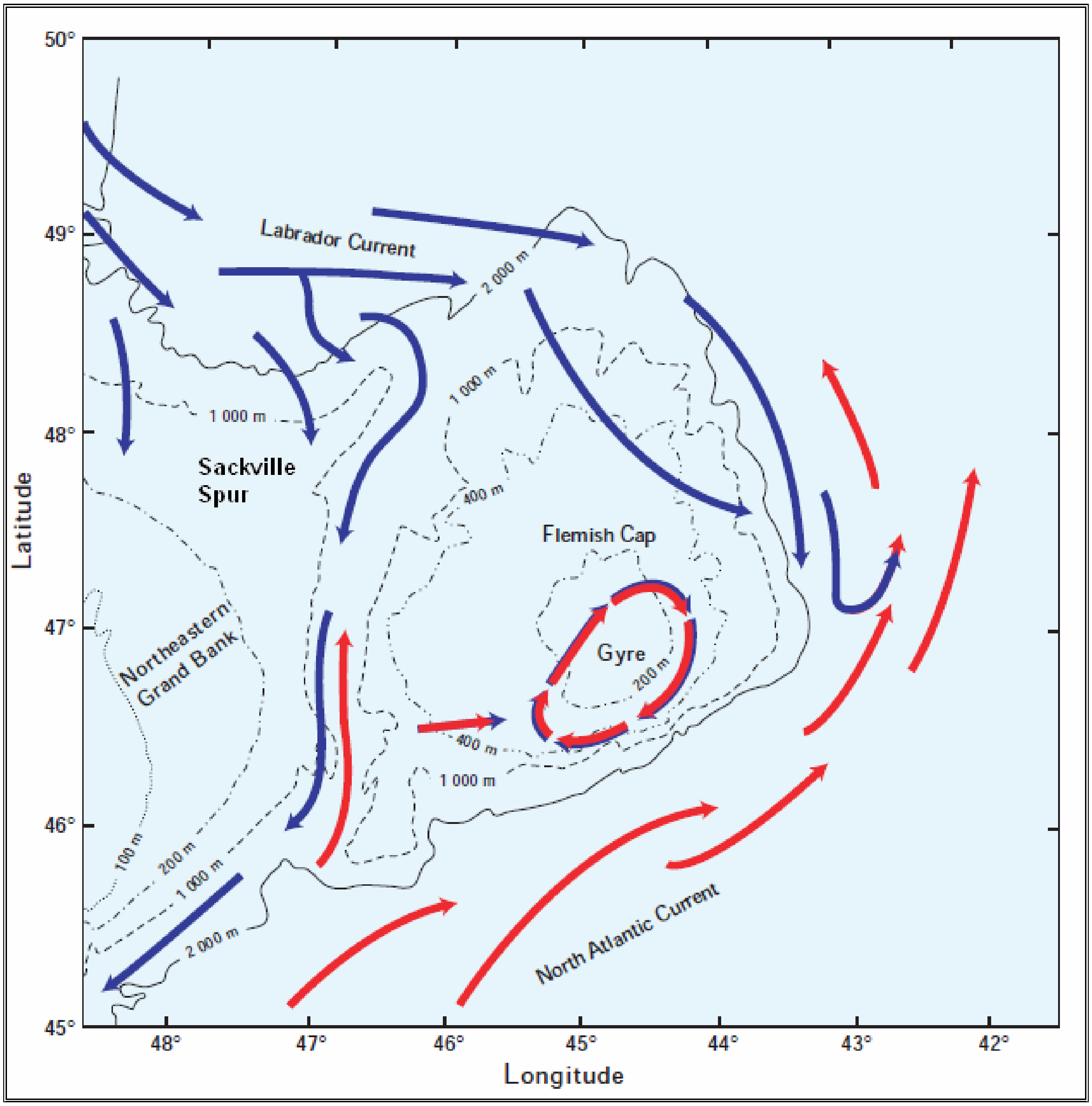


Figure 3.4. The major circulation features around the Flemish Cap and Sackville Spur (modified from Colbourne and Foote 2000).

3.2.2 Water Mass Structure

There are three major water masses in the Study Area: the Labrador Current Water between the surface and approximately 400 m, the Labrador Sea Water with a depth range between 200 m and 1500 m, and the North Atlantic Deep water with a depth range between 1500 m and 4000 m. The Labrador Sea Water and the North Atlantic Deep water are nearly homogeneous with little or no seasonal variability in water properties. The Labrador Sea Water is an intermediate layer water mass with temperatures between 2°C and 4°C and salinities between 34.86% and 35%. The North Atlantic Deep Water is characterized by its high salinity (34.9 to 34.97 psu) and low temperatures (2°C to 3.5°C).

In the Study Area, the North Atlantic Deep Water will be found only in the southern section of Orphan Basin whereas the Labrador Sea Water will be found in Flemish Pass and on the northeast Newfoundland Slope as well as in Orphan Basin.

On the northeastern edge of the Grand Banks the water structure is characterized by three identifiable features.

The first feature is the surface layer which is exposed to interaction with the atmosphere. The surface layer experiences temperature variations from sub zero values in January to above 15°C in the summer and early fall. The salinity of the surface layer is strongly affected by wave action and local precipitation. During summer, the stratified surface layer extends to a depth of 40 m or more. During winter, the surface stratification disappears and the water column becomes well mixed due to atmospheric cooling and mixing processes from wave action.

The second feature of the water structure is the Cold Intermediate Layer (Petrie et al. 1988). In areas where the water is deep enough, this layer of cold water is trapped during summer between the seasonally heated upper layer and warmer slope water near the seabed (Colbourne 2002). Its temperatures range from less than -1.5°C to 0°C (Petrie et al. 1988; Colbourne et al. 1996) and salinities vary within 32 and 33 psu. It can reach a maximum vertical extent of over 200 m (Colbourne 2004). The Cold Intermediate Layer is the residual cold layer that occurs from late spring to fall and is composed of cold waters formed during the previous winter season. It becomes isolated from the sea surface by the formation of the warm surface layer during summer, and disappears again during late fall and winter due to the intense mixing processes that take place in the surface layer from strong winds due to the intense mixing processes that take place in the surface layer from strong winds, high waves, and atmospheric cooling.

The third feature is the sharp density boundary near the Shelf break which separates the water on the shelf from the warmer, more saline water of the Continental Slope. The water over the Slope is the Labrador Sea water which is formed in the Labrador Sea as a result of the deep convection process that takes place during severe winters.

Mean sea temperature in the top 100 m of the water column are shown in Figures 3.5 to 3.7.

CTD transects for the Flemish Cap and Bonavista transects are collected by DFO on a yearly basis. These two transects map the temperature and salinities near the southern and northern boundaries of the Study Area. The temperature and salinity profiles for 2009 and 2010 are shown in Figures 4.17 through 4.24 in Oceans (2011; Appendix D).

3.3 Sea Ice and Icebergs

3.3.1 Sea Ice

A weekly analysis of the Canadian Ice Service's 30-Year Frequency of Presence of Sea Ice indicates that the Project Area is affected by sea ice beginning the week of January 15 and lasting until the week beginning May 7 and thus, will not affect the Project (see Oceans 2011, Appendix D).

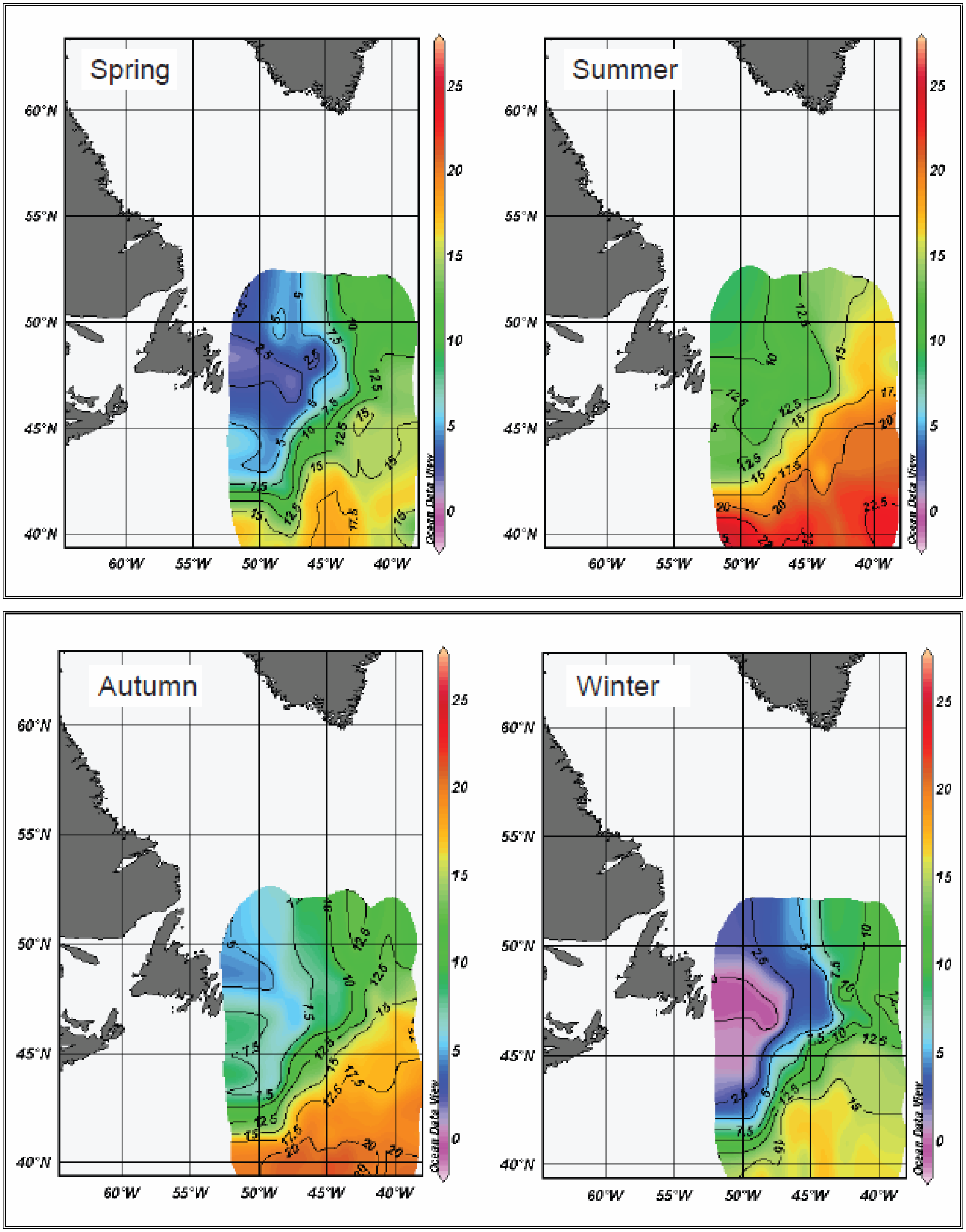


Figure 3.5. **Sea surface temperature (°C) over the Grand Banks of Newfoundland. Spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). From Stein (2007) data in World Ocean Database 2001.**

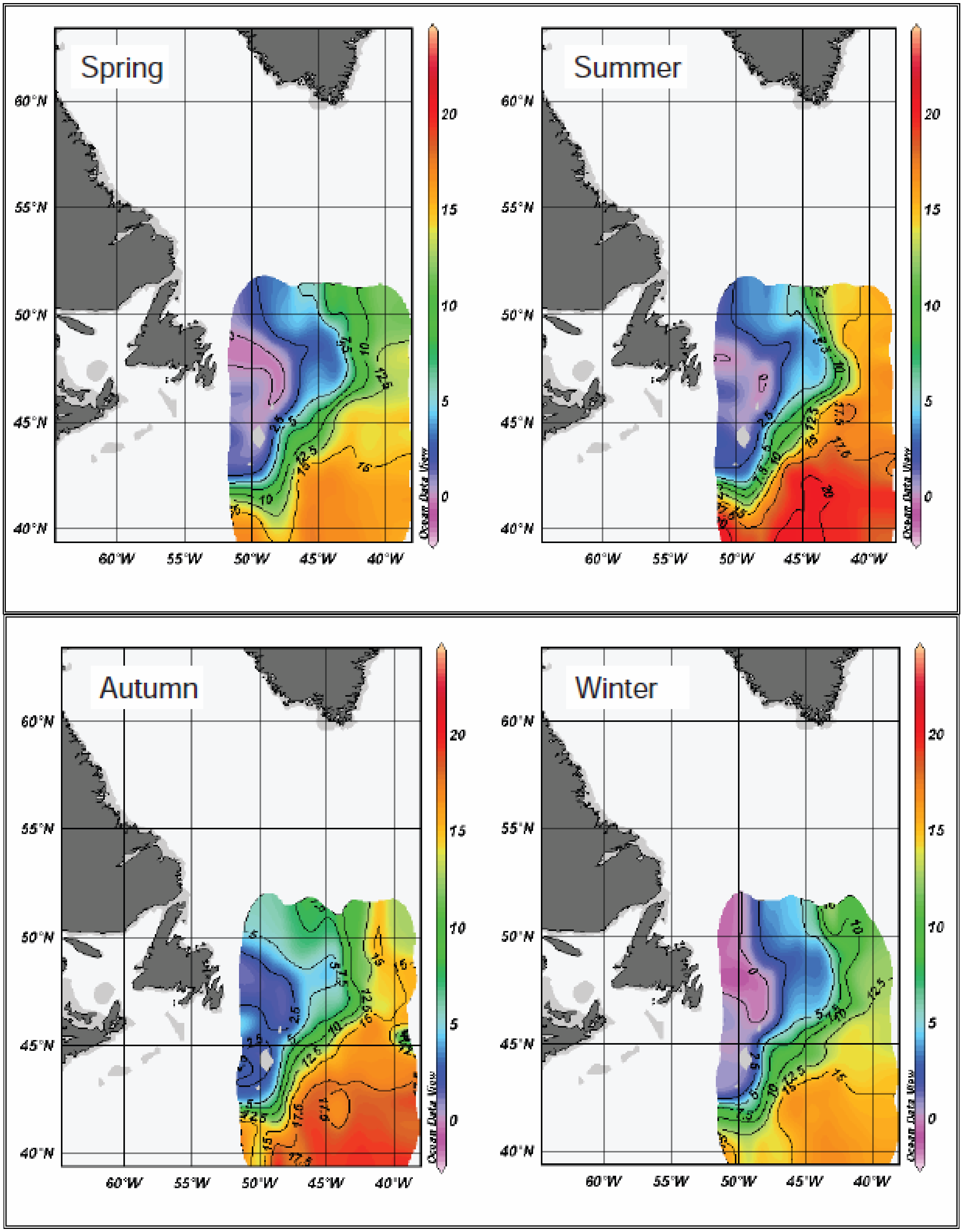


Figure 3.6. Temperature (°C) at 50 m depth over the Grand Banks of Newfoundland. Spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). From Stein (2007) data in World Ocean Database 2001.

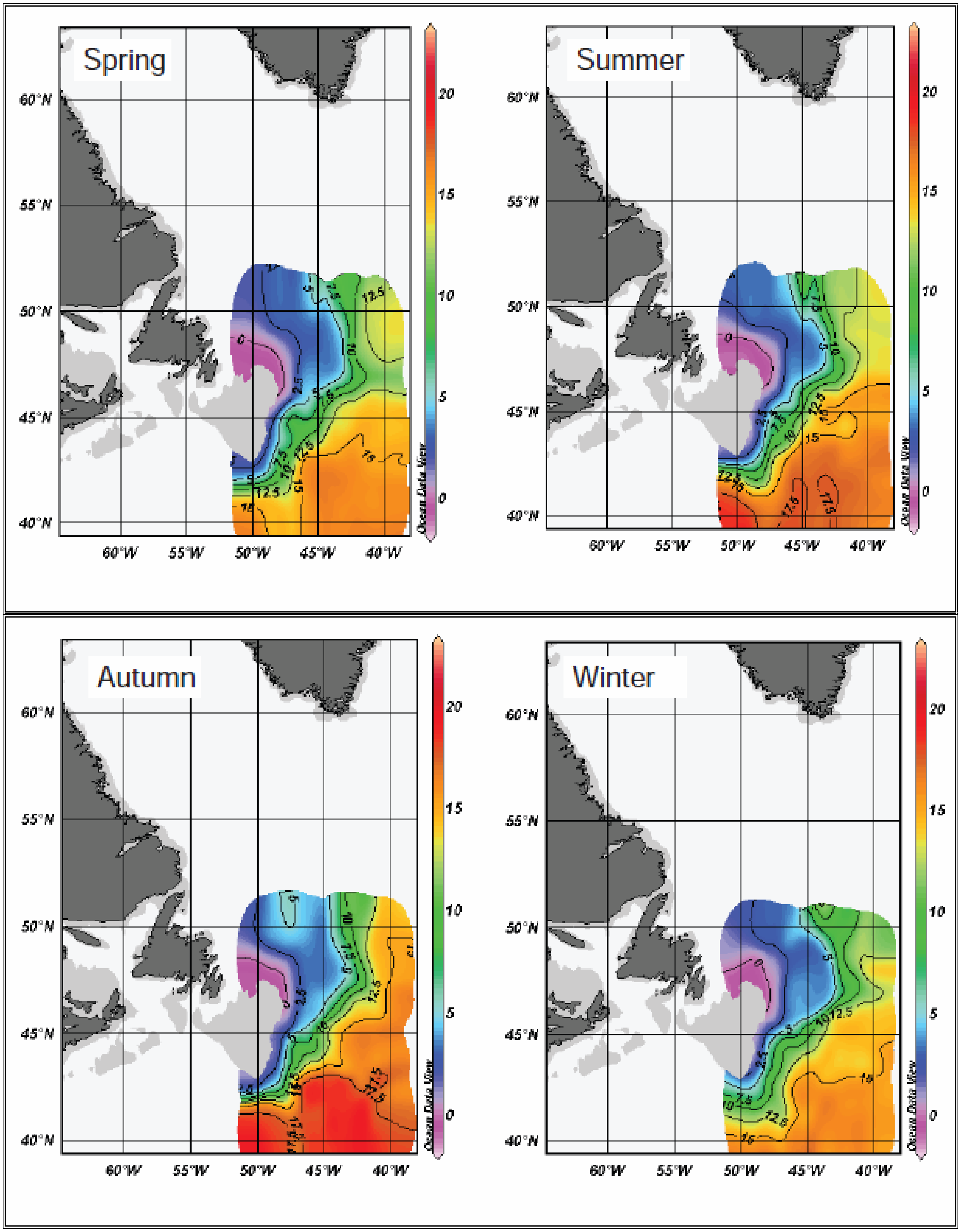


Figure 3.7. Temperature (°C) at 100 m depth over the Grand Banks of Newfoundland. Spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). From Stein (2007) data in World Ocean Database 2001.

3.3.2 Icebergs

An analysis was performed to determine the threat posed by icebergs in the Project Area. The International Ice Patrol Iceberg Sightings Database from 1974-2009 was used as the primary data source in this analysis. Figure 3.8 shows the number of iceberg sightings from 1974-2009. Overall, there is a good distribution of iceberg sightings ranging from 676 in 1974 to none in other years. Only iceberg sightings that occurred within the Project Area were considered in this analysis. Duplicate sightings of the same iceberg were also eliminated from the data set so that only the initial sighting was counted.

A monthly analysis (Table 3.9) shows that icebergs have been recorded within the Project Area from December to August, however, they are most prominent during the month of June. With respect to size, the most prominent icebergs are medium sized, accounting for 26.3% of observed icebergs within the region. Large icebergs occur 8.2% of the time.

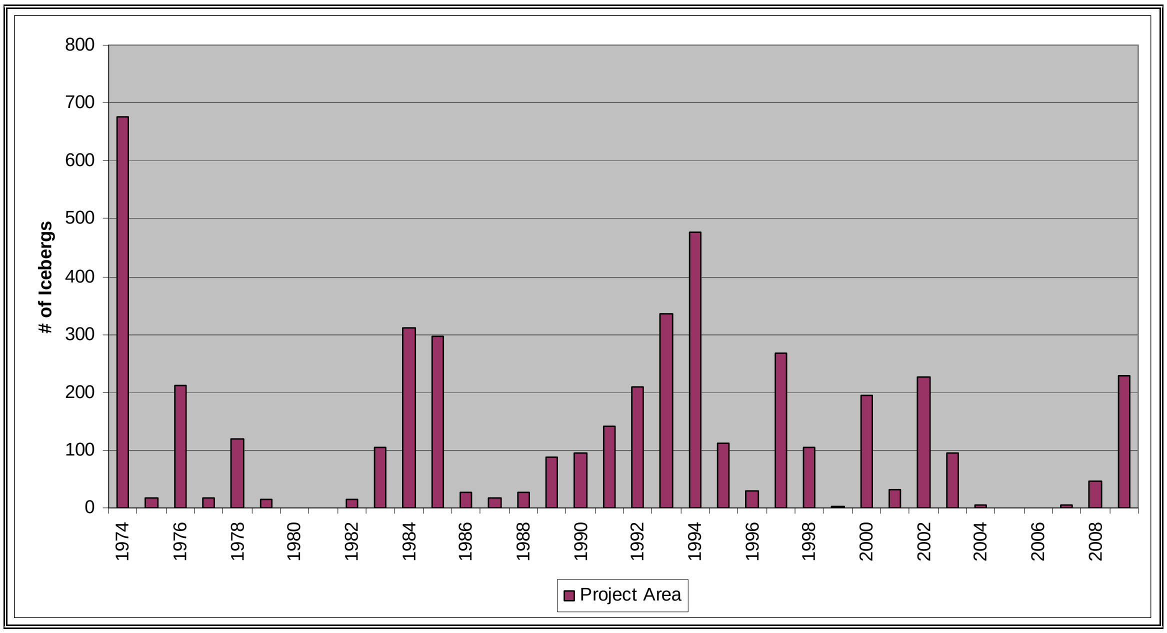


Figure 3.8. Iceberg sightings in the CCL Project Area (Source: IIP).

Table 3.9. Iceberg size (number of icebergs) by month (source: IIP).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
General	0	10	176	185	271	100	57	1	0	0	0	0	800
Unidentified Target	25	30	39	14	53	26	6	0	0	1	0	1	195
Growler	0	5	38	21	40	2	3	0	0	2	0	0	111
Bergy Bit	3	5	16	17	19	2	0	0	0	0	0	0	62
Small	11	85	277	135	133	46	18	3	0	0	0	0	708
Medium	11	41	277	165	176	60	22	5	0	0	0	1	758
Large	1	4	73	44	65	40	7	2	0	0	0	0	236
Very Large	0	0	3	4	1	1	0	1	0	0	0	0	10
Randomized	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Monthly	51	180	899	585	758	277	113	12	0	3	0	2	2880

4.0 Biological and Socio-economic Environments

The biological and socio-economic environments in and near the Study Area have been described in the Orphan Basin Strategic Environmental Assessment (SEA; LGL 2003) and more recently, exploration and drilling EAs and their amendments for Orphan Basin (LGL 2005, 2006, 2009) and Jeanne d'Arc Basin (LGL 2008). In addition to updated information, summaries of relevant information from these documents are presented in the following sections for fish/fish habitat, seabirds, marine mammals, sea turtles and commercial fisheries.

4.1 Ecosystem

An ecosystem is an inter-related complex of physical, chemical, geological, and biological components that can be defined at many different scales, including a Project Area level (i.e., a deep ocean basin ecosystem) to a Regional Area ecosystem that is topographically and oceanographically complicated with shelves, slopes, and valleys and several major water masses and currents. This EA focuses on components of the ecosystem such as certain species and stages of fish, seabirds and marine mammals that are important socially and economically, with potential to interact with the Project. This is the Valued Ecosystem Component (VEC) approach to EA, which is detailed in Section 5. The VECs are discussed below.

4.2 Fish and Fish Habitat

This subsection provides a description of the existing fish and fish habitat in the Study Area. Fish habitat in the Study Area is considered first, followed by a discussion of fish (macroinvertebrates and fishes) in the area.

4.2.1 Fish Habitat

In this EA, fish habitat includes physical, chemical, and biological aspects of the marine environment used by macroinvertebrate and fish species in the Study Area. The physical and chemical nature of the bottom substrate is a critical factor affecting the characterization of associated marine biological communities. The biological component of fish habitat refers to phytoplankton, zooplankton, and benthos (i.e., infaunal and epibenthic invertebrates not typically harvested during commercial fisheries in the Study Area [e.g., polychaetes, echinoderms]).

4.2.2 Geology

As indicated in the Orphan Basin SEA (LGL 2003), the topography of the Study Area is highly diverse and includes at least four distinct types as characterized by depth, location and physiography: (1) eastern portion of the northeast Newfoundland Shelf (depths ≤200 m); (2) northeast Newfoundland Shelf Slope (depths >200 to 2000 m); (3) Orphan Basin proper (depths 2000 to >3000 m); and the Flemish Pass (depths >1000 m). The characterization of surficial sediment in the Study Area ranges from fine (mud and clay) to extremely coarse (boulders and bedrock).

4.2.3 Plankton

Plankton is composed of free-floating organisms that form the basis of the pelagic ecosystem. Members include bacteria, fungi, phytoplankton, and zooplankton (mostly invertebrates, but may also include eggs and larvae of fishes, known as ichthyoplankton). In simplest terms, phytoplankton (e.g., diatoms) produce carbon compounds through the utilization of sunlight, carbon dioxide, and nutrients (e.g., nitrogen, phosphorus, silicon); this process is called primary production. Herbaceous zooplankton (e.g., calanoid copepods, the dominant component of NW Atlantic zooplankton) feed on phytoplankton, a growth process known as secondary production. The herbivores in turn are ingested by predators (i.e., tertiary production) such as predacious zooplankton (e.g., chaetognaths, jellyfish, etc.), all of which may be grazed by higher predators such as fish, seabirds, and marine mammals. This food web also links to the benthic ecosystem through bacterial degradation processes, dissolved and particulate carbon, and direct predation. An understanding of plankton production is important because areas of enhanced production and (or) biomass are areas where fish, seabirds, and marine mammals congregate to feed (LGL 2003).

Phytoplankton distribution, productivity, and growth regulation in high-latitude ecosystems constitute a complex system with light, nutrients, and herbivore grazing being the principal factors limiting phytoplankton regulations (Harrison and Li 2008). In the NW Atlantic, there is generally a spring plankton bloom (May/June) which is often followed by a smaller bloom in the fall (September/October). This general pattern likely applies to the Study Area. There may be areas of enhanced production in the Study Area, similar to other slope areas that have been studied. For example, MODIS chlorophyll ‘a’ concentration images for July 2009 to June 2010 (http://www2.mar.dfo-mpo.gc.ca/bin/cgi/ocean/seawifs_1.pl) indicate highest concentrations in the eastern part of the Study Area in the springtime and in northern and northeastern parts of the Study Area in the fall. Typically, the spring bloom of phytoplankton is the driving force of high-latitude marine ecosystem dynamics. Irradiance has been considered the limiting factor for development of the spring bloom, however, factors such as latitude and water column stratification are also important factors (Wu et al. 2008). Zooplankton reproduction is tied to the phytoplankton bloom, which either coincides with or immediately follows the brief but intense phytoplankton blooms in the high latitudes (Huntley et al. 1983; Head et al. 2000; Head and Pepin 2008). Zooplankton are the primary link between primary production and higher-level organisms in the marine ecosystem. They transfer organic carbon from phytoplankton to fish, marine mammals, and birds higher in the food chain. Zooplankton are a food source for a broad spectrum of species and they contribute faecal matter and dead zooplankton to the benthic communities. More information on phytoplankton within the Study Area is available in Subsection 3.2.1 of the Orphan Basin SEA (LGL 2003).

Planktonic organisms are so ubiquitous and abundant, and many have such rapid generation times that there will be essentially no effect on planktonic communities from the proposed seismic program. Planktonic stages of commercial invertebrates (e.g., shrimp, snow crab) and fishes (e.g., cod) are described in following subsections.

4.2.4 Benthos

Benthic invertebrates are bottom-dwelling organisms that can be classified into three categories: infaunal organisms, sessile organisms, and epibenthic species (Barrie et al. 1980). Infaunal organisms live on or are buried in soft substrates and include bivalves, polychaetes, amphipods, sipunculids, ophiuroids, and some gastropods. Sessile organisms live attached to hard substrates and would include barnacles, tunicates, bryzoans, holothurians, and some anemones. The epibenthic organisms are active swimmers that remain in close association to the seabed and include mysiids, amphipods, and decapods.

Benthic invertebrate communities can be spatially variable due to physical habitat characteristics such as water depth, substrate type, currents, and sedimentation. The primary factors affecting the structure and function of such communities in high latitude communities are water mass differences, sediment characteristics, and ice scour (Carey 1991). The wide range of these characteristics within the Study Area ensures a variety of benthic communities. The structure and metabolism of benthic communities can also be directly affected by the rate of sedimentation of organic detritus in shelf and deeper waters (Desrosiers et al. 2000). The seasonality of phytoplankton can influence production in benthic communities, adding temporal variability to a highly heterogeneous community.

As indicated in the Orphan Basin SEA (LGL 2003), there are large gaps in the current knowledge of benthic ecosystems of the offshore waters of Newfoundland and Labrador. The existing literature, although extensive in appearance, tends to be spatially restricted and often species specific. Subsection 3.2.2 of LGL (2003) includes more general information on benthos in the vicinity of the Study Area. Deepwater corals have gained more focus in recent years. Some information on corals occurring within the Study Area is presented in the following subsection.

4.2.5 Deep-water Corals

A variety of coral groups occur in Newfoundland and Labrador waters and include scleractinians (solitary stony corals), antipatharians (black wire corals), alcyonaceans (large and small gorgonians, soft corals), and pennatulaceans (sea pens) (Wareham and Edinger 2007; Wareham 2009). Corals are largely distributed along the edge of the continental shelf and slope off Newfoundland and Labrador (Edinger et al. 2007; Wareham and Edinger 2007). Typically, they are found in canyons and along the edges of channels (Breeze et al. 1997), deeper than 200 m. Soft corals are distributed in both shallow and deep waters, while horny and stony corals (hard corals) are typically restricted to deep water areas. Most grow on hard substrate (Gass 2003), such as large gorgonian corals (Breeze et al. 1997). Others, such as small gorgonians, cup corals, and sea pens, prefer sand or mud substrates (Edinger et al. 2007). In total, thirty species of corals were documented and comprised of two antipatharians (black wire corals), 13 alcyonaceans (large gorgonians, small gorgonians, and soft corals), four scleractinians (solitary stony corals), and 11 pennatulaceans (sea pens). The authors noted that corals were more widely distributed on the continental edge and slope.

A recently published DFO technical report (Gilkinson and Edinger 2009) presents knowledge on the ecology of deep-sea corals of Newfoundland and Labrador waters, including information on biogeography, life history, biochemistry, and relation to fishes. Wareham (2009) updated deep-sea coral distribution data for the Newfoundland and Labrador and Arctic Regions to partially fill information gaps previously identified by Wareham and Edinger (2007).

According to distribution maps provided by Wareham (2009), there are approximately 15 species of corals occurring within or adjacent to the southwestern part of the Study Area. The species identified include large gorgonians (*Keratoisis ornata*, *Paragorgia arborea*, and *Paramuricea* spp.), small gorgonians (*Acanthogorgia armata*, *Acanella arbuscula*), and soft corals (*Anthomastus grandiflorus*, *Duva florida*, and *Gersemia rubiformis*). One scleractinian species (*Flabellum alabastrum*) and six pennatulacean species (*Pennatula phosphorea*, *Pennatula grandis*, *Anthoptilum grandiflorum*, *Umbellula lindahli*, *Halipteris finmarchica*, and *Funiculinia quandrangularis*) are also noted to occur there. No antipatharian species were noted by Wareham (2009) to occur within this EA's Study Area. According to Kenchington et al. (2010), antipatharian species (i.e., black corals) also occur in the slope region in the southwestern part of the Study Area. A recent DFO Science Advisory Report (DFO 2010a) also discusses the occurrence and ecological function of corals in Canadian waters. The majority of coral species were observed to occur on the continental slope, with the exception of several soft corals (e.g., *Gersemia rubiformis*) found distributed on the shelf.

The patterns of association between deep-sea corals, fish, and invertebrate species, based on DFO scientific surveys and ROV surveys are discussed by Edinger et al. (2009). Although there were no dramatic relationships between corals and abundance of the ten groundfish species studied, there was a weak but statistically significant positive correlation between coral species richness and fish species richness, suggesting that habitats that support diverse corals are also likely to support diverse assemblages of fishes. By increasing the spatial and hydrodynamic complexity of habitats, deep-sea corals may provide important, but probably not critical, habitat for a wide variety of fishes. Effects of deep-sea corals on fish habitat and communities may include higher prey abundance, greater water turbulence, and resting places for a wide variety of fish size classes (Auster et al. 2005, and Costello et al. 2005 *in* Edinger et al. 2009).

4.2.6 Fish

For the purposes of this EA, fish includes commercial fishery-targeted macroinvertebrate and fish species, incidental commercial fishery bycatch species, and macroinvertebrates and fishes caught during DFO Research Vessel (RV) surveys in the Study Area.

4.2.6.1 Commercial Fishery-targeted Macroinvertebrates and Fishes

Two macroinvertebrate species, northern shrimp (*Pandalus borealis*), and snow crab (*Chionoecetes opilio*), and one fish species (Greenland halibut *Reinhardtius hippoglossoidess*), were targeted in commercial fisheries prosecuted within the Study Area during the 2003-2009 period. Commercially-targeted species are discussed below in decreasing order of Study Area average catch weight for the 2003 to 2009 period (see Section 4.3).

Northern Shrimp

The primary cold-water shrimp resource in the N Atlantic, the northern shrimp is distributed from Davis Strait to the Gulf of Maine. It usually occupies soft muddy substrates up to depths of 600 m in temperatures of 1°C to 6°C (DFO 2008a). Larger individuals generally occur in deeper waters (DFO 2006a). Based on DFO RV survey data collected in the Study Area in 2008 and 2009, most of the northern shrimp were caught at mean water depths ranging between 140 and 340 m. A diel vertical migration is undertaken with shrimp moving off the bottom into the water column during the day to feed on small pelagic crustaceans. They migrate up the water column at night, feeding on pelagic copepods and krill (DFO 2006a). Female shrimp also undergo a seasonal migration to shallow water where spawning occurs (DFO 2006a).

Northern shrimp are protandric hermaphrodites (Orr et al. 2009). They first mature as males, mate as males for one to several years, and then change to females for the remainder of their lives (DFO 2008a). Eggs are typically extruded in the summer and remain attached to the female until the following spring, when the female migrates to shallow coastal waters to spawn (Nicolajsen 1994 in Ollerhead et al. 2004). The hatched larvae float to the surface and commence feeding on planktonic organisms (DFO 2006a). Northern shrimp are known to live for more than eight years in some areas and are thought to begin recruitment to the fishery as early as three years of age (DFO 2008a). Some northern populations exhibit slower rates of growth and maturation but greater longevity that results in larger maximum size (DFO 2008a).

As with most crustaceans, northern shrimp grow by moulting their shells. During this period, the new shell is soft, causing them to be highly vulnerable to predators such as Greenland halibut (turbot), cod (DFO 2006a), Atlantic halibut, skates, wolffish and harp seals (*Pagophilus groenlandicus*) (DFO 2000).

Snow Crab

The snow crab, a decapod crustacean, occurs over a broad depth range in the NW Atlantic from Greenland south to the Gulf of Maine (DFO 2010b). Snow crab distribution is widespread and continuous in waters off Newfoundland and southern Labrador. Large males are most common on mud or mud/sand, while smaller crabs are common on harder substrates. Based on DFO RV survey data collected in the study Area in 2008 and 2009, most of the snow crab was caught at mean water depths ranging between 75 to 225 m.

The snow crab life cycle features a 12 to 15 week planktonic larval period, following spring hatching, involving several stages before settlement. Benthic juveniles of both sexes molt frequently, and at about 40 mm CW (~ four years of age) they may become sexually mature. Female crabs carry the fertilized eggs for about two years (DFO 2010b).

Snow crab typically feed on fish, clams, benthic worms, brittle stars, shrimps and crustaceans, including smaller snow crabs. Their predators include various groundfish and seals (DFO 2010b).

Greenland Halibut

The Greenland halibut is distributed throughout cold, deep waters of the Labrador-eastern Newfoundland area, inhabiting the continental shelf and slope at depths of 200 to 600 m or more. Based on DFO RV survey data collected in the Study Area in 2008 and 2009, most of the Greenland halibut were caught at mean water depths ranging from <200 to 700 m, and as deep as 1385 m. The majority of the adult population is distributed in the deep and warm N Atlantic waters (e.g., Davis Strait, between Greenland and Baffin Island) where spawning occurs in winter or early spring (Templeman 1973; Bowering 1983; Bowering and Brodie 1995). Larvae and juveniles are transported south by oceanic currents where they colonize the deep channels (Bowering 1983; Bowering and Brodie 1995). Greenland halibut typically move progressively offshore to the deep edges of the continental slope with increasing age and size

(Bowering and Brodie 1995). With increasing maturity most Greenland halibut presumably migrate northward to areas such as Davis Strait to spawn (Templeman 1973; Chumakov 1975; Bowering and Brodie 1995). Small scale localized spawning may also occur along the deep slopes of the continental shelf throughout its range (Bowering and Brodie 1995).

In addition to shrimp, Greenland halibut feed on a variety of species, including small pelagic crustaceans, small fish (e.g., Arctic cod, capelin), larger fish (e.g., redfish, grenadier), and squid (DFO 2008b).

4.2.6.2 Incidental Commercial Fishery Bycatch Fishes

Other species that have been harvested as incidental bycatch within the Study Area during recent years include redfish (*Sebaste*s spp.) capelin (*Mallotus villosus*), American plaice (*Hippoglossoides platessoides*), Atlantic cod (*Gadus morhua*), roundnose grenadier (*Coryphaenoides rupestris*), roughhead grenadier (*Macrourus berglax*), and wolffishes (*Anarhichas* spp.). All of these species are profiled in this subsection, except for wolffishes, which are profiled in Section 4.6 on Species at Risk.

Redfish

The NW Atlantic redfish consists of a complex of three species identified as Acadian redfish (*S. fasciatus*), golden redfish (*S. marinus*), and deepwater redfish (*S. mentella*) (DFO 2008c). The deepwater redfish is the dominant species in northern areas, including the Study Area. The redfish distribution in the NW Atlantic ranges from the Gulf of Maine, northwards off Nova Scotia and southern Newfoundland banks, in the Gulf of St. Lawrence, and along the continental slope and deep channels from the southwestern Grand Bank to areas as far north as Baffin Island. Redfish are also present in the area of Flemish Cap and west of Greenland.

These species inhabit cool waters (3 to 8°C) along the slopes of banks and deep channels in depths of 100 to 700 m (Scott and Scott 1988; DFO 2008c). Based on DFO RV survey data collected in the study Area in 2008 and 2009, most of the redfish caught were deepwater redfish. The highest catches of deepwater redfish occurred at mean water depths ranging from 280 to 520 m, with some catches as deep as 684 m. Redfish are generally slow growing and long lived fishes (DFO 2008c). The reproductive cycle of redfish differs from that of other fish species. Unlike many other species, fertilization in redfish is internal and females bear live young. Mating takes place in the fall most likely between September and December and females carry the developing embryos until they are extruded as free swimming larvae in spring. Larval extrusion takes place from April to July depending on the areas and species. Mating and larval extrusion do not necessarily occur in the same locations.

Generally found near the bottom, redfish have been observed to undertake diel vertical migrations, moving off the bottom at night to follow the migration of their prey (DFO 2008c). Redfish are pelagic or bathypelagic feeders, feeding primarily on zooplankton such as copepods, amphipods and euphausiids. Fishes and crustaceans become more important in the diet of larger redfish (Scott and Scott 1988).

Deepwater redfish and the Atlantic population of Acadian redfish are currently designated as *threatened* under COSEWIC.

Capelin

Capelin (*Mallotus villosus*) is a small pelagic species that has a circumpolar distribution in the northern hemisphere (DFO 2006b). Capelin are often found along the coasts during the spawning season and occur predominately in offshore waters (e.g., Grand Banks) while immature and maturing. Migration towards the coast precedes spawning on beaches or in deeper waters (Nakashima and Wheeler 2002; DFO 2006b). The preferred spawning substrate is usually fine to coarse gravels. On beaches, capelin usually spawn at 5 to 8.5°C, but have been observed to spawn at 4 to 10°C. Beach spawning is more prevalent at night. On the bottom, spawning temperatures can be as low as 2°C as observed on the Southeast Shoal, located far south of the Study Area. Capelin are able to spawn at the age of two and males and most females usually die following spawning. Spawning commences in early June and may continue through July or August depending upon tides, winds and water temperatures (Scott and Scott 1988; Nakashima and Wheeler 2002). Incubation varies with ambient temperature and lasts approximately 15 days at 10°C (Scott and Scott 1988). Once hatched, larval capelin can be found at the surface to depths >40 m (Frank et al. 1993).

Capelin prey consists of planktonic organisms comprised of primarily of euphausiids and copepods. Capelin feeding is seasonal with intense feeding late winter and early spring leading up to the spawning cycle when feed ceases. Feeding recommences several weeks after cessation of spawning (Scott and Scott 1988).

Capelin is a major component in marine ecosystem dynamics as they facilitate the transfer of energy between trophic levels, principally between primary and secondary producers to higher trophic levels (DFO 2006b). Capelin predators comprise most major fish species including Atlantic cod, haddock, herring, flatfish species, dogfish and others. Several marine mammal species including minke whales, fin whales, harp and ringed seals as well as a variety of seabirds also prey on capelin.

Other than the fishery, the primary cause of capelin mortality is predation and as such variations in capelin abundances are directly linked to natural causes (DFO 2006b). Capelin have a short life span (usually five years or less), abundances are linked to a few age classes. Management of capelin fisheries tends to be conservative as a result of the prominent role of capelin in the marine ecosystem.

Based on DFO RV survey data collected in the study Area in 2008 and 2009, most of the capelin catch was at mean water depths ranging from 180 to 240 m.

American Plaice

American plaice (*Hippoglossoides platessoides*) is a bottom-dwelling flatfish that resides on both sides of the Atlantic (DFO 2006c; COSEWIC 2009). American plaice that reside in the W Atlantic region range from the deep waters off Baffin Island and western Hudson's Bay southward to the Gulf of Maine and Rhode Island (Scott and Scott 1988). In Newfoundland waters, plaice occurs both inshore and offshore over a wide variety of bottom types (Morgan 2000). It is tolerant of a wide range of salinities and has been observed in estuaries (Scott and Scott 1988; Jury et al. 1994). Plaice are typically found at depths of ~ 90 to 250 m, but have been found as deep as 1,383 m. Most commercially harvested plaice are taken at depths of 125 to 200 m. Based on DFO RV survey data collected in the Study Area in 2008 and 2009, most of the American plaice were caught at mean water depths ranging from 77 to 440 m, with some catches recorded at mean water depths up to 840 m. It is a coldwater species, preferring water temperatures of 0°C to 1.5°C (Scott and Scott 1988). Tagging studies in Newfoundland waters suggest that, once settled, juveniles and adults are rather sedentary and do not undertake large scale migrations (DFO 2008d). However, older plaice have been known to move up to 160 km (Powles 1965). Migrations have been observed in Canadian waters to deeper offshore waters in the winter, returning to shallower water in the spring (Hebert and Wearing-Wilde 2002 *in* Johnson 2004).

In Newfoundland waters, American plaice spawn during the spring (Scott and Scott 1988). Within the Study Area, there are limited data with respect to the actual spawning times. American plaice in the Newfoundland Region have no specific spawning areas; rather spawning occurs over the entire area occupied (DFO 2008d) with the most intense spawning coincident with areas where the higher abundance of adults are found (Busby et al. 2007). Large quantities of eggs are released and fertilized over a period of days on the seabed (Johnson 2004). Eggs are buoyant and drift into the upper water column, where they are widely dispersed, allowing for some intermingling of stocks. Intermingling of adults is minimal. Hatching time is temperature dependant, occurring in 11 to 14 days at temperatures of 5°C (Scott and Scott 1988). Larvae are 4 to 6 mm in length when they hatch and begin to settle to the seabed when they reach 18 to 34 mm in length and their body flattens (Fahay 1983).

The Newfoundland and Labrador population of American plaice is currently designated as *threatened* under COSEWIC.

Atlantic Cod

The Atlantic cod is a demersal fish that inhabits cold (10 to 15°C) and very cold (less than 0 to 5°C) waters in coastal areas and in offshore waters overlying the continental shelf throughout the NW and NE Atlantic Ocean (COSEWIC 2003c). The species is found contiguously along the east coast of Canada from Baffin Island to Georges Bank. Outside Canadian waters in the NW Atlantic, cod can be found on the northeast and southeast tips of Grand Bank and on Flemish Cap. Based on DFO RV survey data collected in the study Area in 2008 and 2009, most of the Atlantic cod were caught at mean water depths ranging from 77 to 340 m, with some catches recorded at mean water depths up to 629 m. During the first few weeks of life, cod eggs and larvae are found in the upper 50 m of the water column. As juveniles, cod are settled on the bottom and tend to occur in nearshore habitats with vertical structure such as eelgrass (*Zostera marina*) and macroalgae. As adults, the habitat requirements of cod are increasingly diverse.

Atlantic cod typically spawn over a period of less than three months in water that may vary in depth from tens to hundreds of metres (COSEWIC 2003c). Cod are described as batch spawners because only a small percentage (5 to 25%) of the female's egg total is released at any given time during a three to six week period. After hatching, larvae obtain nourishment from a yolk sac until they have reached a length of 1.5 to 2.0 mm. During the larval stage, the young feed on phytoplankton and small zooplankton in the upper 10 to 50 m of the water column. After the larval stage, the juveniles settle to the bottom where they appear to remain for a period of 1 to 4 years. These settlement areas are known to range from very shallow (<10 to 30 m) coastal waters to moderately deep (50 to 150 m) waters on offshore banks. After this settlement period, it is believed that the fish begin to undertake seasonal movements and migrations characteristic of adults.

Dispersal in Atlantic cod appears to be limited to the egg and larval phases of life, during which surface and near-surface water currents and turbulence are the primary determinants of horizontal and vertical displacement in the water column (COSEWIC 2003c). For some cod populations, eggs and larvae are capable of dispersing very long distances. For example, cod eggs spawned off southeastern Labrador (NAFO Division 2J) may possibly disperse as far south as Grand Bank. By contrast, eggs spawned by cod in inshore, coastal waters, especially at the heads of large bays, may experience dispersal distances of a few kilometres or less.

Long-term movements by cod take the form of seasonal migrations (COSEWIC 2003c). These migrations can be attributed to geographical and seasonal differences in water temperature, food supply, and possibly spawning grounds. At one extreme, some inshore populations are suspected to have extremely short migrations, possibly limited to tens of kilometres, or less, in distance. By contrast, cod in other populations are known to traverse hundreds of kilometres during their seasonal migrations.

Two stocks of Atlantic cod occur within the Study Area; 2J3KL cod that occur off Labrador and eastern Newfoundland, and 3M cod that occur in the vicinity of the Flemish cap and Flemish Pass. Recent DFO fall sampling of the 2J3KL stock indicates that length-at-age and weight-at-age have improved since the low values of the early 1990s, particularly in NAFO Divisions 3K and 3L (DFO 2010c). The condition of cod in 3K and 3L has also improved from that seen in the early 1980s, although it did decline in 2009 from 2008 (DFO 2010c). The NAFO Division 3M cod stock was on fishing moratorium from 1999 to 2009. Recent assessment results indicate a substantial increase in Spawning Stock Biomass, which should continue only if current post-moratorium fishing level is maintained (Gonzàlez-Troncoso and Vázquez 2010).

Atlantic cod as a species is currently designated as *special concern* under Schedule 3 of the *SARA*. The Newfoundland and Labrador population of Atlantic cod is currently designated as *endangered* under COSEWIC.

Roundnose Grenadier

Distributed in the NW Atlantic from Cape Hatteras to Greenland, the roundnose grenadier is a deepwater, demersal fish found in continental slope areas at depths of 200 to 2,000+ m. Based on DFO RV survey data collected in the study Area in 2008 and 2009, the roundnose grenadier catch weight was somewhat evenly distributed across mean water depths ranging from 585 to 1385 m. This species is thought to undergo seasonal migrations with individuals in northeast Newfoundland waters occupying deeper water in winter and shallower water in late summer. Diurnal vertical migrations also occur that may carry them more than 1,000 m off the bottom (COSEWIC 2008). The long-lived, late-maturing, slow-growing species has a low fecundity and is potentially vulnerable to overfishing (Devine and Haedrich 2008). The roundnose grenadier harvest has been under a moratorium in Canadian waters in NAFO Subareas 2 and 3 since the 1990s, but may be harvested as bycatch in other fisheries (Power 1999). Roundnose grenadier spawning grounds are largely unknown and suspected to be in waters deeper than 850 m. Spawning is believed to occur either in different areas throughout the NW Atlantic (COSEWIC 2008) or predominately in Icelandic waters with the passive eggs and larvae carried to other areas in the NW Atlantic by currents (Scott and Scott 1988). The spawning time is uncertain, but believed to occur throughout the year with more intense spawning occurring during particular periods. These periods appear to vary between areas

(Atkinson 1995). The roundnose grenadier feeds on a variety of small crustaceans and euphasiids, squid, and small fishes. This slow swimming species, in turn, is possibly consumed by other fishes (Scott and Scott 1988).

Roundnose grenadier is currently designated as *endangered* under COSEWIC.

Roughhead Grenadier

The roughhead grenadier (*Macrourus berglax*) occurs in deep water along coasts in subarctic to temperate waters on both sides of the N Atlantic. In the NW Atlantic, this species of grenadier occurs from Davis Strait along the continental slope, off Newfoundland, off Nova Scotia on Banquereau, Sable Island and Browns Bank, and on Georges Bank (Scott and Scott 1988). The roughhead grenadier is predominant at depths ranging from 800 to 1,500 m, although they may inhabit depths between 200 and 2,000 m (Murua and De Cardenas 2005 in Gonzalez-Costas and Murua 2007). Catches tend to be highest at water temperatures ranging between 2.0 and 3.5ºC (Scott and Scott 1988). The roughhead grenadier is an abundant and widespread species in the NW Atlantic. This fish generally occurs both on the shelf and on the continental slope at depths ranging from 400 to 1,200 m. It has been found at depths as shallow as 200 m and as deep as 2,700 m. Based on DFO RV survey data collected in the study Area in 2008 and 2009, the roundnose grenadier catch weight was somewhat evenly distributed across mean water depths ranging from 209 to 1385 m.

Spawning is thought to occur during the winter and early spring. Little is known about the spawning grounds of this fish off Newfoundland although some believe that some spawning does occur on the southern and southeastern slopes of the Grand Banks (Scott and Scott 1988; COSEWIC 2007). Food on the roughhead grenadier consists of a variety of benthic invertebrates including bivalve molluscs, shrimp, seastars, polychaetes and some fish. These grenadier have been found in the stomachs of Atlantic cod.

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

Roughhead grenadier is currently designated as *special concern* under COSEWIC.

Wolffishes

All three species of wolffish (i.e., northern, spotted and Atlantic) are discussed in Section 4.6 on Species at Risk. Both the northern and spotted wolffishes are currently designated as *threatened* under Schedule 1 of *SARA* and COSEWIC. The Atlantic wolffish is currently designated as *special concern* under Schedule 1 of *SARA* and COSEWIC.

4.2.7 Macroinvertebrates and Fishes Collected during DFO RV Surveys

Data collected during 2008 and 2009 spring and fall DFO RV surveys in the Study Area were analyzed, and catch weights and catch numbers of species/groups with combined annual catch weights of at least 100 kg are presented in Table 4.1.

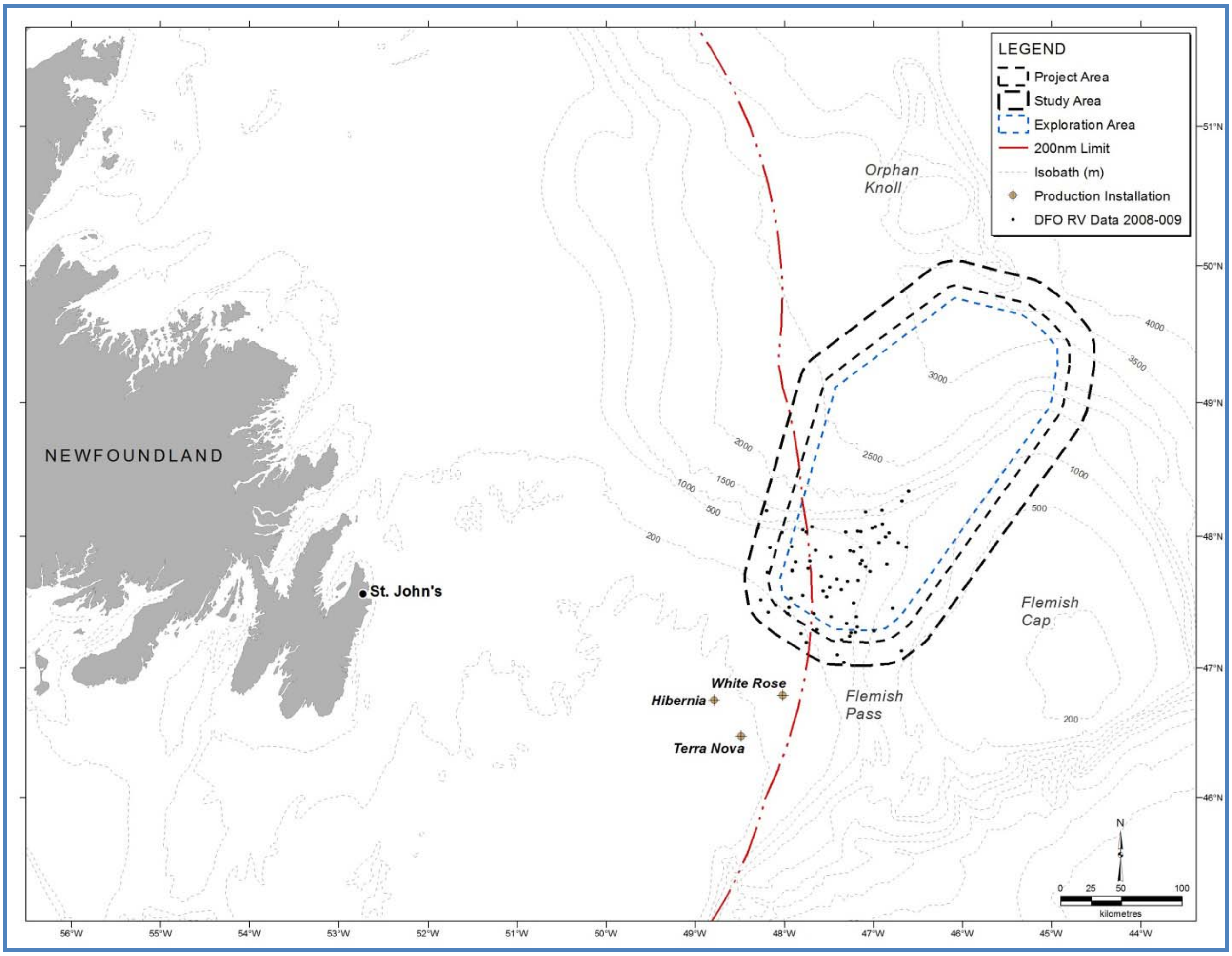
Table 4.1. Catch weights and numbers of macroinvertebrate and fish species collected during 2008 and 2009 DFO RV surveys within the Study Area.

Species	Catch Weight (kg)	Catch Number
Northern shrimp	6607	2,653,456
Deepwater redfish	4918	26,521
Capelin	1375	84,020
Sea anemones	1198	1,347
American plaice	1129	5,795
Sponges	1092	n/a
Greenland halibut	1089	2,598
Atlantic cod	961	1,501
Thorny skate (*Raja radiata*)	915	660
Roughhead grenadier	905	2,298
Shrimp (Natantia)	561	n/a
Snow crab	361	1,971
Sand lance (*Ammodytes dubius*)	312	7,601
Blue hake (*Antimora rostrata*)	305	2,778
Vahl's eelpout (*Lycodes vahlii*)	257	2,364
Sea urchin (*Echinoidea*)	222	3,490
Atlantic wolffish	218	313
Shrimp (*Sergestes arcticus*)	215	201,852
Longnose eel (*Synaphobranchus kaupi*)	171	1,682
Marlin spike (*Nezumia bairdi*)	160	1,831
Lanternfishes (*Myctophidae*)	136	16,217
Roundnose grenadier	129	1,141
Basketstars (*Gorgonocephalidae*)	119	n/a
Northern wolffish	111	33
Spotted wolffish	102	40

Source: DFO RV Survey Data 2008-2009. n/a denotes data unavailable.

Northern shrimp accounted for 25.6% of the total 2008-2009 catch weight, followed by deepwater redfish (19.1%), capelin (5.3%), sea anemones (4.6%), American plaice (4.4%), sponges (4.2%), Greenland halibut (4.2%), Atlantic cod (3.7%), thorny skate (3.5%), and roughhead grenadier (3.5%). The distribution of geo-referenced catch locations reported during the 2008 and 2009 DFO RV surveys within the Study Area are shown in Figure 4.1.

