Environmental Assessment of WesternGeco's Seismic Program for the Jeanne d'Arc Basin, 2012–2015

Prepared by

LGL LIMITED
environmental research associates

for

WesternGeco

April 2012
Project No. SA1150

Environmental Assessment of WesterGeco's Seismic Program for the Jeanne d'Arc Basin, 2012–2015

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1.0 Introduction

WesternGeco Canada (WesternGeco) proposes to undertake a geophysical survey program in the Jeanne d'Arc Basin (Figure 1.1) from 2012 through 2015. WesternGeco anticipates carrying out 2D and/or 3D seismic surveys in one or more years within the 2012–2015 timeframe.

This document is a screening level environmental assessment (EA) intended to allow the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) to fulfill its responsibilities under the Federal Coordination Regulations pursuant to the *Canadian Environmental Assessment Act* (*CEAA*). This EA was guided by the technical and scoping advice received from the C-NLOPB, other federal agencies, and stakeholders consulted by WesternGeco.

1.1. Relevant Legislation and Regulatory Approvals

An *Authorization to Conduct a Geophysical Program* will be required from the 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 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 re 1 μPa@1m) 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 for the EA and acts as the federal environmental assessment coordinator or FEAC. Because seismic survey activities have the potential to affect seabirds, marine mammals, sea turtles, and fish and fisheries, the Fisheries and Oceans Canada (DFO) and Environment Canada (EC) are the federal agencies primarily interested and involved as Federal Authorities under the *CEAA*.

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 Bird Convention Act*
- *Species at Risk Act (SARA)*

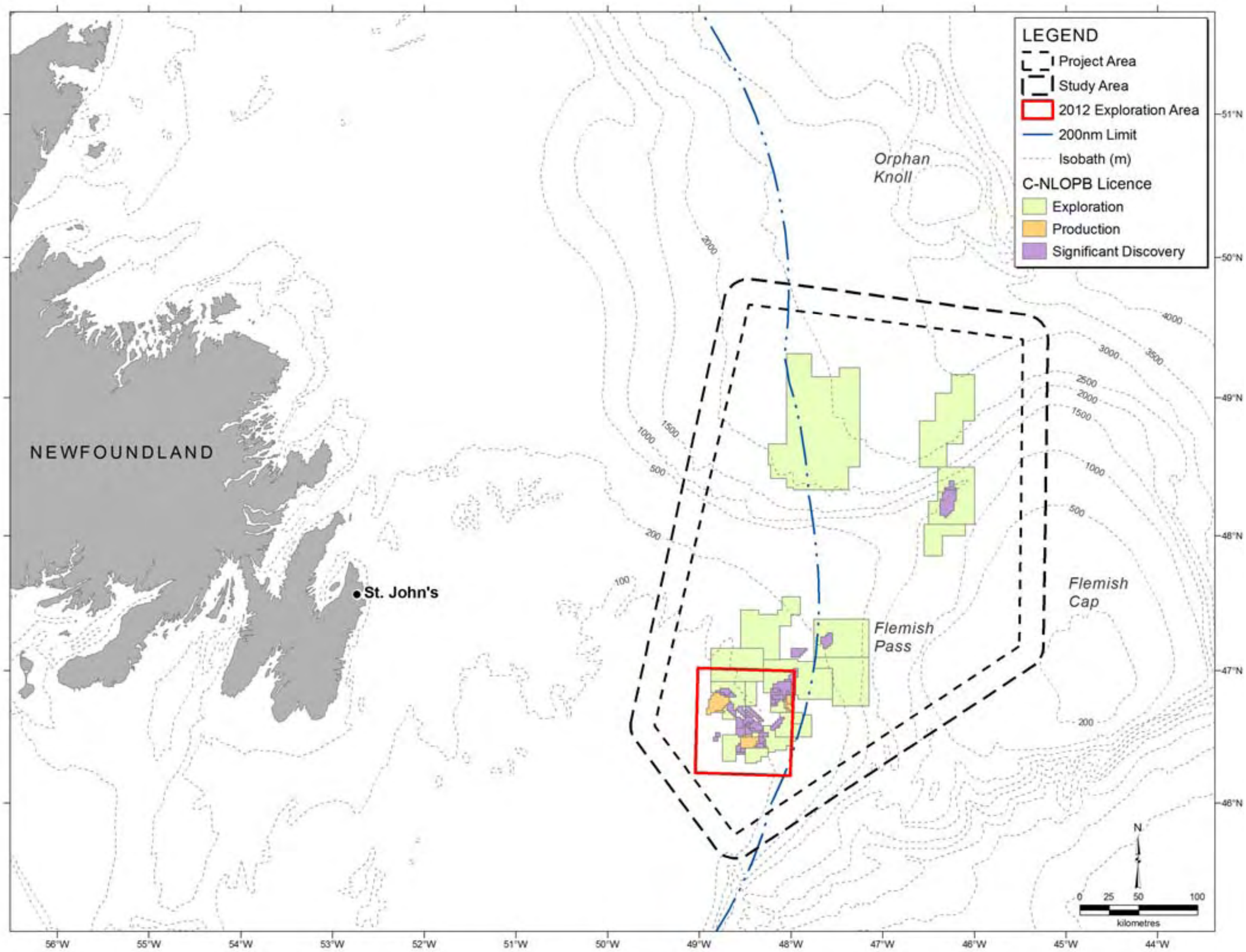

Figure 1.1. The Project Area, Corresponding Study Area, and the 2012 Exploration Area for the Proposed Seismic Program.

One of the specific guidelines issued by the C-NLOPB, the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (February 2011), 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* that forms Appendix 2 of the *Guidelines*.

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

1.1.1 Environmental Assessment Update Process

The geophysical survey activities described in this EA may be undertaken at various times during 2012–2015. This EA takes into account the expected period of time during which these project activities will occur.

Authorizations issued under the *Atlantic Accord Implementation Acts* 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 four years based on the best available knowledge at this time, WesternGeco 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, WesternGeco will during the first quarter of each year that work is planned during 2012–2015, 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 updated and results have not led to predictions of significant effects;
- the nature and extent of the fishing activities being undertaken in the Project Area have been updated 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 WesternGeco 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 update to the EA.

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

1.2 The Proponent

WesternGeco Canada, a division of Schlumberger Canada Limited, is headquartered in Calgary, Alberta, and is a multi-national seismic company actively engaged in exploration worldwide. WesternGeco is a wholly owned subsidiary of Schlumberger Canada and is one of the world's leading seismic companies. WesternGeco has conducted a number of seismic programs in Newfoundland and Labrador offshore waters.

WesternGeco's objectives are to provide high quality seismic data to its various clients and to conduct its business in a socially and environmentally responsible manner.

1.3 Social Responsibility and Canada-Newfoundland and Labrador Benefits

In full participation of the requirements of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland Labrador Act* and the *Canada-Newfoundland Atlantic Accord Implementation Act*, WesternGeco is committed to providing maximum benefits associated with East Coast operations to Canadians and in particular Newfoundland and Labrador individuals and companies where they are commercially achievable in accordance with WesternGeco's operating philosophies and requirements.

WesternGeco will manage its East Coast operations from St. John's, Newfoundland. WesternGeco provides full and fair opportunity to Canadian individuals and organizations, in particular those from Newfoundland and Labrador, to participate in its activities in Newfoundland and Labrador. WesternGeco supports the principle that first consideration be given to personnel, support and other services that can be provided within Newfoundland and Labrador, and to goods manufactured in Newfoundland and Labrador, where such goods and services can be delivered at a high standard of Health, Safety and Environmental competency, be of high quality band are competitive in terms of fair market price. Contractors and subcontractors working for WesternGeco in Newfoundland and Labrador must also apply these principles in their operations.

1.4 Contacts

Relevant contacts at WesternGeco for the seismic program include:

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2.0 Proposed Project

2.1 Name and Location

The official name of the Project is the *"Jeanne d'Arc Basin Seismic Program 2012–2015*." The Exploration Area proposed for 2012 is shown in Figure 1.1.

The ***spatial boundaries*** of the Project Area are shown in Figure 1.1. The Study Area includes the Project Area plus a 20 km buffer around the Project Area to accommodate the seismic vessel's turning radius and to account for the propagation of seismic survey sound that could potentially affect marine biota (see Figure 1.1). The corner coordinates of the Study Area are as follow:

- North: 49.850°N;
- East: 45.196°W;
- South: 45.579°N; and
- West: 49.748°W

The total areas of the Study Area and Project Area are 117,899 and 92,268 km^2, respectively.

The ***temporal boundaries*** of the proposed Project are 2012–2015. Seismic surveys will occur between 1 May and 30 November of any given year. The typical duration of a 2D or 3D survey, depending on the area to be surveyed, could vary from 40 to >150 days within that temporal scope. In 2012, the seismic survey is anticipated to require 60 to 150 days.

2.2 Project Overview

The proposed Project includes a ship-based seismic program consisting of approximately 2,000 to 3,500 km^2 of 3D survey (with potential 2D) in 2012 (or as soon thereafter as possible) and some as yet to be determined areas of 2D and/or 3D surveys in 2013–2015.

The seismic survey vessel(s) used during the program will be approved for operation in Canadian waters and will be typical of the worldwide seismic fleet. Specific vessels have not yet been selected. The 3D seismic survey ship will tow a dual sound source (airgun array) and a multi-streamer composed of receiving hydrophones. The streamers will be up to several kilometers in length.

The C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2011) will be used as the basis for the marine mammal monitoring and mitigation program for the seismic surveys. Dedicated Marine Mammal Observers (MMOs) will monitor for marine mammals (and sea turtles if present) and implement mitigation measures as appropriate. The airgun array will be ramped up, and ramp ups will be delayed if a marine mammal is detected within the appropriate safety zone (minimum of 500 m as noted in DFO's *Statement of Canadian Practice*). The airgun array will be shut down any time an *endangered* or *threatened* (as listed on Schedule 1 of *SARA*) marine mammal (or sea turtle) is detected within the safety zone. These measures are designed to minimize disturbance to marine life, particularly marine mammals and species considered at risk under the *SARA*. In addition, the MMOs will conduct a monitoring and release program for seabirds which may strand on board the seismic vessel. A fisheries liaison officer (FLO) will be on board, as required, to ensure implementation of communication procedures intended to minimize conflict with the commercial fishery.

2.2.1 Objectives and Rationale

The primary objective of the Project is to determine the presence and likely locations of geological structures that might contain hydrocarbon deposits. Existing 2D seismic data in the area indicate structures that may contain significant volumes of producible hydrocarbons. These existing seismic data, while useful, are insufficient to determine exact structural size and internal complexity. Acquisition of new 3D seismic surveys is required to provide images of higher resolution and quality than are currently available, and ultimately determine whether exploration drilling is warranted or not.

2.2.2 Alternatives to the Project, Alternatives within the Project

WesternGeco has made commitments to pursue exploration activities Jeanne d'Arc Basin. The alternative to the Project would be to forgo exploration for oil and gas in offshore Newfoundland and pursue opportunities elsewhere in the world in order to assist in meeting market demand for seismic data and petroleum products.

2.2.3 Project Scheduling

The Project may have two or more phases. The actual timing of these activities within the temporal scope will be dependent on economic feasibility, vessel availability and results of data interpretation of survey work from preceding phases.

1. Phase 1 will include a 3D survey in 2012 in the area defined in Figure 1.1; and
2. Phase 2 will include 2D and/or 3D surveys of any areas that may be identified through analyses of existing and acquired data in preparation for a potential drilling program.

The seismic surveys will be 40 to >150 days in duration and may occur between 1 May and 30 November.

2.2.4 Site Plans

The survey line orientations for the proposed 2D and 3D seismic surveys have not yet been determined. The Project Area proposed for the 2012–2015 seismic programs is shown in Figure 1.1. Water depths in the Project Area range from <100 m to >3,000 m.

2.2.5 Personnel

A seismic vessel can typically accommodate approximately 50–100 personnel. Personnel on seismic vessels typically include the vessel owner/operator (ship's officers and marine crew), and technical and scientific personnel. The seismic vessel will have a FLO and MMO(s) on board. All project personnel will have all of the required certifications as specified by relevant Canadian legislation and the C-NLOPB.

2.2.6 Seismic Vessel

Vessel specifics will be provided in subsequent document submissions once the ship has been identified. The selected vessel will be a fully equipped ship suited to the environment and task with diesel-electric propulsion systems (main and thrusters) and will operate on marine diesel. A typical example of a seismic vessel is the M/V *Western Patriot* which is 78 m long and 17 m wide with a mean draft of 5.9 m. Its maximum speed is 13 knots, and it transits at a speed of 11.5 knots. The *Western Patriot* operates a main engine (two Rolls Royce Bergen/BRM 6: 5,300 kW) and has a bow thruster (590 kW). The ship will deploy a workboat to repair streamers when necessary.

2.2.7 Seismic Energy Source Parameters

The proposed 2D or 3D survey sound source will consist of one or two airgun arrays, 3,000 to 6,000 in^3 in total volume, which will operate at towed depths between 6 and 15 m. The airguns will be operated with compressed air at pressures of 2,000–2,500 psi and produce approximate peak-to-peak pressures of 100 to 150 bar-m. Detailed specifications of the airgun array will be provided once the Project design is completed and parameters are selected.

The airgun array for the *Western Patriot* is described here to provide an example of a typical seismic source as used on the East Coast. [The seismic array size (number of airguns, total volume) and configuration will vary depending on the vessel.] Two 5,085 in^3 arrays of 24 Bolt airguns per array are used by the *Western Patriot*. The largest airgun used is 290 in^3 and the smallest 105 in^3. The two 5,085 in^3 airgun arrays are typically activated alternately (flip-flop arrangement) along the survey lines with a shotpoint interval of 25 m. The airgun arrays are typically towed up to 400 m behind the seismic vessel. Survey speed is around 4.5 knots (8.3 km/h). Airguns typically are operated at 2,000 psi, and the estimated source level[1] of the array is 109.9 bar-m [~255 dB re 1 μPa (0-p)]. The airguns in the array are strategically arranged to direct most of the energy vertically rather than sideways [see Appendix C *in* LGL (2007a)] for a review of airgun sound characteristics.

2.2.8 Seismic Streamers

The 2D and 3D seismic surveys will use towed streamers with an approximate length of 8 km and deployed at depths ranging from 5 to 25 m. Streamer equipment specifications will be provided when the program design is complete. Typically 10 to 14 streamers (strings of hydrophone sound receivers), are towed behind the seismic vessel to record the airgun pulses during 3D seismic surveys. [Individual stand alone 2D profiles might be acquired by the 3D vessel without any change of configuration or by a different vessel towing only one streamer.] Once again, the *Western Patriot* is used as a representative example for the purposes of this EA. The *Western Patriot* tows eight 5-km streamers and the streamers are Sentry and Guardian Solid Streamers (Thompson Marconi). The streamers are separated by 100 m for a total spread width of 900 to 1,300 m (based on 10 to 14 streamers), and are typically deployed at depths of 8 to 10 m.

It is possible that streamers may be fluid-filled but solid streamer vessels will be favoured. Fluid-filled streamers control buoyancy with a fluid 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 Logistics and Support

Offshore seismic operations will be supported by a picket and/or supply vessel and potentially a helicopter. Primary support and supply will be provided by a WesternGeco chartered vessel.

2.2.9.1 Picket Vessel

In order to mitigate any potentially adverse effects on marine animals, the commercial fisheries, and other vessel traffic, a mitigation plan will be developed as part of the Project. A standby or picket vessel may be required as a mitigation measure. This vessel would be used as an additional method to obtain information on commercial fishing activity in the area and to warn other vessels in order to avoid gear losses for all parties involved. It would also be used to scout ahead of the seismic vessel for hazards such as ice and floating debris.

2.2.9.2 Supply Vessel

Heavy re-supply (including water, food, parts and fuel) to the seismic vessel may be conducted by offshore supply vessel throughout the duration of the program. Supply vessels will be typical of those that regularly service Hibernia, Terra Nova and White Rose. A typical supply vessel on the Grand Banks is crewed by about 6 to 12 marine qualified personnel.

2.2.9.3 Helicopter

The seismic vessel will be equipped with a helicopter platform; helicopters are often used for crew changes and light re-supply. It is not known at this time whether helicopters will be used for crew changes during the proposed seismic program(s). Once the final extents of the 2D and 3D programs are determined, the necessity for and feasibility of helicopter support for crew changes will be determined. Helicopter operations will be according to safety requirements as specified by relevant authorities, including the C-NLOPB.

2.2.9.4 Shore Base

The Operator will maintain operational offices and use existing shore facilities in St. John’s. No new shore base facilities will be established as part of this Project.

2.2.10 Waste Management

Wastes produced from the seismic, 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 WesternGeco’s waste management

[1] Includes frequencies up to 128 Hz.

plan. Waste management will be consistent with industry best practices in offshore Newfoundland and Labrador. WesternGeco's waste management plan will be filed with the C-NLOPB in support of the *Authorization to Conduct a Geophysical Program*. A licensed waste contractor will be used for any waste returned to shore.

2.2.11 Air Emissions

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

2.2.12 Accidental Events

In the unlikely event of the accidental release of hydrocarbons during the Project, WesternGeco will implement the measures outlined in its oil spill response plan which will be filed with the C-NLOPB in support of the *Authorization to Conduct a Geophysical Program* application.

2.3 Mitigation

Project mitigation measures are detailed in the EA; measures are reviewed and summarized in Section 5.8, and will follow the guidelines outlined in the *Statement of Canadian Practice*. Mitigation procedures will include ramp ups, implementation of ramp up delays and airgun array shutdowns for designated marine mammal and sea turtle species, use of dedicated MMOs and a FLO, and a fisheries compensation program. The Operator recognizes that the fisheries have a long tradition off Newfoundland and that both industries are legitimate users of the sea and seabed.

2.4 Project Site Information

The Project and Study areas (Figure 1.1) are described in detail in the following sections.

3.0 Physical Environment

The Scoping Document required that the EA include a review of the meterological and oceanographic characteristics, including extreme conditions, in order 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 Oceans (2012). Summaries of the relevant sections of that report are provided below.

3.1 Bathymetry and Geology

As indicated in the Orphan Basin SEA (LGL 2003) and the White Rose Comprehensive Study (Husky 2000), the topography of the Study Area is highly diverse and includes at least four distinct types as characterized by depth, location and physiography: (1) Jeanne d'Arc Basin (depths ≤200 m) in the southwestern portion of the Study Area; (2) northeast Newfoundland Shelf Slope and Flemish Cap Shelf (depths >200 to 2,000 m); (3) Orphan Basin (depths 2,000 to >3,000 m) in the northern portion of the Study Area; and (4) the Flemish Pass (depths >1,000 m). The characterization of surficial sediment in the Study Area ranges from fine (mud and clay) to extremely coarse (boulders and bedrock).

3.2 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 general overview of climatic conditions in the Study Area with a more detailed description of extreme events. The reader is referred to Section 2 of Oceans (2012) for more details.

3.2.1 Weather Systems

The Study Area including the Northeast Grand Banks, Flemish Pass and the southern Orphan Basin experiences weather conditions typical of a marine environment which moderates air temperatures. 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 significant amounts of precipitation.

The climate of the Study 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 arises because of the normal tropical to polar temperature gradient and typifies the upper levels of the atmosphere in the mid-latitudes. 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 greater 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. The intensity of these systems ranges from relatively weak features to major winter storms.

Frequently, intense low pressure systems become 'captured' and slow down or stall off the coast of Newfoundland and Labrador. 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. By summer, the main storm tracks have moved further north than in winter. Low-pressure systems are less frequent and much weaker. With increasing solar radiation during spring, there is a general warming of the atmosphere that is relatively greater at higher latitudes.

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 decreases 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.

3.2.2 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 hourly data for the Project Area. The extreme values for wind speeds and waves were calculated using the peak-over-threshold method. After considering four different distributions, the Gumbel distribution was chosen to be the most representative 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 each of three grid points used in the analyses are presented in Table 3.1 and Figure 3.1.

Table 3.1 Number of Storms Providing Best Fit for Extreme Value Analysis of Winds and Waves.

Grid Point No.	Parameter	Annually	Monthly
14845	Wind	265	66
	Wave	181	58
13912	Wind	314	84
	Wave	192	79
11423	Wind	259	107
	Wave	251	76

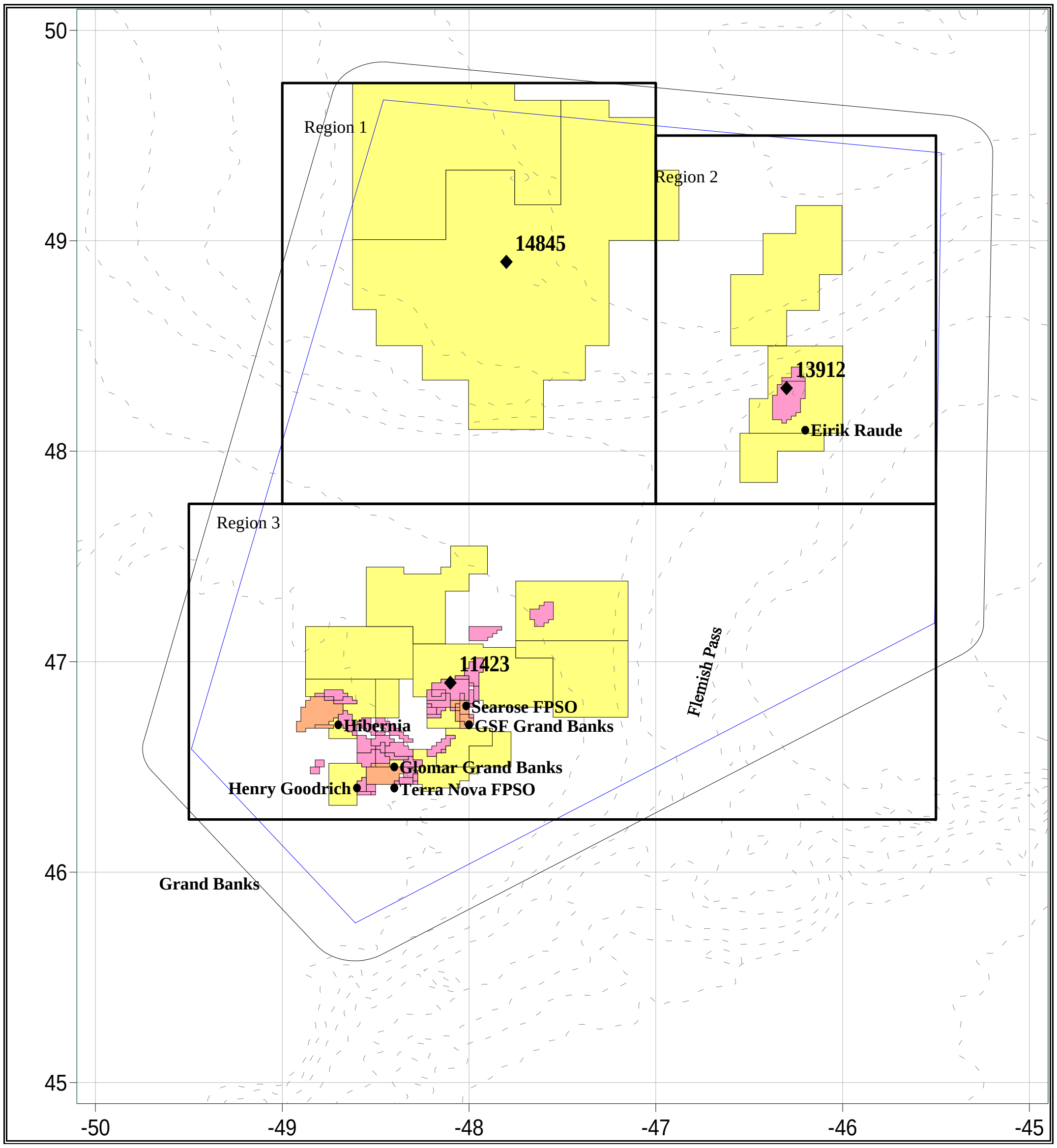


Figure 3.1. **Location of the Grid Points (14845, 13912, and 11423) and Regions used in the Physical Environment Analyses.**

3.2.2.1 Extreme Value Estimates for Winds from the Gumbel Distribution

The extreme value estimates for wind were calculated using Oceanweather's Osmosis software for the return periods of 1-year, 10-years, 25-years, 50-years and 100-years. The analysis used hourly mean 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 ratio of 1.06 and 1.22, respectively (U.S. Geological Survey 1979).

The calculated annual and monthly wind values for 1-hour, 10-minutes and 1-minute are presented in Tables 3.2 to 3.4. The annual 100-year extreme 1-hour wind speed was determined to be 32.8 m/s for grid point 14845, 33.1 m/s for grid point 13912, and 32.3 m/s for grid point 11423. Monthly, the highest 100-year extreme winds occurred during the month of February.

Table 3.2 1-Hr Extreme Wind Speed Estimates (m/s) for Return Periods of 1, 10, 25, 50 and 100 Years.

	Grid Point #14845					Grid Point #13912					Grid Point #11423				
Month	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**
January	23.3	26.8	27.8	28.6	29.3	23.3	27.1	28.4	29.3	30.3	22.8	26.5	27.8	28.8	29.7
February	22.5	28.1	29.8	31.1	32.4	23.0	28.0	29.6	30.9	32.1	22.4	27.2	28.9	30.2	31.5
March	20.9	25.9	27.4	28.6	29.7	20.8	20.6	27.2	28.4	29.6	20.5	24.9	26.5	27.7	28.8
April	18.6	22.4	23.6	24.4	25.3	18.7	22.5	23.8	24.8	25.7	18.2	22.5	24.0	25.2	26.3
May	16.1	21.0	22.5	23.6	24.7	16.5	20.9	22.4	23.5	24.6	15.7	19.7	21.1	22.1	23.2
June	14.8	19.0	20.2	21.2	22.1	15.1	18.8	20.1	21.0	21.9	14.7	18.4	19.8	20.8	21.8
July	13.5	16.6	17.6	18.3	19.0	13.6	16.8	17.8	18.6	19.4	13.5	16.7	17.9	18.7	19.6
August	14.2	19.4	21.0	22.1	23.3	14.4	20.7	22.9	24.5	26.0	14.7	21.1	23.3	25.0	26.7
September	17.3	23.3	25.1	26.5	27.9	17.7	24.0	26.2	27.8	29.4	17.2	22.6	24.6	26.0	27.4
October	18.3	25.0	27.0	28.5	30.0	19.0	24.4	26.3	27.7	29.0	18.6	23.5	25.3	26.6	27.9
November	20.3	25.0	26.4	27.8	28.5	20.5	24.8	26.3	27.3	28.4	20.0	24.4	25.9	27.1	28.2
December	22.2	27.6	29.2	30.4	31.6	22.4	27.6	29.3	30.6	31.8	22.0	26.5	28.1	29.3	30.4
Annual	26.0	29.5	30.8	31.8	32.8	25.9	29.6	31.0	32.1	33.1	25.3	28.9	30.2	31.2	32.3

Table 3.3 10-Minute Extreme Wind Speed (m/s) Estimates for Return Periods of 1, 10, 25, 50 and 100 Years.

	Grid Point #14845					Grid Point #13912					Grid Point #11423				
Month	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**
January	24.7	28.4	29.5	30.3	31.1	24.7	28.7	30.1	31.1	32.1	24.1	28.0	29.4	30.5	31.5
February	23.9	29.8	31.6	33.0	34.3	24.4	29.6	31.4	32.7	34.0	23.8	28.9	30.7	32.0	33.4
March	22.1	27.4	29.1	30.3	31.5	22.1	21.8	28.8	30.1	31.4	21.7	26.4	28.1	29.3	30.5
April	19.8	23.8	25.0	25.9	26.8	19.8	23.9	25.2	26.3	27.3	19.2	23.8	25.5	26.7	27.9
May	17.1	22.3	23.8	25.0	26.2	17.5	22.1	23.7	24.9	26.1	16.6	20.8	22.3	23.5	24.6
June	15.7	20.1	21.4	22.4	23.4	16.0	19.9	21.3	22.3	23.2	15.5	19.5	21.0	22.0	23.1
July	14.3	17.6	18.6	19.4	20.1	14.4	17.8	18.9	19.8	20.6	14.3	17.7	18.9	19.9	20.8
August	15.0	20.5	22.2	23.5	24.7	15.2	22.0	24.2	25.9	27.6	15.6	22.3	24.7	26.5	28.3
September	18.3	24.7	26.6	28.1	29.5	18.7	25.5	27.8	29.5	31.2	18.2	24.0	26.0	27.5	29.1
October	19.4	26.4	28.6	30.2	31.8	20.1	25.9	27.9	29.3	30.8	19.7	24.9	26.8	28.2	29.6
November	21.5	26.5	28.0	29.4	30.3	21.8	26.3	27.8	29.0	30.1	21.2	25.8	27.5	28.7	29.9
December	23.6	29.2	30.9	32.2	33.5	23.8	29.2	31.0	32.4	33.8	23.3	28.0	29.7	31.0	32.3
Annual	27.5	31.2	32.6	33.7	34.8	27.5	31.4	32.8	34.0	35.1	26.8	30.6	32.0	33.1	34.2

Table 3.4 1-Minute Extreme Wind Speed (m/s) Estimates for Return Periods of 1, 10, 25, 50 and 100 Years.

	Grid Point #14845					Grid Point #13912					Grid Point #11423				
Month	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**
January	28.5	32.6	33.9	34.9	35.8	28.4	33.1	34.6	35.8	37.0	27.8	32.3	33.9	35.1	36.3
February	27.5	34.3	36.4	37.9	39.5	28.1	34.1	36.2	37.7	39.2	27.3	33.2	35.3	36.9	38.4
March	25.4	31.6	33.4	34.8	36.2	25.4	25.1	33.2	34.6	36.1	25.0	30.4	32.3	33.7	35.2
April	22.7	27.3	28.7	29.8	30.8	22.8	27.5	29.0	30.2	31.4	22.2	27.4	29.3	30.7	32.1
May	19.7	25.6	27.4	28.8	30.1	20.1	25.5	27.3	28.7	30.0	19.1	24.0	25.7	27.0	28.3
June	18.1	23.1	24.7	25.8	27.0	18.4	23.0	24.5	25.6	26.8	17.9	22.5	24.1	25.4	26.6
July	16.5	20.3	21.4	22.3	23.2	16.6	20.5	21.8	22.7	23.7	16.5	20.4	21.8	22.9	23.9
August	17.3	23.6	25.6	27.0	28.4	17.5	25.3	27.9	29.8	31.8	17.9	25.7	28.4	30.5	32.5
September	21.1	28.4	30.7	32.3	34.0	21.6	29.3	32.0	33.9	35.9	21.0	27.6	30.0	31.7	33.5
October	22.3	30.4	32.9	34.8	36.6	23.1	29.8	32.1	33.7	35.4	22.7	28.7	30.9	32.5	34.1
November	24.8	30.5	32.2	33.9	34.8	25.0	30.3	32.0	33.4	34.7	24.4	29.7	31.6	33.0	34.4
December	27.1	33.6	35.6	37.1	38.6	27.4	33.6	35.7	37.3	38.8	26.8	32.3	34.2	35.7	37.1
Annual	31.7	35.9	37.6	38.8	40.0	31.6	36.1	37.8	39.1	40.4	30.9	35.2	36.9	38.1	39.4

3.2.2.2 Extreme Value Estimates for Waves from a Gumbel Distribution

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 was 14.9 m at grid point 14845, 16.0 metres at grid point 13912, and 15.0 m at grid point 11423. A storm with a return period of 100 years means that the calculated significant wave height will occur once every 100 years, averaged over a long period of time.

The maximum individual wave heights and extreme associated peak periods are presented in Table 3.6 and Table 3.7. Maximum individual wave heights and the extreme associated peak periods peak during the month of December at grid point 14845, and the month of February at grid point 13912 and grid point 11423.

Table 3.5 Extreme Significant Wave Height Estimates (m) for Return Periods of 1, 10, 25, 50 and 100 Years.

	Grid Point #14845					Grid Point #13912					Grid Point #11423				
Month	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**
January	9.2	12.1	12.9	13.5	14.0	10.1	12.8	13.7	14.4	15.0	9.2	12.0	12.9	13.5	14.2
February	8.5	12.1	13.0	13.7	14.4	9.4	13.0	14.2	15.0	15.9	8.5	12.2	13.4	14.3	15.2
March	6.8	10.1	10.9	11.6	12.2	7.8	10.5	11.4	12.1	12.8	7.1	10.0	11.0	11.7	12.4
April	5.7	9.0	9.9	10.5	11.1	6.4	9.2	10.0	10.7	11.4	5.7	8.6	9.6	10.3	11.0
May	4.2	8.1	9.1	9.9	10.6	5.1	8.1	9.1	9.9	10.6	4.6	7.2	8.1	8.7	9.4
June	3.4	6.5	7.3	7.9	8.5	4.1	6.5	7.3	7.9	8.5	3.8	6.1	6.9	7.4	8.0
July	3.1	5.2	5.8	6.2	6.6	3.3	5.4	6.0	6.4	6.8	3.4	5.3	5.9	6.3	6.8
August	3.5	6.2	6.9	7.4	7.9	4.1	6.5	7.2	7.8	8.4	3.8	6.7	7.7	8.4	9.1
September	4.5	10.1	11.5	12.6	13.6	5.8	10.3	11.7	12.8	13.9	5.3	9.3	10.6	11.6	12.5
October	5.7	10.8	12.2	13.1	14.1	6.7	11.1	12.5	13.6	14.6	6.3	10.0	11.2	12.1	13.0
November	7.2	11.3	12.4	13.1	13.9	8.1	11.5	12.6	13.4	14.2	7.4	10.5	11.5	12.3	13.0
December	9.0	12.5	13.5	14.2	14.9	9.7	12.9	14.0	14.8	15.6	8.9	11.7	12.7	13.4	14.1
Annual	11.3	13.2	13.9	14.4	14.9	11.8	14.0	14.8	15.4	16.0	10.8	13.0	13.8	14.4	15.0

Table 3.6 Extreme Maximum Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years.

	Grid Point #14845					Grid Point #13912					Grid Point #11423				
Month	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**
January	16.9	22.6	24.1	25.3	26.4	18.8	24.0	25.7	27.0	28.3	17.0	22.0	23.6	24.8	26.0
February	15.8	22.4	24.2	25.4	26.7	17.5	24.1	26.2	27.9	29.5	15.8	22.6	24.8	26.5	28.1
March	12.5	19.1	20.8	22.1	23.4	14.5	19.7	21.4	22.7	24.0	13.4	18.7	20.4	21.7	23.0
April	10.6	16.5	18.0	19.2	20.3	12.1	17.1	18.7	20.0	21.2	10.7	15.9	17.7	18.9	20.2
May	7.5	15.6	17.7	19.2	20.7	9.9	15.7	17.7	19.1	20.5	8.7	14.0	15.7	17.0	18.3
June	6.6	12.0	13.4	14.4	15.4	7.9	12.1	13.5	14.5	15.6	7.4	11.6	13.0	14.0	15.0
July	5.9	9.9	10.9	11.7	12.4	7.0	10.0	11.1	11.8	12.6	6.5	9.9	11.0	11.8	12.6
August	6.7	11.5	12.7	13.6	14.5	7.8	12.2	13.7	14.7	15.8	7.2	12.3	14.0	15.3	16.6
September	8.7	18.4	20.9	22.8	24.6	10.9	18.6	21.2	23.1	25.0	10.0	17.0	19.2	20.9	22.6
October	10.5	20.0	22.5	24.3	26.1	12.8	20.5	23.1	25.0	26.9	11.8	18.5	20.7	22.4	24.0
November	13.5	21.0	22.9	24.3	25.7	15.0	21.2	23.2	24.7	26.2	13.8	19.5	21.3	22.7	24.0
December	16.6	23.1	24.9	26.3	27.6	18.0	23.9	25.8	27.3	28.7	16.3	21.7	23.5	24.8	26.1
Annual	20.9	24.4	25.7	26.6	27.6	21.8	25.7	27.2	28.3	29.4	20.0	23.9	25.3	26.5	27.6

Table 3.7 **Extreme Associated Peak Period Estimates for Return Periods of 1, 10, 25, 50 and 100 Years.**

	Grid Point #14845					Grid Point #13912					Grid Point #11423				
Month	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**	**1**	**10**	**25**	**50**	**100**
January	12.8	14.5	14.9	15.2	15.5	13.4	14.9	15.3	15.7	16.0	12.8	14.4	14.9	15.3	15.6
February	11.9	14.6	15.3	15.7	16.2	12.7	14.9	15.6	16.1	16.5	12.4	14.3	14.9	15.3	15.7
March	11.7	13.1	13.5	13.7	13.9	12.1	13.3	13.7	14.0	14.2	11.8	13.2	13.6	13.9	14.2
April	10.6	13.1	13.6	14.0	14.4	11.4	12.9	13.3	13.6	13.9	10.7	12.3	12.8	13.1	13.4
May	9.3	12.3	12.9	13.4	13.8	10.2	12.3	12.9	13.3	13.7	9.9	12.0	12.6	13.0	13.4
June	8.6	11.1	11.6	11.9	12.3	9.2	11.2	11.7	12.1	12.5	8.8	10.9	11.5	11.9	12.3
July	7.9	10.4	10.9	11.3	11.7	8.3	10.6	11.2	11.6	12.0	8.5	10.6	11.2	11.6	12.1
August	9.1	10.9	11.3	11.6	11.8	9.4	11.3	11.9	12.3	12.6	9.0	11.8	12.6	13.2	13.7
September	9.9	13.6	14.3	14.8	15.3	11.1	13.8	14.6	15.1	15.6	10.9	13.2	13.9	14.3	14.7
October	11.3	13.6	14.1	14.4	14.7	11.8	14.0	14.5	15.0	15.3	11.4	13.4	14.0	14.4	14.8
November	11.6	13.8	14.3	14.6	15.0	12.3	13.9	14.4	14.7	15.1	12.1	13.4	13.8	14.0	14.3
December	12.6	14.5	14.9	15.3	15.6	13.2	14.9	15.4	15.7	16.1	12.8	14.3	14.7	15.1	15.4
Annual	13.9	15.0	15.3	15.6	15.9	14.3	15.5	15.9	16.3	16.6	13.7	14.9	15.3	15.6	15.9

3.3 Physical Oceanography

A detailed review of current information for the Study Area is provided in Oceans (2012). Current velocities and water mass properties (temperature and salinity) at various water depths are provided in Section 4 of Oceans (2012). A summary of the major currents in the Study Area is provided below.

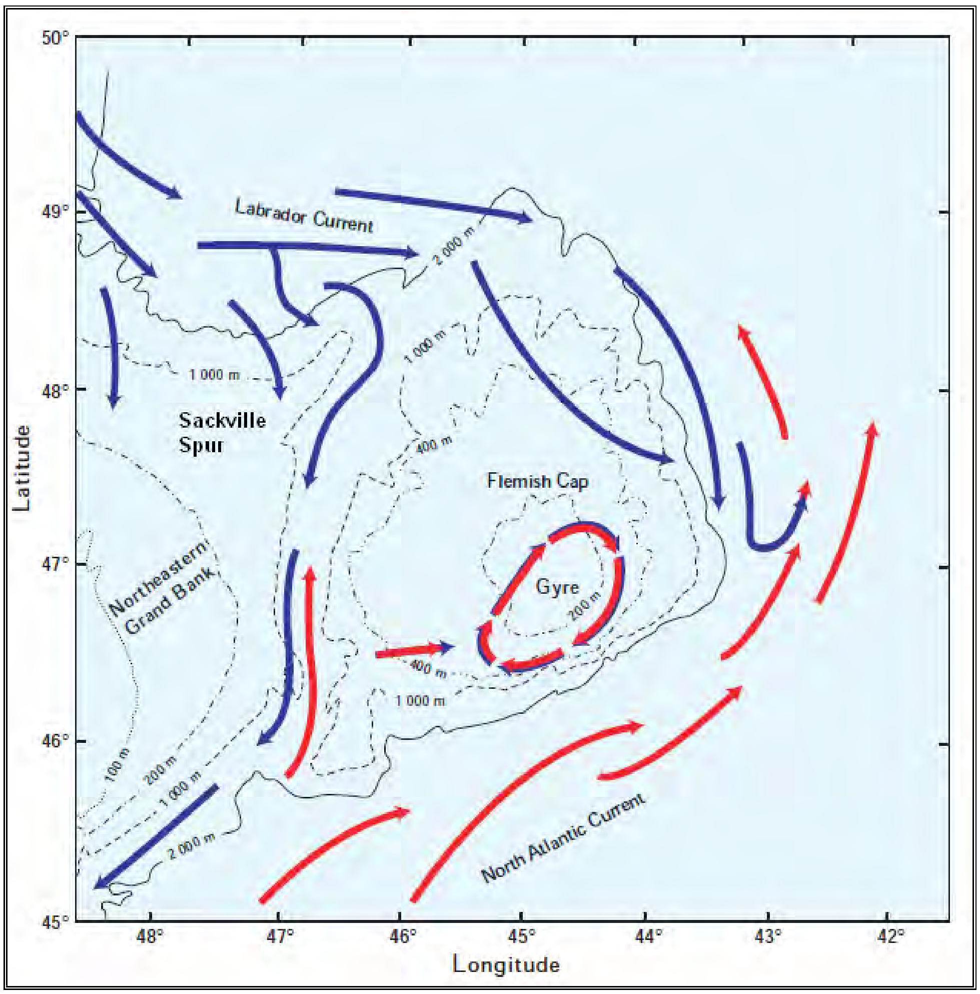
3.3.1 Major Currents in the Study Area

The Study Area overlaps the southern part of Orphan Basin, the Sackville Spur, the Northeast Newfoundland Slope, northern Flemish Pass, and the Jeanne d'Arc Basin. 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 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 (see Figure 4.1 in Oceans 2012).

The Labrador Current consists of two major branches. The inshore branch of the Labrador Current is ~ 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 1,200 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 the Grand Banks and the Flemish Cap (Figure 3.2).

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.



Source: Modified from Colbourne and Foote 2000.

Figure 3.2 The Major Circulation Features Around the Flemish Cap and Sackville Spur.

3.4 Sea Ice and Icebergs

The analysis of sea ice and icebergs in the Study Area was divided into three regions (see Figure 3.1). Table 5.1 in Oceans (2012) provides definitions of the various ice types.

3.4.1 Sea Ice

The 30-year median concentration of sea ice reaches its maximum during the week of 5 March (see Figure 5.1 in Oceans 2012). The median of ice concentration does not extend into any of the three Regions covering the Project Area. The maximum median sea ice extent reaches to approximately 48°N, 49°W.

A weekly analysis of the Canadian Ice Service's 30-Year Frequency of Presence of Sea Ice in Region 1 shows that the area is affected by sea ice beginning the week of 15 January and lasting until the week beginning 28 May. The week of 12 March is the period when the frequency of presence of sea ice is the greatest (see Figure 5.2 in Oceans 2012). The frequency of presence of sea ice over the majority of Region 1 is 1–15%. The frequency of presence of sea ice is greatest in the southwest corner of Region 1 with the highest frequency between 34–50%.

The predominant ice type within the area from 15 January to the week of 5 February is a mixture of grey and grey-white. By 19 February, thin first-year ice begins to form in the northern part of Region 1 and new ice forms to the northwest. Thin first-year ice is the predominate ice type from 19 February until the week of 2 April, with a small amount of medium and thick first-year ice also present. Thick first-year and some old ice are predominate for the remainder of the season.

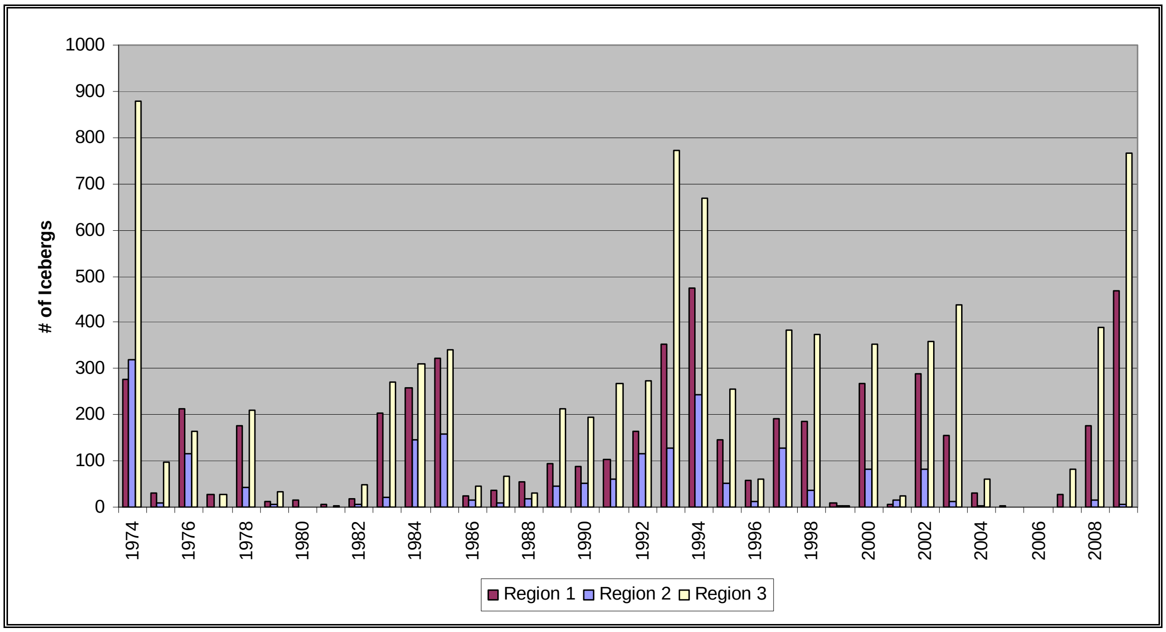
In Region 2, the area is affected by sea ice beginning the week of 29 January and lasting until the week beginning April. The week of 12 March is the period when the frequency of presence of sea ice is the greatest over the area (see Figure 5.2 in Oceans 2012). The frequency of presence of sea ice over the majority of the southern half of Region 2 is 1–15%, while the northern half is mostly ice free. The predominant ice type within the area from 15 January to the week of 12 February is a mixture of grey and grey-white. By 19 February, thin first-year ice begins to form in the southwest region of Region 2. Thin first-year ice is the predominate ice type from 19 February until the week of 26 March, with a small amount of grey-white, medium first-year and thick first-year ice also present. Thick first-year and some old ice are predominate for the remainder of the season.

In Region 3, the area is affected by sea ice beginning the week of 15 January and lasting until the week beginning 21 May. The week of 19 March is the period when the frequency of presence of sea ice is the greatest over the area (see Figure 5.3 in Oceans 2012). The frequency of presence of sea ice over the majority of southern half of Region 3 is 1–15% while the frequency of presence of sea ice in the northern half is highest at 16–33%. There is a small sector in the southeast corner that is ice free. The predominant ice type within the area from 15 January to the week of 12 February is a mixture of grey and grey-white. By 19 February, thin first-year ice begins to form in the eastern part of Region 3. Thin first-year ice is the predominate ice type from 19 February until the week of 2 April, with a small amount of grey-white, medium first-year and thick first-year ice also present. Medium and thick first-year ice is predominate for the remainder of the season.

3.4.2 Icebergs

An analysis was performed to determine the threat posed by icebergs in the Project Area; more specifically in Regions 1, 2, and 3 (see Figure 3.1). The International Ice Patrol Iceberg Sightings Database from 1974-2009 was used as the primary data source in this analysis (NSIDC 2009). Overall there is a good distribution of iceberg sightings ranging from a total of 1,474 in all three regions for 1974 to only one over all three regions in 2006 (Figure 3.3). 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.

Figure 3.4 shows the positions of all icebergs within Region 1 from 1974-2009. Icebergs are concentrated towards the southern portion of the region. Over the 35 years studied, 3,546 icebergs have been sighted inside Region 1. Environmental factors such as iceberg concentration, ocean currents and wind determine how icebergs drift through the area.



Source: IIP.

Figure 3.3 Iceberg Sightings within the Project Area.

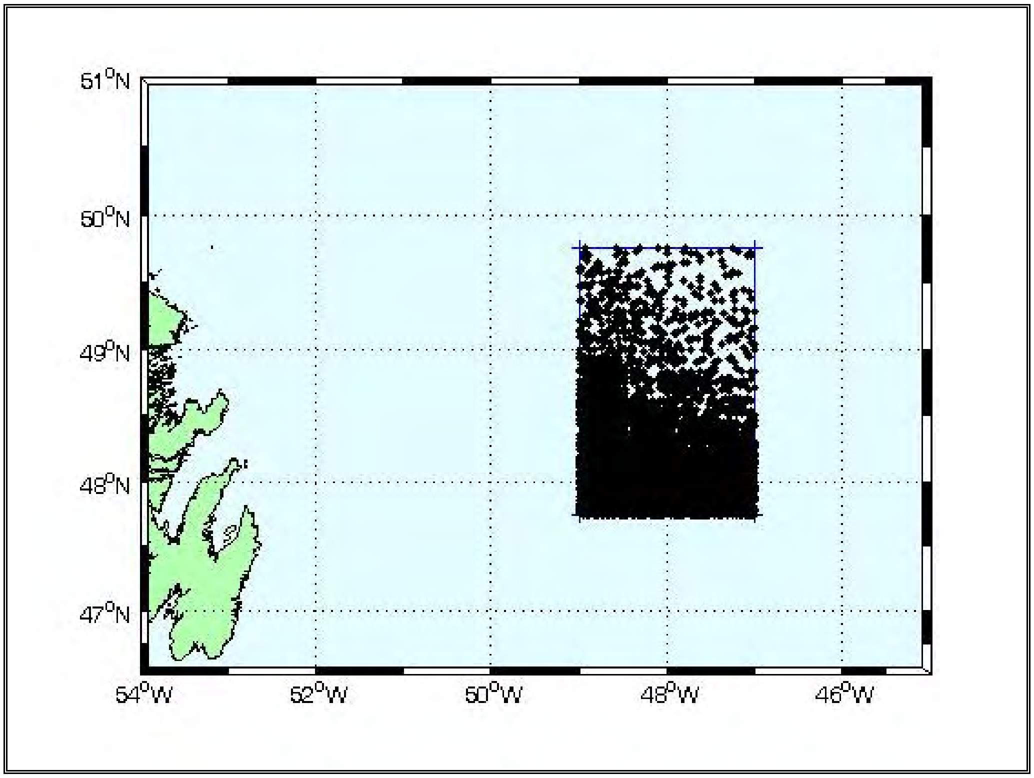
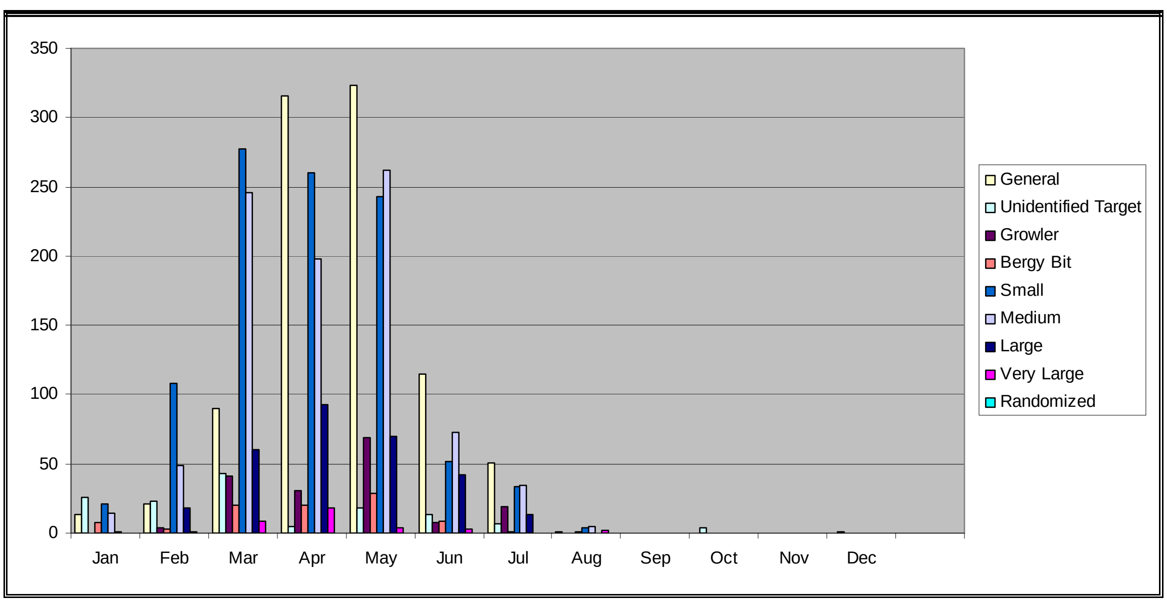


Figure 3.4 Iceberg Sightings in Region 1 of the Project Area from 1974-2009.

A monthly analysis shows that icebergs have been spotted within Region 1 in all months, with the exception of September and November. They are most prominent during the months of April and May (Figure 3.5). With respect to size, the most prominent icebergs are small, accounting for 28.1% of observed icebergs within the region. Large icebergs occur 8.4% of the time.



Source: IIP.

Figure 3.5 Iceberg Size by Month within Region 1 of the Project Area.

In Region 2, icebergs are concentrated towards the southern portion of the region for 1974-2009 (Figure 3.6). Over the 35 years studied, 1,002 icebergs have been sighted inside Region 2. Environmental factors such as iceberg concentration, ocean currents, and wind determine how icebergs drift through the area.

A monthly analysis shows that icebergs have been spotted within Region 2 from January through August; they are most prominent during the month of March (Figure 3.7). With respect to size, the most prominent icebergs are medium, accounting for 25.4% of observed icebergs within the region. Large icebergs occur 8.5% of the time.

The greatest overall distribution of icebergs of all three sectors occurs within Region 3, with icebergs having been spotted over nearly the entire region (Figure 3.8). Over the 35 years studied, 9,527 icebergs have been sighted inside the region. Environmental factors such as iceberg concentration, ocean currents and wind determine how icebergs drift through the area.

A monthly analysis shows that icebergs have been spotted within Region 3 in all months, with the exception of September and November. They are most prominent during April (Figure 3.9). With respect to size, the most prominent icebergs are medium, accounting for 27.6% of observed icebergs within the region. Large icebergs occur 9.7% of the time.

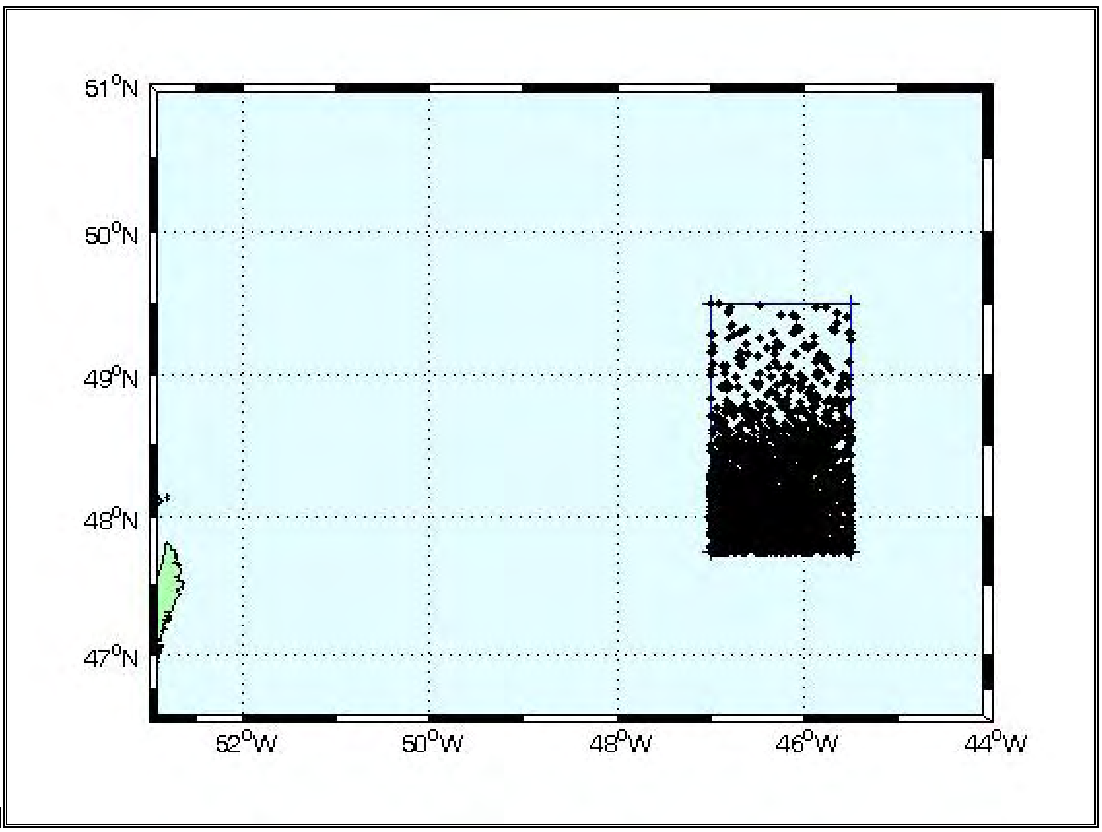
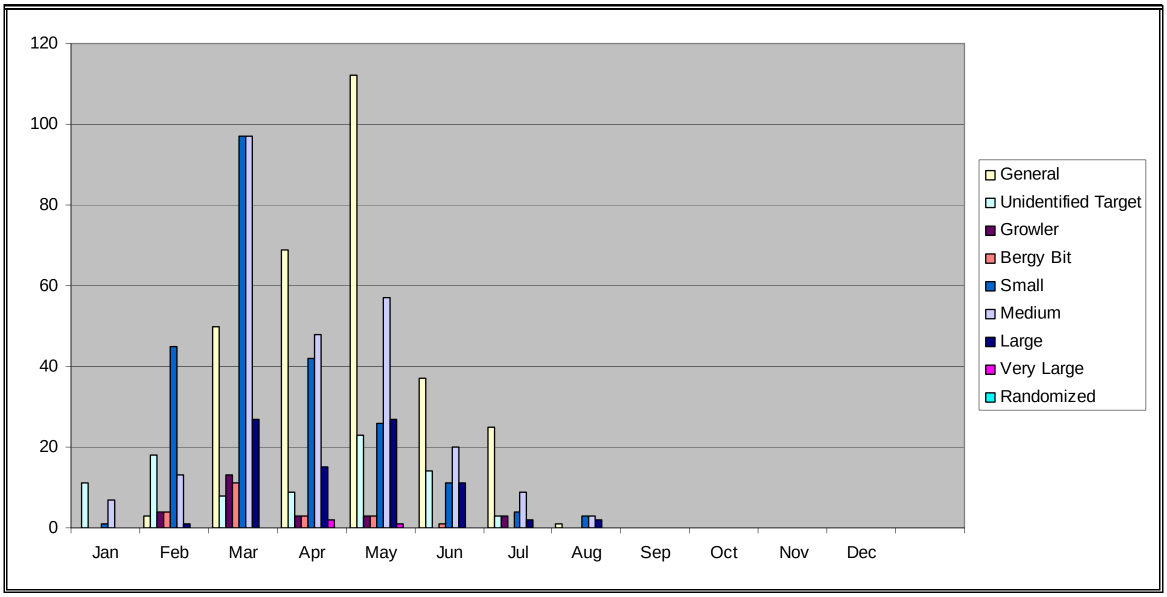


Figure 3.6 Iceberg Sightings in Region 2 of the Project Area from 1974-2009.



Source: IIP.

Figure 3.7 Iceberg Size by Month within Region 2 of the Project Area.

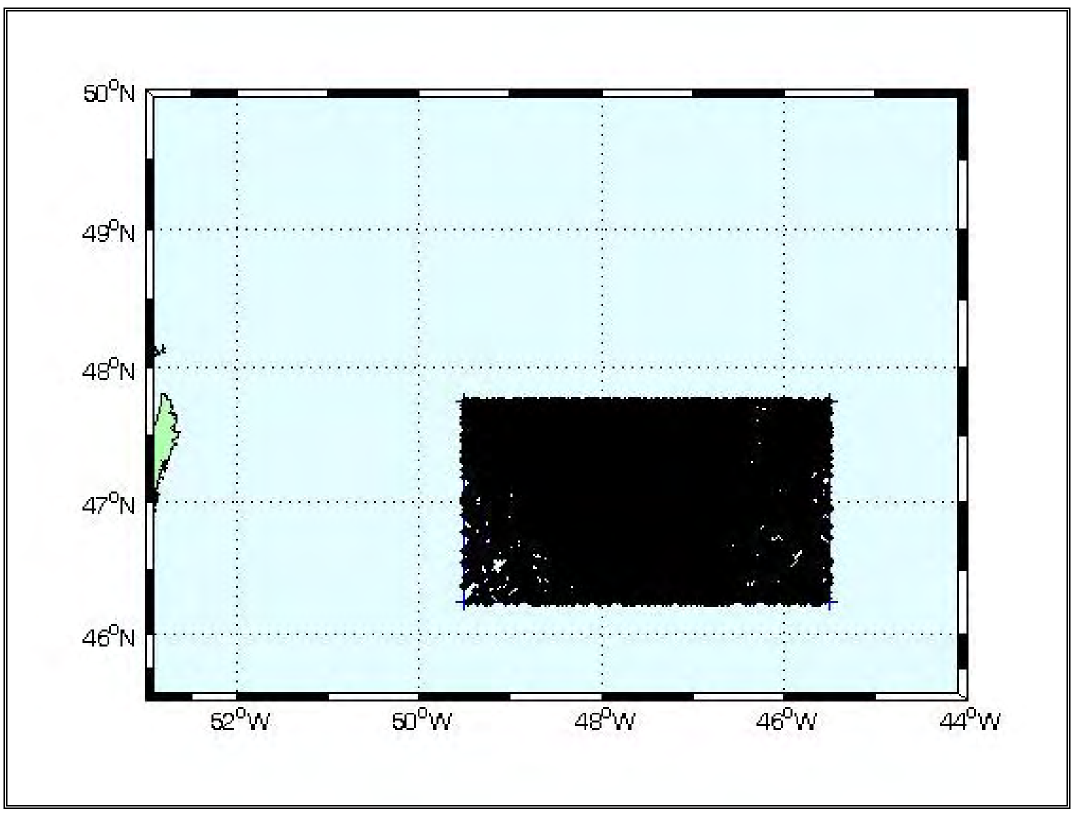
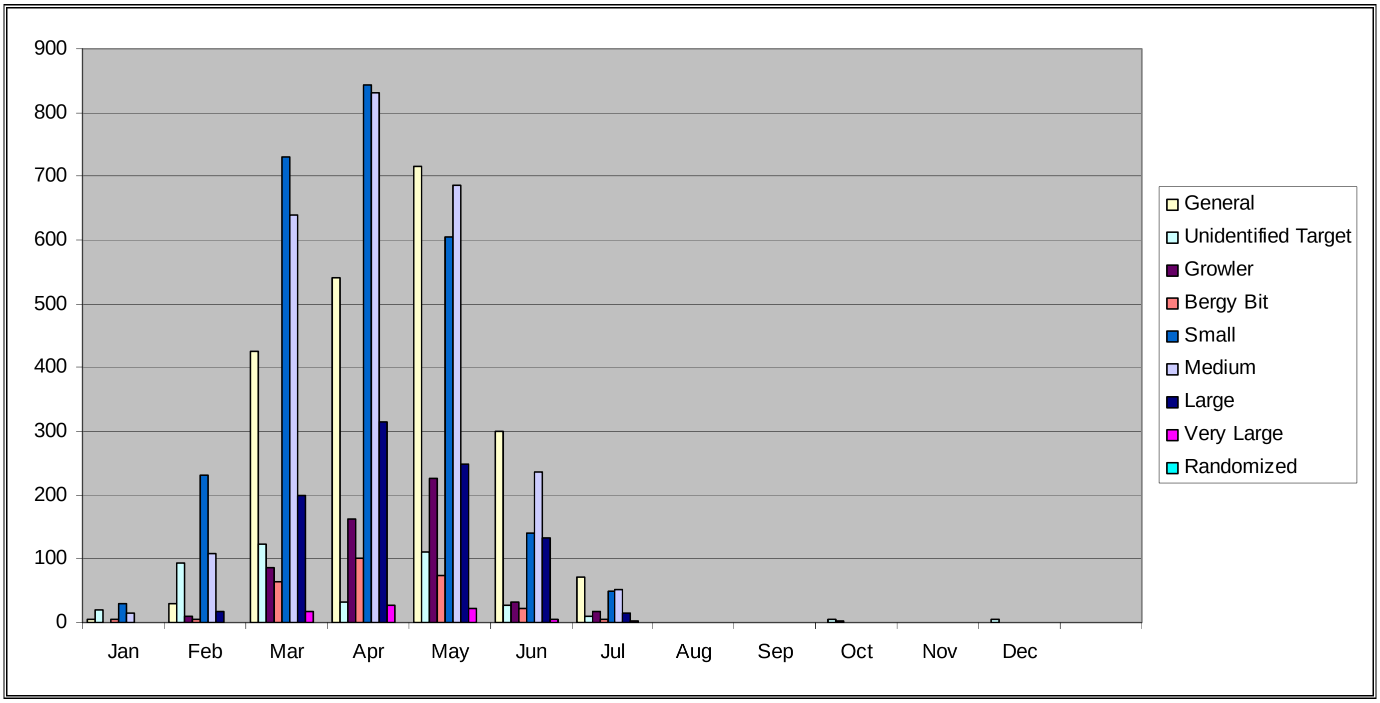


Figure 3.8 Iceberg Sightings in Region 3 of the Project Area from 1974-2009.



Source: IIP.

Figure 3.9 Iceberg Size by Month within Region 3 of the Project Area.

4.0 Biological and Socio-economic Environment

The biological and socio-economic environments in and near the Study Area have been described in the Orphan Basin SEA (LGL 2003; Buchanan et al. 2004) and more recently, in exploration and drilling EAs and their amendments for Orphan Basin (Moulton et al. 2005a,b; LGL 2005, 2006a, 2009), Jeanne d'Arc Basin (Christian 2008; LGL 2006b, 2007a,b, 2008a,b, 2011a,b) and Flemish Pass Basins (LGL 2011). In addition to updated information, summaries of relevant information from these documents are presented in the following subsections for fish and fish habitat, fisheries, seabirds, marine mammals and sea turtles, species at risk, and potentially sensitive areas.

4.1 Ecosystem

An ecosystem is an inter-related complex of physical, chemical, geological, and biological components that can be defined at scales ranging from a relatively small area (that may only contain one habitat type (e.g., a shelf) to a relatively large regional area ecosystem which is topographically and oceanographically complex (e.g., the Northwest Atlantic). This EA focuses on components of the ecosystem such as selected species and life stages of fish, seabirds and marine mammals that are important ecologically, economically, and/or socially, and have potential to interact with the Project. This is the VEC approach to the EA which is detailed in Section 5.0. The VECs are discussed in the following subsections.

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 Study Area.

4.2.1 Fish Habitat

In this EA, fish habitat is considered to include 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 water column and 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, such as polychaetes and echinoderms).

4.2.2 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 zoo-plankton (e.g., calanoid copepods, the dominant component of Northwest 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 Northwest Atlantic, there is usually 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, Moderate Resolution Imaging Spectroradiometer (MODIS) chlorophyll 'a' concentration images from August 2009 to 2011 (http://www2.mar.dfo-mpo.gc.ca/bin/cgi/ocean/seawifs_1.pl) indicate that the highest chlorophyll 'a' concentrations occurred in the Study Area between March and May, followed by a second peak between September and mid-November. Typically, the spring bloom of phytoplankton is the driving force of high-latitude marine ecosystem dynamics. Sunlight has been considered the limiting factor for development of the spring bloom; however, factors such as nutrients, latitude, and water column stratification are also important (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 is the foremost link between primary production and higher-level organisms in the marine ecosystem. They transfer organic carbon from phytoplankton to higher trophic levels including fishes, birds, and marine mammals. Zooplankton is a food source for a broad spectrum of species, and they contribute faecal matter and dead zooplankton to the benthic communities. Pepin et al. (2011) noted that plankton distribution in the Study Area is primarily influenced by local advective transport and mixing processes, and that several species of *Calanus* copepods act as key contributors to the regional secondary production. More information on phyto-plankton in and around the Study Area is available in Section 3.2.1 of the Orphan Basin SEA (LGL 2003) and the Husky New Drill Centre Construction and Operations Program EA (Subsection 5.4 *in* LGL 2006b).

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 on macroinvertebrates and fishes.

4.2.3 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 include barnacles, tunicates, bryozoans, 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 latitudes 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) and the Husky New Drill Centre Construction and Operations Program EA (Subsection 5.4 *in* LGL 2006b), 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) and Subsection 5.5.1.1 of LGL (2006b) include more general information on benthos in the vicinity of the Study Area. Deepwater corals and sponges have gained more focus in recent years. Some information on corals and sponges occurring within the Study Area is presented in the following subsection.

4.2.3.1 Deepwater Corals and Sponges

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, and 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, 30 species of corals were documented and included two antipatharians (black wire corals), 13 alcyonaceans (large gorgonians, small gorgonians, and soft corals), four scleractinians (solitary stony corals), and 11 pennatulaceans (sea pens).

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 ~22 species of corals occurring within the Study Area. The species identified include antipatharians (*Stauropathes arctica* and *Bathypathes* spp.), large gorgonians (*Keratoisis ornata*, *Paragorgia arborea*, and *Paramuricea* spp.), small gorgonians (*Acanella arbuscula*, *Acanthogorgia armata*, *Anthothela grandiflora*, and *Radicipes gracilis*), and soft corals (*Anthomastus grandiflorus*, *Duva florida*, *Gersemia rubiformis*, and *Nephtheid* *spp.*). One scleractinian species (*Flabellum alabastrum*) and eight pennatulacean species (*Anthoptilum grandiflorum*, *Distichoptilum gracile*, *Halipteris finmarchica*, *Pennatula grandis*, *Pennatula phosphorea*, *Umbellula lindahli*, *Funiculinia quadrangularis*, and *Pennatulacea* sp.) are also noted to occur there. According to Murillo et al. (2011), antipatharian species (*Leiopathes* sp.), one scleractinian species (*Desmophyllum dianthus*), and one pennatulacean species (*Pennatula aculeata*) also occur in the Flemish Pass region of the Study Area. The majority of coral species was observed to occur both on the continental slope and within Flemish Pass, with the exception of several soft corals (e.g., *Gersemia rubiformis* and *Duva florida*) found on the shelf of Jeanne d'Arc Basin. Based on DFO Research Vessel (RV) survey data collected in the Study Area from 2005 to 2010, most of the corals were caught at mean water depths of ~300 and 650 m in the spring and fall surveys, respectively. A recent DFO Science Advisory Report (DFO 2010a) also discusses the occurrence and ecological function of corals in Canadian waters.

The patterns of association between deep-sea corals, fish, and invertebrate species, based on DFO scientific surveys and remotely operated vehicle (ROV) surveys are discussed by Edinger et al. (2009). Although there were no dramatic relationships between corals and abundance of the 10 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 may also support diverse assemblages of fishes. Although relationships between corals and groundfish or invertebrates are not obligate and may result from coincidence, conservation areas established for corals may effectively protect populations of groundfish, including some commercial species (Edinger et al. 2009). 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; Costello et al. 2005 *in* Edinger et al. 2009).

Sponges also provide significant deep-sea habitat, enhance species richness and diversity, and exert clear ecological effects on other local fauna. Sponge grounds and reefs support increased biodiversity compared to structurally-complex abiotic habitats or habitats that do not contain these organisms (DFO 2010a).

Morphological forms such as thick encrustations, mounds, and branched, barrel- or fan-like shapes influence near-bottom currents and sedimentation patterns. They provide substrate for other species and offer shelter for associated fauna through the provision of holes, crevices, and spaces. Siliceous hexactinelid sponges can form reefs as their glass spicules fuse together; when the sponge dies, the skeleton remains. This skeleton provides settlement surfaces for other sponges, which in turn form a network that is subsequently filled with sediment (DFO 2010a).

Although some of the siliceous spicules of non-reef-forming species dissolve quickly, there is some accumulation of shed spicules forming a thick sediment-stabilizing mat, which constitutes a special bottom type supporting a rich diversity of species. Organisms commonly associated with sponges and sponge grounds include species of marine worms and bryozoans, as well as higher fauna. Live glass sponge reefs have been shown to provide nursery habitat for juvenile rockfish, and high-complexity reefs are associated with higher species richness and abundance (DFO 2010a).

In 2008 and 2009, the North Atlantic Fisheries Organization (NAFO) Scientific Council identified areas of significant coral and sponge concentrations within the NAFO Regulatory Area. These areas that have been deemed closed to fishing with bottom gear are shown in Section 4.7.2 of Potentially Sensitive Areas (DFO 2010a).

4.2.4 Fishes

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

4.2.4.1 Macroinvertebrates and Fishes Primarily Targeted in Commercial Fisheries

The total commercial fisheries catch weight within the Study Area from 2005 to 2010 was 115,362 mt (DFO Landings Data 2005–2010). Two macroinvertebrate species, northern shrimp (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*), dominated the reported landings of commercial catches within the Study Area during 2005 to 2010 (combined average annual catch weight over 99% of total). Other species that account for at least 0.7% of the 2005 to 2010 average annual total catch weight include Stimpson's surf clam (*Mactromeris polynyma*; 0.4%), and Greenland halibut (0.3%). Thirteen other species/groups accounted for <1% each of the average annual catch weight.

Northern Shrimp

The primary cold-water shrimp resource in the North 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). 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). After insemination, female shrimp may migrate to shallower water areas where the water temperatures are most appropriate for embryonic development and subsequent larval hatch (http://www.dfo-mpo.gc.ca/ science/publications/article/2009/08-31-09-eng.html). 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 large enough for recruitment to the fishery by as early as three years of age (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, Atlantic cod (DFO 2006a), Atlantic halibut, skates, wolffish and harp seals (DFO 2000a).

Georeferenced commercial catch location data for the April to October period, 2005–2010, indicate that most northern shrimp catches within the Study Area occurred on the northeastern Newfoundland Slope in areas with water depths <500 m. Scattered shrimp catches were also reported on the slopes of the Jeanne d'Arc Basin and Flemish Pass. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, the greatest proportion of northern shrimp was caught between the 200 and 500 m isobaths on the northeastern slope of Jeanne d'Arc Basin in the west-central portion of the Study Area.

Snow Crab

The snow crab, a decapod crustacean, occurs over a broad depth range in the Northwest 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.

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 moult frequently, and at ~40 mm CW (~4 years of age) they 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).

Georeferenced commercial catch location data for May to November, 2005–2010, indicate a wider distribution of catch locations for snow crab than for northern shrimp. Most snow crab catches were made between the 100 and 200 m isobaths of the Jeanne d'Arc Basin located in the western, central, and south-central portions of the Study Area. Scattered harvest locations were also reported for the shallower regions of the Jeanne d'Arc Basin and on the Flemish Pass in the western and central portions of the Study Area, respectively. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, the greatest proportion of snow crab were caught between the 100 and 500 m isobaths on the northeastern slope of Jeanne d'Arc Basin in the southwestern portion of the Study Area.

Stimpson's Surf Clam

This bivalve mollusc is a circumboreal species, inhabiting both the Atlantic and Pacific Oceans. It is the largest clam in the Northwestern Atlantic Ocean and occurs from Labrador to Rhode Island, often on medium to coarse sand substrate (Abbott 1974 *in* Christian et al. 2010). In the Canadian part of its range, this species occurs in commercial quantities in the offshore areas of the Scotian Shelf and Eastern Grand Banks, and inshore areas off southwest Nova Scotia and in the Gulf of St. Lawrence (DFO 1989a, 1999, 2004a *in* Christian et al. 2010). The Stimpson's surf clam appears to prefer medium to coarse sand substrate in which it burrows (DFO 2009 *in* Christian et al. 2010).

Surf clam spawning in the offshore areas typically occurs during the fall (DFO 2009 *in* Christian et al. 2010). Davis and Shumway (1996 *in* Christian et al. 2010) report that larval hatch occurs within days of spawning, and that larvae remain planktonic for 1 to 2 months before settlement to the bottom substrate. Stimpson's surf clams are filter feeders with a microalgal diet (e.g., dinoflagellates) (Smith and Wikfors 1992 *in* Christian et al. 2010). Predators of the surf clam include sea stars, whelk, crabs, and large groundfish (Himmelman and Hamel 1993; Rochette et al.1995; Morissette and Himmelman 2000 *in* Christian et al. 2010).

Georeferenced commercial catch location data did not indicate any catches of Stimpson's surf clam in the Study Area during May to November, 2005–2010. However, clams were caught in the south-western portion of the Study Area between January and March of 2006, at locations with water depths <100 m.

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. The majority of the adult population is distributed in the deep and warm North 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).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate Greenland halibut catch locations in the central-western portion of the Study Area, in water depths ranging between 100 and 1,000 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, the greatest proportion of Greenland halibut was caught between the 200 and 1,000 m isobaths on the northeastern slope of Jeanne d'Arc Basin in the central portion of the Study Area.

Cockle

This bottom-dwelling bivalve occurs submerged just under the sediment surface in a variety of substrate types, ranging from soft mud to stony gravel (Franklin 1972). A non-selective filter-feeder, the cockle slightly projects two fleshy siphons through the sediment surface into the water, and directs a continuous flow of water through its body for respiration and feeding (Franklin 1972). Cockles fall prey to a variety of predators, such as various fish (including flounders and plaice), crabs, starfish, and even seabirds in shallower waters (Franklin 1972).

Cockles generally spawn in the spring, but spawning may extend into summer and fall (Franklin 1972). Eggs and sperm are shed freely into the water, and larvae are thought to remain planktonic for approximately three weeks before they settle on the sea bed.

Several species of cockle are known to occur in Northwest Atlantic waters. Of these, the Greenland cockle (*Serripes groenlandicus*) occurs in and around the Study Area and is a common bycatch species in the Arctic surf clam (*Mactromeris polynyma*) commercial fishery (DFO 2011a). As such, it is likely the cockle species in question in the georeferenced DFO commercial catch location data for 2005 to 2010 in the Study Area.

The Greenland cockle is widely distributed throughout the Arctic Ocean and southward in varying degrees (Golikov and Scarlato 1973 *in* Christian et al. 2010). In the Northwest Atlantic Ocean, this bivalve is found from Greenland to Cape Cod at subtidal depths >9 m. Barrie (1979 *in* Christian et al. 2010) found this cockle species on sandy substrates within a depth range of 6 to 18 m at various Labrador locations. It is ~100 mm in diameter at full growth (Gosner 1979 *in* Christian et al. 2010). The life history of the Greenland Cockle is poorly understood.

The Greenland cockle displays intense escape behaviour towards the sea stars *Leptasterias polaris* and *Asterias rubens,* two of its primary predators (Legault and Himmelman 1993 *in* Christian et al. 2010). Other predators of the Greenland cockle include demersal fish (e.g., cod, haddock) (Dolgov and Yaragina 1990 *in* Christian et al. 2010) and marine mammals (Fisher and Stewart 1997 and Born et al. 2003 *in* Christian et al. 2010).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate that most cockle catches occurred in the southwestern portion of the Study Area at locations with water depths <100 m.

Atlantic Herring

Atlantic herring (*Clupea harengus*) occurs on both sides of the North Atlantic, ranging from western Greenland to Cape Hatteras in the Northwest Atlantic (Scott and Scott 1988). Typically a pelagic species, Atlantic herring generally inhabit relatively shallow waters, in depths <200 m. Immature fish and/or mature fish prior to spawning may form particularly large schools (Scott and Scott 1988). Atlantic herring stocks have been shown to undertake extensive annual migrations between spawning grounds, overwintering areas, and feeding areas (Scott and Scott 1988).

Spawning time and location varies with each herring stock. In Canadian waters, Atlantic herring spawning can occur between April and November, with the offshore stocks typically spawning in the fall (Scott and Scott 1988). Atlantic herring eggs remain on the seabed until the time of hatching. Upon hatching, the larvae are slender and light-sensitive and tend to seek deeper water on bright days (Graham and Sampson 1982 *in* Scott and Scott 1988). Egg and larval mortality is high, with relatively few fertilized eggs surviving to adult age (Scott and Scott 1988).

Atlantic herring are visual feeders (Blaxter 1966 *in* Scott and Scott 1988) and consume a variety of small organisms, including phytoplankton (the primary diet of young herring), euphausiids, copepods, fish eggs, pteropods, mollusc larvae, and the larvae of small fishes. Atlantic herring off Newfoundland have been known to eat very little during the winter months, instead surviving on accumulated fat (Hodder 1972 *in* Scott and Scott 1988). Atlantic herring make up the basic food source for numerous organisms, including many fish, marine bird, and marine mammal species.

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate a few Atlantic herring catch locations in the northwestern portion of the Study Area with water depths <500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the Atlantic herring were caught during spring and fall surveys at a mean water depth of ~230 m.

Roughhead Grenadier

The roughhead grenadier occurs in deep water along coasts in subarctic to temperate waters on both sides of the North Atlantic. In the Northwest 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 it may inhabit depths between 200 and 2,000 m (Murua and De Cardenas 2005 *in* González-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 Northwest Atlantic. This fish generally occurs both on the shelf and on the continental slope at depths ranging from 400 to 1,200 m. It has been found at depths as shallow as 200 m and as deep as 2,700 m.

Spawning is thought to occur during the winter and early spring. Little is known about the spawning grounds of this fish off Newfoundland although it is believed that some spawning does occur on the southern and southeastern slopes of the Grand Banks (Scott and Scott 1988; COSEWIC 2007). Food for the roughhead grenadier consists of a variety of benthic invertebrates including bivalve molluscs, shrimp, sea stars, polychaetes, and some fish. Roughhead grenadier has been found in the stomachs of Atlantic cod. This grenadier species is quickly becoming an important commercial fish in the Northwest Atlantic. Presently its fishery is unregulated since it is usually taken as bycatch in the Greenland halibut fishery.

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate most roughhead grenadier catches in the central portion of the Study Area with water depths <1,000 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, the greatest proportion of roughhead grenadier was caught between the 500 and 1,000 m isobaths in the central and south-central portions of the Study Area.