The total catch weight of the 2008 and 2009 DFO RV surveys in the Study Area is divided into spring (March, May, June) and fall (November, December). Spring surveys accounted for 32.7% of the total catch weight, and fall surveys accounted for 67.3%. The average mean depth of catch during March, May and June surveys ranged from 318 to 340 m, and 331 to 1052 for November and December, respectively.



Source: DFO RV Survey Data 2008-2009.

Figure 4.1. DFO RV survey catch locations within the Study Area, 2008 and 2009.

Catch weights of the spring surveys were dominated by northern shrimp, capelin, other shrimp species, deepwater redfish, Greenland halibut, thorny skate, and American plaice (Table 4.2). Catch weights of the fall surveys were dominated by northern shrimp, deepwater redfish, sea anemones, roughhead grenadier, American plaice, Greenland halibut, thorny skate, blue hake, sand lance, and snow crab (Table 4.2). Catch weights of deepwater redfish, Greenland halibut, American plaice and thorny skate were highest during the fall surveys.

Table 4.2. Percentage catch and mean catch depth by survey season for macroinvertebrates and fishes caught during DFO RV surveys within the Study Area, 2008 and 2009 combined.

Species	Percentage Catch in Spring Surveys (%)	Spring Survey Mean Catch Depth (m)	Percentage Catch in Fall Survey (%)	Fall Survey Mean Catch Depth (m)
Northern shrimp	42	291	58	261
Deepwater redfish	16	395	84	399
Capelin	94	232	6	234
Sea anemones	20	378	80	451
American plaice	33	277	67	333
Sponges	8	327	92	517
Greenland halibut	35	367	65	515
Atlantic cod	12	290	88	269
Thorny skate (*Raja radiata*)	43	328	57	365
Roughhead grenadier	11	498	89	642
Shrimp (Natantia)	100	216	-	-
Snow crab	27	208	73	230
Sand lance (*Ammodytes dubius*)	13	100	87	100
Blue hake (*Antimora rostrata*)	6	605	94	812
Vahl's eelpout (*Lycodes vahlii*)	20	377	80	441
Sea urchin (*Echinoidea*)	2	206	98	552
Atlantic wolffish	47	277	53	291
Shrimp (*Sergestes arcticus*)	99	492	1	885
Longnose eel (*Synaphobranchus kaupi*)	8	579	92	810
Marlin spike (*Nezumia bairdi*)	24	507	76	684
Lanternfishes (*Myctophidae*)	5	452	95	736
Roundnose grenadier	9	645	91	930
Basketstars (*Gorgonocephalidae*)	<1	151	>99	229
Northern wolffish	30	558	70	583
Spotted wolffish	40	306	60	308

Source: DFO RV Survey Data 2008-2009
n/a denotes data unavailable

DFO RV survey catch weights in the Study Area during 2008 and 2009 were analyzed for 11 mean catch depth ranges and results are presented in Table 4.3.

Table 4.3. Total catch weights and predominant species caught at various mean catch depth ranges, 2008 and 2009 DFO RV surveys combined.

Mean Catch Depth Range	Total Catch Weight (kg)	Predominant Species
<100 m	535	Sand lance American plaice Sea urchin Snow crab
≥100 m to <200 m	2,861	Northern shrimp Shrimp (Natantia) Capelin Snow crab American plaice
≥200 m to < 300 m	9,853	Northern shrimp Deepwater redfish Capelin Atlantic cod Thorny skate
≥300 m to < 400 m	2,807	Deepwater redfish Northern shrimp Sea anemones Thorny skate Greenland halibut
≥400 m to < 500 m	3,914	Deepwater redfish Sea anemones American plaice Shrimp (*Sergestes arcticus*) Roughhead grenadier Greenland halibut
≥500 m to < 600 m	1,334	Deepwater redfish Roughhead grenadier American plaice
≥600 m to < 700 m	1,780	Sea anemones Roughhead grenadier Greenland halibut Deepwater redfish American plaice
≥700 m to < 800 m	-	-
≥800 m to < 900 m	460	Roughhead grenadier Greenland halibut Blue hake American plaice Longnose eel
≥900 m to < 1,000 m	173	Deepwater redfish Greenland halibut Blue hake Longnose eel
≥1,000 m	2,094	Sponges Greenland halibut Roughhead grenadier Blue hake

Source: DFO RV Survey Data 2008-2009

4.2.8 Macroinvertebrate and Fish Reproduction in the Study Area

Temporal and spatial details of macroinvertebrate and fish reproduction within the Study Area are provided in Table 4.4.

Table 4.4. Reproduction specifics of macroinvertebrate and fish species likely to reproduce within or near the Study Area.

Species	Locations of Reproductive Events	Times of Reproductive Events	Duration of Planktonic Stages
Northern shrimp	On banks and in channels over the extent of its distribution	Spawning in late summer/fall Fertilized eggs carried by female for 8 to 10 months and larvae hatch in the spring	12 to 16 weeks
Greenland halibut	Spawning grounds extend from Davis Strait (south of 67°N) to south of Flemish Pass between 800 m and 2,000 m depth	Winter months	Uncertain
Snow crab	On banks and possibly along some upper slope regions over the extent of its distribution	Mating in early spring Fertilized eggs carried by female for 2 years and larvae hatch in late spring/early summer	12 to 15 weeks
Redfish	Primarily along edge of shelf and banks, in slope waters, and in deep channels	Mating in late winter and release of young between April and July (peak in April)	No planktonic stage
Capelin	Spawning generally on beaches or in deeper waters	Late June to early July	Several weeks
American plaice	Spawning generally occurs throughout the range the population inhabits.	April to May	12 to 16 weeks
Atlantic cod	Spawn along outer slopes of the shelf in depths from tens to hundred of metres	March to June	10 to 12 weeks
Roundnose grenadier	Uncertain	Uncertain	Uncertain
Roughhead grenadier	Uncertain	Winter/early spring	Uncertain
Wolffishes	Likely along the slope regions	September to November	Uncertain
Cusk	Uncertain	May to August	Presumed to be 4 to 16 weeks
Porbeagle shark	Very little known about the location of the pupping grounds	Mating in late summer and pupping during the winter	N/A

4.3 Commercial Fisheries

This section describes the existing commercial fisheries in the Study Area for CCL’s potential seismic and geohazard surveys. It also provides additional context for the area’s foreign commercial fisheries.

This section focuses on the economic and logistical aspects of the fisheries: Section 4.2 of this assessment describes the biological characteristics and status of the main commercial and other marine species, including prey for commercial species.

4.3.1 Data and Information Sources

4.3.1.1 Datasets

Fisheries within the Study Area are primarily managed by DFO and the Northwest Atlantic Fisheries Organization (NAFO), for convention countries. The domestic commercial fisheries analysis in this section is based primarily on data derived from the DFO Newfoundland and Labrador Region catch and effort datasets (DFO 2003-2009). The DFO data used in the report represent all catch landed within Newfoundland and Labrador region (whether managed by NAFO or DFO, described below). Most of these data years are considered "preliminary" still, with the greatest potential for change being in value.

In addition, the DFO datasets are used to provide a historical summary of catches in the general area of the proposed Study Area (Unit Areas 3Le, 3Li and 3Ma) for the 20-year period 1990 – 2009.

Foreign catches landed outside the regions are not included in the DFO data sets. To characterize these foreign fisheries, NAFO STATLANT 21A dataset for 2003-2007 are used to quantify harvesting at the NAFO Division level (3K, 3L and 3M) for NAFO managed stocks/species in these areas. Note that the STATLANT and DFO datasets are not mutually exclusive for Canadian catches.

The DFO catch data in the Study Area are georeferenced (typically >95% of the harvest, by quantity), so that past harvesting locations can be plotted with a high level of accuracy, and these locations are shown on the fisheries maps in this section. (The positions given in the datasets are those recorded in the vessel's fishing log, and are reported in the database by degree and minute of latitude and longitude; thus the positions should be accurate within approximately 0.5 nautical mile of the reported co-ordinates. 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 Atlantic Canada over many years.)

The NAFO datasets capture both domestic and foreign fishers, which is useful for indicating fisheries beyond the 200 NMi Exclusive Economic Zone by non-Canadian vessels. However, these data are not georeferenced and only resolved geographically at the NAFO Division level (see Figure 4.2). (For an indication of location of effort by Convention nations see maps in NAFO Ad Hoc Working Group report, 2009 at http://archive.nafo.int/open/fc/2009/fcdoc09-02.pdf.)

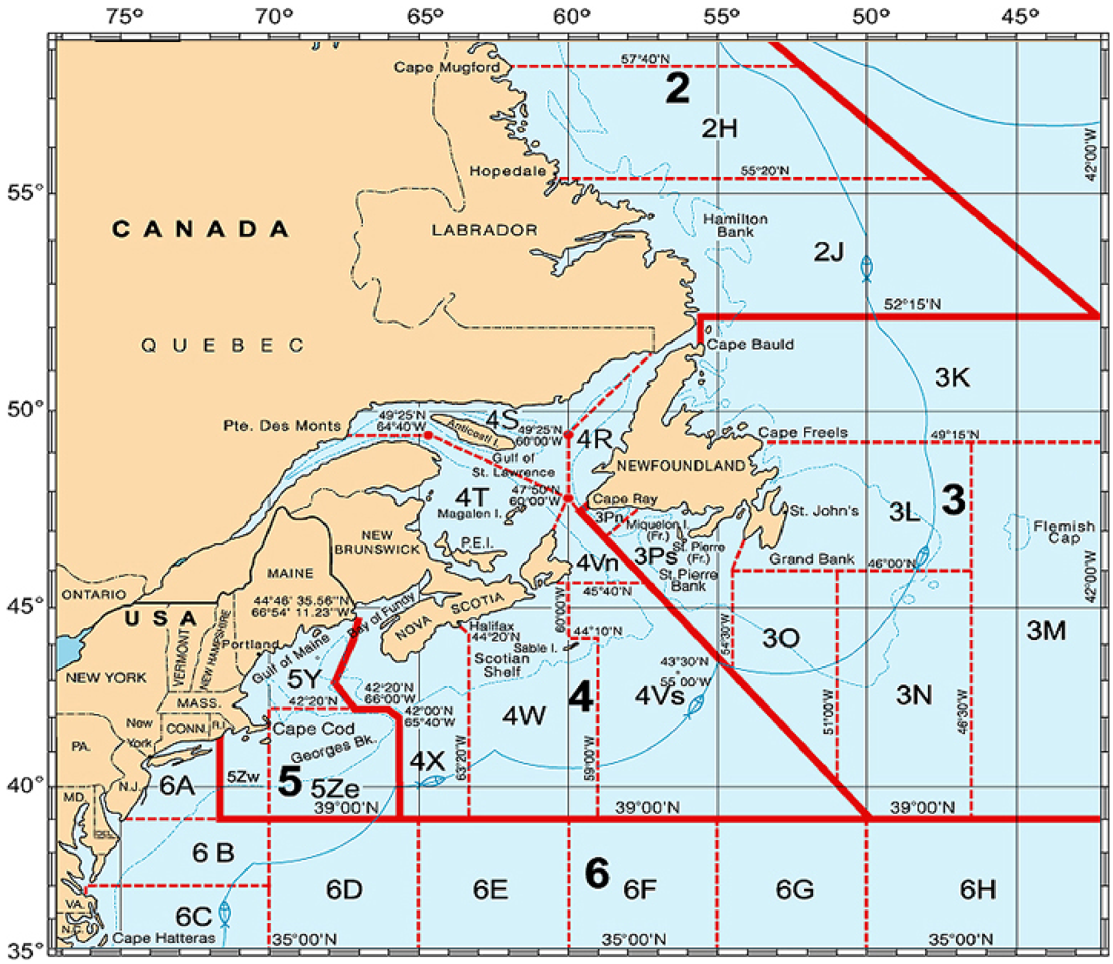


Figure 4.2. **NAFO Regulatory (Convention) Area (southern), showing Divisions (e.g., 3K) and Subareas (e.g., 3).**

Source: based on http://www.nafo.int/image/maps/nafo_map_hr.jpg

4.3.1.2 Consultations

The fisheries consultations and contacts for this assessment included representatives of Fisheries and Oceans Canada (DFO), One Ocean, the Fish, Food and Allied Workers Union (FFAW), the Association of Seafood Producers (ASP), Ocean Choice International (OCI), the Groundfish Enterprise Allocation Council (GEAC; Ottawa), Clearwater Seafoods (in Nova Scotia) and Icewater Seafoods. The consultations were undertaken to inform stakeholders about the proposed CCL surveys, to gather information about fishing activities, and to determine any issues or concerns. Those consulted are listed in Appendix B. Fisheries-related information provided is reported under the discussions of the commercial fisheries below. Further information about the 2011 offshore fisheries obtained from industry stakeholders, as well as any issues and concerns raised by industry representatives, and discussed in the report on consultations in Section 5.1.1.

4.3.1.3 Other Sources

Other sources consulted for this section include fisheries management plans, quota reports and other DFO documents, such as Science Advisory and Stock Status reports.

The majority of the data used to characterize the fisheries in this section are quantities of harvest rather than harvest values since quantities are directly comparable from year to year, while values (for the same quantity of harvest) may vary annually with negotiated prices, changes in exchange rates and fluctuating market conditions. Although some species vary greatly in landed value (e.g. snow crab vs. capelin), in terms of potential interaction with fisheries the level of fishing effort and gear utilized (better represented by quantities of harvest) is the better indicator.

Regional NAFO Fisheries

The majority of the Study Area is outside Canada's 200-NMi EEZ, overlapping portions of NAFO Divisions 3K, 3L and 3M (Figure 4.7, later). Several key fisheries beyond the EEZ are managed by NAFO (e.g. northern shrimp); however, sedentary species (e.g. snow crab) are managed by DFO, and some other species (e.g. salmon and tunas) are managed by other international agencies or conventions. Most fishing for relevant species in the NAFO Convention Regulatory Area (RA) is conducted using mobile bottom-tending trawls.

Table 4.5 presents average annual catches (2003–2007) of NAFO managed species for each Division which overlaps the Study Area. It indicates the catch of these species separately for Canadian vessels and other Convention nations, the total, and the percent the Canadian portion represents of the total, by managed species. As the data indicate, the quantity and proportion of the foreign harvest of these species increases significantly moving north to south / southeast, with virtually no foreign harvest in 3K, 56% in 3L and nearly 100% in 3M. Within these three Divisions collectively, the largest NAFO-managed catches during this period were northern shrimp, redfish, squid and Greenland halibut.

In these areas, the northern shrimp fishery is managed by NAFO in 3L and 3M. Division 3L has a 2011 Total Allowable Catch (TAC) for shrimp of 19,200 t (down from 30,000 t in 2010) of which Canada is allocated just over 83%, and it is planned to lower this again in 2012 to 17,000 t. The 3M shrimp fishery is managed through effort allocation (limiting the number of fishing days). Of the total fishing days (5,277) allowed in 2010, Canada had 4.3% (228 days) distributed amongst 16 vessels. However, for 2011, owing to concerns about the poor status of the shrimp resources, no 3M shrimp fishing will be permitted. NAFO notes that "When the scientific advice estimates that the stock shows signs of recovery, the fishery shall be re-opened in accordance with the effort allocation key in place for this fishery at the time of the closure".[2]

[2] See http://www.nafo.int/fisheries/regulations/tac-quota.html; http://www.dfo-mpo.gc.ca/media/back-fiche/2010/hq-ac46a-eng.htm; Ricardo Federizon, NAFO, pers. comm.

Table 4.5. Average annual catches (tonnes), 2003-2007 for NAFO Convention Managed Species, by NAFO Division.

NAFO 3K				
Species	**Canadian**	**Foreign**	**Total**	**Cdn % of Total**
Redfish (sp)	112.2	9.8	122.0	92.0%
Squid (sp)	1,021.8	0.0	1,021.8	100.0%
Total	1,134.0	9.8	1,143.8	99.1%
NAFO 3L				
Species	**Canadian**	**Foreign**	**Total**	**Cdn % of Total**
Atlantic Cod	926.8	13.0	939.8	98.6%
Greenland Halibut / Turbot	1,120.0	9,205.6	10,325.6	10.8%
American Plaice	55.4	278.0	333.4	16.6%
Redfish (sp)	3.8	303.6	307.4	1.2%
Shrimp (sp)	13,556.8	3,176.4	16,733.2	81.0%
Squid (sp)	1,211.4	0.4	1,211.8	100.0%
Witch Flounder	15.8	174.6	190.4	8.3%
Yellowtail Flounder	163.0	17.8	180.8	90.2%
Total	17,053.0	13,169.4	30,222.4	56.4%
NAFO 3M				
Species	**Canadian**	**Foreign**	**Total**	**Cdn % of Total**
Atlantic Cod	0.6	62.0	62.6	1.0%
Greenland Halibut / Turbot	0.0	2,173.4	2,173.4	0.0%
American Plaice	0.0	96.6	96.6	0.0%
Redfish (sp)	0.0	4,687.2	4,687.2	0.0%
Shrimp (sp)	2.0	33,815.4	33,817.4	0.0%
Squid (sp)	0.0	5.4	5.4	0.0%
Total	2.6	40,840.0	40,842.6	0.0%

NAFO manages collectively the three redfish species found in the northwest Atlantic (Acadian, deepwater, and golden redfish) in Divisions 3KLMNO, 1F and in Subarea 2. Recently (2010), the fishery in 3LN was reopened after having been under moratorium. There is a TAC for each Division or Subarea, ranging between 6,000 t and 20,000 t in 2011; Canada is entitled to 42.6% of the TAC overall.

Squid (*Illex illecebrosus*) has a 2011 quota of 34,000 t, which will remain until at least 2013, managed over Subareas 3 and 4. Greenland halibut, which is managed by NAFO in the 3L and 3M portions of the Study Area (but not 3K), has a 2011 quota of 12,734 t for all of 3LMNO; of this 1,910 t is allocated for Canada. NAFO management of this species has established a "progressive strategy" allowing for the annual adjustment of the TAC based on various indicators.

Although Canada typically has only a small percentage of the NAFO Atlantic cod TAC in Division 3M (0.8% or 80 t for 2011), OCI has stated that they have purchased ~200 t of 3M cod from foreign interests and plans to fish that cod in the April - May period this year (Derek Fudge, OCI, pers. comm., February 2011). The TAC for all the NAFO-managed species (including the Canadian and foreign allocations) can be found at http://www.nafo.int/fisheries/regulations/tac-quota.html.

In 2011, several other NAFO managed species in Convention areas were under moratorium. Relevant to the Study Area, there were bans on fishing cod in 3L, American plaice in 3L and 3M, and witch flounder in 3L.

4.3.2 Study Area Domestic Fisheries

The Canadian fisheries in the eastern Grand Banks area were dominated until the early 1990s by groundfish harvesting using stern otter trawls, primarily harvesting Atlantic cod, American plaice and a few other species. 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. Since the collapse of these fisheries, formerly underutilized species – mainly northern shrimp and snow crab – have come to replace groundfish as the principal harvest on and in the waters east of the eastern Grand Banks, as they have in many other areas. The following graphs, which summarize catch data for the four fisheries Unit Areas that the Study Area overlaps (Study Area UAs), show the quantity of the total annual harvest in that area over the last twenty years (Figure 4.3), the total groundfish harvest (Figure 4.4), and the snow crab and northern shrimp harvest (Figure 4.5) for the same period. As these figures illustrate, in 2009 the shellfish harvest was four times (by quantity) what the groundfish harvest was in 1992, which recorded the highest groundfish harvest in that 20-year period. Although Unit Area 3Ma was the source of nearly 30% of the harvest in the early 1990s, over the past several years all of the Study Area catch has come from 3Le and 3Li.

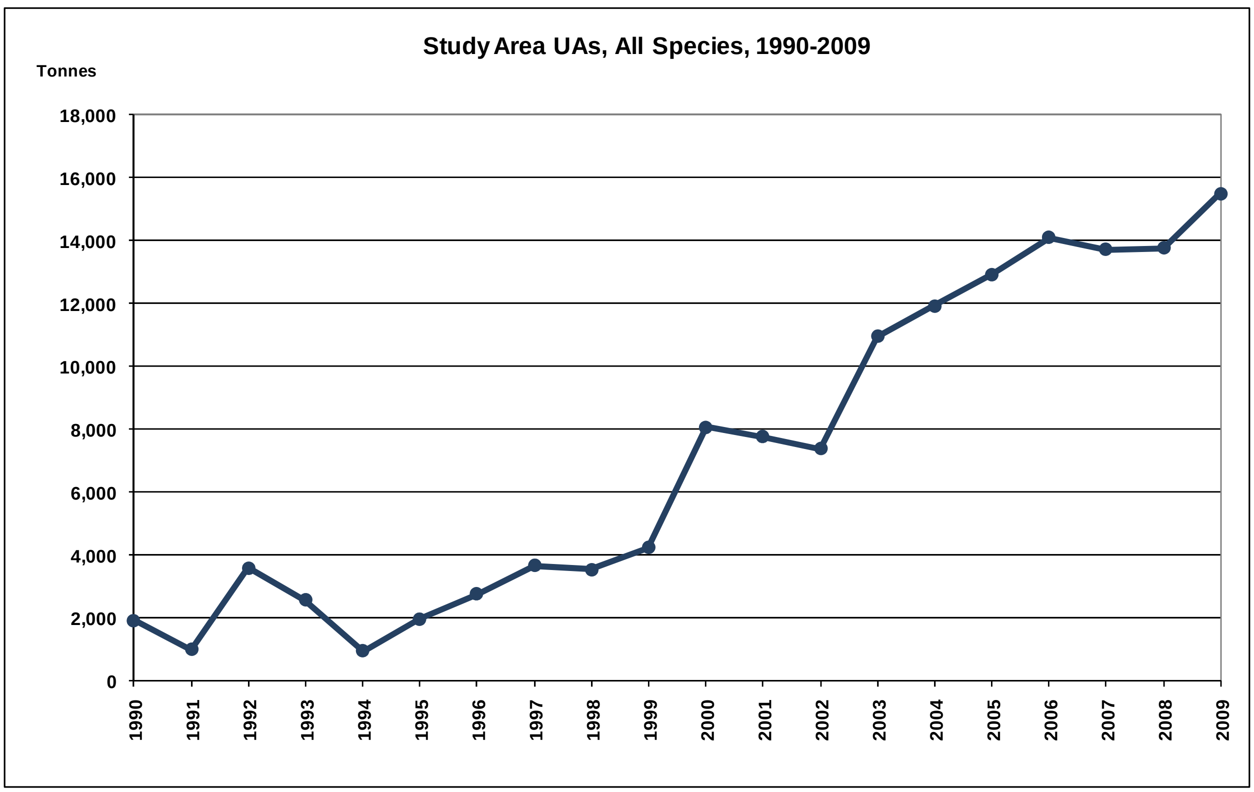


Figure 4.3. Study Area Unit Areas, harvest by year, 1990 – 2009, all species.

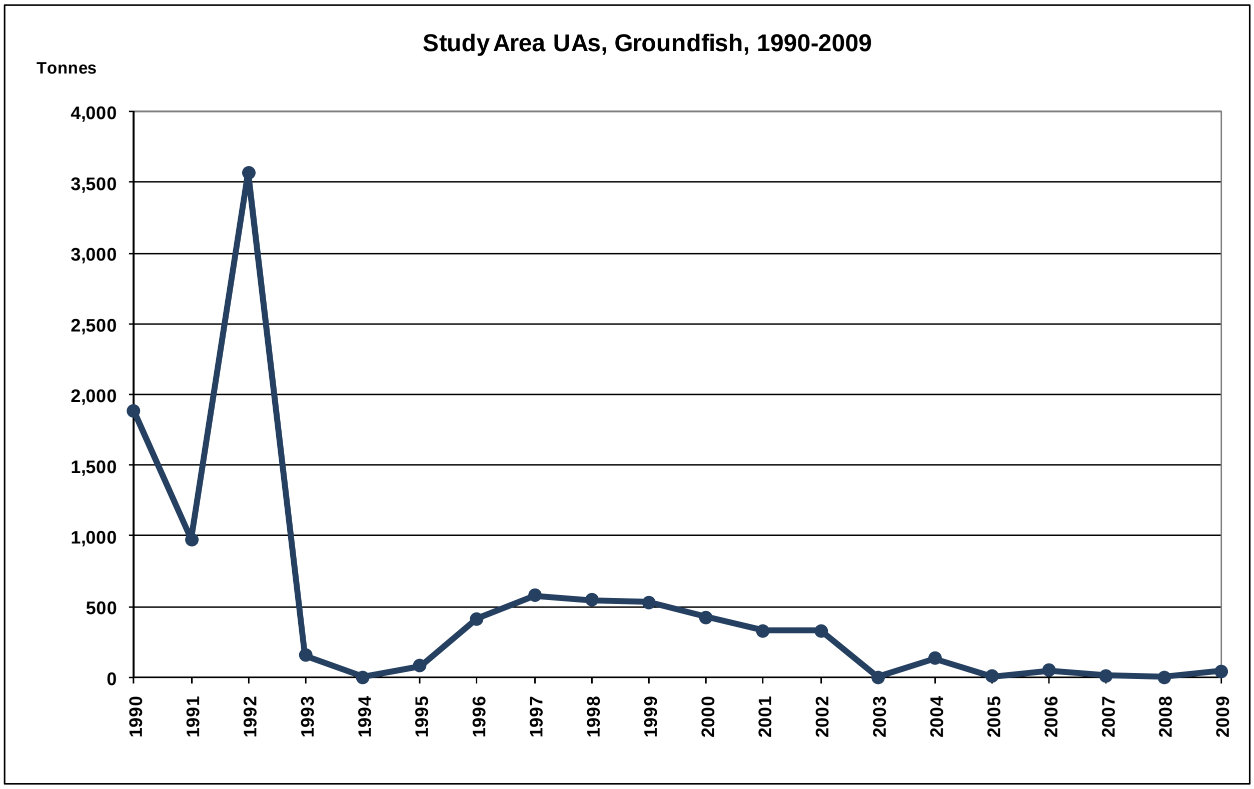


Figure 4.4. Study Area Unit Areas, harvest by year, 1990 – 2009, groundfish.

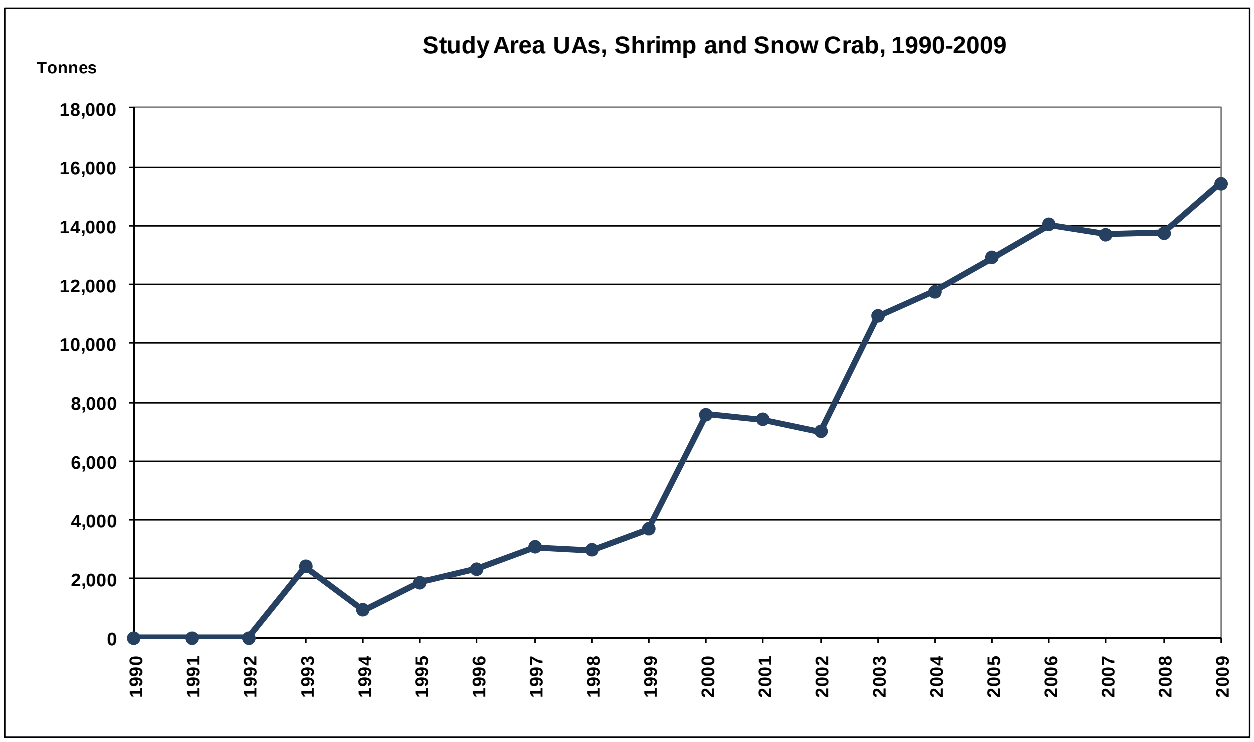


Figure 4.5. Study Area Unit Areas, harvest by year, 1990 – 2009, shrimp and snow crab.

Today, in this area, snow crab harvesting (fixed gear) tends to be focused in areas along the shelf break and slope. Northern shrimp (mobile gear) trawling overlaps some of these areas but the gears have a potential to conflict, and thus do not typically overlap in time or location (as demonstrated clearly in Figures 4.9 to 4.15, below). Shrimp harvesting tends to extend into deeper water in the Study Area and farther eastward into the international waters, where it is also fished by several nations besides Canada within the general area of the Study Area (discussed above).

The following tables show the average annual Canadian-landed harvest by species, 2003 to 2009, from within the Study Area (the full year harvest in Table 4.6 and the May to November period in Table 4.7), based on the georeferenced DFO datasets. As the data show, the domestic harvest in the Study Area has been dominated by shrimp throughout this period.

Table 4.6. Average annual Study Area harvest (quantity and value), by species, 2003-2009.

Species	Tonnes	% of Total	$	% of Total
Shrimp	7,880.9	97.9%	9,952,772	95.8%
Snow Crab	150.5	1.9%	406,548	3.9%
Turbot/Greenland Halibut	15.5	0.2%	25,790	0.2%
Grenadier	2.5	0.0%	878	0.0%
Capelin	2.5	0.0%	380	0.0%
Redfish	0.0	0.0%	14	0.0%
American Plaice	0.0	0.0%	7	0.0%
Total	8,051.9	100.0%	10,386,389	100.0%

Table 4.7. Average annual Study Area harvest (quantity and value), by species, May to November, 2003-2009.

Species	Tonnes	% of Total	$	% of Total
Shrimp	5,669.7	97.2%	6,079,470	93.4%
Snow Crab	143.3	2.5%	404,210	6.2%
Turbot/Greenland Halibut	15.5	0.3%	25,790	0.4%
Grenadier	2.5	0.0%	878	0.0%
Capelin	2.5	0.0%	380	0.0%
Other Groundfish	0.0	0.0%	21	0.0%
Total	5,833.5	100.0%	6,510,748	100.0%

Figure 4.6 indicates the changes in the total catch recorded annually within the Study Area for the 2003 – 2009 period. As the graph indicates, the total quantity of the harvest has increased fairly consistently year over year since 2003, mainly the result of increasing shrimp catches in the Study Area, up to 2009. However, significant reductions in shrimp quotas after 2010 are expected to result in a reversal of this trend (as discussed above and below).

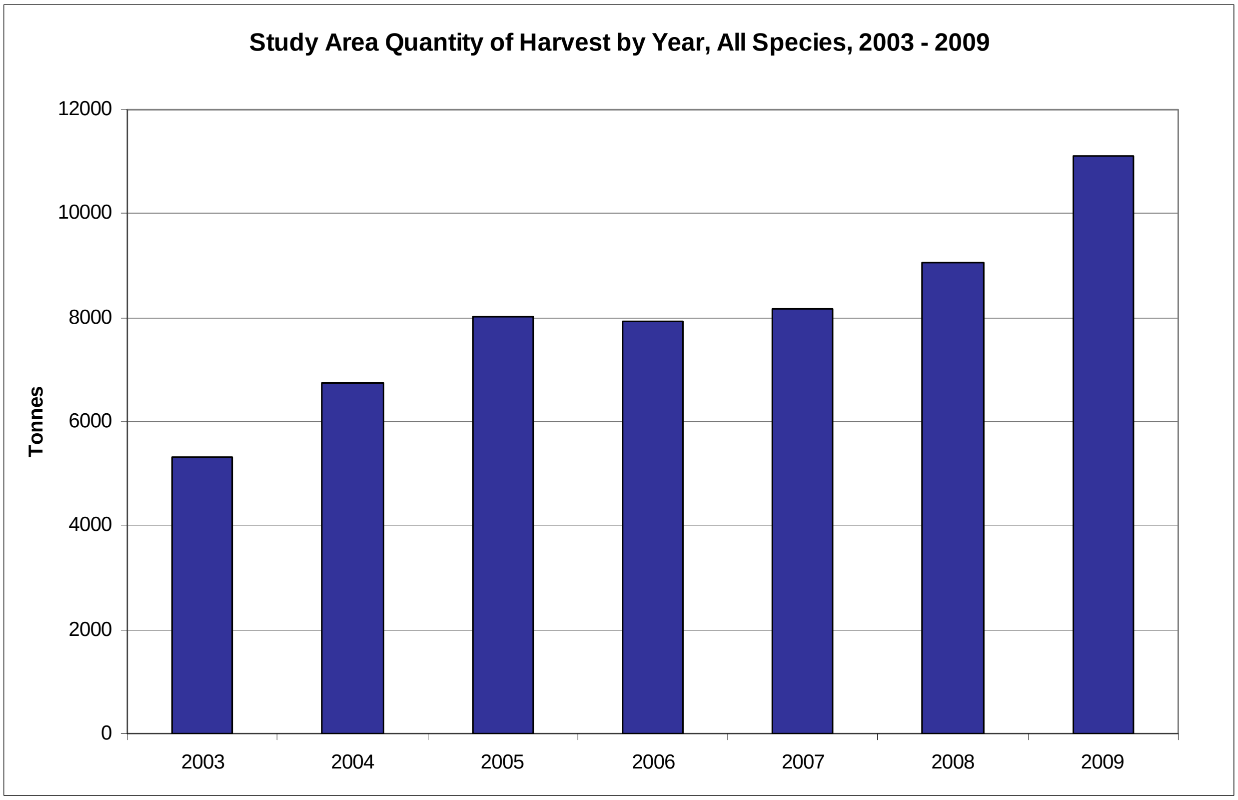


Figure 4.6. Study Area harvest by year, 2003 – 2009, all species.

4.3.2.1 Harvesting Locations

Figure 4.7 shows DFO dataset fishing locations in relation to the Study Area for the period May to November, for 2003 to 2009, aggregated. Figures 4.9 to 4.15 in following sections map the monthly variation in harvest for by principal species (using 2009 data) as well as aggregated (2003 – 2009) harvesting locations for these species. As Figure 4.7 illustrates, most of the domestic fish harvesting in the general area is concentrated between the 100 m and 1000 m contours of the eastern Grand Bank, both inside and - to a lesser extent - outside the 200-NMi EEZ, in particular in the southwestern quadrant of the Study Area. The harvesting locations tend to be quite consistent from year to year, and this has been the case for most of the last decade.

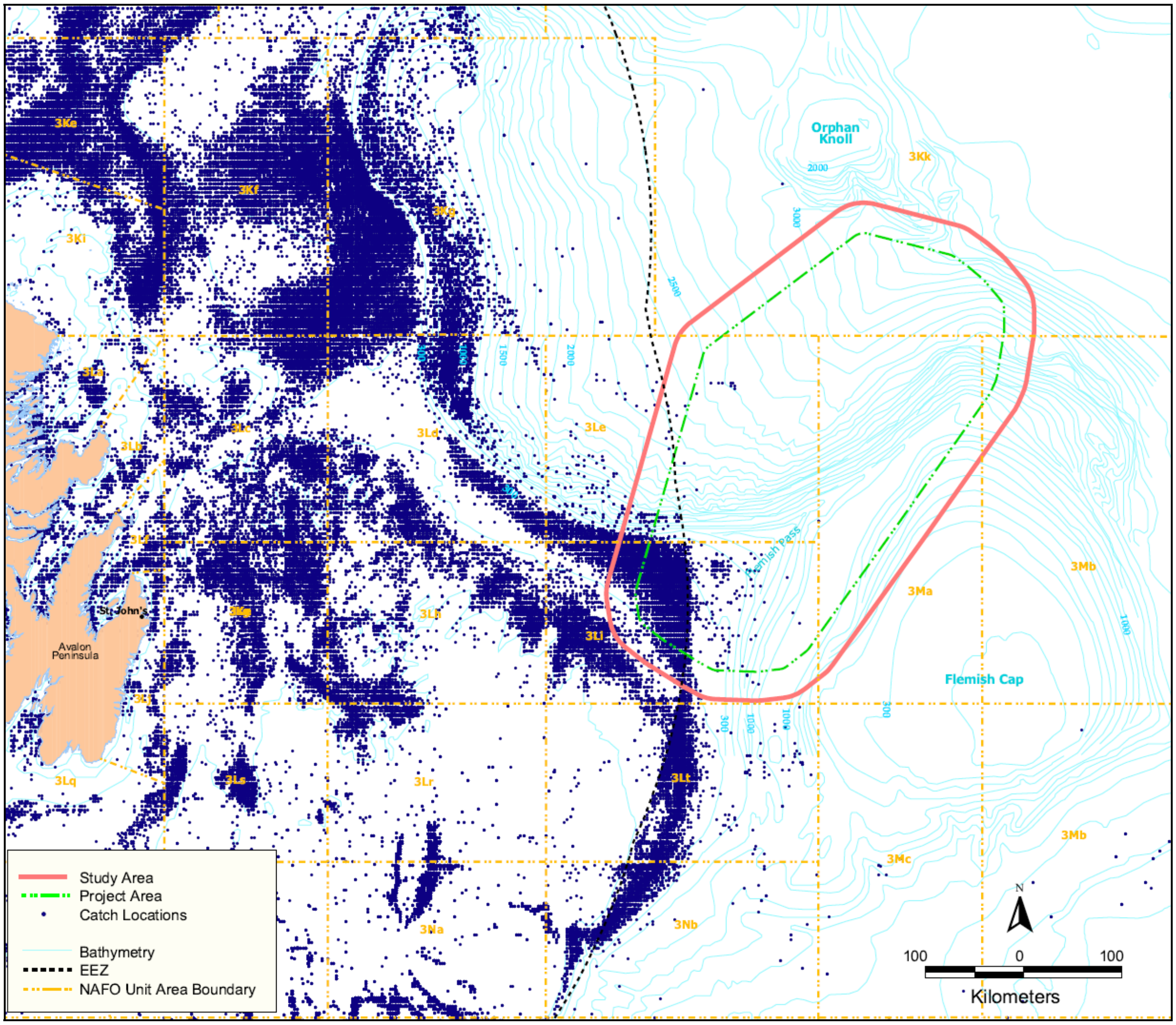


Figure 4.7. All species harvesting locations, May to November, 2003 – 2009, aggregated.

4.3.2.2 Harvest Timing

The times that commercial species are harvested may change, depending on seasons and regulations set by DFO, the harvesting strategies of fishing enterprises, or on the availability of the resource itself. Figure 4.8 shows the 2003 - 2009 catch by month (averaged) from the Study Area. As the graph indicates, June, July and August were the most productive months during this period, accounting for more than 50% of the annual catch.

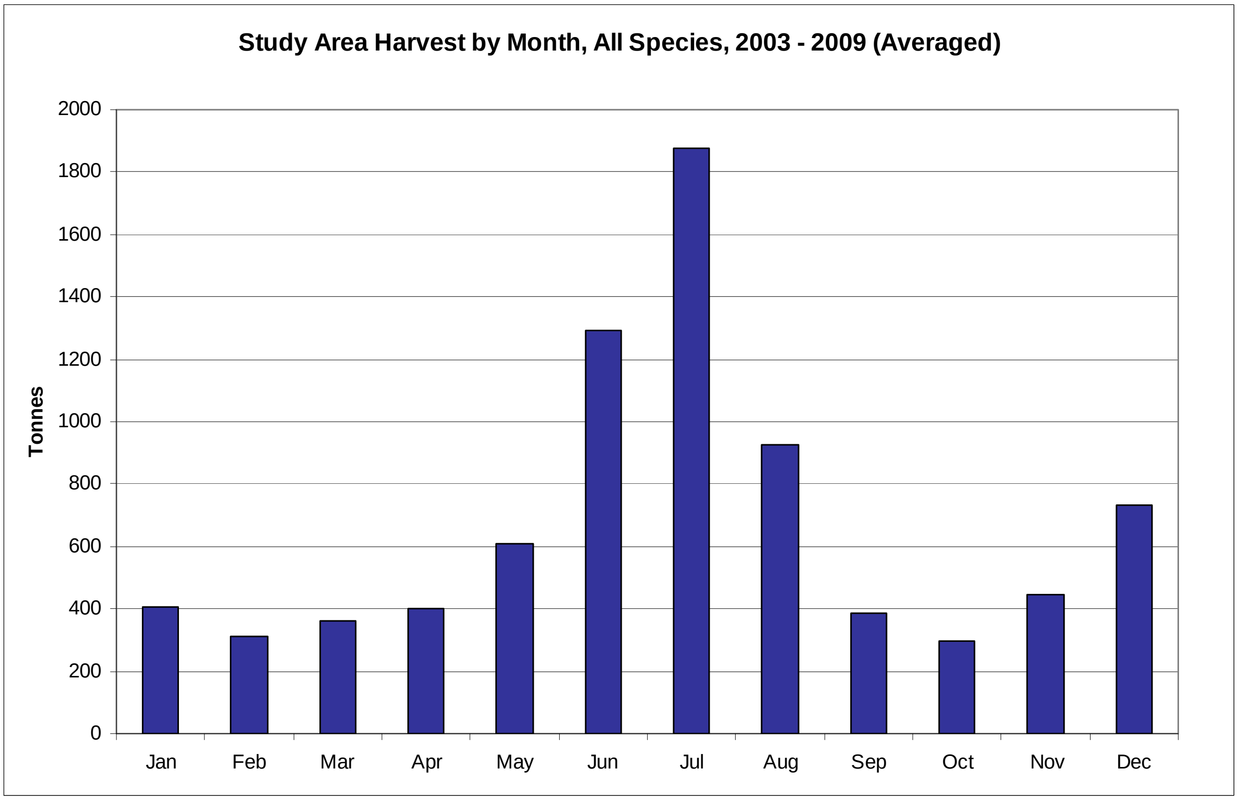


Figure 4.8. Average annual Study Area domestic harvest by month, all species, 2003 to 2009.

Figures 4.9 to 4.15 show the monthly reported domestic harvesting locations for key species (shrimp, crab, and turbot) for May to November 2009. Unlike the aggregated (multi-year) maps which are used to define the recent fishing patterns more prominently, these maps are a better representation of the actual levels of activity that might occur in any actual Project month.

4.3.3 Principal Species Fisheries

As Tables 4.6 and 4.7 indicate, the domestic harvest within the Study Area is very largely northern shrimp, with much lesser quantities of snow crab and Greenland halibut / turbot. Together, these three species have typically made up more than more than 99% of the Study Area harvest in recent years (though with decreasing shrimp quotas the relative importance of the species may change somewhat in the next few years). This section describes these three fisheries in more detail.

4.3.3.1 Northern Shrimp (*Pandalus borealis*)

Northern shrimp is the most significant species harvested within the Study Area in terms of quantity and value of harvest, accounting for, on average, some 5,670 t (more than 97% of the total harvest) between May and November in recent years. The Study Area overlaps with parts of Shrimp Fishing Area (SFA) 6, 7 and 3M (Figure 4.16). As noted above, SFA 7 (which corresponds to Division 3L) and 3M are managed through NAFO, while SFA 6 (consisting of Division 3K plus the Hawke Channel portion of 2J) are managed by Canada's DFO.

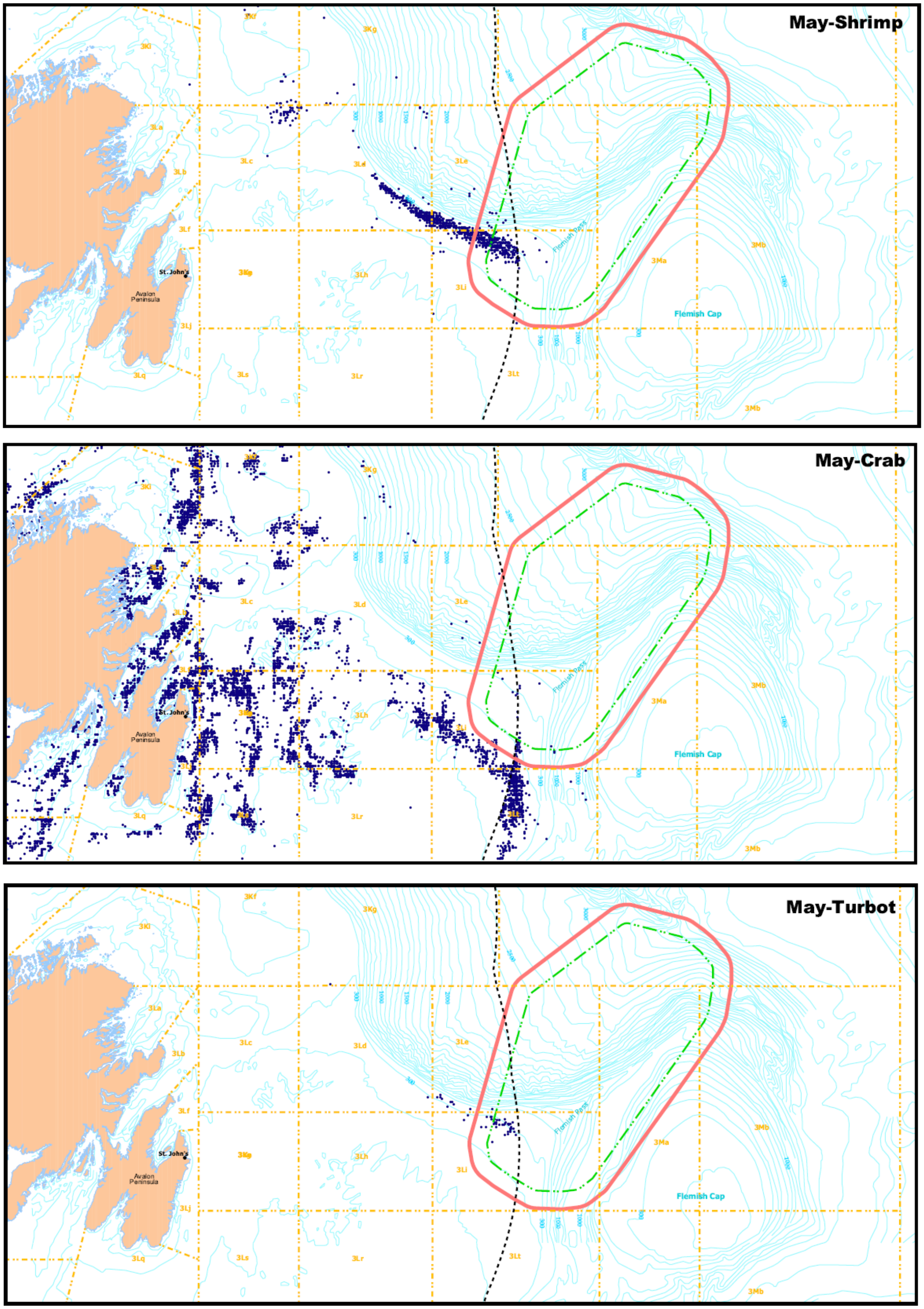


Figure 4.9. Harvesting locations, principal species 2009, May.

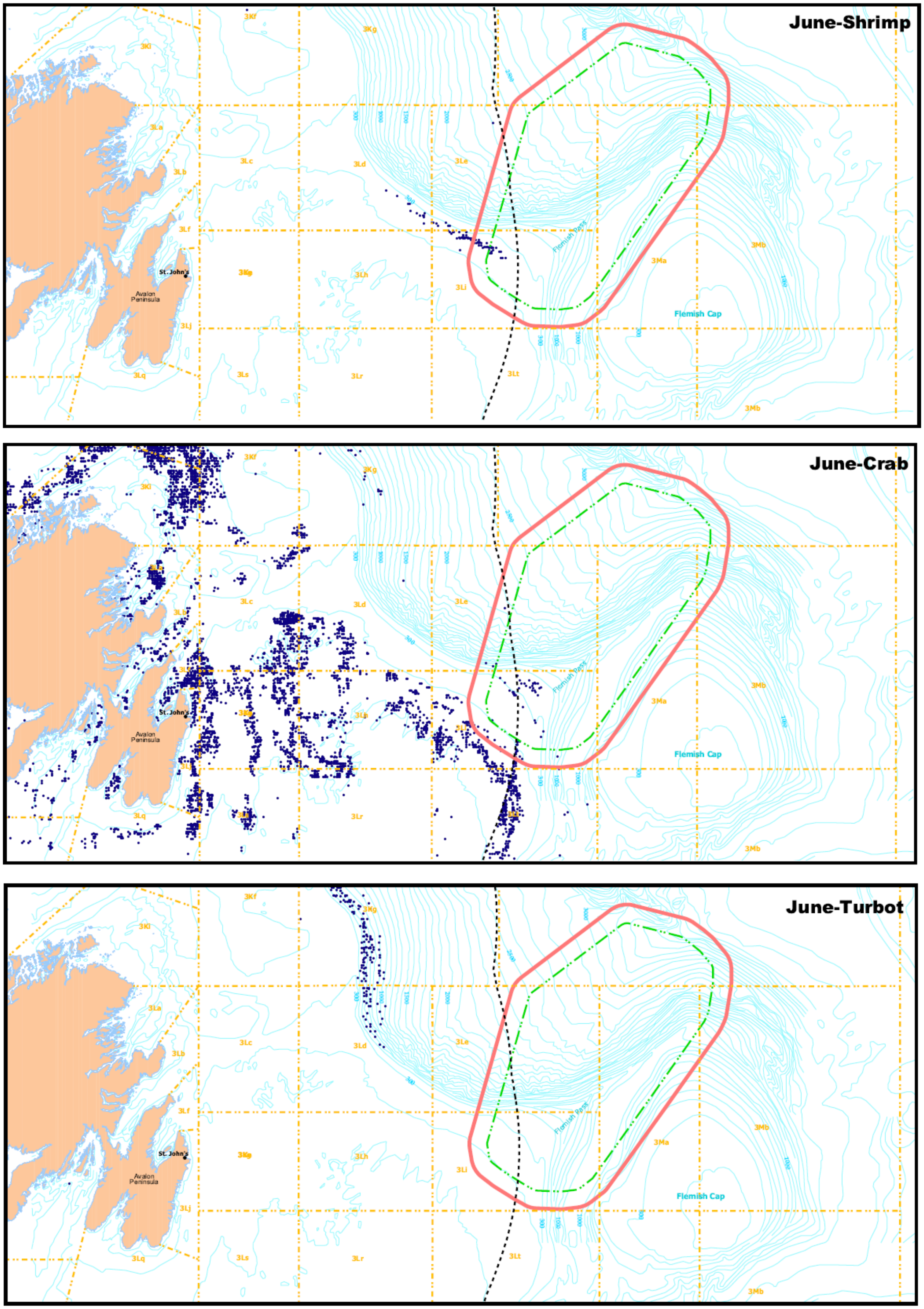


Figure 4.10. Harvesting locations, principal species 2009, June.

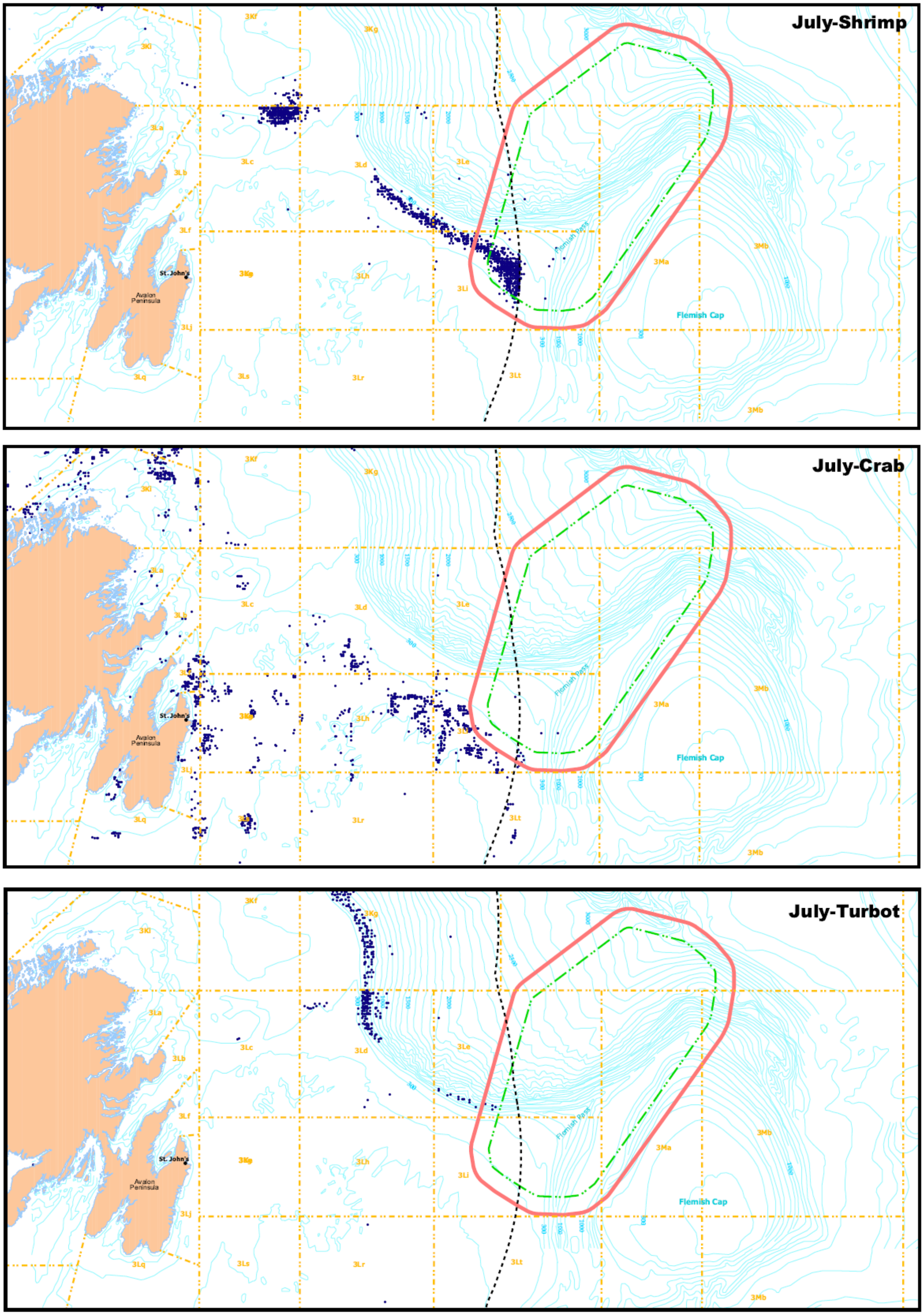


Figure 4.11. Harvesting locations, principal species 2009, July.