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

Redfish

The Northwest Atlantic redfish consists of a complex of three species identified as Acadian redfish (*Sebastes 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 Northwest 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 Banks 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). 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).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate a concentration of redfish catch locations in the central portion of the Study Area with water depths <500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the redfish caught were deepwater redfish. The highest catches of deepwater redfish occurred at a mean water depth of 400 m during both spring and fall surveys. In terms of total catch weight, the greatest proportion of deepwater redfish was caught between the 200 and 500 m isobaths in the central and south-central portions of the Study Area.

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

Skate

Skates are bottom-living fishes that can be found in temperate, arctic, or tropical waters worldwide (Scott and Scott 1988). At least 14 species have been found to occur in Canadian Atlantic waters (BIO and NAFC 2007), with thorny skates (*Amblyraja radiata*) and spinytail skates (*Raja spinicauda*) typically dominating those caught during research surveys in and around the Study Area (e.g., DFO 1998, 2009a; RV survey data 2006–2010).

Skates lay eggs in rectangular, horny capsules known as ‘sea- or mermaids’ purses,’ usually with one egg per capsule (Scott and Scott 1988). Eggs are presumed to be laid on the sea-bottom.

Skates are carnivorous, generalists, and typically opportunistic feeders (BIO and NAFC 2007). They consume a wide variety of organisms, which may include crabs, shrimps, lobsters, amphipods, isopods, mysids, polychaetes, bivalve molluscs, small fish, and occasionally cephalopods (Scott and Scott 1988). Energy-rich skate eggs are preyed upon by gastropods and marine mammals such as seals and sea lions, while hatched skates are consumed by numerous predators including sharks, other skates and rays, and grey seals (BIO and NAFC 2007).

A common bycatch species in offshore trawler catches, skate was traditionally discarded and often not reported in catch statistics (DFO 1998). However, with the decline in the groundfish resources in waters around Newfoundland, interest in skate began to increase in the early 1990s (DFO 1996a). Commercial catches of skates consist of several skate species; however, thorny skate dominates the catch composition. In Canadian commercial catches, about 95% of the skate catch is thorny skate (Kulka and Miri 2007; Kulka and Mowbray 1999 *in* Simpson and Miri 2010). Thus, the skate fishery on the Grand Banks can be considered a directed fishery for thorny skate, and this is likely the species in question in the georeferenced DFO commercial catch location data for 2005 to 2010 in the Study Area.

Thorny skate is a widely distributed species in temperate and arctic waters of the North Atlantic. In the western Atlantic, this skate is distributed from Greenland to South Carolina, with the center of distribution on the Grand Banks in NAFO Divisions 3LNO (Simpson and Miri 2010). Thorny skate occur on both hard and soft substrates (Kulka et al. 1996 *in* JW 2007) but are primarily associated with muddy, sandy and pebble substrates typical of Grand Banks sediment (Kulka and Miri 2003a *in* JW 2007).

The migration patterns of the thorny skate are not fully understood, but evidence suggests a seasonal migration between the continental shelf edge during December to June, and the top of the banks during the remainder of the year (Kulka and Mowbray 1998 *in* JW 2007). All available evidence suggests that thorny skates in Divisions 3LNOPs comprise a single population (Kulka and Miri 2007). Males mature at smaller sizes than females with size at maturity increasing from north to south. Ovaries of sexually mature females hold 10 to 12 pairs of eggs in various developmental stages (Kulka and Miri 2003a *in* JW 2007). Thorny skate deposit 6 to 40 egg cases per year (DFO 2003b *in* JW 2007). Larger thorny skate produce larger egg cases; it is not known if egg case size is related to survival rates (Kulka and Miri 2003a *in* JW 2007).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate a skate catch distribution in the southeastern portion of the Study Area in areas with water depths <500 m on the Jeanne d'Arc Basin, and as great as 1,000 m on the Flemish Pass slope. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the thorny skate catches were at mean water depths of ~300 m during both spring and fall surveys.

Capelin

Capelin 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 pre-dominately 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. Capelin beach spawning typically occurs at a water temperature range of 5 to 8.5°C, but they 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; males and most females usually die following spawning. Spawning commences in early June and may continue through July or August depending on tides, winds, and water temperatures (Scott and Scott 1988; Nakashima and Wheeler 2002). Incubation varies with ambient temperature and lasts ~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 primarily of euphausiids and copepods. Capelin feeding is seasonal with intense feeding in late winter and early spring leading up to the spawning cycle when feeding 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), and 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.

Commercial fishery capelin catches during the May to November period, 2005–2010, were primarily concentrated in the central-western portion of the Study Area, at locations with water depths ranging from 50 to 500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the capelin was caught during springtime surveys at a mean water depth of 160 m. The fall survey mean catch depth was 200 m.

Mackerel

Mackerel (*Scomber scombrus*) is a fast swimming, pelagic, schooling species (NOAA 1999) distributed in both Northeast and Northwest Atlantic waters (DFO 2009b). In the Northwest Atlantic, it ranges from Newfoundland to North Carolina, occurring in coastal waters in spring and summer and deeper waters along the continental shelf edge in fall and winter (DFO 2009b). Mackerel is unique among most other pelagic species, such as capelin, in that it does not possess a swim bladder and must swim continuously or it will sink (DFO 2011b). Mackerel prefer water temperatures between 7 and 15ºC; in the past several years a trend of migration to northerly regions has been observed in response to increased water temperature from climate change, with some mackerel ranging as far as the vicinity of the Arctic Circle at depths of around 20 m (DFO 2011b).

Most mackerel reach sexual maturity by two years of age (Sette 1943), with each female able to spawn repeatedly via batch spawning (Sette 1943; DFO 2009b). In Canadian waters, spawning occurs near the surface, day or night, primarily between June and July in the southern Gulf of St. Lawrence when sea surface temperatures reach 7 to 9ºC and peaks between 10 to 13ºC (Ware and Lambert 1985; DFO 2009b). Eggs, larvae, and juveniles are pelagic, ranging from near surface to 15 to 25 m depth (Sette 1943). Mackerel is an opportunistic feeder, preying on zooplankton (e.g., copepods, euphausiids, amphipods, and chaetognaths), crustaceans (including northern shrimp), molluscs, and fish (including capelin, yellowtail flounder, and other mackerel) (NOAA 1999; DFO 2009b). Mackerel, a muscular and fatty fish, falls prey to numerous cetaceans, pelagic and demersal fish, seals, and seabirds (Savenkoff et al. 2005; DFO 2009b).

Mackerel has traditionally been used as bait in lobster and crab traps, but has become popular commercially within the past several years due to the decline in traditionally harvested groundfish species (DFO 2011b). However, there are concerns regarding management of the mackerel fishery, owing to unreported catch (bait or recreational fishing), and to potentially unreliable biomass estimates from traditional egg surveys due to the climate-induced migrational trends seen in recent years (DFO 2009b, 2011b). As such, the fishery is being managed cautiously by DFO, with freezes put in place for new mobile gear as of 2007, and the potential implementation of marine recreational fishing licences (DFO 2009b).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate a single mackerel catch in the northwestern portion of the Study Area, where water depths range from 2,000 to 2,500 m.

Atlantic Halibut

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

Few commercial catches of Atlantic halibut were reported in the Study Area during the May to November period, 2005–2010. Most of the reported catches were located in the southeastern portion of the Study Area at locations with depths <500 m. Two commercial catches were also reported in the central-western portion of the Study Area at depths of ~500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, Atlantic halibut were caught mostly during the spring surveys. The mean catch depths during spring and fall surveys were 440 and 350 m, respectively.

Rock Crab

Rock crab are found from Labrador to Florida at various depths, ranging from 6 to 456 m (Stehlik et al. 1991 *in* DFO 2006c). This bottom-dwelling species prefers sandy or mud bottom, but is also commonly found on other types of substrate (DFO 2000b).

Rock crabs increase in size through moulting, which occurs primarily in April and May (DFO 2000b). Males reach a larger maximum size than females. These crabs become sexually mature at a carapace width of ~40 mm and 25 mm for males and females, respectively. Mating can occur between July and October, depending on location, and egg extrusion is thought to occur around late October (Scarratt and Lowe 1972; DFO 2000b).

Rock crabs are opportunistic, generalist predators (Salierno et al. 2003). Their prey species vary according to availability, location, and season, and can include polychaetes, mussels, sea stars, sea urchins, molluscs, amphipods, gastropods, and fish, among others (Scarratt and Lowe 1972). These crabs are preyed upon by various fishes, decapods, seabirds, and marine mammals (Donahue et al. 2009).

Rock crabs were traditionally considered pests in the lobster fishery, as they were known to enter lobster traps and steal the bait. However, the commercial fishery for these crabs began in the 1970s in the Atlantic region and has gained more attention with the collapse of traditional groundfish species, such as cod. Rock crabs reach commercial size at approximately six years of age (DFO 2000b), and the fishery is regulated by DFO to include mandatory licences, quotas, minimum size (carapace width of 102 mm), and a ban on catching females or soft-shelled crabs (DFO 1996b).

Georeferenced commercial catch location data indicated a single reported rock crab catch for the May to November period, 2005–2010, which occurred in the southeastern portion of the Study Area in water depths <1,000 m.

Sea Scallops

Sea scallops (*Placopecten magellanicus*) are found in the Northwest Atlantic, from northern Newfoundland to North Carolina. Their preferred habitat consists of sandy or gravel seabeds, ranging in depth from 10 to 384 m (DFO 2011c). Sea scallops can reach up to 20 cm in size and can live up to 21 years.

Sea scallops primarily spawn between late summer and fall (August to October), with a given population generally spawning over a period of two to four weeks (DFO 1993). Two spawning periods, in the spring and fall, have been reported for coastal Newfoundland (Naidu 1970 *in* DFO 1993). The fertilized eggs hatch into planktonic larvae, which metamorphose and settle to the sea bottom within one to two months (DFO 1993).

Sea scallops are suspension filter feeders and feed primarily on plankton (DFO 2011c). Larval scallop mortality is high prior to settling on the seabed, owing to predators, such as zooplankton and fish, and to currents transporting them away from favourable habitats. Adult sea scallops are primarily preyed upon by sea stars, crabs, lobster, and various groundfish (DFO 2011c).

The offshore sea scallop fishery takes place year-round within Canada's 200 nmi Exclusive Economic Zone (EEZ), with some exceptions to avoid interference with the lobster fishery, spawning cod, and yellowtail flounder (DFO 2011c). These bivalves are one of Canada's most important offshore commercial shellfish species, valuing $85 million in 2009.

Commercial fishery sea scallop catches during the May to November period, 2005–2010, were few and primarily concentrated in the central portion of the Study Area at locations with water depths <200 m.

Witch Flounder

Witch flounder range from the Hamilton Inlet Bank to North Carolina in the Northwest Atlantic (DFO 2011d). They preferentially inhabit gullies with clay, muddy sand, or pure mud bottoms, and usually move from shallower, soft mud bottoms in the summer to deeper gullies in the winter, with bottom temperatures ranging from -1 to +11ºC (DFO 2011d). A deepwater species, witch flounder is most abundant at depths of 185 to 400 m, although some have been caught at depths >1,500 m (DFO 2011d).

Witch flounder form dense prespawning concentrations between winter and spring, and spawning occurs in shallow water and on the slopes of the Grand Banks area, in late spring to late summer or early fall (DFO 2011d). Eggs and larvae of witch flounder are pelagic, while juveniles can be either pelagic or deepwater fishes.

Witch flounder have a very small mouth, and their diet consists mainly of polychaetes, small crustaceans and shellfish (DFO 2011d). Although a considerable portion of witch flounder catch occurs as bycatch of other fisheries, it has been a component of the Canadian Atlantic groundfisheries since the early 1940s (DFO 2011d).

There were few georeferenced commercial catch location data for witch flounder in the Study Area during the May to November period, 2005–2010. These were located in the central-western portion of the Study Area where water depths <500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most witch flounder were caught at mean water depths of 400 and 500 m during spring and fall surveys, respectively.

American Plaice

American plaice is a bottom-dwelling flatfish that resides on both sides of the Atlantic (DFO 2006d; COSEWIC 2009). American plaice that reside in the West 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. 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; they begin to settle to the seabed when they reach 18 to 34 mm in length and their body flattens (Fahay 1983).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate a concentration of American plaice catch locations in the western portion of the Study Area, in water depths ranging between 200 and 500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, the greatest proportion of American plaice were caught between the 200 and 500 m isobaths in the west- and south-central regions of the Study Area.

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 (<0 to 5°C) waters in coastal areas and in offshore waters overlying the continental shelf throughout the North Atlantic (COSEWIC 2003a). The species is found contiguously along the east coast of Canada from Baffin Island to Georges Bank. Outside Canadian waters in the Northwest Atlantic, cod can be found on the northeast and southeast tips of the Grand Banks and on Flemish Cap. 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 2003a). 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 2003a). 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 the Grand Banks. 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 2003a). 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 between 2008 and 2009 (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).

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate the majority of Atlantic cod catches occurred in the western portion of the Study Area where water depths <500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, the greatest proportion of Atlantic cod was caught between the 200 and 500 m isobaths in the central portion of the Study Area.

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.

4.2.4.2 Other Fishes Caught in the Commercial Fishery

Other species that have been caught during commercial fisheries being prosecuted within the Study Area during recent years include the following:

- Squid (*Illex* sp.)
- Wolffishes (*Anarhichas* spp.)
- Bluefin tuna (*Thunnus thynnus*);
- White and blue hakes (*Urophycis tenuis*; *Antimora rostrata*);
- Whelks; and
- Yellowtail flounder (*Limanda ferruginea*).

More fishery-related details for these species are included in Section 4.3 of this EA. These species are briefly profiled in this subsection, except for the spotted and northern wolffishes, which are profiled in Subsection 4.6 on Species at Risk. In terms of total catch weight, the greatest proportion of catches of all three wolffish species in the Study Area occurred between the 200 and 500 m isobaths of the northeastern Newfoundland slope in the central and south-central portions of the Study Area.

Squid

Two species of squid, the short-finned squid (*Illex illecebrosus*) and the long-finned squid (*Loligo pealiei*), inhabit the Northwest Atlantic. Of these, only the short-finned squid has been of major commercial importance to the Atlantic Canadian fishery (DFO 2011e). Squid were traditionally caught for bait around Newfoundland until the early 1970s, after which an international *Illex* fishery was developed.

Short-finned squid are a short lived species, believed to have life spans no greater than 12 to 18 months. Adults migrate southwest from feeding areas and are thought to spawn in the fall near Cape Hatteras or possibly further south over the Blake Plateau, although the precise spawning locations are unknown (DFO 2011e). Females create large (up to 1 m diameter), clear, almost neutrally-buoyant egg masses, each containing about 100000 eggs. Larvae hatch after approximately two weeks. Little is known of juvenile growth rates, but adults grow very rapidly, adding ~1.5 mm in mantle length per day (DFO 2011e). Both males and females die after spawning.

Short-finned squid are voracious predators and consume a variety of prey including crustacean and fish (DFO 2011e). Larger individuals are also given to cannibalism. These squid fall prey to numerous fish, marine mammals, and birds, including pilot whales, dolphins, shearwaters, fulmars, gannets, gulls, tunas, swordfish, haddock, cod, Pollock, and sharks (DFO 2011e).

The squid fishery takes advantage of the short-finned squid's diel lifestyle; they spend daylight hours near the sea bottom and disperse upward into the water column at night (DFO 2011e). The offshore squid fishery in Atlantic Canada is primarily carried out via traps or jigging from dories in shallower regions and by trawlers offshore (DFO 2011e). The Atlantic Canadian population has declined since a record high catch in 1979 (162,000 mt); it is a difficult species to manage on account of its short life span.

Georeferenced commercial catch location data for the May to November period, 2005–2010, indicate a few incidences of *Illex* squid in the central-western portion of the Study Area at water depths between 200 and 400 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the relatively few *Illex* squid caught were taken during the spring surveys at a mean depth of ~260 m; the mean catch depth during the fall surveys was 700 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 (<15%) of the spotted wolffish diet (e.g., redfish). Migration by Atlantic wolffish is 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 2006–2010, 2028 Atlantic wolffish were caught, during both spring and fall survey times. Atlantic wolffish catches were most concentrated in the southwestern-central portion of the Study Area where water depths were less than at the primary catch locations of northern wolffish.

Bluefin Tuna

Atlantic bluefin tuna is a very large species (≥400 kg) inhabiting both sides of the Atlantic, ranging from Newfoundland to the Caribbean and occasionally as far south as coastal Brazi (COSEWIC 2011). Bluefin tuna are seasonal migrants to Canadian waters and are fished from July through December in and around the Study Area. Bluefin tuna are able to regulate their body temperature, and as such are able to tolerate a wide thermal and depth range during their yearly migrations (COSEWIC 2011).

The western Atlantic population spawns during the spring in the Gulf of Mexico, and sometimes in the Bahamas and Straits of Florida (COSEWIC 2011). Bluefin tuna are repeat, broadcast spawners (i.e., eggs and sperm are released into the water), usually at night or early dawn for up to a week at a time. Fertilized eggs float to the surface for several days, after which free-swimming larvae remain planktonic for 10 days before descending into deeper waters (Richards et al. 1989; Rooker et al. 2007; Teo et al. 2007).

Atlantic bluefin tuna are highly active predators, consuming both pelagic and bottom fishes in Canadian waters (COSEWIC 2011). Adults have few predators, including humans, killer whales, and mako sharks, but natural mortality is presumed to be greater for smaller individuals vulnerable to other pelagic predators and seabirds (COSEWIC 2011).

Prized for their flesh and often sold either canned or for sushi, Atlantic bluefin tuna are managed by DFO and the International Commission for the Conservation of Atlantic Tunas (ICCAT). There was no georeferenced commercial catch location data for bluefin tuna in the Study Area during the May to November period, 2005–2010. The Atlantic bluefin tuna is currently designated as *endangered* under COSEWIC.

White and Blue Hakes

White hake inhabit the continental shelf and upper slope of the West Atlantic, ranging from southern Labrador (including the southern slope of the Grand Banks) to North Carolina and occasionally deep waters off Florida (DFO 2011f). This species prefers soft-bottomed areas, with water temperatures ranging from 5 to 11ºC (DFO 2011f). White hake move to shallower waters in warmer months and out into deeper areas during colder periods.

Mature female white hake are among the most fertile of the commercial demersal species in the Northwest Atlantic, producing millions of eggs when they spawn in summer to early fall (DFO 2011f). Eggs are buoyant, while larvae and juveniles are pelagic for up to three months.

Young, demersal juveniles feed primarily on shrimps, polychaetes, and small crustaceans, while older juveniles also consume krill and some fish (DFO 2011f). Adult white hake consume a variety of fish species, including Atlantic herring, Atlantic cod, haddock, longfin hake, redfish, Atlantic mackerel, northern sand lance, and winter flounder (DFO 2011f). White hake are preyed upon by larger cod and hake, Atlantic puffins, Arctic terns, and grey seals (DFO 2011f). White hake are targeted in Canadian fisheries, but are also caught as bycatch in other fisheries. They are caught using gillnets, hooks and lines, bottom trawls, and seines (DFO 2011f). There was no georeferenced commercial catch location data for white hake in the Study Area during the May to November period, 2005–2010. Most of the white hake caught during DFO RV surveys in the Study Area from 2005 to 2010 were captured at a mean depth of about 300 m in both spring and fall surveys.

Blue hake occur globally in all oceans. Although their preferred depth ranges are not known, they have been found at depths up to nearly 3,000 m (DFO 2011g). Relatively little is known about their life cycles, but blue hake is presumed to migrate into deeper waters to spawn (DFO 2011g). Blue hake is not particularly attractive as a commercial fish (DFO 2011g).

There were a few georeferenced commercial catches of blue hake in the northeastern portion of the Study Area during the May to November period, 2005–2010. The mean catch depth for this hake species was about 1,500 m. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the blue hake were caught during the fall at a mean water depth of 900 m. The mean catch depth during the spring surveys was 600 m.

Whelks

Whelks are marine snails that are distributed from Newfoundland and Labrador to New Jersey, including the Gulf of St. Lawrence (DFO 2010d). An abundant and relatively inactive species, whelks are typically found partially buried in muddy or sandy substrates at a variety of depths, from the intertidal zone to >200 m (DFO 2003, 2010d).

Whelks spawn between late spring or summer and late autumn, depending on location (DFO 2003). Fertilization occurs internally; females lay their eggs two to three weeks after copulation on irregular surfaces and kelp beds as protection from predators and the environment (DFO 2003). Whelks have no planktonic or pelagic stage.

Whelks feed on both live and dead animals, primarily molluscs and other invertebrates such as urchins, polychaetes, bivalves, and crustaceans (DFO 2003). Whelks are able to detect a scent trail and follow it to a particular source, which is why they are commonly found in lobster, crab, and cod traps. Feeding activity generally decreases with the onset of spawning (DFO 2003). Whelks are preyed upon by lobster, cod, crab, starfish, dogfish, wolffish, rays, and gulls, and their empty shells often serve as habitat for organisms such as hermit crabs (DFO 2003).

Whelks are harvested all year offshore, using various pot designs. This fishery is monitored by DFO; around Newfoundland, fishers are required to have licences and abide by size (minimal acceptable size of 5 cm in length) and pot number regulations (DFO 2003). There was no georeferenced commercial catch location data for whelk in the Study Area during the May to November period, 2005–2010. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the whelks caught during the survey were taken during the fall at a mean water depth of ~900 m. The mean catch depth for whelk during the spring surveys was ~350 m.

Yellowtail Flounder

Yellowtail flounder inhabit the continental shelf of the Northwest Atlantic from Labrador to Chesapeake Bay at depths ranging from 10 to 100 m. The northern limit of commercial concentrations reaches extend to the Grand Banks off the east coast of Newfoundland. Yellowtail spawning on the Grand Banks generally occurs between May and September with peaks during the latter part of June. They tends to occur at depths <100 m and in water temperatures exceeding 2ºC (LGL 2006b). The eggs, larvae and early juvenile stages of yellowtail are pelagic. Because of its small mouth size, this flounder is restricted in its choice of prey. The most common prey of yellowtail flounder includes polychaetes, amphipods, shrimp, cumaceans, isopods, and small fish (LGL 2006b).

Juvenile and adult yellowtail are generally concentrated on the southern Grand Banks, on or near the Southeast Shoal where the substrate consists primarily of sand (Unit Area 3Nc, primarily) (Walsh et al. 2001 *in* LGL 2006b). Walsh et al. (2006 *in* LGL 2006b) discussed the distribution and abundance of yellowtail flounder on the Grand Banks based on spring and fall trawl surveys. They indicated the greatest concentrations of yellowtail flounder southwest of the Project Area near Southeast Shoal.

There was no georeferenced commercial catch location data for yellowtail flounder in the Study Area during the May to November period, 2005–2010. Based on DFO RV survey data collected in the Study Area from 2005 to 2010, most of the yellowtail flounder catch weight was taken at mean water depths of ~70 m during both spring and fall surveys.

4.2.4.3 Macroinvertebrates and Fishes Collected during DFO RV Surveys

Data collected during 2005 to 2010 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.

Deepwater redfish accounted for 30.1% of the total 2005–2010 catch weight, followed by northern shrimp (9.9%), shrimp (Natantia) (9.1%), sand lance (6.3%), thorny skate (4.5%), capelin (4.2%), sponges (4.0%), roughhead grenadier (3.8%), Greenland shark (3.4%), American plaice (3.4%), Greenland halibut (3.3%), sea anemones (1.6%), blue hake (1.3%), and yellowtail flounder (1.1%). All remaining species/groups in Table 4.1 represent ≤1% of the RV survey total catch weight. The distribution of georeferenced catch locations reported during the 2005 to 2010 DFO RV surveys within the Study Area are shown in Figure 4.1.

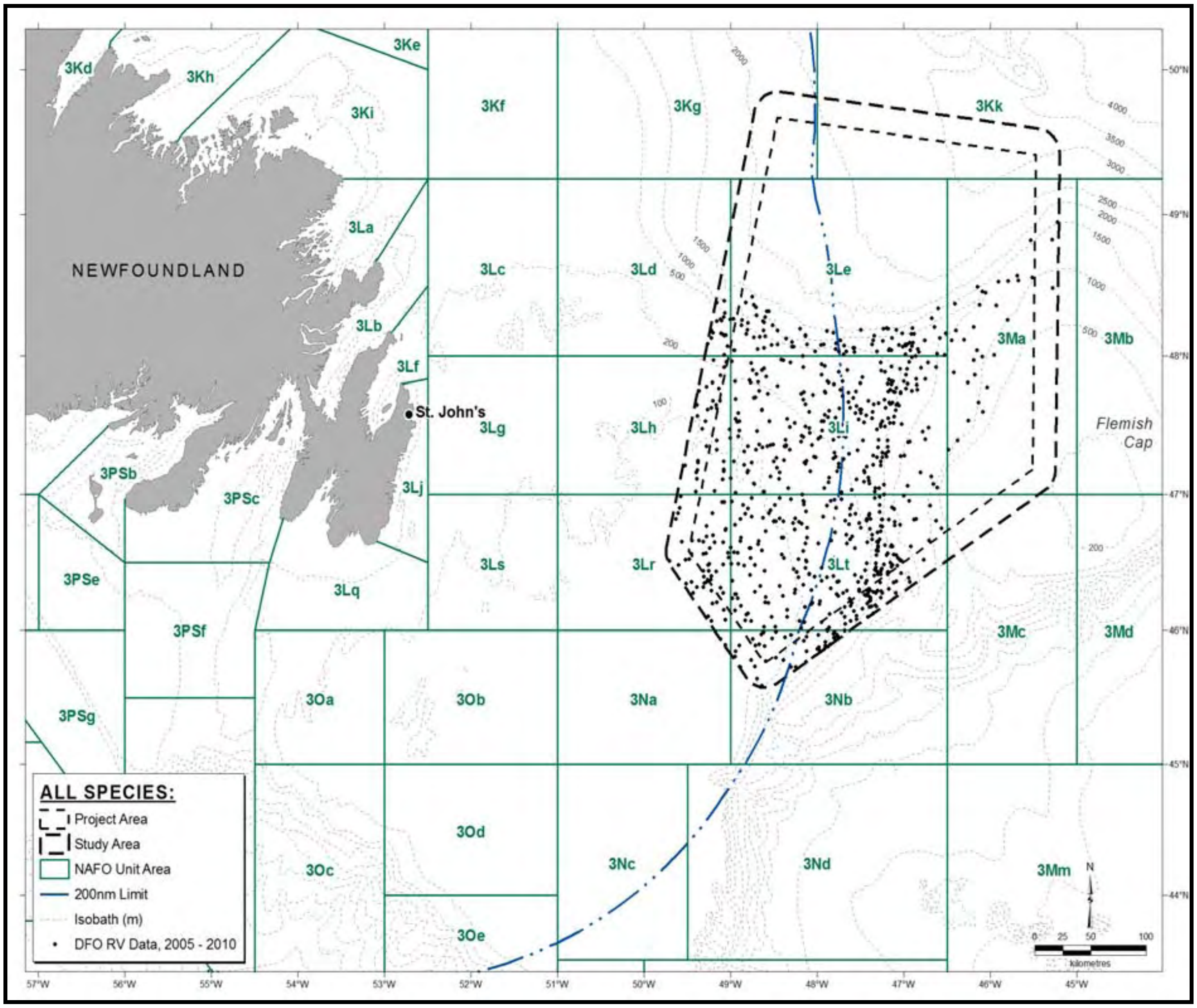
Across all species caught during the 2005 to 2010 DFO RV surveys in the Study Area, total catch weights were greatest in 2007 (47464 kg) and 2010 (32844 kg), and lowest in 2005 (17177 kg). Catches were consistent between years for species type, with an average contribution to yearly total catch weight of 69.0, 30.9, and 0.1% for fish, invertebrates, and corals, respectively. An exception occurred in 2010, when fish recorded in the Study Area accounted for 84.2% of the total catch weight and invertebrates only 15.7%. This exception was driven by catches of deepwater redfish, which accounted for 50.5% of the total catch weight in 2010.

The total catch weight of the 2005 to 2010 DFO RV surveys in the Study Area is divided into spring (May, June, July) and fall (October, November, December). Spring surveys accounted for 43.6% of the total catch weight, and fall surveys accounted for 56.4%. The average mean depths of catch during spring and fall surveys from 2005 to 2010 were 268 m (minimum = 12 m; maximum = 720 m) and 480 m (minimum = 56 m; maximum = 1,436 m), respectively.

Table 4.1 Catch Weights and Numbers of Macroinvertebrate and Fish Species Collected during 2005 to 2010 DFO RV Surveys within the Study Area.

Species	Catch Weight (kg)	Catch Number
Deepwater redfish (*Sebastes mentella*)	52,742	253,410
Northern shrimp	17,290	3,234,975
Shrimp (Natantia)	15,891	n/a
Sand lance (*Ammodytes dubius*)	11,081	867,328
Thorny skate (*Raja radiata*)	7,887	4,601
Capelin (*Mallotus villosus*)	7,273	462,922
Sponges	7,061	n/a
Roughhead grenadier (*Macrourus berglax*)	6,734	14,925
Greenland shark (*Somniosus microcephalus*)	6,000	3
American plaice (*Hippoglossoides platessoides*)	5,949	26,333
Greenland halibut (*Reinhardtius hippoglossoides*)	5,689	12,233
Sea anemones	2,823	3,592
Blue hake (*Antimora rostrata*)	2,236	13,141
Yellowtail flounder (*Limanda ferruginea*)	1,902	5,717
Snow crab (*Chionoecetes opilio*)	1,727	9,322
Atlantic cod (*Gadus morhua*)	1,695	2,989
Longnose eel (*Synaphobranchus kaupi*)	1,452	12,138
Brittle star (Ophiuroidea)	1,329	525
Unspecified invertebrates	1,293	n/a
Jellyfishes (Scyphozoa)	1,215	n/a
Roundnose grenadier (*Coryphaenoides rupestris*)	1,159	8,736
Black dogfish (*Centroscyllium fabricii*)	1,017	826
Atlantic wolffish (*Anarhichas lupus*)	978	2,028
Marlin spike (*Nezumia bairdi*)	867	10,623
Spotted wolffish (*Anarhichas minor*)	796	269
Sea urchins (Echinoidea)	703	36,797
Vahl's eelpout (*Lycodes vahlii*)	703	7,818
Mailed sculpins (*Triglops* sp.)	687	58,118
Northern wolffish (*Anarhichas denticulatus*)	685	235
Witch flounder (*Glyptocephalus cynoglossus*)	501	1,558
Arctic eelpout (*Lycodes reticulatus*)	393	1,630
Lanternfishes (*Myctophidae*)	389	68,113
Comb jellies (Ctenophora)	317	n/a
Spinytail skate (*Raja* [*Bathyraja*] *spinicauda*)	288	41
Large scale tapirfish (*Notacanthus nasus*)	285	477
Longfin hake (*Urophycis chesteri*)	269	2,254
Shrimp (*Sergestes arcticus*)	244	228,746
Sand dollar (*Echinarachinus parma*)	210	7,635
Threebeard rockling (*Gaidropsarus* sp.)	200	841
Corals	198	n/a
Moustache sculpin (*Triglops murrayi*)	198	15,893
Eelpouts	176	2,998
Basket star	162	57
Eelpouts (*Lycodes* sp.)	147	1,400
Sea star (*Leptasterias polaris*)	132	1,104
Toad crab (*Hyas* sp.)	119	7,982
Atlantic halibut (*Hippoglossus hippoglossus*)	116	7
Sea star (Asteroidea)	108	848
Snake blenny (*Lumpenus lumpretaeformis*)	100	3,554

Source: DFO RV Survey Data 2005-2010. n/a denotes data unavailable.



Source: DFO RV Survey Data, 2005-2010.

Figure 4.1 DFO RV Survey Catch Locations within the Study Area, 2005 to 2010 Combined.

The top five species/groups in terms of catch weight during the spring surveys were deepwater redfish, shrimp (Natantia), capelin, sand lance, and thorny skate. The top five species/groups in terms of catch weight during the fall surveys were deepwater redfish, shrimp (Natantia), sand lance, sponges, and Greenland shark.

Species/groups that were caught predominantly during the spring surveys included shrimp (*Sergestes arcticus*), capelin, sand dollar, snake blenny, and Atlantic halibut. Species/groups that were caught predominantly during the fall surveys included basket star, eelpouts (*Lycodes* sp.), moustache sculpin, sponges, brittle star, roundnose grenadier, blue hake, black dogfish, longnose eel, threebeard rockling, large scale tapirfish, Greenland shark, comb jellies, jellyfishes, lanternfishes, eelpouts, marlin spike, and Atlantic cod. The survey depth differences between spring and fall surveys likely account for some of the seasonal differences (Table 4.2).

DFO RV survey catch weights in the Study Area from 2005 to 2010 were analyzed for 11 mean catch depth ranges; results are presented in Table 4.3.

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, 2005 to 2010 Combined.

Species	% Catch in Spring Surveys	Spring Survey Mean Catch Depth (m)	% Catch in Fall Surveys	Fall Survey Mean Catch Depth (m)
Deepwater redfish (*Sebastes mentella*)	52	380	48	452
Northern shrimp	50	201	50	199
Shrimp (Natantia)	51	255	49	607
Sand lance (*Ammodytes dubius*)	38	120	62	100
Thorny skate (*Raja radiata*)	46	298	54	279
Capelin (*Mallotus villosus*)	93	164	7	213
Sponges	3	359	97	561
Roughhead grenadier (*Macrourus berglax*)	31	439	69	729
Greenland shark (*Somniosus microcephalus*)	17	458	83	500
American plaice (*Hippoglossoides platessoides*)	39	199	61	267
Greenland halibut (*Reinhardtius hippoglossoides*)	44	375	56	561
Sea anemones	33	348	67	462
Blue hake (*Antimora rostrata*)	4	606	96	926
Yellowtail flounder (*Limanda ferruginea*)	50	71	50	67
Snow crab (*Chionoecetes opilio*)	32	175	68	188
Atlantic cod (*Gadus morhua*)	28	235	72	219
Longnose eel (*Synaphobranchus kaupi*)	6	574	94	889
Brittle star (Ophiuroidea)	3	191	97	331
Unspecified invertebrates	42	262	58	406
Jellyfishes (Scyphozoa)	19	505	81	824
Roundnose grenadier (*Coryphaenoides rupestris*)	3	640	97	971
Black dogfish (*Centroscyllium fabricii*)	5	656	95	1,042
Atlantic wolffish (*Anarhichas lupus*)	55	265	45	257
Marlin spike (*Nezumia bairdi*)	24	491	76	743
Spotted wolffish (*Anarhichas minor*)	47	292	53	275
Sea urchins (Echinoidea)	36	124	64	460
Vahl's eelpout (*Lycodes vahlii*)	32	403	68	375
Mailed sculpins (*Triglops* sp.)	36	156	64	164
Northern wolffish (*Anarhichas denticulatus*)	39	475	61	667
Witch flounder (*Glyptocephalus cynoglossus*)	35	407	65	488
Arctic eelpout (*Lycodes reticulatus*)	42	190	58	179
Lanternfishes (*Myctophidae*)	19	511	81	802
Comb jellies (Ctenophora)	18	73	82	65
Spinytail skate (*Raja* [*Bathyraja*] *spinicauda*)	55	555	45	841
Large scale tapirfish (*Notacanthus nasus*)	10	609	90	901
Longfin hake (*Urophycis chesteri*)	40	445	60	624
Shrimp (*Sergestes arcticus*)	98	545	2	869
Sand dollar (*Echinarachinus parma*)	88	150	12	208
Threebeard rockling (*Gaidropsarus* sp.)	8	492	92	818
Corals	41	305	59	651
Moustache sculpin (*Triglops murrayi*)	2	153	98	155
Eelpouts	23	296	77	551
Basket star	<1	243	>99	363
Eelpouts (*Lycodes* sp.)	<1	252	>99	481
Sea star (*Leptasterias polaris*)	34	80	66	106
Toad crab (*Hyas* sp.)	59	126	41	130
Atlantic halibut (*Hippoglossus hippoglossus*)	70	440	30	351
Sea star (Asteroidea)	36	309	64	639
Snake blenny (*Lumpenus lumpretaeformis*)	75	275	25	267

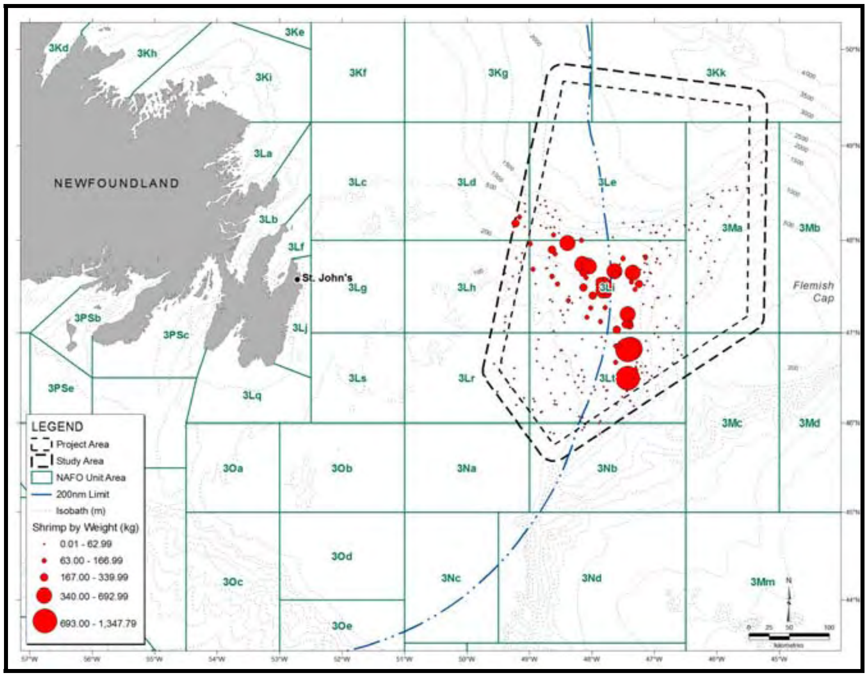
Source: DFO RV Survey Data 2005-2010.

Table 4.3 Total Catch Weights and Predominant Species Caught at various Mean Catch Depth Ranges, 2005 to 2010 DFO RV Surveys Combined.

Mean Catch Depth Range	Total Catch Weight (kg)	Predominant Species
<100 m	15,001	Sand lance (52%) Yellowtail flounder (13%) Capelin (10%) American plaice (6%)
≥100 m to <200 m	20,870	Northern shrimp (19%) Shrimp (Natantia; 18%) Sand lance (15%) Capelin (9%) American plaice (7%) Brittle star (6%) Thorny skate (5%) Snow crab (5%)
≥200 m to <300 m	45,193	Deepwater redfish (27%) Northern shrimp (25%) Shrimp (Natantia; 22%) Capelin (7%) Thorny skate 5(%)
≥300 m to <400 m	43,512	Deepwater redfish (68%) Thorny skate (7%) Shrimp (Natantia; 4%)
≥400 m to <500 m	13,849	Deepwater redfish (49%) Sea anemones (11%) Thorny skate (7%) Greenland shark (7%)
≥500 m to <600 m	3,472	Deepwater redfish (46%) Sand lance (8%) American plaice (6%) Greenland halibut (5%) Sponges (3%)
≥600 m to <700 m	13,219	Greenland shark (30%) Deepwater redfish (21%) Roughhead grenadier (12%) American plaice (6%) Greenland halibut (6%) Sea anemones (4%)
≥700 m to <800 m	1,714	Greenland halibut (26%) Roughhead grenadier (24%) Blue hake (8%) Black dogfish (6%) Marlin spike (4%) Deepwater redfish (4%)
≥800 m to <900 m	4,233	Sponges (53%) Roughhead grenadier (13%) Blue hake (6%) Greenland halibut (5%)
≥900 m to < 1,000 m	1,742	Roughhead grenadier (22%) Black dogfish (16%) Blue hake (13%) Greenland halibut (11%) Longnose eel (9%)
≥1,000 m	12,300	Sponges (33%) Roughhead grenadier (12%) Blue hake (11%) Greenland halibut (8%) Roundnose grenadier (7%) Longnose eel (7%)

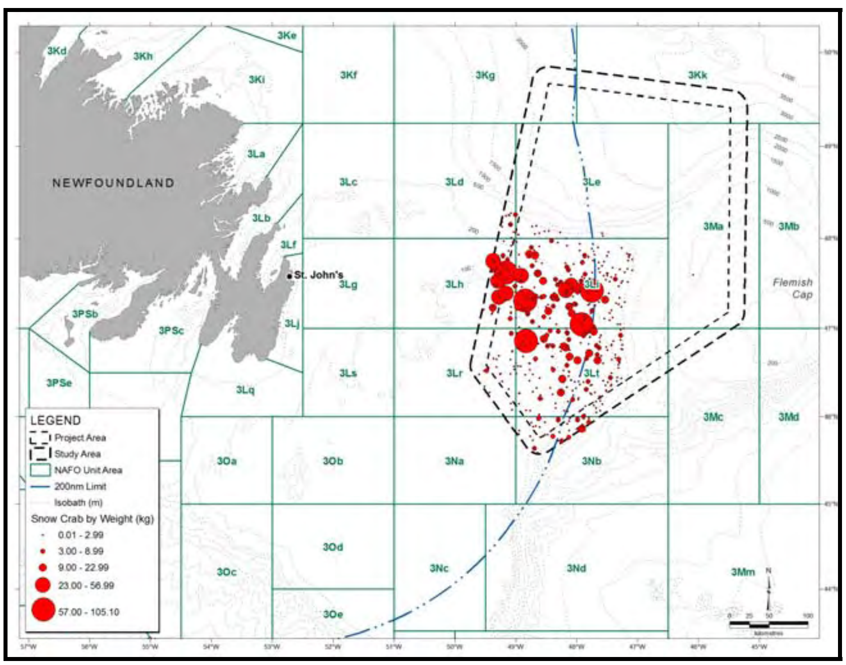
Source: DFO RV Survey Data 2005-2010.

The locations of proportional catches of notable macroinvertebrates and fishes during the DFO RV survey, 2005–2010 combined, are indicated in Figures 4.2 to 4.9.



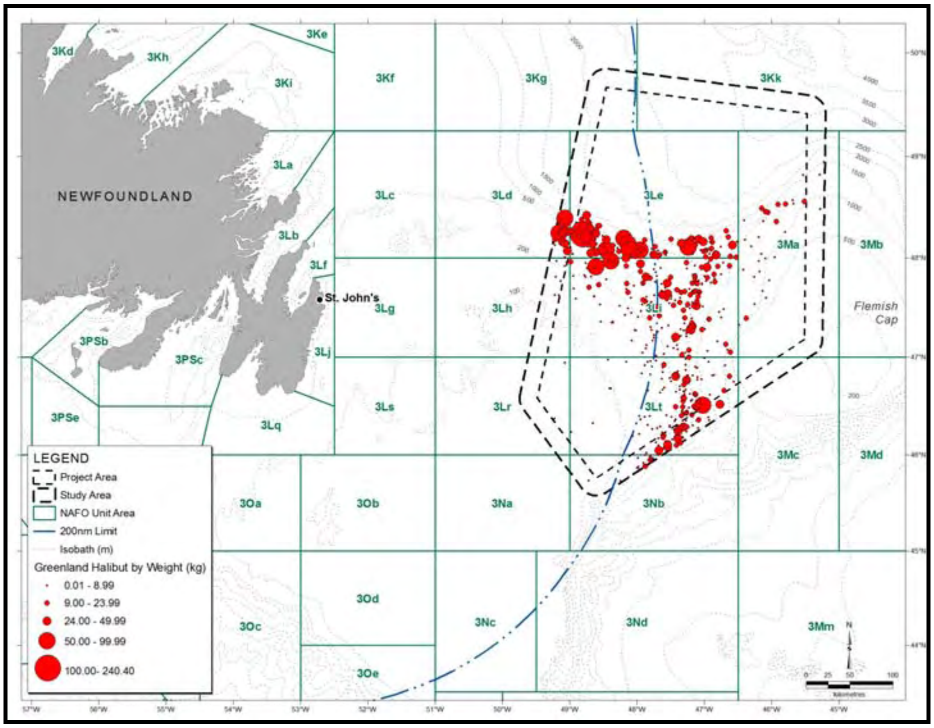
Source: DFO RV Survey Data, 2005-2010.

Figure 4.2 DFO RV Survey Proportional Northern Shrimp Catch Locations within the Study Area, 2005 to 2010 Combined.



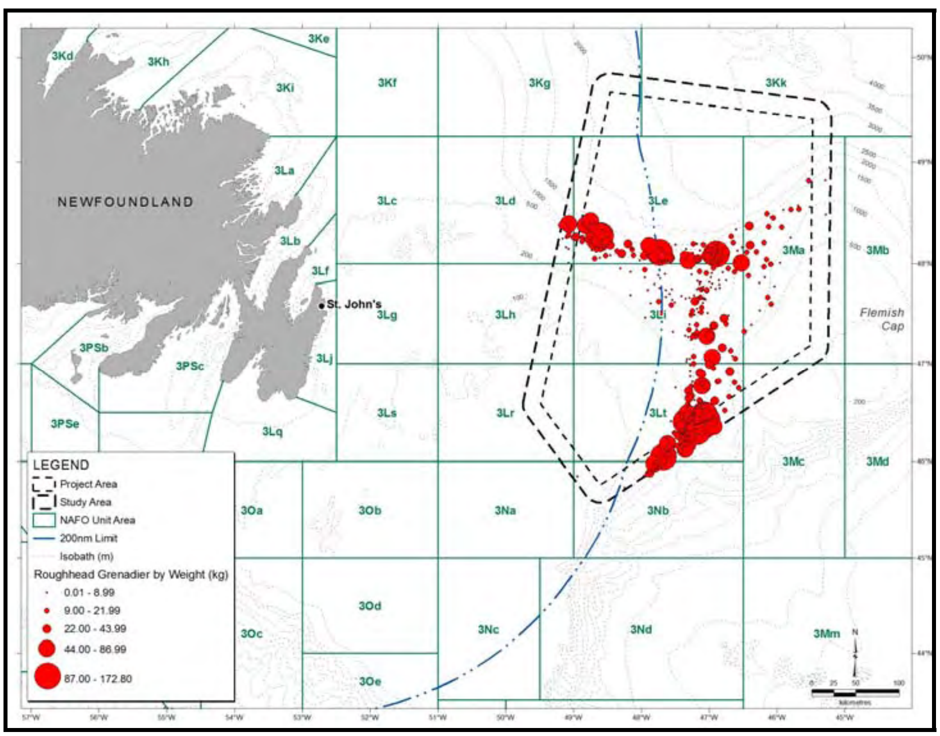
Source: DFO RV Survey Data, 2005-2010.

Figure 4.3 DFO RV Survey Proportional Snow Crab Catch Locations within the Study Area, 2005 to 2010 Combined.



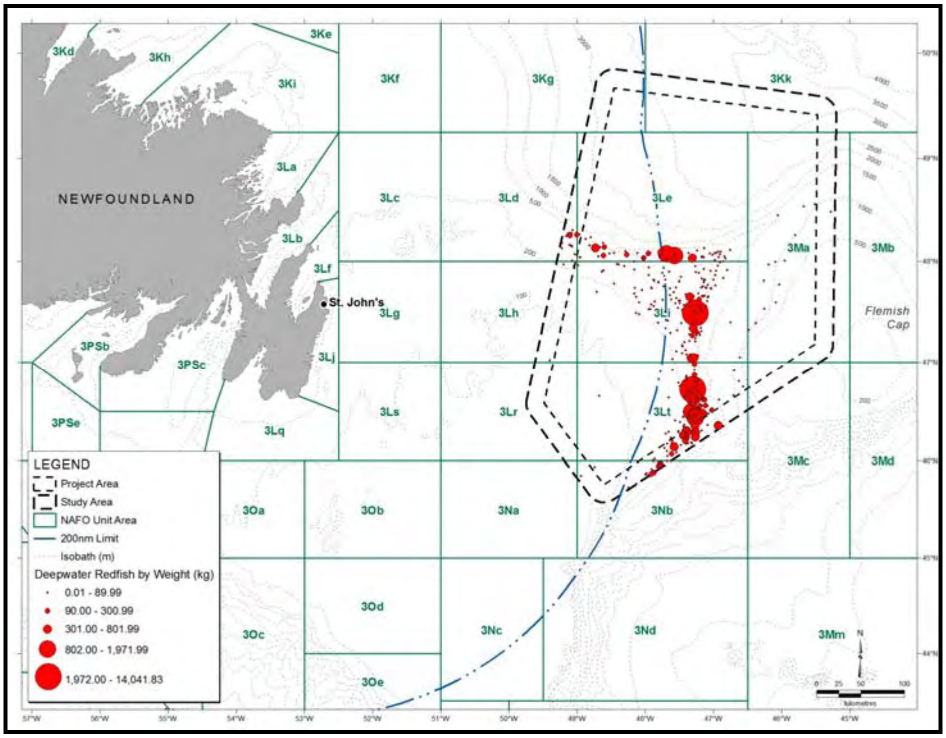
Source: DFO RV Survey Data, 2005-2010.

Figure 4.4 DFO RV Survey Proportional Greenland Halibut Catch Locations within the Study Area, 2005 to 2010 Combined.



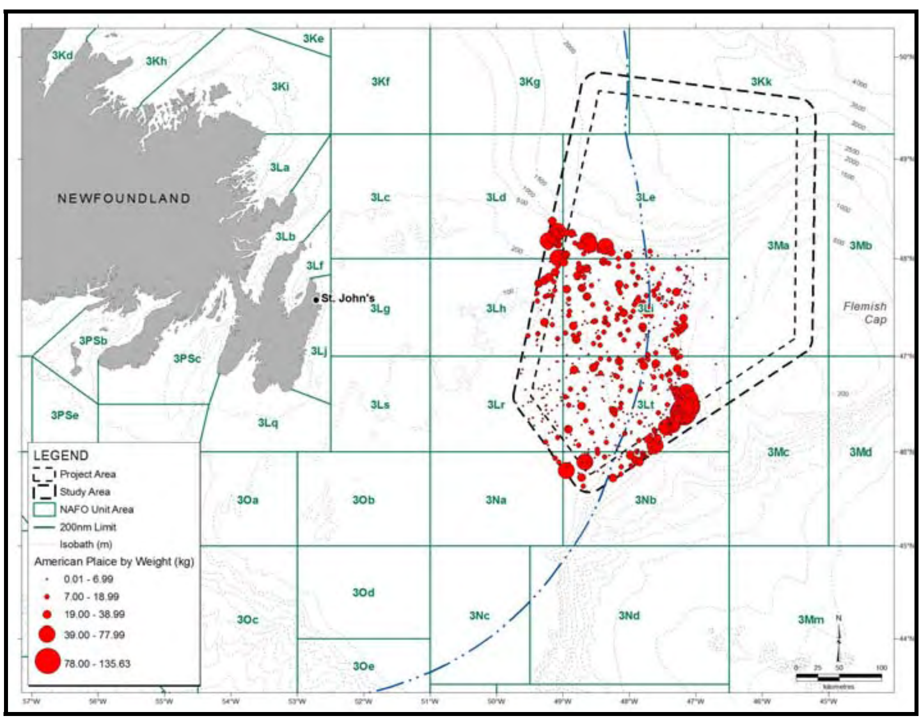
Source: DFO RV Survey Data, 2005-2010.

Figure 4.5 DFO RV Survey Proportional Roughhead Grenadier Catch Locations within the Study Area, 2005 to 2010 Combined.



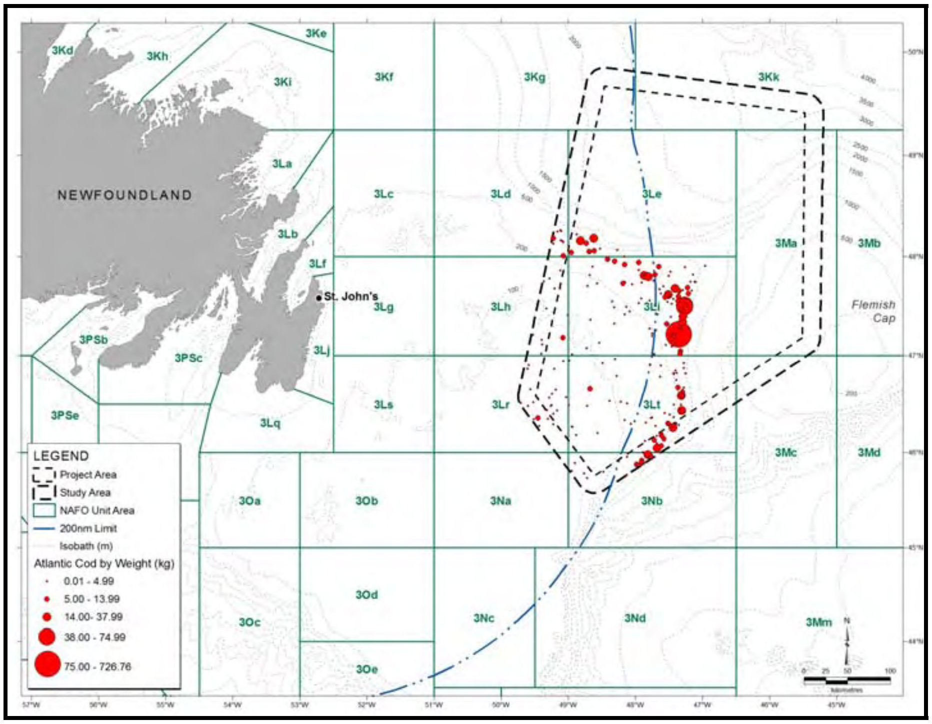
Source: DFO RV Survey Data, 2005-2010.

Figure 4.6 DFO RV Survey Proportional Deepwater Redfish Catch Locations within the Study Area, 2005 to 2010 Combined.



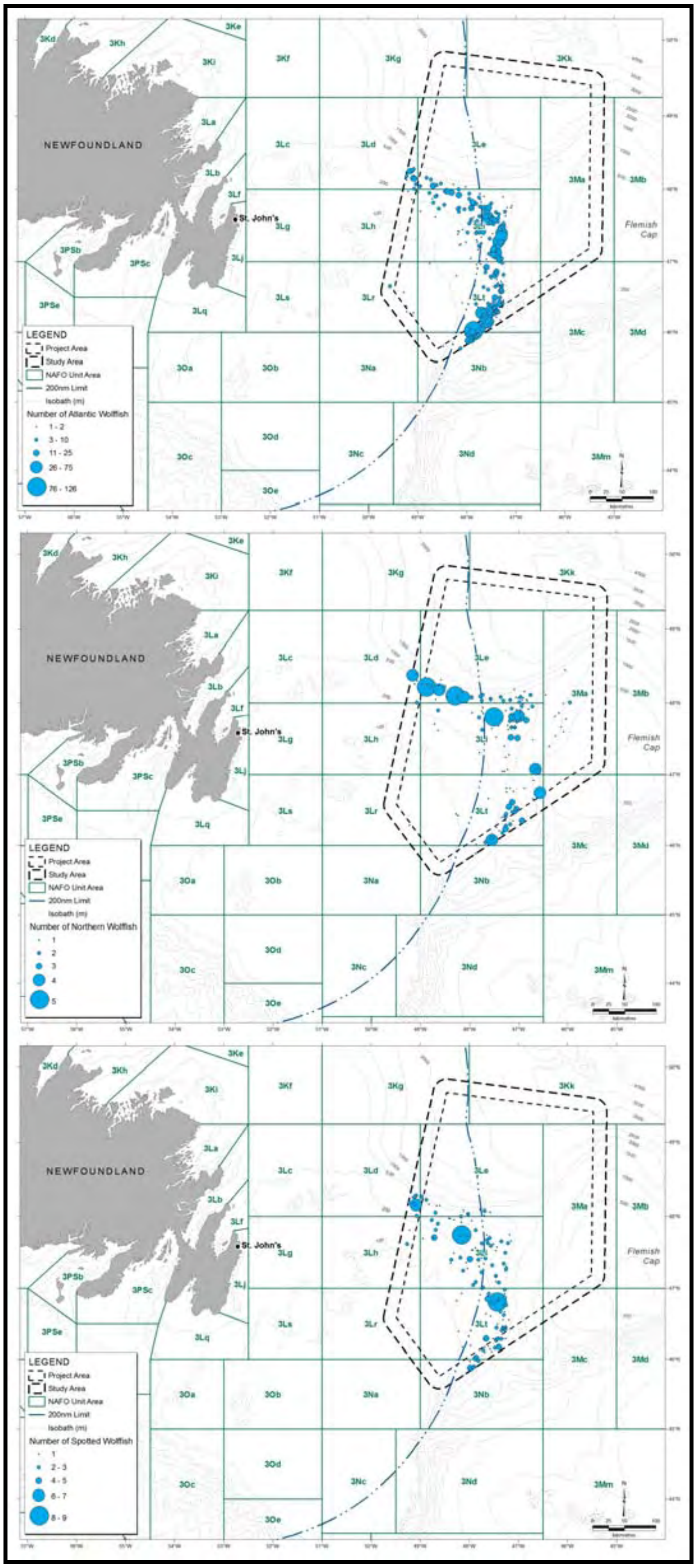
Source: DFO RV Survey Data, 2005-2010.

Figure 4.7 DFO RV Survey Proportional American Plaice Catch Locations within the Study Area, 2005 to 2010 Combined.



Source: DFO RV Survey Data, 2005-2010.

Figure 4.8 DFO RV Survey Proportional Atlantic Cod Catch Locations within the Study Area, 2005 to 2010 Combined.



Source: DFO RV Survey Data, 2005-2010.

Figure 4.9 DFO RV Survey Proportional Wolffish Catch Locations within the Study Area, 2005 to 2010 Combined.

4.2.4.4 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
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
Stimpson's surf clam	Eastern Grand Banks	Fall	4 to 8 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	Spring/summer or winter months	Uncertain
Greenland cockle	Eastern Grand Banks	Uncertain	Uncertain
Yellowtail flounder	Shallower sandy areas – typically <100 m water depth – at bottom	May to September, typically peaking in June/July Both eggs and larvae are planktonic.	Pelagic larvae are brief residents in the plankton
Witch flounder	Throughout the Grand Banks, particularly along slopes >500 m	Late spring to late summer/early fall	Uncertain
Thorny skate	Throughout distribution range	Year-round Eggs deposited in capsule (one egg per capsule), possibly on bottom	None
Roundnose grenadier	Uncertain	Year-round Eggs are free-floating	Uncertain
Roughhead grenadier	Likely along southern and southeastern slopes of Grand Banks	Winter/early spring	Uncertain
Capelin	Spawning generally on beaches or in deeper waters	Late June to early July	Several weeks
Atlantic halibut	Uncertain	Likely spawns between January and May. Both eggs and larvae are planktonic	6 to 8 weeks
American plaice	Spawning generally occurs throughout the range the population inhabits.	April to May	12 to 16 weeks

Species	Locations of Reproductive Events	Times of Reproductive Events	Duration of Planktonic Stages
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
Atlantic cod	Spawn along outer slopes of the shelf in depths from tens to hundreds of metres	March to June	10 to 12 weeks
Wolffishes	Along bottom in deeper water, typically along continental slope	Summer to early winter (species dependent)	Uncertain
Cusk	Uncertain	May to August Eggs are buoyant	Presumed to be 4 to 16 weeks
Porbeagle shark	Very little known about the location of the pupping grounds; likely southern Grand Banks	Mating in late summer/fall and pupping between early April and early June	Uncertain
Sand lance	On sand in shallow water of the Grand Banks	November to January	Several weeks

4.3 Commercial Fisheries

This subsection describes the existing fisheries (i.e., both commercial and research survey fisheries) in the Study Area for WesternGeco's proposed seismic program and provides additional context for the area's foreign commercial fisheries. It also describes economic and logistical aspects of the fisheries.

4.3.1 Information Sources

The majority of the information used to characterize the fisheries in this subsection are landed quantities (i.e., catch weight) rather than landed values since quantities are directly comparable from year to year but values may vary annually due to variable negotiated prices, changes in exchange rates, and fluctuating market conditions.

4.3.1.1 Data Sets

Commercial fisheries within the Study Area are managed by either DFO or NAFO. The domestic commercial fisheries analyses in this subsection are based on DFO Newfoundland and Labrador Region catch and effort data. NAFO catch weight data are used to describe both domestic and foreign fisheries beyond the 200 nmi EEZ. The NAFO data are derived from the STATLANT 21A data set for 2005 to 2010. The STATLANT reporting system of questionnaires is a long-standing standardized statistical inquiry for submission of national catch data to international fisheries agencies by national reporting offices. These data are not georeferenced but rather are resolved geographically at the NAFO Division level. Thus the following analysis quantifies harvesting for NAFO Divisions 3K, 3L, 3M, and 3N (see Figure 4.10)[2] for NAFO managed stocks/species in these areas. Note that the STATLANT and DFO data sets are not mutually exclusive for Canadian catches.

[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.

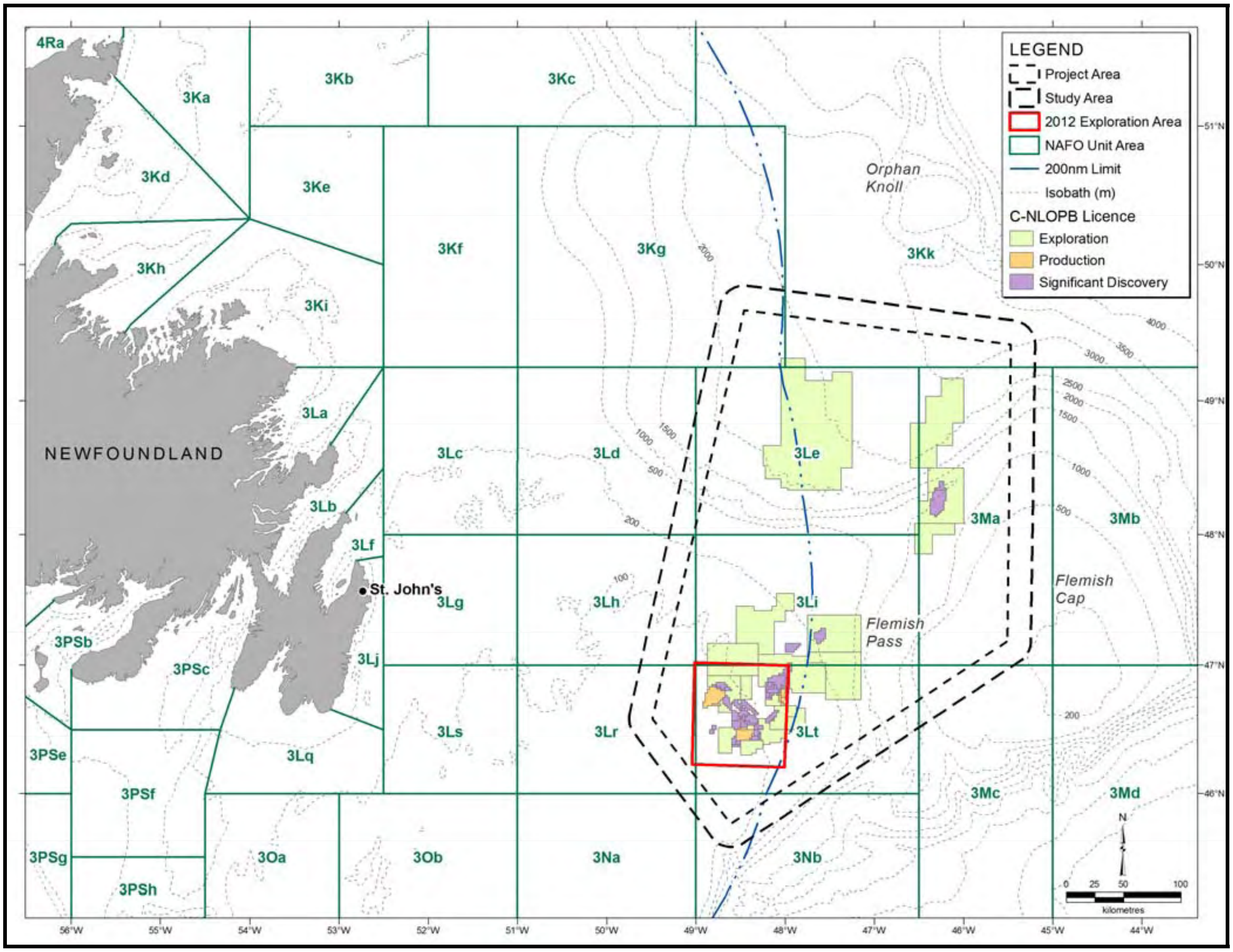


Figure 4.10 Study Area Location Relative to NAFO Unit Areas.

The DFO data used in the report (DFO 2005 to 2010) represent all catch landed within the Newfoundland and Labrador region (whether managed by NAFO or DFO, as described above).[3] The DFO catch data within 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 subsection. 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 ~0.5 nmi 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. In addition, to provide a historical summary of catches in the general area of the proposed Study Area, DFO data for Unit Areas NAFO 3Kgk, 3Ldehirt, 3Mac, and 3Nab are used (the Study Area UAs) for 1990 to 2010.

[3] Some of the later data years are considered "preliminary", with the greatest potential for change being in value.

4.3.1.2 Consultations

Consultations for WesternGeco's proposed 2012–2015 geophysical program were undertaken with the following agencies, stakeholders and interest groups:

- Fisheries and Oceans Canada (DFO);
- Environment Canada (EC);
- Nature Newfoundland and Labrador (NNL) (and various member organizations);
- One Ocean;
- Fish, Food and Allied Workers Union (FFAW) and fleet representatives;
- Association of Seafood Producers (ASP);
- Ocean Choice International (OCI);
- Groundfish Enterprise Allocation Council (GEAC, Ottawa);
- Clearwater Seafoods;
- Icewater Fisheries; and
- Newfound Resources Ltd./Fame Fisheries.

The consultations were undertaken to inform stakeholders about the proposed WesternGeco seismic program, 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 are discussed in Section 5.1.1.

4.3.1.3 Other Sources

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

4.3.2 Regional NAFO Fisheries

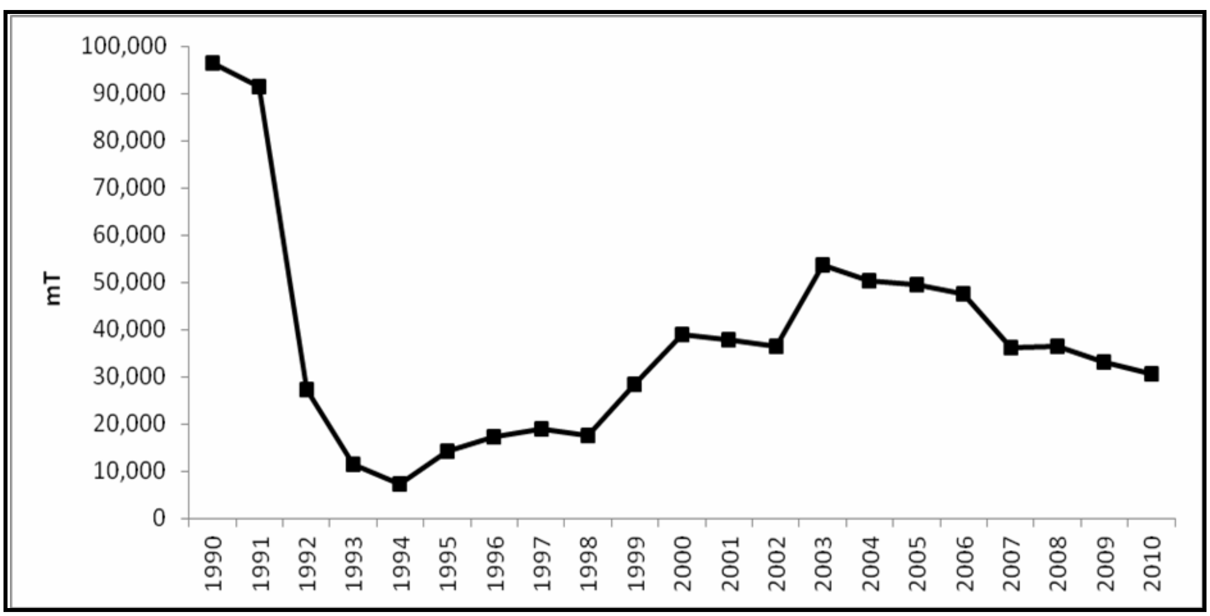
More than half of the Study Area occurs outside of Canada's 200 nmi EEZ, overlapping portions of NAFO Divisions 3K, 3L, 3M, and 3N (see Figure 4.10). NAFO manages 19 stocks comprised of 11 species: Atlantic cod (3L, 3M, 3NO stocks), redfish (3LN, 3M, 3O, Sub-area 2 and Div. 1F+3K stocks), American plaice (3LNO, 3M stocks), witch flounder (3L, 3NO stocks), yellowtail flounder (3LNO stock), Greenland halibut (3LMNO stock), white hake (3NO stock), skates (3LNO stock), capelin (3NO stock), squid (Subareas 3+4 stock), and shrimp (3L and 3NO stocks). Of the 19 stocks managed by NAFO, 16 straddle the EEZ; only the 3M cod, redfish, and American plaice stocks occur entirely outside of the EEZ. Most fishing for relevant species in the NAFO Convention Regulatory Area is conducted using mobile bottom-tending trawls.

During the 2005–2010 period, commercial harvest beyond the 200 nmi EEZ, in terms of catch weight, was dominated by northern shrimp (~31% of total catch weight) (primarily in NAFO Division 3K), snow crab (~19%) (primarily in NAFO Divisions 3K and 3L), capelin (~16%) (primarily in NAFO Divisions 3K and 3L), and Atlantic mackerel (~11%) (primarily in NAFO Division 3K). Greenland halibut catches accounted for <3% of the 2005–2010 commercial fishery catch weight outside of the EEZ. The highest catch weights during the six-year period were taken in NAFO Divisions 3K (~46%) and 3L (~39%), followed by 3N and 3M. Canadian vessels accounted for >94% of the commercial catch weight reported for this area during 2005–2010. Only in Division 3M did the foreign vessels dominate catches (>99% of total catch weight in this Division). Catches in 3M were dominated by northern shrimp, redfish, great blue shark, swordfish, Greenland halibut, unspecified shark species, Atlantic cod, and roundnose grenadier.

4.3.3 Domestic Fisheries

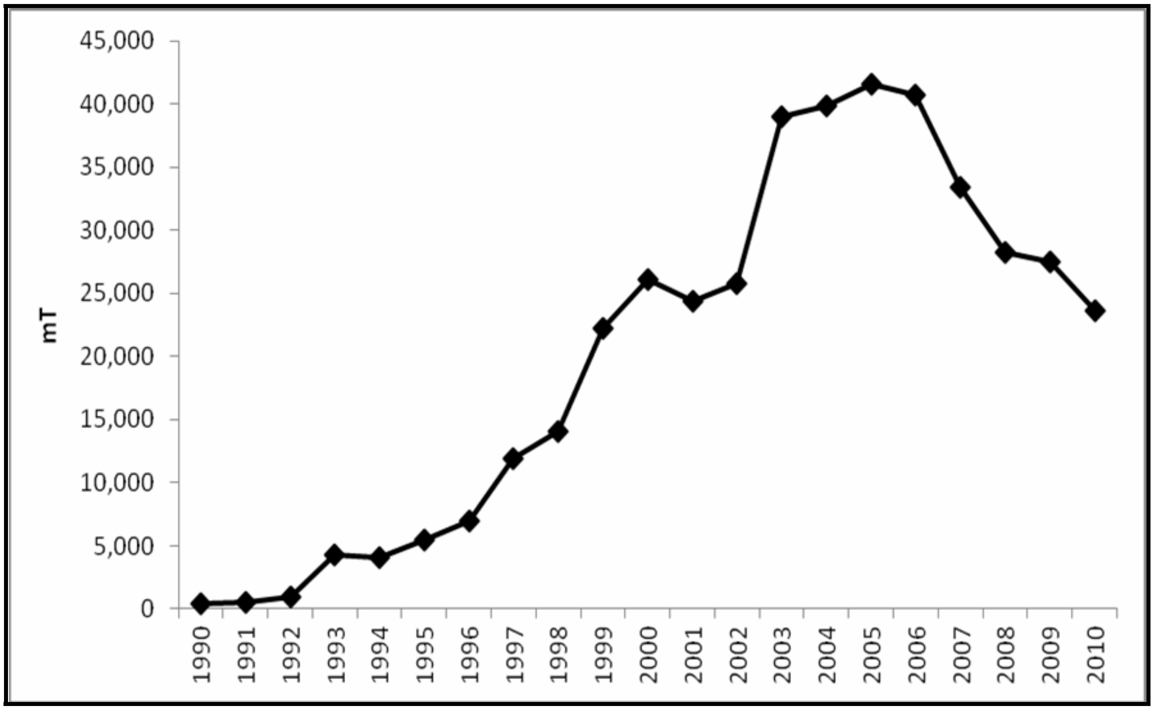
4.3.3.1 1990 to 2010 Catch Trends

Until the early 1990s, the Canadian fisheries in the northern Grand Banks area were dominated by groundfish harvesting using stern otter trawls which primarily targeted Atlantic cod, American plaice, and a few other groundfish 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, specifically snow crab and northern shrimp, have come to replace groundfish as the principal target species on the northern Grand Banks, as they have in many other areas. Based on georeferenced DFO landings data, Figures 4.11 to 4.13 summarize catch weight data for the 12 NAFO Unit Areas (UAs) with which the Study Area overlaps (Study Area UAs) during the 1990–2010 period. Presented are total annual harvest (Figure 4.11), combined snow crab and shrimp harvest (Figure 4.12), and total groundfish harvest (Figure 4.13). Snow crab harvesting with fixed gear tends to be concentrated in areas along the shelf break and slope. Northern shrimp harvesting with mobile gear tends to extend into deeper water in the Study Area, along the northeastern slope of Jeanne d'Arc Basin. Since the two gear types have a potential to conflict with each other, crab and shrimp harvesting do not typically overlap in time or location.



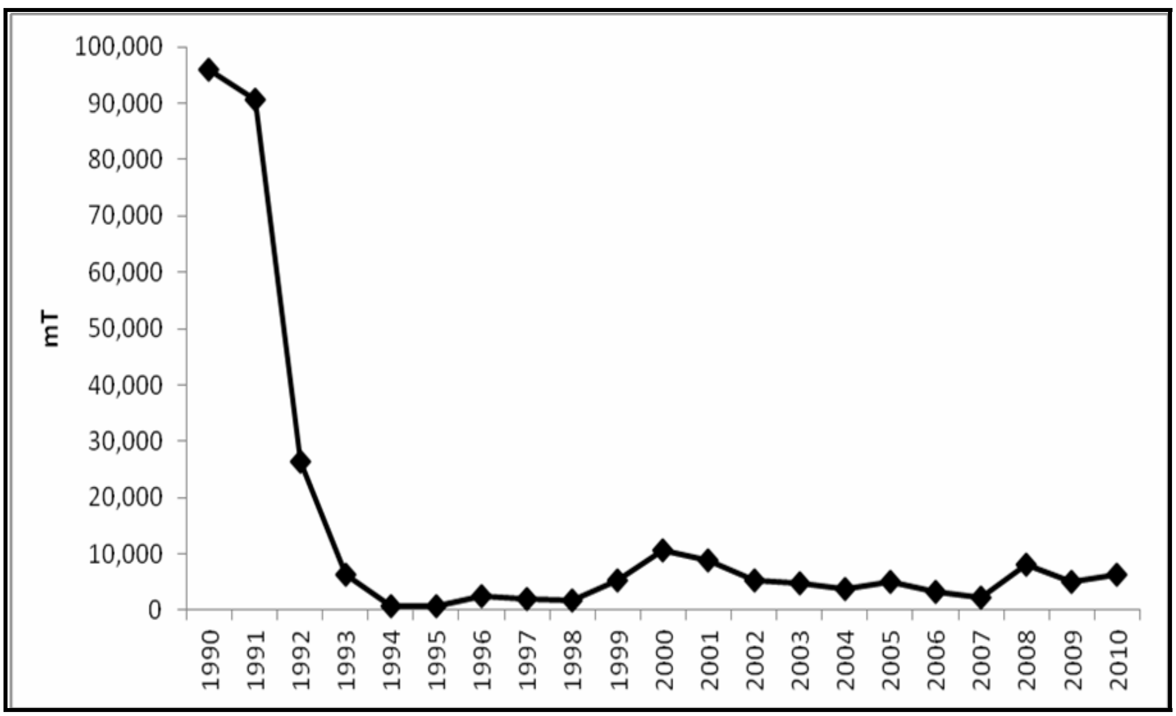
Source: DFO Newfoundland Commercial Fishery Landings Database, 1990-2010.

Figure 4.11 Annual Catch Weight within Study Area UAs, 1990-2010, All Species Combined.



Source: DFO Newfoundland Commercial Fishery Landings Database, 1990-2010.

Figure 4.12 Annual Catch Weight within Study Area UAs, 1990-2010, Shrimp and Snow Crab.



Source: DFO Newfoundland Commercial Fishery Landings Database, 1990-2010.

Figure 4.13 Annual Catch Weight within Study Area UAs, 1990-2010, Groundfish.

4.3.3.2 2005 to 2010 Study Area Catch Analysis

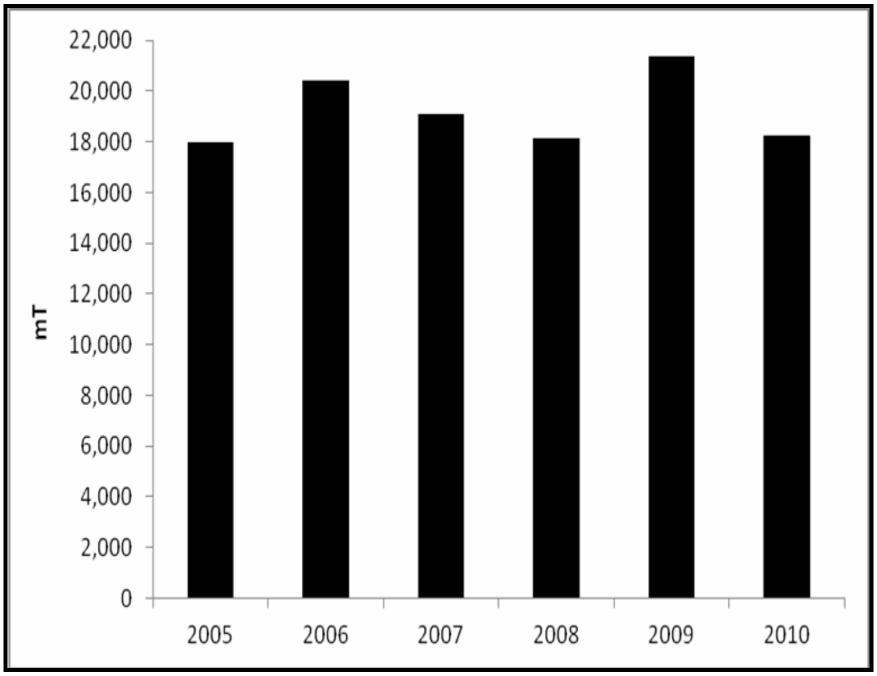
The average annual Newfoundland-landed species harvests from the Study Area, 2005 to 2010, based on the georeferenced DFO data sets are shown in Table 4.5. The domestic harvest in the Study Area has been dominated by northern shrimp (63.8%) and snow crab (35.3%) throughout this period in terms of average catch weight, although snow crab landed value was higher than that of shrimp (Table 4.5).

Figure 4.14 indicates the variability in annual total catch weight in the Study Area during the 2005 to 2010 period. The annual total catch weight has remained relatively steady over this six-year period. Despite the collapse of traditional groundfisheries, the total catch weight has been maintained at this level mainly as the result of increasing shrimp catches in the Study Area.

Table 4.5 Average Annual Study Area Catch Weight by Species, 2005 to 2010.

Species	Quantity (mt)	% of Total	Value ($)	% of Total
Northern Shrimp	12,267	63.8	18,049,676	46.3
Snow Crab	6,792	35.3	20,682,192	53.1
Stimpson's Surf Clam	81	0.4	119,983	0.3
Greenland Halibut	54	0.3	103,797	0.3
Cockles	9	<0.1	9,708	<0.1
Herring	6	<0.1	1,164	<0.1
Roughhead Grenadier	6	<0.1	1,711	<0.1
Redfish (spp.)	3	<0.1	1,136	<0.1
Skate	3	<0.1	834	<0.1
Capelin	3	<0.1	443	<0.1
Mackerel	2	<0.1	1,042	<0.1
Atlantic Halibut	<1	<0.1	4,563	<0.1
Rock Crab	<1	<0.1	74	<0.1
Sea Scallops	<1	<0.1	154	<0.1
Witch Flounder	<1	<0.1	27	<0.1
American Plaice	<1	<0.1	10	<0.1
Atlantic cod	<1	<0.1	13	<0.1
Totals	**19,227**	**100.0**	**38,976,525**	**100.0**

Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.