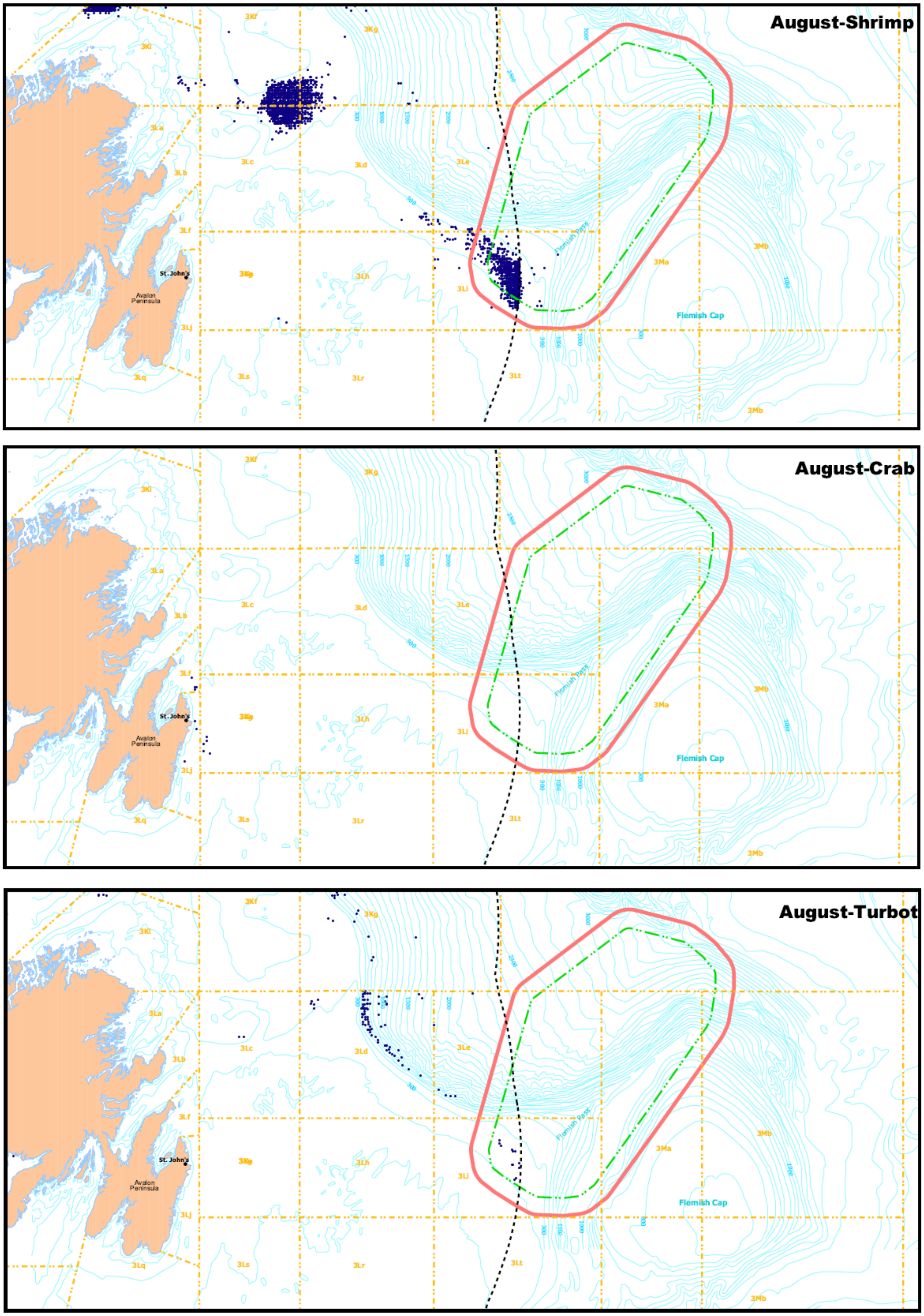


Figure 4.12. Harvesting locations, principal species 2009, August.

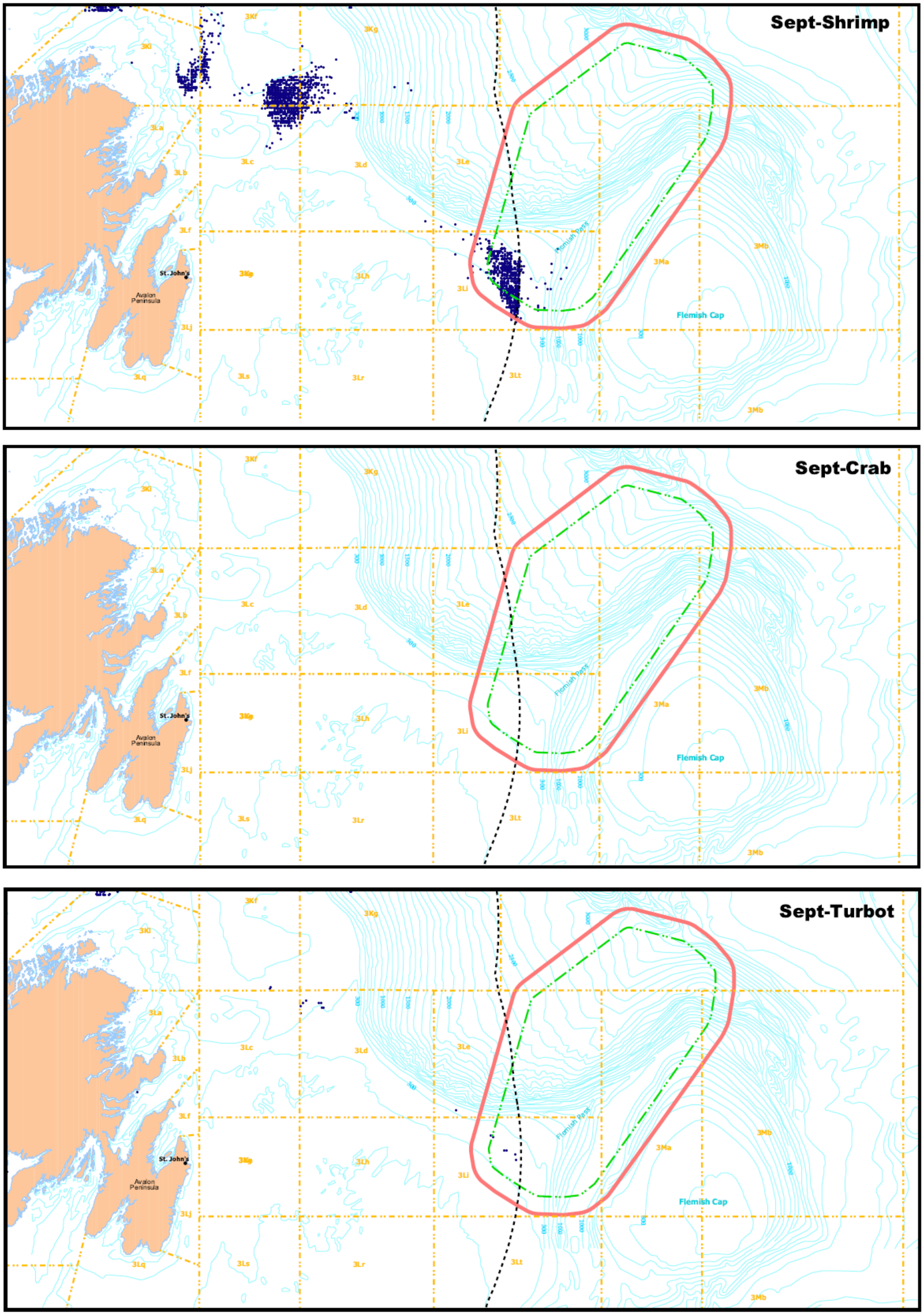


Figure 4.13. Harvesting locations, principal species 2009, September.

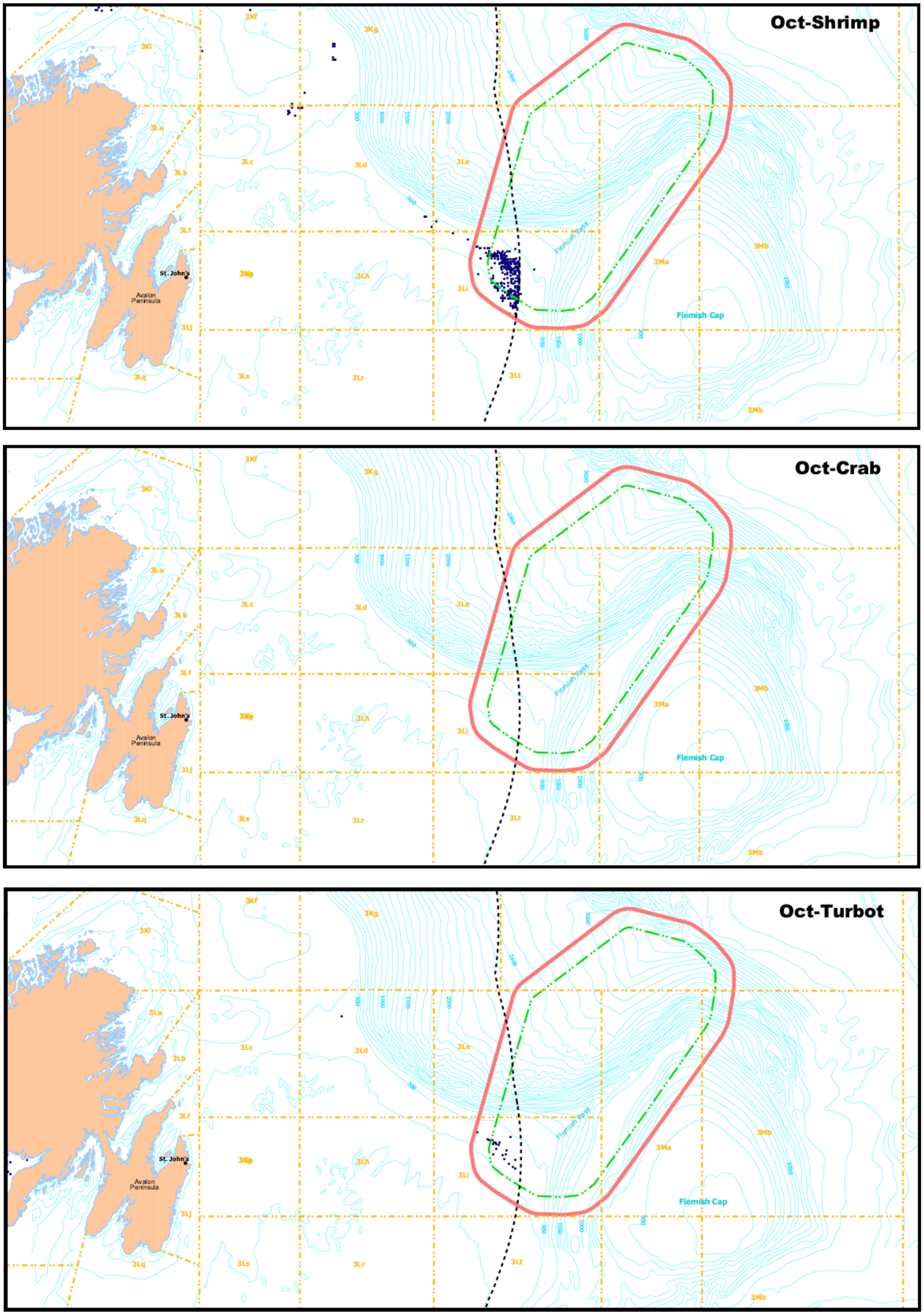


Figure 4.14. Harvesting locations, principal species 2009, October.

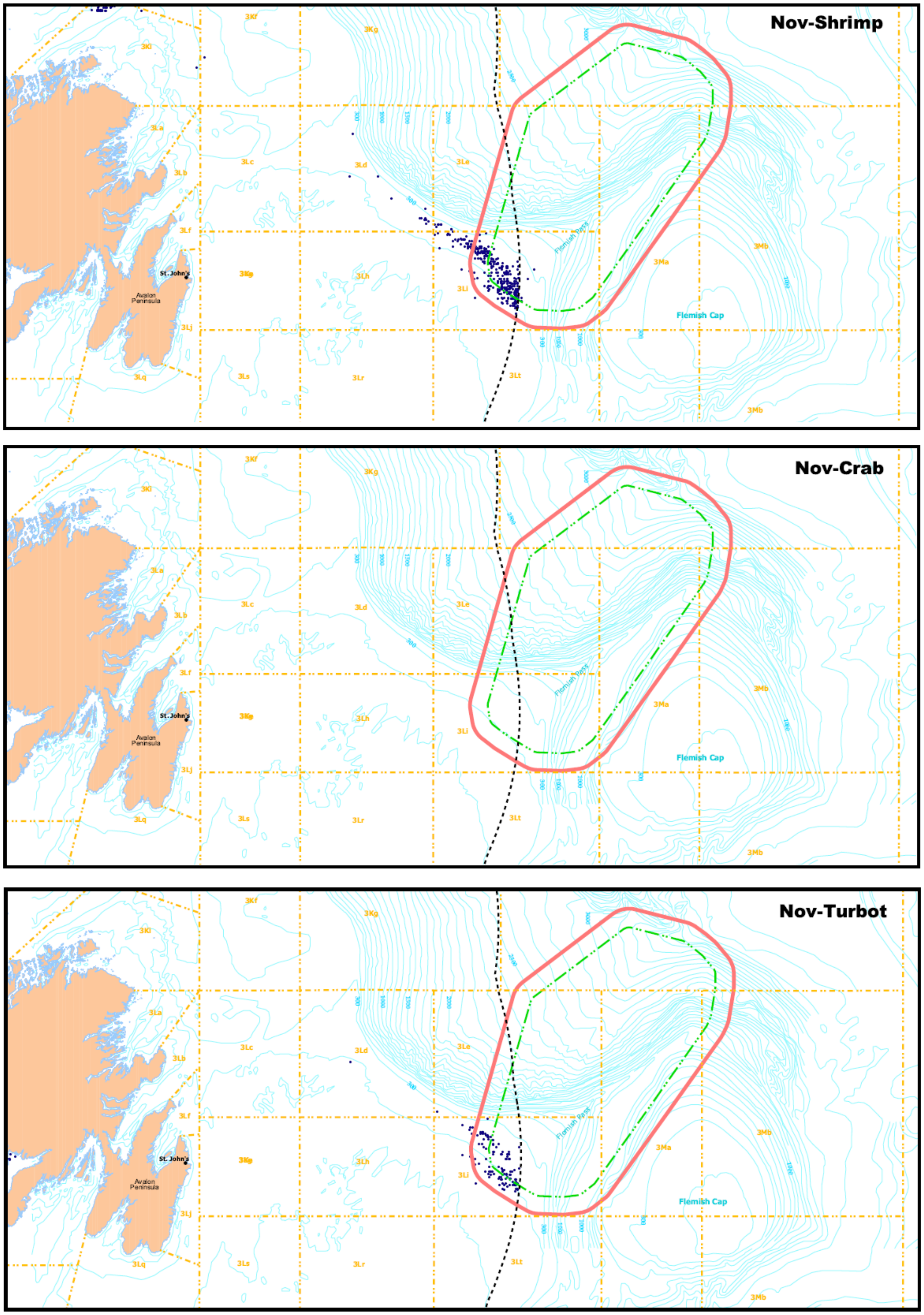


Figure 4.15. Harvesting locations, principal species 2009, November.

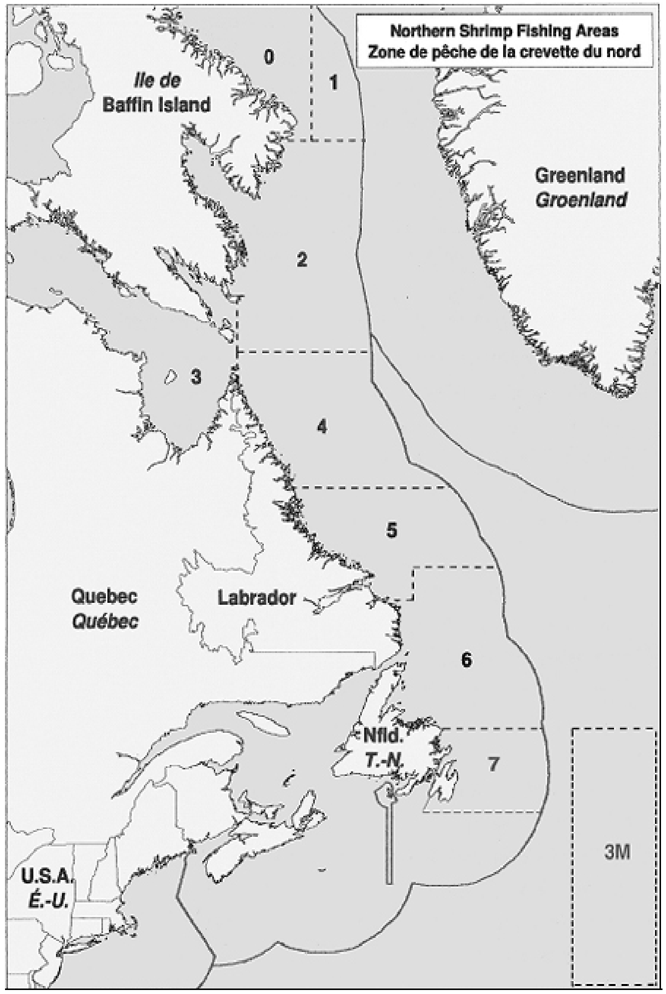


Figure 4.16. Northern shrimp Fishing Areas.

Figure 4.17 shows domestic harvesting locations for 2003 to 2009, May to November, aggregated for northern shrimp. As indicated, this fishery is confined to a well-defined zone in the southwestern part of the Study and Project areas.

Figure 4.18 shows the quantity of the northern shrimp harvest taken from the Study Area over the past seven years. The increase has been largely the result of increasing quotas. However, because of increasing science concerns about the status of the resource, catch allowances have been cut in all three areas since 2009/10 so this trend is expected to change, potentially for the next several years. As discussed above, the overall quota for SFA 7 has been reduced by a third and will drop further in 2012, and all shrimp fishing in 3M has been banned. The SFA 6 quota, which was 85,725 t in 2009/10 (DFO 2010/018) was reduced by nearly 30% to 61,632 t for 2010/11.

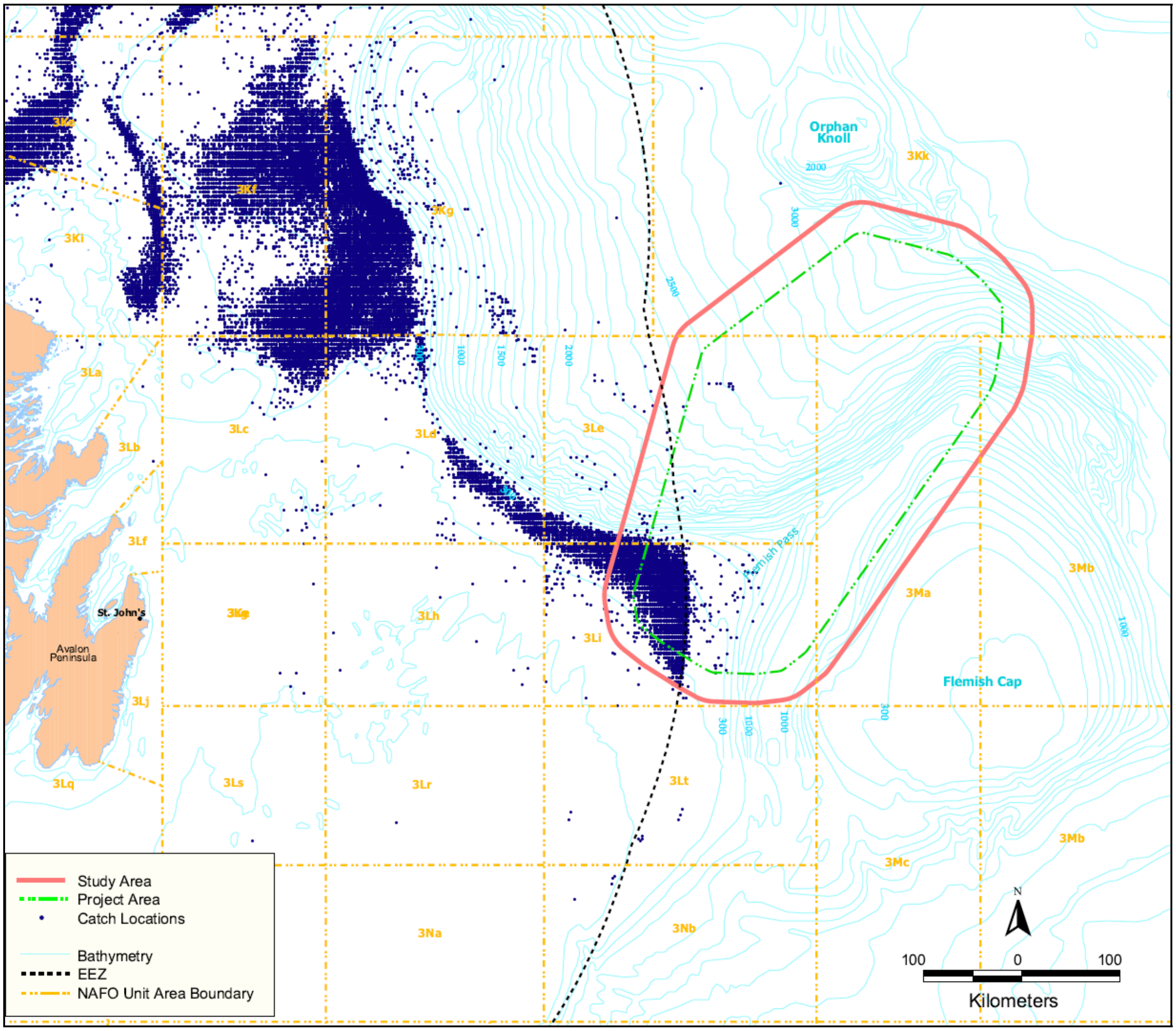


Figure 4.17. Northern shrimp harvesting locations, May - November 2003-2009, aggregated.

Figure 4.19 shows the northern shrimp harvest by month (averaged) from the Study Area, for the period 2003 to 2009. The maps above (Figures 4.9 to 4.15) show the 2009 monthly shrimp harvest locations.

4.3.3.2 Snow Crab (*Chionoecetes opili)*

Snow crab has occupied a distant second place in importance in the Study Area's fisheries, averaging just 2.5% by quantity and 6.2% by value since 2003, with just over 143 t harvested on average from May to November. Nevertheless, because the fishery uses fixed gear (crab pots), the fishery poses the greatest potential for seismic / fishing gear conflicts in those areas where the two marine activities might overlap.

Figure 4.20 shows the regulatory fishing areas for snow crab. The Study Area overlaps with portions of Crab Fishing Areas (CFA) 3Lex (from 170 miles to 200 miles from shore) and 3L200 (beyond 200 nautical miles), both of which are within Division 3L.

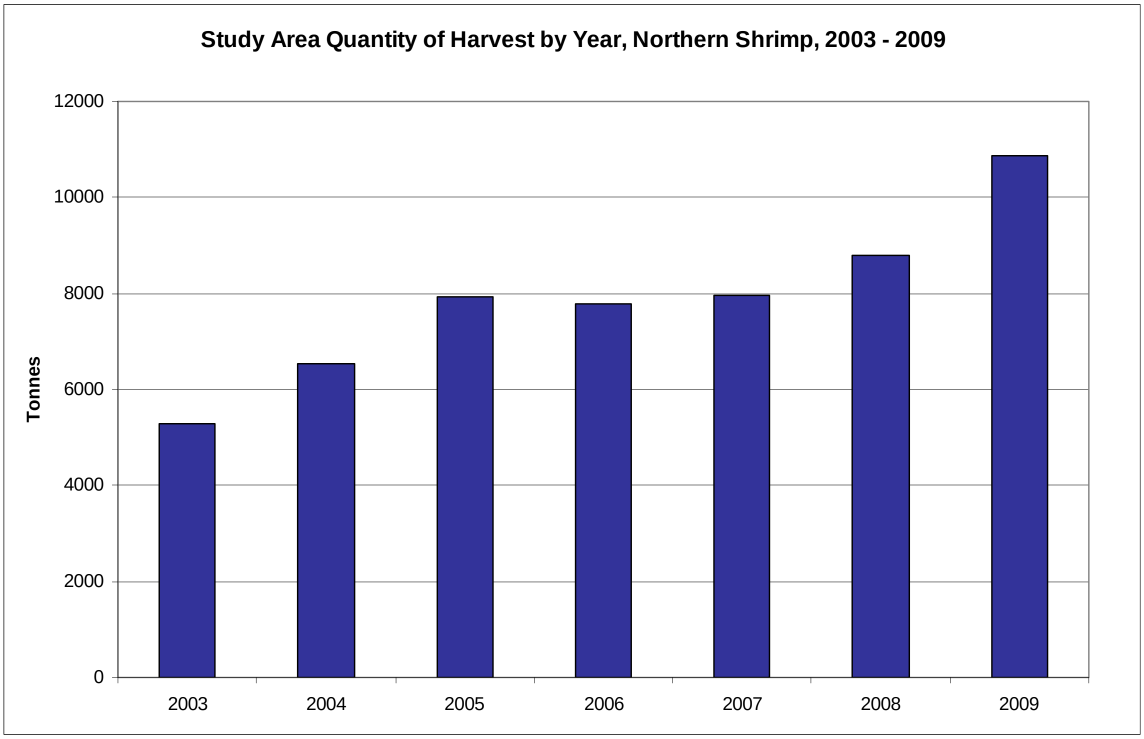


Figure 4.18. Study Area harvest by year, 2003 – 2009, northern shrimp.

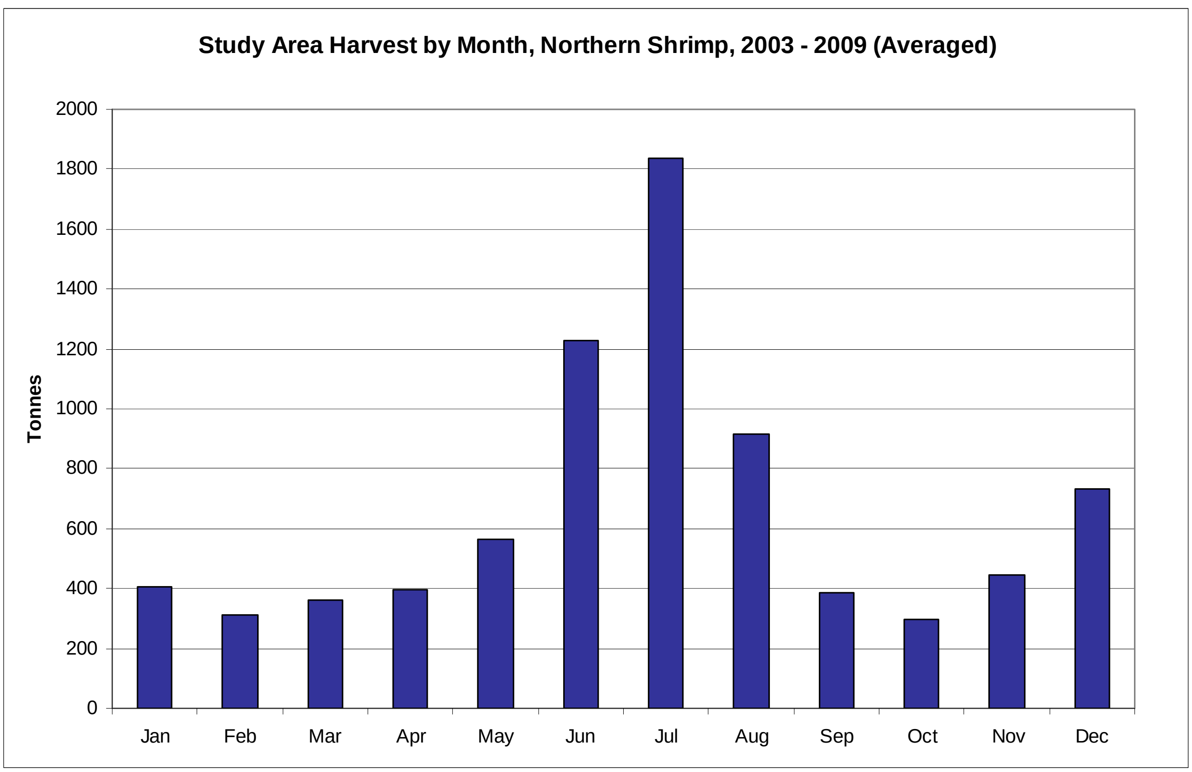


Figure 4.19. Study Area northern shrimp harvesting by month, 2003 – 2009, averaged.

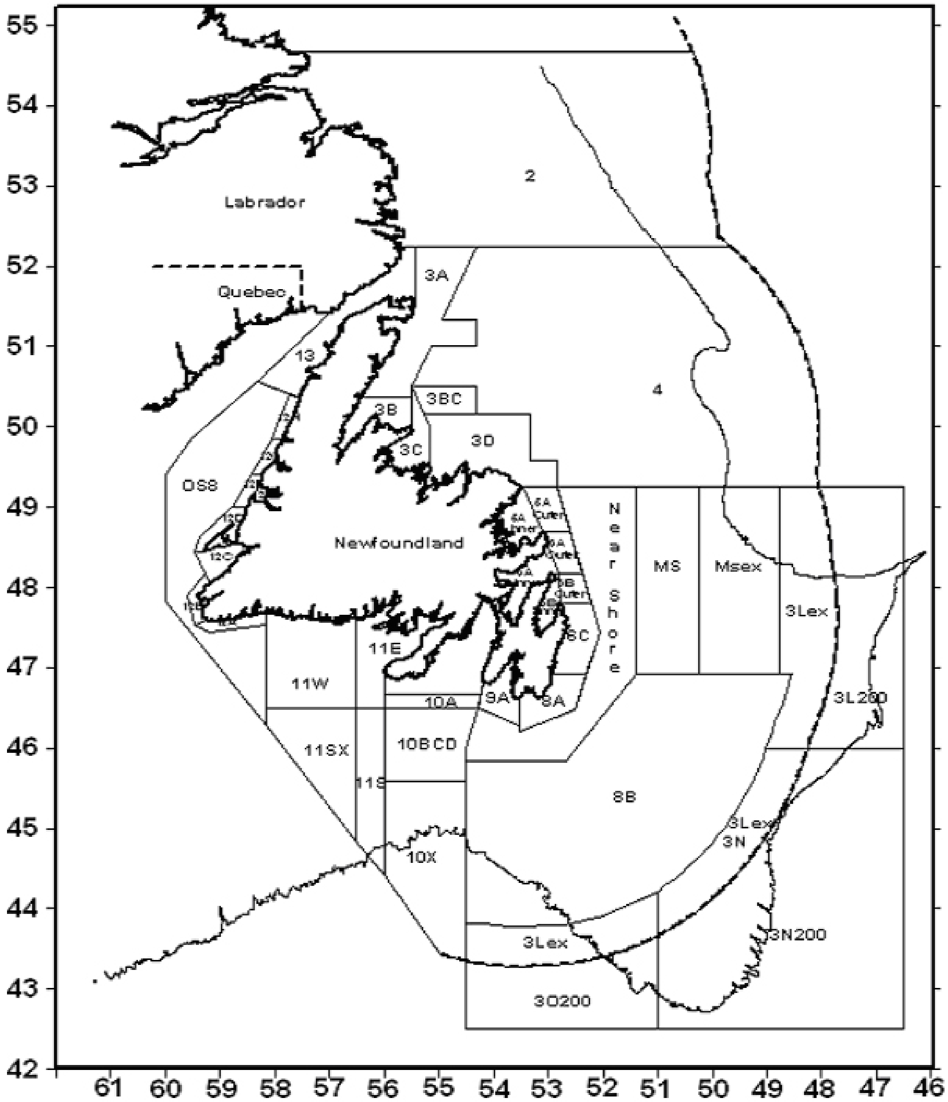


Figure 4.20. Newfoundland snow crab Fishing Areas.

Over the past decade, the Newfoundland and Labrador snow crab fishery has gone through a number of fluctuations, with changes in both quantity and value in many CFAs. Prices have been lower in recent years compared to the late 1990s and early 2000s, and in 2006 averaged under $1 a pound. In 2010, the average price per pound was $1.38 ($3.04/Kg)[3]

The most recent DFO snow crab science advisory report (DFO 2010/020) notes that "Offshore landings, mostly in Div. 3L, peaked at 27,300 t in 1999 and decreased to about 22,100 t in 2000 due to a reduction in the TAC. Landings remained at 22,000-25,000 t since 2000. Effort increased steadily from 2000-2007 and changed little since." Specifically describing the 3LNO offshore area, the report states, "The exploitable biomass has recently increased. The exploitable biomass index from the trawl survey declined steadily from 2001-2007 but has since more than doubled. The CPS index [based on an Industry-DFO collaborative post-season trap survey] declined steadily from 2004-2008 but increased in 2009)."

[3]See http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Land_All_Vessels_Debarquer_Tous_Les_Navires_2010_eng.htm

The FRCC's 2005 *Strategic Conservation Framework for Atlantic Snow Crab* (FRCC 2005) describes the general conduct of the offshore sector: "Vessels fishing up to and beyond 200 miles from the coast conduct voyages up to four and five days and greater depending on the vessel's holding system. Typically these vessels leave the traps for shorter periods, sometimes only a few hours, prior to retrieving the catch. Given that snow crab must be live at the time of landing and processing, the duration of fishing trips is limited, although some vessels are now able to keep crab live on board in tanks permitting them to extend the length of their trips." Quotas have been established in all management areas, the different fleets have trap limits and trip limits and fish specified CFAs. Since the mid-2000s, electronic vessel monitoring systems (VMS) are required on all offshore vessels to ensure compliance (DFO 2010/020).

Figure 4.21 shows the annual snow crab quantity of harvest from the Study Area for 2003 to 2009. Figure 4.22 following shows the aggregated harvesting locations for the species (May – November, 2003-2009) in relation to the Study and Project areas. The quotas have not yet been released for 2011 (as of February); in 2010 the 3Lex quota was 2,822 t and the 3L200 was 2,057 t.[4]

Figure 4.23 shows (average snow crab harvest by month, 2003-2009), the harvest has been focused between May and July in the Study Area. In 2010, both the 3Lex and the 3L200 seasons were closed on 15 August.

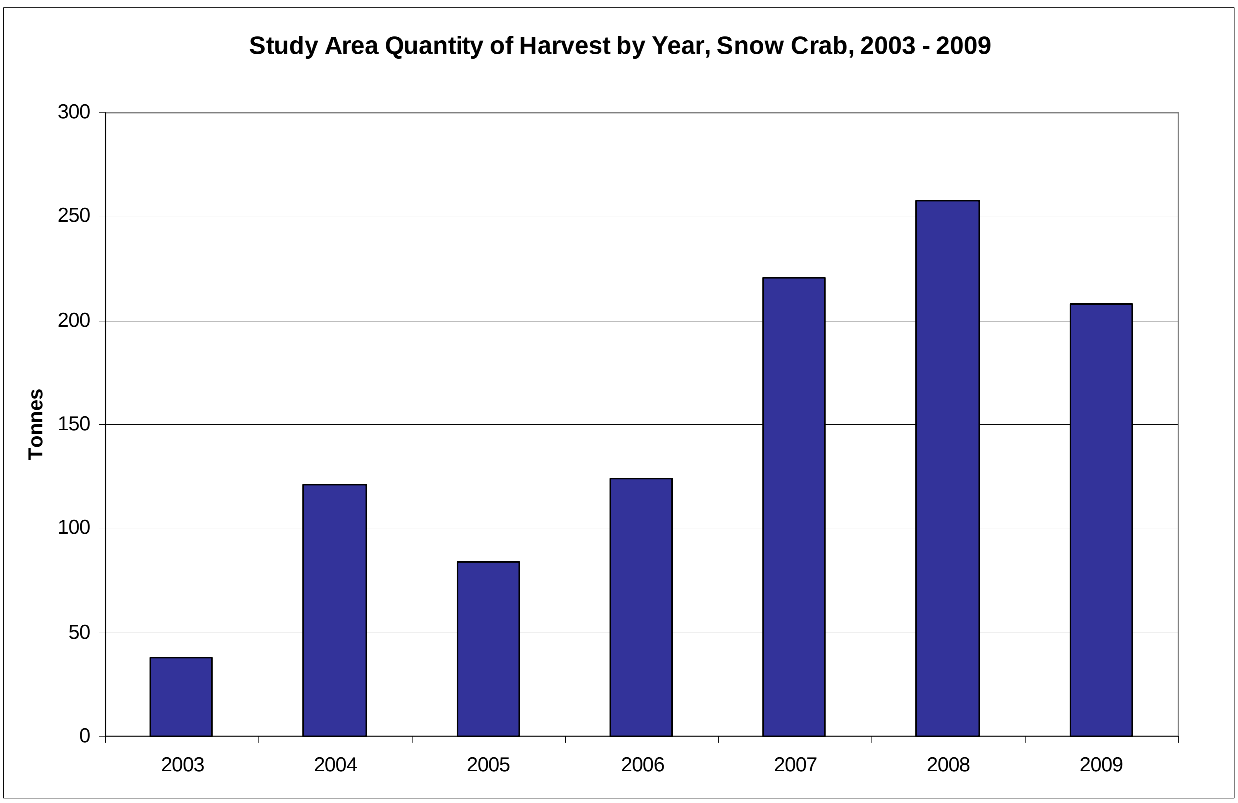


Figure 4.21. Study Area harvest by year, 2003 – 2009, snow crab.

[4] http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Crab_Crabe_2010_eng.htm

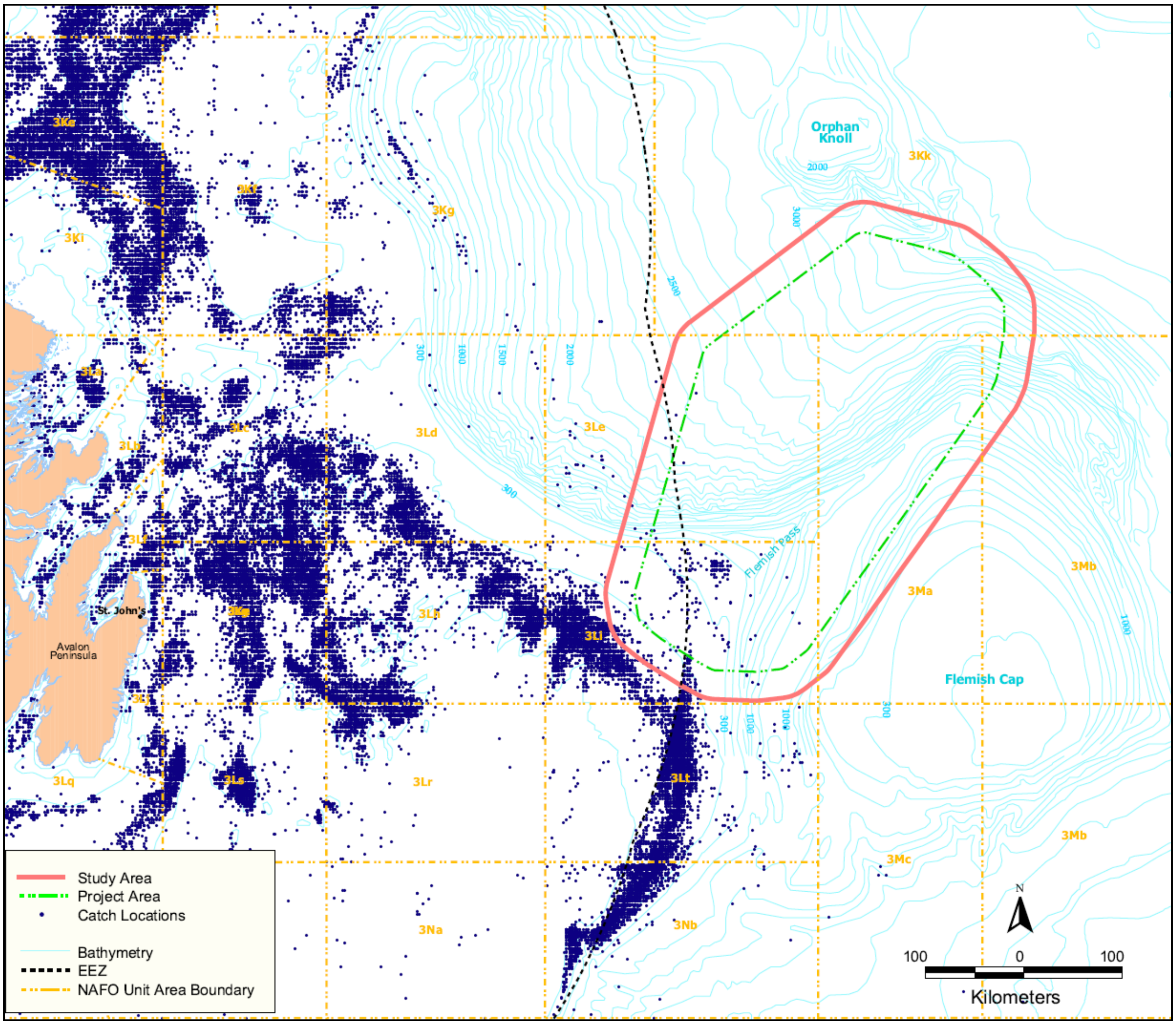


Figure 4.22. Snow crab harvesting locations, May - November 2003-2009, aggregated.

4.3.3.3 Greenland Halibut / Turbot (*Reinhardtius hippoglossoides*)

Greenland halibut (often called turbot) represents less than half of 1% of the Study Area catch by quantity and value, an average of just over 15 t a year. Most (about 99%) of this harvest in the Study Area is taken using fixed gear gillnets. In NAFO Division 3L and 3M, the fishery is managed by NAFO, and by DFO in 3K (and north), but quotas/TACs are set in all areas based on science advice provided through NAFO (see for e.g., Brodie et al. 2010; Healey 2010). NAFO management of this species has established a "progressive strategy" allowing for the annual adjustment of the TAC based on various indicators. For 2011, the 3LMNO Greenland halibut quota is 12,734 t for all of 3LMNO; of this 1,910 t is allocated for Canada, an increase over 2010. The 2011 DFO quota for 3K is not yet announced, but in 2010 it was 2,199 t.

Figure 4.24 shows the annual Greenland halibut harvest from the Study Area, indicating a widely varied fishery in this area. Figure 4.25 indicates that the Study Area domestic harvest in May to November is quite focused inside the EEZ, mainly within 4Li.

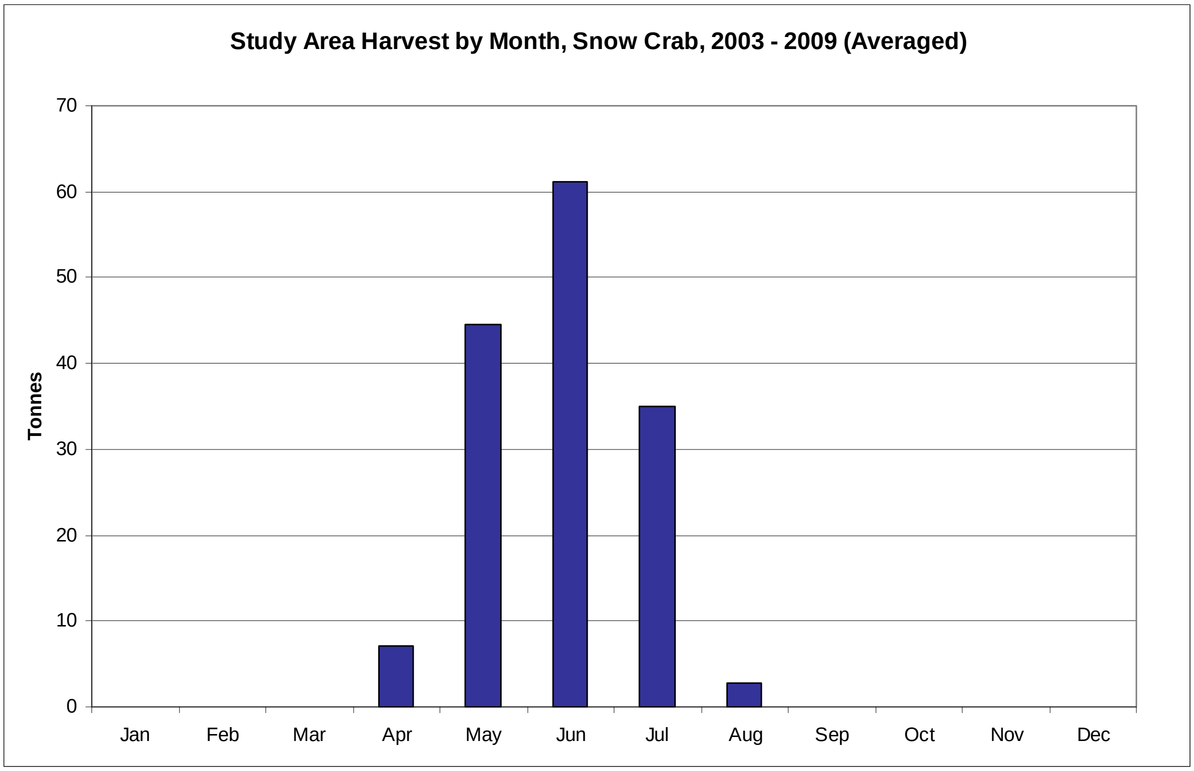


Figure 4.23. Snow crab harvesting by month, 2003 – 2009, averaged.

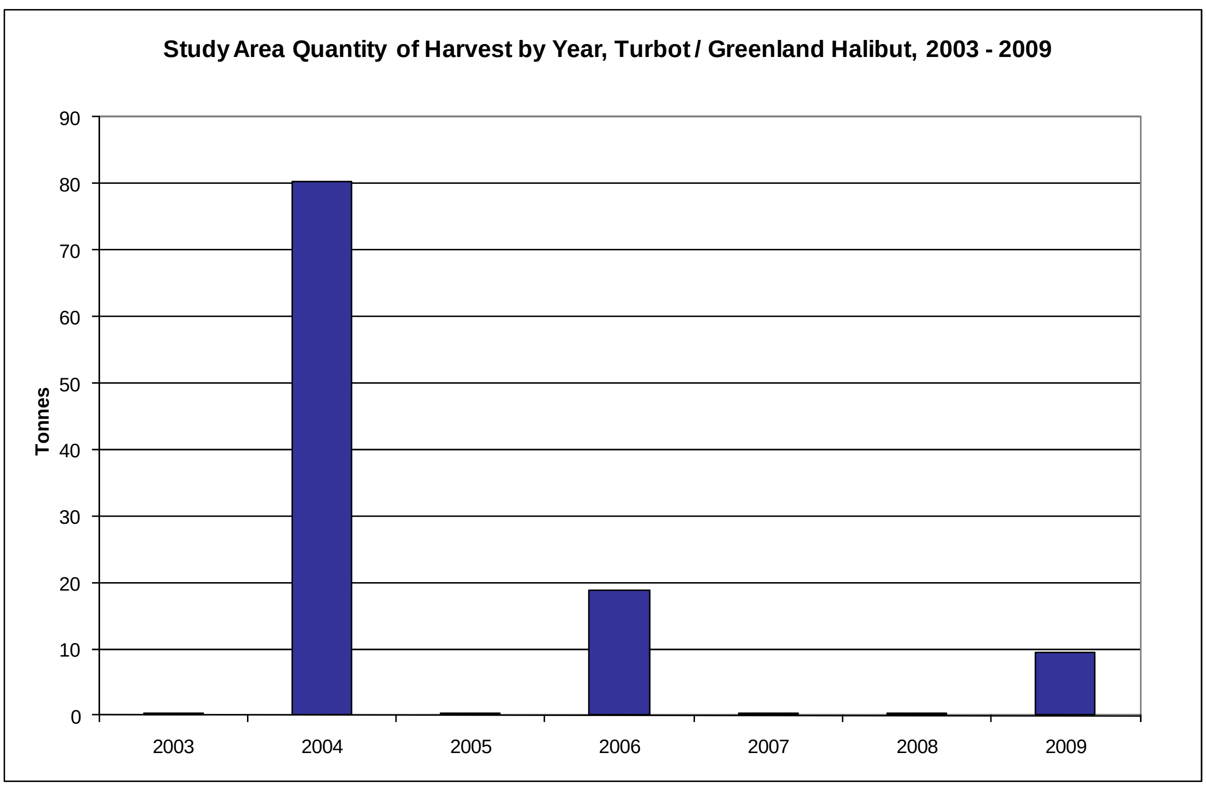


Figure 4.24. Study Area harvest by year, 2003 – 2009, Greenland halibut.

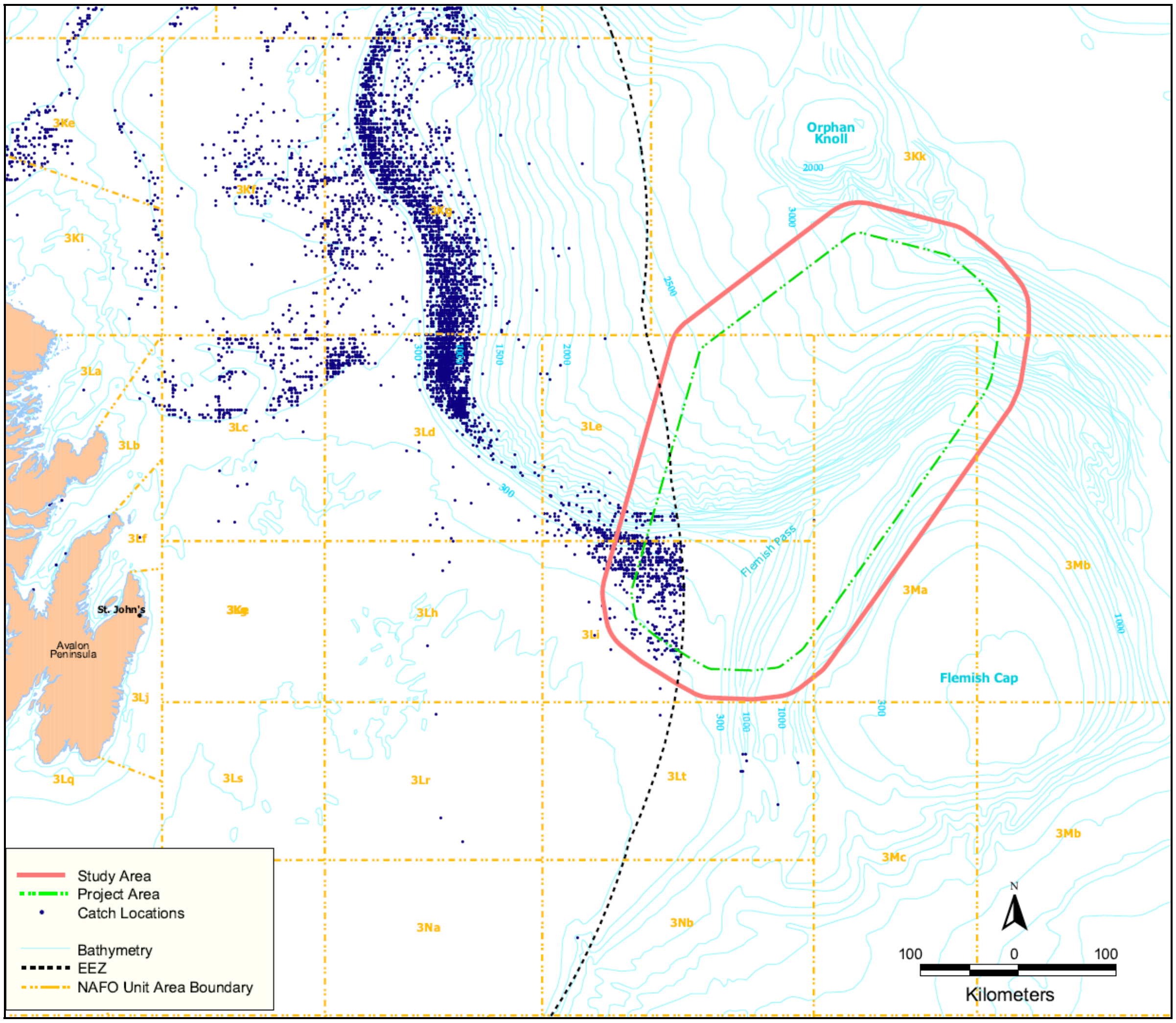


Figure 4.25. Greenland halibut harvesting locations, May - November 2003-2009, aggregated.

Figure 4.26 shows the average monthly harvest (2003-2009) inside the Study Area. The most productive month has been August, with nearly 50% of the catch occurring then.

4.3.4 Fishing Gear

The commercial fisheries within the Study and Project areas are conducted using both mobile gear (shrimp trawls) and fixed gear (crab pots and gillnets), though the great majority of the harvest (more than 97% of the catch by weight) is harvested using mobile shrimp trawls. 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 nearby, and it may be set out over long distances in the water. In particular, crab pots pose a significant potential for conflict if a seismic survey vessel encounters them. 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 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.

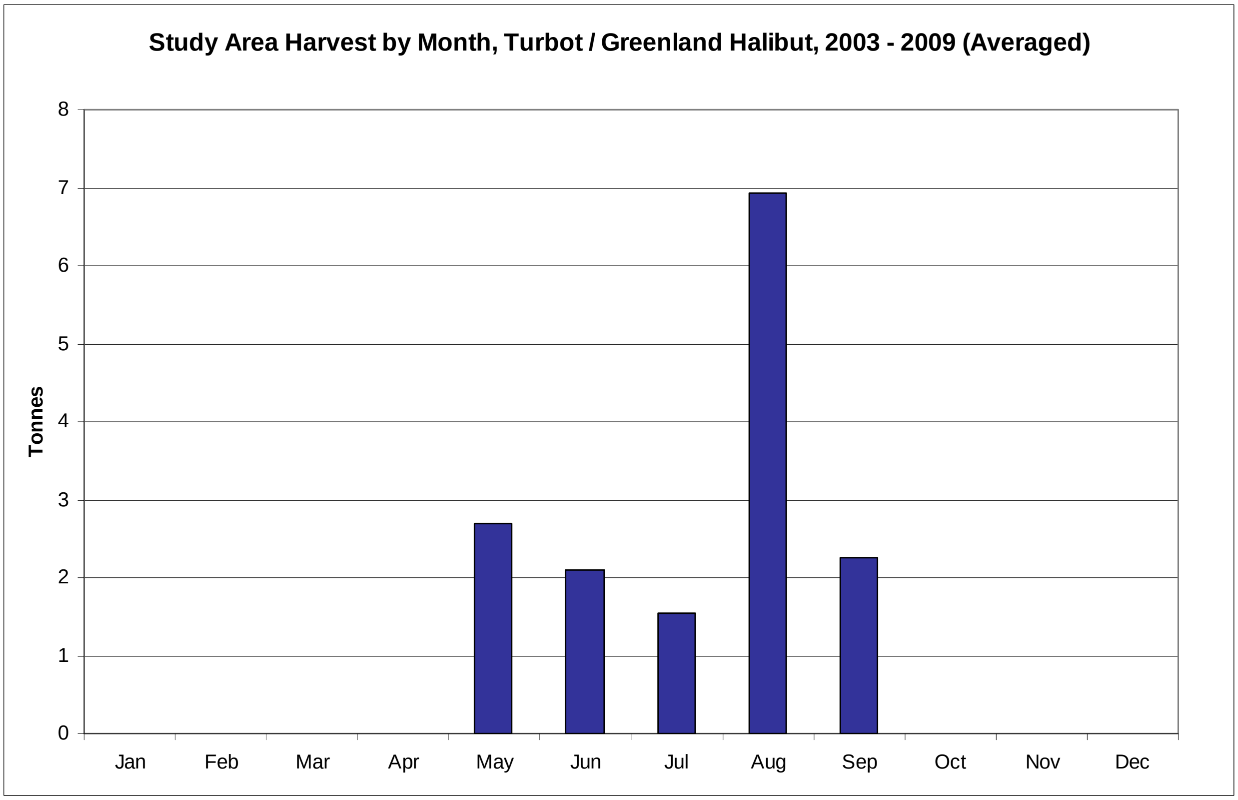


Figure 4.26. Study Area Greenland halibut harvesting by month, 2003 – 2009, averaged.

Though they only account for about 0.3% of the harvest, Greenland halibut gillnets (e.g. 200 nets per boat) are also fixed gear and may pose a potential to conflict with seismic gear if in the same area at the same time.

Shrimp harvesting uses mobile shrimp trawls. These are modified stern otter trawls, for both inshore and offshore vessels, though some use beam trawls. Over the past several years offshore Newfoundland and Labrador, shrimp vessels and survey ships, with good communications, typically avoid each other without interference to either industry, which has been noted by industry participants during previous consultations.

Because of the potential for conflict between shrimp trawls and fixed gears, the two fisheries generally stay apart, as discussed above.

4.3.5 Industry and DFO Science Surveys

Fisheries research surveys conducted by DFO, and sometimes by the fishing industry, are important to the commercial fisheries to determine stock status, as well as for scientific investigation. In any year, there may be overlap between the Study and/or Project areas and DFO research surveys in NAFO 3KLM, depending on the timing in a particular year. Typically, DFO conducts a spring survey in sections of 3LNOPs (April-July), and a fall survey of 2HJ3KLMNO (September / October to December). The fall survey may employ two vessels. The deeper waters of 3L (slope areas) are typically surveyed in October, and the shallower areas in November or December. The 2011 schedule has not yet been complete (as of February 2011), but exact timing is likely to vary somewhat in each future Project year (B. Brodie, pers.

comm., February 2011). Because of this, it will be necessary to maintain contact with DFO throughout each work season.

Members of the FFAW have been involved in an industry survey for crab in various offshore harvesting locations over the past few years, such as the snow crab Industry-DFO collaborative post-season trap survey (CPS). This survey is conducted every year. It starts on September 1 and may continue until November before it is completed. The set locations are determined by DFO and do not change from year to year. These stations do not appear to be within CCL's Project Area, and all are within the 200 mile limit (R. Lee, pers comm., February 2011; E. Dawe, pers comm., February 2011). Actual latitude and longitude locations of the stations will be obtained from DFO before the survey. Research stations are shown in Figure 4.27.