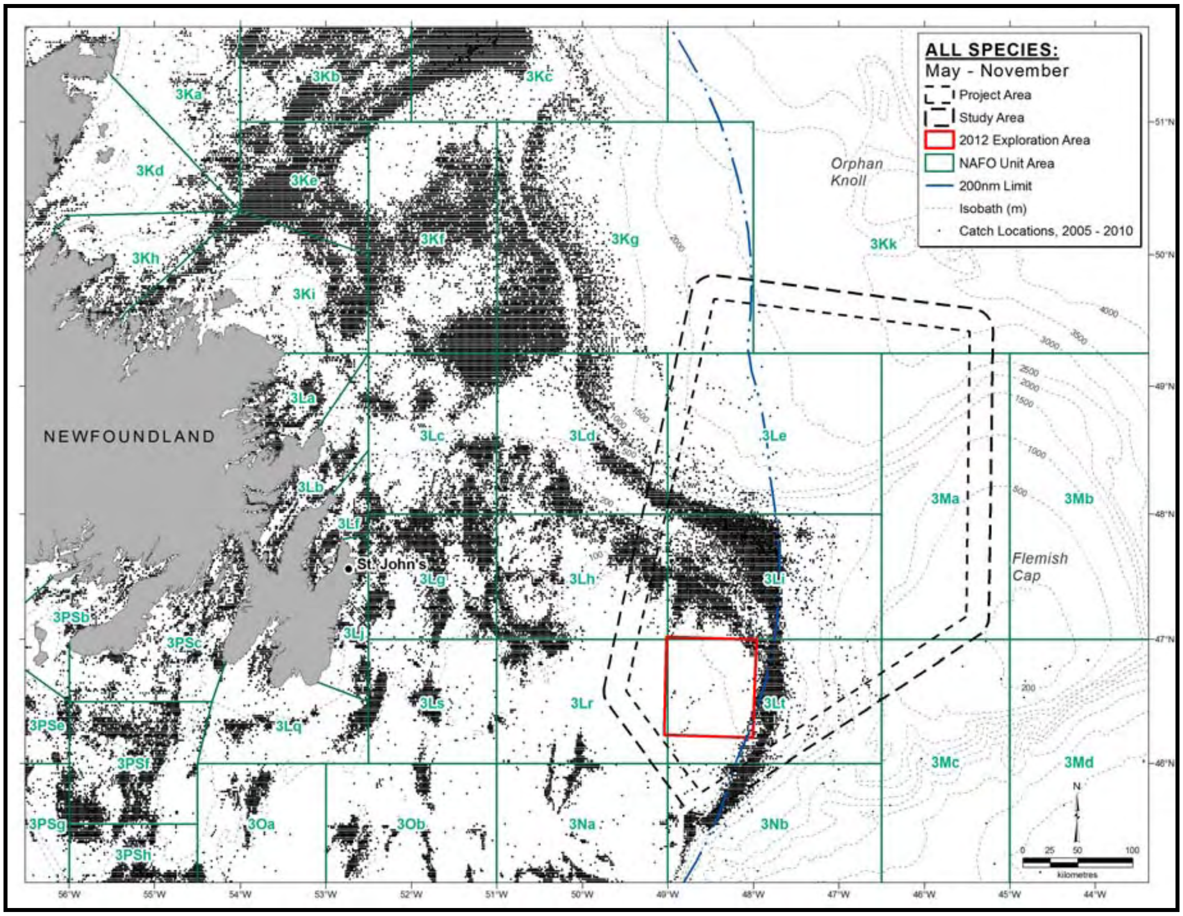
Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.14 Annual Total Catch Weight of Newfoundland-landed Harvests within the Study Area, All Species Combined, 2005 to 2010.

4.3.3.3 Harvesting Locations

The georeferenced harvest locations in the Study Area for Newfoundland-landed commercial catches of all species during May to November, 2005 to 2010 are presented in Figure 4.15. The majority of total catch weight was harvested between May and July (61.4%). As Figure 4.15 illustrates, most of the domestic fish harvesting in the Study Area is concentrated between the 100 and 1,000 m contours of NAFO UA 3Li, and outside the 200 nmi EEZ in NAFO UAs 3Lt and 3Nb. The pattern of harvesting locations tends to be quite consistent from year to year. Very little harvesting was reported for WesternGeco's proposed 2012 exploration area.

In terms of catch weight differences between gear types, mobile gear accounted for slightly more of the average annual catch weight of Newfoundland-landed commercial harvests in the Study Area than fixed gear (Table 4.6; Figure 4.16). Northern shrimp accounted for essentially all of the mobile gear catch weight, and snow crab accounted for essentially all of the fixed gear catch weight.



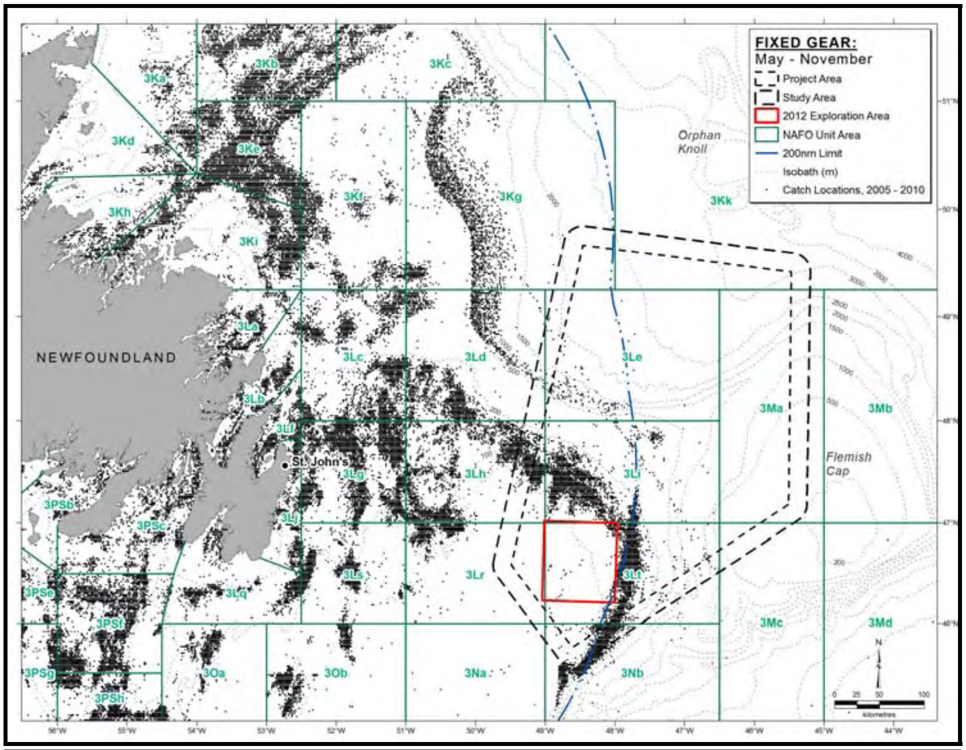
Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

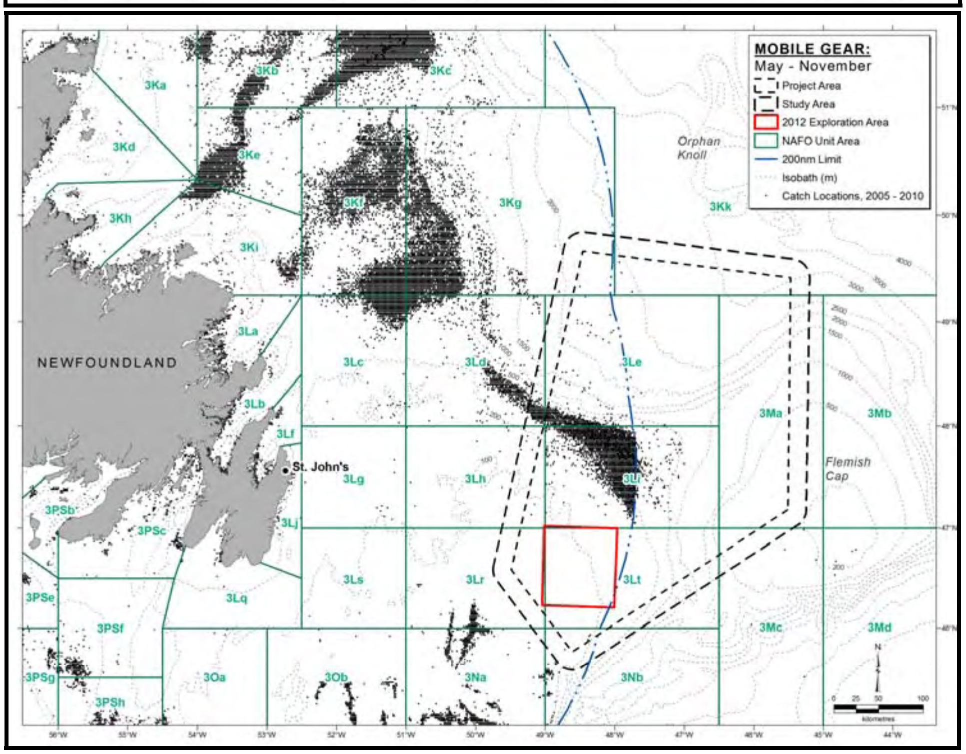
Figure 4.15 Harvesting Locations of All Species Combined, May to November 2005-2010.

Table 4.6 Average Annual Study Area Catch Weight by Gear Type, May to November, 2005 to 2010.

Species	Fixed Gear	% of Total	Mobile Gear (mt)	% of Total
Northern Shrimp	0	0.0	8,954	99.8
Snow Crab	6,032	99.0	0	0.0
Stimpson's Surf Clam	0	0.0	0	0.0
Greenland Halibut	52	0.9	1	0.0
Cockles	0	0.0	0	0.0
Herring	0	0.0	6	0.1
Roughhead Grenadier	5	0.1	<1	<0.1
Redfish (spp.)	<1	<0.1	3	0.0
Skate	<1	<0.1	<1	<0.1
Capelin	0	0.0	3	0.0
Mackerel	0	0.0	2	0.0
Atlantic Halibut	<1	<0.1	0	0.0
Rock Crab	<1	<0.1	0	0.0
Sea Scallops	0	0.0	<1	<0.1
Witch Flounder	0	0.0	<1	<0.1
American Plaice	0	0.0	<1	<0.1
Atlantic cod	0	0.0	<1	<0.1
Totals	**6,090**	**100**	**8,970**	**100**

Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.



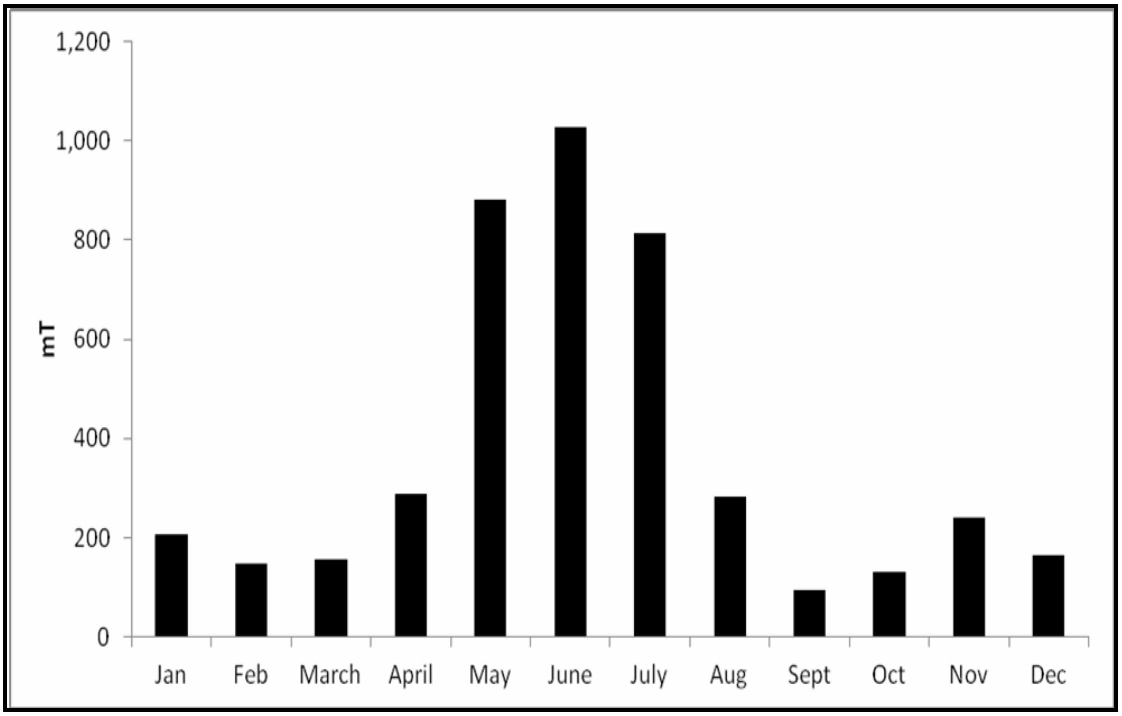


Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.16 Fixed (top) and Mobile (bottom) Harvesting Locations, May to November, 2005 to 2010 Combined.

4.3.3.4 Harvest Timing

The timing of commercial harvesting for any particular species can vary, depending on seasons and regulations set by DFO, the harvesting strategies of fishing enterprises, and on the availability of the resource itself. May to July during 2005–2010 accounted for much of the harvest catch weight (61%) from the Study Area (Figure 4.17).



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.17 Average Monthly Catch Weight of all Species in the Study Area, 2005 to 2010 Combined.

4.3.4 Principal Species

As noted above, the domestic harvest within the Study Area is primarily constituted of northern shrimp and snow crab catches, with minor components of Stimpson`s surf clam and Greenland halibut. These four species have typically accounted for more than 99% of the Study Area harvest catch weight in recent years. This subsection describes these four fisheries in more detail.

4.3.4.1 Northern Shrimp

Northern shrimp was the most significant species harvested within the Study Area during May to November, 2005–2010 in terms of average annual catch weight (59.4% of total) (Table 4.6), and the second-most significant species harvested within the Study Area in 2005–2010 in terms of average annual catch value (46.3% of total) (Table 4.5). The Study Area overlaps with parts of Shrimp Fishing Area (SFA) 7, and a very small portion of SFA 6 (Figure 4.18). As noted above, SFA 7 (which corresponds to NAFO Division 3L) and Divisions 3MN are managed by NAFO, while SFA 6 (which corresponds to Division 3K) is managed by DFO. Domestic northern shrimp harvest locations in the Study Area during May to November, 2005–2010 are indicated in Figure 4.19. Relatively little commercial shrimp harvest was reported for WesternGeco's proposed 2012 exploration area during 2005–2010. The annual quantity of the northern shrimp caught in the Study Area from 2005 to 2010 is indicated in Figure 4.20. The overall increase prior to 2010 was largely the result of increasing quotas.

The average monthly quantity of the northern shrimp caught in the Study Area from 2005 to 2010 is indicated in Figure 4.21. The largest average monthly harvests of northern shrimp in the Study Area during the six-year period occurred mainly during the summer, although harvesting did occur throughout the year.

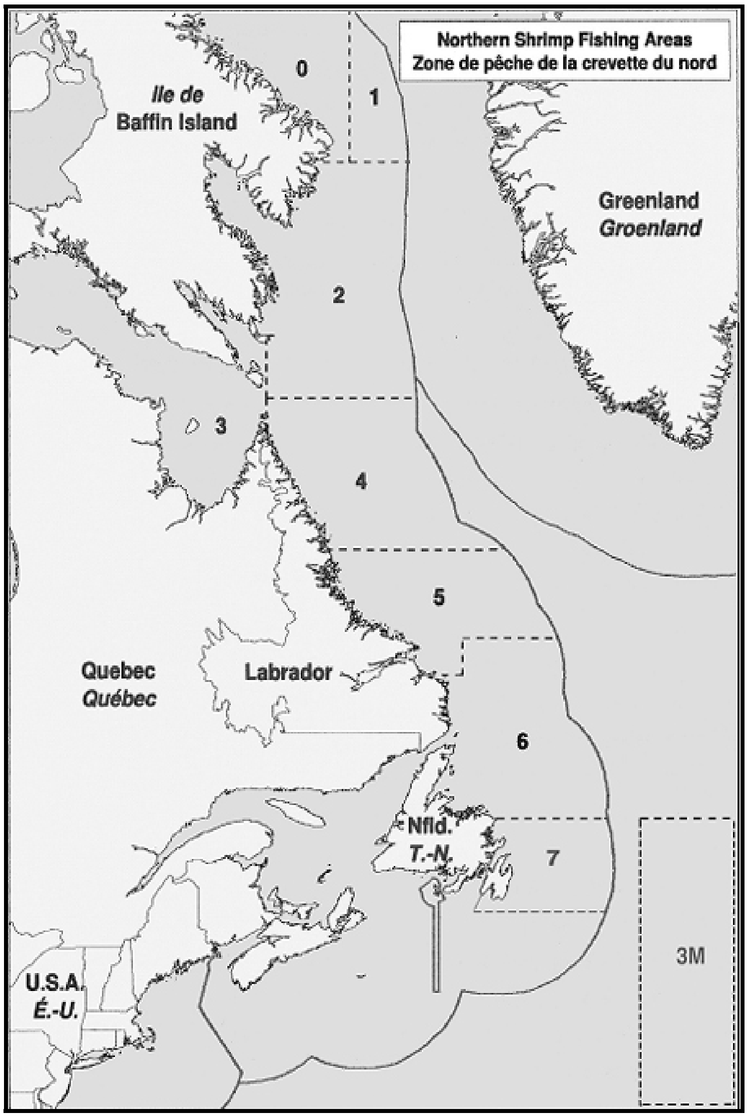
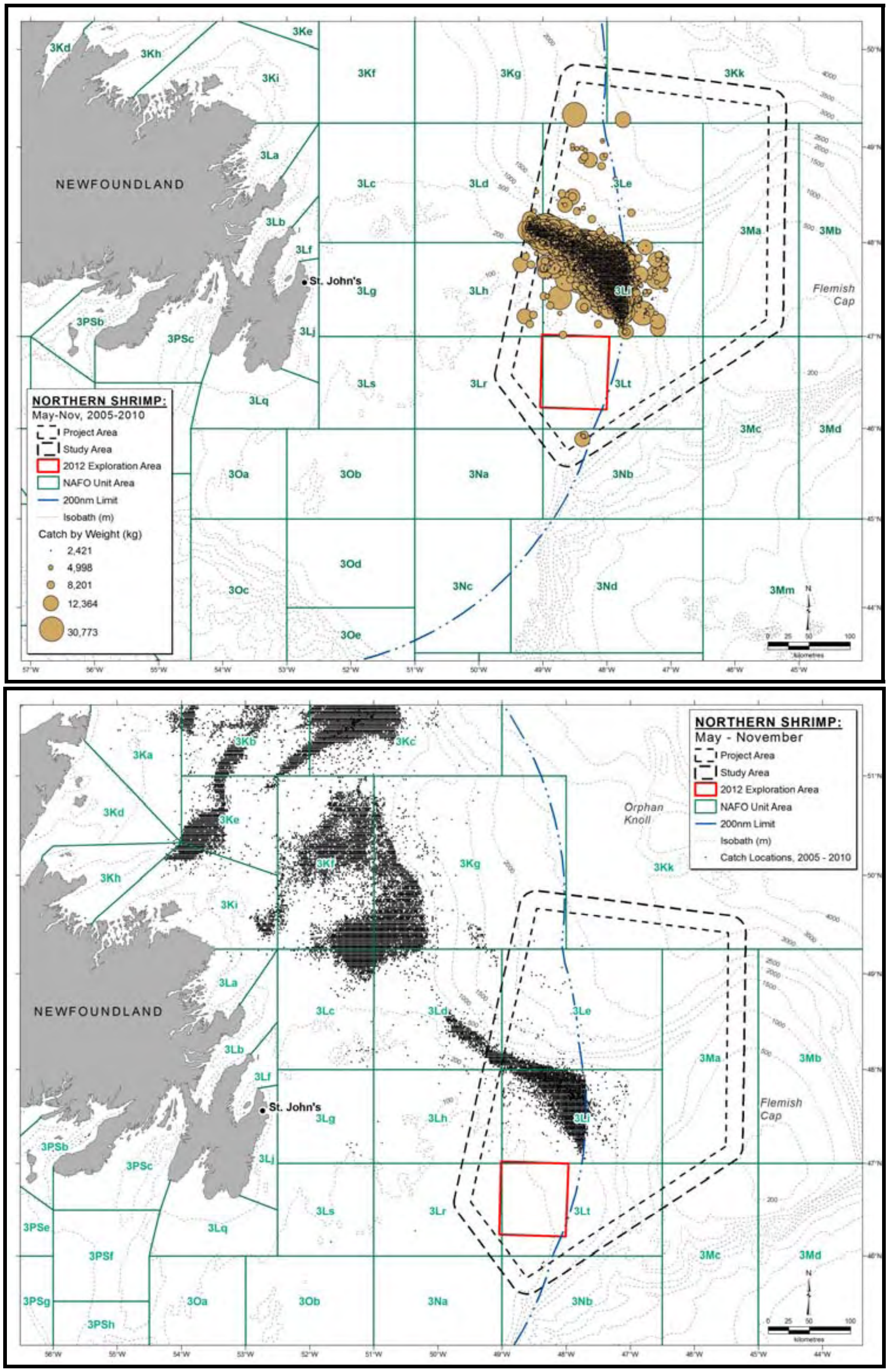
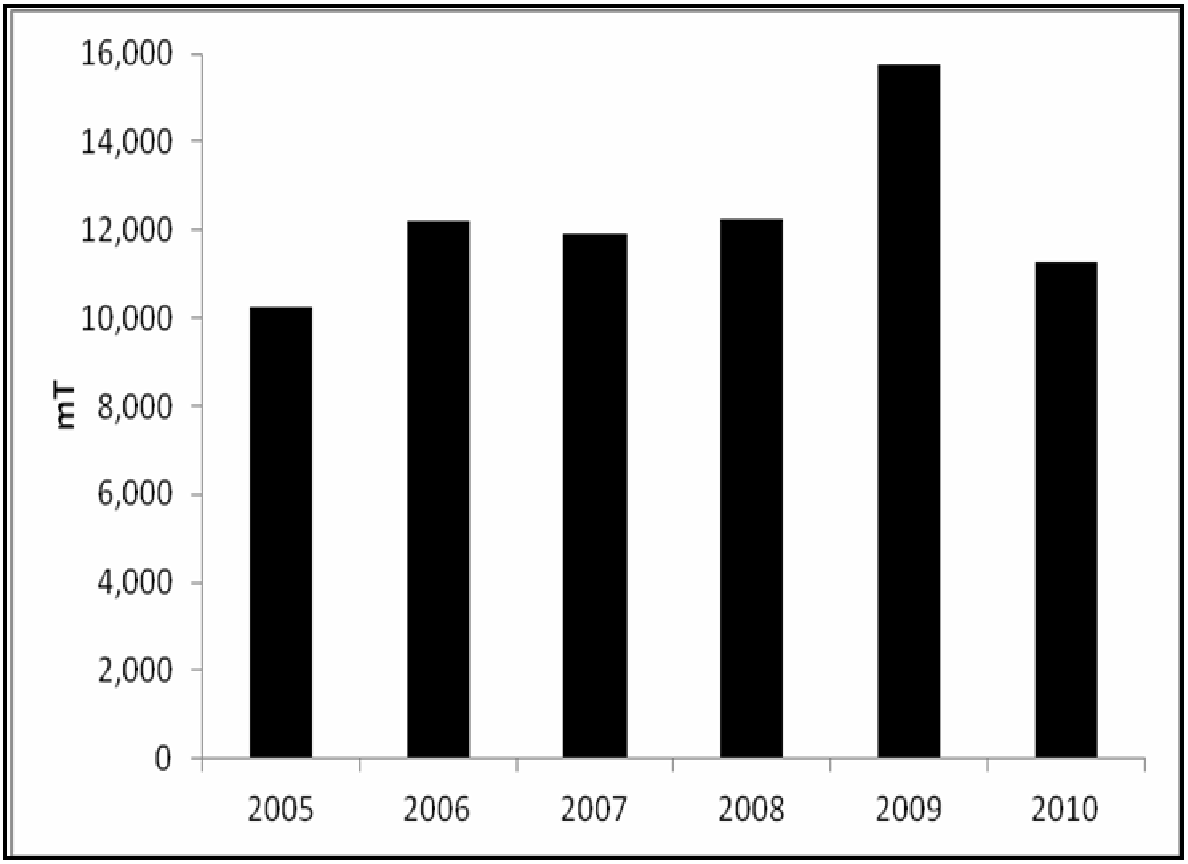


Figure 4.18 Northern Shrimp Fishing Areas.



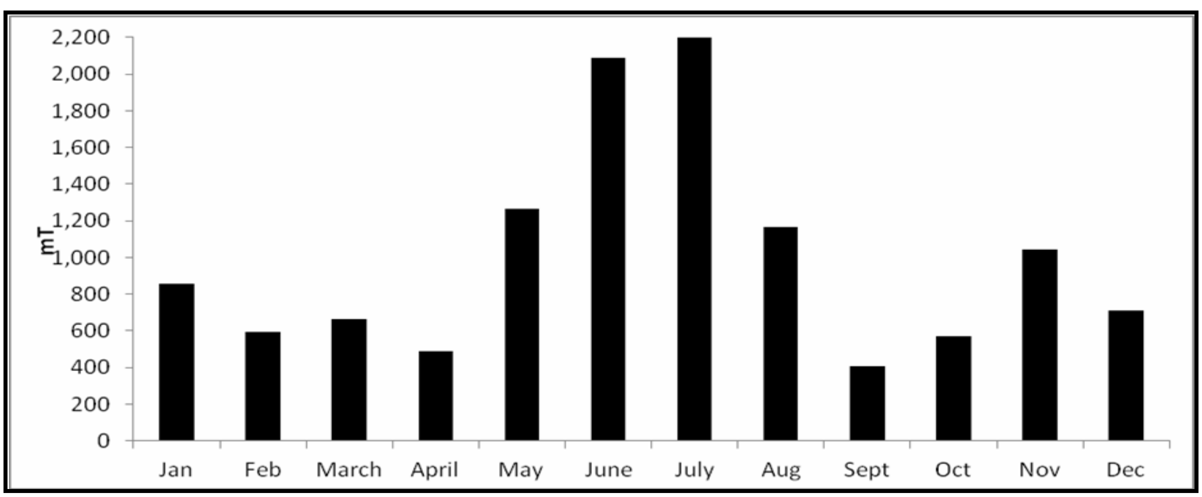
Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.19 Proportional (top) and Non-proportional (bottom) Northern Shrimp Harvesting Locations in the Study Area, May to November, 2005 to 2010.



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.20 Annual Northern Shrimp Catch Weight in the Study Area, 2005 to 2010.



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.21 Average Monthly Northern Shrimp Catch Weight in the Study Area, 2005 to 2010.

4.3.4.2 Snow Crab

Snow crab was the most significant species harvested within the Study Area during May to November, 2005–2010 in terms of average annual catch value (53.1% of total) (Table 4.5), and the second-most significant species harvested within the Study Area in 2005–2010 in terms of average annual catch weight (40.1% of total) (Table 4.6).

The season is defined each year, but typically runs from April to either July or August. The Study Area overlaps with portions of Crab Fishing Areas (CFA) 4 (offshore Division 3K), 8B (southern Avalon, outside of 50 nmi), Msex (mid-shore extended), 3Lex (from 170 miles to 200 nmi from shore) and 3L200 (>200 nmi), which are partly within Divisions 3KLMN (Figure 4.22).

The most recent DFO snow crab science advisory report (DFO 2010b) notes:

> *"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 to 25,000 mt since 2000. Effort increased steadily from 2000 to 2007 and changed little since."*

Specifically describing the 3LNO offshore area, DFO 2010b states:

> *"The exploitable biomass has recently increased. The exploitable biomass index from the trawl survey declined steadily from 2001 to 2007, but has since more than doubled. The CPS index [based on an Industry-DFO collaborative post-season trap survey] declined steadily from 2004 to 2008, but increased in 2009."*

Domestic snow crab harvest locations in the Study Area during May to November, 2005–2010 are indicated in Figure 4.23. Notable commercial snow crab catches were reported primarily in the eastern part of WesternGeco's proposed 2012 exploration area during 2005–2010, with some harvesting also occurring in the central part of the area. Between 2005 and 2010, annual landings of snow crab caught within the exploration area proposed for 2012 ranged from about 14 to 111 mt. The total landings of snow crab from that area over the entire six-year period was ~358 mt, <1% of the Study Area catch weight during the same six-year period. All catches were made during the May to August period, primarily during May and June.

The annual quantity of the snow crab caught in the Study Area from 2005 to 2010 is indicated in Figure 4.24. The average monthly quantity of the snow crab caught in the Study Area from 2005 to 2010 is indicated in Figure 4.25. The largest average monthly harvests of snow crab in the Study Area during the six-year period occurred mainly during the April to July period.

During the snow crab fishery, 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 ~20 fathoms (36.5 m or 120 feet) on the seabed between each pot. This allows 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 to 60 pot string of crab gear would be 6,000 to 7,500 feet or ~1.8 km to 2.3 km.

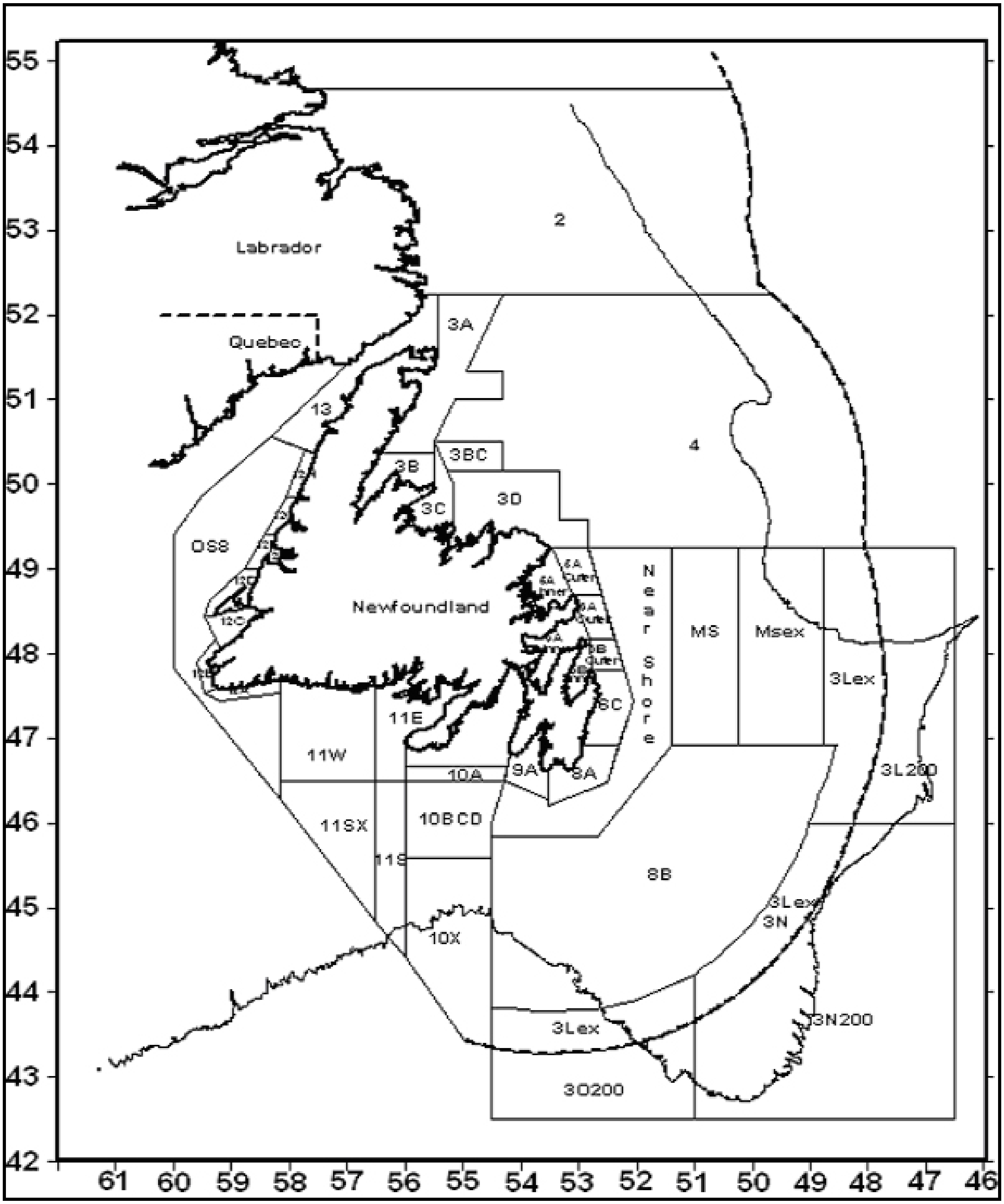
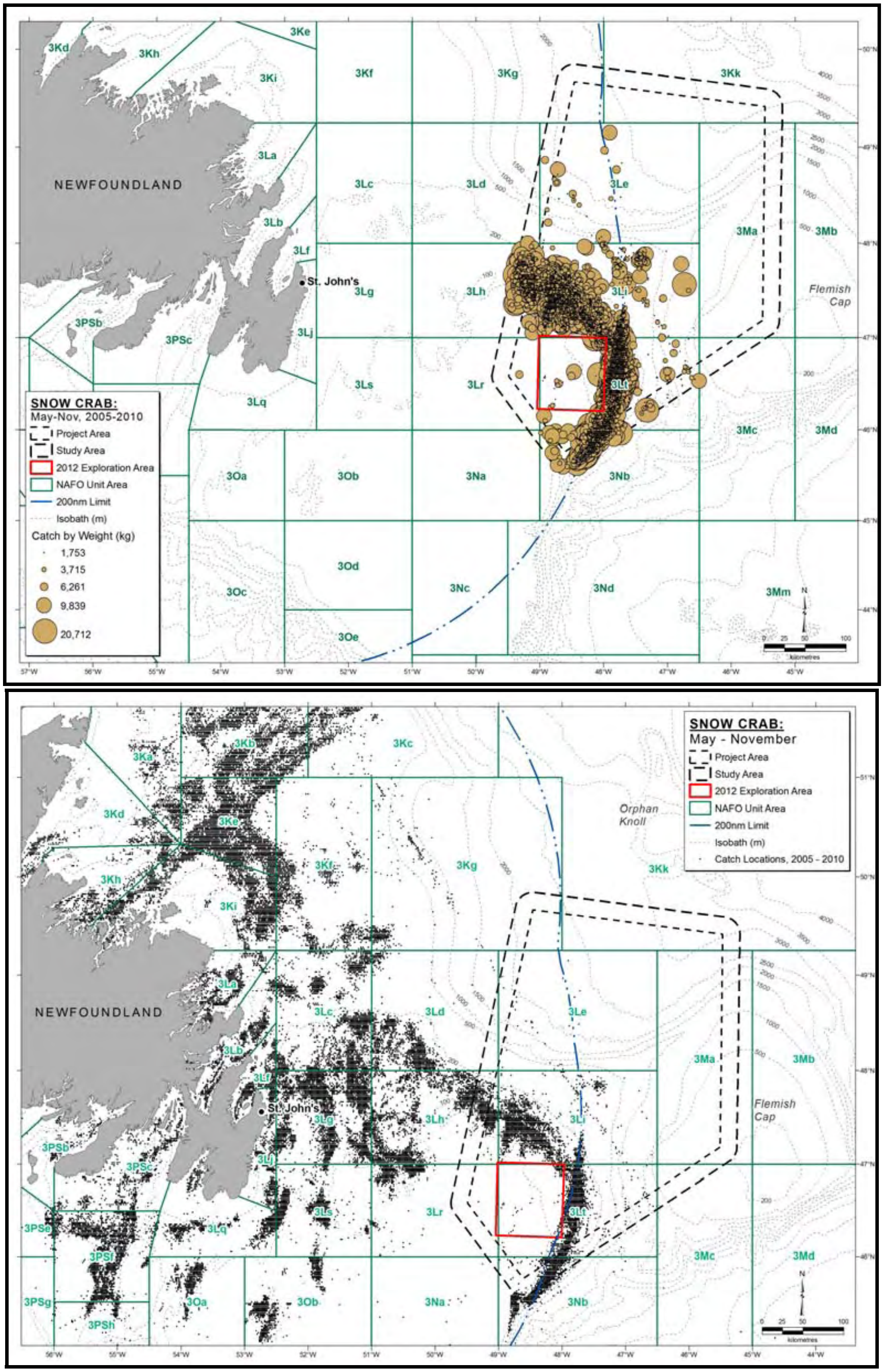
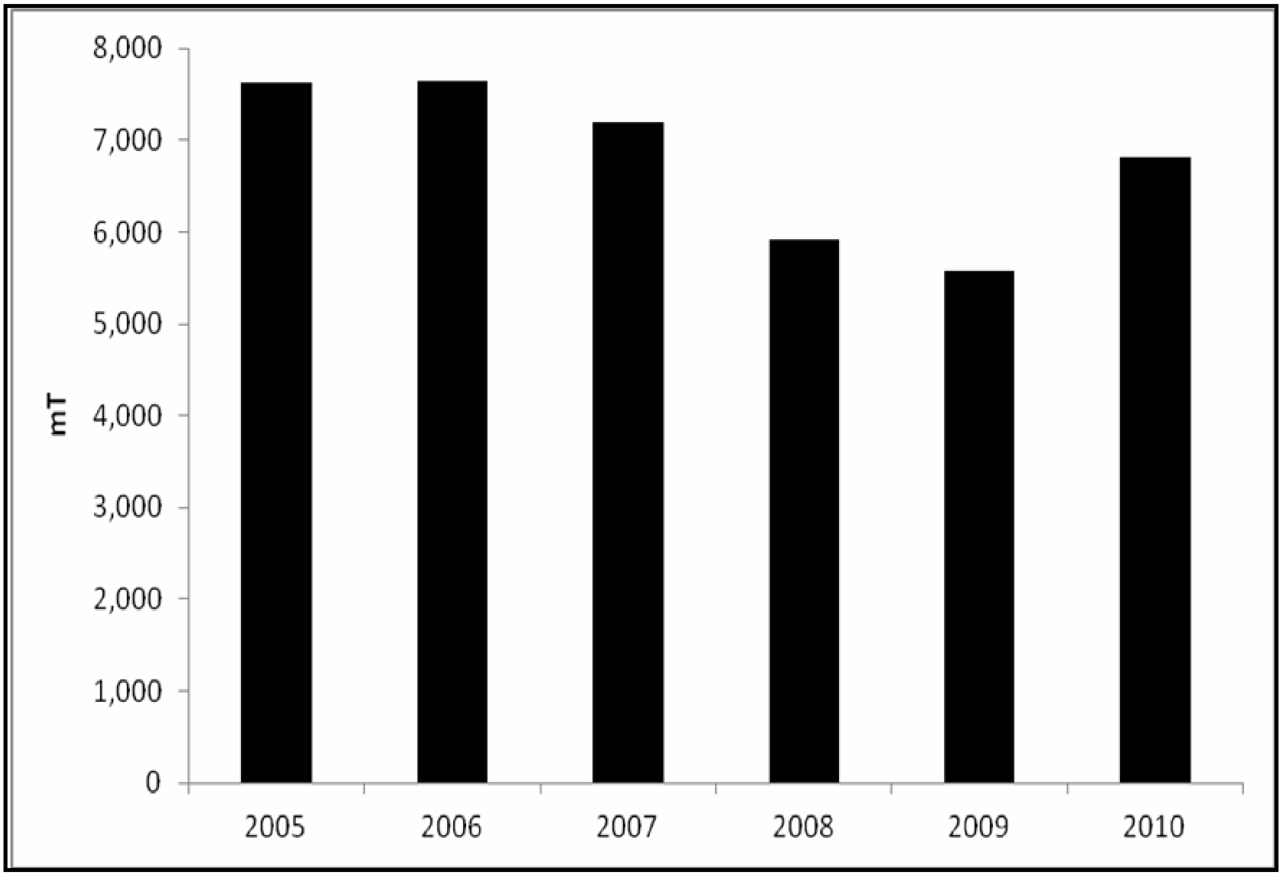


Figure 4.22 Newfoundland Snow Crab Fishing Areas.



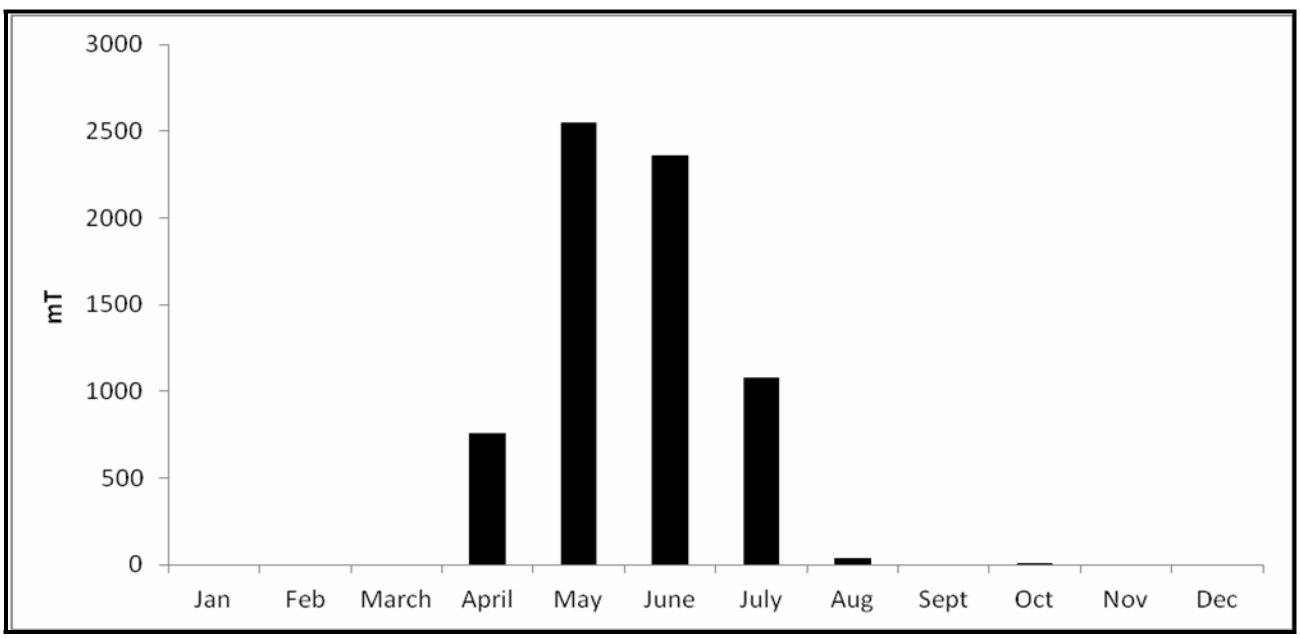
Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.23 Proportional (top) and Non-proportional (bottom) Snow Crab Harvesting Locations in the Study Area, May to November, 2005 to 2010.