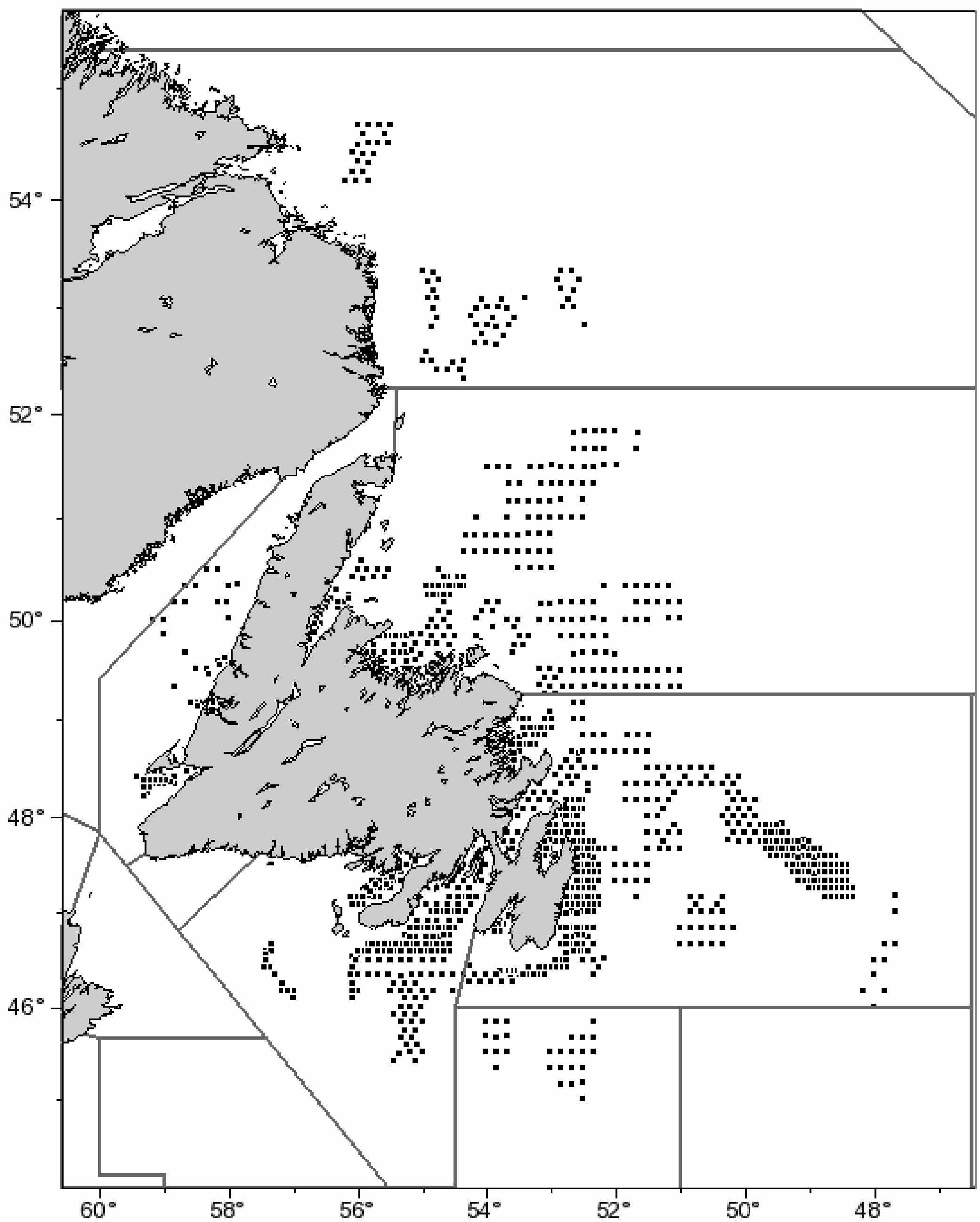


Figure 4.27. CPS Occupied Stations, 2010.

4.4 Seabirds

The Study Area is located over the Sackville Spur projecting off the northeast corner of the Grand Banks. The southeastern half of the Study Area includes the part of the Grand Banks, the Sackville Spur, the northern Flemish Pass and the northwestern slope of the Flemish Pass. Orphan Basin covers about half of the northwestern portion of the Study Area.

A branch of the Labrador Current flows south along the shelf edge off eastern Newfoundland including the Grand Banks. The combination of shelf edge and Labrador Current are prime conditions for productivity of zooplankton, the basis of marine food chains, including those involving seabirds.

4.4.1 Information Sources

The Orphan Basin SEA (LGL 2003) provides summaries of seabird species (see Section 3.2.4) and previously available sighting data for the Study Area and adjacent waters. More recently, exploration and drilling EAs and their amendments for Orphan Basin (LGL 2005–Section 4.7.1; LGL 2009–Section 3.4.2) and Jeanne d'Arc Basin (LGL 2008–Section 4.4) have provided updated information on seabirds. As requested in the Scoping Document, the following "biological background" overview of seabird species likely to occur in the Study Area summarizes and updates relevant information with particular focus on spatial and temporal distribution and life history parameters.

Seabird surveys in the Study Area and surrounding areas have been conducted by the Canadian Wildlife Service (CWS) and during monitoring programs for geophysical surveys. Prior to 2000, seabird data were lacking for the Orphan Basin, northern Grand Banks and Flemish Cap. Original baseline information has been collected in Atlantic Canada by the CWS through PIROP (Programme intégré de recherches sur les oiseaux pélagiques). These data have been published for 1969-1983 (Brown 1986) and up to the early 1990s (Lock et al. 1994). Since the late 1990s additional seabird observations have been collected on the northeast Grand Banks by the offshore oil and gas industry from drill platforms and supply vessels (Baillie et al. 2005; Burke et al. 2005; Fifield et al. 2009). From 2004 to 2007 seabird surveys were conducted from vessels conducting seismic and controlled source electromagnetic (CSEM) surveys in the Orphan Basin and northern Grand Banks as part of marine bird monitoring programs (Lang and Moulton 2004, 2008; Moulton et al. 2005, 2006; Lang et al. 2006; Lang 2007; Abgrall et al. 2008a, 2008b). These surveys took place in the months of May to November. The CWS initiated a program called Eastern Canadian Seabirds at Sea (ECSAS). The Environmental Studies Research Funds (ESRF) combined with CWS to fund a 3.5 year project (2006-2009) focused on improving the knowledge of seabirds at sea on the northern Grand Banks and other areas of oil industry activity in eastern Canada (Fifield et al. 2009). A total of 76 survey trips were made and many included the Grand Banks and Orphan Basin.

The results from all of the above surveys have been used to describe the abundance, diversity and spatial distribution of seabirds in the Study Area. The predicted monthly relative abundance for each species expected to occur regularly in the Study Area are provided in Table 4.8 (later).

4.4.2 Summary of Seabirds in the Study Area

The highly productive Grand Banks supports large numbers of seabirds during all seasons (Lock et al. 1994). During the ECSAS surveys of Newfoundland and Nova Scotia waters, the Sackville Spur, Orphan Basin and Flemish Pass all emerged as important to one or more species/groups in one or more seasons (Fifield et al. 2009). The Orphan Knoll held high numbers of Black-legged Kittiwake during summer. Northern Fulmar and gulls were found in the highest concentrations in the Newfoundland and Labrador Shelves region on the Sackville Spur during spring. Substantial numbers of these birds were also present in winter. Northern Fulmars, Leach's Storm-Petrels and shearwaters were found in summer along the southern edge of the Orphan Basin. ECSAS surveys in the Flemish Pass and Flemish Cap showed local hotspots during winter and spring for Northern Fulmar, Black-legged Kittiwake, Dovekie, gulls (spring only) and murres. Shearwaters were in high densities in summer.

4.4.3 Breeding Seabirds in Eastern Newfoundland

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 of seabirds nest at these three locations alone (see Table A.2 in Appendix A). This includes the largest Atlantic Canada colonies of Leach's Storm-Petrel (3,336,000 pairs on Baccalieu Island; Cairns et al. 1989), Black-legged Kittiwake (23,606 pairs on Witless Bay Islands; Cairns et al. 1989; Stenhouse et al. 2000; Robertson et al. 2002), Thick-billed Murre (1,000 pairs at Cape St. Mary's; Cairns et al. 1989), and Atlantic Puffin (272,729 pairs on Witless Bay Islands; Cairns et al. 1989; Rodway et al. 2003; Robertson et al. 2004). All these birds feed on the Grand Banks during the nesting season from May to September. In addition, Funk Island, 150 km northwest of the Grand Banks supports the largest colony of Common Murre (412,524 pairs) in Atlantic Canada (Chardine et al. 2003). Many of these birds could reach the Study Area in the non-breeding season.

There are nine significant seabird nesting sites on the southeast coast of Newfoundland from Cape Freels to the Burin Peninsula. Each meets the criteria for an Important Bird Area (IBA) (Figure 4.28). An IBA is a site that provides essential habitat for one or more species of breeding or non-breeding birds. These sites may contain threatened species, endemic species, species representative of a biome, or highly exceptional concentrations of birds (www.ibacanada.com). The closest IBA is ~350 km from the Study Area.

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 the summer months after completion of nesting in the Southern Hemisphere. Depending on the species, seabirds require more than one to four years 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. 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.

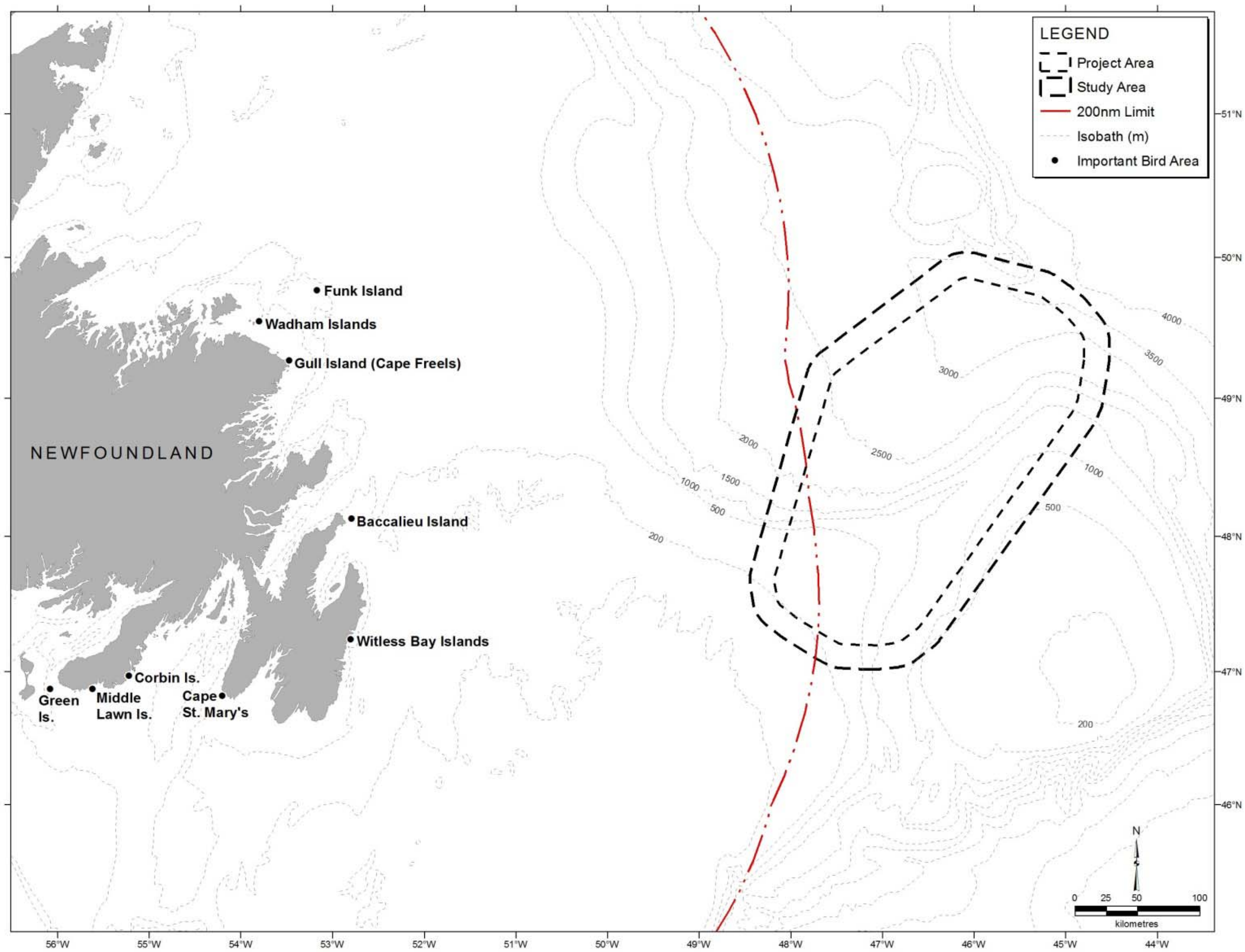


Figure 4.28. Locations of seabird nesting colonies at Important Bird Areas (IBAs) relative to the Study Area.

4.4.4 Seasonal Occurrence and Abundance

The world range and seasonal occurrence and abundance of seabirds occurring regularly in the Project Area are described below. Table 4.8 summarizes the predicted abundance status for each species monthly. The table uses four categories to define a relative abundance of seabirds species observed:

1. *Common* = occurring daily in moderate to high numbers,
2. *Uncommon* = occurring regularly in small numbers,
3. *Scarce* = a few individuals occurring, and
4. *Very Scarce* = very few individuals.

A species world population estimate is taken into consideration when assessing relative abundance; for example, Greater Shearwater is far more numerous on a world wide scale compared to a predator like the Great Skua. Information was derived from Brown (1986), Lock et al. (1994), Baillie et al. (2005), Lang et al. (2006), Moulton et al. (2006), Lang (2007), Abgrall et al. (2008a), and Fifield et al. (2009).

Table 4.8. Predicted monthly abundances of seabird species occurring in the Study Area.

Common Name	Scientific Name	Monthly Abundance											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Procellariidae													
Northern Fulmar	*Fulmarus glacialis*	C	C	C	C	C	C	C	C	C	C	C	C
Greater Shearwater	*Puffinus gravis*					U	C	C	C	C	C	S	
Sooty Shearwater	*Puffinus griseus*					S	S-U	S-U	S-U	S-U	S-U	S	
Manx Shearwater	*Puffinus puffinus*					S	S	S	S	S	S		
Hydrobatidae													
Leach's Storm-Petrel	*Oceanodroma leucorhoa*				U-C	C	C	C	C	C	C	S	
Wilson's Storm-Petrel	*Oceanites oceanicus*						S	S	S	S			
Sulidae													
Northern Gannet	*Morus bassanus*				S	S	S	S	S	S	S		
Phalaropodinae (Scolopacidae)													
Red Phalarope	*Phalaropus fulicarius*					S	S	S	S	S	S		
Red-necked Phalarope	*Phalaropus lobatus*					S	S	S	S	S			
Laridae													
Herring Gull	*Larus argentatus*	U	U	U	U	U	VS	VS	VS	S	S	S	S
Iceland Gull	*Larus glaucoides*	S	S	S	S						S	S	S
Lesser Black-backed Gull	*Larus fuscus*					VS	VS	VS	VS	VS	VS	VS	VS
Glaucous Gull	*Larus hyperboreus*	S	S	S	S						S	S	S
Great Black-backed Gull	*Larus marinus*	U	U	U	U	U	S	S	U	U	U	U	U
Ivory Gull	*Pagophila eburnea*	VS?	VS?	VS?	VS?								
Black-legged Kittiwake	*Rissa tridactyla*	C	C	C	C	C	S	S	S	U	C	C	C
Arctic Tern	*Sterna paradisaea*					S	S	S	S	S			
Stercorariidae													
Great Skua	*Stercorarius skua*					S	S	S	S	S	S		
South Polar Skua	*S. maccormicki*					S	S	S	S	S	S		
Pomarine Jaeger	*S. pomarinus*				S	S	S	S	S	S	S		
Parasitic Jaeger	*S. parasiticus*					S	S	S	S	S	S		
Long-tailed Jaeger	*S. longicaudus*					S	S	S	S	S			
Alcidae													
Dovekie	*Alle alle*	C	C	C	C	U	VS	VS	VS	S	C	C	C
Common Murre	*Uria aalge*	S-U	S-U	S-U	S-U	S	S	S	S	S	S-U	S-U	S-U

Table 4.8 (concluded). Predicted monthly abundances of seabird species occurring in the Study Area.

Common Name	Scientific Name	Monthly Abundance											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thick-billed Murre	*Uria lomvia*	U-C	U-C	U-C	U-C	S	S	VS-S	VS-S	VS-S	U-C	U-C	U-C
Razorbill	*Alca torda*				VS	VS	VS	VS	VS	VS	VS	VS	
Atlantic Puffin	*Fratercula arctica*				S	S	S	S	S	S-U	S-U	S-U	

Notes: C = Common, present daily in moderate to high numbers; U = Uncommon, present daily in small numbers; S = Scarce, present, regular in very small numbers; VS = Very Scarce, very few individuals or absent. Blank spaces indicate not expected to occur in that month. Predicted monthly occurrences derived from 2004, 2005, 2006, 2007 and 2008 monitoring studies in the Orphan Basin and Jeanne d'Arc Basin and extrapolation of marine bird distribution at sea in eastern Canada in Brown (1986); Lock et al. (1994) and Fifield et al. (2009).

Sources: Brown (1986); Lock et al. (1994); Baillie et al. (2005); Moulton et al. (2005b, 2006b); Lang et al. (2006); Lang (2007); Lang and Moulton (2008); Abgrall et al. (2008a, 2008b).

4.4.4.1 Procellariidae (fulmars and shearwaters)

Northern Fulmar

Northern Fulmar is common in the Study Area year round. The Northern Fulmar breeds in the North Atlantic, North Pacific, and Arctic oceans. In the Atlantic Ocean, it winters south to North Carolina and southern Europe. (Brown 1986; Lock et al. 1994). Through band recoveries, it is known that most individuals in Newfoundland waters are from Arctic breeding colonies. Adults and sub-adult birds are present in the winter with sub-adults remaining through the summer. About 80 pairs breed in eastern Newfoundland (Stenhouse and Montevecchi 1999; Robertson et al. 2004). Fulmars were found to be most numerous during spring and autumn 1999 to 2002 on the northeast Grand Banks, based on observations from drill rigs (Baillie et al. 2005). Similar observations were noted for Orphan and Jeanne d'Arc basins (Tables A.3 to A.7 in Appendix A).

ECSAS survey data from 2006-2009 in the Study Area shows Northern Fulmar was present during all seasons (spring, summer and winter) surveyed (Fifield et al. 2009). Densities within the Study Area (considering 1° survey blocks) ranged from 1.0 to 22.4 birds/km^2 in spring to 0 to 10.7 birds/km^2 in summer, and 0 to 33.7 birds/km^2 in winter. High densities were observed along the southern edge of Orphan Basin at the Sackville Spur in winter (Fifield et al. 2009).

Greater Shearwater

Greater Shearwater migrate north from breeding islands in the South Atlantic and arrive in the Northern Hemisphere during summer. A large percentage of the world population of Greater Shearwaters is thought to moult their flight feathers during the summer month while in Newfoundland waters (Brown 1986; Lock et al 1994). Greater Shearwater was among the top four most numerous species observed on the Orphan Basin during seismic monitoring 2004-2007 from June to September (Moulton et al. 2005; Tables A.3 to A.5 in Appendix A). ECSAS survey data from 2006-2009 combines all shearwater species and confirms that within the Study Area shearwaters are common during the summer (Fifield et al. 2009).

Sooty Shearwater

The Sooty Shearwater follows movements similar to Greater Shearwater but is scarce to uncommon during May to early November on the Study Area. Manx Shearwater breeds in the North Atlantic in relatively small world wide numbers compared to Greater Shearwater. It is expected to be scarce in the Study Area during May to October.

4.4.4.2 Hydrobatidae (storm-petrels)

Leach's Storm-Petrel is common in offshore waters of Newfoundland from April to early November. Adults range far from nesting sites on multiday foraging trips during the breeding season. Non-breeding sub-adults stay at sea during the breeding season. Leach's Storm-Petrel is widespread in Newfoundland waters. This species was among the top four most numerous species observed on the Orphan Basin during seismic monitoring 2004-2007 from May to September (Moulton et al. 2005; Tables A.3 to A.5 in Appendix A). Densities of Leach's Storm-Petrels were much lower in the Jeanne d'Arc Basin (in July and

August) vs. Orphan Basin (see Appendix A). ECSAS survey data from 2006-2009 for storm-petrels within the Study Area shows densities per 1º survey blocks ranging from 0 to 5.56 birds/km^2 during the summer period, May to August (Fifield et al. 2009). The highest densities in the Study Area were observed inside the Orphan Basin. Four of five 1º survey blocks on the Sackville Spur and adjacent Grand Banks had densities of zero in the same time period.

The Wilson's Storm-Petrel migrates north from breeding islands in the South Atlantic to the North Atlantic in the summer months. Newfoundland is at the northern edge of its range. It is expected to be scarce in the Study Area from June to September.

4.4.4.3 Sulidae (gannets)

More than 26,000 pairs of Northern Gannets nest on three colonies in eastern Newfoundland (Table A.2 in Appendix A). Gannets are common near shore and scarce beyond 100 km from shore. The Study Area is beyond the range of most Northern Gannets. Very few were observed during seabird monitoring on the Orphan Basin and Jeanne d'arc Basin in 2004-2007 (Tables A.3 to A.7 in Appendix A). This species is expected to be scarce visitor from April to October within the Study Area.

4.4.4.4 Phalaropodinae (phalaropes)

The Red Phalarope and Red-necked Phalarope both breed in the Arctic to sub-Arctic regions of North America and Eurasia. They winter at sea mostly in the Southern Hemisphere. They migrate and feed offshore, including Newfoundland waters during their spring and autumn migrations. Phalaropes seek out areas of upwelling and convergence where rich sources of zooplankton are found. In 2004-2007, very small numbers of migrant Red Phalaropes and Red-necked Phalaropes have been observed in the Orphan Basin and northern Grand Banks during monitoring surveys (Tables A.3 to A.7 in Appendix A). Phalaropes are expected to be scarce in the Study Area during May to October.

4.4.4.5 Laridae (skuas, jaegers, gulls and terns)

Great Skua and South Polar Skua

These two skua species occur regularly but in the very low densities in offshore waters of Newfoundland during the May to October period. The Great Skua breeds in the Northern Hemisphere, in Iceland and northwestern Europe. The South Polar Skua breeds in the Southern Hemisphere from November to March and migrates to the Northern Hemisphere where it is present May to October. Identifying skuas to species is very difficult at sea. They usually occur where other marine birds are numerous, particularly along shelf edges. Skuas occurred in such low densities that they were infrequently recorded during systematic surveys during monitoring programs on the Orphan Basin and Jeanne d'Arc Basin in 2004-2007 (Tables A.3 to A.7 in Appendix A). Skuas are expected to be scarce in the Study Area from May to October, or early November.

Pomarine Jaeger, Parasitic Jaeger and Long-tailed Jaeger

All three species of jaeger nest in the subarctic and 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 Jaegers winter mainly south of the equator. Adults migrate through Newfoundland waters in spring and late summer and fall, while sub-adults migrate only part way to the breeding grounds and are present in Newfoundland waters all summer. Because of the low densities of jaegers they are infrequently recorded during systematic surveys. All three jaeger species were observed in low densities during monitoring programs on the Orphan Basin (Moulton et al. 2005; Tables A.3 to A.5 in Appendix A) and Jeanne d'Arc Basin (Tables A.6 to A.7 in Appendix A). Jaegers are expected to be scarce in the Study Area from May to October or early November.

Great Black-backed, Herring, Glaucous, Iceland and Lesser Black-backed Gull

Great Black-backed Gull, Herring Gull, Iceland Gull, Glaucous Gull and Lesser Black-backed Gull occur in the Study Area. Great Black-backed Gull and Herring Gull are widespread nesters on the north Atlantic including Newfoundland and Labrador. Glaucous Gull and Iceland Gull breed in sub Arctic and Arctic latitudes. They are winter visitors to Newfoundland. Lesser Black-backed Gull is a European gull increasing in numbers as a migrant and wintering species in eastern North America.

Great Black-backed Gull is usually the most numerous of the large gulls found in the offshore regions of Newfoundland. The Sackville Spur has been identified as an area with a high concentration of large gulls, particularly in late winter and early spring (Fifield et al. 2009). On drilling platforms on the northeast Grand Banks during 1999 to 2002, Great Black-backed Gull was common from September to February and nearly absent from March to August (Baillie et al. 2005). A similar pattern was observed by environmental observers on offshore installations on the Terra Nova oil field from 1999 to 2009 (Suncor, unpubl. data). Herring Gulls were present in consistent numbers throughout the year but in lower numbers than Great Black-backed Gulls. Results from seismic monitoring programs in Jeanne d'Arc Basin indicate that large gulls were most numerous from mid August to October (Tables A.6 and A.7 in Appendix A). In the Orphan Basin, highest densities of Great Black-backed Gull occurred in September (Table A.3 and A.4 in Appendix A).

Black-legged Kittiwake

Black-legged Kittiwake is an abundant species in the N Atlantic Ocean. It is a pelagic gull that goes to land only during the nesting season. Non-breeding sub-adults remain at sea for the first year of life. Black-legged Kittiwake is expected to be present within the Study Area year round, and most numerous during the non-breeding season (August to May). 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 during 1999 to 2002 showed Black-legged Kittiwakes were present in October to May, but were most prevalent during November to December (Baillie et al. 2005). It was among the most numerous species observed by environmental observers on offshore installations on the Terra Nova oil field during the winter months (Suncor, unpubl. data).

Results from monitoring programs on the Orphan Basin indicate that Black-legged Kittiwake is uncommon from mid May to September (Moulton et al. 2005; Tables A.3 to A.5 in Appendix A). In the Jeanne d'Arc Basin, highest densities were observed in October and November vs. summer months (Tables A.6 and A.7 in Appendix A). Based on ECSAS survey data collected within the Study Area from 2006-2009, densities of Black-legged Kittiwakes ranged from 0 to 10.22 birds/km^2 during the winter period (November to February) , 0 to 5.83 birds/km^2 during the spring period (March and April), and 0 to 2.03 birds/km^2 during the summer period (May to August; Fifield et al. 2009).

Ivory Gull

The Ivory Gull is listed as *endangered* on Schedule 1 of *SARA* and this species is reviewed in Section 4.6.

Arctic Tern

Arctic Tern is the only species of tern expected in offshore waters of Newfoundland. It breeds in sub-Arctic to Arctic regions of North America and Eurasia. It winters at sea in the Southern Hemisphere. It migrates in small numbers through the Study Area from May to September. The species is present in such low densities that it is rarely recorded during systematic surveys (Appendix A).

4.4.4.6 Alcidae (Dovekie, murres, Black Guillemot, Razorbill and Atlantic Puffin)

There are six species of alcidae breeding in the North Atlantic. All of these except for Dovekie nest in large numbers in eastern Newfoundland (Table A.2 in Appendix A). Dovekies nest mainly in Greenland. Dovekie, Common Murre, Thick-billed Murre and Atlantic Puffin occur in the Study Area during part of the year.

Dovekie

Dovekies breed in the North Atlantic, primarily in Greenland and east Nova Zemlya, Jan Mayen and Franz Josef Land in northern Russia. This species winters at sea south to 35°N. The 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 predicted status in the Study Area is common from October to April, uncommon during the end of spring migration in May and at the beginning of fall migration in September, and very scarce during the summer months (June to August; Tables A.3 to A.6 in Appendix A; Fifield et al. 2009).

Murres

The two species of murre, Common and Thick-billed, are often difficult to identify with certainty at sea so are often grouped as "murres" during offshore seabird surveys. Common Murre is an abundant breeding species in eastern Newfoundland with just over a half million pairs nesting (see Table A.2 in Appendix A). They spend the winter from eastern Newfoundland south to Massachusetts. Thick-billed Murre is an uncommon breeder in eastern Newfoundland. But Newfoundland waters are an important wintering area for many of the two million pairs breeding in Arctic Canada and Greenland.

Murres were present in low densities during May to September in Orphan Basin (Moulton et al. 2005; Tables A.3 to A.5 in Appendix A) and in moderate densities during October and early November in Jeanne d'Arc Basin (Tables A.6 and A.7 in Appendix A). ECSAS survey data from 2006-2009 collected within the Study Area show that murre densities ranged from 0 to 6.65 birds/km^2 (per 1º survey blocks) during the spring period (March and April), 0 to 6.39 birds/km^2 during the summer period (May to August) and 0 to 9.98 birds/km^2 during the winter period (November to February; Fifield et al. 2009).

Other Alcids (Atlantic Puffin, Razorbill and Black Guillemot)

Atlantic Puffins winter off southern Newfoundland and Nova Scotia and they occur in low densities as far offshore as the Study Area. Non-breeding sub-adults occur throughout the summer whereas adults and juveniles can occur in late summer and fall. As expected, very low densities of puffins were recorded during surveys conducted from mid-May to late September in the Orphan and Jeanne d'Arc basins (Tables A.5 to A.7 in Appendix A). Densities of Atlantic Puffins increased in October and November in Jeanne d'Arc Basin (Table A.6 in Appendix A). Within the Study Area, Atlantic Puffin is expected to be scarce during the breeding season (April to August) and scarce to uncommon during the post-breeding season (September to November; Table 4.8). Razorbills tend to occur closer to shore than the murres. Very few were recorded during monitoring programs on the Orphan and Jeanne d'Arc basins in 2004-2007 between mid-May and early-November (Tables A.3 to A.7 in Appendix A). Razorbill is expected to be very scarce in the Study Area during April to November and absent during December to March (Table 4.8). Black Guillemot is common near shore in Newfoundland and Labrador but would not be expected as far offshore as the Study Area.

4.4.5 Prey and Foraging Habits

Seabirds in the Study Area consume a variety of prey ranging from small fish to zooplankton. Different foraging methods include plunge diving from a height of 30 m into the water, feeding on the surface, and sitting on the water then diving. Table 4.9 summarizes the feeding habits of birds expected to occur in the Study Area. This information is of relevance because it provides an indication of the duration seabird species spend below water where they may be exposed to seismic survey sound.

4.4.5.1 Procellariidae (fulmar and shearwaters)

Northern Fulmar and the three species of shearwaters that are expected to occur in the Study Area feed on a variety of invertebrates, fish and zooplankton at or very near the surface. Capelin is an important food source for shearwaters. They secure their prey by swimming on the surface and picking at items on the surface, or dipping their head under the water. Shearwaters are also capable of diving a short distance under the surface, probably no more than a metre 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 4.9. Foraging strategy and prey of seabirds in the Study Area.

Species	Prey	Foraging Strategy	Time with Head Under Water	Depth (m)
Procellariidae				
Northern Fulmar	Fish, cephalopods, crustaceans, zooplankton, offal	Surface feeding	Brief	< 1
Greater Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Sooty Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Manx Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Hydrobatidae				
Wilson's Storm-Petrel	Crustaceans, zooplankton	Surface feeding	Brief	<0.5
Leach's Storm-Petrel	Crustaceans, zooplankton	Surface feeding	Brief	<0.5
Phalaropodinae				
Red Phalarope	Zooplankton, crustaceans	Surface feeding	Brief	0
Red-necked Phalarope	Zooplankton, crustaceans	Surface feeding	Brief	0
Laridae				
Herring Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging, scavenging	Brief	< 0.5
Iceland Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	< 0.5
Glaucous Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging, scavenging	Brief	< 0.5
Great Black-backed Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging, scavenging	Brief	< 0.5
Ivory Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging, scavenging	Brief	< 0.5
Black-legged Kittiwake	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	< 0.5
Arctic Tern	Fish, crustaceans, zooplankton	Surface feeding, shallow plunging	Brief	< 0.5
Stercorariidae				
Great Skua	Fish, cephalopods, offal	Kleptoparasitism	Brief	< 0.5
Pomarine Jaeger	Fish	Kleptoparasitism	Brief	< 0.5
Parasitic Jaeger	Fish	Kleptoparasitism	Brief	< 0.5
Long-tailed Jaeger	Fish, crustaceans	Kleptoparasitism, surface feeding	Brief	< 0.5
Alcidae				
Dovekie	Crustaceans, zooplankton, fish	Pursuit diving	Prolonged	Max 30, average is < 30
Common Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100 , average 20-50
Thick-billed Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100 , average 20-60
Razorbill	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 120, average 25
Atlantic Puffin	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 60, average < 60

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

4.4.5.2 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.

4.4.5.3 Sulidae (Northern Gannet)

Northern Gannet feeds on cephalopods and small fish such as capelin, 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.

4.4.5.4 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. The head probably rarely goes beneath surface.

4.4.5.5 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 is 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 the entire body is rarely 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. Capelin is an important part of their diet when available. They feed by locating prey from the wing then dropping to the 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.

4.4.5.6 Alcidae (Dovekie, murres, Razorbill and Atlantic Puffin)

This group of birds is different than the other seabirds of the Study 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 is expected to be less (Gaston and Jones 1998). Atlantic Puffin will dive to 60 m but 10 to 45 m is thought to be typical. Maximum length of time recorded under water is 115 seconds but a more typical dive would be about 30 seconds.

4.5 Marine Mammals and Sea Turtles

4.5.1 Marine Mammals

A total of 20 marine mammals, including 17 cetacean and three seal species are known or expected to occur in the Study Area (see Table 4.10 later). Most marine mammals use the Study Area seasonally, and the region likely represents important foraging areas for many.

4.5.1.1 Information Sources

Much of the information on marine mammal occurrence and abundance in the Study Area is based upon the results of marine mammal monitoring for seismic and controlled source electromagnetic surveys in Orphan and Jeanne d'Arc basins (Moulton et al. 2005, 2006; Abgrall et al. 2008a,b). There are also sighting data (incidental and systematic) compiled by DFO (see below). The Orphan Basin SEA (LGL 2003) provides summaries of marine mammal species (see Section 3.2.5) and previously available sighting data for the Study Area and adjacent waters. More recently, exploration and drilling EAs and their amendments for Orphan Basin (LGL 2005–Section 4.8.1; LGL 2009–Section 3.4.1) and Jeanne d'Arc Basin (LGL 2008–Section 4.5) have provided updated information on marine mammals. As requested in the Scoping Document, the following "biological background" overview of marine mammal species likely to occur in the Study Area summarizes and updates relevant information with particular focus on spatial and temporal distribution and life history parameters.

DFO Cetacean Database.—A large database of cetacean sightings in Newfoundland and Labrador waters has been compiled by DFO in St. John's (J. Lawson, DFO Research Scientist, pers. comm.) and has also been made available for the purposes of describing cetacean sightings within the Study Area. These data can be used to indicate what species have occurred in the region, but cannot typically provide fine-scale descriptions or predictions of abundance or distribution. The DFO database also includes marine mammal sightings collected as part of Chevron's 2004 and 2005 seismic monitoring programs in Orphan Basin.

As noted by DFO, a number of *caveats* should be considered when using the DFO cetacean sighting data, and include:

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 abundance for an area),
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 and seasons. Effort (and number of sightings) is not necessarily consistent among months, years, and areas. There are large gaps between years. Thus seasonal, depth, and distribution information should be interpreted with caution, and
8. Many sightings could not be identified to species, but are listed to the smallest taxonomic group possible.

4.5.1.2 Overview of Marine Mammals

As noted earlier, a total of 20 marine mammals, including 17 cetacean and three seal species are known or expected to occur in the Study Area (Table 4.10). Several cetaceans are considered at risk by COSEWIC and listed under the *SARA*. Those species listed under Schedule 1 of *SARA* are described in Section 4.6.

A summary of the prey of marine mammals that occur in the Study Area is summarized in Table 4.14 in LGL (2008). For most species of marine mammals there are no reliable population estimates for Atlantic Canada; most estimates are based on data collected in northeastern U.S. waters. The following website: http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2010_draft_summary.pdf was reviewed to acquire updated population estimates for cetaceans considered a part of the Western North Atlantic stock.

Results from DFO Cetacean Database.—The summary of sightings below combines the data sources described above as well as historical and new sightings from commercial whaling, fisheries observers, MMOs aboard seismic vessels, and the general public. Within the Study Area, sighting dates ranged from 1961 to 2009 and included baleen whales (Figure 4.29), large toothed whales (Figure 4.30), and dolphins and porpoises (Figure 4.31). These data are summarized in Table 4.11.

4.5.1.3 Baleen Whales (Mysticetes)

Six species of baleen whales occur in the Study Area, four of which are considered regular visitors (Table 4.10). Blue whales are considered rare and North Atlantic right whales are considered extremely rare in the Study Area; these species are described in the Species at Risk section (Section 4.6). Although some individual baleen whales may be present in offshore waters of Newfoundland and Labrador year-round, most baleen whale species presumably migrate to lower latitudes during winter months.

Table 4.10. Marine mammals known or expected to occur in the northern Grand Banks Study Area.

Common Name	Study Area		Habitat	*SARA* Status [a]	COSEWIC Status [b]
	Occurrence	Season			
Baleen Whales (Mysticetes)					
Blue whale (*Balaenoptera musculus*)	Rare	Year-round but mostly spring to summer	Coastal, pelagic	Schedule 1: Endangered	Endangered
North Atlantic right whale (*Eubalaena glacialis*)	Extremely Rare	Summer?	Coastal, shelf	Schedule 1: Endangered	Endangered
Fin whale (*B. physalus*)	Common	Year-round but mostly summer	Pelagic, slope	Schedule 1: Special Concern	Special Concern
Sei whale (*B. borealis*)	Uncommon	May - Sept.	Pelagic, offshore	No Status	Data Deficient
Humpback whale (*Megaptera novaeangliae*)	Common	Year-round but mostly May - Oct.	Coastal, banks	Schedule 3: Special Concern	Not at Risk
Minke whale (*B. acutorostrata*)	Common	Year-round but mostly May - Oct.	Shelf, banks, coastal	No Status	Not at Risk
Toothed Whales (Odontocetes)					
Sperm whale (*Physeter macrocephalus*)	Uncommon to Common	Year-round but mostly summer	Pelagic, slope, canyons	No Status	Not at Risk; Low priority candidate
Northern bottlenose whale (*Hyperoodon ampullatus*)	Uncommon	Year-round?	Pelagic, slope, canyons	No Status	Not at Risk
Sowerby's beaked whale (*Mesoplodon bidens*)	Rare	Summer?	Pelagic, deep slope, canyons	Schedule 3: Special Concern	Special Concern
Killer whale (*Orcinus orca*)	Rare	Year-round but mostly June-Oct.	Widely distributed	No Status	Special Concern
Long-finned pilot whale (*Globicephala melas*)	Common	May - Sept.	Mostly pelagic	No Status	Not at Risk
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Common	Year-round but mostly June-Oct.	Shelf, slope	No Status	Not at Risk

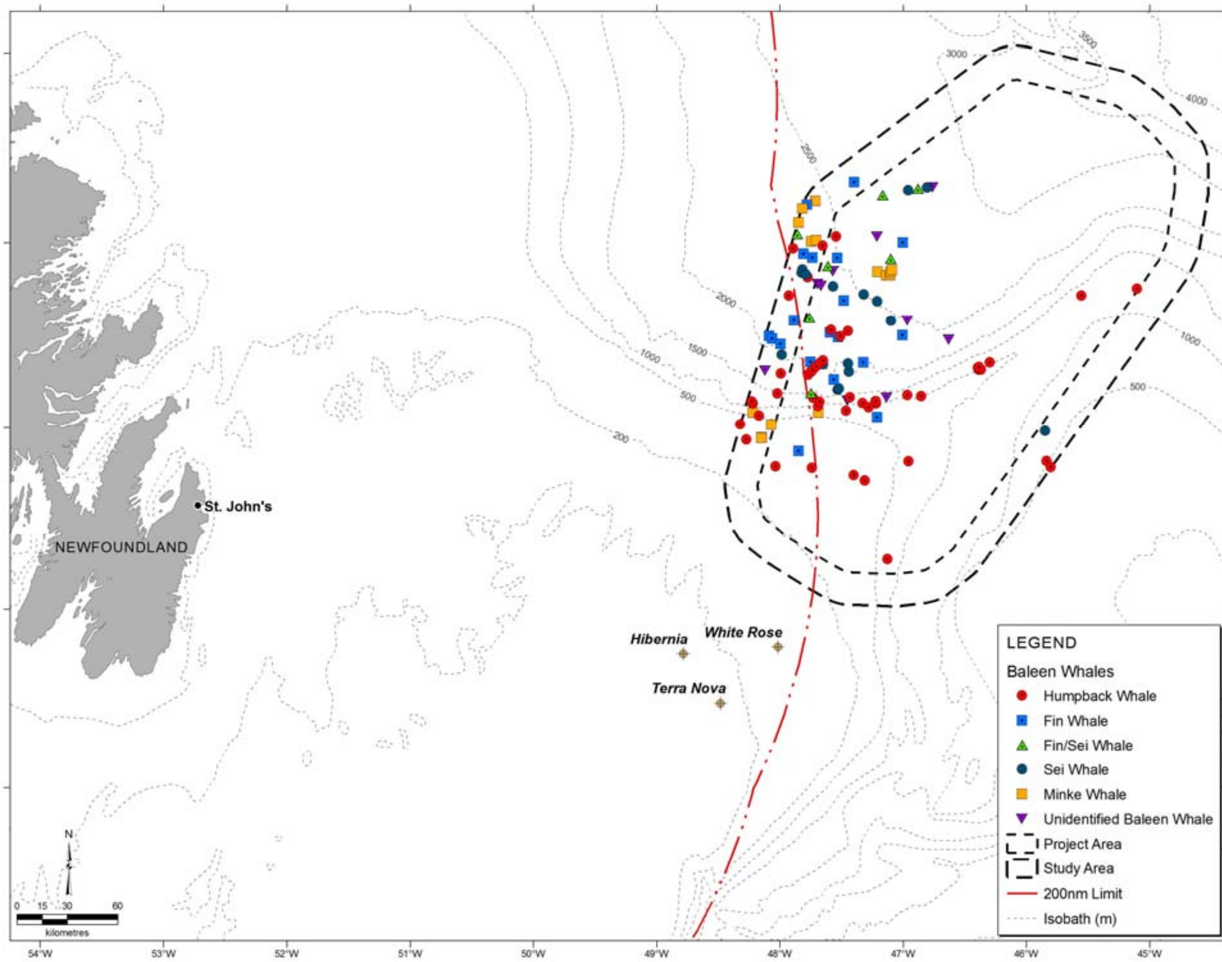
Table 4.10 (concluded). Marine mammals known or expected to occur in the northern Grand Banks Study Area.

Common Name	Study Area		Habitat	*SARA* Status [a]	COSEWIC Status [b]
	Occurrence	Season			
Baleen Whales (Mysticetes)					
Short-beaked common dolphin (*Delphinus delphis*)	Common	Summer-fall	Nearshore, pelagic	No Status	Not at Risk
White-beaked dolphin (*L. albirostris*)	Uncommon	Year-round but mosty June-Sept.	Shelf	No Status	Not at Risk
Common bottlenose dolphin (*Tursiops truncatus*)	Rare	Summer?	Shelf, coastal, pelagic (occasionally)	No Status	Not at Risk
Striped dolphin (*Stenella coeruleoalba*)	Uncommon	Summer?	Offshore convergence zones and upwellings	No Status	Not at Risk
Harbour porpoise (*Phocoena phocoena*)	Uncommon	Year-round but mostly spring to fall	Shelf, coastal, pelagic (occasionally)	Schedule 2: Threatened	Special Concern
True Seals (Phocids)					
Harp seal (*Pagophilus groenlandicus*)	Common	Year-round	Pack ice and pelagic	No Status	Not considered; Low priority candidate
Hooded seal (*Cystophora cristata*)	Common	Year-round	Pack ice and pelagic	No Status	Not at Risk; Low priority candidate
Grey seal (*Halichoerus grypus*)	Rare	Year-round	Coastal and continental shelf	No Status	Not at Risk

Notes: ? indicates uncertainty. [a] www.sararegistry.gc.ca/default_e.cfm, accessed February 2011.
[b] www.cosewic.gc.ca/eng/sct5/index_e.cfm, accessed February 2011.

Fin Whale

The Atlantic population of fin whale is currently designated as *special concern* under Schedule 1 of *SARA* and by COSEWIC (Table 4.13). Fin whales are distributed throughout the world's oceans, but are most common in temperate and polar regions (Jefferson et al. 2008). Fin whales were heavily targeted by commercial whalers in Newfoundland and Labrador, and the current estimate for the western North Atlantic stock is 3,985 individuals (CV = 0.24; SAR 2010). Fin whales continue to regularly occur in Newfoundland and Labrador waters, particularly during summer months. Based on the DFO cetacean sightings database, fin whales have been sighted throughout the Study Area (Figure 4.29) and from May



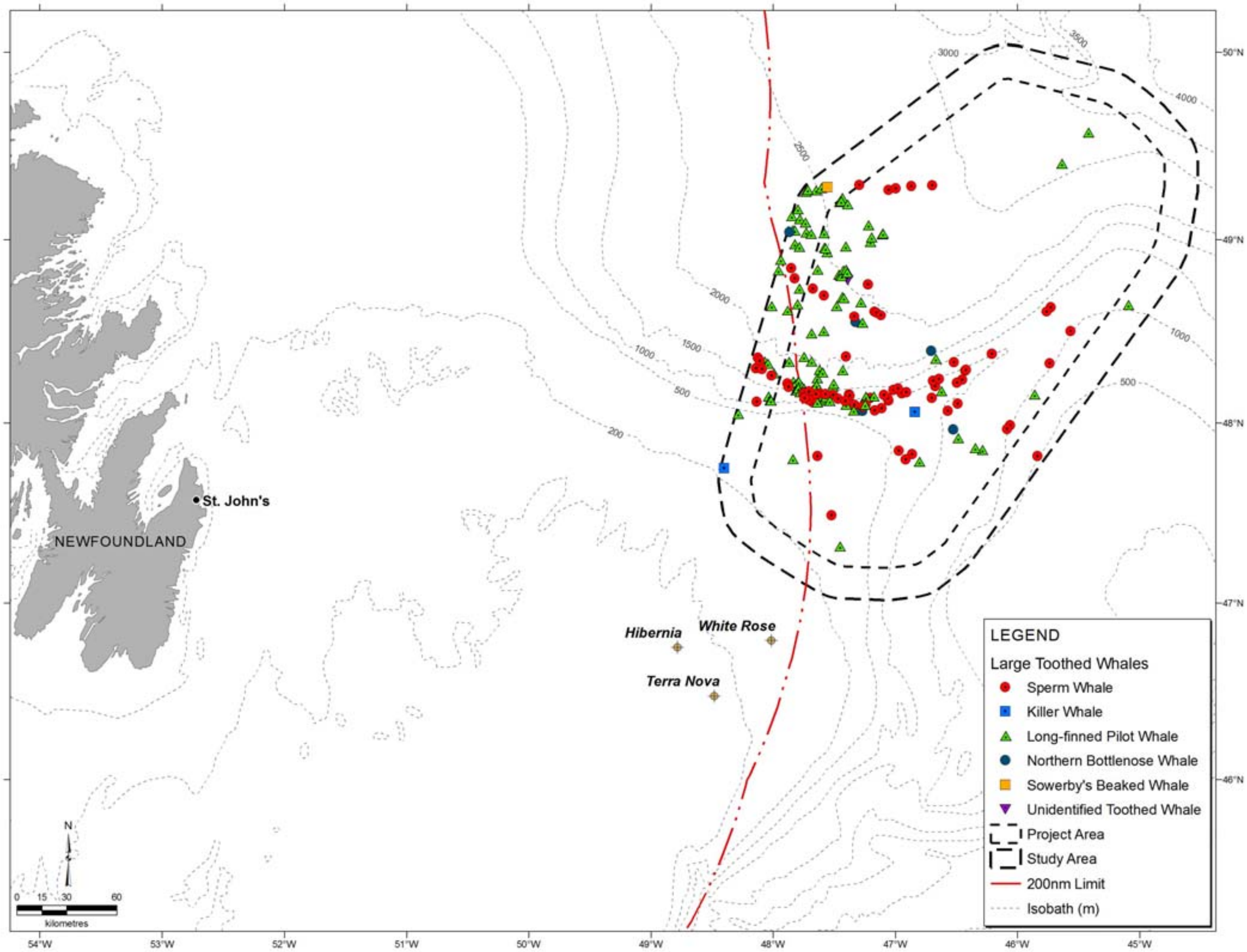
Source: DFO cetacean sightings database, see text for description of data and *caveats* associated with these data.

Figure 4.29. Baleen whale sightings in the Study Area.

to September (Table 4.11). Fin whales were commonly observed in Orphan Basin during the 2004 and 2005 seismic monitoring programs (Moulton et al. 2005, 2006). They feed on small schooling fish and krill and tend to be found in areas where these prey concentrate, such as in areas of upwelling, shelf breaks, and banks (COSEWIC 2005). It is likely that fin whales commonly occur in the Study Area at least during late spring to fall.

Humpback Whale

The humpback whale is cosmopolitan in distribution and is most common over the continental shelf and in coastal areas (Jefferson et al. 2008). There are an estimated 11,570 individuals in the N Atlantic (Stevick et al. 2003). Based on aerial surveys conducted off the south and northeast coast of Newfoundland, an estimated 1,427 humpback whales occur there (Table 6 *in* Lawson and Gosselin 2009). In eastern Canada, humpback whales are considered *special concern* on Schedule 3 of the *SARA* and are considered *not at risk* by COSEWIC. Humpback whales migrate annually from high-latitude summer foraging areas to Caribbean breeding grounds in the winter. Primary feeding areas in the N Atlantic have been described using genetic and individual identification data as the Gulf of Maine,



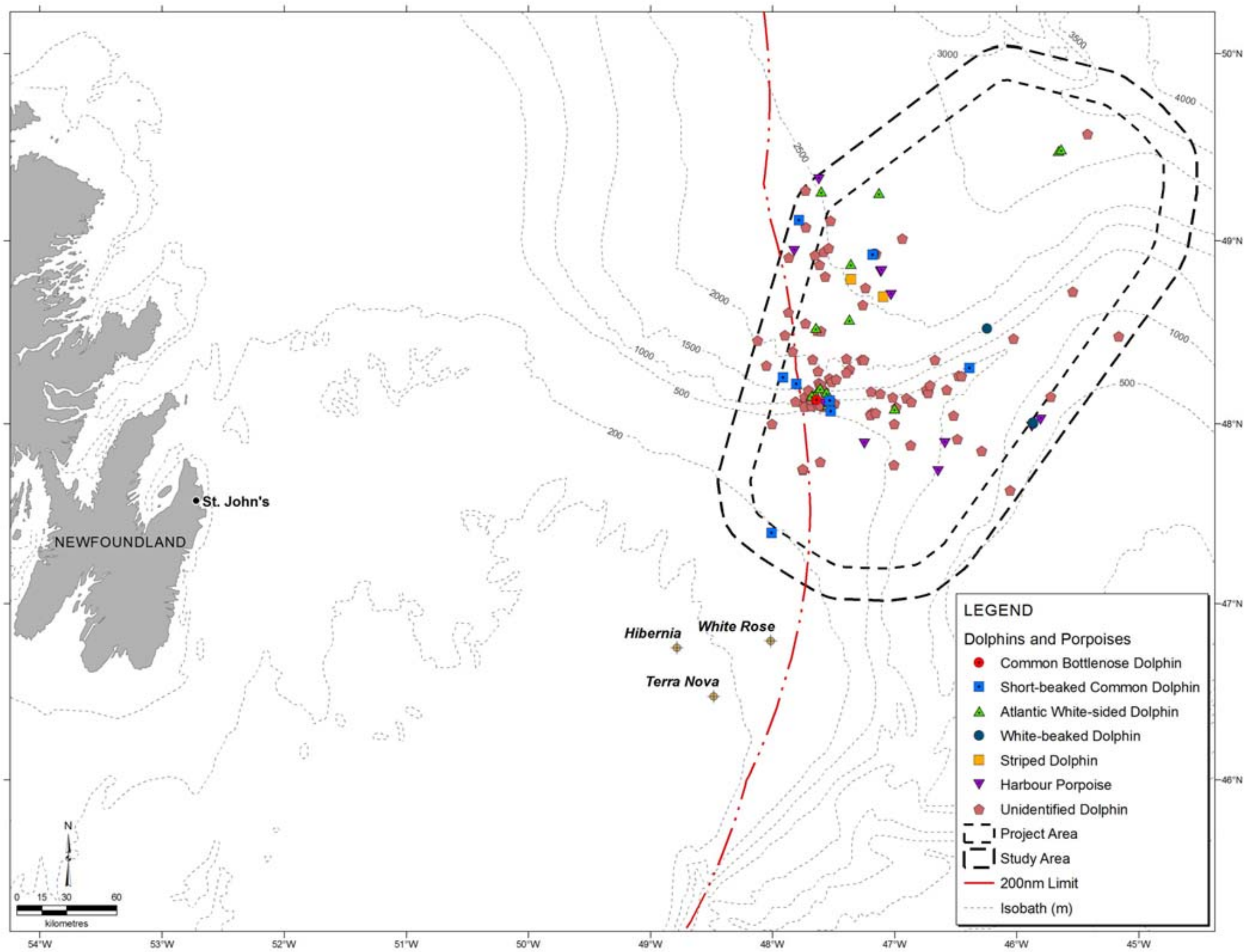
Source: DFO cetacean sightings database, see text for description and *caveats* associated with these data.

Figure 4.30. Large toothed whale sightings in the Study Area.

eastern Canada, west Greenland, and the NE Atlantic (Stevick et al. 2006). Humpback whales are common over the banks and nearshore areas of Newfoundland and Labrador from June through September, sometimes forming large aggregations to feed primarily on spawning capelin, sand lance, and krill. Humpbacks are the most commonly recorded mysticete in the Study Area, with sightings occurring year-round (Table 4.11), but predominantly during summer. Clapham et al. (1993) note that not all individuals migrate to the tropics each year; some presumably remain near their foraging grounds in high and mid latitudes during the winter.

Sei Whale

Sei whale distribution is poorly known, but it occurs in all oceans and appears to prefer mid latitude temperate waters (Jefferson et al. 2008). In the Canadian Atlantic, sei whales have no status under *SARA* and are considered *data deficient* by COSEWIC. Two stocks of sei whales are currently considered to occur in eastern Canada, on the Scotian Shelf and in the Labrador Sea, although there is limited evidence supporting the definition of the Labrador Sea stock (COSEWIC 2003b). The best



Source: DFO cetacean sightings database, see text for description and *caveats* associated with these data.

Figure 4.31. Dolphin and porpoise sightings in the Study Area.

estimate of abundance for the Nova Scotia stock of sei whales is 386 (CV=0.85; SAR 2010). Sei whales were regularly sighted in the Orphan Basin during the Chevron seismic monitoring programs in 2004 and 2005 (6 and 15 sightings, respectively; Moulton et al. 2005, 2006). Based on the DFO cetacean sightings database, seven sei whale sightings have been reported in the Study Area (Table 4.11). Sei whales appear to prefer offshore, pelagic, deep areas that are often associated with the shelf edge, and feed primarily on copepods (COSEWIC 2003b).

Minke Whale

The smallest of the baleen whales, minke whales have a cosmopolitan distribution and use polar, temperate, and tropical regions (Jefferson et al. 2008). Minke whales have no status under *SARA* and are considered *not at risk* in the Atlantic by COSEWIC. There are four populations recognized in the N Atlantic, including the Canadian east coast, west Greenland, central N Atlantic, and NE Atlantic stocks (Waring et al. 2009). There are an estimated 8,987 individuals (CV=0.32) in the Canadian east coast

Table 4.11 Cetacean sightings that occurred within the offshore CCL Study Area, dating from 1961 to 2009.

Species	Number of Sightings	Minimum Number of Individuals	Months Observed
Mysticetes			
North Atlantic right whale	1	2	June
Humpback whale	50	101	Jan-Feb; May-Sep; Nov
Fin whale	19	30	May-Sep
Sei/fin whale	7	8	Jul-Sep
Sei whale	16	25	May-Sep
Minke whale	15	15	Jan; Jul-Sep; Nov
Large Odontocetes			
Sperm whale	87	170	Year round
Killer whale	2	4	Jun
Long-finned pilot whale	112	2,869	Jan-Feb; May-Dec
Northern bottlenose whale	5	19	May-Jul; Sep
Sowerby's beaked whale	1	4	Sep
Dolphins and Porpoises			
Common bottlenose dolphin	1	15	Sep
Short-beaked dolphin	8	82	Jul-Oct
Atlantic white-sided dolphin	17	234	Feb; May-Jul; Sep
White-beaked dolphin	5	26	Mar; Jun-Jul
Striped dolphin	2	15	Aug
Harbour porpoise	11	25	May-Sep
Unidentified Cetaceans			
Unidentified baleen whale	11	19	May-Sep
Unidentified toothed whale	1	3	Aug
Unidentified whale	3	22	Aug
Unidentified dolphin	87	1,863	Year round
Unidentified cetacean	159	292	Year round

stock, which ranges from the continental shelf of the northeastern United States to the eastern half of Davis Strait (SAR 2010). Minke whales are common over the banks and coastal regions of Newfoundland and Labrador from early spring to fall, arriving as early as April and remaining as late as October and November. Within the Study Area, minke whales were the fourth most commonly recorded mysticete in the DFO sightings database, with sightings predominantly recorded during summer months (Table 4.11). Minke whales tend to forage in continental shelf waters on small schooling fish like capelin and sand lance, making relatively short duration dives (Stewart and Leatherwood 1985).

4.5.1.4 Toothed Whales (Odontocetes)

Eleven species of toothed whales occur in the Project Area (see Table 4.10), ranging from the largest of odontocetes, the sperm whale, to the one of the smallest, the harbour porpoise. Many of these species seem to be present in the Study Area only seasonally, but there is generally little information on the distribution and abundance of these species.