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.24 Annual Snow Crab Catch Weight in the Study Area, 2005 to 2010.



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.25 Average Monthly Snow Crab Catch Weight in the Study Area, 2005 to 2010.

4.3.4.3 Stimpson's Surf Clam

Stimpson's surf clam accounts for an average of 0.4% of the total Study Area catch weight and 0.3% of the total catch value during 2005–2010 (Table 4.5). Most of this fishery in the Study Area uses clam dredges, although some clams are also taken as bycatch in other dredge fisheries. The fishery is managed by DFO in the Study Area.

The Study Area domestic harvest of this bivalve in 2006 only is entirely within the EEZ, in NAFO Divisions 3Lrt and 3Nb (Figure 4.26). This clam harvesting occurred in the southwestern corner of WesternGeco's proposed 2012 exploration area. Harvesting has also occurred outside of the Study Area, in Divisions 3Nab. All harvesting of this clam in 2006 occurred during the January to March period.

4.3.4.4 Greenland Halibut

Greenland halibut accounts for an average of 0.3% of the total Study Area catch weight and 0.3% of the total catch value during 2005–2010 (Table 4.5). Most of this harvest in the Study Area is taken using gillnets, although some are also taken as bycatch in bottom trawl fisheries. The fishery is managed by NAFO in the Study Area.

The Study Area domestic harvest of Greenland halibut is almost entirely within the EEZ, in NAFO Divisions 3Kg and 3Ldeit (Figure 4.27). The majority of the harvest occurred in the west-central portion of the Study Area, in Divisions 3Lde.

The annual quantity of the Greenland halibut caught in the Study Area from 2005 to 2010 is indicated in Figure 4.28. Negligible commercial Greenland halibut harvest was reported for WesternGeco's proposed 2012 exploration area during 2005–2010. The average monthly quantity of the Greenland halibut caught in the Study Area from 2005 to 2010 is indicated in Figure 4.29. The largest average monthly harvests of Greenland halibut in the Study Area during the six-year period occurred mainly during the June to September period.

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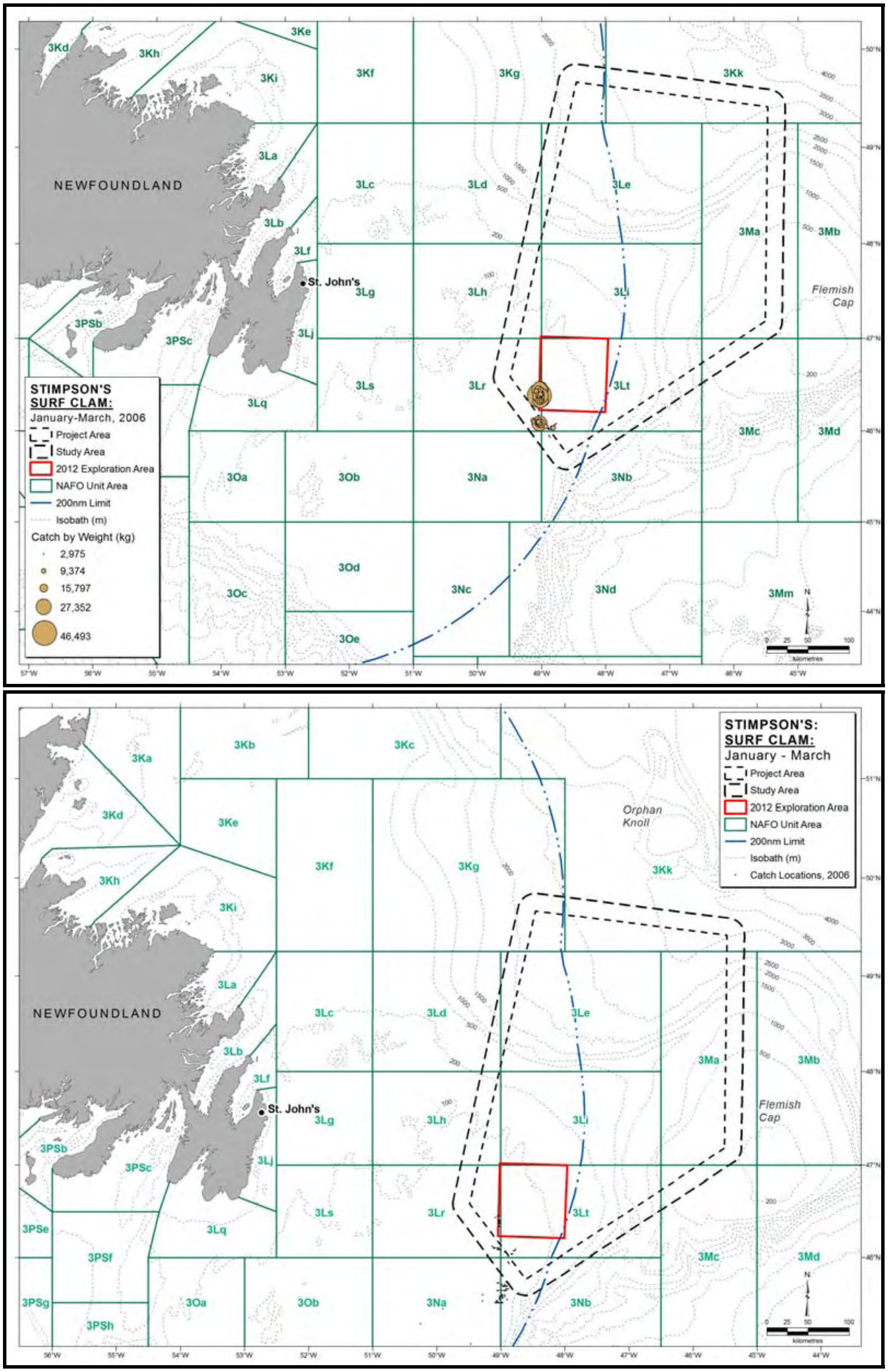
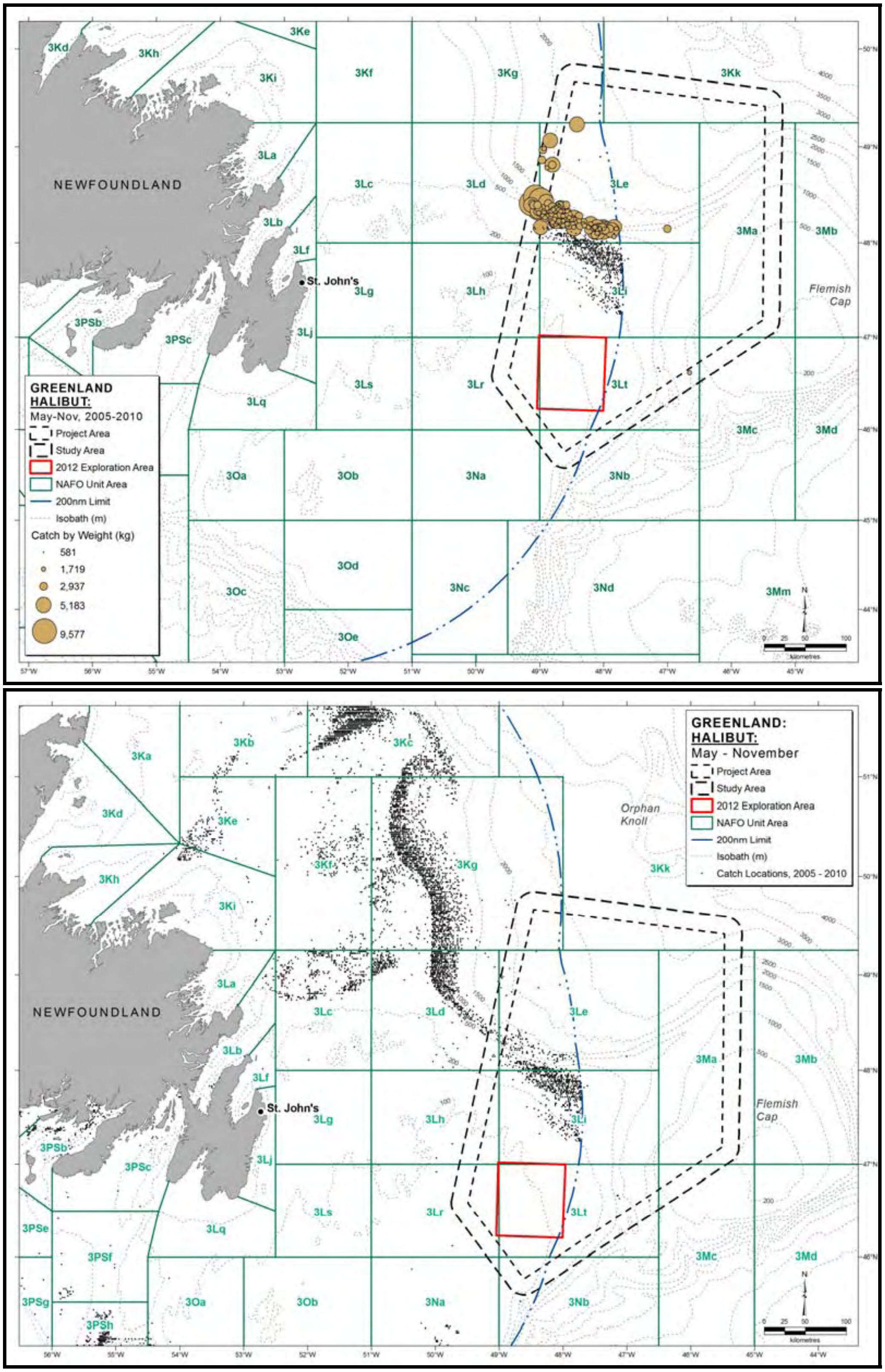


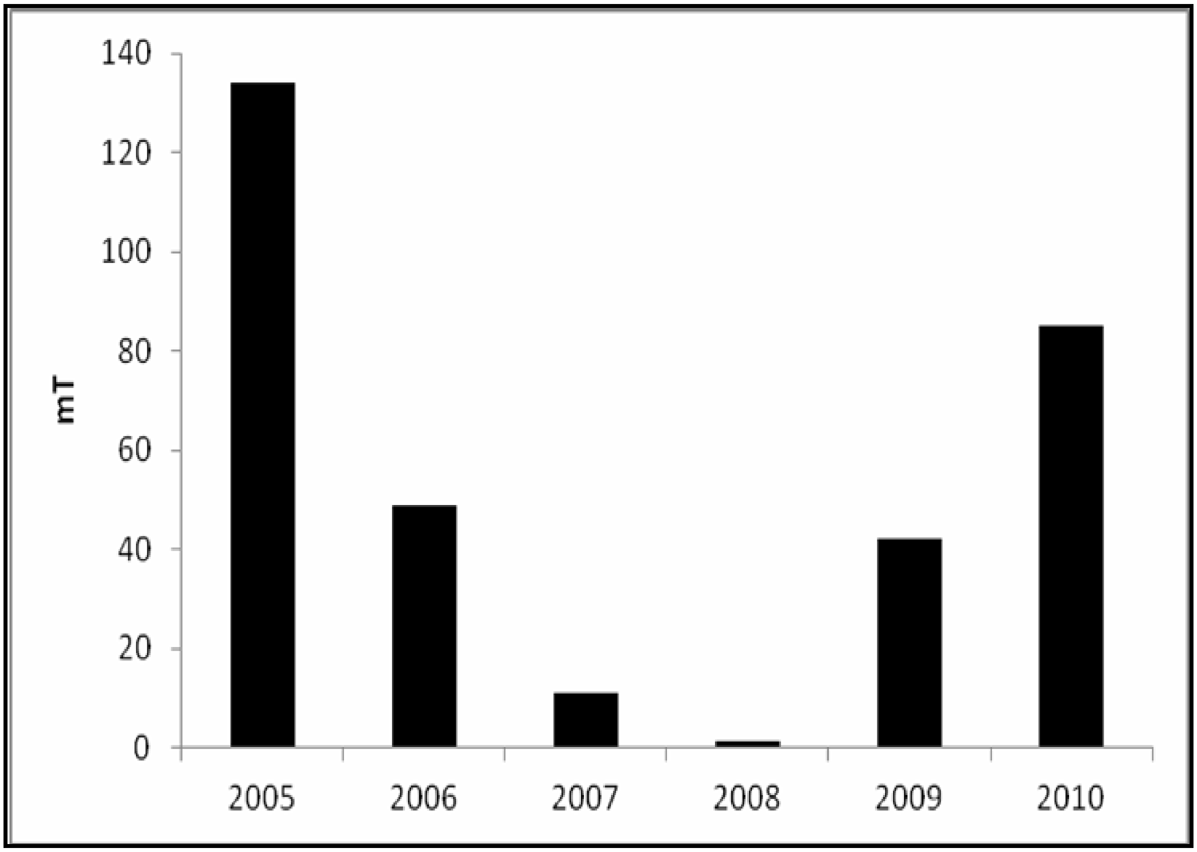
Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.26 Proportional (top) and Non-proportional (bottom) Stimpson's Surf Clam Harvesting Locations in the Study Area, January to March, 2006.



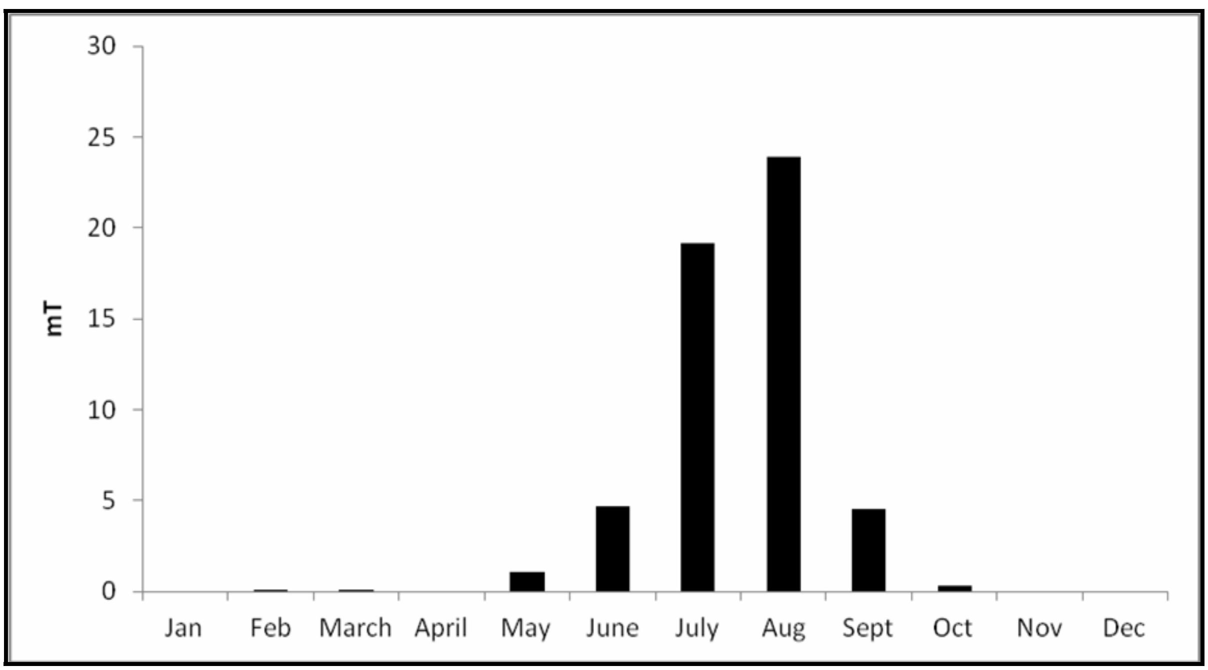
Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.27 Proportional (top) and Non-proportional (bottom) Greenland Halibut Harvesting Locations in the Study Area, May to November, 2005 to 2010.



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.28 Annual Greenland Halibut Catch Weight in the Study Area, 2005 to 2010.



Source: DFO Newfoundland Commercial Fishery Landings Database, 2005-2010.

Figure 4.29 Average Monthly Greenland Halibut Catch Weight in the Study Area, 2005 to 2010.

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 Area and DFO research surveys in NAFO 3LM, depending on the timing in a particular year. Typically, DFO conducts a spring survey in parts of 3LNOPs (April to July), and a fall survey of 2HJ3KLMNO (September or 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 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 DFO-industry collaborative post-season trap survey. This survey is conducted every year. It starts on September 1 and may continue until November. The set locations are determined by DFO and do not change from year to year. Many of the eastern stations fall within WesternGeco's Study Area. Research stations are shown in Figure 4.30.

Scheduling of the 2012 DFO multispecies science surveys is currently being finalized and should be completed by the end of February (G. Sheppard, DFO pers. comm.). The exact timing is likely to vary between years so it is necessary to update the science survey scheduling each year of the program.

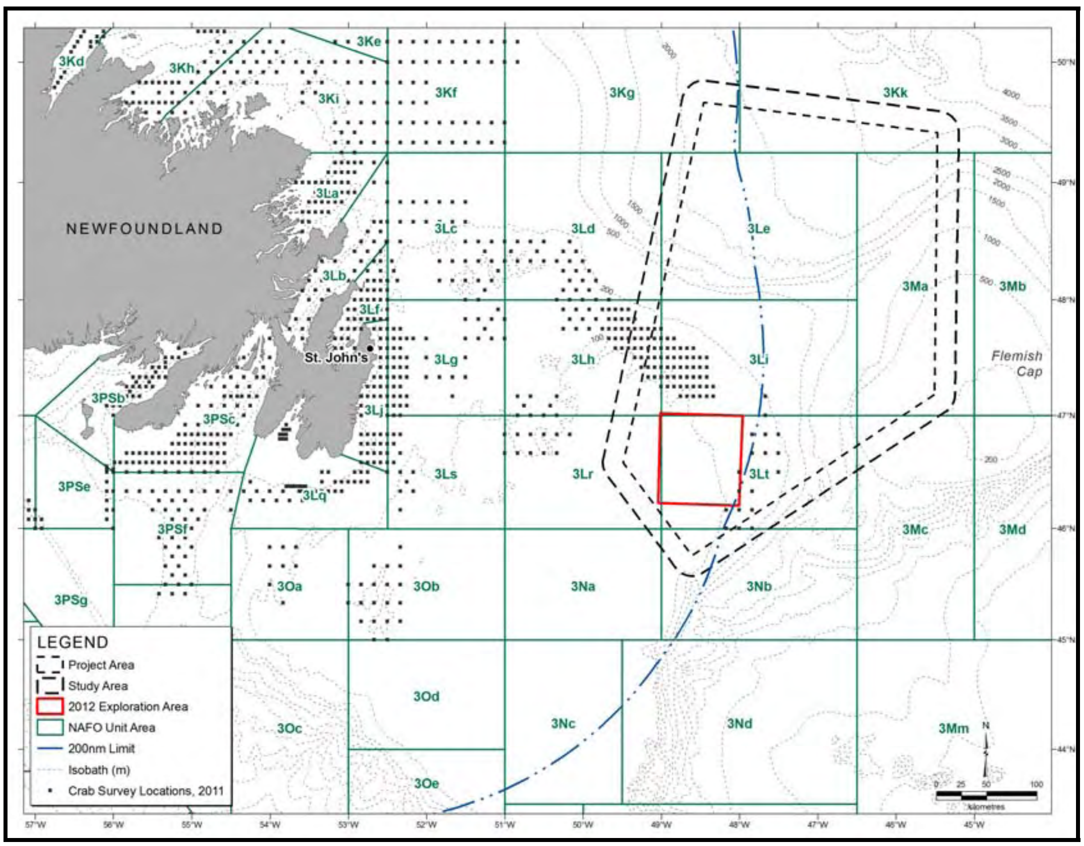


Figure 4.30 Joint DFO-Industry Post-season Crab Survey Locations, 2011.

4.4 Seabirds

The Study Area is located over the southern Orphan Basin, Jeanne d'Arc Basin at the northeast corner of the Grand Banks, the Sackville Spur, the Flemish Pass, and western edge of the Flemish Cap (Figure 1.1). The highly productive Grand Banks support large numbers of seabirds in all seasons (Lock et al. 1994; Fifield et al. 2009). Seabirds are not spread evenly over the ocean but tend to be concentrated over anomalies such as shelf edges and along currents. In such areas, mixing in the water column creates a productive environment for zooplankton. The Project Area is located on the edge of the Grand Banks where it begins to slope into the deep waters beyond the continental shelf. A branch of the Labrador Current flows south along the shelf edge off eastern Newfoundland including the Grand Banks and through the Flemish Pass. The combination of shelf edge and Labrador Current are prime conditions for enhanced productivity of plankton, the basis of oceanic food chains.

4.4.1 Information Sources

Seabird surveys in the Study Area and surrounding areas have been conducted by the Canadian Wildlife Service (CWS) and through oil industry related seabird monitoring. Prior to 2000, seabird surveys were sparse on the Orphan Basin, northern Grand Banks and Flemish Cap. Original baseline information has been collected by the CWS through PIROP (Programme intégré de recherches sur les oiseaux pélagiques). These data have been published for 1969-1983 (Brown 1986) and 1984-1992 (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). Seabird surveys were also conducted from vessels conducting seismic surveys or control source electromagnetic surveys within the Study Area from 2004-2008 as part of marine bird monitoring programs required by the C-NLOPB (Moulton et al. 2005a, 2006; Lang et al. 2006; Lang 2007; Lang and Moulton 2008; Abgrall et al. 2008a,b, 2009). In addition, 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 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 surveys conducted in this time span include many from the Grand Banks and Orphan Basin. Monthly surveys were conducted to the northeast Grand Banks production area from 2006 to 2009.

The results from all of the above surveys have been used here 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 4.7 (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). Northern Fulmar and gulls were found in the highest concentrations in the Newfoundland and Labrador shelves region on the Sackville Spur during spring. Significant 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

Hundreds of thousands of pairs of seabirds nesting on the Avalon Peninsula reflect the richness of the offshore regions off southeastern Newfoundland. The seabird breeding colonies on Baccalieu Island, the Witless Bay Islands, and Cape St. Mary's are among the largest in Atlantic Canada. More than 4.6 million pairs nest at these three locations alone (Figure 4.31; Table 4.8). This includes the largest Atlantic Canada colonies of Leach's storm-petrel (3,336,000 pairs on Baccalieu Island), black-legged kittiwake (23,606 pairs on Witless Bay Islands), thick-billed murre (1,000 pairs at Cape St. Mary's), and Atlantic puffin (216,000 pairs on Witless Bay Islands). These birds, along with non-breeding seabirds, 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 4.31; Table 4.8). An IBA is defined as 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).

In addition to local breeding birds, there are many non-breeding seabirds on the Grand Banks during the summer months. A significant portion of the world's population of great 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 (Lock et al. 1994). Depending on the species, seabirds require two to four years to become sexually mature. Many non-breeding sub-adult seabirds, notably northern fulmars and black-legged kittiwakes are present on the Grand Banks and Flemish Cap year-round. During the non-breeding season large numbers of Arctic breeding thick-billed murre, dovekie, northern fulmar, and black-legged kittiwake migrate to eastern Newfoundland, including the Grand Banks and Flemish Cap to spend the winter.

The ivory gull was designated as an *endangered* species by COSEWIC in April 2006 and is listed as *endangered* under *SARA* Schedule 1. Ivory gull is likely of less than annual occurrence in the Project Area. See Section 4.6 for more detail.

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 4.7 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.

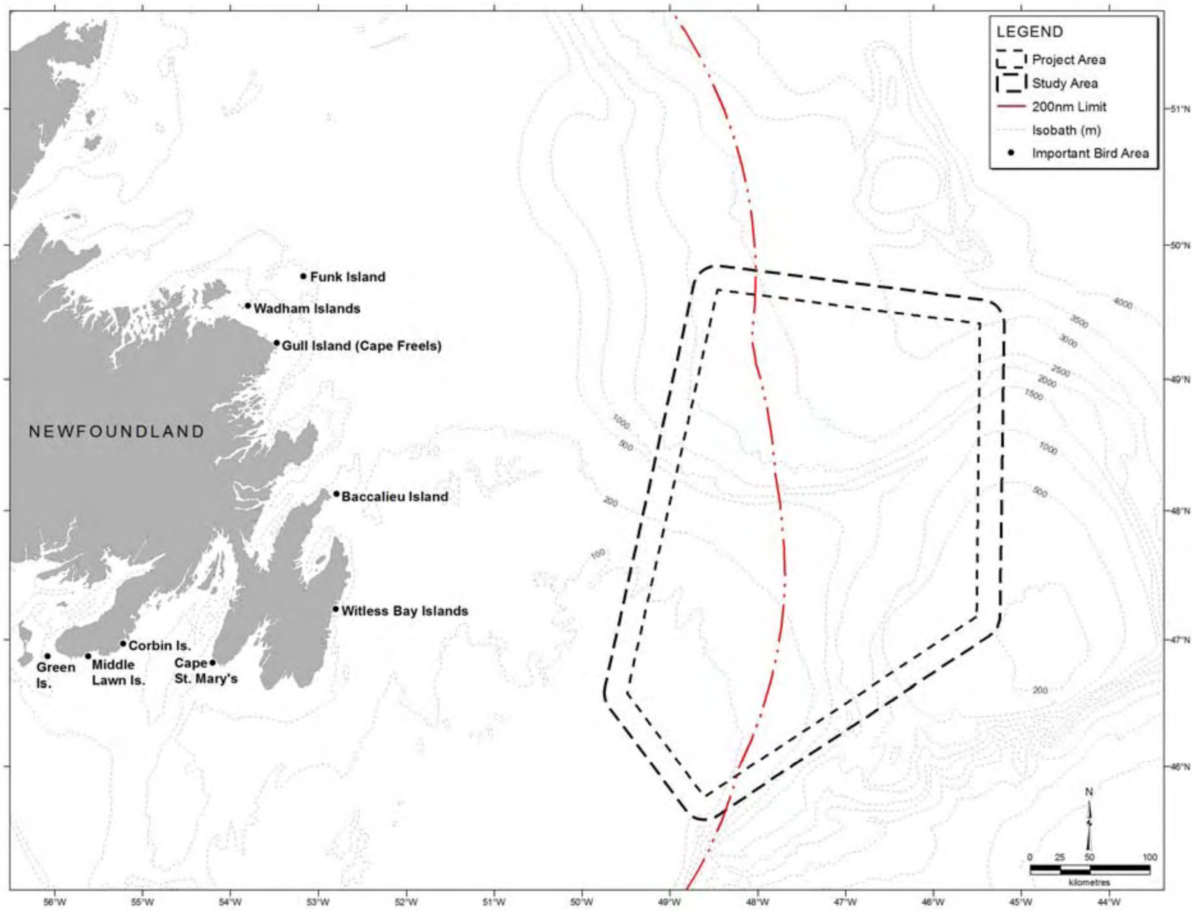


Figure 4.31 **Locations of Seabird Nesting Colonies at Important Bird Areas (IBAs) relative to the Study Area.**

A species world population estimate is taken into consideration when assessing relative abundance; for example, great shearwater is far more numerous on a worldwide 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 (2008a,b), and Fifield et al. (2009).

4.4.4.1 Procellariidae (Fulmars and Shearwaters)

<u>Northern Fulmar</u>

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, 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 the most numerous during spring and autumn 1999 to 2002 on the northeast Grand Banks (Baillie et al. 2005).

Table 4.7 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
Great 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			
Herring Gull	*Larus argentatus*	U	U	U	U	U	S	S	S	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	*Stercorarius*					S	S	S	S	S	S		
Pomarine Jaeger	*Stercorarius pomarinus*				S	S	S	S	S	S	S		
Parasitic Jaeger	*Stercorarius parasiticus*					S	S	S	S	S	S		
Long-tailed Jaeger	*Stercorarius 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
Thick-billed Murre	*Uria lomvia*	U-C	U-C	U-C	U-C	S-U	S-U	S-U	S-U	U-C	U-C	U-C	U-C
Razorbill	*Alca torda*				S	S	S	S	S	S	S	S	
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. (2005a, 2006); Lang et al. (2006); Lang (2007); Lang and Moulton (2008); Abgrall et al. (2008a,b, 2009.)

Table 4.8 Numbers of Pairs of Marine Birds Nesting at Marine Bird Colonies in Eastern Newfoundland.

Species	Wadham Islands	Funk Island	Cape Freels and Cabot Island	Baccalieu Island	Witless Bay Islands	Cape St. Mary's	Middle Lawn Island	Corbin Island	Green Island
Northern Fulmar	-	46[A]	-	12[A]	22[A,F]	Present[A]	-	-	-
Manx Shearwater	-	-	-	-	-	-	13[K]	-	-
Leach's Storm-Petrel	1,038[D]	-	250[J]	3,336,000[J]	667,086[H,I,J]	-	13,879[H]	100,000[J]	103,833[M]
Northern Gannet		9,837[b]		1,712[B]	-	14,789[L]	-	-	-
Herring Gull	-	500[J]	-	Present[A]	4,638[e,j]	Present[J]	20[J]	5,000[J]	Present[mM]
Great Black-backed Gull	Present[D]	100[J]	-	Present[A]	166[E,J]	Present[J]	6[J]	25[J]	-
Black-legged Kittiwake	-	810[J]	-	12,975[J]	23,606[F,J]	10,000[J]	-	50[J]	-
Arctic and Common Terns	376[J]	-	250[J]	-	-	-	-	-	-
Common Murre	-	412,524[C]	2,600[J]	4,000[J]	83,001[F,J]	15,484[J]	-	-	-
Thick-billed Murre		250[J]	-	181[J]	600[J]	1,000[J]	-	-	-
Razorbill	273[D]	200[J]	25[J]	100[J]	676[F,J]	100[J]	-	-	-
Black Guillemot	25[J]	1[J]	-	100[J]	20+[J]	Present[J]	-	-	-
Atlantic Puffin	6,190[D]	2,000[J]	20[J]	30,000[J]	272,729[F,G,J]	-	-	-	-
TOTALS	**7,902**	**426,268**	**3,145**	**3,385,080**	**1,052,546**	**32,256**	**13,918**	**105,075**	**103,833**

Sources: [A] Stenhouse and Montevecchi (1999); [B] Chardine (2000); [C] Chardine *et al.* (2003); [D] Robertson and Elliot (2002); [E] Robertson *et al.* (2001); [F] Robertson *et al.* (2004); [G] Rodway *et al.* (2003); [H] Robertson *et al.* (2002); [I] Stenhouse *et al.* (2000); [J] Cairns *et al.* (1989); [K] Robertson (2002); [L] CWS (unpubl. Data); [M] Russell (2008)

Results from monitoring programs on the Orphan Basin 2004–2007 show northern fulmar as being among the top four most numerous species from mid May to September (Table A.1 to A.3 in Appendix A). Monthly average densities during June, July and August ranged from 1.7 birds/km^2 to 4.8 birds/km^2. Higher densities were recorded in May and September with 30.1 birds/km^2 in May 2005 and 16.1 birds/km^2 in September 2005 and 5.8 birds/km^2 in September 2006. Results from the Jeanne d'Arc Basin show an average of 5.1 birds/km^2 for July and August 2006, 1.2 birds/km^2 in late May to September 2008, and 14.7 birds/km^2 in October and early November in 2005 (Table A.4 to A6 in Appendix A).

The ECSAS survey data from 2006–2009 in the Study Area show that northern fulmar was present during all seasons (spring, summer and winter) surveyed (Fifield et al. 2009). Densities within the Study Area (considering 1º 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).

Great Shearwater

Great shearwater migrates north from breeding islands in the South Atlantic and arrives in the Northern Hemisphere during summer. A large percentage of the world population of great shearwaters is thought to moult their flight feathers during the summer month while in Newfoundland waters (Brown 1986; Lock et al 1994). Great shearwater was among the top four most numerous species observed on the Orphan Basin during seismic monitoring 2004–2007 from June to September (Table A.4 to A.6 in Appendix A). Monthly density averages ranged from 2.4 to 35.4 birds/km^2. Highest densities were in July and August 2005 with averages of 35.4 birds/km^2 and 21.2 birds/km^2 respectively. Great shearwater can still be numerous in September on the Orphan Basin where an average density of 9.2 birds/km^2 was recorded during September 2005. Seismic monitoring on the Jeanne d'Arc Basin showed great shearwater was common in summer with a mean weekly density of 5.1 birds/km^2 from 9 July to 16 August 2006 (Table A.5 in Appendix A) and 11.9 birds/km^2 from 21 May to 29 September 2008 (Table A.6 in Appendix A). The ECSAS survey data from 2006–2009 lumps all shearwater species within the Study Area and shows densities per 1º survey blocks ranging from 0 to 14.1 birds/km^2 during the summer period May to August (Fifield et al. 2009).

Other Shearwaters

Sooty shearwater follows movements similar to great shearwater but is scarce to uncommon during May to early November in the Study Area. Manx shearwater breeds in the North Atlantic in relatively small world widenumbers compared to great 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

Leach's storm-petrel is common in offshore waters of Newfoundland from April to early November. Very large numbers nest in eastern Newfoundland with more than 3,300,000 pairs breeding on Baccalieu Island (Table 4.8). Adults range far from nesting sites on multi-day 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. It was among the top four most numerous species observed on the Orphan Basin during seismic monitoring 2004–2007 from May to September (Table A.1 to A.3 in Appendix A). The average monthly densities from May to September 2005 was 11.3 birds/km^2 (Table A.1 in Appendix A). The average monthly densities during August and September 2006 were 6.1 birds/km^2 (Table A.2 in Appendix A). And the average density per survey in the period 23 July to 6 September 2007 was 4.3 birds/km^2 (Table A.3 in Appendix A). Densities of Leach's storm-petrels were lower on seismic surveys on the Jeanne d'Arc Basin with an average of 0.6 birds/km^2 during the survey period 9 July to 16 August 2006 (Tables A.5 in Appendix A) and 0.9 birds/km^2 during the period 21 May to 29 September 2008 (Tables A.6 in Appendix A). The ECSAS survey data from 2006–2009 for storm-petrels within the Study Area shows densities per 1º survey blocks ranging from 0 to 4.2 birds/km^2 during the summer period May to August (Fifield et al. 2009).

Wilson's Storm-Petrel

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)

Northern Gannet

More than 26,000 pairs of northern gannet nest on three colonies in eastern Newfoundland (Table 4.8). 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 and Jeanne d'Arc basins in 2004–2007 (Tables A.1 to A.6 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)

Red and Red-necked Phalarope

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. 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 in 2005–2008 (Abgrall et al. 2008a, 2009). Phalaropes are expected to be scarce in the Study Area during May to October.

4.4.4.5 Laridae (Gulls and Terns)

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

Great black-backed, herring gull, Iceland, glaucous, and lesser black-backed gulls occur in the Study Area. Great black-backed gull and herring gull are widespread nesters on the North Atlantic including Newfoundland and Labrador. Glaucous and Iceland gulls breed in Subarctic 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.4 to A.6 in Appendix A). In the Orphan Basin, highest densities of great black-backed gull occurred in September (Tables A.1 to A.3 in Appendix A).

The ECSAS survey data from 2006–2009 in the Study Area shows 'large gulls' were present during all seasons (spring, summer, fall and winter) surveyed (Fifield et al. 2009). Densities within the Study Area (considering 1º survey blocks) were highest during the non-breeding season ranging from 0 to 7.1 birds/km^2 in spring and 0 to 3.8 birds/km^2 in winter. 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 between May and October showed that large gulls were most numerous from mid August to October (Tables A.4 to A.6 in Appendix A).

Black-legged Kittiwake

Black-legged kittiwake is an abundant species in the North Atlantic. 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 drilling 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 2004–2007 show black-legged kittiwake as being uncommon from mid May to September (Table A.1 to A.3 in Appendix A). The monthly average density during surveys from 14 May to 24 September 2005 was 0.3 birds/km^2 (Table A.1 in Appendix A). Higher densities were recorded in August and September 2006 with an average of 3.9 birds/km^2 (Table A.3 in Appendix A). The average density during the survey period of 23 July to 6 September 2007 was 0.01 birds/km^2 (Table A.3 in Appendix A). Results from monitoring programs in the Jeanne d'Arc Basin show an average of 0.01 birds/km^2 for July and August 2006, 0.02 birds/km^2 for late May to September 2008, and 6.6 birds/km^2 in October and early November 2005 (Table A.4 to A.6 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 10.2 birds/km^2 during the winter period (November to February), 0 to 5.8 birds/km^2 during the spring period (March and April), and 0 to 2.1 birds/km^2 during the summer period (May to August; Fifield et al. 2009).

Ivory Gull

Concerns over reduced numbers of ivory gulls at known breeding colonies in the Canadian Arctic have resulted in COSEWIC listing it as *endangered*; 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 Stercorariidae (Skuas and Jaegers)

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 from 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.1 to A.6 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 and Atlantic oceans. 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, 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 (Tables A.1 to A.3 in Appendix A) and Jeanne d'Arc Basin (Tables A.4 to A.6 in Appendix A). Jaegers are expected to be scarce in the Study Area from May to October or early November.

4.4.4.7 Alcidae (Dovekie, Murres, Black Guillemot, Razorbill and Atlantic Puffin)

There are six species of alcids breeding in the North Atlantic. All of these except for dovekie nest in large numbers in eastern Newfoundland (Table 4.8). Dovekies nest mainly in Greenland. Dovekie, common murre, thick-billed murre, and Atlantic puffin occur in the Study Area during part of the year. Black guillemot and razorbills are more coastal and are expected to be rare within the Study Area.

Dovekie

Dovekie breeds in the North Atlantic, primarily in Greenland and eastern 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 Northwest 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). The low numbers of dovekies observed from the drill platforms on the northeast Grand Banks 1999 to 2002 was attributed to the difficulty in seeing the small birds from the observation posts (Baillie et al. 2005).

During seismic monitoring programs on the Orphan Basin in 2005 there was a density of 1.3 birds/km^2 during the last two weeks of May (Table A.1 Appendix A). These were mostly birds flying north in late spring migration. Sightings were rare on the Orphan Basin monitoring programs between mid June and mid September (Table A.1 to A.3 in Appendix A).

During seismic monitoring programs on the Jeanne d'Arc Basin in 2005, 2006 and 2008, dovekies were most numerous in October with an average density of 6.6 birds/km^2 during the period of 1 October to 8 November 2005 (Table A.4 in Appendix A). Incidental observations of dovekies during these monitoring programs suggest larger numbers were present than the systematic surveys showed. For example, approximate daily totals from incidental observations were 500 on 3 October, 2,000 on 13 October, and 2,500 on 4 November (Abgrall et al. 2008a).

The ECSAS survey data from 2006–2009 for dovekie within the Study Area shows densities per 1º survey blocks ranging from 0 to 22.59 birds/km^2 during the spring period (March and April), 0 to 5.17 birds/km^2 during the summer (May to August) and 0 to 11.41 birds/km^2 during winter (November to February; 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 lumped as "murres" during offshore seabird surveys. Common Murre is an abundant breeding species in eastern Newfoundland with just over a half million pairs nesting. Most of these occur at two colonies, Funk Island (412,524 pairs) (Chardine et al. 2003) and the Witless Bay Islands (83,001 pairs) (Robertson et al. 2004) (Table 4.8). They spend the winter from eastern Newfoundland south to Massachusetts. Thick-billed murre is an uncommon breeder in eastern Newfoundland with about 2,000 pairs (Table 4.8). But Newfoundland waters are an important wintering area for many of the two million pairs breeding in Arctic Canada and Greenland.

The ECSAS survey data from 2006–2009 for murres within the Study Area shows densities per 1º survey blocks ranging from 0 to 6.65 birds/km^2 during the spring period (March and April), 0 to 6.39 birds/km^2 during summer (May to August) and 0 to 9.98 birds/km^2 during winter (November to February; Fifield et al. 2009).

During monitoring surveys on the Orphan Basin in 2005, 2006 and 2007 murres were present in low densities May to September (Table A.1 to A.3 in Appendix A). For example during the 14 May to 24 September 2005 surveys, average monthly densities for thick-billed murre were 0.6 birds/km^2 in May and 0.7 birds/km^2 in June, but there were none in July to September (Moulton et al. 2006). During the same survey, common murre densities were recorded as 0.05 birds/km^2 in May, 0.06 birds/km^2 in June, 0.14 birds/km^2 in July, and none were recorded during surveys in August and September.

On the Jeanne d'Arc Basin, murres were present in moderate densities during seismic monitoring from 1 October to 8 November 2005 with average densities for the period of 4.11 birds/km^2 for thick-billed murre and 0.81 birds/km^2 for common murre (Table A.4 to A.6 in Appendix A). Global location sensors deployed on 10 common murre during the breeding season at Funk Island showed the birds were present on the Grand Banks year-round particularly at the shelf edge (Hedd et al. 2011). All 10 birds were present on the Jeanne d'Arc Basin area in November and December. This indicates the source of some of the murres on the northern Grand Banks.

Other Alcids (Atlantic Puffin, Razorbill and Black Guillemot)

There are more than 310,000 pairs of Atlantic puffin nesting in eastern Newfoundland (Table 4.8). 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. Seabird surveys during monitoring seismic operations in 2004-2008 conducted within the period mid May to late September on the Orphan Basin and Jeanne d'Arc Basin recorded very low densities of Atlantic puffins (Table A.1 to A6 in Appendix A). During monitoring of the seismic survey of Jeanne d'Arc Basin 1 October to 8 November 2005 there was an average density of 1.46 birds/km^2 (Table A.4 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).