Sperm Whale

The sperm whale is most common in tropical and temperate waters, but is widely distributed and occurs from the edge of the polar pack ice to the equator (Jefferson et al. 2008). Sperm whales have no status under *SARA* and are designated *not at risk* by COSEWIC. They are currently considered a *low priority candidate species* by COSEWIC. Whitehead (2002) estimated a total of 13,190 sperm whales for the Iceland-Faroes area, the area north of it, and the east coast of North America combined, but Waring et al. (2009) reported an estimate of 4,804 animals (CV=0.38) for the N Atlantic. Since males tend to range further north (Whitehead 2003), sperm whales encountered in the Study Area are more likely to be single males. However, mixed groups with females and juveniles have occasionally been observed in higher latitudes and males can still form large same-sex aggregations (Whitehead and Weilgart 2000; Whitehead 2003). Sperm whales appear to prefer deep waters off the continental shelf, particularly areas with high secondary productivity, steep slopes, and canyons that may concentrate their primary prey of large-bodied squid (Jaquet and Whitehead 1996; Waring et al. 2001). Sperm whales are deep divers, routinely diving to hundreds of metres, sometimes to depths over 1,000 m and remaining submerged up to an hour (Whitehead and Weilgart 2000). Sperm whales were regularly sighted in the deep waters of Orphan Basin during the summers of 2004-2007 (Moulton et al. 2005, 2006; Abgrall et al. 2008b) but were not observed in the shallower waters of Jeanne d'Arc Basin in 2005-2007 (Lang et al. 2006; Abgrall et al. 2008a; Lang and Moulton 2007). There are 87 sightings of sperm whales reported in the DFO cetacean sightings database that occurred in the Study Area (Table 4.11); these sightings occurred year-round.

Northern Bottlenose Whale

The distribution of northern bottlenose whales is restricted to the N Atlantic, primarily in deep, offshore areas with two regions of concentration: The Gully and adjacent submarine canyons on the eastern Scotian Shelf, and Davis Strait off northern Labrador (Reeves et al. 1993). Throughout their range, northern bottlenose whales were harvested extensively during industrial whaling, which likely greatly reduced total numbers (COSEWIC 2002b). The total abundance of northern bottlenose whales in the N Atlantic is unknown, but ~163 individuals comprise the Scotian Shelf population (Whitehead and Wimmer 2005). Although the Scotian Shelf population is designated *endangered* under Schedule 1 of *SARA* and by COSEWIC, the Davis Strait population has no status under *SARA* and is considered *not at risk* by COSEWIC. It is expected that northern bottlenose whales in the Study Area belong to the Davis Strait population. This population is considered to occur in the area year-round, with mating and births occurring in April (COSEWIC 2002b). Occurring primarily in deep waters over canyons and the shelf edge, northern bottlenose whales routinely dive to depths over 800 m and remained submerged for over an hour (Hooker and Baird 1999). Foraging apparently occurs at depth, primarily on deep-water squid and fish (COSEWIC 2002b). Northern bottlenose whales may occur at low densities, but year-round, throughout the deep, offshore waters of the Orphan Basin. Based on the DFO cetacean sightings database, there have been five sightings of northern bottlenose whales in the deeper waters of the Study Area (Figure 4.30) from May to September (Table 4.11). This species is not expected to occur in the shelf waters of the Study Area.

Sowerby's Beaked Whale

The Sowerby's beaked whale is a small beaked whale found only in the N Atlantic, primarily in deep, offshore temperate to subarctic waters (COSEWIC 2006c). Designated as *special concern* (Schedule 3) under *SARA* and by COSEWIC, it is unclear if Sowerby's beaked whales are uncommon or poorly surveyed due to their deep-diving behaviour, small size, and offshore habitat. It is the most northerly distributed of the *Mesoplodon* spp., with all but one record occurring in the NW Atlantic between New England and Labrador (MacLeod 2000; MacLeod et al. 2006). There are an unknown number of Sowerby's beaked whales in the N Atlantic, but they are occasionally encountered offshore of eastern Newfoundland and Labrador. One Sowerby's beaked whale sighting was recorded in the Study Area (Figure 4.31) based on the DFO cetacean sightings database (Table 4.11). They are most often observed in deep water, along the shelf edge and slope. Based on analysis of stomach contents, they appear to prefer mid to deep-water fish and squid (MacLeod et al. 2003). Despite the paucity of confirmed sightings, Sowerby's beaked whales may occur in low densities in deep areas in the Study Area.

Killer Whale

Killer whales have a cosmopolitan distribution and occur in all oceans from polar pack ice to the equator, but they appear to be most common in coastal areas of higher latitudes (Jefferson et al. 2008). Killer whales offshore of eastern Newfoundland are likely members of the eastern Arctic or Atlantic populations, which were recently categorized as *special concern* by COSEWIC but have no status under *SARA*. An unknown number of killer whales occur in the NW Atlantic, but at least 63 individuals have been identified in NL (Lawson et al. 2007). Killer whale movements are generally related to the distribution and abundance of their primary prey, which can include fish, other marine mammals, seabirds, and cephalopods (Ford et al. 2000). In NL, killer whales have been observed approaching, attacking, and/or consuming other cetaceans, seals, seabirds and several species of fish; however, it is not known if there is any prey specialization among killer whale groups or individuals (Lawson et al. 2007). Observed group sizes range from 1 to 60 individuals, averaging 5.1 whales (Lawson et al. 2007). Although they occur at relatively low densities, killer whales are considered year-round residents of NL (Lien et al. 1988; Lawson et al. 2007). Sightings seem to be increasing in recent years, but it is unclear if this is due to increasing abundance or observer effort. There were two killer whale sightings in the Study Area (Figure 4.31), based on sightings in the DFO cetacean sightings database; both occurred in June (Table 4.11).

Long-finned Pilot Whale

The long-finned pilot whale is widespread in the N Atlantic and considered an abundant year-round resident of Newfoundland and Labrador (Nelson and Lien 1996). Long-finned pilot whales have no status under *SARA* and are considered *not at risk* by COSEWIC (Table 4.10). An estimated 12,619 individuals (CV=0.37) occur in the NW Atlantic (SAR 2010). Long-finned pilot whales were the most commonly recorded toothed whale in the DFO cetacean database, occurring most months of the year (Table 4.11) and primarily in waters >500 m deep in the Study Area (Figure 4.30). Pilot whales studied near Nova Scotia have an average group size of 20 individuals, but groups ranged in size from 2 to 135 animals (Ottensmeyer and Whitehead 2003). Pilot whale distribution is linked with areas of high relief, the shelf break, or slope, and they often exhibit inshore-offshore movements coinciding with movements of their prey (Jefferson et al. 2008). Short-finned squid have historically been the primary prey item in Newfoundland, but they also consume other cephalopods and fish (Nelson and Lien 1996).

Atlantic White-sided Dolphin

Atlantic white-sided dolphins occur in temperate and sub-Arctic regions of the N Atlantic (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (Table 4.10). There may be at least three distinct stocks in the N Atlantic, including the Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea areas, which combined are estimated to total ~63,368 animals (CV=0.27) in the NW Atlantic (SAR 2010). However, their abundance off NL is unknown. Atlantic white-sided dolphins occur regularly from spring to fall in offshore areas of Newfoundland, but less is known of their winter distribution. Sightings in the N Atlantic seem to coincide with the 100 m depth contour and areas of high relief; there were 17 sightings in the DFO cetacean sightings database (Table 4.11), all in water >500 m deep (Figure 4.31). Prey items range from cephalopods to pelagic or benthopelagic fishes like capelin, herring, hake, sand lance, and cod (Selzer and Payne 1988). Off New England, calving occurs from May to August and Atlantic white-sided dolphins tend to occur in large groups ranging from 2 to 2500 individuals and averaging 52.4 (Weinrich et al. 2001).

Short-beaked Common Dolphin

The short-beaked common dolphin is an oceanic species that is widely distributed in temperate to tropical waters of the Atlantic (and Pacific) Ocean (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (Table 4.10). An estimated 120,743 individuals (CV=0.23) occur in the NW Atlantic (SAR 2010). There were eight sightings of this species recorded in the Study Area in the DFO database (Table 4.11); with the exception of one sighting on the shelf, all other sightings were in waters >500 m deep (Figure 4.31).

White-beaked Dolphin

White-beaked dolphins have a more northerly distribution than most dolphin species, occurring in cold temperate and sub-Arctic waters of the N Atlantic (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (Table 4.10). Waring et al. (2009) estimated a total of 2003 individuals (CV=0.94) in the NW Atlantic, but it is unknown how many occur off northeastern Newfoundland. Sightings of white-beaked dolphins are considered uncommon in the Study Area. There were five sightings recorded in the Study Area (Table 4.11) in waters >1000 m (Figure 4.31) based on the DFO cetacean database. White-beaked dolphins are thought to remain at high latitudes year-round and are generally observed in continental shelf and slope areas, although they also occur in shallow coastal areas (Lien et al. 1997). They typically occur in groups of less than 30 animals, but group sizes up to the low hundreds have also been reported (Lien et al. 1997). White-beaked dolphins have a range of prey items, including squid, crustaceans, and a number of small mesopelagic and schooling fishes like herring, haddock, hake, and cod (Jefferson et al. 2008).

Common Bottlenose Dolphin

This species is very widely distributed and are found most commonly in coastal and continental shelf waters of tropical and temperate regions (Jefferson et al. 2008). Bottlenose dolphins have no status under *SARA* and are considered *not at risk* by COSEWIC (Table 4.10). An estimated 81,588 individuals (CV=0.17) occur in the NW Atlantic (SAR 2010). It is considered rare in the Study Area; there was only one sighting of bottlenose dolphins (15 individuals) in the DFO cetacean database (Table 4.11). It was made in September 2005 during the Chevron seismic monitoring program in the Orphan Basin (Moulton et al. 2006).

Striped Dolphin

The striped dolphin 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). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (Table 4.10). Offshore waters of Newfoundland are thought to be at the northern limit of its range. An estimated 94,462 individuals (CV=0.40) occur in the NW Atlantic (SAR 2010). There were only two sightings of this species recorded in the Study Area based on the DFO cetacean database; both occurred in August (Table 4.11).

Harbour Porpoise

Harbour porpoises occur in continental shelf regions of the northern hemisphere, including from Baffin Island to New England in the NW Atlantic (Jefferson et al. 2008). There are at least three populations recognized in the NW Atlantic: eastern Newfoundland and Labrador, the Gulf of St. Lawrence, and the Gulf of Maine/Bay of Fundy (Palka et al. 1996). There are currently no range-wide population estimates for eastern Canada, largely due to a lack of any estimates for the Newfoundland and Labrador sub-population (COSEWIC 2006b). In the Atlantic, harbour porpoises are considered *threatened* (Schedule 2) on *SARA* and of *special concern* by COSEWIC. Limited information is available regarding distribution and movements of harbour porpoises in NL. Data on harbour porpoises incidentally caught in groundfish gillnets suggest that they occur around the entire island of Newfoundland and in southern Labrador (Lawson et al. 2004); bycatch data also indicate that harbour porpoises occur over the continental shelf and as far north as Nain and in the Labrador Sea (Stenson and Reddin 1990 *in* COSEWIC 2006b). In general, harbour porpoises are primarily observed over continental shelves and in areas with coastal fronts or upwelling that concentrate small schooling fish, although sightings also occasionally occur in deeper waters (Read 1999). Bycaught porpoises in Newfoundland appear to primarily consume capelin, Atlantic herring, sand lance, and lantern fish (COSEWIC 2006b). Harbour porpoises typically occur singly or in small groups of up to three individuals, occasionally occurring in larger groups (COSEWIC 2006b). There were eleven harbour porpoise sightings in the Study Area in the DFO cetacean sightings database (Table 4.11; Figure 4.31).

4.5.1.5 True Seals (Phocids)

Three species of seals including harp, hooded, and perhaps grey seals occur in the Project Area (Table 4.10). None of these species are designated under *SARA* or by COSEWIC.

Harp Seal

Harp seals are widespread in the North Atlantic and Arctic Ocean, ranging from northern Hudson Bay and Baffin Island to the western North Atlantic and the Gulf of St. Lawrence; vagrants have been reported as far south as Virginia (Scheffer 1958; Rice 1998). The total NW Atlantic population is estimated at 6.85 million seals in 2009 (Hammill and Stenson 2010). Harp seals are common during spring off northeast Newfoundland and southern Labrador where they congregate to breed and pup on the pack ice; the majority of the NW Atlantic population uses this region while the small remainder uses the Gulf of St. Lawrence (Lavigne and Kovacs 1988). Harp seals migrate to Arctic and Greenland waters during summer, while offshore areas of southern Labrador and eastern Newfoundland appear to be major wintering areas (Stenson and Sjare 1997; Lacoste and Stenson 2000). Off NL, harp seal diets are composed of capelin, Arctic cod, sand lance, herring, Atlantic cod, redfish, and Greenland halibut (Hammill and Stenson 2000).

Hooded Seal

Hooded seals are found in the N Atlantic, ranging from Nova Scotia to the high Arctic in Canada (Jefferson et al. 2008). There are an estimated 593,500 individuals in the Canadian Atlantic, the majority of which (~535,800 animals) whelp and breed in the pack ice off northeast Newfoundland/southern Labrador in late winter-early spring (Hammill and Stenson 2006). Four primary pupping and mating areas occur in the N Atlantic and include northeast Newfoundland/southern Labrador, the Gulf of St. Lawrence, Davis Strait, and northeast Greenland (Jefferson et al. 2008). Hooded seals aggregate in eastern Greenland to moult during early summer before dispersing to Davis Strait or the Greenland Sea for late summer and fall (see Hammill and Stenson 2006). Less is known about winter distribution, although there have been winter sightings on the Grand Banks; recent telemetry data suggests that hooded seals move along the continental shelf edge after leaving Greenland moulting grounds to Davis Strait and Baffin Bay followed by southerly migrations into the Labrador Sea during winter (Andersen et al. 2009). Hooded seals consume benthic invertebrates like shrimp, Greenland halibut, redfish, Arctic cod, and squid (Hammill and Stenson 2000).

Grey Seal

Grey seals inhabit cold temperate to sub-Arctic regions of the N Atlantic, ranging in Canada from Nova Scotia to Labrador (Jefferson et al. 2008). An estimated ~300,000 grey seals occur in the NW Atlantic, with the majority breeding and moulting on Sable Island, south of Nova Scotia, over the winter and spring, respectively (Thomas et al. 2007). An unknown number range into eastern NL. Although generally coastal, grey seals forage over the continental shelf and consume primarily herring, Atlantic cod, and sand lance (Lesage and Hammill 2001). Grey seals are considered rare in the Study Area.

4.5.2 Sea Turtles

Sea turtles regularly occur on the Grand Banks and adjacent waters; three species could potentially occur within the Study Area. Table 4.12 provides a summary of habitat, occurrence and status in the Project Area for leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and Kemp's Ridley sea turtles (*Lepidochelys kempii*). Of these species, the leatherback sea turtle is designated as *endangered* under COSEWIC and *SARA* (Table 4.12; see Section 4.6 on Species at Risk for profile) and the loggerhead sea turtle is designated as *endangered* under COSEWIC and has no status under the *SARA*. Kemp's Ridley sea turtle has no status under *SARA* and has not been considered by COSEWIC.

Table 4.12. Sea turtles potentially occurring in the northern Grand Banks Study Area.

Species	Project Area		*SARA* Status[a]	COSEWIC Status[b]	Activities	Habitat
	Occurrence	Timing				
Leatherback sea turtle	Rare	June to Nov	Schedule 1: Endangered	Endangered	Feeding	Open water, bays
Loggerhead sea turtle	Very rare	Summer	NS	Endangered	Feeding	Open water
Kemp's Ridley sea turtle	Very rare	Summer	NS	NC	Feeding	Open water

[a] Species designation under the *Species at Risk Act*; NS = No Status.
[b] Species designation by COSEWIC; E = Endangered, NC = Not Considered

4.5.2.1 Loggerhead Sea Turtle

Although the loggerhead sea turtle is the most common sea turtle in North American waters (Spotila 2004), it was recently designated as *endangered* by COSEWIC (2010). Its distribution is largely constrained by water temperature and it does not generally occur where the water temperature is below 15°C (O'Boyle 2001; Brazner and McMillan 2008), which limits its northern range. Loggerheads can migrate considerable distances between near-equatorial nesting areas and temperate foraging areas, some moving with the Gulf Stream into eastern Canada waters during the summer and fall (Hawkes et al. 2007). While foraging at sea, loggerheads likely consume gelatinous zooplankton and squid (Spotila 2004); there is no diet information available for Canadian waters (DFO 2010). Information to date indicates a seasonal population of juvenile loggerheads in Atlantic Canada (COSEWIC 2010). Loggerheads may be seen in the open seas during migration and foraging; they have not been reported in the Study Area. Most loggerhead records offshore Newfoundland have occurred in deeper waters south of the Grand Banks and sightings have extended as far east as the Flemish Cap (Figures 6 and 7 *in* COSEWIC 2010).

4.5.2.2 Kemp's Ridley Sea Turtle

The Kemp's Ridley sea turtle is more restricted in distribution, primarily occurring only in the Gulf of Mexico, but some juveniles sometimes feed along the U.S. east coast and rarely range into eastern Canada waters (Spotila 2004). Movements outside of the Gulf of Mexico likely occur during summer and in coastal areas. Juveniles have been sighted along the southern Newfoundland coast, in St. Mary's Bay, and off of Nova Scotia (Ernst et al. 1994), but there are no known reports in the Study Area.

4.6 Species at Risk

The *Species at Risk Act* (*SARA*) was assented to in December 2002 with certain provisions coming into force in June 2003 (e.g., independent assessments of species by COSEWIC and June 2004 (e.g., prohibitions against harming or harassing listed *endangered* or *threatened* species or damaging or destroying their critical habitat).

Species are listed under *SARA* on Schedules 1 to 3 with only those designated as *endangered* or *threatened* on Schedule 1 having immediate legal implications. Schedule 1 is the official list of wildlife Species at Risk in Canada. Once a species/population is designated, the measures to protect and recover it are implemented. The two cetacean species/populations, one sea turtle species, one seabird species, and two fish species/populations that are legally protected under *SARA* and have potential to occur in the Study

Area are listed in Table 4.13. Atlantic wolffish and the Atlantic population of fin whales are designated as *special concern* on Schedule 1 (Table 4.13). Schedules 2 and 3 of *SARA* identify species that were designated "at risk" by COSEWIC prior to October 1999 and must be reassessed using revised criteria before they can be considered for addition to Schedule 1. Species that potentially occur in the Study Area and are considered at risk but which have not received specific legal protection (i.e., proscribed penalties and legal requirement for recovery strategies and plans) under *SARA* are also listed in Table 4.13 as *endangered*, *threatened* or species of *special concern* under COSEWIC.

Under *SARA*, a 'recovery strategy' and corresponding 'action plan' must be prepared for *endangered*, *threatened*, and *extirpated* species. A 'management plan' must be prepared for species considered as *special concern*. Final recovery strategies have been prepared for five species currently designated as either *endangered* or *threatened* under Schedule 1 and potentially occurring in the Study Area: (1) the leatherback sea turtle (ALTRT 2006); (2) the spotted wolffish (Kulka et al. 2007), (3) the northern wolffish (Kulka et al. 2007), and (4) the blue whale (Beauchamp et al. 2009). A management plan has also been prepared for the Atlantic wolffish (Kulka et al. 2007), currently designated as *special concern* on Schedule 1.

CCL will monitor *SARA* issues through the Canadian Association of Petroleum Producers (CAPP), the law gazettes, the Internet and communication with DFO and EC, and will adaptively manage any issues that may arise in the future. The company will comply with relevant regulations pertaining to *SARA* Recovery Strategies and Action Plans. CCL acknowledges the rarity of the Species at Risk and will continue to exercise due caution to minimize effects on them during all of its operations. CCL also acknowledges the possibility of other marine species being designated as *endangered* or *threatened* on Schedule 1 during the course of the Project. Due caution will also be extended to any other species added to Schedule 1 during the life of this Project.

Species profiles of fish, birds, marine mammals, and sea turtles listed on Schedule 1 as *endangered* or *threatened* and any related special or sensitive habitat in the Study Area are described in the following subsections.

4.6.1 Profiles of *SARA*-listed Species

4.6.1.1 Fish

Only three fish species, the wolffishes, are listed under Schedule 1 of the *SARA*. Profiles of these three species are provided in this subsection.

Some of the other fish species/populations that are included in Table 4.13 (i.e., Atlantic cod, American plaice, grenadiers, and redfishes) are profiled in Section 4.2 related to fishes caught incidentally as bycatch during commercial fisheries.

Northern Wolffish

The northern wolffish is a deepwater fish of cold northern seas that has been caught at depths ranging from 38 to 1504 m, with observed densest concentrations between 500 and 1000 m at water temperatures of 2 to 5°C. During 1980-1984, this species was most concentrated on the northeast Newfoundland and Labrador

Table 4.13. SARA-listed and COSEWIC-listed marine species that potentially occur in the Study Area.

Species		*SARA*[a]			COSEWIC[b]		
Common Name	**Scientific Name**	**Endangered**	**Threatened**	**Special Concern**	**Endangered**	**Threatened**	**Special Concern**
Marine Mammals							
Blue whale	*Balaenoptera musculus*	Schedule 1			X		
North Atlantic right whale	*Eubalaena glacialis*	Schedule 1			X		
Fin whale (Atlantic population)	*Balaenoptera physalus*			Schedule 1			X
Sowerby's beaked whale	*Mesoplodon bidens*			Schedule 3			X
Harbour porpoise	*Phocoena phocoena*		Schedule 2				X
Killer whale (NW Atlantic/ E Arctic populations)	*Orcinus orca*						X
Sea Turtles							
Leatherback sea turtle	*Dermochelys coriacea*	Schedule 1			X		
Loggerhead sea turtle	*Caretta caretta*				X		
Seabirds							
Ivory Gull	*Pagophila eburnea*	Schedule 1			X		
Marine Fish							
Northern wolffish	*Anarhichas denticulatus*		Schedule 1			X	
Spotted wolffish	*Anarhichas minor*		Schedule 1			X	
Atlantic wolffish	*Anarhichas lupus*			Schedule 1			X
Atlantic cod	*Gadus morhua*			Schedule 3			
Atlantic cod (NL[a] population)	*Gadus morhua*				X		
Porbeagle shark	*Lamna nasus*				X		
White shark	*Carcharodon carcharias*				X		
Roundnose grenadier	*Coryphaenoides rupestris*				X		
Atlantic salmon (various)	*Salmo salar*				X	X	X
Cusk	*Brosme brosme*					X	
Shortfin mako shark	*Isurus oxyrinchus*					X	
American plaice (NL population)	*Hippoglossoides platessoides*					X	
Acadian redfish (Atlantic population)	*Sebastes fasciatus*					X	
Deepwater redfish	*Sebastes mentella*					X	
Blue shark (Atlantic population)	*Prionace glauca*						X
Basking shark	*Cetorhinus maximus*						X
Roughhead grenadier	*Macrourus berglax*						X
Spiny dogfish (Atlantic population)	*Squalus acanthis*						X

Sources: [a]*SARA* website (http://www.sararegistry.gc.ca/default_e.cfm) (as of Feb. 2011); [b]COSEWIC website (http://www.cosewic.gc.ca/index.htm) (as of Feb. 2011).

shelf and banks, the southwest and southeast slopes of the Grand Banks, and along the Laurentian Channel. Between 1995 and 2003, the area occupied and density within the area was considerably reduced. Northern wolffish are uncommon in the Gulf of St. Lawrence. These wolffish are known to inhabit a wide range of bottom substrate types, including mud, sand, pebbles, small rock and hard bottom, with highest concentrations observed over sand and shell hash in the fall, and coarse sand in the spring. Unlike other wolffish species, both juvenile and adult stages of this species have been found a considerable distance above the bottom, as indicated by diet (Kulka et al. 2008).

Prey of northern wolffish are primarily bathypelagic (>200 m depth) biota such as ctenophores and medusa, but also include mesopelagic biota (<200 m depth) and benthic invertebrates. Pelagic fish represent the largest percentage of stomach contents on the basis of volume. Tagging studies have suggested limited migratory behaviour by these wolffish. Northern wolffish typically spawn late in the year on rocky bottom. Cohesive masses of fertilized eggs are laid in crevices but are unattached to the substrate. Pelagic larvae hatch after an undetermined egg incubation time, and typically feed on crustaceans, fish larvae and fish eggs (Kulka et al. 2008).

During DFO RV surveys conducted in the Study Area during 2008 and 2009, 33 northern wolffish were caught at mean water depths ranging from 292 to 1243 m (average mean depth of 576 m).

Spotted Wolffish

The life history of the spotted wolffish is very similar to that of the northern wolffish except that it seldom inhabits the deepest areas used by the northern wolffish. Although spotted wolffish have been caught at depths ranging from 56 to 1046 m, the observed densest concentrations occur between 200 and 750 m at water temperatures of 1.5 to 5°C. During 1980-1984, spotted wolffish were most concentrated on the northeast Newfoundland and Labrador shelf and banks, the southwest and southeast slopes of the Grand Banks, along the Laurentian Channel, and in the Gulf of St. Lawrence. Between 1995 and 2003, the area occupied and density within the area was considerably reduced. As with northern wolffish, spotted wolffish also inhabit a wide range of bottom substrate types, including mud, sand, pebbles, small rock and hard bottom, with highest concentrations observed over sand and shell hash in the fall, and coarse sand in the spring (Kulka et al. 2008).

Prey of spotted wolffish are primarily benthic (>75%), typically including echinoderms, crustaceans, and molluscs associated with both sandy and hard bottom substrates. Fish also constitutes part of the spotted wolffish diet (<25%). Tagging studies indicate the spotted wolffish migrations are local and limited. Spotted wolffish exhibit internal fertilization which typically occurs in July and August on stony bottom in Newfoundland and Labrador waters. Cohesive masses of eggs are deposited in crevices, remaining unattached to the substrate. After an undetermined incubation time, pelagic larvae hatch and start to feed on crustaceans, fish larvae and fish eggs within a few days of hatching (Kulka et al. 2008).
During DFO RV surveys conducted in the Study Area during 2008 and 2009, 40 spotted wolffish were caught at mean water depths ranging from 163 to 469 m (average mean depth of 307 m).

Atlantic Wolffish

Atlantic wolffish are primarily demersal and inhabit shallower areas than the northern and spotted wolffishes. This species has been observed from near shore to a depth of 918 m at water temperatures ranging from -1 to 10°C, but are most common at water depths of 150 to 350 m with water temperatures ranging from 1.5 to 4°C. During 1980-1984, this species was most concentrated in the same areas as the northern wolffish, with additional concentrations on the southern Grand Banks and the Gulf of St. Lawrence. More recently, the area occupied and density within the area was considerably reduced in the northern part of its confirmed range, but has remained relatively constant in the Gulf of St. Lawrence. Unlike the northern and spotted wolffishes, Atlantic wolffish are often observed by divers close to shore, and they form dense concentrations offshore. During its feeding period, this wolffish species appears to prefer complex reliefs of rocks without algal growth and sand. Shelters in these rock reliefs are typically situated on 15-30° slopes with good water circulation. There is some indication that Atlantic wolffish form colonial settlements during the feeding period (Kulka et al. 2008).

Prey of Atlantic wolffish are primarily benthic (>85%), typically including echinoderms (e.g., sea urchins), crustaceans (e.g., crabs) and molluscs (e.g., scallops) associated with both sandy and hard bottom substrates. Fish also constitutes part of the spotted wolffish diet (<15%) (e.g., redfish). Migration by Atlantic wolffish is also limited, with seasonal inshore movement in the spring when mature fish are found in areas with water depths <15 m. These wolffish seem to prefer stony bottom substrate for spawning in September and October in Newfoundland and Labrador waters. After internal fertilization, cohesive masses of eggs are deposited in crevices on the bottom, remaining unattached to the substrate. The egg mass is guarded and maintained by the male Atlantic wolffish for the 7 to 9 month incubation time, after which pelagic larvae hatch and commence to feed on crustaceans, fish larvae and fish eggs within a few days of hatching (Kulka et al. 2008).

During DFO RV surveys conducted in the Study Area during 2008 and 2009, 313 Atlantic wolffish were caught at mean water depths ranging from 77 to 502 m (average mean depth of 285 m).

4.6.1.2 Marine Mammals and Sea Turtles

Blue Whale

The blue whale has a cosmopolitan distribution, but tends to be more frequently observed in deep water than in coastal environments (Jefferson et al. 2008). Blue whales became severely depleted during industrial whaling and still occur at relatively low densities in the N Atlantic. The Atlantic population of blue whales is considered *endangered* on *SARA* Schedule 1, and by COSEWIC. A recently finalized recovery strategy for blue whales in the NW Atlantic is available with a long-term recovery goal to reach a total of 1,000 mature individuals through the achievement of three 5-year objectives (Beauchamp et al. 2009). No critical habitat was identified. Blue whales likely number in the low hundreds in the NW Atlantic and have been sighted only sporadically off the NE coast of Newfoundland (COSEWIC 2002a). There were no sightings of blue whales in the Study Area in the DFO cetacean sightings database (Table 4.11). During a CSEM monitoring program in 2007, there were two sightings of blues whales in the Study Area, both occurred in August and in water depths of 2366 m and 2551 m (Abgrall et al. 2008b).

Blue whales feed primarily on krill and their distribution is often associated with areas of upwelling or shelf edges where their prey may concentrate. Blue whales are considered rare in the Study Area.

North Atlantic Right Whale

Research results suggest the existence of six major habitats or congregation areas for western North Atlantic right whales: the coastal waters of the southeastern United States; the Great South Channel; Georges Bank/Gulf of Maine; Cape Cod and Massachusetts Bays; the Bay of Fundy; and the Scotian Shelf (COSEWIC 2003a; Waring et al. 2009). The North Atlantic right whale is currently listed as *endangered* on Schedule 1 of *SARA* and by COSEWIC (Table 4.13). Waring et al. (2009) suggest that the current best estimate of the minimum population size is 325 individuals. This species is considered extremely rare in the Study Area. However, there have been some relatively recent sightings of small numbers of right whales off Iceland and Norway, and it is possible (although highly unlikely) that this species may occur in the Study Area. Right whales were recorded once in the Study Area; on 27 June 2003 during a PAL reconnaissance survey (J. Lawson, DFO, pers. comm.).

Leatherback Turtle

The largest and most widely ranging of sea turtles, the leatherback sea turtle ranges from sub-polar and cool temperate foraging grounds to tropical and sub-tropical nesting areas in all of the world's oceans (Spotila 2004). There are an estimated 26,000 to 43,000 individuals globally (Dutton et al. 1999), but there is no current estimate of the number of leatherbacks using eastern Canada waters. Leatherback sea turtle is designated as *endangered* (Schedule 1) on *SARA* and by COSEWIC. In the recovery strategy for leatherback sea turtle in the Canadian Atlantic Ocean, the recovery goal is to "achieve the long-term viability of the leatherback turtle populations frequenting Atlantic Canadian waters" via six supporting objectives (ALTRT 2006). No critical habitat was designated in ALTRT (2006). Adult leatherbacks are considered regular summer visitors to eastern Newfoundland, with the northernmost records occurring off Labrador at nearly 54ºN; observations around Newfoundland and Labrador occur from June to November, but are most common in August and September (Goff and Lien 1988). Exhibiting wide-ranging oceanic movements, leatherbacks occur in pelagic regions of the N Atlantic to forage on gelatinous zooplankton (Hays et al. 2006). Most leatherbacks that occur in Atlantic Canadian waters are large sub-adults and adults, with a female-biased sex ratio among mature turtles (James et al. 2007). These turtles represent nesting populations in a minimum of 10 countries in South and Central America, and the Caribbean (James et al. 2007). DFO Newfoundland Region has maintained a database of leatherback turtle sightings and entanglements in Newfoundland and Labrador (J. Lawson, DFO Research Scientist, pers. comm.). However, no leatherback turtle observations were made in the Study Area.

4.6.1.3 Seabirds

Ivory Gull

The Ivory Gull has a circumpolar breeding distribution and is associated with pack ice throughout the year. In Canada, the Ivory Gull breeds exclusively in Nunavut. Breeding colonies occur on southeastern Ellesmere Island, eastern Devon Island and northern Baffin Island. In Canadian waters, Ivory Gulls occur among the pack ice of the Davis Strait, the Labrador Sea, Strait of Belle Isle, and northern Gulf of St. Lawrence. The Ivory Gull is designated as *endangered* by COSEWIC, and listed as *endangered* on

Schedule 1 of *SARA*, and considered Near Threatened on the Red List of Threatened Species (Table 4.13; IUCN 2009).

Ivory Gulls depart from colonies immediately following breeding (~mid-August) for offshore foraging areas associated with the ice edge of permanent, multi-year pack ice. At sea, the Ivory Gull is a surface-feeder where its main prey includes small fish and macro-zooplankton. It is also an opportunistic scavenger of carrion found on ice and marine mammals killed by large predators (Haney and MacDonald 1995). Currently, the Canadian breeding population is estimated at 500 to 600 individuals (COSEWIC 2006a). Surveys conducted during 2002 to 2005 indicate a total decline of 80% and an annual decline of 8.4% over the last 18 years. If this decline continues at a steady rate, the breeding population will decrease by a further 62% over the next decade, to approximately 190 individuals. A March 2004 survey conducted within the pack ice off the coast of Newfoundland and Labrador observed a substantial decrease in Ivory Gull observations as compared to 1978 results (COSEWIC 2006a). Considering that changes to the breeding environment have been insignificant, causes for the observed decline are likely related to factors occurring during migration or on the wintering grounds (Stenhouse 2004). During heavy ice winters, the Ivory Gull may occasionally reach the southern Orphan Basin and northern Grand Banks in the Study Area. The thirty-year median of ice concentration shows ice extending into the northern edge of the Grand Banks east to 48°W during late February to late March. Ivory Gull is reported regularly along the coast of Labrador and the tip of the Great Northern Peninsula of Newfoundland in winter. There are occasional sightings of Ivory Gulls south along the east coast of Newfoundland. This species is expected to be very rare in most winters in the Study Area and absent during the summer.

4.7 Potentially Sensitive Areas

There are a variety of regulatory frameworks that deal directly or indirectly with sensitive areas in Newfoundland and Labrador. Marine fisheries are administered by DFO through the federal *Fisheries Act*. Management of marine mammals, including species at risk, is controlled by DFO under the *Marine Mammals Regulations* of the *Fisheries Act*. All species at risk are administered under the *Species at Risk Act* (2002) which lists the species and provides measures to protect those species. Migratory birds, including species at risk, are solely or jointly managed (depending on the species) between Canada and the US through the CWS branch of Environment Canada. Current legislation and agreements regarding migratory birds include the Convention for the Protection of Migratory Birds (1916), *Migratory Birds Convention Act* and the North American Waterfowl Management Plan (CWS and United States Fish and Wildlife Services (USFWS) 1986; CWS, USFWS, and SEMARNAP 1998). Waterfowl are managed according to "flyways" denoting wintering and summering habitat connected by international migration corridors.

4.7.1 Integrated Management Areas

The Study Area includes a portion of the Placentia Bay Grand Banks (PBGB) Large Ocean Management Area (LOMA), one of the marine regions established to form the planning basis for implementation of integrated-management plans by DFO. LOMAs are typically thousands of square kilometres in size. Their boundaries are determined using a combination of ecological and administrative considerations. For each LOMA, all levels of government, aboriginal groups, industry organizations, environmental and community groups, and academia work together to develop a strategic, long-term plan for sustainable management of resources within its boundaries. LOMAs are delineated so that ecosystem health and economic development issues within their boundaries can be addressed and suitably managed. This can best be accomplished using an integrated ocean management approach, an approach based on addressing the socio-economic needs of humankind while preserving the health of the marine ecosystem (DFO 2007a,b).

The PBGB LOMA has been recognized by DFO as one of five priority LOMAs in Canada. The PBGB LOMA Committee comprises a group of stakeholders partnering for the sustainable use and development of coastal and ocean resources within the LOMA. DFO NL Region has identified 11 Ecologically and Biologically Significant Areas (EBSAs) within the PBGB LOMA as potential Areas of Interest (AOIs) for Marine MPA designation, one of which overlaps the Study Area, namely the Northeast Shelf and Slope EBSA. This EBSA overlaps the southwestern end of the Study Area and includes an edge of the Shelf and Slope area down to the 1000 m isobaths at the Nose of the Grand Bank (DFO 2007a,b).

The Northeast Shelf and Slope EBSA has an overall 'low priority' rating relative to other EBSAs within the PBGB LOMA. Aspects of this EBSA, relative to other areas within the same LOMA, considered during its assessment include the following (DFO 2007a):

- ***Uniqueness (rarity)*** – the EBSA may be deemed significant to some species, based on function, but has no apparent uniqueness otherwise;
- ***Aggregation (density/concentration)*** – (1) the greatest proportion of spotted wolffish are aggregated in this EBSA in the spring; and (2) the highest concentration of Greenland halibut is aggregated in this EBSA in the spring;
- ***Fitness Consequences (importance to reproduction/survival***) – (1) important to the short- and long-term sustainability of the spotted wolfish; and (2) potentially important feeding area for marine mammals; and
- ***Sensitivity (resilience to disturbance)*** – not particularly sensitive compared to other slope areas in the region.

4.7.2 Bonavista Cod Box

In March 2003, as protection for the Northern cod, the *Fisheries Resource Conservation Council* (FRCC) recommended the establishment of an experimental 'cod box' in the Bonavista Corridor. The Corridor has been identified as an area important for cod spawning and juvenile cod. The FRCC recommended that this area be protected from all forms of commercial fishery (excluding snow crab trapping) and other invasive activity such as seismic exploration (see www.frcc.ccrh.ca). In April 2003, DFO announced that special conservation measures were required for the Bonavista Corridor, including the Bonavista Cod Box, located about 135 km west of the Study Area.

5.0 Effects Assessment

Two general types of effects are considered in this document:

1. Effects of the environment on the Project; and
2. Effects of the Project on the environment, particularly the biological environment.

Methods of effects assessment used here are comparable to those used in recent east coast offshore drilling (e.g., LGL 2005) and seismic EAs (e.g., LGL 2008). These documents conform to the *Canadian Environmental Assessment Act* (*CEAA*) and its associated Responsible Authority's Guide and the CEA Agency Operational Policy Statement (OPS-EPO/5-2000) (CEA Agency 2000). Cumulative effects are incorporated within the procedures in accordance with *CEAA* (CEA Agency 1994) as adapted from Barnes and Davey (1999) and used in the White Rose EA (Husky 2000).

5.1 Scoping

The C-NLOPB provided a scoping document (dated 14 February 2011) for the Project which outlined the factors to be considered in the assessment. In addition, various stakeholders were contacted for input (see below). Another aspect of scoping for the effects assessment involved reviewing relevant and recent EAs that were conducted in Newfoundland and Labrador waters including (but not limited to) the Orphan Basin SEA (LGL 2003), the Jeanne d'Arc Basin area seismic and geohazard program EA for StatoilHydro (LGL 2008), exploration and drilling EAs and their amendments for Orphan Basin (LGL 2005, 2006, 2009), and Chevron's Labrador offshore seismic EA (LGL 2010). Reviews of present state of knowledge were also conducted.

5.1.1 Consultations

In preparing the EA report for CCL's proposed 2011-2117 Regional Seismic Program, consultations were undertaken with relevant government agencies, representatives of the fishing industry and other interest groups. The purpose of these consultations was to describe the proposed exploration program, to identify any issues and concerns and to gather additional information relevant to the EA.

A short description of the proposed program and location map were sent to all agencies and stakeholder groups in early February, and relevant key species fisheries maps were later sent to all industry stakeholders. They were asked to review this information, provide any comments on the proposed activities and to let the proponent know if they would like to meet to discuss the proposed program in more detail.

Consultations for the 2011-2017 seismic program were undertaken with the following agencies, stakeholders and interest groups:

- Fisheries and Oceans Canada
- Environment Canada
- Natural History Society

- One Ocean
- Fish, Food and Allied Workers Union (FFAW)
- Association of Seafood Producers
- Ocean Choice International
- Groundfish Enterprise Allocation Council (GEAC, Ottawa)
- Clearwater Seafoods
- Icewater Seafoods

Appendix B provides a list of agency and industry officials who were consulted during the preparation of the EA document.

5.1.1.1 Issues and Concerns

Comments and responses received to date from various stakeholders are provided below.

DFO

DFO's EA and Major Projects Co-ordinator did not have any significant concerns about the proposed seismic program. He noted that because this is a multi-year assessment, the EA document should indicate any relevant COSEWIC species since some of these might subsequently be designated as species at risk over the EA time frame (2011-2017).

He noted that his office would be contacting relevant departmental managers to assist and expedite the various information requests, such as any data available on such topics as: known spawning areas for 3M cod; 2011 turbot quotas and regulations; activity levels and number of shrimp vessels in the southwest corner of the Study Area; the 2011 RV Survey schedule; surveillance statistics on fishing operations outside of Canada's EEZ; and updated information on the Placentia Bay/Grand Banks Large Ocean Management Area and EBSAs.

Environment Canada

Representatives from CCL and LGL Limited met with members of Environment Canada (EC) to provide information about the proposed seismic program. No specific concerns or issues with the proposed project were indicated by EC, although it was noted that seabird data should be collected using the EC data protocols to the extent possible. It was recommended that these data should be shared with EC at the end of the seismic program. EC biologists inquired about the possibility of placing individuals on supply vessels that service the seismic vessel to collect additional seabird data. The possibility of banding seabirds (notably Leach's Storm-Petrels) that strand on the seismic vessel was also discussed.

Natural History Society

Though the Society's representative did not have any significant concerns with the proposed survey, he did raise a number of points for discussion with CCL representatives. He noted, for example, that some members of the academic community have suggested that the marine mammal and sea bird observers on board seismic vessels are not entirely "independent" and there has been some suggestion that these personnel should be recruited from the university research community. He asked if it might be possible for offshore operators to permit such "independent" observers to be part of the regular monitoring process, or if the 2011 survey vessel could be used as a "research platform". CCL representatives noted in response that the idea of using seismic vessels for academic research has some merit, however, the primary challenge to any such initiative is the availability of space (i.e., berths) on board most seismic vessels. The issue of liability is another significant barrier.

Following this exchange, there was a lengthy discussion about the new Passive Acoustic Monitoring (PAM) technology, which the seismic vessel – the *WG Tasman* – is now equipped with. The Society's representative and CCL managers both agreed that this new system opens up possibilities for implementing mitigation measures during periods of poor visibility and collecting important new data on marine mammals. The NHS representative offered some suggestions on how the PAM system might be best utilized to obtain data on marine mammals in the vicinity of the vessel. He also suggested that, with respect to minimizing potential negative effects on marine mammals, the most effective mitigative measure would be for seismic vessels to conduct their operations during times of the year when the least number of marine mammals are in a survey area.

FFAW

In addition to CCL managers and its consultants, the meeting with FFAW representatives was attended by the Union's Petroleum Industry Liaison manager and a member of the Inshore Council who is also an independent fish harvester that is familiar with the fisheries in the proposed survey area.

Following the CCL presentation on the Project, the FFAW's Petroleum Industry Liaison manager asked how far the sound of the airgun array will travel in the water. She mentioned that she raised this matter because some fishers have mentioned that they can hear this noise many miles away from a survey vessel. In response, CCL's representative stated that the distance the sound travels and which it can be detected depends on many factors, including the technology one is using to listen to this sound.

Commenting on the fisheries species harvesting maps, the member of the Inshore Council noted that the entire southwest corner of the proposed survey area is a very important and busy fishing ground. Harvesting activities generally begin after about April 1 (with the start of the crab season) and continue on until November. He noted that, at any one point in time, there are usually about 100 vessels operating in the general vicinity, though a total of 300 vessels are licensed to fish various species in this part of the Grand Banks.

Shrimp and crab are the two key fisheries and most of the vessels are licensed to fish both species. Shrimp harvesting usually starts 1 August and could continue to October, or until the quota is taken. Crab activities are usually completed by mid-August and this fishery involves 128 licence holders. The fixed gear (gill nets) fishery for turbot usually starts in May.

He noted that the heaviest concentration of harvesting activities occur during July and mid-August with the overlap between shrimp and crab harvesting operation. There are generally fewer vessels in the southwest corner of the Study Area in September.

The FFAW's Petroleum Industry Liaison manager mentioned the "new" 3M cod fishery, and noted that the FFAW has some concern about potential impacts on cod, as well as other species. She stated that there is some anecdotal information regarding "erratic" behavioural effects on cod near seismic operations. She mentioned that new research studies on the behavioural effects are planned in the next few years.

The meeting ended with some discussion of the FLOs for the survey vessels, and the FFAW's Petroleum Industry Liaison manager also mentioned that the FFAW has the capability to provide "guide" vessels for the survey. There was also some discussion about whether the FLO should be located on the seismic vessel or the "picket" vessel.

One Ocean

No specific comments were received from One Ocean.

OCI

OCI's Manager of Fleet Administration and Scheduling reported that his company has recently obtained a 200 tonne allocation of 3M cod from foreign interests outside 200 miles and that it plans to fish this cod in 2011 in the April to May period. In a follow-up email, the consultants asked OCI if the company knows where it expects its vessels would be harvesting this cod. To date, however, OCI has not responded to this inquiry.

GEAC

The Council's Executive Director noted that the Canadian offshore sector (i.e., vessels > 100 feet) have competitive quotas of 3M redfish and 3M cod and expects to harvest these species commencing in 2011, probably during the spring-summer period.

Other Industry Stakeholders

ASP's Executive Director indicated that his Association had no significant concerns or issues. To date, no response has been received from other offshore harvesting firms such as Clearwater and Icewater Fisheries.

5.2 Valued Ecosystem Components

The Valued Ecosystem Component (VEC) approach was used to focus the assessment on those biological resources of most potential concern and value to society.

VECs include the following groups:

- rare or threatened species or habitats (as defined by COSEWIC and *SARA*);
- species or habitats that are unique to an area, or are valued for their aesthetic properties;

- species that are harvested by people (e.g., commercial fish species); and
- species that have at least some potential to be affected by the Project.

VECs were identified based on previous EAs conducted in the Jeanne d'Arc Basin and Orphan Basin areas (see Section 5.0), the scoping document received from the C-NLOPB, DFO and EC comments, and consultations with other stakeholders and regulators.

The VECs and the rationale for their inclusion are as follows:

- **Commercial fish** (including fish habitat considerations) with emphasis on the three primary species: (1) shrimp, (2) snow crab, and (3) Greenland halibut (turbot), and a representative fish species that has a swim bladder (e.g., Atlantic cod), and hence, may be more susceptible to seismic survey sound. It is recognized that there are many other fish species, commercial or prey species, that could be considered but it is LGL's professional opinion that this suite of species captures 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. The commercial fishery is a universally acknowledged important element in the society, culture, economic and aesthetic environment of Newfoundland and Labrador. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.

- **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). Newfoundland and Labrador waters support some of the largest seabird colonies in the world and the Study Area hosts large populations during all seasons. They are important socially, culturally, economically, aesthetically, ecologically and scientifically. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Marine Mammals** with emphasis on those species potentially most sensitive to low frequency sound (e.g., baleen whales) or *SARA* species (e.g., blue whale). Whales and seals are key elements in the social and biological environments of Newfoundland and Labrador. The economic and aesthetic importance of whales is evidenced by the large number of tour boats that feature whale watching as part of a growing tourist industry. This VEC is also of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Sea Turtles**, although very uncommon in the Study Area, are mostly *threatened* and *endangered* on a global scale and the leatherback sea turtle which forages in eastern Canadian waters is considered *endangered* under *SARA*. While they are of little or no economic, social or cultural importance to Newfoundland and Labrador, their *endangered* status warrants their inclusion as a VEC.

- **Species at Risk** are those designated as *endangered* or *threatened* on Schedule 1 of *SARA*. All species at risk in Newfoundland and Labrador offshore waters are captured in the VECs listed above. However, due to their special status, they are also discussed separately.

5.3 Boundaries

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

5.3.1 Temporal

The temporal boundaries of the Project are 1 May to 30 November in 2011. In subsequent years (2012 to 2017), seismic surveys may also occur from 1 May to 30 November and geohazard surveys may be conducted at any time of the year.

5.3.2 Project Area

The 'Project Area' is defined as the area where seismic data could be acquired plus an additional area around the outer perimeter of the data acquisition area to accommodate the ships' turning radii (see Figure 1.1). The geographic coordinates (latitude, longitude; datum NAD83) of the approximate "corners" of the Project Area starting in the northwest and moving clockwise are as follows:

NW = 49°51'28" N, 46°7"18' W
NE = 49°25'6" N, 44°47"57' W
SE = 47°13'0" N, 46°50"5' W
SW = 47°41'4" N, 48°10"50' W
W = 49°10'18" N, 47°31"57' W

5.3.3 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 most potential effects will be confined within the Project Area.

5.3.4 Study Area

An area larger than the Project Area that encompasses any potential effects (including those from accidental events) reported in the literature.

5.3.5 Regional Area

The regional boundary is the boundary as defined in the Orphan Basin SEA Area (Figure 2.2 in LGL 2003) and is retained here for consistency. An exception to this boundary is the inclusion of the major Grand Banks developments when considering cumulative effects.

5.4 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.

5.4.1 Identification and Evaluation of Effects

Interaction matrices were prepared that identify all possible Project activities which could interact with any of the VECs. 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 EAs for offshore Nova Scotia and Newfoundland and Labrador);
- when necessary, consultation with other experts; and
- results of similar effects assessments, 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.

5.4.2 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 (CEA Agency 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.

5.4.3 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.

5.4.4 Evaluation Criteria for Assessing Environmental Effects

Several criteria were taken into account when evaluating the nature and extent of environmental effects. These criteria include (CEA Agency 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^2) 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. The Study Area is not considered to be strongly affected by human activities.

Magnitude was defined as:

Negligible	An interaction that may create a measureable effect on individuals but would never approach the value of the 'low' rating. ating = 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. Some example assessments include the Petro-Canada seismic EA (LGL 2007), the White Rose Oilfield Comprehensive Study (Husky 2000), the StatoilHydro Jeanne d'Arc Basin area seismic and geohazard program EA (LGL 2008), the ConocoPhillips Laurentian Sub-Basin exploration drilling EA (Buchanan et al. 2006), and the Chevron Labrador seismic EA (LGL 2010).

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.

5.4.5 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 Orphan Basin and Northern Grand Banks area.

- Survey program within-project cumulative impacts. For the most part, and unless otherwise indicated, within-project cumulative effects are fully integrated within this assessment;
- Existing offshore oil developments in Newfoundland and Labrador: Hibernia (GBS platform), Terra Nova FPSO, and White Rose FPSO;
- Other offshore oil exploration activity (particularly seismic surveys and exploratory drilling as outlined on the C-NLOPB website). In the Orphan Basin and Jeanne d'Arc Basin area for 2011, activity may include additional seismic and geohazard programs. Statoil is proposing to conduct seismic surveys (2D, 3D, and/or geohazard) in the Jeanne d'Arc and Central Ridge/Flemish Pass Basins. Similar seismic surveys may also be conducted by Husky and/or Suncor in future years. The amount and timing and locations of other seismic operations and potential drilling programs in and near the Study Area in 2011 to 2017 are not currently available, with the exception of Statoil's 2011 program. Seismic programs may also occur offshore Labrador, including Multi Klient Invest's 2011 proposed program.

- Commercial fisheries;
- Marine transportation (tankers, cargo ships, supply vessels, naval vessels, fishing vessel transits, etc.); and
- Hunting activities (marine birds and seals).

5.4.6 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 and near the Orphan and Jeanne d'Arc basins.

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.

5.4.7 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 100 km*^{2}

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

5.4.8 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. Data gaps in knowledge are considered in these rankings.

5.4.9 Determination of Whether Predicted Environmental Effects are Likely to Occur

As per other EAs (e.g., LGL 2007), the following criteria for the evaluation of the likelihood of any predicted significant effects are used.

- probability of occurrence; and
- scientific certainty.

It should be noted that these two criteria are used only for predictions of significant effects.

5.4.10 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-NLOPB.

5.5 Effects of the Environment on the Project

The physical environment of the Project Area is described in Section 3.0 and the detailed report by Oceans (2011) and the reader is referred to these sources 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 lead to effects on the environment. For example, accidental spills of streamer fluid (if indeed this type of streamer is used during future seismic programs in 2012-2017) may be more likely to occur during rough weather.

Given the Project time frame of May to November for seismic operations 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 early summer may cause some survey delays if tracks have to be altered to avoid them. Most environmental constraints on seismic surveys are those imposed by wind and wave. The Project scheduling avoids the most continuous extreme weather conditions and CCL's contractors will be thoroughly familiar with east coast operating conditions. As a prediction of the effects of the environment on the Project, CCL will likely use an estimate of 25% weather-related down time for the Project for planning purposes. This cannot be considered a significant effect on the Project otherwise the Project would not be acceptable to the Proponent. Seismic (and geohazard) 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.

5.6 Effects of the Project on the Environment

The main pathway that links the Project and environment is the transmission of sound from the seismic (and geohazard) source to the receivers or various VECs. The basics of sound and its propagation in the marine environment are described in Richardson et al. (1995). Of principal concern during seismic and geohazard programs is the potential effects of sound from airguns on VECs as airguns used during marine seismic operations introduce strong sound impulses into the water (see Appendix C *in* LGL 2007) for a review of the characteristics of airgun pulses). 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 following sections review the hearing/detection abilities of VECs and the available information on potential effects of sound (as well as other Project activities) from seismic and geohazard sources on VECs.

5.6.1 Fish and Fish Habitat VEC

Although there will be interaction between Project activities and the 'fish habitat' component of the Fish and Fish Habitat VEC (i.e., water and sediment quality, phytoplankton, zooplankton, and benthos) (Table 5.1), the *negligible* residual effects are predicted to be *not significant*. The seismic/geohazard survey program will not result in any direct physical disturbance of the bottom substrate and the probability of any significant accidental event (i.e., hydrocarbon release) is even lower than the improbability of it in association with drilling activities. Therefore, other than in Table 5.1, no other reference to the 'fish habitat' component of the Fish and Fish Habitat VEC is made in this assessment subsection. Ichthyoplankton, invertebrate eggs and larvae, and macrobenthos are discussed as part of the 'fish' component of the Fish and Fish Habitat VEC.

The following sections discuss the Project activities that will interact with the Fish and Fish Habitat VEC, including assessment of the potential effects of those interactions.

5.6.1.1 Sound

The potential effects of exposure to airgun sound on invertebrates and fishes can be categorized as either physical (includes both pathological and physiological) or behavioural. Pathological effects include lethal and sub-lethal damage, physiological effects include temporary primary and secondary stress responses, and behavioural effects refer to deviations from normal behavioural activity. Physical and behavioural effects are likely related in some instances and should therefore not be considered as completely independent of one another.

Table 5.1. Potential interactions of the Project activities and the fish and fish habitat VEC.

Project Activities	Non-Biological Environment	Feeding		Reproduction		Adult Stage	
	Water and Sediment Quality	Plankton	Benthos	Eggs and Larvae	Juveniles [a]	Pelagic Fish	Groundfish
Vessel Lights		X		X		X	
Sanitary/Domestic Waste	X	X		X		X	
Air Emissions	X	X		X		X	
Garbage [b]							
Sound							
Airgun Array		X	X	X	X	X	X
Seismic Vessel						X	
Supply Vessel						X	
Picket Vessel						X	
Geohazard Vessel						X	
Helicopter [c]							
Echo Sounder						X	
Side Scan Sonar						X	
Boomer			X	X	X		X
Presence of Vessel							
Seismic Vessel							
Supply Vessel							
Picket Vessel							
Geohazard Vessel							
Helicopter [c]							
Shore Facilities [d]							
Accidental Spills	X	X		X		X	
OTHER PROJECTS AND ACTIVITIES							
Oil and Gas Activities on Grand Banks and Orphan Basin	X	X	X	X	X	X	X
Fisheries	X	X	X	X	X	X	X
Marine Transportation	X	X		X		X	

[a] Juveniles are young fish that have left the plankton and are often found closely associated with substrates.
[b] Not applicable as garbage will be brought ashore.
[c] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[d] There will not be any new onshore facilities. Existing infrastructure will be used.

The following sections provide an overview of available information on relationships of underwater sound to invertebrates and fishes. The overview includes discussion of sound detection, sound production, and possible effects of exposure to airgun sounds and higher frequency sounds that could be emitted from survey gear such as sonar.

Sound Detection

Sensory systems, like those that allow for hearing, provide information about an animal's physical, biological, and social environments, in both air and water. Extensive work has been done to understand the structures, mechanisms, and functions of animal sensory systems in aquatic environments (Atema et al. 1988; Kapoor and Hara 2001; Collin and Marshall 2003).

Underwater sound has both a pressure component and a particle displacement component associated with it. While all marine invertebrates and fishes appear to have the capability of detecting the particle displacement component of underwater sound, only certain fish species appear sensitive to the pressure component.

Invertebrates

The hearing abilities of marine invertebrates are the subject of ongoing debate. Aquatic invertebrates (with the exception of aquatic insects) do not possess the equivalent physical structures present in fish and marine mammals that can be stimulated by the pressure component of sound. It appears that marine invertebrates respond to vibrations rather than pressure (Breithaupt 2002). Statocyst organs (an organ of balance containing mineral grains that stimulate sensory cells as the animal moves) apparently function as a vibration detector for at least some species of marine invertebrates (Popper and Fay 1999). The statocyst is a gravity receptor and allows the swimming animal to maintain a horizontal attitude.

Among the marine invertebrates, decapod crustaceans have been the most intensively studied. Crustaceans appear to be most sensitive to low frequency sounds (i.e., <1000 Hz; Budelmann 1992; Popper et al. 2001), with some species being particularly sensitive to low-frequency sound (Lovell et al. 2006). Other studies suggest that some species (such as American lobster) may also be more sensitive to high frequencies than has been previously reported (Pye and Watson III 2004).

It is likely that cephalopods also use statocysts to detect low-frequency aquatic vibrations (Budelmann and Williamson 1994). Kaifu et al. (2008) provided evidence that the cephalopod *Octopus ocellatus* detects particle motion with its statocyst. Studies by Packard et al. (1990), Rawizza (1995), Komak et al. (2005) and Mooney et al. (2010) have quantified some of the optimally detected sound frequencies for various octopus (1–100 Hz), squid (1–500 Hz), and cuttlefish (20–8000 Hz) species. Using the auditory brainstem response approach, Hu et al. (2009) showed that auditory evoked potentials can be obtained in the frequency ranges 400–1500 Hz for the squid *Sepiotheutis lessoniana* and 400–1000 Hz for the octopus *Octopus vulgaris*, higher than frequencies previously observed to be detectable by cephalopods.

A recent study concluded that coral larvae can detect and respond to sound, the first description of an auditory response in the invertebrate phylum Cnidaria (Vermeij et al. 2010).

Fishes

Marine fish are known to vary widely in their ability to hear sounds. Although hearing capability data only exist for fewer than 100 of the 27,000 fish species (Hastings and Popper 2005), current data suggest that most species of fish detect sounds below 1500 Hz (Popper and Fay 2010). Some marine species, such as shads and menhaden, can detect sounds above 180 kHz (Mann et al. 1997, 1998, 2001). Also, at least some species are acutely sensitive to infrasound, down to below 1 Hz (Sand and Karlsen 2000). Reviews of fish-hearing mechanisms and capabilities can be found in Fay and Popper (2000) and Ladich and Popper (2004).

All fish species have hearing (inner ear) and skin-based mechanosensory systems (lateral lines). Amoser and Ladich (2005) hypothesized that, as species within a particular family of fish may live under different ambient sound conditions, the hearing abilities of the individual species are likely to have adapted to the dominant conditions. The ability of fish to hear a range of biotic and abiotic sounds may affect their survival rate, with better adapted fish having an advantage over those that cannot detect prevailing sounds (Amoser and Ladich 2005).

Fish ears are able to respond to changes in pressure and particle motion in the water (van Bergeijk 1964; Schuijf 1981; Kalmijn 1988, 1989; Shellert and Popper 1992; Hawkins 1993; Fay 2005). Two major pathways have been identified for sound transmittance: (1) the otoliths, which are calcium carbonate masses in the inner ear that act as accelerometers when exposed to the particle motion component of sound, cause shearing forces, and stimulate sensory hair cells; and (2) the swim bladder, which expands and contracts in a sound field, re-radiating the sound's signal within the fish and in turn stimulating the inner ear (Popper and Fay 1993).

Researchers have noted that fish without an air-filled cavity (swim bladder), or with reduced swim bladders or limited connectivity between the swim bladder and inner ear, are limited to detecting particle motion and not pressure, and therefore have relatively poor hearing abilities (Casper and Mann 2006). These species have commonly been known as 'hearing generalists' (Popper and Fay 1999), although a recent reconsideration suggests that this classification is oversimplified (Popper and Fay 2010). Rather, there is a range of hearing capabilities across species that is more like a continuum, presumably based on the relative contributions of pressure to the overall hearing capabilities of a species (Popper and Fay 2010). Results of direct study of fish sensitivity to particle motion have been reported in numerous recently published papers (Horodysky et al. 2008; Wysocki et al. 2009; Kojima et al. 2010).

Sound Production

Many invertebrates and fishes produce sounds. 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).

Invertebrate groups with species capable of producing sound including barnacles, amphipods, shrimps, crabs, and lobsters (Au and Banks 1998; Tolstoganova 2002; Pye and Watson III 2004; Henninger and Watson III 2005). Invertebrates typically produce sound by scraping or rubbing various parts of their bodies, although they also produce sound in other ways.

More than 700 fish species are known to produce sounds (Myrberg 1981, Kaatz 2002 *in* Anderson et al. 2008). Fishes produce sounds mainly by using modified muscles attached to their swim bladders (i.e., drumming) or rubbing body parts together (i.e., stridulating). Examples of 'soniferous' fishes include Atlantic cod (Finstad and Nordeide 2004; Rowe and Hutchings 2004), toadfishes (Locascio and Mann 2008; Vasconcelos and Ladich 2008), and basses (Albers 2008; Johnston et al. 2008).

5.6.1.2 Effects of Exposure to Airgun Sound

Most airgun sound energy is associated with frequencies <500 Hz, although there is some energy at higher frequencies.

Physical

Invertebrates

In a field study, Pearson et al. (1994) exposed Stage II larvae of the Dungeness crab *Cancer magister* to single discharges from a seven-airgun array and compared their mortality and development rates with those of unexposed larvae. No statistically significant differences were found in immediate survival, long-term survival, or time to molt between the exposed and unexposed larvae, even those exposed within one metre of the seismic source.

The pathological impacts of seismic survey sound on marine invertebrates were investigated in a pilot study on snow crabs *Chionoecetes opilio* (Christian et al. 2003, 2004). Under controlled field experimental conditions, captive adult male snow crabs, egg-carrying female snow crabs, and fertilized snow crab eggs were exposed to variable Sound Pressure Levels (SPLs) (191 to 221 dB re 1 $\mu Pa_{0\text{-}p}$) and sound exposure levels (SELs) (<130–187 dB re 1 $\mu Pa^2 \cdot s$). Neither acute nor chronic (12 weeks post-exposure) mortality was observed for the adult crabs. However, a significant difference in development rate was noted between the exposed and unexposed fertilized eggs/embryos. The egg mass exposed to seismic energy had a higher proportion of less-developed eggs than did the unexposed mass. It should be noted that both egg masses came from a single female and any measure of natural variability was unattainable (Christian et al. 2003, 2004).

In 2003, a collaborative study was conducted in the southern Gulf of St. Lawrence, Canada, to investigate the effects of exposure to sound from a commercial seismic survey on egg-bearing female snow crabs (DFO 2004a). This study had design problems that impacted interpretation of some of the results (DFO 2004b). Caged animals were placed on the ocean bottom at a location within the survey area and at a location outside of the survey area. The maximum received SPL was ~195 dB re 1 $\mu Pa_{0\text{-}p}$. The crabs were exposed for 132 hours of the survey, equivalent to thousands of seismic shots of varying received SPLs. The animals were retrieved and transferred to laboratories for analyses. Neither acute nor chronic lethal or sub-lethal injury to the female crabs or crab embryos was indicated. DFO (2004b) reported that some exposed individuals had short-term soiling of gills, antennules and statocysts, bruising of the hepatopancreas and ovary, and detached outer membranes of oocytes. However, these differences could not be linked conclusively to exposure to seismic survey sound. Boudreau et al. (2009) presented the proceedings of a workshop held to evaluate the results of additional studies conducted to answer some questions arising from the original study discussed in DFO (2004b). Proceedings of the workshop did not include any more definitive conclusions regarding the original results.

Payne et al. (2007) conducted a pilot study of the effects of exposure to airgun sound on various health endpoints of the American lobster. Adult lobsters were exposed either 20 to 200 times to 202 dB re 1$\mu Pa_{p\text{-}p}$ or 50 times to 227 dB re 1$\mu Pa_{p\text{-}p}$, and then monitored for changes in survival, food consumption, turnover rate, serum protein level, serum enzyme levels, and serum calcium level. Observations extended over a period of a few days to several months. Results showed no delayed mortality or damage to the mechanosensory systems associated with animal equilibrium and posture (as assessed by turnover rate).

McCauley et al. (2000a,b) exposed caged cephalopods to sound from a single 20 in^3 airgun with maximum SPLs of >200 dB re 1 μPa_{0-p}. Statocysts were removed and preserved, but at the time of publication, results of the statocyst analyses were not available. No squid or cuttlefish mortalities were reported as a result of these exposures.

Biochemical responses by marine invertebrates to acoustic exposure have also been studied to a limited degree. Such studies of stress responses could possibly provide some indication of the physiological consequences of acoustic exposure and perhaps any subsequent chronic detrimental effects. Stress responses could potentially affect animal populations by reducing reproductive capacity and adult abundance.

Stress indicators in the haemolymph of adult male snow crabs were monitored immediately after exposure of the animals to seismic survey sound (Christian et al. 2003, 2004) and at various intervals after exposure. No significant acute or chronic differences were found between exposed and unexposed animals in which various stress indicators (e.g., proteins, enzymes, cell type count) were measured.

Payne et al. (2007), in their study of the effects of exposure of adult American lobsters to airgun sound, noted decreases in the levels of serum protein, particular serum enzymes and serum calcium, in the haemolymph of animals exposed to the sound pulses. Statistically significant differences (p=0.05) were noted in serum protein at 12 days post-exposure, serum enzymes at 5 days post-exposure, and serum calcium at 12 days post-exposure. During the histological analysis conducted 4 months post-exposure, Payne et al. (2007) noted more deposits of PAS-stained material, likely glycogen, in the hepatopancreas of some of the exposed lobsters. Accumulation of glycogen could be due to stress or disturbance of cellular processes.

Price (2007) found that blue mussels *Mytilus edulis* responded to a 10 kHz pure tone continuous signal by decreasing respiration. Smaller mussels did not appear to react until exposed for 30 minutes whereas larger mussels responded after 10 minutes of exposure. The oxygen uptake rate tended to be reduced to a greater degree in the larger mussels than in the smaller animals.

In general, the limited studies done to date on the effects of acoustic exposure on marine invertebrates have not demonstrated any serious pathological and physiological effects.

Fishes

Review papers on the effects of anthropogenic sources of underwater sound on fishes have been published recently (Payne et al. 2008; Popper 2009; Popper and Hastings 2009a,b). These papers consider various sources of anthropogenic sound, including seismic airguns.

Fertilized capelin (*Mallotus villosus*) eggs and monkfish (*Lophius americanus*) larvae were exposed to seismic airgun sound and subsequently examined and monitored for possible effects of the exposure (Payne et al. 2009). The laboratory exposure studies involved a single airgun. Approximate received

SPLs measured in the capelin egg and monkfish larvae exposures were 199 to 205 dB re 1 μPa_{p-p} and 205 dB re 1 μPa_{p-p}, respectively. The capelin eggs were exposed to either 10 or 20 airgun discharges, and the monkfish larvae were exposed to either 10 or 30 discharges. No statistical differences in mortality/morbidity between control and exposed subjects were found at 1 to 4 days post-exposure in any of the exposure trials for either the capelin eggs or the monkfish larvae.

In uncontrolled experiments, Kostyuchenko (1973) exposed the eggs of numerous fish species (anchovy, red mullet, crucian carp, blue runner) to various sound sources, including seismic airguns. With the seismic airgun discharge as close as 0.5 m from the eggs, over 75% of them survived the exposure. Egg survival rate increased to over 90% when placed 10 m from the airgun sound source. The range of received SPLs was about 215 to 233 dB re 1 μPa_{0-p}.

Eggs, yolk sac larvae, post-yolk sac larvae, post-larvae, and fry of various commercially important fish species (cod, saithe, herring, turbot, and plaice) were exposed to received SPLs ranging from 220 to 242 dB re 1 µPa (unspecified measure type) (Booman et al. 1996). These received levels corresponded to exposure distances ranging from 0.75 to 6 m. The authors reported some cases of injury and mortality but most of these occurred as a result of exposures at very close range (i.e., <15 m). The rigor of anatomical and pathological assessments was questionable.

Saetre and Ona (1996) applied a "worst-case scenario" mathematical model to investigate the effects of seismic sound on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic airgun sound 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.

Evidence for airgun-induced damage to fish ears has come from studies using pink snapper *Pagrus auratus* (McCauley et al. 2000a,b 2003). In these experiments, fish were caged and exposed to the sound of a single moving seismic airgun every 10 seconds over a period of 1 hour and 41 minutes. The source SPL at 1 m was about 223 dB re 1 µPa at 1 m_{p-p}, and the received SPLs ranged from 165 to 209 dB re 1 μPa_{p-p}. The sound energy was highest over the 20 to 70 Hz frequency range. The pink snapper were exposed to more than 600 airgun discharges during the study. In some individual fish, the sensory epithelium of the inner ear sustained extensive damage as indicated by ablated hair cells. Damage was more extensive in fish examined 58 days post-exposure compared to those examined 18 hours post-exposure. There was no evidence of repair or replacement of damaged sensory cells up to 58 days post-exposure. McCauley et al. (2000a,b, 2003) included the following *caveats* in the study reports: (1) fish were caged and unable to swim away from the seismic source, (2) only one species of fish was examined, (3) the impact on the ultimate survival of the fish is unclear, and (4) airgun exposure specifics required to cause the observed damage were not obtained (i.e., a few high SPL signals or the cumulative effect of many low to moderate SPL signals).

Popper et al. (2005) tested the hearing sensitivity of three Mackenzie River fish species after exposure to five discharges from a seismic airgun. The mean received peak SPL was 205 to 209 dB re 1 µPa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1 $\mu Pa^2 \cdot s$ per discharge. While the broad whitefish (*Coregonus nasus*) showed no Temporary Threshold Shift (TTS) as a result of the exposure, adult northern pike (*Esox lucius*; a *hearing generalist*), and lake chub (*Couesius plumbeus*; *hearing specialist*) exhibited TTSs of 10 to 15 dB, followed by complete recovery within 24 hours of exposure. The same animals were also examined to determine whether there were observable effects on the sensory cells of the inner ear as a result of exposure to seismic sound (Song et al. 2008). No damage to the ears of the fishes was found, including those that exhibited TTS.

In uncontrolled experiments using a very small sample of different groups of young salmonids, including Arctic cisco (*Coregonus autumnalis*), fish were caged and exposed to various types of sound. One sound type was either a single firing or a series of four firings 10 to 15 seconds apart of a 300 in^3 seismic airgun at 2,000 to 2,200 psi (Falk and Lawrence 1973). Swim bladder damage was reported but no mortality was observed when fish were exposed within 1 to 2 m of an airgun source with source level ~230 dB re 1 µPa at 1 m (unspecified measure) (as estimated by Turnpenny and Nedwell 1994).

<u>Behavioural</u>

Invertebrates

Some studies have focused on potential behavioural effects on marine invertebrates. Christian et al. (2003) investigated the behavioural effects of exposure to airgun sound on snow crabs. Eight animals were equipped with ultrasonic tags, released, and monitored for multiple days prior to exposure and after exposure. Received SPL and SEL were ~191 dB re 1 $\mu Pa_{0\text{-}p}$ and <130 dB re 1 $\mu Pa^2 \cdot s$, respectively. The crabs were exposed to 200 discharges over a 33 minute period. None of the tagged animals left the immediate area after exposure to the seismic survey sound. Five animals were captured in the snow crab commercial fishery the following year, one at the release location, one 35 km from the release location, and three at intermediate distances from the release location.

Another study approach used by Christian et al. (2003) involved monitoring snow crabs with a remote video camera during their exposure to airgun sound. The caged animals were placed on the ocean bottom at a depth of 50 m. Received SPL and SEL were ~202 dB re 1 $\mu Pa_{0\text{-}p}$ and 150 dB re 1 $\mu Pa^2 \cdot s$, respectively. The crabs were exposed to 200 discharges over a 33 minute period. They did not exhibit any overt startle response during the exposure period.

Caged female snow crabs exposed to airgun sound associated with a recent commercial seismic survey conducted in the southern Gulf of St. Lawrence, Canada, exhibited a higher rate of 'righting' than those crabs not exposed to seismic survey sound (J. Payne, Research Scientist, DFO, St. John's, NL, pers. comm.). 'Righting' refers to a crab's ability to return itself to an upright position after being placed on its back. Christian et al. (2003) made the same observation in their study. Payne et al. (2007), in their study of the effects of exposure to airgun sound on adult American lobsters, noted a trend for increased food consumption by the animals exposed to seismic sound.

Caged brown shrimp *Crangon crangon* reared under different acoustical conditions exhibited differences in aggressive behaviour and feeding rate (Lagardère 1982). Those exposed to a continuous sound source showed more aggression and less feeding behaviour. It should be noted that behavioural responses by caged animals may differ from behavioural responses of animals in the wild.

McCauley et al. (2000a,b) provided the first evidence of the behavioural response of southern calamari squid *Sepioteuthis australis* exposed to seismic survey sound. McCauley et al. (2000a,b) reported on the exposure of caged cephalopods (50 squid and two cuttlefish) to sound from a single 20 in^3 airgun. The cephalopods were exposed to both stationary and mobile sound sources. The two-run total exposure times during the three trials ranged from 69 to 119 min. at a firing rate of once every 10 to 15 seconds. The maximum SPL was >200 dB re 1 $\mu Pa_{0\text{-}p}$. 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. In addition to the above-described startle responses, some squid also moved towards the water surface as the airgun approached. McCauley et al. (2000a,b) reported that the startle and avoidance responses occurred at a received SPL of 174 dB re 1 μPa_{rms}. They also exposed squid to a ramped approach-depart airgun signal whereby the received SPL was gradually increased over time. No strong startle response (i.e., ink discharge) was observed, but alarm responses, including increased swimming speed and movement to the surface, were observed once the received SPL reached a level in the 156 to 161 dB re 1 μPa_{rms} range.

Komak et al. (2005) also reported the results of a study of cephalopod behavioural responses to local water movements. In this case, juvenile cuttlefish *Sepia officinalis* exhibited various behavioural responses to local sinusoidal water movements of different frequencies between 0.01 and 1,000 Hz. These responses included body pattern changing, movement, burrowing, reorientation, and swimming. Similarly, the behavioural responses of the octopus *Octopus ocellatus* to non-impulse sound have been investigated by Kaifu et al. (2007). The sound stimuli, reported as having levels 120 dB re 1 μPa_{rms}, were at various frequencies: 50, 100, 150, 200 and 1,000 Hz. The respiratory activity of the octopus changed when exposed to sound in the 50–150 Hz range but not for sound at 200–1,000 Hz. Respiratory suppression by the octopus might have represented a means of escaping detection by a predator.

Low-frequency sound (<200 Hz) has also been used as a means of preventing settling/fouling by aquatic invertebrates such as zebra mussels *Dreissena polymorpha* (Donskoy and Ludyanskiy 1995) and balanoid barnacles *Balanus* sp. (Branscomb and Rittschof 1984). Price (2007) observed that blue mussels *Mytilus edulis* closed their valves upon exposure to 10 kHz pure tone continuous sound.

Although not demonstrated in the invertebrate literature, masking can be considered a potential effect of anthropogenic underwater sound on marine invertebrates. Some invertebrates are known to produce sounds (Au and Banks 1998; Tolstoganova 2002; Latha et al. 2005). The functionality and biological relevance of these sounds are not understood (Jeffs et al. 2003, 2005; Lovell et al. 2005; Radford et al. 2007). If some of the sounds are of biological significance to some invertebrates, then masking of those sounds or of sounds produced by predators, at least the particle displacement component, could potentially have adverse effects on marine invertebrates. However, even if masking does occur in some invertebrates, the intermittent nature of airgun sound is expected to result in less masking effect than would occur with continuous sound.

Invertebrate Fisheries

Christian et al. (2003) investigated the pre- and post-exposure catchability of snow crabs during a commercial fishery. Received SPLs and SELs were not measured directly and likely ranged widely considering the area fished. Maximum SPL and SEL were likely similar to those measured during the telemetry study. There were seven pre-exposure and six post-exposure trap sets. Unfortunately, there was considerable variability in set duration because of poor weather. Results indicated that the catch-per-unit-effort did not decrease after the crabs were exposed to seismic survey sound.

Andriguetto-Filho et al. (2005) attempted to evaluate the impact of seismic survey sound on artisanal shrimp fisheries off Brazil. Bottom trawl yields were measured before and after multiple-day shooting of an airgun array. Water depth in the experimental area ranged between 2 and 15 m. Results of the study did not indicate any significant deleterious impact on shrimp catches. Anecdotal information from Newfoundland indicated that catch rates of snow crabs showed a significant reduction immediately following a pass by a seismic survey vessel (G. Chidley, Newfoundland fisherman, pers. comm.). Additional anecdotal information from Newfoundland indicated that a school of shrimp observed via a fishing vessel sounder shifted downwards and away from a nearby seismic airgun sound source (H. Thorne, Newfoundland fisherman, pers. comm.). This observed effect was temporary.

Parry and Gason (2006) statistically analyzed data related to rock lobster *Jasus edwardsii* commercial catches and seismic surveying in Australian waters from 1978 to 2004. They did not find any evidence that lobster catch rates were affected by seismic surveys.

Fishes

Pearson et al. (1992) investigated the effects of seismic airgun sound on the behaviour of captive rockfishes *Sebastes* sp. exposed to the sound of a single stationary airgun at a variety of distances. The airgun used in the study had a source SPL at 1 m of 223 dB re 1 µPa at 1 $m_{0\text{-}p}$, and measured received SPLs ranged from 137 to 206 dB re 1 $\mu Pa_{0\text{-}p}$. The authors reported that rockfishes reacted to the airgun sounds by exhibiting varying degrees of startle and alarm responses, depending on the species of rockfish and the received SPL. Startle responses were observed at a minimum received SPL of 200 dB re 1 $\mu Pa_{0\text{-}p}$, and alarm responses occurred at a minimum received SPL of 177 dB re 1 $\mu Pa_{0\text{-}p}$. Other observed behavioural changes included the tightening of schools, downward distributional shift, and random movement and orientation. Some fishes ascended in the water column and commenced to mill (i.e., "eddy") at increased speed, while others descended to the bottom of the enclosure and remained motionless. Pre-exposure behaviour was reestablished from 20 to 60 minutes after cessation of seismic airgun discharge. Pearson et al. (1992) concluded that received SPL thresholds for overt rockfish behavioural response and more subtle rockfish behavioural response are 180 dB re 1 $\mu Pa_{0\text{-}p}$ and 161 dB re 1 $\mu Pa_{0\text{-}p}$, respectively.

Fish exposed to the sound from a single airgun in the study by McCauley et al. (2000a,b) exhibited startle responses to short range start up and high level airgun signals (i.e., with received SPLs of 182 to 195 dB re 1 μPa_{rms}. Smaller fish were more likely to display a startle response. Responses were observed above received SPLs of 156 to 161 dB re 1 μPa_{rms}. The occurrence of both startle response (classic C-turn response) and alarm responses (e.g., darting movements, flash school expansion, fast swimming) decreased over time. Other observations included downward distributional shift that was restricted by the 10 m x 6 m x 3 m cages, increase in swimming speed, and the formation of denser aggregations. Fish behaviour appeared to return to pre-exposure state 15 to 30 min after cessation of seismic firing.

Using an experimental hook and line fishery approach, Skalski et al. (1992) studied the potential effects of seismic airgun sound on the distribution and catchability of rockfishes. The source SPL of the single airgun used in the study was 223 dB re 1 µPa at 1 $m_{0\text{-}p}$, and the received SPLs at the bases of the rockfish aggregations ranged from 186 to 191 dB re 1 $\mu Pa_{0\text{-}p}$. Characteristics of the fish aggregations were assessed using echosounders. During long-term stationary seismic airgun discharge, there was an overall downward shift in fish distribution. The authors also observed a significant decline in total catch of rockfishes during seismic discharge. It should be noted that this experimental approach was quite different from an actual seismic survey, in that duration of exposure was much longer.

In another study, caged European sea bass *Dicentrarchus labrax* were exposed to multiple discharges from a moving seismic airgun array with a source SPL of about 256 dB re 1 µPa at 1 $m_{0\text{-}p}$ (unspecified measure type) (Santulli et al. 1999). The airguns were discharged every 25 seconds during a two hour period. The minimum distance between fish and seismic source was 180 m. The authors did not indicate any observed pathological injury to the sea bass. Blood was collected from both exposed fish (6 h post-exposure) and control fish (6 h pre-exposure) and subsequently analyzed for cortisol, glucose, and lactate levels. Levels of cortisol, glucose, and lactate were significantly higher in the sera of exposed fish compared to sera of control fish. The elevated levels of all three chemicals returned to pre-exposure levels within 72 hours of exposure (Santulli et al. 1999).

Santulli et al. (1999) also used underwater video cameras to monitor fish response to seismic airgun discharge. Resultant video indicated slight startle responses by some of the sea bass when the seismic airgun array discharged as far as 2.5 km from the cage. The proportion of sea bass that exhibited startle response increased as the airgun sound source approached the cage. Once the seismic array was within 180 m of the cage, the sea bass were densely packed at the middle of the enclosure, exhibiting random orientation, and appearing more active than they had been under pre-exposure conditions. Normal behaviour resumed about 2 hours after airgun discharge nearest the fish (Santulli et al. 1999).

Boeger et al. (2006) reported observations of coral reef fishes in field enclosures before, during and after exposure to seismic airgun sound. This Brazilian study used an array of eight airguns that was presented to the fishes as both a mobile sound source and a static sound source. Minimum distances between the sound source and the fish cage ranged from 0 to 7 m. Received sound levels were not reported by Boeger et al. (2006). Neither mortality nor external damage to the fishes was observed in any of the experimental scenarios. Most of the airgun array discharges resulted in startle responses although these behavioural changes lessened with repeated exposures, suggesting habituation.

Chapman and Hawkins (1969) investigated the reactions of free-ranging whiting (silver hake), *Merluccius bilinearis*, to an intermittently discharging stationary airgun with a source SPL of 220 dB re 1 µPa at 1 $m_{0\text{-}p}$. Received SPLs were estimated to be 178 dB re 1 $\mu Pa_{0\text{-}p}$. The whiting were monitored with an echosounder. Prior to any airgun discharge, the fish were located at a depth range of 25 to 55 m. In apparent response to the airgun sound, the fish descended, forming a compact layer at depths greater than 55 m. After an hour of exposure to the airgun sound, the fish appeared to have habituated as indicated by their return to the pre-exposure depth range, despite the continuing airgun discharge. Airgun discharge ceased for a time and upon its resumption, the fish again descended to greater depths, indicating only temporary habituation.

Hassel et al. (2003, 2004) studied the potential effects of exposure to airgun sound on the behaviour of captive lesser sandeel, *Ammodytes marinus*. Depth of the study enclosure used to hold the sandeel was about 55 m. The moving airgun array had an estimated source SPL of 256 dB re 1 µPa at 1 m (unspecified measure type). Received SPLs were not measured. Exposures were conducted over a three day period in a 10 km x 10 km area with the cage at its centre. The distance between airgun array and fish cage ranged from 55 m when the array was overhead to 7.5 km. No mortality attributable to exposure to the airgun sound was noted. Behaviour of the fish was monitored using underwater video cameras, echosounders, and commercial fishery data collected close to the Study Area. The approach of the seismic vessel appeared to cause an increase in tail-beat frequency although the sandeels still appeared to swim calmly. During seismic airgun discharge, many fish exhibited startle responses, followed by flight from the immediate area. The frequency of occurrence of startle response seemed to increase as the operating seismic array moved closer to the fish. The sandeels stopped exhibiting the startle response once the airgun discharge ceased. The sandeel tended to remain higher in the water column during the airgun discharge, and none of them were observed burying themselves in the soft substrate. The commercial fishery catch data were inconclusive with respect to behavioural effects.

Various species of demersal fishes, blue whiting, and some small pelagic fishes were exposed to a moving seismic airgun array with a source SPL of about 250 dB re 1 µPa at 1 m (unspecified measure type) (Dalen and Knutsen 1986). Received SPLs estimated using the assumption of spherical spreading ranged from 200 to 210 dB re 1 µPa (unspecified measure type). Seismic sound exposures were conducted every 10 seconds during a one week period. The authors used echosounders and sonars to assess the pre- and post-exposure fish distributions. The acoustic mapping results indicated a significant decrease in abundance of demersal fish (36%) after airgun discharge but comparative trawl catches did not support this. Non-significant reductions in the abundances of blue whiting and small pelagic fish were also indicated by post-exposure acoustic mapping.

La Bella et al. (1996) studied the effects of exposure to seismic airgun sound on fish distribution using echosounder monitoring and changes in catch rate of hake by trawl, and clupeoids by gill netting. The seismic array used was composed of 16 airguns and had a source SPL of 256 dB re 1 µPa at 1 $m_{0\text{-}p}$. The shot interval was 25 seconds, and exposure durations ranged from 4.6 to 12 hours. Horizontal distributions did not appear to change as a result of exposure to seismic discharge, but there was some indication of a downward shift in the vertical distribution. The catch rates during experimental fishing did not differ significantly between pre- and post-seismic fishing periods.

Wardle et al. (2001) used video and telemetry to make behavioural observations of marine fishes (primarily juvenile saithe (*Pollachius virens*), adult pollock (*Pollachius pollachius*), juvenile cod, and adult mackerel) inhabiting an inshore reef off Scotland before, during, and after exposure to discharges of a stationary airgun. The received SPLs ranged from about 195 to 218 dB re 1 $\mu Pa_{0\text{-}p}$. Pollock did not move away from the reef in response to the seismic airgun sound, and their diurnal rhythm did not appear to be affected. However, there was an indication of a slight effect on the long-term day-to-night movements of the pollock. Video camera observations indicated that fish exhibited startle responses ("C-starts") to all received levels. There were also indications of behavioural responses to visual stimuli. If the seismic source was visible to the fish, they fled from it. However, if the source was not visible to the fish, they often continued to move toward it.

The potential effects of exposure to seismic sound on fish abundance and distribution were also investigated by Slotte et al. (2004). Twelve days of seismic survey operations spread over a period of one month used a seismic airgun array with a source SPL of 222.6 dB re 1 µPa at 1 $m_{p\text{-}p}$. The SPLs received by the fish were not measured. Acoustic surveys of the local distributions of various kinds of pelagic fish, including herring, blue whiting (*Micromesistius poutassoa*), and mesopelagic species, were conducted during the seismic surveys. There was no strong evidence of short-term horizontal distributional effects. With respect to vertical distribution, blue whiting and mesopelagics were distributed deeper (20 to 50 m) during the seismic survey compared to pre-exposure. The average densities of fish aggregations were lower within the seismic survey area, and fish abundances appeared to increase in accordance with increasing distance from the seismic survey area.

During a Mackenzie River project, Jorgenson and Gyselman (2009) investigated the behavioural responses of Arctic riverine fishes to seismic airgun sound. The mean received peak SPL was 205 to 209 dB re 1 µPa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1 $\mu Pa^2 \cdot s$ per discharge. They used hydroacoustic survey techniques to determine whether fish behaviour upon exposure to airgun sound can either mitigate or enhance the potential impact of the sound. The study indicated that fish behavioural characteristics were generally unchanged by the exposure to airgun sound. The tracked fish did not exhibit herding behaviour in front of the mobile airgun array and, therefore, were not exposed to sustained high sound levels.

Thomsen (2002) exposed rainbow trout (*Oncorhynchus mykiss*) and Atlantic salmon held in aquaculture enclosures to the sounds from a small airgun array. Received SPLs were 142 to 186 dB re 1 μPa_{p-p}. The fish were exposed to 124 pulses over a three day period. In addition to monitoring fish behaviour with underwater video cameras, the authors also analyzed cod and haddock catch data from a longline fishing vessel operating in the immediate area. Only eight of the 124 shots appeared to evoke behavioural reactions by the salmonids, but overall impacts were minimal. No fish mortality was observed during or immediately after exposure. The author reported no significant effects on cod and haddock catch rates, and the behavioural effects were hard to differentiate from normal behaviour.

Finfish Fisheries

The most comprehensive experimentation on the effects of seismic airgun sound on catchability of fishes was conducted in the Barents Sea by Engås et al. (1993, 1996). They investigated the effects of seismic airgun sound on distributions, abundances, and catch rates of cod and haddock using acoustic mapping and experimental fishing with trawls and longlines. The maximum source SPL was about 248 dB re 1 µPa at 1 m_{0-p} based on calculations using sound measurements collected by a hydrophone suspended at a depth of 80 m. No measurements of the received SPLs were made. Davis et al. (1998) estimated the received SPL at the sea bottom immediately below the array and at 18 km from the array to be 205 dB re 1 μPa_{0-p} and 178 dB re 1 μPa_{0-p}, respectively. Engås et al. (1993, 1996) concluded that there were indications of distributional change during and immediately following the seismic airgun discharge (45 to 64% decrease in acoustic density according to sonar data). The lowest densities were observed within 9.3 km of the seismic discharge area. The authors indicated that trawl catches of both cod and haddock declined after the seismic operations. While longline catches of haddock also showed decline after seismic airgun discharge, those for cod increased.

Løkkeborg (1991), Løkkeborg and Soldal (1993), and Dalen and Knutsen (1986) also examined the effects of seismic airgun sound on demersal fish catches. Løkkeborg (1991) examined the effects on cod catches. The source SPL of the airgun array used in his study was 239 dB re 1 µPa at 1 m (unspecified measure type), but received SPLs were not measured. Approximately 43 hours of seismic airgun discharge occurred during an 11 day period, with a five-second interval between pulses. Catch rate decreases ranging from 55 to 80% within the seismic survey area were observed. This apparent effect persisted for at least 24 hours within about 10 km of the survey area. The effect of exposure to seismic sound on commercial demersal fishes was again studied in 2009 using gillnet and longline fishery methods off the coast of Norway (Løkkeborg et al. 2010). Study results indicated that fishes did react to airgun sound based on observed changes in catch rates during seismic shooting. Gillnet catches increased during the seismic shooting, likely a result of increased fish activity, while longline catches decreased overall.

Turnpenny et al. (1994) examined results of these studies as well as the results of other studies on rockfish. They used rough estimations of received SPLs at catch locations and concluded that catchability is reduced when received SPLs exceed 160 to 180 dB re 1 μPa_{0-p}. They also concluded that reaction thresholds of fishes lacking a swim bladder (e.g., flatfish) would likely be about 20 dB higher. Given the considerable variability in sound transmission loss between different geographic locations, the SPLs that were assumed in these studies were likely quite inaccurate.

Turnpenny and Nedwell (1994) also reported on the effects of seismic airgun discharge on inshore bass fisheries in shallow U.K. waters (5 to 30 m deep). The airgun array used had a source level of 250 dB re 1 μPa at 1 m_{0-p}. Received levels in the fishing areas were estimated to range between 163 and 191 dB re 1 μPa_{0-p}. Using fish tagging and catch record methodologies, they concluded that there was not any distinguishable migration from the ensonified area, nor was there any reduction in bass catches on days when seismic airguns were discharged. The authors concluded that effects on fisheries would be smaller in shallow nearshore waters than in deep water because attenuation of sound is often more rapid in shallow water, depending on the physical characteristics of the water and substrate in the area.

Skalski et al. (1992) used a 100 in^3 airgun with a source level of 223 dB re 1 μPa at 1 m_{0-p} to examine the potential effects of airgun sound on the catchability of rockfishes. The moving airgun was discharged along transects in the study fishing area, after which a fishing vessel deployed a set line, ran three echo-sounder transects, and then deployed two more set lines. Each fishing experiment lasted one hour and 25 minutes. Received SPLs at the base of the rockfish aggregations ranged from 186 to 191 dB re 1 μPa_{0-p}. The catch-per-unit-effort (CPUE) for rockfish declined on average by 52.4% when the airguns were operating. Skalski et al. (1992) believed that the reduction in catch resulted from a change in behaviour of the fishes. The fish schools descended towards the bottom and their swimming behaviour changed during airgun discharge. Although fish dispersal was not observed, the authors hypothesized that it could have occurred at a different location with a different bottom type. Skalski et al. (1992) did not continue fishing after cessation of airgun discharge. They speculated that CPUE would quickly return to normal in the experimental area, because fish behaviour appeared to normalize within minutes of cessation of airgun discharge. However, in an area where exposure to airgun sound might have caused the fish to disperse, the authors suggested that a lower CPUE might persist for a longer period.

European sea bass were exposed to sound from seismic airgun arrays with a source SPL of 262 dB re 1 μPa at 1 m_{0-p} (Pickett et al. 1994). The seismic survey was conducted over a period of 4 to 5 months. The study was intended to investigate the effects of seismic airgun discharge on inshore bass fisheries. Information was collected through a tag and release program, and from the logbooks of commercial fishermen. Most of the 152 recovered fish from the tagging program were caught within 10 km of the release site, and it was suggested that most of these bass did not leave the area for a prolonged period.

With respect to the commercial fishery, no significant changes in catch rate were observed (Pickett et al. 1994).

5.6.1.3 Effects of Exposure to Marine Vessel Sound

Numerous papers about the behavioural responses of fishes to marine vessel sound have been published in the primary literature. They consider the responses of small pelagic fishes (e.g., Misund et al. 1996; Vabo et al. 2002; Jørgensen et al. 2004; Skaret et al. 2005; Ona et al. 2007; Sand et al. 2008), large pelagic fishes (Sarà et al. 2007), and groundfishes (Engås et al. 1998; Handegard et al. 2003; De Robertis et al. 2008). Generally, most of the papers indicate that fishes typically exhibit some level of reaction to the sound of approaching marine vessels, the degree of reaction being dependent on a variety of factors including the activity of the fish at the time of exposure (e.g., reproduction, feeding, migration), characteristics of the vessel sound, and water depth.

Sound Exposure Effects Assessment

The best approach when assessing the effects of exposure to sound associated with the proposed seismic program on the Fish and Fish Habitat VEC is to use species that best represent the variability associated with crucial criteria considered during the assessment. The Project-related sound source of most concern is the airgun array that will be used during the seismic and geohazard surveying. It would be most effective to assess the effects of exposure to sound using species that have been studied in that context. Snow crab and Atlantic cod best serve that purpose.

The most notable criteria in the assessment include (1) distance between airgun array 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), and (4) reproductive strategy (snow crabs carry fertilized eggs at the bottom until larval hatch, and cod eggs are planktonic).

Potential impacts on other marine invertebrate and fish species are inferred from the assessment using snow crab and Atlantic cod. Potential interactions between the proposed Project activities and the Fish and Fish Habitat VEC are shown in Table 5.1.

As indicated in Section 5.6.1.2, although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain. 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 airgun 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. Developing embryos, juvenile and adult snow crab are benthic and generally far enough from the sound source to receive energy levels well below levels that may have impact. In the case of eggs and larvae, it is likely that the numbers negatively affected by exposure to seismic sound would be similar to those succumbing to natural mortality. Atlantic cod do have swim bladders and are therefore generally more sensitive to underwater sounds than fishes without swim bladders. Spatial and temporal avoidance of critical life history times (e.g., spawning aggregations) should mitigate the behavioural effects of exposure to airgun sound.

Snow crab, sensitive to the particle displacement component of sound only, will be at least 200 m from the airguns and will not likely be affected by any particle displacement resulting from airgun discharge.

Limited data regarding physiological impacts on fish and invertebrates indicate that these impacts are both short-term and most obvious after exposure at close range.

The physical effects of exposure to sound with frequencies >500 Hz are *negligible*, based on the available information from the scientific literature. Effects of exposure to >500 Hz sound and marine vessel sound appear to be primarily behavioural and somewhat temporary.

Table 5.2 provides the details of the assessment of the effects of exposure to Project-related sound on the Fish and Fish Habitat VEC.

As indicated in Table 5.2, sound produced as a result of the proposed Project (airgun array sound being the worst-case scenario) is predicted to have at most *low* residual effects on the various life stages of the Fish and Fish Habitat VEC over a duration of *<1 month to 1 to 12 months* in an area of *<1 to 100* km^2. Based on these criteria ratings, the *reversible* residual effects of *continuous* Project-related sound on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3)

5.6.1.4 Other Project Activities

Vessel Lights

As indicated in Table 5.1, there are potential interactions between vessel lights and certain components of the Fish and Fish Habitat VEC. However, other than the relatively neutral effect of attraction of certain species/life stages to the upper water column at night, there are not any notable effects of vessel lights on this VEC (Table 5.2). Based on these criteria ratings, the residual effects of vessel lights associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Sanitary/Domestic Waste

As indicated in Table 5.1, there are potential interactions between sanitary/domestic waste and certain components of the Fish and Fish Habitat VEC. After application of mitigation measures, including treatment of the waste, the residual effects of sanitary/domestic waste on the Fish and Fish Habitat VEC would be *negligible to low* in magnitude, *<1* km^2 in geographic extent, and *<1 to 12 months* in duration (Table 5.2). Based on these criteria ratings, the *reversible* residual effects of infrequent exposure to sanitary/domestic waste associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Table 5.2. Assessment of effects on the fish and fish habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat								
			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Vessel Lights	Neutral effect	N/A	-	-	-	-	-	-
Sanitary/Domestic Waste	Pathological effects (N); Contamination (N)	Treatment	0-1	1	1	1-2	R	2
Air Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Sound								
Airgun Array	Physical effects (N); Disturbance (N)	Ramp-up of array; Spatial and temporal avoidance	1	3	6	1-2	R	2
Seismic Vessel	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1	R	2
Picket Vessel	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1-2	R	2
Geohazard Vessel	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1	R	2
Echo Sounder	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1	R	2
Boomer	Disturbance (N)	Spatial and temporal avoidance	0-1	1	6	1	R	2
Accidental Spills	Pathological effects (N); Contamination (N)	Prevention protocols; Response plan	0-1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.

Table 5.3. Significance of potential residual environmental effects of Project activities on the fish and fish habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat				
Project Activity	Significance Rating	Level of Confidence	Likelihood[a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Airgun Array	NS	2-3	-	-
Seismic Vessel	NS	2-3	-	-
Supply Vessel	NS	2-3	-	-
Picket Vessel	NS	2-3	-	-
Geohazard Vessel	NS	2-3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).
Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence
Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted

Air Emissions

As indicated in Table 5.1, there are potential interactions between air emissions and certain components of the Fish and Fish Habitat VEC that occur near surface. Considering that the amount of air emissions produced during the proposed seismic program will rapidly disperse to undetectable levels, the residual effects of exposure to them on the Fish and Fish Habitat VEC would be *negligible* in magnitude, *<1 km^2* in geographic extent, and *<1 to 12 months* in duration (Table 5.2). Based on these criteria ratings, the *reversible* residual effects of *continuous* air emissions associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Accidental Events

Planktonic invertebrate and fish eggs and larvae are less resistant to effects of contaminants than are adults because they are not physiologically equipped to detoxify them or to actively avoid them. In addition, many eggs and larvae develop at or near the surface where hydrocarbon exposure may be the greatest (Rice 1985). Generally, fish eggs appear to be highly sensitive at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Larval sensitivity varies with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to high concentrations of hydrocarbons generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. The natural mortality rate in fish eggs and larvae is extremely high and very large numbers would have to be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985). Hydrocarbon-related mortalities would probably not affect year-class strength unless >50% of the larvae in a large proportion of the spawning area died (Rice 1985).

There is an extensive body of literature regarding the effects of exposure to hydrocarbons on juvenile and adult fish. Although some of the literature describes field observations, most refers to laboratory studies. Reviews of the effects of hydrocarbons on fish have been prepared by Rice et al. 1986; Armstrong et al. (1995), Payne et al. (2003) and numerous other authors. If exposed to hydrocarbons in high enough concentrations, fish may suffer effects ranging from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects. Actual effects depend on a variety of factors such as the amount and type of hydrocarbon, environmental conditions, species and life stage, lifestyle, fish condition, degree of confinement of experimental subjects, and others.

As indicated in Table 5.1, there are potential interactions between accidental events and certain components of the Fish and Fish Habitat VEC that occur near surface. The effects of hydrocarbon spills on marine invertebrates and fish have been discussed and assessed in numerous recent environmental assessments of proposed offshore drilling programs and assessments have concluded that the residual effects of accidental events on the Fish and Fish Habitat VEC are predicted to be *not significant*. With proper mitigations in place, the residual effects of an accidental event associated with the proposed seismic/geohazard program on the Fish and Fish habitat VEC would be *negligible to low* in magnitude, *<1 to 10 km^2* in geographic extent, and *<1 month* in duration (Table 5.2). Based on these criteria ratings and consideration that the probability of hydrocarbon releases during seismic surveying are low, the *reversible* residual effects of accidental events associated with the proposed seismic/geohazard program on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

5.6.1.5 Cumulative Effects

As indicated in Table 5.1, oil and gas exploration and production activity, fisheries, and marine transportation all have the potential to interact with the Fish and Fish Habitat VEC. Commercial fisheries obviously impact marine invertebrates and fish but fisheries management is intended to maintain populations at sustainable levels. Marine transportation may cause some behavioural effects but these should be temporary. Given the predicted minimal effects of other projects and activities, and the prediction that the residual effects of the proposed seismic program on the Fish and Fish Habitat VEC would be *not significant*, the cumulative effects on this VEC are also predicted to be *not significant*.

5.6.2 Commercial Fisheries

The potential interactions of Project activities and the Commercial Fisheries VEC are indicated in Table 5.4. DFO and Industry Research Surveys were included in the assessment of the Commercial Fisheries VEC.

Table 5.4. Potential interactions of Project activities and the commercial fisheries VEC.

Valued Ecosystem Component: Commercial Fisheries			
Project Activities	**Mobile Invertebrates and Fishes (fixed [e.g., gillnet] and mobile gear [e.g., trawls])**	**Sedentary Benthic Invertebrates (fixed gear [e.g., crab pots])**	**Research Surveys (mobile gear-trawls)**
Vessel Lights			
Sanitary/Domestic Waste	X	X	X
Air Emissions			
Garbage [a]			
Sound			
Airgun Array	X	X	X
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Geohazard Vessel	X	X	X
Echo Sounder	X		
Side Scan Sonar	X		X
Boomer	X	X	X
Presence of Vessels			
Seismic Vessel/Streamers	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Geohazard Vessel/Towed High Frequency Gear	X	X	X
Helicopter [b]			
Shore Facilities [c]			
Accidental Spills	X	X	X
OTHER PROJECTS AND ACTIVITIES			
Oil and Gas Activities on the Grand Banks and Orphan Basin	X	X	X
Marine Transportation	X	X	X

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

The seismic survey vessel and Project-related support vessel traffic will be present within subunits (Unit Areas) of NAFO Divisions 3M, 3L and 3K. Behavioural changes in commercial fisheries target species in relation to catchability and conflict with harvesting activities and fishing gear were raised as a potential issue during the consultations and issues scoping for this assessment (see Section 5.1.1). Seismic streamers and vessels can conflict with and damage fishing gear, particularly fixed gear (i.e., crab pots and Greenland halibut gillnets in the Study Area), and such conflicts have occurred a few times a season in Atlantic Canada when seismic vessels were operating in heavily fished areas. There is also a potential for interference from seismic activities with DFO and/or fishing industry stock assessment activities and catch success if they are in a seismic survey area at the same time. An accidental release of streamer floatation fluid (if fluid-filled streamers are used in any future programs) may result in tainting (or perceived tainting) thus, affecting product quality and marketing.

The chief means of mitigating potential effects on commercial fisheries activities is to avoid active fishing areas, particularly fixed gear zones, when they are occupied by harvesters. Effects on DFO assessment/research surveys would occur either as a result of behavioural responses or fishing interference (i.e., through the same pathways as impacts on commercial fishing) and avoidance is also an appropriate mitigation for these potential effects. For the commercial fisheries, gear damage compensation provides a means of final mitigation of effects, in case a conflict does occur with fishing gear (i.e., accidental contact with the survey airgun array, streamers or the ship).

The C-NLOPB 2008 "Geophysical, Geological, Environmental and Geotechnical Program Guidelines" provide guidance aimed at minimizing any impacts of petroleum industry surveys on commercial fish harvesting and other marine users. The mitigations described below to avoid fisheries disturbance and gear conflicts will apply generally to DFO science cruises. 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 (in Appendix 2, Environmental Planning, Mitigation and Reporting - Interaction with Other Ocean Users):

For VSP and Well Site surveys

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.

b. The operator should publish a Canadian Coast Guard "Notice to Mariners" and a "Notice to Fishers" via the CBC Radio program Fisheries Broadcast.

c. 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.

d. 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 CNLOPB Duty Officer.

For 2D and 3D seismic programs

In addition to the measures indicated in Section 1 above, the following mitigation measures should also be implemented:

a. Surveys should be scheduled, to the extent possible, to reduce potential for impact or interference with Department of Fisheries and Ocean (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.

b. 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 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) onboard the seismic vessel is considered best practice in this respect.

c. 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 assess the impacts on the commercial fisheries VEC organized under the potential effects pathway identified in Table 5.4, above.

5.6.2.1 Waste Emissions

Impacts related to physical effects on fish and invertebrates, including those potentially resulting from waste releases and accidental spills, are not discussed any further in this subsection because assessment of the Fish and Fish Habitat predicted that the residual physical effects would be *not significant*.

5.6.2.2 Sound Emissions

As indicated in the description of Commercial Fisheries in Section 4.3, there has been substantial harvesting only within NAFO Units 3Le and 3Li in the Study Area between 2003 and 2009. Only three species, snow crab, shrimp and turbot, made up the harvest within the Study Area during the 2003 to 2009 period. Shrimp accounted for over 97% of the catch by landed weight and value within the planned survey window. Of note, there is expected to be an increase in the Canadian Atlantic cod fishery in 3M as a result of OCI's purchased of approximately 200 t of foreign 3M cod from foreign interests (described in Section 4.3). In the past, the Canadian NAFO 3M cod allocation has not usually been fished within the Study Area boundary but OCI has not indicated where they will fish this within 3M in 2011.

The potential for impacts on fish harvesting will therefore depend on the location of the surveying activities in relation to these fishing areas, and the type of fishing gear used in any given season. If the survey work is situated away from these fishing areas, the likelihood of any impacts on commercial harvesting will be greatly reduced.

The DFO research surveys are conducted by "fishing" for species. As such, 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 research vessel operations.

The discussion of the behavioural effects on fish and invertebrates in Section 5.6.1.2 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. Snow crab, being relatively sedentary benthic species, are not likely to disperse and catch rates are not as likely to be affected. Shrimp fishing operators report no observed impact on catch rates offshore Newfoundland and Labrador but request that communications be maintained so that seismic streamers and fishing trawls do not overlap in the same area.

If survey work is planned in areas of snow crab fishing, the gear sets will have to be avoided by the seismic ship because of the risk of gear or vessel conflicts, so direct overlap of activities should not occur. The residual effects of seismic surveys on the catchability of fish and shellfish are predicted to be *negligible to low*, *continuous* over a *short-term*, over an area of *10 to 100* km^2 and *reversible* (Table 5.5). With mitigations described below in place, effects of seismic survey sound on the commercial fisheries VEC would be *not significant* (Table 5.6).

As previously noted, there is some potential for overlap with DFO research surveys of 2J, 3L and/or M, though schedules may change from year to year. For the last few years, surveys in some parts of the eastern Grand Banks and slope areas have occurred in May and June, and September to December. In any survey year, it will be necessary to obtain more specific information on survey timing and locations as it becomes available. This information will be forwarded to the survey operators. It has been accepted during past surveys, that the best way to prevent overlap between the surveys is to exchange detailed locational information and establish a tailored temporal and spatial separation plan, as was implemented with DFO Newfoundland and Labrador in past seasons. This is discussed in more detail in the Mitigations section, below.

As discussed below, any research 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 of both noise and the seismic streamer on DFO science surveys will be negligible and not significant (see Tables 5.5 and 5.6). The long term observations and experience with seismic programs offshore Newfoundland provides a high level of confidence in this assessment.

Mitigation

Mitigations intended to minimize the effects of Project activities on the harvesting success component of the Commercial Fisheries VEC are as follow:

Avoidance.—Potential impacts on fishing catch success will be mitigated by avoiding heavily fished areas when these fisheries are active (specifically the shrimp and snow crab areas) to the greatest extent possible. As described in this report, most of the domestic fishing in the past has been concentrated in well-defined areas within the Project Area, in NAFO subunits 3Le and 3Li. During any survey, the location of current activities will be monitored by the ship and the Fisheries Liaison Officer (see below) and plotted by project vessels, and fishing boats will be contacted by radio. Survey personnel (through the Single Point of Contact, 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 5.5. Assessment of effects on the commercial fisheries VEC.

Valued Ecosystem 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**
Sound								
Airgun Array	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	3	6	1-2	R	2
Seismic Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1-2	R	2
Supply Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance;communication	0	1	6	1	R	2
Picket Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1-2	R	2
Geohazard Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1	R	2
Echo Sounder	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance;communication	0	1	6	1	R	2
Side Scan Sonar	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1	R	2
Boomer	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1	R	2
Presence of Vessel								
Seismic Vessel/Streamers	Conflict with gear (N)	FLO; communication	0-1	1-3	6	1-2	R	2
Supply Vessel	Conflict with gear (N)	FLO; communication	0-1	1-3	1	1-2	R	2
Picket Vessel	Conflict with gear (N)	FLO; communication	0-1	1-3	6	1	R	2
Geohazard Vessel/Towed High Frequency Gear	Conflict with gear (N)	FLO; communication	0-1	1-2	6	1	R	2
Accidental Spills	Taint (N); Perceived taint (N)	Preventative protocols; Response plan; Communications	0-1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = > 200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Geographic Extent:
1 = < 1-km^2
2 = 1-10-km^2
3 = 11-100-km^2
4 = 101-1000-km^2
5 = 1001-10,000-km^2
6 = > 10,000-km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not affected by human activity
2 = Evidence of existing effects

[a] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[b] This is considered negligible since, if a conflict occurs, compensation will eliminate any economic impact.

Table 5.6. Significance of potential residual environmental effects on the commercial fisheries VEC.

Valued Ecosystem Component: Commercial Fisheries				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood** [a]	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Sound				
Airgun Array	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
Towfish				
Presence of Vessels				
Seismic Vessel/Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel/Towed High Frequency Gear	NS	3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted

***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 FFAW, and managers of other key corporate fisheries in the area. The Proponent's consultants will keep in communication with OCI as it firms up its 2011 harvesting plans, and will pass this info along to the survey vessel when known.

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), the CBC (Newfoundland) Radio's *Fisheries Broadcast*, by the FFAW in the FFAW *Union Forum* (as suggested during previous consultations), and by direct communications between the survey vessel and fishing vessels via marine radio at sea. This will also include any transit routes.

Fisheries Liaison Officer (FLO).—As a specific means of facilitating at-sea communications, and informing the survey vessel operators about local fisheries, CCL will have an on-board fisheries industry liaison officer as a "fisheries representative". The FLO will be hired through, and on the advice of, the FFAW. 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 any local fishing activities.

Observers have proven effective in the Nova Scotia sector since 1998. 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. (Appendix C contains a description of the FLO responsibilities and qualifications, as agreed in previous discussions with the FFAW.)

5.6.2.3 Vessel Presence

Commercial fish harvesting activities occur throughout the May to November period being assessed. Of these, the fixed gear (e.g. pot fishery for snow crab, and to a lesser extent the Greenland halibut gillnet fishery) poses the highest potential for interaction conflict, particularly if they are concurrent with seismic survey operations. For the 2-D/3-D program, the seismic vessel will operate intermittently on a 24 hour basis for a 20 to 30 day or up to a 90 day period. Because of the length of equipment towed behind the survey vessel, its manoeuverability is restricted and other vessels must give way.

Also, as noted in the project description, the turning radius, between each track line extends the assessment area beyond the 2-D/3-D survey grid. Therefore, fixed gear has the potential for entanglement with seismic gear. Depending on the scheduling of surveys, moderate to concentrated fisheries activity is expected within the assessment period. Operation of the seismic survey vessel and associated support vessels may overlap with most shrimp, crab and turbot fisheries, as well as the emerging cod fishery.

When gear conflict events have occurred, they have been assessed and compensation paid for losses attributable to the survey vessel or other petroleum industry activities.

For the transit routes to the survey area, where the survey streamers may be deployed during the outbound segment, a separate route analysis will be prepared and discussions with fishing interests undertaken before the transits, to avoid fixed gear fishing activities. CCL may initially deploy streamers within the Project Area (i.e., not during transit) and if this occurs then a specific route analysis would not be required but fishing interests would be notified of the commencement of the seismic program.

The residual effects of vessel and seismic gear presence are predicted to be *negligible to low*, *continuous* over a *short-term*, over an area of *10s to 100* km^2 and *reversible*. The long term observations and experience with seismic programs offshore Newfoundland provides a high level of confidence in this assessment. With precautions and compensation plans in place (described below), and considering the avoidance of fixed gear fishing areas that will be necessary in general, the economic impacts on fishers would be negligible, and thus *not significant* (Tables 5.5 and 5.6).

Mitigation

Mitigations intended to minimize the effects of Project activities on the conflict with fishing gear component of the Commercial Fisheries VEC are as follow:

Avoidance.—As discussed above, potential impacts on fishing gear will be mitigated by avoiding active fixed gear fishing areas during the survey. If gear is deployed in a survey area, the diligence of the FLO, good at-sea communications and mapping of current fishing locations have usually proven effective at preventing such conflicts.

For streamer deployment during transits to a survey area, the principal mitigation will also be avoidance, based on route selection aimed at deviating around fixed gear fishing areas. Since the patterns of fishing vary by month, a final route, taking into account the avoidance of active areas, will be chosen shortly before the survey work begins. As noted above, a route analysis for this purpose will be prepared and discussions with fishing interests undertaken before the transits.