About 38,000 pairs of razorbills nest in eastern Canada (Chapdelaine et al. 2001). Fewer than 2,000 pairs nest in eastern Newfoundland (Table 4.8). Razorbills tend to occur closer to shore than the murres. Very few were recorded during monitoring programs on the Orphan Basin and Jeanne d'Arc Basin 2004–2008 between mid May and early November (Table A.1 to A6 in Appendix A). Razorbill is expected to be very scarce in the Study Area from April to November and absent from December to March (Table 4.7). Black guillemot is common nearshore 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.

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	1-2
Greater Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	Usually <2, recorded maximum of 18.
Sooty Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	Usually <10, maximum recorded 60.
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); Ronconi (2010a,b).

4.4.5.1 Procellariidae (Fulmars 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 deeper 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 resting position on the surface.

4.4.5.2 Hydrobatidae (Storm-petrels)

Leach's and Wilson's storm-petrels 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 feed on cephalopods and small fish such as capelin, mackerel, herring and Atlantic saury. They secure prey in a 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 the surface.

4.4.5.5 Laridae (Gulls and Terns)

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 feeds from the wing over water, dip feeding for small fish and invertebrates on the surface. It occasionally plunge dives so that the entire body may be submerged momentarily. It also swims and picks at the surface of the water and walks on ice to scavenge animal remains.

Black-legged kittiwake feeds on a variety of invertebrates and small fish. Capelin is an important part of their diet when available. It feeds by locating prey from the wing then dropping to the water's surface and plunge-diving. The body may be submerged very briefly. It also swims and picks at small invertebrates near the surface.

Arctic tern feeds on small fish and invertebrate that it catches from the wing with a shallow plunge-dive. The entire bird rarely goes beneath the surface. It rarely rest on the water.

4.4.5.6 Stercorariidae (Skuas and Jaegers)

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

4.4.5.7 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. It 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 recorded diving to 50 m spending a maximum of 147 seconds under water. Average depth and duration of dives is expected to be less (Gaston and Jones 1998). Atlantic puffin dives 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). 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. 2005a, 2006; Abgrall et al. 2008a,b, 2009). 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 (Buchanan et al. 2004; Moulton et al. 2005b; LGL 2005, 2009), Jeanne d'Arc Basin (LGL 2008a, 2011a), and the northern Grand Banks (LGL 2011b) 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 seismic monitoring programs.

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 LGL (2008a; Table 4.14). 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. Thus, Waring et al. (2011) was reviewed to acquire updated population estimates for cetaceans considered a part of the Western North Atlantic stock.

Table 4.10 Marine Mammals Known or Expected to Occur in the Study Area.

Common Name	Study Area: Occurrence	Study Area: Season	Habitat	SARA Status [a]	COSEWIC Status [b]
Baleen Whales (Mysticetes)					
Blue whale (*Balaenoptera musculus*)	Rare	Year-round but mostly spring to summer	Coastal, pelagic	Schedule 1: E	E
North Atlantic right whale (*Eubalaena glacialis*)	Extremely Rare	Summer?	Coastal, shelf	Schedule 1: E	E
Fin whale (*B. physalus*)	Common	Year-round but mostly summer	Pelagic, slope	Schedule 1: SC	SC
Sei whale (*B. borealis*)	Uncommon	May - Sept.	Pelagic, offshore	NS	DD
Humpback whale (*Megaptera novaeangliae*)	Common	Year-round but mostly May - Oct.	Coastal, banks	Schedule 3: SC	NAR
Minke whale (*B. acutorostrata*)	Common	Year-round but mostly May - Oct.	Shelf, banks, coastal	NS	NAR
Toothed Whales (Odontocetes)					
Sperm whale (*Physeter macrocephalus*)	Uncommon to Common	Year-round but mostly summer	Pelagic, slope, canyons	NS	NAR; LPC
Northern bottlenose whale (*Hyperoodon ampullatus*)[c]	Uncommon	Year-round?	Pelagic, slope, canyons	NS	SC
Sowerby's beaked whale (*Mesoplodon bidens*)	Rare	Summer?	Pelagic, deep slope, canyons	Schedule 1: SC	SC
Killer whale (*Orcinus orca*)	Rare	Year-round but mostly June-Oct.	Widely distributed	NS	SC
Long-finned pilot whale (*Globicephala melas*)	Common	May - Sept.	Mostly pelagic	NS	NAR
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Common	Year-round but mostly June-Oct.	Shelf, slope	NS	NAR
Short-beaked common dolphin (*Delphinus delphis*)	Common	Summer-fall	Nearshore, pelagic	NS	NAR
White-beaked dolphin (*L. albirostris*)	Uncommon	Year-round but mosty June-Sept.	Shelf	NS	NAR
Common bottlenose dolphin (*Tursiops truncatus*)	Rare	Summer?	Shelf, coastal, pelagic (occasionally)	NS	NAR
Striped dolphin (*Stenella coeruleoalba*)	Uncommon	Summer?	Offshore convergence zones and upwellings	NS	NAR
Harbour porpoise (*Phocoena phocoena*)	Uncommon	Year-round but mostly spring to fall	Shelf, coastal, pelagic (occasionally)	Schedule 2: T	SC
True Seals (Phocids)					
Harp seal (*Pagophilus groenlandicus*)	Common	Year-round	Pack ice and pelagic	NS	NC; MPC
Hooded seal (*Cystophora cristata*)	Common	Year-round	Pack ice and pelagic	NS	NAR; MPC
Grey seal (*Halichoerus grypus*)	Rare	Year-round	Coastal and continental shelf	NS	NAR

Notes: E=Endangered, T=Threatened, SC=Special Concern, NAR=Not at Risk, NC=Not Considered, DD=Data Deficient, NS=No Status, LPC=Low Priority Candidate, MPC=Medium Priority Candidate. ? indicates uncertainty.
[a] www.sararegistry.gc.ca/default_e.cfm, accessed November 2011.
[b] www.cosewic.gc.ca/eng/sct5/index_e.cfm, accessed November 2011.
[c] Davis Strait population.

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 4.32), large toothed whales (Figure 4.33), and dolphins and porpoises (Figure 4.34). These data are summarized in Table 4.11.

Table 4.11 Cetacean Sightings within the Study Area, 1961 to 2009.

Species	Number of Sightings	Minimum Number of Individuals	Months Observed
Mysticetes			
North Atlantic Right Whale	1	2	June
Humpback Whale	257	740	Year round
Fin Whale	54	110	May-Oct
Fin/Sei Whale	14	19	Jul-Sep
Sei Whale	25	40	May-Sep
Minke Whale	45	57	Jan; Apr-Dec
Large Odontocetes			
Sperm Whale	106	196	Year round
Killer Whale	15	67	May-Aug; Oct-Nov
Long-finned Pilot Whale	190	3,630	Jan-Mar; May-Dec
False Killer Whale[a]	1	2	Jun
Northern Bottlenose Whale	11	39	May-Sep
Sowerby's Beaked Whale	1	4	Sep
Beluga[b]	1	1	Jul
Delphinids			
Common Bottlenose Dolphin	1	15	Sep
Short-beaked Common Dolphin	17	253	Mar; Jul-Oct
Atlantic White-sided Dolphin	29	351	Feb; May-Oct
White-beaked Dolphin	14	88	Mar; May-Aug
Striped Dolphin	3	15	Aug
Harbour Porpoise	23	177	Mar; May-Oct
Unidentified Cetaceans			
Unidentified Baleen Whale	25	39	May-Sep
Unidentified Toothed Whale	2	13	Jul-Aug
Unidentified Dolphin	141	2325	Jan-Nov
Unidentified Cetacean	260	474	Year round

[a] extralimital record. [b] dead.

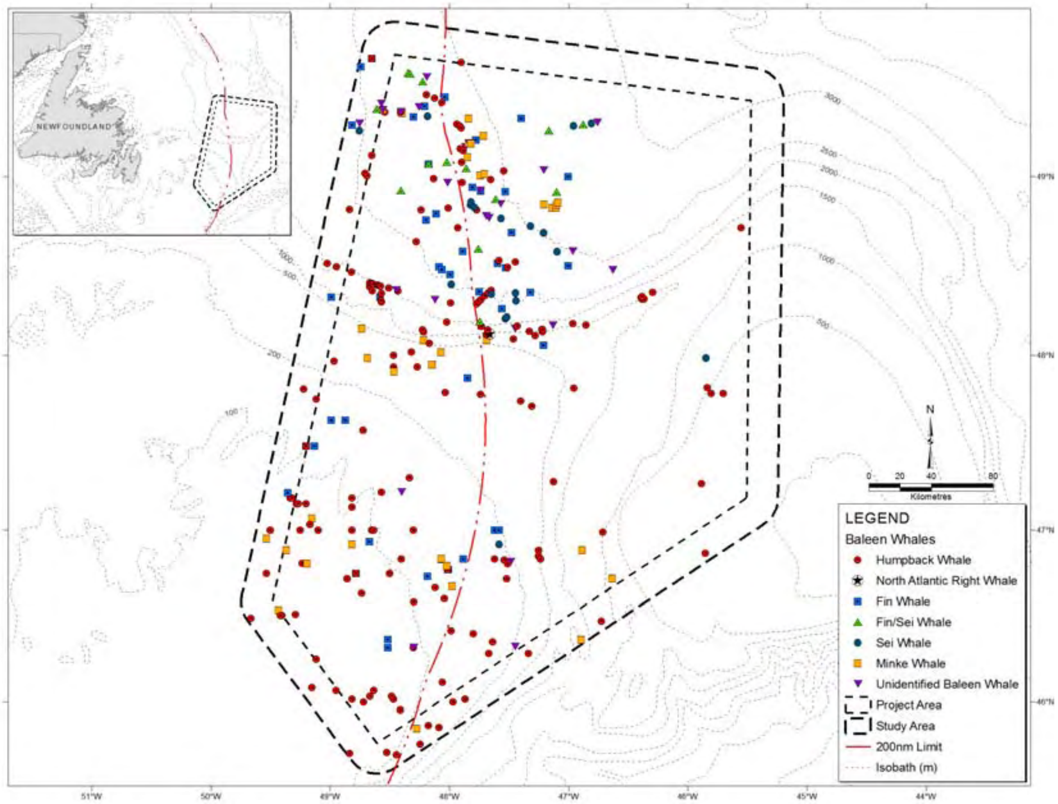


Figure 4.32 Baleen Whale Sightings in the Study Area.

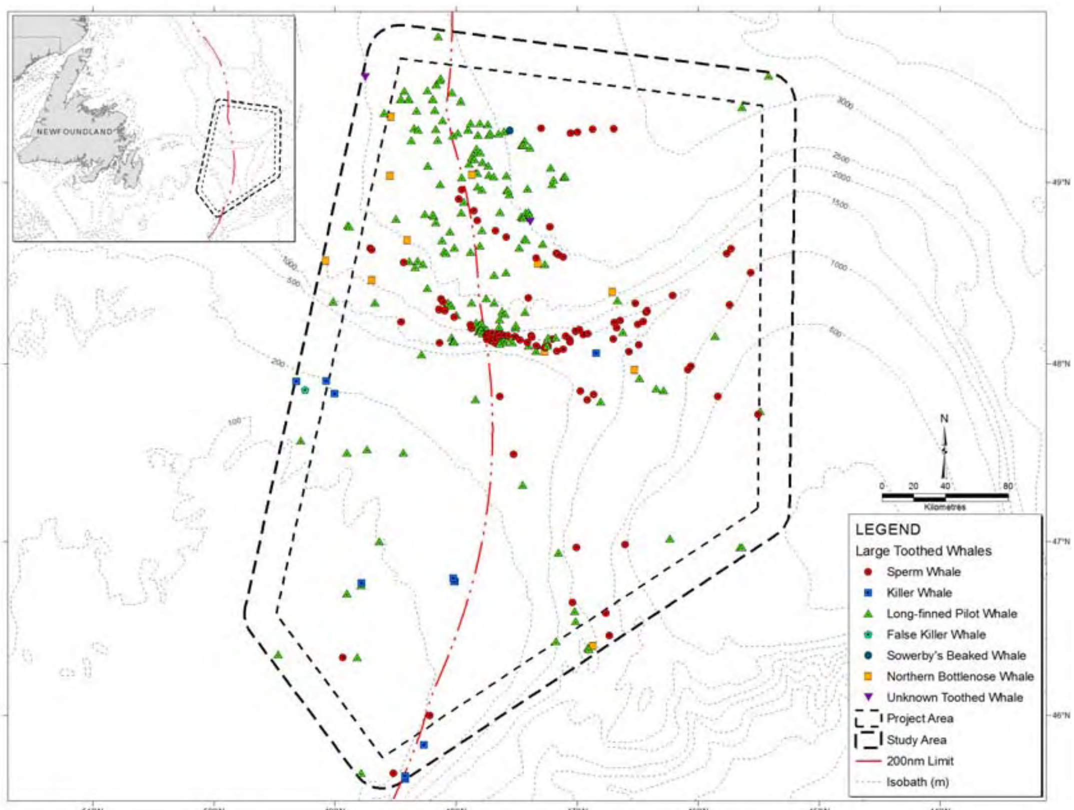


Figure 4.33 Large Toothed Whale Sightings in the Study Area.

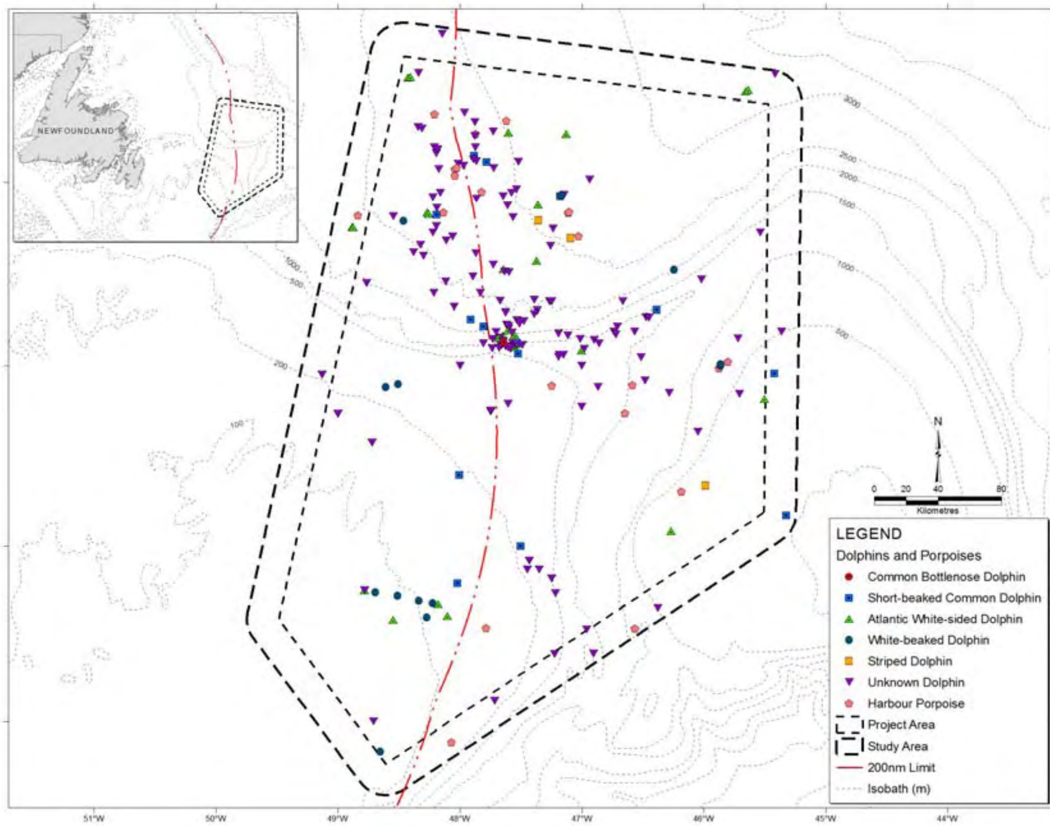


Figure 4.34 Dolphin and Porpoise Sightings in the Study Area.

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.

Fin Whale

The Atlantic population of fin whale is currently designated as *special concern* under Schedule 1 of *SARA* and by COSEWIC (Table 4.10). 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 Northwest Atlantic stock is 3,985 individuals (CV = 0.24; Waring et al. 2011). 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 in the Study Area (Figure 4.32) from May to October (Table 4.11). Fin whales were commonly observed in Orphan Basin during the 2004 and 2005 seismic monitoring programs (Moulton et al. 2005a,b, 2006) and were also sighted during the Statoil/Husky seismic monitoring program in Jeanne d'Arc Basin (Abgrall et al. 2009). 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 North 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 North Atlantic have been described using genetic and individual identification data as the Gulf of Maine eastern Canada, west Greenland, and the Northeast 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 (Figure 4.32; 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 estimate of abundance for the Nova Scotia stock of sei whales is 386 (CV=0.85; Waring et al. 2011). Satellite telemetry data showed that sei whales migrated from the southeast North Atlantic to the Labrador Sea, suggesting a productive feeding ground for sei whales in that area (Olsen et al. 2009; Prieto et al. 2010). One of the tagged individuals spent up to 96 h near the northwest corner of the Study Area en route to the Labrador Sea (Prieto et al. 2010). Sei whales were regularly sighted in the Orphan Basin during the seismic monitoring programs in 2004 and 2005 (6 and 15 sightings, respectively; Moulton et al. 2005a,b, 2006), and one sei whale sighting was recorded in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009). Based on the DFO cetacean sightings database, at least 25 sei whale sightings have been reported in the Study Area (Figure 4.32; 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 North Atlantic based on feeding areas, including the Canadian east coast, west Greenland, central

North Atlantic, and Northeast Atlantic stocks (Donovan 1991). However, DNA data suggest that there may be as few as two different stocks in the North Atlantic (Anderwald et al. 2011). There are an estimated 8,987 individuals (CV=0.32) in the Canadian east coast stock, which ranges from the continental shelf of the northeastern United States to the eastern half of Davis Strait (Waring et al. 2011). 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 third most commonly recorded mysticete in the DFO sightings database, with sightings predominantly recorded during summer months (Table 4.11). Thirty-one sightings of minke whales were recorded in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009). 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. (2011) reported an estimate of 4,804 animals (CV=0.38) for the North 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. 2005a,b, 2006; Abgrall et al. 2008b) but were not observed in the shallower waters of Jeanne d'Arc Basin in 2005-2008 (Lang et al. 2006; Lang and Moulton 2008; Abgrall et al. 2008a, 2009). There are 106 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 North 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 2002a; DFO 2011h). The total abundance of northern bottlenose whales in the North Atlantic is unknown, but ~163 individuals comprise the Scotian Shelf population (Whitehead and Wimmer 2005). There is no abundance estimate for Davis Strait, and few sightings were made during recent surveys (DFO 2011h). 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 *special concern* by COSEWIC. The proposed recovery target for northern bottlenose whales is to increase population size and maintain the current distribution (DFO 2011h). Although the stock origin of northern bottlenose whales off Newfoundland and Labrador is unknown (DFO 2011h), it is expected that 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 between April and June, with a peak in April (COSEWIC 2002a; DFO 2011h). Occurring primarily in deep waters over canyons and the shelf edge, northern bottlenose whales routinely dive to depths over 800 m and remain submerged for over an hour (Hooker and Baird 1999). Foraging apparently occurs at depth, primarily on deep-water squid and fish (COSEWIC 2002a; DFO 2011h). Northern bottlenose whales may occur at low densities, but year-round, throughout the deep, offshore waters of the Orphan Basin and the Flemish Pass area. Based on the DFO cetacean sightings database, there have been 11 sightings of northern bottlenose whales in the deeper waters of the Study Area (Figure 4.33) from May to September (Table 4.11). This species is not expected to occur in the shelf waters of the Study Area.

<u>Sowerby's Beaked Whale</u>

The Sowerby's beaked whale is a small beaked whale found only in the North Atlantic, primarily in deep, offshore temperate to subarctic waters (COSEWIC 2006a). Designated as *special concern* (Schedule 1) 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 Northwest Atlantic between New England and Labrador (MacLeod 2000; MacLeod et al. 2006). There are an unknown number of Sowerby's beaked whales in the North Atlantic, but they are occasionally encountered offshore of eastern Newfoundland and Labrador. They are most often observed in deep water, along the shelf edge and slope. Based on analysis of stomach contents, their main prey type appears to be mid to deep-water fish, with squid making up a small portion of the diet (MacLeod et al. 2003; Pereira et al. 2011). Despite the paucity of confirmed sightings, Sowerby's beaked whales may occur in low densities in deep areas in the Study Area. Based on the DFO cetacean sightings database, there has been one sighting of four Sowerby's beaked whales in the Study Area (Figure 4.33) in September (Table 4.11).

<u>Killer Whale</u>

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 Northwest Atlantic, but at least 63 individuals have been identified in Newfoundland and Labrador (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 Newfoundland and Labrador, 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). Stable isotope analysis of samples from seven killer whales suggests that killer whales off Newfoundland and Labrador mainly feed on fish, although one individual was found to have fed mostly on baleen whales (Matthews and Ferguson 2011). 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 Newfoundland and Labrador (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 15 killer whale sightings in the Study Area (Figure 4.33). Sightings in the DFO cetacean sightings database occurred from May through November (Table 4.11). Four sightings of killer whales were recorded in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009).

Long-finned Pilot Whale

The long-finned pilot whale is widespread in the North 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 4.9). An estimated 12,619 individuals (CV=0.37) occur in the Northwest Atlantic (Waring et al. 2011). 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 >600 m deep in the Study Area (Figure 4.33). Pilot whales studied near Nova Scotia had 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 North Atlantic (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (Table 4.9). There may be at least three distinct stocks in the North 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 Northwest Atlantic (Waring et al. 2011). However, their abundance off Newfoundland and Labrador 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 North Atlantic seem to coincide with the 100 m depth contour and areas of high relief; there were 29 sightings in the DFO cetacean sightings database (Figure 4.34; Table 4.11). 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 4.9). An estimated 120,743 individuals (CV=0.23) occur in the Northwest Atlantic (Waring et al. 2011). There were 17 sightings of this species recorded in the Study Area in the DFO database (Table 4.11); most sightings were in waters >500 m deep (Figure 4.34).

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 North Atlantic (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (Table 4.9). Waring et al. (2011) estimated a total of 2003 individuals (CV=0.94) in the Northwest 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 14 sightings recorded in the Study Area (Table 4.11) in both shelf and slope waters (Figure 4.34) 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 is 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 Northwest Atlantic (Waring et al. 2011). 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 Chevron's 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 Northwest Atlantic (Waring et al. 2011). There were only three sightings of this species recorded in the Study Area based on the DFO cetacean database; all sightings 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 Northwest Atlantic (Jefferson et al. 2008). There are at least three populations recognized in the Northwest 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 Newfoundland and Labrador. 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 as far north as Nain, and in deep water (>2,000 m) in the Newfoundland Basin and Labrador Sea (Stenson and Reddin 1990 *in* COSEWIC 2006b; Stenson et al. 2011). 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 23 harbour porpoise sightings in the Study Area in the DFO cetacean sightings database (Table 4.11; Figure 4.34).

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 Northwest Atlantic population is estimated at 6.85 million seals in 2009 (Hammill and Stenson 2010). Harp seals are common during late winter/early spring off northeast Newfoundland and southern Labrador where they congregate to breed and pup on the pack ice; the majority of the Northwest Atlantic population uses this region while the small remainder uses the Gulf of St. Lawrence (Lavigne and Kovacs 1988). Large concentrations are found on the sea ice off northeastern Newfoundland where they moult during April and May (DFO 2010e). During the summer, the majority of harp seals migrate to Arctic and Greenland waters, but some harp seals remain in southern waters (DFO 2010f). Offshore areas of southern Labrador and eastern Newfoundland appear to be major wintering areas (Stenson and Sjare 1997; Lacoste and Stenson 2000). Off Newfoundland and Labrador, 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 North 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 North Atlantic and include northeast Newfoundland/southern Labrador, the Gulf of St. Lawrence, Davis Strait, and northeast Greenland (Jefferson et al. 2008). Hooded seals fitted with transmitters in the Gulf of St. Lawrence in March started their migration to Greenland in May by traveling through Cabot Strait or the Strait of Belle Isle (Bajzak et al. 2009). 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 and in the Study Area; 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 North Atlantic, ranging in Canada from Nova Scotia to Labrador (Jefferson et al. 2008). An estimated 348,900 grey seals occur in the Northwest Atlantic (Thomas et al. 2011). The majority breed during the winter on Sable Island, south of Nova Scotia, but pups are also born in the Gulf of St. Lawrence, and along the coast of Nova Scotia (DFO 2010f). An unknown number range into eastern Newfoundland and Labrador. 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 Study Area.

Species	Project Area		*SARA* Status[a]	COSEWIC Status[b]	Activities	Habitat
	Occurrence	Timing				
Leatherback sea turtle	Rare	June to Nov	Schedule 1: E	E	Feeding	Open water, bays
Loggerhead sea turtle	Very rare	Summer	NS	E	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*; E = Endangered, 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 2010g). 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 (e.g., Mansfield et al. 2009). Although they have not been reported in the Study Area, juvenile loggerhead turtles tagged in U.S. waters were recorded just south of the Study Area (Mansfield et al. 2009). 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 three 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 wolfish, the Atlantic population of fin whales, and Sowerby's beaked whale 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. 2008), (3) the northern wolffish (Kulka et al. 2007), (4) the blue whale (Beauchamp et al. 2009), and (5) the North Atlantic right whale (Brown 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.

WesternGeco will monitor *SARA* issues through the Canadian Association of Petroleum Producers (CAPP), the law gazettes, the Internet and communication with DFO and Environment Canada, 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.

WesternGeco 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. WesternGeco 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

Only those marine species that are listed under Schedule 1 of the *SARA* as either *endangered* or *threatened* are profiled in this subsection.

4.6.1.1 Fish

Only three fish species are listed under Schedule 1 of the *SARA* as either *endangered* or *threatened*. 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.

Table 4.13 *SARA*- 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 (Atlantic pop.)	*Balaenoptera musculus*	Schedule 1			X		
North Atlantic right whale	*Eubalaena glacialis*	Schedule 1			X		
Fin whale (Atlantic pop.)	*Balaenoptera physalus*			Schedule 1			X
Sowerby's beaked whale	*Mesoplodon bidens*			Schedule 1			X
Harbour porpoise	*Phocoena phocoena*		Schedule 2				X
Humpback whale	*Megaptera novaeangliae*			Schedule 3			
Killer whale	*Orcinus orca*						X
Northern bottlenose whale (Davis Strait pop.)	*Hyperoodon ampullatus*						X
Sea Turtles							
Leatherback sea turtle	*Dermochelys coriacea*	Schedule 1			X		
Loggerhead sea turtle	*Caretta caretta*				X		
Fish							
White shark	*Carcharodon carcharias*	Schedule 1			X		
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 pop.)	*Gadus morhua*				X		
Porbeagle shark	*Lamna nasus*				X		
Roundnose grenadier	*Coryphaenoides rupestris*				X		
Cusk	*Brosme brosme*					X	
Shortfin mako shark	*Isurus oxyrinchus*					X	
American plaice (Newfld. pop.)	*Hippoglossoides platessoides*					X	
Atlantic salmon (South Newfdl. pop.)	*Salmo salar*					X	
Acadian redfish (Atlantic pop.)	*Sebastes fasciatus*					X	
Deepwater redfish (Northern pop.)	*Sebastes mentella*					X	
Blue shark	*Prionace glauca*						X
Basking shark (Atlantic pop.)	*Cetorhinus maximus*						X
Spiny dogfish	*Squalus acanthis*						X
Roughead grenadier	*Macrourus berglax*						X
Birds							
Ivory gull	*Pagophila eburnea*	Schedule 1			X		

Sources: [a] *SARA* website (http://www.sararegistry.gc.ca/default_e.cfm) (as of 22 November 2011); [b] COSEWIC website (http://www.cosewic.gc.ca/index.htm) (as of 22 November 2011); COSEWIC candidate species not included. Pop. = population; Newfld. = Newfoundland; NL = Newfoundland and Labrador.

White Shark

The white shark is known worldwide for its large size, predatory nature and reputation for attacking humans. Worldwide, this species is rare but does occur with some predictability in certain areas. The white shark is widely distributed in sub-polar to tropical seas of both hemispheres, but it is most frequently observed and captured in inshore waters over the continental shelves of the Northwest Atlantic, Mediterranean Sea, southern Africa, southern Australia, New Zealand, and the eastern North Pacific. The species is not found in cold polar waters (*SARA* website accessed January 2012).

Off Atlantic Canada, the white shark has been recorded from the northeast Newfoundland Shelf, the Strait of Belle Isle, the St. Pierre Bank, Sable Island Bank, the Forchu Misaine Bank, in St. Margaret's Bay, off Cape La Have, in Passamaquoddy Bay, in the Bay of Fundy, in the Northumberland Strait, and in the Laurentian Channel as far inland as the Portneuf River Estuary. The species is highly mobile, and individuals in Atlantic Canada are likely seasonal migrants belonging to a widespread Northwest Atlantic population. It occurs in both inshore and offshore waters, ranging in depth from just below the surface to just above the bottom, down to a depth of at least 1,280 m (*SARA* website accessed January 2012).

In reproduction, the female produces eggs which remain in her body until they are ready to hatch. When the young emerge, they are born live. Gestation period is unknown, but may be about 14 months. Litter size varies, with an average of 7 pups. Length at birth is assumed to be between 109 and 165 cm. Possible white shark pupping areas on the west and east coasts of North America include off southern California and the Mid-Atlantic Bight, respectively (*SARA* website accessed January 2012).

White sharks are an apex predator with a wide prey base feeding primarily on many types of fish, and marine mammals, as well as squid, molluscs, crustaceans, marine birds, and reptiles. There has, however, been one recorded occurrence of a killer whale preying on a white shark (*SARA* website accessed January 2012).

Northern Wolffish

The northern wolffish is a deepwater fish of cold northern seas that has been caught at depths ranging from 38 to 1,504 m, with observed densest concentrations between 500 and 1,000 m at water temperatures of 2 to 5°C. During 1980–1984, this species was most concentrated on the northeast Newfoundland and Labrador 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 2006–2010, 125 northern wolffish were caught, during both spring and fall survey times. Northern wolffish catches were most concentrated in the eastern portion of the Study Area (see Figure 4.8 in Section 4.2.6 of this EA).

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 1,046 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 wolfish reproduction includes internal fertilization; in Newfoundland and Labrador waters, this typically occurs in July and August on stony bottom. 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 2006–2010, 162 spotted wolffish were caught, during both spring and fall survey times. Spotted wolffish catches were most concentrated in the central and northwestern portions of the Study Area where water depths were less than at the primary catch locations of northern wolffish (see Figure 4.8 in Section 4.2.6 of this EA).

4.6.1.2 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 south-eastern 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 (COSEWIC 2008; IUCN 2011).

In comparison to most gulls, ivory gulls have reduced reproductive output, in that they usually only lay one to two eggs (Haney and MacDonald 1995). They depart from colonies immediately following breeding 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 2006c). 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 recorded a decrease in ivory gull observations as compared to 1978 results. Numbers of ivory gulls observed per 10-minute watch period were 0.69 and 0.02 individuals for 1978 and 2004, respectively (COSEWIC 2006c). 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 northern Grand Banks in the Study Area, late in the winter or early spring when sea ice reaches the maximum southern extremity. The 30-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. A total of 21 ivory gulls reported from drill platforms on the northeast Grand Banks during 1999 to 2002, seems improbable, especially considering that most sightings were reported during ice-free periods (Baillie et al. 2005). Ivory gull is reported regularly along the coast of Labrador and the tip of the Great Northern Peninsula of Newfoundland in winter (Stenhouse 2004). There are occasional sightings of ivory gulls south along the east coast of Newfoundland. It is expected to be very rare in the Study Area.

4.6.1.3 Marine Mammals

North Atlantic Right Whale

Research results suggest the existence of six major habitats or congregation areas for Northwest 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. 2011). The North Atlantic right whale is currently listed as *endangered* on Schedule 1 of *SARA* and by COSEWIC (Table 4.12; COSEWIC 2003a). Waring et al. (2011) suggest that the current best estimate of the minimum population size is 361 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 (Figure 4.29; on 27 June 2003 during a PAL reconnaissance survey (J. Lawson, DFO, pers. comm.).

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 North 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 Northwest 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 Northwest Atlantic and have been sighted only sporadically off the northeast coast of Newfoundland (COSEWIC 2002b). There were no sightings of blue whales in the Study Area in the DFO cetacean sightings database. During a monitoring program in 2007 for a controlled source electromagnetic (CSEM) survey in Orphan Basin, there were two sightings of blues whales in the Study Area; they occurred in August-September in water depths of 2,366 m and 2,551 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.

4.6.1.4 Sea Turtles

<u>Leatherback Turtle</u>

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. The 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 North 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.). One leatherback turtle was recorded just south of the Study Area in August 2007. There was also a sighting of a leatherback turtle in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009).

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. The *Oceans Act* Marine Protected Areas are established by DFO to protect and conserve important fish and marine mammal habitats, *endangered* marine species, unique features and areas of high biological productivity or biodiversity. Migratory birds, including species at risk, are solely or jointly managed (depending on the species) between Canada and the U.S. 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. The 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. The 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).

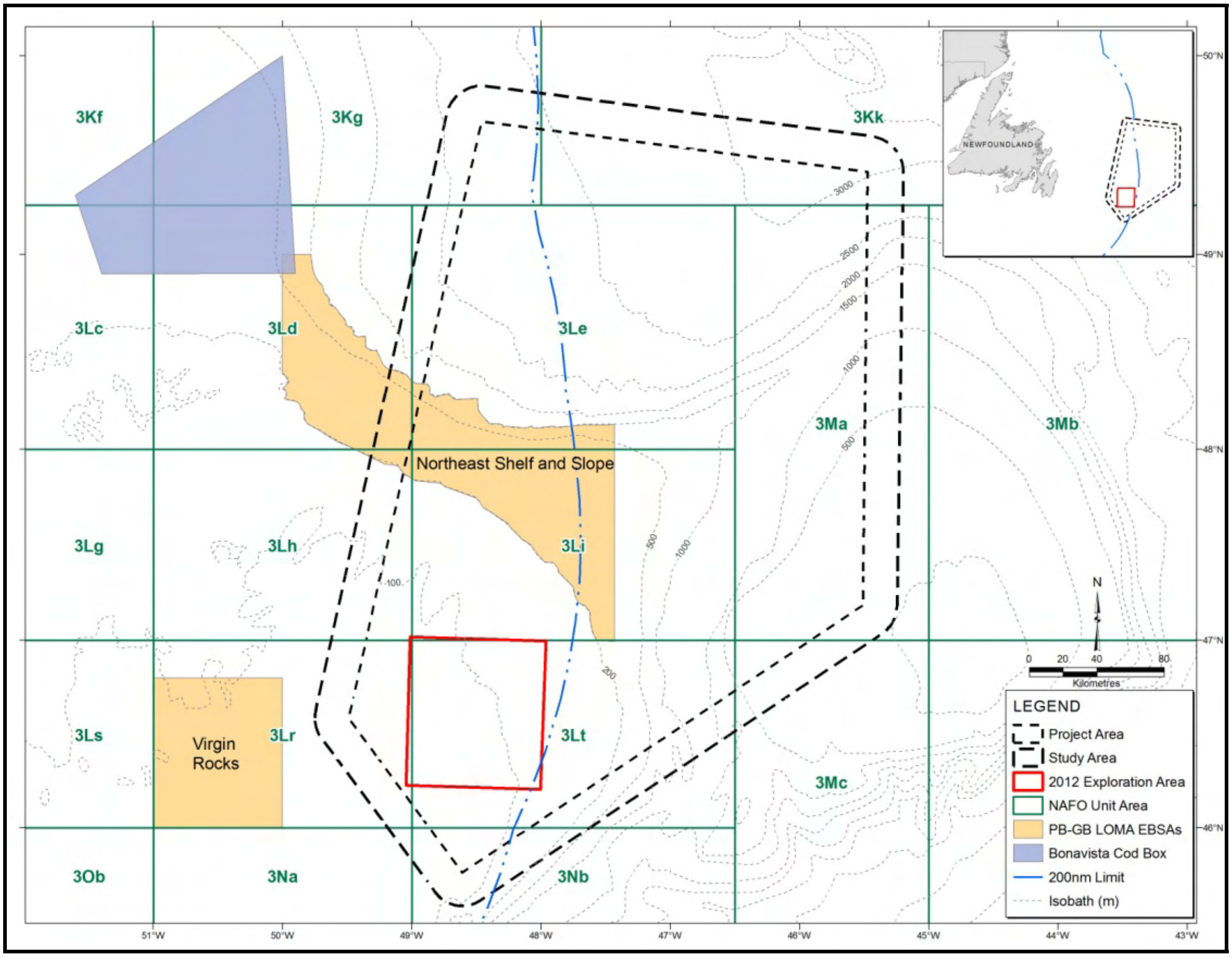
The PBGB LOMA has been recognized by DFO as one of five priority LOMAs in Canada. The PBGB LOMA Committee comprises a group of stakeholders partnering for the sustainable use and development of coastal and ocean resources within the LOMA. DFO Newfoundland and Labrador Region has identified 11 Ecologically and Biologically Significant Areas (EBSAs) within the PBGB LOMA as potential Areas of Interest (AOIs) for Marine Protected Area (MPA) designation, one of which overlaps the Study Area, namely the Northeast Shelf and Slope EBSA (Figure 4.35). This EBSA overlaps the west-central portion of the Study Area and includes an edge of the Shelf and Slope area down to the 1,000 m isobaths at the Nose of the Grand Bank (DFO 2007a,b). The Study Area also occurs within 20 km of the Virgin Rocks EBSA.

The Northeast Shelf and Slope EBSA have 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.

The *Oceans Act* provides the Minister of Fisheries and Oceans with a leadership role for coordinating the development and implementation of a federal network of MPAs, which can include areas within and outside of the Integrated Management (IM) area that have yet to be developed within the Region.

Therefore, there remains potential for further identification of EBSAs, AOI, MPAs and other sensitive areas within the Study Area.



Source: DFO 2007a.

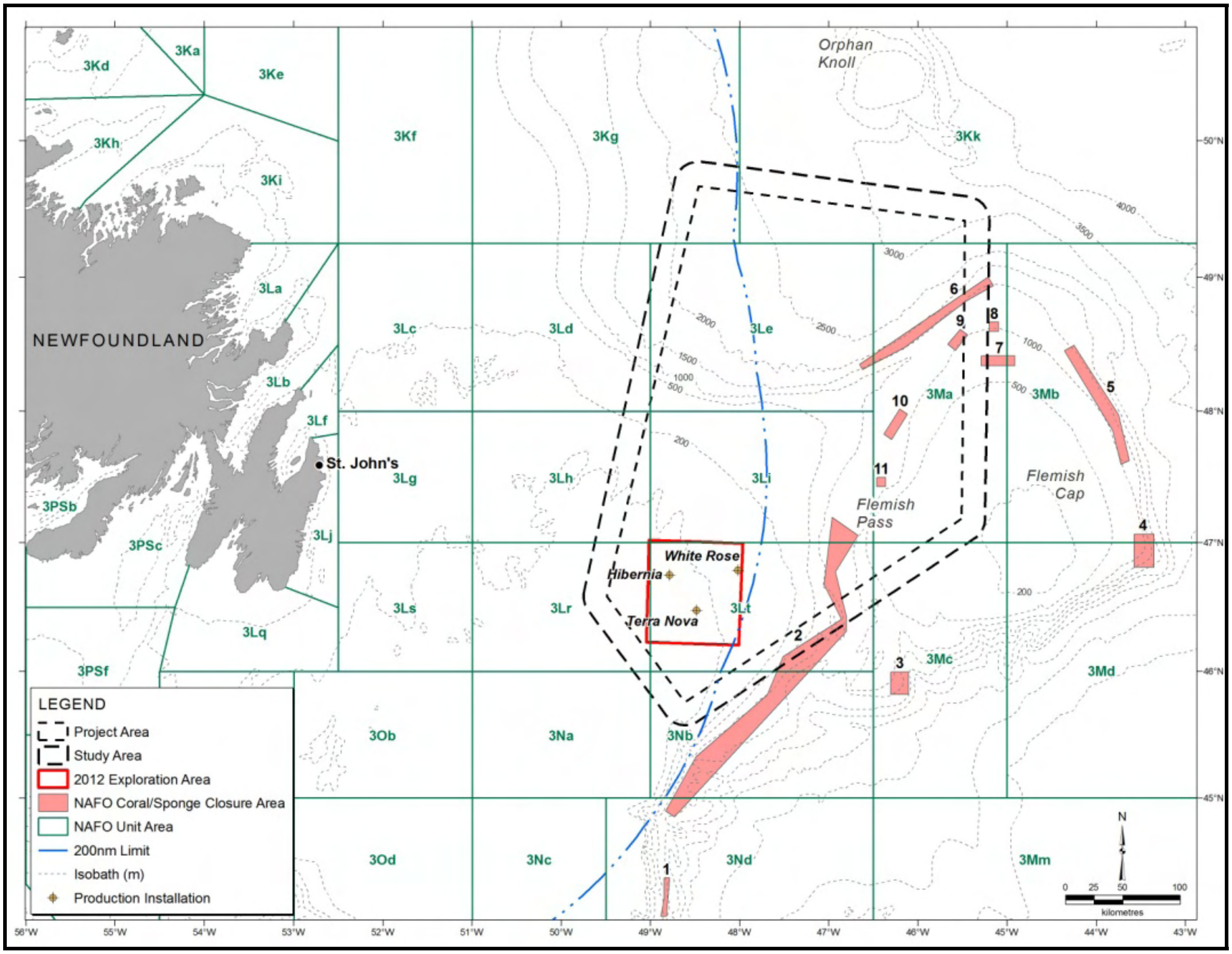
Figure 4.35 Locations of the PBGB LOMA EBSAs and Bonavista Cod Box Relative to the WesternGeco Project Area, Study Area, and 2012 Exploration Area.