In addition to avoidance based on route analysis and selection, the onshore Single Point of Contact and the at-sea Fisheries Liaison Officer will advise the vessel en-route, to ensure fishing gear is avoided. In case avoidance fails, a gear damage program will be in place to compensate fishers who lose gear as a result.

As in past surveys, the survey vessel and DFO (and/or other research surveys) will need to exchange detailed locational information. In 2002 when the plan was first 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. Specifically, the avoidance protocol to avoid sound overlap with the research work has been 30 km (16 NMi) separation from research set location, seven days in advance of the locations being surveyed by DFO (i.e. seven days of “quiet time”).

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, including during the transit from the port of St. John’s.

Single Point of Contact (SPOC).—The SPOC 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 Single Point of Contact with the fisheries industry, as described in the C-NLOPB 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 endeavour 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, CCL 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 vessels for surveys and for transits to the sites, 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.

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

CCL 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-NLOPB, 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 2008 Guidelines, Appendix 2. CCL will provide the C-NLOPB with details of any compensation to be paid.

5.6.2.4 Accidental Events

In the event of an accidental release of hydrocarbons (e.g., streamer breakage), there is some possibility of perception of tainting of invertebrate and fish resources in the proximity of a release, even if there is no actual tainting of resources. The perception alone can have economic effects in that the invertebrates and fish lose marketability. Preventative measures/protocols and prepared response plans are essential to minimize the effects of any accidental event. If there is a spill event, the length of time that fish are exposed to a slick is a determining factor in whether or not their health is substantially affected or if there is tissue tainting. Diesel and/or floatation fluid can be expected to dissipate relatively rapidly. Any effect on access to fishing grounds would be of relatively short duration. In the unlikely event of a substantial spill, the need for compensation to commercial fishers will be determined through the C-NLOPB's guidelines. Therefore, there is not likely to be a significant adverse residual effect on commercial fisheries as a result of an accidental spill.

Mitigation

Mitigations intended to minimize the effects of Project-related accidental events on the 'product quality component of the Commercial Fisheries VEC include preventative protocols, rapid response plans, and good communications/public relations.

5.6.3 Seabird VEC

There are three main potential types of effects to seabirds from offshore seismic (and geohazard) programs: (1) underwater sound from airgun arrays, (2) leakage of petroleum product from streamer(s), and (3) attraction to ship lights at night. Potential interactions between the Project and seabirds are shown in Table 5.7 and a review of available information on potential effects related to these interactions is provided below.

The effects of underwater sound on birds have not been well studied. A study on the effects of underwater seismic surveys on moulting Long-tailed Ducks in the Beaufort Sea showed little effect on their movement or diving behaviour (Lacroix et al. 2003). The study did not monitor potential 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 effects of seismic testing.

Table 5.7. Potential interactions between the Project and seabird VEC.

Project Activities	**Valued Ecosystem Component: Seabirds**
Vessel Lights	x
Sanitary/Domestic Waste	x
Air Emissions	x
Garbage [a]	x
Noise	
Seismic Vessel	x
Seismic Array	x
Supply Vessel	x
Picket Vessel	x
Geohazard Vessel	x
Helicopter b	x
Echo Sounder	x
Side Scan Sonar	x
Boomer	x
Presence of Vessels	
Seismic Vessel	x
Supply Vessel	x
Picket Vessel	x
Geohazard Vessel	x
Helicopters [b]	x
Shore Facilities [c]	
Accidental Spills	x
Other Projects And Activities	
Oil and Gas Activities on the Grand Banks and Orphan Basin	x
Fisheries	x
Marine Transportation	x

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

5.6.3.1 Sound

Most species of seabirds that are expected to occur in the Study Area feed at the surface or at <1 m below the surface of the ocean (Table 4.9). This includes members of *Procellariidae* (Northern Fulmar,), *Hydrobatidae* (Wilson's Storm-Petrel and Leach's Storm-Petrel), *Phalaropodinae* (Red Phalarope and

Red-necked Phalarope), and *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 Gannets plunge dive to a depth of 10 m. They are under the surface for a few seconds during each dive so would have minimal exposure to underwater sound. Greater Shearwater, Sooty Shearwater and Manx Shearwater feed mainly at the surface but also chase prey briefly beneath the surface down to a distance of 2-10 m below the surface (Brown et al. 1978, 1981).

There is only one group of seabirds occurring regularly in the Study Area that require relatively 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 considerable 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 to 40 seconds reaching an average depth of 20-60 m, but murres are capable of diving to 120 m and have been recorded underwater for up to 202 seconds (Gaston and Jones 1998). The effects of underwater sounds on *Alcidae* are unknown. Foraging Long-tailed Ducks did not alter their diving intensity during seismic operations (Lacroix et al. 2003) but the authors of this study acknowledge that more research is required. Sounds are probably not important to *Alcidae* in securing food. However, all six species are quite vocal (in-air) at breeding sites indicating auditory capabilities are important in that part of their life cycle.

The sound created by airguns is focused downward below the surface of the water. In air, 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 that 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.

Noise produced as a result of the proposed Project is predicted to have *negligible to low* magnitude effects on the seabird VEC over a duration of *<1 month* to *1 to 12 months* in a small area (probably <1 km^2) (Table 5.8). Therefore, the residual effects of Project noise on the seabird VEC would be *not significant* (Table 5.9).

5.6.3.2 Leakage from Streamers

The seismic vessel in 2011 will employ solid streamers which will eliminate the risk of streamer leakage. Depending on the seismic contractor, the streamers may be solid-filled or contain a paraffinic hydrocarbon called Isopar in future years (2012-2017). The precise effects of Isopar M on birds are not known. However, petroleum products have detrimental effects on the insulating attributes of seabird's feathers. Isopar M is a kerosene-like product that leaves a relatively thin layered slick on the surface of water. It evaporates readily. Typical fluid-filled streamers are constructed of self-contained units 100 m in length. Therefore, a single leak in a streamer could result in a maximum loss 208 L of Isopar M.

All seabirds expected to occur in the Study Area, except Arctic Tern, spend considerable time resting on the water. Birds that spend most of their time on water, such as the murres, Dovekies and Atlantic Puffins,

Table 5.8. Assessment of effects on the seabird VEC.

Valued Ecosystem Component: Seabirds									
			Evaluation Criteria for Assessing Environmental Effects						
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Vessel Lights	Attraction (N)	Reduce lighting (if possible)	1-2	2	2-3	1-2	R	2
Sanitary/Domestic Waste	Increased Food (N/P)		0	1	1	1-2	R	2
Air Emissions	Air Contaminants (N)		0	2	6	1-2	R	2
Sound								
Airgun Array	Disturbance (N)		0	2	6	1-2	R	2
Airgun Array	Physical Effects (N)	Ramp-up	0-1	1	6	1-2	R	2
Seismic Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)		0	1	6	1	R	2
Picket Vessel	Disturbance (N)		0	1	6	1-2	R	2
Geohazard Vessel	Disturbance (N)		0	1	6	1	R	2
Helicopter [a]	Disturbance (N)		0-1	2	1	1	R	2
Echosounder	Disturbance (N)		0-1	2	6	1	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1	R	2
Boomer	Disturbance (N)		0-1	1	6	1	R	2
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0	2	6	1-2	R	2
Supply Vessel	Disturbance (N)		0	2	1	1	R	2
Picket Vessel	Disturbance (N)		0	2	6	1-2	R	2
Geohazard Vessel	Disturbance (N)		0	2	6	1	R	2
Helicopter [a]	Disturbance (N)	Maintain high Altitude	0-1	2	1	1	R	2
Accidental Spills	Mortality (N)	Solid streamer[b]; Spill Response	1-2	1-3	1	1	R	2

Key:

Magnitude:
0 = Negligible, (essentially no effect)
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = < 1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not affected by human activity
2 = Evidence of existing effects

[a] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[b] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.9. Significance of potential residual environmental effects of the Project on the seabird VEC.

Valued Ecosystem Component: Seabirds				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood [a]**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopters	NS	3	-	-
Accidental Spills	NS	2	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] Considered only in the case where 'significant negative effect' is predicted.

would be the most likely species to suffer negative effects from an accidental release of Isopar M. Northern Fulmar, the shearwaters and storm-petrels are attracted to sheens but would not likely confuse it with a natural oceanic "sheen" 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 area with Isopar M.

An exposure to a surface release of a kerosene-like substance under calm conditions may harm or kill individual birds. However, because potential spills will likely be small and evaporation and dispersion rapid, the magnitude (*low*), and geographic extent (*<1 km*^{2}) (Table 5.8) of any spill is not expected to cause significant effects on seabird populations and therefore, any effects will be *not significant* (Table 5.9).

5.6.3.3 Attraction to Lights on Ships

Birds that spend most of their lives at sea are often influenced by artificial light (Montevecchi et al. 1999; Montevecchi 2006). Even before the era of electrical lights, humans used fires on shore to attract seabirds for food (Montevecchi 2006). Birds are more strongly attracted to lights at sea during fog and drizzle conditions. In Newfoundland waters, the Leach's Storm-Petrel is the species most often found stranded on the decks of offshore vessels after being attracted to lights at night (Moulton et al. 2005, 2006; Abgrall et al. 2008a, 2008b). Occasionally, other Newfoundland seabirds e.g., Greater Shearwater, Northern Fulmar, Thick-billed Murre and Dovekie have been found stranded on vessels in Newfoundland waters at night, presumably attracted to lights on ships. Birds may be confused or blinded by the contrast between a vessel's lights and the surrounding darkness. Many seabirds have great difficulty becoming airborne from flat surfaces. Once on a hard surface, stranded seabirds tend to crawl into corners or under objects such as machinery to hide. Here they may die from exposure, dehydration or starvation over hours or days. A stranded seabird's plumage is prone to oiling from residual oil that may be present in varying degrees on the ship's decks. The open ended structure of the stern of a typical seismic ship allows entry of seabirds to several decks. These decks are lighted to various degrees, sometimes brightly. This is unavoidable as seismic surveying is conducted around the clock and adequate lighting is required for safe work practices. During CCL's seismic monitoring programs in the summers of 2004 and 2005, 42 and 49 Leach's Storm-Petrels stranded on the seismic vessels, respectively; over 92% of these birds were released (Moulton et al. 2005, 2006).

Mitigation measures to rescue stranded storm-petrels on board the seismic vessel will be the responsibility of the MMO. The MMO will conduct daily searches of the ship and the ship's crew will also be notified to contact the MMO if a bird is found. Procedures developed by the CWS and Petro-Canada (now Suncor) will be used to handle the birds and gently release them (Williams and Chardine, n.d.). Other vessels, while working on the Project will be made aware of the potential problem of storm-petrels stranding on their vessels. Each vessel will have a copy of the manual developed by CWS and Suncor on proper procedure and handling of stranded storm-petrels (Williams and Chardine, n.d.). CCL acknowledges that a CWS *Bird Handling Permit* will be required. Project personnel will also be made aware of bird attraction to the lights on offshore structures. Deck lighting can be minimized (if it is safe and practical to do so) to reduce the likelihood of stranding. Mitigation and monitoring for stranded birds will reduce any effects of attraction to lights to a *low* magnitude, over a geographic extent of *1-10 km*^{2}, and for a duration of *<1 month* to *1 to 12 months* (Table 5.8). Thus, effects are predicted to be *not significant* (Table 5.9). A report documenting each stranded bird including the date, global position and the general condition of the feathers when found, and if releasable, the condition upon release, will be completed and delivered to the CWS by the end of the calendar year.

5.6.3.4 Other Project Activities

Sanitary/Domestic Wastes

Sanitary waste generated by the vessels will be macerated before subsurface discharge. While it is possible that seabirds (mostly gulls) may be attracted to the sewage particles, the small amount discharged below surface over a limited period of time will be unlikely to increase the far-offshore gull populations. Thus, any increase in gull predation on Leach's Storm-Petrels, as suggested by Wiese and Montevecchi

(1999), is likely to be minimal. If this event occurs, the number of smaller seabirds involved will likely be low and effects will be *negligible* (Table 5.8). Thus, effects are predicted to be *not significant* (Table 5.9).

Since it is unlikely that these discharges will lead to an overall increase in gull populations, any increase in gull predation at the site is likely to be accompanied by decreases elsewhere.

Air Emissions

Although atmospheric emissions could, in theory, affect the health of some resident marine seabirds, the effects will be *negligible*, because emissions of potentially harmful materials will be small and they will rapidly disperse to undetectable levels due to their volatility, temperature of emission and the exposed and often windy nature of the offshore.

Presence of Vessels

The seismic vessel, picket vessel and supply boats could potentially affect birds through discharges, lights, noise and physical presence of the structures. The potential effects of discharges, lights and noise from vessels have been discussed in previous sections. Potential effects related to physical presence of structures are likely minimal. Seabird may be attracted to the seismic, picket or supply vessel prospecting for fish wastes associated with fishing vessels. Since there is little or no food made available by these vessels seabird have a short term interest in the vessels and soon go elsewhere in search of food. Seabirds sitting on the water in the path of these vessels can move out of the way. The physical presence of the vessels will have a *negligible* effect that is *not significant* on seabirds (Tables 5.8 and 5.9).

Helicopters

Personnel may be transported to and from the seismic vessel via helicopters with flights occurring at about five to six week intervals. Potential effects of helicopters on the marine environment are mainly related to noise (see a review of the effects of noise on seabirds above). The residual effect of helicopters on seabirds is expected to be *negligible to low* and *not significant* (Tables 5.8 and 5.9).

5.6.4 Marine Mammals and Sea Turtles VEC

The potential effects of marine seismic activities on marine mammals and sea turtles have recently been reviewed for several 3-D seismic projects in the Jeanne d'Arc Basin on the Grand Banks (e.g., LGL 2007—Section 5.6.6; LGL 2008—Section 5.6.4), Chevron's Labrador seismic EA (LGL 2010—Section 5.7.7), the Orphan Basin SEA as well as in several other reviews (e.g., Richardson et al. 1995; Gordon et al. 2004; Stone and Tasker 2006; Southall et al. 2007; Abgrall et al. 2008c). The following review is based largely on these documents with new and relevant literature included.

5.6.4.1 Effects of Seismic Sound and Geohazard Equipment

Airgun arrays used during marine seismic operations introduce strong sound impulses into the water. These sound impulses could have several types of effects on marine mammals and are the main issue associated with the proposed seismic survey. The effects of human-generated noise on marine mammals are quite variable and depend on the species involved, the activity of the animal when exposed to the noise, and the distance of the animal from the sound source.

The potential effects of sound from airgun arrays on marine mammals and sea turtles are the principal concerns associated with seismic programs. Sounds from geohazard equipment are of less concern given their relatively lower source levels, emission in a narrow beam, short duration of the geohazard 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 the low level sonar sounds that would be produced during a geohazard survey. Sounds from the geohazard equipment are typically very short pulses, one to four times every second.

To assess the potential effects of the proposed seismic survey on marine mammals and sea turtles in the Study Area, this section reviews: (A) the hearing abilities of marine mammals and sea turtles, (B) the potential for masking by seismic surveys, (C) disturbance effects of seismic surveys, (D) the possibility of hearing impairment by seismic surveys, and (E) the possibility of physical and non-auditory physiological effects.

5.6.4.2 Categories of Noise Effects

The effects of noise on marine mammals are highly variable, and can be categorized as follows (adapted from 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, i.e., the mammals may tolerate it, either without or with some deleterious effects (e.g., masking, stress);
3. The noise may elicit behavioural 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 anthropogenic 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, intermittent airgun or sonar pulses could

cause masking for only a small proportion of the time, given the short duration of these pulses relative to the inter-pulse intervals; and

6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical or physiological 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.

(A) Hearing Abilities of Marine Mammals and Sea Turtles

Marine mammals rely heavily on the use of underwater sounds to communicate and gain information about their environment. Experiments and monitoring studies also show that they hear and may react to man-made sounds including those made during seismic exploration (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Tyack 2008).

Toothed Whales

The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. Most of the odontocete species have been classified as having functional hearing from about 150 Hz to 160 kHz (Southall et al. 2007). There are very few data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales. However, Cook et al. (2006) report that a stranded Gervais' beaked whale showed evoked potentials from 5 to 80 kHz, with best sensitivity at 80 kHz. In another study, Finneran et al. (2009) found that an adult Gervais' beaked whale had a similar upper cutoff of 80 to 90 kHz. Porpoises have higher functional hearing from about 200 Hz to 180 kHz (Southall et al. 2007).

Airguns produce a small proportion of their sound at mid- and high-frequencies, although at progressively lower levels with increasing frequency. In general, most of the energy in the sound pulses emitted by airgun arrays is at low frequencies. Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in seismic sound pulses, airgun sounds are sufficiently strong and contain sufficient mid- and high-frequency energy that their received levels sometimes remain above the hearing thresholds of odontocetes at distances out to several tens of kilometres (Richardson and Würsig 1997). There is no evidence that small odontocetes react to airgun pulses at such long distances. However, beluga whales do seem quite responsive at intermediate distances (10 to 20 km) where sound levels are well above the ambient noise level (see below).

Boomers operated from geohazard vessels typically emit pulsed sounds with frequency bandwidths from 500 Hz to 6 kHz. That frequency is within the hearing range of many odontocetes. Side scan sonars often emit pulsed sounds at dual frequencies of 100 kHz and 398 kHz. The 100 kHz channel can likely be heard by some odontocetes. Multibeam echosounders operate typically at frequencies of 240 kHz although frequencies of 10 to 15 kHz may be used in waters greater than 1,000 m deep. Thus, sound pulses from boomers and sidescan sonars will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam. However, the multibeam echosounder frequencies (240 kHz) 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). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpback whales, with components >24 kHz (Au et al. 2006). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000; Parks et al. 2007b). Although humpbacks and minke whales may have some auditory sensitivity to frequencies above 22 kHz (Berta et al. 2009), for baleen whales as a group, the functional hearing range is thought to be about 7 Hz to 22 kHz (Southall et al. 2007).

The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small toothed whales that have been studied directly. 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 toothed whales.

Sound pulses from boomers operated from a geohazard vessel 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 phocid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002, 2009). The functional hearing range for pinnipeds in water is considered to extend from 75 Hz to 75 kHz (Southall et al. 2007). Compared to odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, better auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30 to 50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, and range between 60 and 85 dB re 1 μPa. Measurements for harbour seals indicate that, below 1 kHz, their thresholds under quiet background conditions deteriorate gradually to ~75 dB re 1 μPa at 125 Hz (Kastelein et al. 2009).

Sound pulses from the airgun arrays and from a boomer operated from a geohazard vessel 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

There are limited available data on sea turtle hearing capabilities, but it appears that sea turtles are low-frequency specialists with a hearing range extending from 50 to 1600 Hz for the species that have been tested (i.e., green, loggerhead, and Kemp's ridley sea turtles). Hearing in sea turtles occurs through a combination of bone and water conduction rather than air conduction, with best hearing sensitivity ranging in frequencies from ~200 to 700 Hz (Ketten and Moein Bartol 2006). Thus, the available information suggests that there is substantial overlap in the frequencies that sea turtles can hear and the dominant frequencies of airgun pulses. It is likely sea turtles can hear sounds from a boomer but unlikely that they can hear a side scan sonar or echosounder.

(B) Masking Effects of Airgun Sounds

Masking is the obscuring of sounds of interest by interfering sounds, generally at similar frequencies (Richardson et al. 1995). Introduced underwater sound will, through masking, reduce the effective communication distance of a marine mammal species if the frequency of the source is close to that used as a signal by the marine mammal, and if the anthropogenic sound is present for a significant fraction of the time (Richardson et al. 1995). If little or no overlap occurs between the introduced sound and the frequencies used by the species, communication is not expected to be disrupted. Also, if the introduced sound is present only infrequently, communication is not expected to be disrupted much, if at all. The duty cycle of airguns is low; the airgun sounds are pulsed, with relatively quiet periods between pulses. In most situations, strong airgun sound will only be received for a brief period (<1 s or much less), with these sound pulses being separated by at least several seconds of relative silence, and longer in the case of deep-penetration surveys or refraction surveys. A single airgun array might cause appreciable masking in only one situation: When propagation conditions are such that sound from each airgun pulse reverberates strongly and persists for much or the entire interval up to the next airgun pulse (e.g., Simard et al. 2005; Clark and Gagnon 2006). Situations with prolonged strong reverberation are infrequent, in our experience. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Guerra et al. 2009), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies on this. Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a,b; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006; Dunn and Hernandez 2009). However, there is one recent summary report indicating that calling fin whales distributed in one part of the N Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that preliminary paper whether the whales ceased calling because of masking, or whether this was a behavioural response not directly involving masking. Castellote et al. (2010) reported that singing fin whales moved away from an operating airgun array rather than ceasing vocalizations; fin whales also changed their acoustic behaviour in the presence of seismic sounds. Also bowhead whales in the Beaufort Sea may decrease their call rates in response to seismic operations, although movement out of the area might also have contributed to the lower call detection rate (Blackwell et al. 2010). In contrast, Di Iorio and Clark (2009) found evidence of *increased* calling by blue whales during operations by a lower-energy seismic source—a sparker.

Among the odontocetes, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). However, more recent studies of sperm whales found that they continued calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2008). Madsen et al. (2006) noted that airgun sounds would not be expected to mask sperm whale calls given the intermittent nature of airgun pulses. Dolphins and porpoises are also commonly heard calling while airguns are operating (Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocetes, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are the dominant components of airgun sounds.

Pinnipeds have best hearing sensitivity and/or produce most of their sounds at frequencies higher than the dominant components of airgun sound, but there is some overlap in the frequencies of the airgun pulses and the calls. However, the intermittent nature of airgun pulses presumably reduces the potential for masking.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or to shift their peak frequencies in response to strong sound signals, or otherwise modify their vocal behaviour in response to increased noise (Dahlheim 1987; Au 1993; reviewed in Richardson et al. 1995:233*ff*, 364*ff*; Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007a, Di Iorio and Clark 2009; Hanser et al. 2009). It is not known how often these types of responses occur upon exposure to airgun sounds. However, blue whales in the St. Lawrence Estuary significantly increased their call rates during sparker operations (Di Iorio and Clark 2009). The sparker, used to obtain seismic reflection data, emitted frequencies of 30 to 450 Hz with a source level of 193 dB re 1 μPa_{pk-pk}. If cetaceans exposed to airgun sounds sometimes respond by changing their vocal behaviour, this adaptation, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking by seismic pulses.

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 or geohazard surveys.

(C) Disturbance by Seismic and Geohazard Vessels

Disturbance includes a variety of effects, including subtle to conspicuous changes in behaviour, movement, and displacement. Behavioural reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal reacts to an underwater sound by changing its behaviour or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Also, various authors have noted that even marine mammals that show no obvious avoidance or behavioural changes may still be adversely affected by noise (Brodie 1981; Richardson et al. 1995: 317*ff*; Romano et al. 2004; Weilgart 2007; Wright et al. 2009). For example, some research suggests that animals in poor condition or in an already stressed state may not react as strongly to human disturbance as would more robust animals (e.g., Beale and Monaghan 2004).

Recently, a committee of specialists on noise impact issues has proposed new science-based impact criteria (Southall et al. 2007). Available detailed data on reactions of marine mammals to airgun sounds (and other anthropogenic sounds) are limited to relatively few species and situations (see Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). Detailed studies have been done on humpback, grey, bowhead and sperm whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, small toothed whales, and sea turtles, but for many species there are no data on responses to marine seismic surveys.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable among species, locations, whale activities, oceanographic conditions affecting sound propagation, etc. (reviewed in Richardson et al. 1995; Gordon et al. 2004). Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometres, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong sound pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. Some of the major studies and reviews on this topic are 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,b), Miller et al. (1999, 2005), Gordon et al. (2004), Stone and Tasker (2006), Johnson et al. (2007), Nowacek et al. (2007), Weir (2008a), and Moulton and Holst (2010). Although baleen whales often show only slight overt responses to operating airgun arrays (e.g., Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010), strong avoidance reactions by several species of mysticetes have been observed as far as 20 to 30 km from the source vessel when large arrays of airguns were used (e.g., Miller et al. 1999; Richardson et al. 1999). Experiments with a single airgun showed that bowhead, humpback and grey whales all showed localized avoidance to a single airgun of 20 to 100 in^3 (Malme et al. 1984, 1985, 1986, 1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b).

Studies of grey, bowhead, and humpback whales have shown that seismic pulses with received levels of 160 to 170 dB re 1 μPa_{rms} seem to cause obvious avoidance behaviour in a substantial portion of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4 to 15 km from the source. More recent studies have shown that some species of baleen whales (bowheads and humpbacks in particular) at times show strong avoidance at received levels lower than 160 to 170 dB re 1 μPa_{rms}. The largest avoidance radii involved migrating bowhead whales, which avoided an operating seismic vessel by 20 to 30 km (Miller et al. 1999; Richardson et al. 1999; see also Manly et al. 2007). In the cases of migrating bowhead (and grey) 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 (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995). Feeding bowhead whales, in contrast to migrating whales, show much smaller avoidance distances (Miller et al. 2005; Harris et al. 2007), presumably because moving away from a food concentration has greater cost to the whales than does a course deviation during migration.

The following subsections provide more details on the documented responses of particular species and groups of baleen whales to marine seismic operations.

Humpback Whales: Responses of humpback whales to seismic surveys have been studied during migration, on the summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998, 2000a) studied the responses of migrating humpback whales off western Australia to a full-scale seismic survey with a 16 airgun 2678 in^3 array, and to a single 20 in^3 airgun with a (horizontal) source level of 227 dB re 1 $\mu Pa \cdot m_{p-p}$. They found that the overall distribution of humpbacks migrating through their Study Area was unaffected by the full-scale seismic program, although localized displacement varied with pod composition, behaviour, and received sound levels. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km. Avoidance reactions (course and speed changes) began at 4 to 5 km for traveling pods, with the closest point of approach (CPA) being 3 to 4 km at an estimated received level of 157 to 164 dB re 1 μPa_{rms} (McCauley et al. 1998, 2000a). A greater stand-off range of 7 to 12 km was observed for more sensitive resting pods (cow-calf pairs; McCauley et al. 1998, 2000a). The mean received level for initial avoidance of an approaching airgun was 140 dB re 1 μPa_{rms} for humpback pods containing females, and at the mean CPA distance the received level was 143 dB re 1 μPa_{rms}. One startle response was reported at 112 dB re 1 μPa_{rms}. The initial avoidance response generally occurred at distances of 5 to 8 km from the airgun array and 2 km from the single airgun. However, some individual humpback whales, especially males, approached within distances of 100 to 400 m, where the maximum received level was 179 dB re 1 μPa_{rms}. The McCauley et al. (1998, 2000a,b) studies show evidence of greater avoidance of seismic airgun sounds by pods with females than by other pods during humpback migration off western Australia.

Data collected by observers during several seismic surveys in the NW Atlantic showed that sighting rates of humpback whales were significantly greater during periods of no seismic compared with periods when a full array was operating (Moulton and Holst 2010). In addition, humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010).

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64 L (100 in^3) airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150 to 169 dB re 1 µPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 µPa on an approximate *rms* basis.

Among wintering humpback whales off Angola ($n = 52$ useable groups), there were no significant differences in encounter rates (sightings/hr) when a 24 airgun array (3147 in^3 or 5085 in^3) was operating vs. silent (Weir 2008a). There was also no significant difference in the mean CPA (closest observed point of approach) distance of the humpback sightings when airguns were on vs. off (3050 m vs. 2700 m, respectively).

It has been suggested that S Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004). The evidence for this was circumstantial and subject to alternative explanations (IAGC 2004). Also, the evidence was not consistent with subsequent results from the same area of Brazil (Parente et al. 2006), or with direct studies of humpbacks exposed to seismic surveys in other areas and seasons (see above). After allowance for data from subsequent years, there was "no observable direct correlation" between strandings and seismic surveys (IWC 2007, p. 236).

Rorquals: Blue, sei, fin, and minke whales (all of which are members of the genus *Balaenoptera*) often have been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006; Moulton and Holst 2010), and calls from blue and fin whales have been localized in areas with airgun operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009; Castellote et al. 2010). Sightings by observers on seismic vessels during 110 large-source seismic surveys off the U.K. from 1997 to 2000 suggest that, during times of good sightability, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of airguns were shooting vs. silent (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the airgun array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). The average CPA distances for baleen whales sighted when large airgun arrays were operating vs. silent were about 1.6 vs. 1.0 km. Baleen whales, as a group, were more often oriented away from the vessel while a large airgun array was shooting compared with periods of no shooting (Stone and Tasker 2006). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003). Castellote et al. (2010) reported that singing fin whales in the Mediterranean moved away from an operating airgun array.

During seismic surveys in the NW Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods, baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp-up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, the mean CPA distance for fin whales was significantly farther during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were also seen significantly closer to the vessel during non-seismic periods compared with periods of seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010). MacLean and Haley (2004) occasionally observed minke whales approaching active airgun arrays where received sound levels were estimated to be near 170 to 180 dB re 1 μPa.

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 kilometres, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, studies done since the late 1990s of migrating humpback and migrating bowhead whales show reactions, including avoidance, that 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 can be biased. Observations over broader areas may be needed to determine the range of potential effects of some large-source seismic surveys where effects on cetaceans may extend to considerable distances (Richardson et al. 1999; Bain and Williams 2006; Moore and Angliss 2006). Longer-range observations, when required, can sometimes be obtained via systematic aerial surveys or aircraft-based observations of behaviour (e.g., Richardson et al. 1986, 1999; Miller et al. 1999, 2005; Yazvenko et al. 2007a,b) or by use of observers on one or more scout boats operating in coordination with the seismic vessel (e.g., Smultea et al. 2004; Johnson et al. 2007). However, the presence of other vessels near the source vessel can, at least at times, reduce sightability of cetaceans from the source vessel (Beland et al. 2009), thus complicating interpretation of sighting data.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioural changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of grey, bowhead, and humpback whales have determined that received levels of pulses in the 160 to 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 to 15 km from the source. A substantial proportion of the baleen whales within such distances may show avoidance or other strong disturbance reactions to the operating airgun array. However, in other situations, various mysticetes tolerate exposure to full-scale airgun arrays operating at even closer distances, with only localized avoidance and minor changes in activities. At the other extreme, in migrating bowhead whales, avoidance often extends to considerably larger distances (20 to 30 km) and lower received sound levels (120 to 130 dB re 1 μPa_{rms}). Also, even in cases where there is no conspicuous avoidance or change in activity upon exposure to sound pulses from distant seismic operations, there are sometimes subtle changes in behaviour (e.g., surfacing–respiration–dive cycles) that are only evident through detailed statistical analysis (e.g., Richardson et al. 1986; Gailey et al. 2007).

Mitigation measures for seismic surveys, especially nighttime seismic surveys, typically assume that many marine mammals (at least baleen whales) tend to avoid approaching airguns, or the seismic vessel itself, before being exposed to levels high enough for there to be any possibility of injury. This assumes that the ramp-up (soft-start) procedure is used when commencing airgun operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As noted above, single-airgun experiments with three species of baleen whales show that those species typically do tend to move away when a single airgun starts firing nearby, which simulates the onset of a ramp-up. The three species that showed avoidance when exposed to the onset of pulses from a single airgun were grey whales (Malme et al. 1984, 1986, 1988); bowhead whales (Richardson et al. 1986; Ljungblad et al. 1988); and humpback whales (Malme et al. 1985; McCauley et al. 1998, 2000a,b). In addition, results from Moulton and Holst (2010) showed that blue whales were seen significantly farther from the vessel during operations with a single airgun and during ramp up compared with periods without airgun operations. Since startup of a single airgun is equivalent to the start of a ramp-up (=soft start), this strongly suggests that many baleen whales will begin to move away during the initial stages of a ramp-up.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, grey whales have continued 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; Richardson et al. 1995), and there has been a substantial increase in the population over recent decades (Allen and Angliss 2010). The W Pacific grey whale population did not seem affected by a seismic survey in its feeding ground during a prior year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987), and their numbers have increased notably (Allen and Angliss 2010). Bowheads also have been observed over periods of days or weeks in areas ensonified repeatedly by seismic pulses (Richardson et al. 1987; Harris et al. 2007). However, it is generally not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. In any event, in the absence of some unusual circumstances, the history of coexistence between seismic surveys and baleen whales suggests that brief exposures to sound pulses from any single seismic survey are unlikely to result in prolonged effects.

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. However, there are recent systematic data on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is also an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008a; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

Delphinids (Dolphins and similar) and Monodontids (Beluga): Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008a; Richardson et al. 2009; Barkaszi et al. 2009; Moulton and Holst 2010). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance. Studies that have reported cases of small toothed whales close to the operating airguns include Duncan (1985), Arnold (1996), Stone (2003), and Holst et al. (2006). When a 3959 in^3, 18 airgun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when a large array of airguns is firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away or maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010).

Weir (2008b) noted that a group of short-finned pilot whales initially showed an avoidance response to ramp-up of a large airgun array, but that this response was limited in time and space. Moulton and Holst (2010) did not find any indications that long-finned pilot whales, or delphinids as a group, responded to ramp-ups by moving away from the seismic vessel during surveys in the Northwest Atlantic (Moulton and Holst 2010). Although the ramp-up procedure is a widely-used mitigation measure, it remains uncertain if it is effective in alerting marine mammals and causing them to move away from seismic operations (Weir 2008b).

Goold (1996a,b,c) studied the effects on common dolphins of 2-D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone. 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 airguns (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). Based on data from 21 offshore surveys from 2001-2008, Barry et al. (2010) found that bottlenose and short-beaked common dolphins were more often seen exhibiting "close to boat" behaviours during non-seismic than seismic periods, and that higher proportions of both species were seen "travelling" during seismic operations compared with non-seismic periods.

The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea in summer found that sighting rates of belugas were significantly lower at distances 10 to 20 km compared with 20 to 30 km from an operating airgun array (Miller et al. 2005). The low number of beluga sightings by marine mammal observers on the vessel seemed to confirm there was a strong avoidance response to the 2250 in^3 airgun array. More recent seismic monitoring studies in the same area have confirmed that the apparent displacement effect on belugas extended farther than has been shown for other small odontocetes exposed to airgun pulses (e.g., Harris et al. 2007).

Observers stationed on seismic vessels operating off the U.K. from 1997 to 2000 have provided data on the occurrence and behaviour of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004; Stone and Tasker 2006). 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 when large-volume[5] airgun arrays were shooting. Except for pilot whale and bottlenose dolphin, CPA distances for all of the small odontocete species tested, including killer whales, were significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales were less responsive than other small odontocetes in the presence of seismic surveys (Stone and Tasker 2006). For small odontocetes as a group, and most individual species, orientations differed between times when large airgun arrays were operating vs. silent, with significantly fewer animals traveling towards and/or more traveling away from the vessel during shooting (Stone and

[5] Large volume means at least 1,300 in^3, with most (79%) at least 3,000 in^3.

Tasker 2006). Observers' records suggested that fewer cetaceans were feeding and fewer were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating, and small odontocetes tended to swim faster during periods of shooting (Stone and Tasker 2006). For most types of small odontocetes sighted by observers on seismic vessels, the median CPA distance was ≥0.5 km larger during airgun operations (Stone and Tasker 2006). Killer whales appeared to be more tolerant of seismic shooting in deeper waters.

Data collected during seismic operations in the Gulf of Mexico and off Central America show similar patterns. A summary of vessel-based monitoring data from the Gulf of Mexico during 2003 to 2008 showed that delphinids were generally seen farther from the vessel during seismic than during non-seismic periods (based on Barkaszi et al. 2009, excluding sperm whales). Similarly, during two NSF-funded Lamont-Doherty Earth Observatory of Columbia University (L-DEO) seismic surveys that used a large 20 airgun array (~7000 in^3), sighting rates of delphinids were lower and initial sighting distances were farther away from the vessel during seismic than non-seismic periods (Smultea et al. 2004; Holst et al. 2005a, 2006; Richardson et al. 2009). Monitoring results during a seismic survey in the southeast Caribbean showed that the mean CPA of delphinids during seismic operations was 991 m during seismic operations vs. with 172 m when the airguns were not operational (Smultea et al. 2004). Surprisingly, nearly all acoustic detections via a towed passive acoustic monitoring (PAM) array, including both delphinids and sperm whales, were made when the airguns were operating (Smultea et al. 2004). Although the number of sightings during monitoring of a seismic survey off the Yucatán Peninsula, Mexico, was small (n = 19), the results showed that the mean CPA distance of delphinids during seismic operations there was 472 m during seismic operations vs. with 178 m when the airguns were silent (Holst et al. 2005a). The acoustic detection rates were nearly five times higher during non-seismic compared with seismic operations (Holst et al. 2005a).

For two additional NSF-funded L-DEO seismic surveys in the eastern Tropical Pacific, both using a large 36 airgun array (~6600 in^3), the results are less easily interpreted (Richardson et al. 2009). During both surveys, the delphinid detection rate was lower during seismic than during non-seismic periods, as found in various other projects, but the mean CPA distance of delphinids was closer (not farther) during seismic periods (Hauser et al. 2008; Holst and Smultea 2008).

During seismic surveys in the Northwest Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly farther (by approximately 200 m) during seismic operations compared with non-seismic periods; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Among Atlantic spotted dolphins off Angola (n = 16 useable groups), marked short-term and localized displacement was found in response to seismic operations conducted with a 24 airgun array (3147 in^3 or 5085 in^3) (Weir 2008a). Sample sizes were low, but CPA distances of dolphin groups were significantly larger when airguns were on (mean 1080 m) vs. off (mean 209 m). No Atlantic spotted dolphins were seen within 500 m of the airguns when they were operating, whereas all sightings when airguns were silent occurred within 500 m, including the only recorded "positive approach" behaviours.

Reactions of toothed whales to a single airgun or other small airgun sources are not well documented, but tend to be less substantial than reactions to large airgun arrays (e.g., Stone 2003; Stone and Tasker 2006). During 91 site surveys off the U.K. in 1997 to 2000, sighting rates of all small odontocetes combined were significantly lower during periods the low-volume[6] airgun sources were operating, and effects on orientation were evident for all species and groups tested (Stone and Tasker 2006). Results from four NSF-funded L-DEO seismic surveys using small arrays (up to 3 GI guns and 315 in^3) were inconclusive. During surveys in the eastern Tropical Pacific (Holst et al. 2005b) and in the NW Atlantic (Haley and Koski 2004), detection rates were slightly lower during seismic compared to non-seismic periods. However, mean CPAs were closer during seismic operations during one cruise (Holst et al. 2005b), and greater during the other cruise (Haley and Koski 2004). Interpretation of the data was confounded by the fact that survey effort and/or number of sightings during non-seismic periods during both surveys was small. Results from two small-array surveys in southeast Alaska were even more variable (MacLean and Koski 2005; Smultea and Holst 2008).

Captive bottlenose dolphins and beluga whales exhibited changes in behaviour when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005). Finneran et al. (2002) exposed a captive bottlenose dolphin and beluga to single impulses from a water gun (80 in^3). 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 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 beluga 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 transient sounds may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound before exhibiting the aversive behaviours mentioned above.

Odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to airgun pulses) may be indicative of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were “not always effective” in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by “scare” charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges; the received level was ~185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for causing auditory impairment (see below), the tolerance to these charges may indicate a lack of effect, or the failure to move away may simply indicate a stronger desire to feed, regardless of circumstances.

[6] For low volume arrays, maximum volume was 820 in^3, with most (87%) ≤180 in^3.

Phocoenids (Porpoises): Porpoises, like delphinids, show variable reactions to seismic operations, and reactions apparently depend on species. The limited available data suggest that the harbour porpoise shows stronger avoidance of seismic operations than Dall's porpoise (Stone 2003; MacLean and Koski 2005; Bain and Williams 2006). In Washington State waters, the harbour porpoise—despite being considered a high-frequency specialist—appeared to be the species affected by the lowest received level of airgun sound (<145 dB re 1 μPa_{rms} at a distance >70 km; Bain and Williams 2006). Similarly, during seismic surveys with large airgun arrays off the U.K. in 1997 to 2000, there were significant differences in directions of travel by harbour porpoises during periods when the airguns were shooting vs. silent (Stone 2003; Stone and Tasker 2006). A captive harbour porpoise exposed to single sound pulses from a small airgun showed aversive behaviour upon receipt of a pulse with a received level above 174 dB re 1 $\mu Pa_{pk\text{-}pk}$ or SEL >145 dB re 1 $\mu Pa^2 \cdot s$ (Lucke et al. 2009). In contrast, Dall's porpoises seem relatively tolerant of airgun operations (MacLean and Koski 2005; Bain and Williams 2006), although they too have been observed to avoid large arrays of operating airguns (Calambokidis and Osmek 1998; Bain and Williams 2006). The apparent tendency for greater responsiveness in harbour porpoise is consistent with their relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

Beaked Whales: There are almost no specific 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), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006b). In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, regardless of whether or not the airguns are operating. However, this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels not emitting airgun pulses (Reeves et al. 1993; Hooker et al. 2001). Several studies have indicated that some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005). Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the NW Atlantic; seven of those sightings were made at times when at least one airgun was operating. There was little evidence to indicate that beaked whale behaviour was affected by airgun operations; sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

There are increasing indications that some beaked whales tend to strand when military exercises involving mid-frequency sonar operation are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; Barlow and Gisiner 2006; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries or other physiological effects may also be a factor. Whether beaked whales would ever 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. No conclusive link has been established between seismic surveys and beaked whale strandings. There was a stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) in September 2002 when the R/V *Maurice Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002; Hildebrand 2005). However, NMFS did not establish a cause and effect relationship between this stranding and the seismic survey activities (Hogarth 2002). Cox et al. (2006) noted the "lack of knowledge regarding the temporal and spatial correlation between the [stranding] and the sound source". Hildebrand (2005) illustrated the approximate temporal-spatial relationships between the stranding and the *Ewing*'s tracks, but the time of the stranding was not known with sufficient precision for accurate determination of the CPA distance of the whales to the *Ewing*. Another stranding of Cuvier's beaked whales in the Galápagos occurred during a seismic survey in April 2000; however "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry [ed.] 2002).

Sperm Whales: All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998; McAlpine 2002; Baird 2005). However, most studies of sperm whales exposed to airgun sounds indicate that this species shows considerable tolerance of airgun pulses. The whales usually do not show strong avoidance (i.e., they do not leave the area) and they continue to call.

There were some early and limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km) seismic exploration. However, other operations in the area could also have been a factor (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, there was an early preliminary account of possible long-range avoidance of seismic vessels by sperm whales in the Gulf of Mexico (Mate et al. 1994). However, this has not been substantiated by subsequent more detailed work in that area (Gordon et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009).

Recent and more extensive data from vessel-based monitoring programs in U.K. waters, the Northwest Atlantic, and off Angola suggest that sperm whales in those areas show little evidence of avoidance or behavioural disruption in the presence of operating seismic vessels (Stone 2003; Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010). Among sperm whales off Angola (n = 96 useable groups), there were no significant differences in encounter rates (sightings/h) when a 24 airgun array (3147 in^3 or 5085 in^3) was operating vs. silent; encounter rate tended to increase over the 10 month duration of the seismic survey (Weir 2008a). There was also no significant difference in the CPA distances of the sperm whale sightings when airguns were on vs. off (means 3039 m vs. 2594 m, respectively). Similarly, in the Northwest Atlantic, sighting rates and distances of sperm whales did not differ between seismic and non-seismic periods (Moulton and Holst 2010). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive animals, which may be beyond visual range. However, these results do seem to indicate considerable tolerance of seismic surveys by at least some sperm whales. Also, a study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa_{p-p} (Madsen et al. 2002).

Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behaviour of sperm whales (McCall Howard 1999). Sightings of sperm whales by observers on seismic vessels operating in the Gulf of Mexico during 2003 to 2008 were at very similar average distances regardless of the airgun operating conditions (Barkaszi et al. 2009). For example, the mean sighting distance was 1839 m when the airgun array was in full operation (n = 612) vs. 1960 m when all airguns were off (n = 66).

A detailed study of sperm whale reactions to seismic surveys has been done recently in the Gulf of Mexico — the Sperm Whale Seismic Study or SWSS (Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). During SWSS, D-tags (Johnson and Tyack 2003) were used to record the movement and acoustic exposure of eight foraging sperm whales before, during, and after controlled exposures to sound from airgun arrays (Jochens et al. 2008; Miller et al. 2009).

Whales were exposed to maximum received sound levels of 111 to 147 dB re 1 μPa_{rms} (131 to 162 dB re 1 μPa_{pk-pk}) at ranges of ~1.4 to 12.8 km from the sound source (Miller et al. 2009). Although the tagged whales showed no discernible horizontal avoidance, some whales showed changes in diving and foraging behaviour during full-array exposure, possibly indicative of subtle negative effects on foraging (Jochens et al. 2008; Miller et al. 2009; Tyack 2009). Two indications of foraging that they studied were oscillations in pitch and occurrence of echolocation buzzes, both of which tend to occur when a sperm whale closes in on prey. "Oscillations in pitch generated by swimming movements during foraging dives were on average 6% lower during exposure than during the immediately following post-exposure period, with all 7 foraging whales exhibiting less pitching (p = 0.014). Buzz rates, a proxy for attempts to capture prey, were 19% lower during exposure…" (Miller et al. 2009). Although the latter difference was not statistically significant (p = 0.141), the percentage difference in buzz rate during exposure vs. post-exposure conditions appeared to be strongly correlated with airgun-whale distance (Miller et al. 2009: Fig. 5; Tyack 2009).

Discussion and Conclusions: Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies near the U.K., Newfoundland, Angola, in the Gulf of Mexico, and off Central America have shown localized avoidance. Also, belugas summering in the Canadian Beaufort Sea showed larger-scale avoidance, tending to avoid waters out to 10 to 20 km from operating seismic vessels. In contrast, recent studies show little evidence of conspicuous reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are almost no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars; if they ever do so in response to seismic survey noise is unknown. Northern bottlenose whales seem to continue to call when exposed to pulses from distant seismic vessels.

Overall, odontocete reactions to large arrays of airguns are variable and, at least for delphinids and some porpoises, seem to be confined to a smaller radius than has been observed for some mysticetes. However, other data suggest that some odontocetes species, including belugas and harbour porpoises, may be more responsive than might be expected given their poor low-frequency hearing. Reactions at longer distances may be particularly likely when sound propagation conditions are conducive to transmission of the higher-frequency components of airgun sound to the animals' location (DeRuiter et al. 2006; Goold and Coates 2006; Tyack et al. 2006a; Potter et al. 2007).

For delphinids, and possibly the Dall's porpoise, the available data suggest that a ≥170 dB re 1 μPa_{rms} disturbance criterion (rather than ≥160 dB) would be appropriate. With a medium to large airgun array, received levels typically diminish to 170 dB within 1 to 4 km, whereas levels typically remain above 160 dB out to 4 to 15 km (e.g., Tolstoy et al. 2009). Reaction distances for delphinids are more consistent with the typical 170 dB re 1 μPa_{rms} distances. The 160 dB (rms) criterion currently applied by NMFS was developed based primarily on data from grey and bowhead whales. Avoidance distances for delphinids and Dall's porpoises tend to be shorter than for those two mysticete species. For delphinids and Dall's porpoises, there is no indication of strong avoidance or other disruption of behaviour at distances beyond those where received levels would be ~170 dB re 1 μPa_{rms} (on the order of 2 or 3 km for a large airgun array).

Pinnipeds

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review of the early literature, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies. Monitoring in the Beaufort Sea during 1996 to 2002 provided a substantial amount of information on avoidance responses (or lack thereof) and associated behaviour. Additional monitoring of that type has been done in the Beaufort and Chukchi seas in 2006 to 2010. Pinnipeds exposed to airgun sounds have also been observed during seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of pinnipeds exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* 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 to habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the U.K., a radio-telemetry study demonstrated short-term changes in the behaviour of harbour and grey seals exposed to airgun pulses (Thompson et al. 1998). Harbour seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 airguns), and behavioural responses differed among individuals. One harbour seal avoided the array at distances up to 2.5 km from the source and only resumed foraging dives after seismic stopped. Another harbour seal exposed to the same small airgun array showed no detectable behavioural response, even when the array was within 500 m. Grey seals exposed to a single 10 in^3 airgun showed an avoidance reaction: they moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

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 harbour 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 Osmek 1998). Bain and Williams (2006) also stated that their small sample of harbour seals and sea lions tended to orient and/or move away upon exposure to sounds from a large airgun array.

Monitoring work in the Alaskan Beaufort Sea during 1996 to 2001 provided considerable information regarding the behaviour of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). Those seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1500 in^3. Subsequent monitoring work in the Canadian Beaufort Sea in 2001 to 2002, with a somewhat larger airgun system (24 airguns, 2250 in^3), provided similar results (Miller et al. 2005).

The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not (Moulton and Lawson 2002). Also, seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997. However, the avoidance movements were relatively small, on the order of 100 m to (at most) a few hundreds of metres, and many seals remained within 100 to 200 m of the trackline as the operating airgun array passed by.

The operation of the airgun array had minor and variable effects on the behaviour of seals visible at the surface within a few hundred metres of the airguns (Moulton and Lawson 2002). 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).

Monitoring results from the Canadian Beaufort Sea during 2001 to 2002 were more variable (Miller et al. 2005). During 2001, sighting rates of seals (mostly ringed seals) were similar during all seismic states, including periods without airgun operations. However, seals tended to be seen closer to the vessel during non-seismic than seismic periods. In contrast, during 2002, sighting rates of seals were higher during non-seismic periods than seismic operations, and seals were seen farther from the vessel during non-seismic compared to seismic activity (a marginally significant result). The combined data for both years showed that sighting rates were higher during non-seismic periods compared to seismic periods, and that sighting distances were similar during both seismic states. Miller et al. (2005) concluded that seals showed very limited avoidance to the operating airgun array.

Vessel-based monitoring also took place in the Alaskan Chukchi and Beaufort seas from 2006 to 2008 (Funk et al. 2010). In the Chukchi Sea, seal sightings rates were greater from non-seismic monitoring than source vessels at locations with received sound levels ≥160 and 159-120 dB rms, and sighting rates were greater from source than monitoring vessels at locations with received sound levels were <120 dB rms

(Haley et al. 2010). In the Beaufort Sea, sighting rates for seals exposed to received sound levels ≥160 dB rms were also significantly higher from monitoring than from seismic source vessels, and sighting rates were significantly higher from source vessels in areas exposed to <120 compared to ≥160 dB rms (Savarese et al. 2010). In addition, seals tended to stay farther away and swam away from source vessels more frequently than from monitoring vessels when received sound levels were ≥160 dB rms. These observations are indicative of a tendency for phocid seals to exhibit localized avoidance of the seismic source vessel when airguns are firing (Funk et al. 2010).

Over the three years, seal sightings rates were greater from monitoring than source vessels at locations with received sound levels ≥160 and 159-120 dB rms, whereas seal sighting rates were greater from source than monitoring vessels at locations with received sound levels were <120 dB rms, suggesting that seals may be reacting to active airguns by moving away from the source vessel.

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 many pinnipeds do not avoid the area within a few hundred metres of an operating airgun array. However, based on the studies with large sample size, or observations from a separate monitoring vessel, or radio telemetry, it is apparent that some phocid seals do show localized avoidance of operating airguns. The limited nature of this tendency for avoidance is a concern. It suggests that one cannot rely on pinnipeds to move away, or to move very far away, before received levels of sound from an approaching seismic survey vessel approach those that may cause hearing impairment (see below).

Sea Turtles

There have been far fewer studies of the effects of airgun noise (or indeed any type of noise) on sea turtles. Three studies have focused on short-term behavioural responses of sea turtles in enclosures to single airguns. However, 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. Although responses of free-ranging sea turtles to seismic surveys are now being reported, we are not aware of any directed 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.

The most recent of the studies of caged sea turtles exposed to airgun pulses was a study by McCauley et al. (2000a,b) off western Australia. This is apparently the only such study in which received sound levels were estimated carefully. The authors exposed caged green and loggerhead sea turtles (one of each) to pulses from an approaching and then receding 20 in^3 airgun operating at 1500 psi and 5 m airgun 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 swim speed relative to periods when no airguns were operating. The behaviour of the sea turtles became more erratic when received levels exceeded 175 dB re 1 µPa rms. The authors suggested that the erratic behaviour exhibited by the caged sea turtles would likely, in unrestrained turtles, be expressed as an avoidance response (McCauley et al. 2000a,b).

O'Hara and Wilcox (1990) tested the reactions to airguns by loggerhead sea turtles held in a 300 x 45 m area of a canal in Florida with a bottom depth of 10 m. Nine turtles were tested at different times. The sound source consisted of one 10 in^3 airgun plus two 0.8 in^3 "poppers" operating at 2000 psi [7] and airgun depth of 2 m for prolonged periods of 20 to 36 hours in duration. The turtles maintained a standoff range of about 30 m when exposed to airgun pulses every 15 s or every 7.5 s. It was also possible that some turtles remained on the bottom of the enclosure when exposed to airgun pulses. O'Hara and Wilcox (1990) did not measure the received airgun sound levels. McCauley et al. (2000a,b) estimated that "the level at which O'Hara saw avoidance was around 175 to 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 to 176 dB because the calculations by McCauley et al. apparently did not allow for the shallow 2 m airgun depth in the Florida study. The effective source level of airguns is less when they are near 2 m depth than at 5 m (Greene et al. 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 as summarised earlier. The turtles were held in a netted enclosure ~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; the firing rate was one shot every 5 to 6 s. 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. However, there was an indication of slight initial avoidance followed by rapid waning of the avoidance response which the authors described as "habituation." Their auditory study indicated that exposure to the airgun pulses may have resulted in TTS (discussed earlier). Reduced hearing sensitivity may also have contributed to the waning response upon continued exposure. Based on physiological measurements, there was some evidence of increased stress in the sea turtles, but this stress could also have resulted from handling of the turtles.

Once again, inconsistencies in reporting procedures and experimental design prevent direct comparison of this study with either McCauley et al. (2000a,b) or O'Hara and Wilcox (1990). Moein et al. (1994) stated, without further details, that "three different decibel levels (175, 177, 179) were utilised" during each test. These sound levels probably are received levels in dB re 1 µPa, and probably relate to the initial exposure distance (mean 24 m), but these details were not specified. Also, it was not specified whether these values were measured or estimated, or whether they are expressed in peak-peak, peak, rms, SEL, or some other units. Given the shallow water in the enclosure (3.6 m), any estimates based on simple assumptions about propagation would be suspect.

Despite the problems in comparing these studies, there is a consistent trend showing that, at some received level, sea turtles show avoidance of an operating airgun. Lenhardt (2002) reported behavioural responses to Bolt 600 airguns at received levels of 151 to 161 dB SPL re 1 µm, and initial avoidance responses at

[7] 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.

received levels near 175 dB. McCauley et al. (2000a,b) found evidence of behavioural responses when the received level from a single small airgun was 166 dB re 1 µPa rms, and avoidance responses at 175 dB re 1 µPa rms. Based on these data, McCauley et al. (2000a,b) estimated that, for a typical airgun array (2678 in^3, 12 elements) operating in 100 to 120 m water depth, sea turtles may exhibit behavioural changes at approximately 2 km and avoidance around 1 km. These estimates are subject to great variation, depending on the seismic source and local propagation conditions.

A further potential complication is that sea turtles on or near the bottom may receive sediment-borne "headwave" signals from the airguns (McCauley et al. 2000a,b). As previously discussed, it is believed that sea turtles use bone conduction to hear. It is unknown how sea turtles might respond to the headwave component of an airgun impulse, or to bottom vibrations.

A pair of related studies involving stimuli other than airguns may also be relevant.

1) Two loggerhead turtles resting on the bottom of shallow tanks responded repeatedly to low-frequency (20 to 80 Hz) tones by becoming active and swimming to the surface. They remained at the surface or only slightly submerged for the remainder of the 1 min trial (Lenhardt 1994). Although no detailed data on sound levels at the bottom vs. surface were reported, the surfacing response probably reduced the levels of underwater sound to which the turtles were exposed.
2) In a separate study, a loggerhead and a Kemp's Ridley sea turtle responded similarly when 1 s vibratory stimuli at 250 or 500 Hz were applied to the head for 1 s (Lenhardt et al. 1983). There appeared to be rapid habituation to these vibratory stimuli. The tones and vibratory stimuli used in these two studies were quite different from airgun pulses. However, it is possible that resting sea turtles may exhibit a similar "alarm" response, possibly including surfacing or alternatively diving, when exposed to any audible noise, regardless of whether it is a pulsed sound or tone.

Data on sea turtle behaviour near airgun operations have also been collected during marine mammal and sea turtle monitoring and mitigation programs associated with various seismic operations around the world. Results suggest it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. During six large-source (10 to 20 airguns; 3050 to 8760 in^3) and small-source (up to six airguns or three GI guns; 75 to 1350 in^3) surveys conducted by L-DEO during 2003 to 2005, the mean closest point of approach (CPA) for turtles was closer during non-seismic than seismic periods: 139 m vs. 228 m and 120 m vs. 285 m, respectively (Holst et al. 2006). During one of these surveys an observer sighted an olive Ridley sea turtle (*Lepidochelys olivacea*) that appeared at the surface within the 190 dB re 1 µPa isopleth while the 10 airgun array was operating (Holst et al. 2005a). The turtle was "logging sedately" at the surface for a period, during which it floated within about 10 m of the array and then swam away. Based on the observed behaviour, it was surmised that the turtle was agitated by its exposure to the sound source (Holst et al. 2005a). During a seismic survey off the Pacific coast of Central America, the turtle sighting rate during non-seismic periods was seven times greater than that during seismic periods (Holst and Smultea 2008). In addition, turtles were seen significantly farther from the airgun array when it was operating (mean 159 m, n = 77) than when the airguns were off (mean 188 m, n = 69; Mann-Whitney U test, P<0.001) (Holst and Smultea 2008). During another survey in the eastern Tropical Pacific, the turtle sighting rate during non-seismic was 1.5 times greater than that during seismic periods; however, turtles tended to be seen closer to the airgun array when it was operating (Hauser et al. 2008).

Weir (2007) reported on the behaviour of sea turtles near seismic exploration operations off Angola, West Africa. A total of 240 sea turtles were seen during 676 h of associated marine mammal mitigation and monitoring observations. Alternating airgun arrays with total volumes 5085 and 3147 in^3 were used during the seismic program. Sea turtles were seen closer to the seismic source and sighting rates were twice as high during non-seismic vs. seismic periods (Weir 2007). However, there was no significant difference in the median distance of turtle sightings from the array during non-seismic vs. seismic periods (means of 743 m [n = 112] and 779 m [n = 57]). Off northeastern Brazil, 46 sea turtles were seen during 2028 h of marine mammal mitigation and monitoring of seismic exploration using 4 to 8 GI airguns; no evidence of adverse impacts on sea turtles from seismic operations was apparent (Parente et al. 2006).

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) avoidance of the entire seismic survey area to the extent that the turtles move to less preferred habitat; (2) avoidance of 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) 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 kilometres (McCauley et al. 2000b). Avoidance reactions on that scale could prevent sea turtles from using an important coastal area or bay if there was a prolonged seismic operation in the area. Sea turtles might be excluded from the area for the duration of the seismic operation, or they might remain but exhibit abnormal behavioural patterns (e.g., lingering at the surface where received sound levels are lower). Whether those that were displaced would return quickly after the seismic operation ended is generally unknown. 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 Study Area. The limited available data indicate that sea turtles will hear airgun sounds. Based on available data, it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. Seismic operations in or near areas where turtles concentrate are likely to have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Study Area is not a breeding area for sea turtles and it is not known or thought to be an important feeding area; thus, high concentrations of sea turtles are unlikely.

(D) Hearing Impairment Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. Temporary threshold shift (TTS) has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. 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 ≥180 and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shut-down) radii planned for numerous seismic surveys conducted under U.S. jurisdiction. 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.

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters have been published (Southall et al. 2007). Those recommendations have not, as of early 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain EISs and small-take authorizations. NMFS has indicated that it may issue new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

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, at least in theory, cause hearing impairment. In addition, many cetaceans and (to a limited degree) pinnipeds show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) 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, 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. The following subsections summarize available data on noise-induced hearing impairment and non-auditory physical effects.

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. It is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or "injury" (Southall et al. 2007). Rather, the onset of TTS is an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility.

The magnitude of TTS depends on the level and duration of noise exposure, and to some degree on frequency, among other considerations (Kryter 1985; Richardson et al. 1995; Southall et al. 2007). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. In terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. Only a few data have been obtained on sound levels and durations necessary to elicit mild TTS in marine mammals (none in mysticetes), and none of the published data concern TTS elicited by exposure to multiple pulses of sound during operational seismic surveys (Southall et al. 2007).

Toothed Whales: There are empirical data on the sound exposures that elicit onset of TTS in captive bottlenose dolphins and belugas. The majority of these data concern non-impulse sound, but there are some limited published data concerning TTS onset upon exposure to a single pulse of sound from a watergun (Finneran et al. 2002). A detailed review of all TTS data from marine mammals can be found in Southall et al. (2007). The following summarizes some of the key results on odontocetes.

Recent information corroborates earlier expectations that the effect of exposure to strong transient sounds is closely related to the total amount of acoustic energy that is received. Finneran et al. (2005) examined the effects of tone duration on TTS in bottlenose dolphins. Bottlenose dolphins were exposed to 3 kHz tones (non-impulsive) for periods of 1, 2, 4 or 8 s, with hearing tested at 4.5 kHz. For 1 s exposures, TTS occurred with SELs of 197 dB, and for exposures >1 s, SEL >195 dB resulted in TTS (SEL is equivalent to energy flux, in dB re 1 $\mu Pa^2 \cdot s$). At an SEL of 195 dB, the mean TTS (4 min after exposure) was 2.8 dB. Finneran et al. (2005) suggested that an SEL of 195 dB is the likely threshold for the onset of TTS in dolphins and belugas exposed to tones of durations 1 to 8 s (i.e., TTS onset occurs at a near-constant SEL, independent of exposure duration). That implies that, at least for non-impulsive tones, a doubling of exposure time results in a 3 dB lower TTS threshold.

The assumption that, in marine mammals, the occurrence and magnitude of TTS is a function of cumulative acoustic energy (SEL) is probably an oversimplification. Kastak et al. (2005) reported preliminary evidence from pinnipeds that, for prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer, i.e., the results were not fully consistent with an equal-energy model to predict TTS onset. Mooney et al. (2009a) showed this in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130 to 178 dB re 1 μPa for periods of 1.88 to 30 min. Higher SELs were required to induce a given TTS if exposure duration short than if it was longer. Exposure of the aforementioned bottlenose dolphin to a sequence of brief sonar signals showed that, with those brief (but non-impulse) sounds, the received energy (SEL) necessary to elicit TTS was higher than was the case with exposure to the more prolonged octave-band noise (Mooney et al. 2009b). Those authors concluded that, when using (non-impulse) acoustic signals of duration ~0.5 s, SEL must be at least 210 to 214 dB re 1 $\mu Pa^2 \cdot s$ to induce TTS in the bottlenose dolphin.

On the other hand, the TTS threshold for odontocetes exposed to a single impulse from a watergun (Finneran et al. 2002) appeared to be somewhat lower than for exposure to non-impulse sound. This was expected, based on evidence from terrestrial mammals showing that broadband pulsed sounds with rapid rise times have greater auditory effect than do non-impulse sounds (Southall et al. 2007). The received energy level of a single seismic pulse that caused the onset of mild TTS in the beluga, as measured without frequency weighting, was ~186 dB re 1 $\mu Pa^2 \cdot s$ or 186 dB SEL (Finneran et al. 2002).[8] The rms level of an airgun pulse (in dB re 1 μPa measured over the duration of the pulse) is typically 10 to 15 dB higher than the SEL for the same pulse when received within a few kilometres of the airguns. Thus, a single airgun pulse might need to have a received level of ~196 to 201 dB re 1 μPa_{rms} in order to produce brief, mild TTS. Exposure to several strong seismic pulses that each has a flat-weighted received level near 190 dB_{rms} (175 to 180 dB SEL) could result in cumulative exposure of ~186 dB SEL (flat-weighted) or ~183 dB SEL (M_{mf}-weighted), and thus slight TTS in a small odontocete. That assumes that the TTS threshold upon exposure to multiple pulses is (to a first approximation) a function of the total received pulse energy, without allowance for any recovery between pulses.

The above TTS information for odontocetes is derived from studies on the bottlenose dolphin and beluga. For the one harbour porpoise tested, the received sound level of airgun sound that elicited onset of TTS was lower. The animal was exposed to single pulses from a small (20 in^3) airgun, and auditory evoked potential methods were used to test the animal's hearing sensitivity at frequencies of 4, 32, or 100 kHz after each exposure (Lucke et al. 2009). Based on the measurements at 4 kHz, TTS occurred upon exposure to one airgun pulse with received level ~200 dB re 1 μPa_{pk-pk} or an SEL of 164.3 dB re 1 $\mu Pa^2 \cdot s$. If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (*cf.* Southall et al. 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin.

Insofar as we are aware, there are no published data confirming that the auditory effect of a sequence of airgun pulses received by an odontocete is a function of their cumulative energy. Southall et al. (2007) consider that to be a reasonable, but probably somewhat precautionary, assumption. It is precautionary

[8] If the low-frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005a) and Southall et al. (2007) using their M_{mf}-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007).

because, based on data from terrestrial mammals, one would expect that a given energy exposure would have somewhat less effect if separated into discrete pulses, with potential opportunity for partial auditory recovery between pulses. However, as yet there has been little study of the rate of recovery from TTS in marine mammals, and in humans and other terrestrial mammals the available data on recovery are quite variable. Southall et al. (2007) concluded that—until relevant data on recovery are available from marine mammals—it is appropriate not to allow for any assumed recovery during the intervals between pulses within a pulse sequence.

Additional data are needed 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. To determine how close an airgun array would need to approach in order to elicit TTS, it is necessary to determine the total energy that a mammal would receive as an airgun array approaches, passes at various CPA distances, and moves away (e.g., Erbe and King 2009). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy even though that energy is received in multiple pulses separated by gaps. The lack of data on the exposure levels necessary to cause TTS in toothed whales when the signal is a series of pulsed sounds, separated by silent periods, remains a data gap, as is the lack of published data on TTS in odontocetes other than the beluga, bottlenose dolphin, and harbour porpoise.

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. The frequencies to which mysticetes are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in mysticetes (Southall et al. 2007). However, based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, Gedamke et al. (2008) suggested that some baleen whales whose closest point of approach to a seismic vessel is 1 km or more could experience TTS or even PTS.

In practice during seismic surveys, few if any cases of TTS are expected given the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for there to be any possibility of TTS (see above for evidence concerning avoidance responses by baleen whales). This assumes that the ramp-up (soft-start) procedure is used when commencing airgun operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As discussed earlier, results from numerous studies indicate that many baleen whales, particularly bowhead, grey, humpback, and blue whales are likely to move away from the source vessel during the initial stages of a ramp-up.

Pinnipeds: In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels of ~178 and 183 dB re 1 μPa_{rms} and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbour seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001). Kastak et al. (2005) reported that the amount of threshold shift increased with increasing SEL in a California sea lion and harbour seal. They noted that, for non-impulse sound, doubling the exposure duration from 25 to 50 min (i.e., a +3 dB change in SEL) had a greater effect on TTS than an increase of 15 dB (95 vs. 80 dB) in exposure level. Mean threshold shifts ranged from 2.9 to 12.2 dB, with full recovery within 24 h (Kastak et al. 2005). Kastak et al. (2005) suggested that, for non-impulse sound, SELs resulting in TTS onset in three species of pinnipeds may range from 183 to 206 dB re 1 $\mu Pa^2 \cdot s$, depending on the absolute hearing sensitivity.

As noted above for odontocetes, it is expected that—for impulse as opposed to non-impulse sound—the onset of TTS would occur at a lower cumulative SEL given the assumed greater auditory effect of broadband impulses with rapid rise times. The threshold for onset of mild TTS upon exposure of a harbour seal to impulse sounds has been estimated indirectly as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007). That would be approximately equivalent to a single pulse with received level ~181 to 186 dB re 1 μPa_{rms}, or a series of pulses for which the highest rms values are a few dB lower.

At least for non-impulse sounds, TTS onset occurs at appreciably higher received levels in California sea lions and northern elephant seals than in harbour seals (Kastak et al. 2005). Thus, the former two species would presumably need to be closer to an airgun array than would a harbour seal before TTS is a possibility. Insofar as we are aware, there are no data to indicate whether the TTS thresholds of other pinniped species are more similar to those of the harbour seal or to those of the two less-sensitive species.

Sea Turtles: Few studies have directly investigated hearing or noise-induced hearing loss in sea turtles. Moein et al. (1994) studied the effect of sound pulses from a single airgun of unspecified size on loggerhead sea turtles. Apparent TTS was observed after exposure to a few hundred airgun pulses at distances no more than 65 m. The hearing capabilities had returned to "normal" when the turtles were re-tested two weeks later. Studies with terrestrial reptiles have also demonstrated that exposure to impulse noise can cause hearing loss. For example, desert tortoises (*Gopherus agassizii*) exhibited 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). 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.

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 will sustain 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.

Likelihood of Incurring TTS: A marine mammal within a radius of ≤100 m around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

Most cetaceans show some degree of avoidance of seismic vessels operating an airgun array (see above). 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. TTS would be more likely in any odontocetes that bow- or wake-ride or otherwise linger near the airguns. However, while bow- or wake-riding, odontocetes would be at the surface and thus not exposed to strong sound pulses given the pressure-release and Lloyd Mirror effects at the surface. But if bow- or wake-riding animals were to dive intermittently near airguns, they would be exposed to strong sound pulses, possibly repeatedly.

If some cetaceans did incur mild or moderate TTS through exposure to airgun sounds in this manner, this would very likely be a temporary and reversible phenomenon. However, even a temporary reduction in hearing sensitivity could be deleterious in the event that, during that period of reduced sensitivity, a marine mammal needed its full hearing sensitivity to detect approaching predators, or for some other reason.

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are generally not as strong or consistent as those of cetaceans. Pinnipeds occasionally seem to be attracted to operating seismic vessels. There are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. However, given the indirect indications of a lower TTS threshold for the harbour seal than for odontocetes exposed to impulse sound (see above), it is possible that some pinnipeds close to a large airgun array could incur TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels >180 dB re 1 μPa_{rms}. The corresponding limit for pinnipeds has been set by NMFS at 190 dB, although the HESS Team (HESS 1999) recommended a 180 dB limit for pinnipeds in California. The 180 and 190 dB re 1 μPa_{rms} levels have not been considered to be the levels above which TTS might occur. Rather, they were 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 summarized above, data that are now available imply that TTS is unlikely to occur in various odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses in which the strongest pulse has a received level substantially exceeding 190 dB re 1 μPa_{rms}. On the other hand, for the harbour seal, harbour porpoise, and perhaps some other species, TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single pulse with a SEL of 175 to 180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible in harbour seals and harbour porpoises with a cumulative SEL of ~171 and ~164 dB re 1 $\mu Pa^2 \cdot s$, respectively.

It has been shown that most large whales and many smaller odontocetes (especially the harbour porpoise) show at least localized avoidance of ships and/or seismic operations (see above). Even when avoidance is limited to the area within a few hundred metres of an airgun array, that should usually be sufficient to avoid the possibility of TTS based on what is currently known about thresholds for TTS onset in cetaceans. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans near the airguns at the time of startup to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array (see above). Thus, most baleen whales likely will not be exposed to high levels of airgun sounds provided the ramp-up procedure is applied. Likewise, many odontocetes close to the trackline are likely to move away before the sounds from an approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for baleen whales or odontocetes that show avoidance of ships or airguns to be close enough to an airgun array to experience TTS. In the event that a few individual cetaceans did incur TTS through exposure to strong airgun sounds, this is a temporary and reversible phenomenon unless the exposure exceeds the TTS-onset threshold by a sufficient amount for PTS to be incurred (see below). If TTS but not PTS were incurred, it would most likely be mild, in which case recovery is expected to be quick (probably within minutes).

Sea Turtles: There have been few studies that have directly investigated hearing or noise-induced hearing loss in sea turtles. The apparent occurrence of TTS in loggerhead turtles exposed to many pulses from a single airgun ≤65 m away (Moein et al. 1994) 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.

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, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985). 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. [Rise time is the interval required for sound pressure to increase from the baseline pressure to peak pressure.]

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal or sea turtle, even with large arrays of airguns. However, given the likelihood that some animals close to an airgun array might incur at least mild TTS (see above), there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS.

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 (Southall et al. 2007). Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is at least 6 dB higher than the TTS threshold on a peak-pressure basis, and probably >6 dB higher (Southall et al. 2007). The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during 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, 2005; Nachtigall et al. 2003, 2004). 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; Southall et al. 2007). However, there is special concern about strong sounds whose pulses have very rapid rise times. In terrestrial mammals, there are situations when pulses with rapid rise times (e.g., from explosions) can result in PTS even though their peak levels are only a few dB higher than the level causing slight TTS. The rise time of airgun pulses is fast, but not as fast as that of an explosion.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- exposure to single very intense sound;
- fast rise time from baseline to peak pressure;
- 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) 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 rather rapid rise time.

More recently, Southall et al. (2007) estimated that received levels would need to exceed the TTS threshold by at least 15 dB, on an SEL basis, for there to be risk of PTS. Thus, for cetaceans exposed to a sequence of sound pulses, they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 $\mu Pa^2 \cdot s$ (15 dB higher than the M_{mf}-weighted TTS threshold, in a beluga, for a watergun impulse). Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertain to non-impulse sound (see above). Southall et al. (2007) estimated that the PTS threshold could be a cumulative M_{pw}-weighted SEL of ~186 dB re 1 $\mu Pa^2 \cdot s$ in the case of a harbour seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher given the higher TTS thresholds in those species. Southall et al. (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 µPa, respectively. Thus, PTS might be expected upon exposure of cetaceans to either SEL ≥198 dB re 1 $\mu Pa^2 \cdot s$ or peak pressure ≥230 dB re 1 µPa. Corresponding proposed dual criteria for pinnipeds (at least harbour seals) are ≥186 dB SEL and ≥ 218 dB peak pressure (Southall et al. 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model is not be entirely correct.

Sound impulse duration, peak amplitude, rise time, number of pulses, and inter-pulse interval are the main factors thought to determine the onset and extent of PTS. 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.

As described above for TTS, in estimating the amount of sound energy required to elicit the onset of TTS (and PTS), it is assumed that the auditory effect of a given cumulative SEL from a series of pulses is the same as if that amount of sound energy were received as a single strong sound. There are no data from marine mammals concerning the occurrence or magnitude of a potential partial recovery effect between pulses. In deriving the estimates of PTS (and TTS) thresholds quoted here, Southall et al. (2007) made the precautionary assumption that no recovery would occur between pulses.

The TTS section (above) concludes that exposure to several strong seismic pulses that each have flat-weighted received levels near 190 dB re 1 μPa_{rms} (175 to 180 dB re 1 $\mu Pa^2 \cdot s$ SEL) could result in cumulative exposure of ~186 dB SEL (flat-weighted) or ~183 dB SEL (M_{mf}-weighted), and thus slight TTS in a small odontocete. Allowing for the assumed 15 dB offset, expressed on an SEL basis, between PTS and TTS thresholds, exposure to several strong seismic pulses that each have flat-weighted received levels near 205 dB_{rms} (190 to 195 dB SEL) could result in cumulative exposure of ~198 dB SEL (M_{mf}-weighted), and thus slight PTS in a small odontocete. However, the levels of successive pulses that will be received by a marine mammal that is below the surface as a seismic vessel approaches, passes and moves away will tend to increase gradually and then decrease gradually, with periodic decreases superimposed on this pattern when the animal comes to the surface to breathe. To estimate how close an odontocete's CPA distance would have to be for the cumulative SEL to exceed 198 dB SEL (M_{mf}-weighted), one would (as a minimum) need to allow for the sequence of distances at which airgun shots would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Erbe and King 2009).

It is unlikely that an odontocete would remain close enough to a large airgun array long enough to incur PTS. There is some concern about bow-riding odontocetes, but for animals at or near the surface, auditory effects are reduced by Lloyd's mirror and surface release effects. The presence of the vessel between the airgun array and bow-riding odontocetes could also, in some but probably not all cases reduce the levels received by bow-riding animals (e.g., Gabriele and Kipple 2009). The TTS (and thus PTS) thresholds of baleen whales are unknown but, as an interim measure, assumed to be no lower than those of odontocetes. Also, 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. The TTS (and thus PTS) thresholds of some pinnipeds (e.g., harbour seal) as well as the harbour porpoise may be lower (Kastak et al. 2005; Southall et al. 2007; Lucke et al. 2009). If so, TTS and potentially PTS may extend to a somewhat greater distance for those animals. Again, Lloyd's mirror and surface release effects will ameliorate the effects for animals at or near the surface.

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.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in marine mammals or sea turtles, caution is warranted given:

- the limited knowledge about noise-induced hearing damage in sea turtles and marine mammals (particularly baleen whales and pinnipeds);
- the seemingly greater susceptibility of certain species (e.g., harbour porpoise and harbour seal) to TTS and presumably also PTS; and
- the lack of knowledge about TTS and PTS thresholds in many species, including various species closely related to the harbour porpoise and harbour seal.

The avoidance reactions of many marine mammals and sea turtles, along with commonly-applied monitoring and mitigation measures (visual and passive acoustic monitoring, ramp-ups, and power downs or shut downs when mammals are detected within or approaching the "safety radii"), would reduce the already-low probability of exposure of marine mammals and sea turtles to sounds strong enough to induce PTS.

(E) Physical and Non-Auditory Physiological Effects

Strandings and Mortality

Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). However, explosives are no longer used in marine waters for commercial seismic surveys or (with rare exceptions) for seismic research; they have been replaced by airguns and other non-explosive sources. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, a seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioural reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007). Hildebrand (2005) reviewed the association of cetacean strandings with high-intensity sound events and found that deep-diving odontocetes, primarily beaked whales, were by far the predominant (95%) cetaceans associated with these events, with 2% mysticete whales (minke). However, as summarized below, there is no definitive evidence that airguns can lead to injury, strandings, or mortality even for marine mammals in close proximity to large airgun arrays.

Specific sound-related processes that may lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behaviour (such as a change in diving behaviour that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioural change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioural response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz. Typical military mid-frequency sonars emit non-impulse sounds at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the frequency may change over time). Thus, it is not appropriate to assume that the effects of seismic surveys on beaked whales or other species would be the same as the apparent effects of military sonar. For example, resonance effects (Gentry 2002) and acoustically-mediated bubble-growth (Crum et al. 2005) are implausible in the case of exposure to impulsive broadband source like an airgun array. Nonetheless, evidence that sonar signals can, in special circumstances, lead (at least indirectly) to physical damage and mortality (e.g., Balcomb and Claridge 2001; NOAA and USN 2001; Jepson et al. 2003; Fernández et al. 2004, 2005; Hildebrand 2005; Cox et al. 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity "pulsed" sound.

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004; IWC 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO seismic vessel R/V *Maurice Ewing* was operating a 20 airgun, 8490 in^3 airgun array in the general area. The evidence linking the stranding to the seismic survey was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam echosounder at the same time, but this had much less potential than the aforementioned naval sonars to affect beaked whales, given its downward-directed beams, much shorter pulse durations, and lower duty cycle. Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggest a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005).

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.

Other potential direct physical effects to sea turtles during seismic operations include entanglement with seismic gear (e.g., cables, buoys, streamers, etc.) and ship strike (Pendoley 1997; Hazel et al. 2007; Ketos Ecology 2007; Weir 2007). Entanglement of sea turtles with marine debris, fishing gear, dredging operations, and equipment operations are a documented occurrence and of elevated concern for sea turtles. Turtles can become wrapped around cables, lines, nets, or other objects suspended in the water column and become injured or fatally wounded, drowned, or suffocated (e.g., Lutcavage et al. 1997; NMFS 2007). Seismic personnel have reported that sea turtles (number unspecified) became fatally entrapped between gaps in tail-buoys associated with industrial seismic vessel gear deployed off West Africa in 2003 (Weir 2007). With dedicated monitoring by trained biological observers, no incidents of entanglements of sea turtles with this gear have been documented in over 40,000 n.mi. (74,000 km) of previous NSF-funded seismic surveys (e.g., Smultea and Holst 2003; Haley and Koski 2004; Holst 2004; Smultea et al. 2004; Holst et al. 2005a,b; Holst and Smultea 2008). Towing of the hydrophone streamer or other equipment is not expected to significantly interfere with sea turtle movements, including migration, unless they were to become entrapped as indicated above.

The Study Area is not a breeding area for sea turtles and it is not known or thought to be an important feeding area; thus, it is not expected that high concentrations of sea turtles could potentially be physically affected.

Non-auditory Physiological Effects

Based on evidence from terrestrial mammals and humans, sound is a potential source of stress (Wright and Kuczaj 2007; Wright et al. 2007a,b, 2009). However, almost no information is available on sound-induced stress in marine mammals, or on its potential (alone or in combination with other stressors) to affect the long-term well-being or reproductive success of marine mammals (Fair and Becker 2000; Hildebrand 2005; Wright et al. 2007a,b). Such long-term effects, if they occur, would be mainly associated with chronic noise exposure, which is characteristic of some seismic surveys and exposure situations (McCauley et al. 2000a:62*ff*; Nieukirk et al. 2009) but not of some others.

Available data on potential stress-related impacts of anthropogenic noise on marine mammals are extremely limited, and additional research on this topic is needed. We know of only two specific studies of noise-induced stress in marine mammals. Romano et al. (2004) examined the effects of single underwater impulse sounds from a seismic water gun (source level up to 228 dB re 1 μPa · $m_{p\text{–}p}$) and single short-duration pure tones (sound pressure level up to 201 dB re 1 μPa) on the nervous and immune systems of a beluga and a bottlenose dolphin. They found that neural-immune changes to noise exposure were minimal. Although levels of some stress-released substances (e.g., catecholamines) changed significantly with exposure to sound, levels returned to baseline after 24 h. During playbacks of recorded drilling noise to four captive beluga whales, Thomas et al. (1990) found no changes in blood levels of stress-related hormones. Long-term effects were not measured, and no short-term effects were detected. For both studies, caution is necessary when extrapolating these results to wild animals and to real-world situations given the small sample sizes, use of captive animals, and other technical limitations of the two studies.

In summary, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause direct physical and non-auditory physiological effects in marine mammals or sea turtles. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways.

<u>Sound Effects – Summary</u>

Based on the above review, marine mammals and sea turtles will likely exhibit certain behavioural reactions, including displacement from an area around a seismic and some geohazard acoustic sources. 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 a 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, seals, and sea turtles given their different hearing abilities and sensitivities to sound. Potential interactions between Project activities and marine mammals and sea turtles are shown in Table 5.10.

Sound Criteria for Assessing Effects

Impact zones for marine mammals are commonly defined by the areas within which specific received sound level thresholds are exceeded. The U.S NMFS (1995, 2000) has concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 µPa (*rms*). The corresponding limit for seals has been set at 190 dB re 1 µPa (*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. For over a decade, it has been common for marine seismic surveys conducted in some areas of U.S. jurisdiction and in some areas of Canada (Canadian Beaufort Sea and on the Scotian Shelf), to include a "shutdown" requirement for cetaceans based on the distance from the airgun array at which the received level of underwater sounds is expected to diminish below 180 dB re 1 µPa (*rms*). An additional criterion that is often used in predicting "disturbance" impacts is 160 dB re 1 µPa; at this received level, some marine mammals exhibit behavioural effects. There is ongoing debate about the appropriateness of these parameters for impact predictions and mitigation (see Appendix C in LGL 2007).

For marine seismic programs in Newfoundland and Labrador, the C-NLOPB (2008) recommends that seismic operators follow the "*Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*" (hereafter referred to as the *Statement*) issued by the DFO. The *Statement* does not include noise criteria as part of the recommended mitigation measures, rather it defines (see Point 6.a) a safety zone as "a circle with a radius of at least 500 metres as measured from the centre of the air source array (s)". The *Statement* does not provide the specific objective of establishing the safety zone or rationale for using 500 m.

In the absence of site-specific acoustic modelling, we have used the acoustic monitoring results in Austin and Carr (2005) to provide guidance on the ranges one might expect sound levels to be 190, 180 and 160 dB re 1 µPa (*rms*) (from a 28 airgun 3090 in^3 array). The 180 and 190 dB zones were estimated at 700 m and 300 m, respectively. The 160 dB zone occurred at distances of 5123 m to 6393 m. We used the distance of 6.5 km as a guide when estimating disturbance effects on marine mammals. We recognize that the distances from airgun arrays where received sound levels exceed these noise criteria are dependent upon site-specific variations in the environment that influence underwater sound propagation.

5.6.4.3 Assessment of Effects of Sound on Marine Mammal VEC

The marine mammal effects assessment is summarized in Table 5.11 and discussed in detail below.

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

Table 5.10. Potential interactions between the Project and the (1) marine mammal and (2) sea turtle VECs.

Valued Ecosystem Components: (1) Marine Mammals (2) Sea Turtles				
Project Activities	**Toothed Whales**	**Baleen Whales**	**Seals**	**Sea Turtles**
Vessel Lights				
Sanitary/ Domestic Waste	X	X	X	X
Air Emissions	X	X	X	X
Garbage [a]				
Sound				
Seismic Vessel	X	X	X	X
Seismic Array	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Geohazard Vessel	X	X	X	X
Helicopter [b]	X	X	X	X
Echo Sounder	X	X	X	X
Side Scan Sonar	X	X	X	X
Boomer	X	X	X	X
Presence of Vessels				
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Geohazard Vessel	X	X	X	X
Helicopters [b]	X	X	X	X
Shore Facilities [c]				
Accidental Spills	X	X	X	X
OTHER PROJECTS AND ACTIVITIES				
Oil and Gas Activities on the Grand Banks	X	X	X	X
Fisheries	X	X	X	X
Marine Transportation	X	X	X	X

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

strong that they remain above the hearing threshold of odontocetes at tens of kilometres from the source. Species of most concern are those that are designated under *SARA* and that may occur in the Study Area. Sowerby's beaked whales, killer whales, and harbour porpoises, all with special status by COSEWIC, are not expected to occur in large numbers in the Project Area. The received sound level of 180 dB re 1 μPa (*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 μPa (*rms*). However, it is noted that there is no good scientific basis for using this 160 dB criterion for odontocetes and that a 170 dB re 1 μPa (*rms*) is a more realistic indicator of the area within which disturbance is likely.

Table 5.11. Assessment of effects on the marine mammal VEC.

Valued Ecosystem Components: Marine Mammals								
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**
Sanitary/Domestic Waste	Increased Food (N/P)	-	0-1	1	1	1-2	R	2
Air Emissions	Surface Contaminants (N)	-	0	1	6	1-2	R	2
Sound								
Seismic Array	Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start; shutdown [a]	0-1	1-2	6	1-2	R	2
Seismic Array	Disturbance (N)	Ramp-up; delay start; shutdown [a]	1	3-4	6	1-2	R	2
Seismic Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Geohazard Vessel	Disturbance (N)		0-1	1-2	6	1	R	2
Helicopter [b]	Disturbance (N)		0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)		0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1	R	2
Boomer	Disturbance (N)	Gradual power increase; delay start; shutdown [a]	0-1	1-2	6	1	R	2
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)		0-1	1	6	1	R	2
Geohazard Vessel	Disturbance (N)		0-1	1	6	1	R	2
Helicopter [b]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Accidental Spills	Injury/Mortality (N)	Solid streamer[c]; spill response	1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Hearing Impairment and Physical Effects: Given that whales typically avoid at least the immediate area around seismic (and other strong) noise sources, whales in and near the Project Area will likely not be exposed to levels of sound from the airgun array and geohazard sources 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 Project activities. The mitigation measure of ramping-up the airgun array (over a 30 min period) 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 toothed whale is sighted within the 500 m safety zone. There is little potential for toothed whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". As per Table 5.11, the seismic and geohazard program is predicted to have *negligible to low* hearing impairment and physical effects on toothed whales, over a duration of *<1 month* or *1 to 12 months* (~30 to 90 days in 2011), in an area *<1 to 1-10 km*^{2}. Therefore, hearing impairment and/or physical effects on toothed whales would be *not significant* (Table 5.12).

Disturbance Effects: Based on the above review, there could be behavioural effects on some species of toothed whales within the Study 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 µPa (*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:

- 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 Study Area at various times of the year. The Study Area is not known to be an important feeding or breeding areas for toothed whales (however, there has been little research to verify this). As per Table 5.11, disturbance effects from Project activity noise on toothed whales would likely be *low*, over a *<1 month* or *1 to 12 months* (~30 to 90 days in 2011), in an area of *11 to 100* or *101 to 1,000 km*^{2}. Therefore, potential effects related to disturbance, are judged to be *not significant* for toothed whales (Table 5.12).

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 (see Section 5.6.3) and over a small portion of a whale's foraging range within the Project Area. Potential effects of reduced prey availability on toothed whales are predicted to be *negligible*.

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 designated under *SARA* and that may occur in and near the Project Area (blue whales). As with toothed whales, the 180 dB re 1 µPa (*rms*) criterion is used when estimating the area where hearing impairment and/or physical effects may occur for baleen whales (although there are no data to support this criterion for baleen whales). For all

Table 5.12. Significance of potential residual environmental effects of the proposed seismic program on the marine mammal VEC.

Valued Ecosystem Component: Marine Mammals				
Project Activity	Significance Rating	Level of Confidence	Likelihood (Significant Effect Only)	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – hearing/physical effects	NS	2-3	-	-
Array – behavioural effects	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopters	NS	3	-	-
Accidental Spills	NS	3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

baleen whale species, it is assumed that disturbance effects (avoidance) may occur at sound levels greater than 160 dB re 1 µPa (*rms*).

Hearing Impairment and Physical Effects: Given that baleen whales typically exhibit at least localized avoidance of seismic (and other strong) noise, baleen 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 500 m safety zone. Therefore, there is little potential for baleen whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". As per Table 5.11, the seismic and geohazard program is predicted to have *negligible to low* hearing impairment and physical effects on baleen whales, over a duration of *<1 month* or *1 to 12 months* (~ 30 to 90 days in 2011), in an area *<1 to 1-10 km²*. Therefore, hearing impairment and/or physical effects on baleen whales would be *not significant* (Table 5.12).

Disturbance Effects: Based on the above review, there could be behavioural effects on some species of baleen whales in the Study Area. Reported effects range from changes in swimming behaviour to avoidance of the seismic vessel. The area where displacement would most likely occur would have a predicted geographic extent of *11 to 100 km²* or *101 to 1,000 km²*. This is likely a conservative estimate given that:

- some baleen whale species 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 Study Area.

It is uncertain how many baleen whales may occur in the Study Area during the period when seismic and geohazard activity is most likely to occur (May to November). The Project Area is not known to be a unique feeding or breeding area for baleen whales. As per Table 5.11, disturbance effects on species of baleen whales would likely be *low*, over a duration of *<1 month* or *1 to 12 months*, in an area of *11 to 100 km²* or *101 to 1,000 km²*. Therefore, residual effects related to disturbance, are judged to be *not significant* for baleen whales (Table 5.12).

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 (see Section 5.6.3) and over a small portion of a whale's foraging range within the seismic area. Potential effects of reduced prey availability on baleen whales are predicted to be *negligible*.

Seals

Seals are not expected to be abundant within the Study Area, particularly in the time period when seismic and geohazard operations will likely occur (summer, fall). Harp and hooded seals are expected to have a more northerly distribution during the survey period (May to November), although they could be moving through the Study Area. Grey seals are likely uncommon and would be most common in coastal areas. None of the species of seal that occur within the Study Area are considered at risk by COSEWIC or are designated on a *SARA* schedule.

Hearing Impairment and Physical Effects: Given that seals typically avoid the immediate area around a seismic array, seals will likely not be exposed to levels of sound from the airgun array (and other noise sources) high enough to cause non-auditory physical effects or hearing impairment. The mitigation 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 potential for hearing impairment. Also, a ramp-up will not be initiated if a seal is sighted within the 500 m safety zone. Therefore, there is limited 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". As per Table 5.11, the seismic and geohazard program is predicted to have *negligible to low* hearing impairment and/or physical effects on seals, over a duration of *<1 month* or *1 to 12 months*, in an area *<1 km²*. Therefore, hearing impairment and physical effects on seals would be *not significant* (Table 5.12).

Disturbance Effects: Based on the above review, there could be behavioural effects on seals in the Study Area. Known effects include changes in diving behaviour and localized avoidance of the seismic vessel. It is uncertain how many seals may occur in the Study Area during the period when seismic (and geohazard) activities are most likely to occur (May to November). 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 potential effect at *11 to 100 or 101 to 1,000 km*^{2}. This estimated area around the seismic and geohazard vessels would be ensonified periodically for a duration of *<1 month* or *1 to 12 months*. As per Table 5.11, the seismic and geohazard program is predicted to have *low* disturbance effects on seals. Therefore, residual effects related to disturbance, are judged to be *not significant* for seals (Table 5.12).

5.6.4.4 Assessment of Effects of Sound on Sea Turtle VEC

The effects assessment for sea turtles is summarized in Table 5.13.

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, ramp-up will not commence if a sea turtle is sighted within the 500 m safety zone and the airgun array will be shutdown if a leatherback or loggerhead sea turtle is sighted within the safety zone.

It is very unlikely that many sea turtles will occur in the Study Area. Therefore, there is likely limited 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". As per Table 5.13, the seismic program is predicted to have *negligible* to *low* physical effects on sea turtles, over a duration of *<1 month* or *1 to 12 months*, in an area *<1 to 1-10 km*^{2}. Therefore, auditory and physical effects on sea turtles would be *not significant* (Table 5.14).

Disturbance Effects: It is possible that sea turtles will occur in the Study Area, although the cooler water temperatures likely preclude some species from occurring there. If sea turtles did occur near the seismic (and geohazard) vessel, it is likely that sea turtles would exhibit avoidance within a localized area. Based on observations of green and loggerhead sea turtles, behavioural avoidance may occur at received sound levels of 166 dB re 1 µPa *rms*. Based on available evidence, the area where displacement would most likely occur would have a scale of impact at 11 to 100 km^2. As per Table 5.13, the seismic program is predicted to have *low* disturbance effects on sea turtles, over a duration of *<1 month* or *1 to 12 months*, in an area *11 to 100 km*^{2}. Therefore, effects related to disturbance, are judged to be *not significant* for sea turtles (Table 5.14).

Table 5.13. Assessment of effects on the sea turtle VEC.

Valued Ecosystem Components: Sea Turtles								
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**
Sanitary/Domestic Waste	Increased Food (N/P)	-	0-1	1	1	1-2	R	2
Air Emissions	Surface Contaminants (N)	-	0	1	6	1-2	R	2
Sound								
Seismic Array	Hearing Impairment (N); Physical Effects (N)	Ramp-up; delay start; shutdown [a]	0-1	1-2	6	1-2	R	2
Seismic Array	Disturbance (N)	Ramp-up; delay start; shutdown [a]	1	3	6	1-2	R	2
Seismic Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Geohazard Vessel	Disturbance (N)		0-1	1	6	1	R	2
Helicopter [b]	Disturbance (N)		0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)		0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1	R	2
Boomer	Disturbance (N)	Gradual power increase; delay start; shutdown [a]	0-1	1	6	1	R	2
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Geohazard Vessel	Disturbance (N)		0-1	1	6	1	R	2
Helicopter [b]	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
Accidental Spills	Injury/Mortality (N)	Solid streamers[c]; Spill Response	1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.14. Significance of potential residual environmental effects of the proposed seismic program on the sea turtle VEC.

Valued Ecosystem Component: Sea Turtles				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – hearing/physical effects	NS	2-3	-	-
Array – behavioural effects	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopters	NS	3	-	-
Accidental Spills	NS	2	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence
Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Prey Species: Leatherback sea turtles are expected to feed primarily on jellyfish. It is unknown how jellyfish react to seismic and geohazard noise sources, 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 effects of reduced prey availability are predicted to be *negligible*.

5.6.4.5 Effects of Helicopter Overflights

A crew change may occur via helicopter if the seismic program is longer than five to six weeks, depending on the contractor. The 2011 seismic program is anticipated to be ~30 to 90 days in duration, so a helicopter crew change may not be necessary. However, some contractors may choose to conduct crew changes in port. Helicopters will maintain a regulated flight altitude above sea level unless it is necessary to fly lower for safety reasons. Helicopters will not be used during geohazard surveys.

Marine Mammals

Available information indicates that single or occasional aircraft overflights will cause no more than brief behavioural responses in baleen whales, toothed whales and seals (summarized in Richardson et al. 1995). As per Table 5.11, disturbance impacts are assessed as *negligible to low* impact, over a duration of *<1 month*, in an area *1 to 10 km*^{2} to *11 to 100 km*^{2}. Therefore, effects related to disturbance, are judged to be *not significant* for marine mammals (Table 5.12).

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. As per Table 5.13, disturbance impacts are assessed as *negligible*, over a duration of *<1 month*, in an area *<1 km*^{2} to *1 to 10 km*^{2}. Therefore, impacts related to disturbance, are judged to be *not significant* for sea turtles (Table 5.14).

5.6.4.6 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 program (30 to 90 days in 2011). It is anticipated that a supply ship will also be on site occasionally. Geohazard surveys will involve one vessel in the Project Area for short periods of time. There is some risk for collision between marine mammals and vessels, but given the slow surveying speed (4.5 to 5 knots; 8.3 to 9.3 km/h) of the seismic vessel (and its picket vessel) plus the geohazard vessel, this risk is minimal (Laist et al. 2001; Vanderlaan and Taggart 2007). 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 to 274. More recent studies are described in LGL (2007). Marine mammal responses to the presence of vessels are variable. Seals often show considerable tolerance to vessels. Toothed whales sometimes show no avoidance reactions and occasionally approach them; however, some species are displaced by vessels. Baleen whales often interrupt their normal behaviour and swim rapidly away from vessels that have strong or rapidly changing noise, especially when a vessel heads directly towards a whale. Stationary vessels or slow-moving, "non-aggressive" vessels typically elicit very little response from baleen whales.

To the best of our knowledge, there are few systematic studies on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound. Hazel et al. (2007) evaluated behavioural responses of green turtles to a research vessel approaching at slow, moderate, or fast speeds (4, 11, and 19 km/h, respectively). Proportionately fewer turtles fled from the approaching vessel as speed increased, and turtles that fled from moderate to fast approaches did so at significantly shorter distances from the vessel than those that fled from slow approaches. The authors conclude that sea turtles cannot be relied on to avoid vessels with speeds greater than 4 km/h. However, studies were conducted in a 6 m aluminum boat powered by an outboard engine, which would presumably be more challenging for a sea turtle to detect than a seismic or supply vessel.

Effects of the presence of vessels on marine mammals or sea turtles, including the risk of collisions, are predicted to be *negligible to low,* over a duration of *<1 month to 1-12 months*, in an area *1 to 10 km^2*. Therefore, effects related to the presence of vessels, are judged to be *not significant* for marine mammals and sea turtles (Tables 5.11 to 5.14).

5.6.4.7 Effects of Accidental Spills

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with CCL's policy, and handling and reporting procedures. If fluid-filled streamers are used in surveys in 2012 to 2017, it is possible that small amounts of Isopar could be leaked from the streamers; 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 propeller action. The effects of hydrocarbon spills on marine mammals and sea turtles were reviewed in Husky (2000) in Section 5.9.1.3 and 5.9.2.3, respectively and are not repeated here. Based on multiple 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 (Husky 2000). Effects of an accidental spill on marine mammals or sea turtles would be *low,* over a duration of *<1 month,* in an area *<1 km^2 to 1 to 10 km^2* and are judged to be *not significant* (Tables 5.11 to 5.14).

5.6.4.8 Effects of Other Project Activities

There is potential for marine mammals and sea turtles to interact with domestic and sanitary wastes, and air emissions from the seismic ship and its support vessels. Any effects from these interactions are predicted to be *negligible* (Tables 5.11 to 5.14).

5.6.5 Species at Risk

A biological overview of all species considered *endangered* or *threatened* under Schedule 1 of the *SARA* that are likely or may occur in the Study Area was provided in Section 4.6. No critical habitat has been defined for the Study Area. As discussed in previous sections and presented in Table 4.13, *SARA* species of relevance to the Study Area include:

- northern, spotted, and Atlantic wolffish;
- Ivory Gull;
- blue and North Atlantic right whale; and
- leatherback sea turtle.

Species not currently designated (see Table 4.13) on Schedule 1 of *SARA* but listed on Schedule 2 or 3 or being considered for addition to Schedule 1 (as per their current COSEWIC listing of *endangered, threatened* or *special concern*), are not included in the SAR VEC here but have been assessed in the appropriate VEC in sections 5.6.1 (Fish), 5.6.3 (Seabirds) and 5.6.4 (Marine Mammals and Sea Turtles) of this EA. If species not currently designated on Schedule 1 of *SARA* do become listed on this legal list during the remainder of the life of the Project (2012 to 2017), the Proponent will re-assess these species considering the prohibitions of *SARA* and any recovery strategies or action plans that may be in place. Possible mitigation measures as they relate to Species at Risk will be reviewed with DFO and EC. Potential interactions between the Project and SAR are shown in Table 5.15.

As per the detailed effects assessment contained in Section 5.6.1 and shown again in Tables 5.2 to 5.3, physical effects of the Project on the various life stages of wolffish species will range from *negligible* to *low* over a duration of *<1 month to 1-12 months*, within an area of *<1 km*^{2} (Table 5.16). Behavioural effects may extend out to a larger area but are still predicted to be *not significant* (Table 5.17). The mitigation measure of ramping up the airgun array (over a 30 min period) is expected to minimize the potential for impacts on wolffish.

As per the detailed effects assessment in Section 5.6.3, the predicted effect of the Project on Ivory Gulls is *not significant* as this species foraging behaviour would not likely expose it to underwater sound and this species is unlikely to occur in the Study Area, particularly during the summer when seismic surveys are likely to being conducted (Tables 5.16 and 5.17). Furthermore, Ivory Gulls are not known to be prone to stranding on vessels. The mitigation measure of monitoring the seismic vessel and releasing stranded birds (in the unlikely event that an Ivory Gull will strand on the vessel) and ramping up the airgun array will minimize the potential for impacts on this species.

Based on available information, blue whales, right whales and leatherback sea turtles are not expected to occur regularly in the Study Area. It is extremely unlikely that a North Atlantic right whale will occur in the Study Area. There is a recently finalized recovery strategy for blue whales in Atlantic Canada (Beauchamp et al. 2009) as well as a final recovery strategy for North Atlantic right whales (Brown et al. 2009). A recovery strategy for leatherback sea turtles is available (ALTRT 2006). However, critical habitat in the Study Area has not been proposed or designated for any SAR whales or leatherback sea turtles. Mitigation and monitoring designed to minimize potential effects of airgun array noise on *SARA*-listed marine mammals and sea turtles will include:

- ramp-up of the airgun array over a 30 min period;
- monitoring by MMO(s) (with assistance from a FLO) during daylight hours that the airgun array is active;
- shutdown of the airgun array when an *endangered* or *threatened* marine mammal or sea turtle is sighted within the 500 m safety zone; and
- delay of ramp-up if any marine mammal or sea turtle is sighted within the 500 m safety zone.

With these mitigation measures in place and as per the detailed effects assessment in Section 5.6.3, the Project is predicted to have *no significant effect* (hearing impairment/physical or behavioural) on SAR marine mammals and sea turtles (Table 5.12 and 5.14, respectively).

Table 5.15. Potential interactions between the Project and species at risk VEC.

Project Activities	Valued Ecosystem Components: Species at Risk			
	Wolffish	Ivory Gull	Blue and Right Whales	Leatherback Sea Turtle
Vessel Lights	X	X		
Sanitary/ Domestic Waste	X	X	X	X
Air Emissions	X	X	X	X
Garbage [a]				
Sound				
Airgun Array	X	X	X	X
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Geohazard Vessel	X	X	X	X
Helicopter [b]		X	X	X
Echosounder	X	X	X	X
Side Scan Sonar	X	X	X	X
Boomer	X	X	X	X
Presence of Vessels				
Seismic Vessel		X	X	X
Supply Vessel		X	X	X
Picket Vessel		X	X	X
Geohazard Vessel		X	X	X
Helicopters [b]		X	X	X
Shore Facilities [c]				
Accidental Spills	X	X	X	X
OTHER PROJECTS AND ACTIVITIES				
Oil and Gas Activities on Grand Banks	X	X	X	X
Fisheries	X	X	X	X
Marine Transportation	X	X	X	X

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

In summary, potential effects of the proposed 2-D and 3-D seismic programs, including geohazard surveys, are not expected to contravene the prohibitions of *SARA* (Sections 32(1), 33, 58(1)).

5.7 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 CCL seismic and geohazard survey activities in the Project Area.

Table 5.16. Assessment of effects on the species at risk VEC.

Valued Ecosystem Component: Species At Risk								
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**
Vessel Lights	Attraction (N); Mortality (N)	Reduce lighting (if safe); release protocols	0-2	1-2	2-3	1-2	R	2
Sanitary/Domestic Waste	Increased food (N/P)	-	0-1	1	1	1-2	R	2
Air Emissions	Surface contaminants (N)	-	0	1	6	1-2	R	2
Sound								
Seismic Array	Hearing Impairment (N); Physical Effects (N)	Ramp-up; delay start[a]; shutdown [b]	0-1	1-2	6	1-2	R	2
Seismic Array	Disturbance (N)	Ramp-up; delay start[a]; shutdown [b]	0-1	3-4	6	1-2	R	2
Seismic Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)		0-1	1-2	6	1	R	2
Geohazard Vessel	Disturbance (N)		0-1	1-2	6	1	R	2
Helicopter [b]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echosounder	Disturbance (N)		0-1	1-2	6	1	R	2
Side Scan Sonar	Disturbance (N)		0-1	1-2	6	1	R	2
Boomer	Disturbance (N)	Gradual power increase; delay start; shutdown	0-1	1-2	6	1	R	2
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)		0-1	1	6	1	R	2
Geohazard Vessel	Disturbance (N)		0-1	1	6	1	R	2
Helicopter [c]	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
Accidental Spills	Injury/Mortality (N)	Solid Streamer[d]; Spill Response	1-2	1-3	1	1-2	R	2

Key:

Magnitude:
0 = Negligible, essentially no effect
1 = Low
2 = Medium
3 = High

Frequency:
1 = <11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Duration:
1 = <1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative effects

[a] Ramp-up will be delayed if any marine mammal or sea turtle is sighted within the 500 m safety zone.
[b] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[c] A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.
[d] Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.

Table 5.17. Significance of potential residual environmental effects of the proposed seismic program on the species at risk VEC.

Valued Ecosystem Component: Species At Risk				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Noise				
Array – hearing/physical effects	NS	2-3	-	-
Array – behavioural effects	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Goehazard Vessel	NS	3	-	-
Helicopters	NS	3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence
Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

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 the northern Grand Banks region.]
- Vessel traffic (e.g., transportation, defense, yachts)
- Hunting (e.g., seabirds, seals)
- Offshore oil and gas industry

Commercial fishing has been discussed and assessed in detail in Section 5.6.2. 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. CCL is committed to ongoing communication to prevent and/or minimize disruption to other users of the Study Area. 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 murres) 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 projects listed on the C-NLOPB public registry (www.cnlopb.nl.ca as viewed 28 February 2011) include:

- 2-D seismic program on Labrador Shelf, 2011-2013 (Multi Klient Invest, PGS, TGS)
- 2-D, 3-D seismic program plus geohazard and VSP surveys on Labrador Shelf, 2010-2017 (Investcan)
- 2-D, 3-D seismic program plus geohazard surveys on Labrador Shelf, 2009-2017 (Husky)
- 2-D and/or 3-D seismic program plus geohazard survey offshore Labrador, 2010-2017 (Chevron Canada Resources; no surveys planned for 2011)
- 3-D and/or 2-D seismic program plus geohazard survey in the Jeanne d'Arc Basin and Central Ridge/Flemish Pass Basin, 2011-2019 (Statoil Canada Limited; 2011 survey planned)
- Exploration, appraisal, and delineation drilling program in Jeanne d'Arc Basin area, 2008-2016 (StatoilHydro)
- Exploration drilling in Jeanne d'Arc Basin, 2009-2017 (Petro-Canada)
- White Rose new drill centre construction and operations program, 2008-2015 (Husky Energy)
- Exploration and delineation drilling program in Jeanne d'Arc Basin, 2008-2017 (Husky Energy)

In addition, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. The existing developments fall outside of the boundaries of the CCL's Study Area. 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 Statoil Jeanne d'Arc Basin and Central Ridge/Flemish Pass Basin 3-D seismic program proposed for 2011. The CCL and Statoil seismic programs have the potential to overlap in time and space. However, given the primarily 2-D nature of CCL's seismic program and the 3-D nature of Statoil's seismic program, during most of the survey period, the two seismic programs will remain fairly far apart and will not create synergistic noise effects on marine mammals (and other VECs). However, there is potential that for some days the CCL and Statoil seismic programs may be operating in close proximity. During these periods, marine mammals may be exposed to noise from each of the seismic survey programs. In order to avoid acoustic interference with each other's program, seismic vessels will remain at least 40 km apart during surveying. There will need to be good coordination between the two programs to minimize potential acoustic interference. CCL will attempt to acquire most or all of the seismic data near Statoil's survey area before the Statoil seismic program begins. CCL has been in communication with Statoil in this regard, and CCL is committed to ongoing communication with Statoil (and other operators) in the Study Area. Given that seismic vessels will maintain a minimum separation distance of 40 km and that CCL will attempt to survey the area near Statoil's exploration license (EL1123) before Statoil begins surveying, noise effects on marine mammals are expected to be additive and not synergistic. Effects on marine mammals (and other VECs) are predicted to be *not significant*. However, there are uncertainties regarding this prediction. The potential for temporal and spatial overlap of future seismic programs (2012-2017) in the CCL and Statoil Project Areas will be assessed in the EA update process.

As discussed in this EA, negative effects on key sensitive VECs such as marine mammals appear unlikely beyond a localized area from the sound source. In addition, all programs will use mitigation measures such as ramp-ups, delayed start ups, and shutdowns of the airgun arrays. Thus, it seems likely that while some animals may receive sound from one or more oil and gas programs, the current scientific prediction is it that *no significant residual effects* will result.

5.8 Mitigations and Follow-up

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 5.18. CCL and contractors will adhere to mitigations detailed in Appendix 2 of the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB, May 2008) as well as the *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*.

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-NLOPB 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. CCL will advise the C-NLOPB prior to compensating and settling all valid lost gear/income claims promptly and satisfactorily.

Table 5.18. Summary of mitigations measures.

Potential Effects	Primary Mitigations
Interference with fishing vessels	• Upfront planning to avoid high concentrations of fishing vessels • SPOC • advisories and communications • FLO • planned transit route to and between Survey Areas (if required)
Fishing gear damage	• upfront planning to avoid high concentrations of fishing gear • SPOC • advisories and communications • FLO • compensation program • planned transit route to and between Survey Areas (if required)
Interference with shipping	• SPOC • advisories and communications • FLO
Interference with DFO/FFAW research vessels	• Communications and scheduling
Temporary or permanent hearing damage/disturbance to marine animals	• Delay start-up if marine mammals or sea turtles are within 500 m • ramp-up of airguns over 30 min-period • shutdown of airgun arrays for *endangered* or *threatened* marine mammals and sea turtles within 500 m • use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations
Temporary or permanent hearing damage/ disturbance to Species at Risk or other key habitats	• delay start-up if marine mammals or sea turtles are within 500 m • ramp-up of airguns • shutdown of airgun arrays for *endangered* or *threatened* marine mammals and sea turtles • survey timing that minimizes potential for Ivory Gulls in the Study Area • use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations. [No critical habitat has been identified in or near the Study Area.]
Injury (mortality) to stranded seabirds	• daily monitoring of vessel • handling and release protocols • minimize lighting if safe
Exposure to hydrocarbons	• adherence to MARPOL • spill contingency plans • use of solid streamer when feasible

Specific mitigations to minimize potential conflicts and any negative 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;
- MMO(s) and FLO onboard;
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast;
- Compensation program in the event any project vessels damage fishing gear; and
- Single Point of Contact (SPOC).

CCL will also coordinate with DFO, St. John's, and the FFAW to avoid any potential conflicts with survey vessels that may be operating in the area. CCL commits to ongoing communications with other operators with active seismic programs within the general vicinity of the CCL program to minimize the potential for cumulative effects on VECs.

Mitigation measures designed to reduce the likelihood of impacts on marine mammals and sea turtles will include ramp-ups, no initiation of airgun array if a marine mammal or sea turtle 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* (or *threatened*) 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 activated first and then the volume of the array will be increased gradually over a recommended 30 min period. An observer 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 and sea turtles when the airgun array is active (during daylight periods) and note the location and behaviour of these animals. The seismic array will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within the safety zone. The planned monitoring and mitigation measures, including ramp-ups, visual monitoring, and shut-down of the airguns when *endangered* or *threatened* marine mammals or turtles are seen within the "safety radii", will minimize the already-low probability of exposure of marine animals to sounds strong enough to induce hearing impairment. Any dead or distressed marine mammals or sea turtles will be recorded and reported to the C-NLOPB.

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 CCL that a CWS *Migratory Bird Handling Permit* will likely be required. In the unlikely event that marine mammals, turtles or birds are injured or killed by Project equipment or accidental spills of fuel or streamer flotation fluid, a report will immediately be filed with C-NLOPB 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. A monitoring program will be designed in consultation with DFO and CWS as per the C-NLOPB *Guidelines*. Data will be collected by a qualified MMO and FLO. A monitoring report will be submitted to the C-NLOPB within one year after completion of the surveys.

5.9 Residual Effects of the Project

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 5.19. CCL's seismic program is predicted to have *no significant effects* on VECs.

Table 5.19. Significance of potential residual environmental effects of the proposed seismic program on VECs in the Study Area.

Valued Ecosystem Component: Fish and Fish Habitat, Fisheries, Birds, Turtles, Marine Mammals, Species at Risk				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – physical effects	NS	2-3	-	-
Array – behavioural effects	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Geohazard Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Helicopters	NS	3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
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 >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgment:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

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