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 80 km northwest of the Study Area (Figure 4.35).

4.7.3 Coral and Sponge Areas

In 2008 and 2009, the NAFO Scientific Council identified areas of significant coral and sponge concentrations within the NAFO Regulatory Area. Based on these identifications, areas for closure to fishing with bottom contact gear were delineated. Figure 4.36 shows the locations of these 11 areas, six of which occur either entirely or partially within the proposed WesternGeco Study Area, and one other closure area which is located at the boundary of the Study Area. Implementation date of the closures started on 1 January 2010 (NAFO website). Given the nature of seismic surveys, survey equipment is not expected to come in contact with the corals and sponges.



Source: NAFO 2011.

Figure 4.36. Locations of NAFO Coral/Sponge Closure Areas Relative to WesternGeco's Proposed Study Area, Project Area and 2012 Exploration 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 represented by VECs as described below in Section 5.2.

Methods of effects assessment used here are comparable to those used in recent east coast offshore drilling (e.g., LGL 2005, 2008b) and seismic EAs (e.g., LGL 2008a). 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 21 December 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 2008a), exploration and drilling EAs and their amendments for Orphan Basin (Buchanan et al. 2004; LGL 2005, 2006a, 2009), and Chevron's Labrador offshore seismic EA (LGL 2010). Reviews of present state of knowledge were also conducted.

In preparing the EA report for WesternGeco's proposed geophysical program in 2012–2015, consultations were undertaken with relevant government agencies, representatives of the fishing industry and other interest groups. The purpose of these consultations was to describe WesternGeco's proposed seismic program, to identify any issues and concerns, and to gather any additional information relevant to the EA. A summary of the results of these consultations is provided in the following subsection

5.1.1 Consultations

During preparation of the environmental assessment (EA) of WesternGeco's proposed 2012-2015 Jeanne d'Arc Basin Seismic Program, consultations were undertaken with relevant government agencies, representatives of the fishing industry and other interest groups. The objectives of these consultations were to describe the proposed seismic program, identify any issues and concerns, and gather additional information relevant to the EA.

A short description of the proposed program, including location map and species harvesting location maps, were sent to the relevant agencies and industry stakeholder groups in mid-January 2012. They were asked to review this information, provide any comments on the proposed activities and to indicate whether or not they would like to meet to discuss the proposed program in more detail.

Consultations for the proposed 2012-2015 seismic program were undertaken with the following agencies, stakeholders and interest groups:

- Fisheries and Oceans Canada (DFO)
- Environment Canada (EC)
- Nature Newfoundland and Labrador (NNL) (and various member organizations)
- One Ocean
- Fish, Food and Allied Workers Union (FFAW) and fleet representatives
- Association of Seafood Producers (ASP)
- Ocean Choice International (OCI)
- Groundfish Enterprise Allocation Council (GEAC) Ottawa
- Clearwater Seafoods
- Icewater Fisheries
- Newfound Resources Ltd. (NRL)

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

5.1.1.1 Issues and Concerns

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

Fisheries and Oceans Canada

The DFO EA and Major Projects' manager did not have any significant concerns about the proposed seismic program. He noted that DFO's guidance on seismic programs is based upon the "*Statement of Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*" (*SOCP*) to protect fish (including marine mammals), *SARA* species and fisheries. As such, mitigations from the *SOCP* and updated fisheries and *SARA* information should be incorporated into the EA. Additionally, coordination with DFO research vessel activities should be documented, with respect to its ongoing concern about potential effects of seismic operations on research surveys.

Environment Canada

Environment Canada managers did not have any particular concerns or questions about the proposed seismic program, and did not think it was necessary to meet with WesternGeco representatives and their consultants.

Nature Newfoundland and Labrador (NNL)

At the meeting with a representative of NNL, Dr. Len Zedel, WesternGeco provided more detailed information about the proposed 2012-2015 seismic program. NNL's representatives did not raise any particular concerns about the proposed program. However, Dr. Zedel reiterated a point he has raised in previous seismic program consultations regarding the possibility of collecting oceanographic "meta data" (e.g., information on water salinity and temperature) from the survey vessel. He explained the importance and usefulness of such data, and encouraged the proponent to make this information available to independent researchers. He said that he would be pleased to provide WesternGeco with a “wish list” of the kinds of data that would be of interest to the scientific community.

Fish, Food and Allied Workers Union / One Ocean

During a meeting with the FFAW Petroleum Industry Liaison manager, One Ocean’s Director of Operations and a representative of the independent harvesting sector, a number of general issues and specific concerns were noted and discussed. The following points summarize the topics and concerns raised and discussed at the meeting:

1. FFAW representatives asked a general question about the “multi-client” focus of the proposed survey with respect to the location and size of the area to be surveyed in 2012. WesternGeco managers responded that the survey area was located in the Jeanne d’Arc Basin, an area which is currently of significant interest to a number of oil companies, and that WesternGeco would be working with these potential clients to obtain the maximum coverage of the prospect area.

2. The FFAW indicated its general, on-going concern about seismic surveys in established offshore fishing grounds, in particular their potential negative effects on shrimp and crab harvesting activities. It was noted that a previous survey in 2008 appeared to have had an effect on subsequent crab catches. Fishers reported that these seismic operations might have caused crab to migrate into deeper water depths along the shelf break where they could not be readily harvested. The FFAW manager also mentioned the concern that a 2011 survey operation may have been responsible for a sudden significant decrease in shrimp catch rates within Shrimp Fishing Area (SFA) 7 last July.

3. The discussion also focused on the proximity of WesternGeco’s proposed 2012 survey operations to established shrimp grounds in SFA 7 and to crab fishing quota areas to the east of the proposed survey area. A review of the survey area location map showed that the northern boundary of the proposed survey would be well to the south of SFA 7, but that the eastern portion of the planned survey area would be relatively close to established crab harvesting areas within quota areas 3L EX and outside 200. The FFAW noted that approximately 120 vessels fish these areas and operators usually leave their crab gear in the water when they return to port to off-load their catches. According to fisher reps, only a small portion (around 20%) of the gear is marked with highflyers, and usually a string of pots will have just one such marker.

4. Considering the above points, FFAW representatives asked if it would be possible for the WesternGeco vessel to wait until early August to shoot its lines in the eastern part of the proposed 2012 survey area since most of the crab quota would have been taken by 31 July. Delaying survey operations in the eastern portion of the area until then would minimize possible contact with the crab gear and also reduce the potential for seismic noise effects on crab resources. In other words, the FFAW suggested that WesternGeco commence its 2012 survey in the west part of the survey area and move east as the survey progressed.

5. In response to the ‘west to east’ survey progression suggested by the FFAW, WesternGeco managers said that there was some flexibility in the shooting plan. As such, the survey area could perhaps be divided into smaller “swaths” and the vessel could conduct and complete its operations in each swath before moving to the next area. This approach would leave survey lines in the east part of the survey area to be shot after 31 July, allowing crab fishers the maximum amount of time to complete their crab fishing in 3L EX and outside 200 miles before the closest approach of the seismic vessel. WesternGeco said it could keep fishers

informed of the vessel's area of operations via the Notices to Shipping, and would also publicize the co-ordinates of each end of the lines being shot. One Ocean's representative said that her agency should be able to supply DFO VMS data to the survey vessel so that ships' personnel would be kept aware of the location of fishing vessels in the vicinity of the survey area on a daily basis.

6. Commenting on the possibility of seismic noise causing effect on crab behaviour, G. Chidley suggested that a buffer of 20 km between seismic operations and active crab fishing areas should be sufficient to mitigate behavioural effects and thus effects on the fishery. The FFAW and One Ocean fully support Mr. Chidley's suggested buffer.

7. The matter of streamer deployment was briefly discussed and fisher representatives noted that there had been some problems in 2011 when one of the survey vessels deployed its streamers outside of the authorized area. Mention was also made of the "mis-communication" incident that occurred in early July 2011. WesternGeco stated that, prior to the start of the survey, it would confer with the FFAW and One Ocean regarding the location of the streamer deployment box and appropriate protocols for at-sea communications with fishing vessels. The industry-led post-season crab survey was also discussed briefly, and the FFAW's Liaison manager noted that only a very small number of the research stations fall within the proposed survey area.

8. At the end of the meeting, a number of "action items" were agreed:

   (a) WesternGeco will provide more detailed information about the grid pattern for the proposed survey lines;
   (b) WesternGeco will examine the feasibility of commencing seismic survey operations at the west end of the proposed 2012 survey area and then progressing eastwards. This approach would maximize the distance between seismic operations and the densest areas of snow crab harvesting activity. This approach could also result in the easternmost portion of the proposed 2012 survey area being surveyed after completion of the 2012 snow crab season [WesternGeco has subsequently noted that if practicable, attempts will be made to maintain a 20 km buffer as recommended by the FFAW.] ;
   (c) WesternGeco will provide more detailed information about where it will locate the streamer deployment box;
   (d) Appropriate at-sea communications protocols will be discussed and agreed at the start-up meeting, before the survey commences. Representatives from the FFAW, One Ocean, as well as the FLO, will attend this meeting.

One Ocean

One Ocean's Director attended the meeting with FFAW representatives.

Groundfish Enterprise Allocation Council (GEAC)

GEAC's Executive Director reiterated some of the same points that he had raised during consultations for other recent seismic survey EAs. His concern was that proponents had not provided enough information about the specific location of their survey activities and this made it somewhat difficult to comment on the extent to which those operations might overlap spatially or temporally with the established harvesting activities of his member firms. (Considering this comment, WesternGeco provided all fisheries industry stakeholders with a map showing the location of its planned 2012 survey area.)

He also mentioned GEAC's ongoing concern about possible interference with shrimp fishing operations in SFA 7 and potential behavioral effects on 3L shrimp resources in general. These concerns are related to significant decreases in reported 2011 catch rates that some vessel operators believe might have resulted due to the proximity of seismic operations to shrimp harvesting activities.

Newfound Resources Ltd. (NRL)

A very informative meeting was held with NRL managers, including the captain of one of the firm's shrimp vessels (the *Newfoundland Pioneer*). Following a detailed presentation by WesternGeco representatives, NRL officials provided relevant details about the company's extensive offshore shrimp harvesting operations in 3L, and in other offshore quota areas. Managers reviewed the firm's established shrimp harvesting plans in detail, and noted the critical economic importance of 3L shrimp resources in NRL's overall harvesting strategy. Much of the discussion at the meeting focused on the significant decrease in SFA 7 catch rates which NRL's shrimp vessels experienced during the 2011 fishing season, particularly around mid-July.

Company representatives were not able to offer a logical explanation for the sudden drop in SFA 7 catch rates, but raised their concern that these catch rate changes might have been due to the proximity of seismic survey operations to shrimp grounds in SFA 7.

WesternGeco's consultants briefly reviewed the research initiative currently underway that is designed to shed further light on the matter of decreased shrimp catch rates in 2011, and any possible connection that these changes in harvesting patterns might have had with seismic survey operations. NRL managers said they were very interested in any such analysis and indicated that they would be willing to provide any relevant internal company data that might assist this research.

<u>Other Fishing Industry Stakeholders</u>

To date, there has been no response from the ASP, Clearwater Seafoods, Ocean Choice International or Icewater Fisheries.

5.2 Valued Ecosystem Components

The VEC approach was used to focus the assessment on those biological resources of most potential concern and value to society. The VEC approach was introduced by Beanlands and Duinker (1983) and is commonly used in Canada.

VECs include the following groups:

- Rare or threatened species or habitats (as defined by *SARA* and COSEWIC);
- 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 fishery target species); and
- Species that have at least some potential to be affected by the Project.

VECs were identified based on the scoping exercise as described in Section 5.0 above. The VECs and the rationale for their inclusion are as follows:

- **Fish and Fish Habitat** with emphasis on the Study Area's four most important (past and present) commercial species: (1) shrimp, (2) snow crab, and (3) Greenland halibut (turbot), and (4) Atlantic cod (a representative fish species that has a swim bladder and hence, may be susceptible to seismic survey sound). It is recognized that there are many other fish species, important 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 and fish habitat 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 uncommon in the Study Area, are mostly *threatened* and *endangered* on a global scale and the leatherback sea turtle that 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. Also, this VEC is of prime concern from both a public and scientific perspective, at national and international scales.

- **Species at Risk (SAR)** are those listed 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 temporal and spatial boundaries are defined.

5.3.1 Temporal

The temporal boundaries of the Project are 1 May to 30 November in 2012. In subsequent years (2013 to 2015), seismic surveys may occur from 1 May to 30 November.

5.3.2 Spatial

Project Area—the area where geophysical data could be acquired during the four year period plus additional area to accommodate the ship's turning radius (see Figure 1.1).

Study Area—an area larger than the Project Area that encompasses any potential effects of the Project on the VECs; it is based on the scientific literature. The Study Area is equivalent to the "Affected Area" as defined by *CEAA*.

Regional Area—the area indicated as the Orphan Basin SEA Area (Figure 2.2 in LGL 2003) plus Jeanne d'Arc Basin, including the major Grand Banks developments. This area is referred to 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 identifying all possible Project activities that could interact with any of the VECs were prepared. The interaction matrices are used to identify potential interactions only; they do not make any 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 to be impossible or extremely remote, or if it was obvious that any effects would be extremely small, these interactions were not considered further. This approach allows the assessment to 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:

- Location and timing of the interaction;
- Literature on similar interactions and associated effects (including previous seismic EAs for offshore Nova Scotia and Newfoundland and Labrador);
- Consultation with other experts, when necessary; and
- Results of similar effects assessments, especially monitoring studies done in other areas.

If data were insufficient to allow certain or precise effects evaluations, predictions were made based on professional judgement. In such cases, the uncertainty was documented in the EA. Effects were evaluated for the proposed geophysical surveys, and included the consideration of mitigation measures that are either 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, positive, or neutral. The following are 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. These effects after application of the mitigation measures are known as ‘residual effects’. 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 (as per guidance in CEA Agency 1994):

- Magnitude;
- Geographic extent;

- Duration;
- Frequency;
- Reversibility; and
- Ecological, socio-cultural and economic context.

5.4.4.1 Magnitude

Magnitude describes the nature and extent of the environmental effect for each activity. Ratings for this criterion are defined as:

(0) *Negligible* - Measureable effect on individuals but less than the 'low' rating.

(1) *Low* - Affecting >0 to 10 percent of individuals in the affected area (i.e. Study Area) (e.g., geographic extent). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

(2) *Medium* - Affecting >10 to 25 percent of individuals in the affected area (i.e. Study Area). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

(3) *High* - Affecting > 25 percent of individuals in the affected area (i.e. Study Area). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

Definitions of magnitude used here have been used previously in numerous offshore EAs under *CEAA*. Some examples include the Petro-Canada seismic EA (LGL 2007a), the White Rose Comprehensive Study (Husky 2000), the StatoilHydro Jeanne d'Arc Basin area seismic and geohazard EA (LGL 2008a), the ConocoPhillips Laurentian Sub-Basin drilling EA (Buchanan et al. 2006), the Chevron Labrador seismic EA (LGL 2010), and the Hebron Comprehensive Study (ExxonMobil 2011).

5.4.4.2 Geographic Extent

Geographic extent refers to the specific area (km^2) of the residual effected caused by the Project activity. Geographic extent will likely vary depending on the activity and the relevant VEC. Ratings for this criterion are defined as:

1 = <1 km^2
2 = 1-10 km^2
3 = >10-100 km^2
4 = >100-1,000 km^2
5 = >1.000-10,000 km^2
6 = >10,000 km^2

5.4.4.3 Duration and Frequency

Duration describes how long a residual effect will occur. Ratings for this criterion 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, medium duration 13 to 36 months, and long duration >36 months.

5.4.4.4 Frequency

Frequency describes how often a residual effect will occur. Ratings for this criterion are defined as:

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

5.4.4.5 Reversibility

Reversibility refers to the capability of a VEC population to return to either its pre-Project or an improved condition, after the Project has ended. Ratings for this criterion are defined as:

R = reversible
I = irreversible

5.4.4.6 Ecological, Socio-cultural and Economic Context

The ecological, socio-cultural and economic context refers to the pre-Project status of the Study Area (i.e., potential affected area) in terms of existing environmental effects. The Study Area is not considered to be strongly affected by human activities. Ratings for this criterion are defined as:

1 = environment not negatively affected by human activity (i.e., relatively pristine area)
2 = evidence of existing negative effects on the environment

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.

- 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 2012, other possible oil exploration activity in the Regional Area include 2D seismic surveying by Husky, 2D/3D seismic surveying by Suncor, 2D/3D seismic surveying by Statoil, 2D seismic surveying by MKI. There is also some potential for several geohazard and VSP surveys in any given year. There is also the possibility that Chevron will drill an exploratory well in the Regional Area in 2012.
- 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;
- Cumulative effects of activities within the Project; and
- Cumulative effects of combined projects in the Regional Area.

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 associated with each prediction are presented in the table of residual environmental effects. In the case of a significant predictive rating, ratings for probability of occurrence and determination of scientific certainty are also included in the table of residual environmental effects. The guidelines used to determine these ratings are discussed in the following subsections.

5.4.6.1 Significance Rating

Significant residual 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 criterion is based on professional judgment but is transparent and repeatable. In this EA, a significant residual 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*

A residual effect can be considered significant (S), not significant (NS), or positive (P).

5.4.6.2 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 are difficult due to the limitations of available data (i.e., technical boundaries). Ratings are therefore provided to qualitatively indicate the level of confidence for each prediction. The level of confidence is considered low (1), medium (2) or high (3).

5.4.6.3 Probability of Occurrence

The probability of occurrence of a significant residual effect, based on professional judgement, is considered low (1), medium (2) or high (3).

5.4.6.4 Scientific Certainty

The scientific certainty of a *significant* residual effect, based on scientific information, statistical analysis and/or professional judgement, is considered low (1), medium (2) or high (3).

5.5 Effects of the Environment on the Project

The physical environment is described in Section 3 and the reader is referred to this section and Oceans (2012) to assist in determining the effects of the environment on the Project. Furthermore, safety issues are assessed in some detail during the permitting and program application processes established by the C-NLOPB as the regulatory authority in this matter. Nonetheless, effects on the Project are important to consider, at least on a high level, because they may sometimes cause effects on the environment. For example, accidental spills of streamer fluid may be more likely to occur during rough weather.

Given the Project time frame of May to November and the requirement for a seismic survey to avoid periods and locations of sea ice, sea ice should have no effect on the Project. Icebergs in the spring and early summer may cause some survey delays if tracks have to be altered to avoid them. Most environmental constraints on seismic surveys are those imposed by wind and wave. The Project scheduling avoids the most continuous extreme weather conditions and WesternGeco's contractors will be thoroughly familiar with east coast operating conditions. As a prediction of the effects of the environment on the Project, WesternGeco 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 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.

It is predicted that any effects of the environment on the Project will be *not significant*.

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 survey source to the various VECs (or "receivers"). The basics of sound and its propagation in the marine environment are described in Richardson et al. (1995). Of principal concern is the potential effect of airgun sound on VECs as they introduce strong sound impulses into the water (see Appendix C *in* LGL 2007a for a review of the characteristics of airgun pulses). The seismic pulses produced by the airguns are intentionally directed downward toward the seafloor, insofar as possible; however, energy will also propagate laterally from the source. 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) on the 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), residual effects are predicted to be *negligible* and thus *not significant*. The seismic program will not result in any direct physical disturbance of the bottom substrate. Also, the probability is very low of any accidental event (i.e., hydrocarbon release) being of large enough magnitude to cause a significant effect on fish habitat. Therefore, other than in Table 5.1, no further 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 considered as part of the 'fish' component of the Fish and Fish Habitat VEC.

The following subsections discuss the Project activities that will interact with the Fish and Fish Habitat VEC, and include assessment of the potential effects of these interactions.

5.6.1.1 Underwater 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 very likely related in some instances and should therefore not be considered as completely independent of one another.

The following subsections 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 and vessel operational sound.

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 to be sensitive to the pressure component (Breithaupt 2002; Casper and Mann 2006; Popper and Fay 2010).

Table 5.1 Potential Interactions of the Project Activities and the Fish and Fish Habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat							
Project Activities	**Non-Biological Environment**	**Feeding**		**Reproduction**		**Adult Stage**	
	Water and Sediment Quality	**Plankton**	**Benthos**	**Eggs and Larvae**	**Juveniles [a]**	**Pelagic Fish**	**Groundfish**
Sound							
Airguns		X	X	X	X	X	X
Seismic Vessel						X	
Supply Vessel						X	
Picket Vessel						X	
Helicopter [c]							
Vessel Lights							
Vessel Presence							
Seismic Vessel							
Supply Vessel							
Picket Vessel							
Helicopter Presence							
Sanitary/Domestic Waste	X	X		X		X	
Atmospheric Emissions	X	X		X		X	
Garbage [b]							
Shore Facilities [d]							
Accidental Releases	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.

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). Statocysts (organs 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 suitable orientation.

Among the marine invertebrates, decapod crustaceans have been the most intensively studied in this regard. Crustaceans appear to be the most sensitive to low frequency sounds (i.e., <1,000 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 (20–8,000 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 planktonic 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 1,500 Hz (Popper and Fay 2010). Some marine species, such as shads and menhaden, can detect higher frequency sounds above 180 kHz (Mann et al. 1997, 1998, 2001). Also, at least some species are acutely sensitive to infrasound (very low frequency), 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 of their specific environments. 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, calcium carbonate masses in the inner ear that act as accelerometers when exposed to the particle motion component of sound, which cause shearing forces that 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 a reduced swim bladder 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 include barnacles, amphipods, shrimps, crabs, and lobsters (Au and Banks 1998; Tolstoganova 2002; Pye and Watson III 2004; Henninger and Watson III 2005; Buscaino et al. 2011). 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 associated with higher frequencies.

Physical Effects

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 moult 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 in 2007 to evaluate the results of additional studies conducted to answer some questions arising from the original study discussed in DFO (2004b). A series of scientific papers was presented to address issues of concern, including (1) actual sound pressure levels received by the snow crab; (2) reasons for the differences in presence of foreign particles on the gills, antennules and statocysts between study group crabs; (3) effect of seismic surveys on crab distribution and abundance; (4) reasons for differences in the cellular structure of certain organs between study group crabs; (5) reasons for differences in rate of leg loss between study group carbs; and (6) effect of exposure to seismic sound on snow crab embryos (Courtenay et al. 2009). 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 $\mu Pa_{0\text{-}p}$. 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 $\mu Pa_{p\text{-}p}$ and 205 dB re 1 $\mu Pa_{p\text{-}p}$, 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 $\mu Pa_{0\text{-}p}$.

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).

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 $µPa^2 \cdot s$ 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*; *a 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. 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.

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 Effects</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 $µPa_{0-p}$ and <130 dB re 1 $µPa^2 \cdot s$, 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 µ$Pa_{0\text{-}p}$ and 150 dB re 1 µ$Pa^2 \cdot s$, 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 µ$Pa_{0\text{-}p}$. 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. 2006; 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 associated telemetry study. There were seven pre-exposure and six post-exposure trap sets. Catch-per-unit-effort did not decrease after the crabs were exposed to seismic survey sound. Unfortunately, there was considerable variability in set duration because of poor weather.

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 that study did not indicate any significant impact on shrimp catches. Anecdotal information from Newfoundland suggested that catch rates of snow crabs showed a 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.). These observed behaviours were 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 found no evidence that lobster catch rates were affected by seismic surveys. They also noted that due to natural variability and fishing pressure, a large effect on lobster would be required to make any link to seismic surveys.

Fishes

Pearson et al. (1992) investigated the effects of seismic airgun sound on the behaviour of captive rockfishes *Sebastes* spp. 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 re-established 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-p}. Received SPLs were estimated to be 178 dB re 1 μPa_{0-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-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 µ$Pa_{0\text{-}p}$. 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 µ$Pa^2 \cdot s$ 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 µ$Pa_{p\text{-}p}$. 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

Early 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 $m_{0\text{-}p}$ 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$_{0\text{-}p}$ and 178 dB re 1 µPa$_{0\text{-}p}$, 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$_{0\text{-}p}$. 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$_{0\text{-}p}$. Received levels in the fishing areas were estimated to range between 163 and 191 dB re 1 µPa$_{0\text{-}p}$. 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$_{0\text{-}p}$ 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$_{0\text{-}p}$. 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 $m_{0\text{-}p}$ (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, and migration), characteristics of the vessel sound, and water depth.

5.6.1.4 Sound Exposure Effects Assessment

The assessment in this and subsequent subsections is structured such that the reader should first refer to the interaction table (e.g., Table 5.1) to determine if there are any interactions with Project activities, secondly to the assessment table (e.g., Table 5.2) which contains ratings for magnitude, extent, and duration, and so forth, and thirdly to the significance predictions table (e.g., Table 5.3).

It is impossible to assess in detail the potential effects of every type of sound on every species in the Study Area. The best approach, and common practice in EA, is to provide focus by selecting (1) the strongest sound source, in this case the airgun array, and (2) several species that are locally important and representative of the different types of sensitivities, and (3) species or groups that offer a relevant literature base. Snow crab and Atlantic cod best serve this purpose.

The most notable criteria in the assessment include (1) distance between airgun array and animal under normal conditions (e.g., 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 (e.g., post-larval snow crabs are 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.

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
Sound								
Airguns	Physical effects (N); Disturbance (N)	Ramp-up of array; Spatial & temporal avoidance	1	1-3	6	1-2	R	2
Seismic Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Picket Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
Vessel Lights	Neutral effect	-	-	-	-	-	-	-
Sanitary/ Domestic Waste	Pathological effects (N); Contamination (N)	Treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Accidental Releases	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

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
Sound				
Airguns	NS	2-3	-	-
Seismic Vessel	NS	2-3	-	-
Supply Vessel	NS	2-3	-	-
Picket Vessel	NS	2-3	-	-
Vessel Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	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.

As already indicated in this subsection, 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 effects. In the case of eggs and larvae, it is likely that the numbers negatively affected by exposure to seismic sound would be within the range of 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) as well as ramp-up should mitigate the 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 *negligible* to *low* magnitude residual effects on the various life stages of the Fish and Fish Habitat VEC for a duration of *<1 month* to *1 to 12 months* over an area of *<1 to 11-100* 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)

5.6.1.5 Other Project Activities

Vessel Lights

There are potential interactions between vessel lights and certain components of the Fish and Fish Habitat VEC (Table 5.1). However, other than the relatively neutral effect of attraction of certain species/life stages to the upper water column at night, there will be *negligible* effects of vessel lights on this VEC (Table 5.2). Therefore, 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

There are potential interactions between sanitary/domestic waste and certain components of the Fish and Fish Habitat VEC (Table 5.1). After application of mitigation measures, including treatment of the waste, the residual effects of sanitary/domestic waste on the Fish and Fish Habitat VEC are predicted to be *negligible to low* in magnitude for a duration of *<1 to 1-12 months* over an area of *<1* km^2 (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).

Atmospheric Emissions

There are potential interactions between atmospheric emissions and certain components of the Fish and Fish Habitat VEC that occur very near surface (Table 5.1). Considering that the amount of atmospheric 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 are predicted to be *negligible* (Table 5.2). Therefore, the *reversible* residual effects of *continuous* atmospheric emissions associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

Accidental Releases

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).

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 refer 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 of accidental releases and 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 hydrocarbon releases on the Fish and Fish Habitat VEC are predicted to be *not significant*. With proper mitigations in place, the residual effects of an accidental release associated with the WesternGeco's proposed seismic program on the Fish and Fish habitat VEC would be *negligible* to *low* in magnitude for a duration of *<1 month* over an area of *<1* to *1-10 km^2* (Table 5.2). Based on these criteria ratings and consideration that the probability of accidental hydrocarbon releases during the proposed seismic program are low, the *reversible* residual effects of accidental releases associated with the proposed program on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

5.6.2 Effects on Fishery VEC

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

The seismic survey vessel and Project-related support vessel traffic will be present within NAFO Division 3L. Behavioural changes in commercial species in relation to catchability, and conflict with harvesting activities and fishing gear were raised as potential issues 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., snow crab pots and turbot gillnets in the Study Area). Such conflicts have occurred in Atlantic Canada in the past when seismic vessels were operating in heavily fished areas. There is also a potential for interference from seismic activities with DFO and DFO/Industry research surveys if both are being conducted in a same general area at the same time. An accidental release of petroleum hydrocarbons such as streamer floatation fluid (if fluid-filled streamers are used) may result in tainting (or perceived tainting), thus affecting product quality and marketing.

Table 5.4 Potential Interactions of Project Activities and the Commercial Fisheries VEC.

Valued Ecosystem Component: Fishery			
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; fixed gear-crab pots)**
Sound			
Airguns	X	X	X
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Vessel Lights			
Vessel Presence			
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Helicopter Presence [b]			
Sanitary/Domestic Waste	X	X	X
Atmospheric Emissions			
Garbage [a]			
Shore Facilities [c]			
Accidental Releases	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 chief means of mitigating potential impacts on fishery activities is to avoid active fishing areas, particularly fixed gear zones. For the commercial fisheries, gear damage compensation provides a means of final mitigation of impacts, in case a conflict does occur with fishing gear (i.e., accidental contact of gear with the survey airgun array, streamers or seismic vessel).

The document *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2011) provides guidance aimed at minimizing any impacts of petroleum industry surveys on commercial fish harvesters and other marine users. The mitigations described below are also relevant to DFO and joint DFO/Industry research surveys. Development of the guidelines was based on best practices applied during previous surveys in Atlantic Canada, as well as guidelines from other national jurisdictions. The relevant guidelines state the following (in Appendix 2 of C-NLOPB (2011) - Environmental Planning, Mitigation and Reporting – II. Interaction with Other Ocean Users):

1. *VSP Programs 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 (i.e., to the C-NLOPB).*

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 C-NLOPB Duty Officer.*

2. *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 heavily 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 subsections assess the potential effects of Project activities on the Fishery VEC.

5.6.2.1 Sound

As indicated in the description of commercial fisheries in Section 4.3, there has been substantial harvesting within NAFO Units 3Lh, 3Li, 3Lr, 3Lt in the Study Area between 2005 and 2010. Snow crab and northern shrimp accounted for most of the commercial harvest within the Study Area during that period. Shrimp and snow crab each accounted for almost 50% of the total catch weight within the Study Area, followed by Stimpson's surf clam at 3-4% of the total catch weight.

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 and joint DFO/Industry research surveys are also conducted using fishing gear. As such, the issues related to potential interference with DFO and joint DFO/Industry research surveys are much the same as for commercial fish harvesting (i.e., potential effects on catch rates and conflicts with research vessel operations).

Potential effects on marine fish behaviour are assessed in Section 5.6.1. While adult fish could be injured by airgun sound if they are within a few metres of a sound source, this is unlikely since fish are likely to disperse during array ramp-up or vessel approach. Therefore, the most likely type of effect will be behavioural. Seismic surveys could cause reduced trawl and longline catches during and following a survey if the fish exhibit behavioural changes (e.g., horizontal and vertical dispersion). There are various research studies on this subject as discussed in Section 5.6.1. While some of the behavioural effects studies report decreases in catch rates near the seismic survey area, there is some disagreement on the duration and geographical extent of the effect.

Mitigation

Mitigations are detailed in a previous subsection. The primary measures intended to minimize the effects of Project activities on the harvesting success component of the Fishery VEC include:

- Avoidance in time and space of concentrated fishing areas;
- Good communications, and
- Deployment of Fisheries Liaison Officers (FLOs).

Avoidance.—The potential effects of seismic sound on fishery catch success can 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 Study Area. During any seismic survey, the location of current fishing activities will be monitored by the ship and the FLO (see below), and fishing boats will be contacted by radio as required. Survey personnel (through the Single Point of Contact (SPOC), described below) will also continue to be updated about fisheries near the active survey area. The mapping of fishing activities contained in this EA report will also be an important source of fisheries information for the survey operators.

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 between the seismic operations and fishing activities. Communication will be maintained (both directly at sea and through the survey SPOC) to facilitate information exchange, which 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.

Relevant information about the seismic survey operations will also be transmitted 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 communication between the seismic survey vessels and fishing vessels via marine radio at sea. This includes seismic survey vessel transit before and after the survey itself.

Fisheries Liaison Officer (FLO).—As a specific means of facilitating at-sea communications and informing the survey vessel operators about local fisheries, WesternGeco will have an on-board fisheries industry liaison officer serving 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 seismic operations to discuss interactions and resolve any problems that may arise at sea. This person will inform the vessel's bridge personnel about any local fishing activities.

Since 2002, FLOs have been utilized in Newfoundland and Labrador waters and have proven highly effective in communicating with fishers at sea and thereby 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).

Assessment of the Effects of Seismic Survey Sound

Since commercial catches are quota-based, the overlap between fishing activity and seismic activity is unknown at the moment, but will be determined prior to the commencement of the seismic surveys. The best way to prevent overlap between the DFO and joint DFO/Industry research 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. With application of the mitigations discussed above, effects of seismic survey sound on the Fishery VEC are predicted to be a *negligible* to *low* magnitude during *<1* to *1-12 months* over an area of *<1* to *11-100* km^2 (Table 5.5). Based on these criteria ratings, the *reversible* residual effects of seismic survey sound on the Fishery VEC are predicted to be *not significant* (Tables 5.6).

5.6.2.2 Vessel Presence (including towed seismic equipment)

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 conflict, particularly if it is deployed concurrently with seismic survey operations. During 3D seismic surveying, operations will be conducted continuously for 40–150 days. Because of the length of the streamers being towed behind it, the manoeuvrability of a seismic vessel is restricted and other vessels must give way. As already noted in the EA, the turning radius required between each track line extends the assessment area beyond the actual survey area. During transit to the seismic survey area, streamers may be deployed. Therefore, a separate route analysis will be prepared and discussions with fishing interests will be conducted before such transit. When gear conflict events occur, they will be assessed and compensation will be paid for losses attributable to the seismic survey.

Table 5.5 Assessment of Effects on the Commercial Fisheries VEC.

Valued Ecosystem Component: Fishery								
			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
Sound								
Airguns	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0-1	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	1	1-2	R	2
Picket Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1-2	R	2
Vessel Presence								
Seismic Vessel	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	R	2
Picket Vessel	Conflict with gear (N)	FLO; communication	0-1	1-3	6	1-2	R	2
Sanitary/Domestic Wastes	Taint (N); Perceived taint (N)	Treatment	0-1	1	1	2	R	2
Accidental Releases	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 Fishery VEC.

Valued Ecosystem Component: Fishery				
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	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Accidental Releases	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.

Mitigation

Mitigations measures intended to minimize the conflict effects of Project activities on the fishing gear component of the Fishery VEC include:

- Avoidance;
- Communications;
- Fisheries Liaison Officers;
- Single Point of Contact; and
- Fishing Gear Compensation.

Avoidance.—As discussed above, potential impacts on fishing gear will be mitigated by avoiding active fixed gear fishing areas during the seismic 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 SPOC and the at-sea FLO will advise the vessel en-route to ensure fishing gear is avoided. In the case the avoidance mitigative measure fails, a gear damage program will be in place to compensate fishers whose gear is damaged or lost.

As with the commercial fishery, those involved in DFO and joint DFO/Industry research surveys will need to exchange detailed locational information with those involved in the seismic surveying. In 2002 when the plan was first implemented in the eastern Newfoundland Region, positional information was exchanged between DFO and the seismic survey company. A temporal and spatial separation plan was then agreed to with DFO and implemented by the seismic vessel to ensure that seismic operations did not interfere with the research survey. This included adequate "quiet time" before the research vessel arrived at its survey location. The avoidance protocol includes a 30 km (16 nmi) spatial separation and a seven day pre-research survey temporal separation.

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. Communications will be maintained (directly at sea, and through the SPOC) 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. 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 communication between the survey vessel and fishing vessels via marine radio at sea. This will also include information about transit routes.

Fisheries Liaison Officer (FLO).—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 those on the bridge, including during transit to and from 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 SPOC with the fisheries industry, as described in the C-NLOPB Guidelines. In addition, as part of their SPOC role, Canning & Pitt Associates, Inc. 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.—WesternGeco has developed a fishing gear damage compensation policy consistent with C-NLOPB guidelines that will be filed with the Board in support of the *Authorization to Conduct a Geophysical Program* application. In case of accidental damage to fishing gear or vessels, WesternGeco will implement gear damage compensation contingency plans to provide appropriate and timely compensation to any affected fishery participants. The Notices to Shipping, filed by the vessels for surveys and for transits to and from the survey 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. WesternGeco will follow the procedures (which have been employed successfully in the past by other Operators) outlined in Appendix C for documenting any incidents; Appendix C also contains an incident reporting form that will be used, and meets the requirements of the C-NLOPB Guidelines.

Assessment of the Effects of Vessel and Seismic Equipment Presence

With application of the mitigations discussed above, effects of vessel presence, including all gear being towed by the seismic vessel, on the Fishery VEC are predicted to be a *negligible* to *low* magnitude during *<1 to 1-12 months* over an area of *<1 to 11-100* km^2 (Table 5.5). Based on these criteria ratings, the *reversible* residual effects of vessel presence during the seismic program on the Fishery VEC are predicted to be *not significant* (Tables 5.6).

5.6.2.3 Sanitary/Domestic Wastes

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

5.6.2.4 Accidental Events

In the event of an accidental release of hydrocarbons (e.g., streamer breakage, fuel spill), there is some possibility of the perception of tainting of invertebrate and fish resources in the proximity of a release, even if there is no actual tainting. Perception alone can have economic effects if the invertebrates and fish lose marketability. Preventative measures/protocols, rapid response plans and good communications are essential mitigations to minimize the effects of any accidental hydrocarbon release. In the event of a release, the length of time that fish are exposed is a determining factor in whether or not their health is substantially affected or if there is actual or perceived tissue tainting. Streamer 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 hydrocarbon release, the need of compensation for commercial fishers will be determined through the C-NLOPB's guidelines.

With application of the mitigations discussed above, the effect of accidental hydrocarbon releases on the Fishery VEC is predicted have a *negligible* to *low* magnitude during *<1 month* over an area of *<1* to *1-10* km^2 (Table 5.5). Based on these criteria ratings, the *reversible* residual effect of accidental releases on the Fishery VEC during the seismic program is predicted to be *not significant* (Tables 5.6).

5.6.3 Seabirds

There are three main potential types of effects to seabirds from offshore seismic 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.

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
Sound	
Seismic Vessel	X
Airguns	X
Supply Vessel	X
Picket Vessel	X
Helicopter [b]	X
Vessel Presence	
Seismic Vessel	X
Supply Vessel	X
Picket Vessel	X
Helicopter Presence [b]	X
Shore Facilities [c]	
Accidental Releases	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 and Leach's storm-petrel), *Phalaropodinae* (red and red-necked phalarope), *Stercorariidae* (great skua, South Polar skua, pomarine jaeger, parasitic jaeger, and long-tailed jaeger), and *Laridae* (herring, Iceland, glaucous, great black-backed, and ivory gull; black-legged kittiwake; and Arctic tern). The northern gannet plunge-dives to a depth of 10 m; it is under the surface for a few seconds during each dive so would have minimal exposure to underwater sound. Manx, great, and sooty shearwaters 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; Ronconi 2010a,b).

There is only one group of seabirds occurring regularly in the Study Area that requires relatively considerable time under water to secure food. It is the *Alcidae* (dovekie, common murre, thick-billed murre, razorbill and Atlantic puffin). From a resting position on the water these species 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, as 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). However, 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. 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* with a small geographic extent (probably *1 to 10 km²)* (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 will likely 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. 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, dovekie and Atlantic puffin, 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 them 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. O' Hara and Morandin (2010) demonstrated that it only requires a small amount of oil (e.g., 10 ml) to affect the feather structure of common murre and dovekie. Such modifications to feather structure cause a loss of insulation, which in turn can result in mortality. However, because potential spills will likely be small and evaporation and dispersion rapid, the magnitude (*low to medium*), geographic extent (*<1 km^2 to 1-10 km^2)* and duration (*<1month*) (Table 5.8) of any spill is not expected to cause significant effects on seabird populations; therefore, any effects will be *not significant* (Table 5.9).

Table 5.8 Assessment of Effects on the Seabird VEC.

Valued Ecosystem Component: Seabirds								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound								
Airguns	Disturbance (N)		0	2	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
Helicopter	Disturbance (N)		0-1	2	1	1	R	2
Vessel Presence								
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
Helicopter Presence	Disturbance (N)	Maintain high altitude	0-1	2	1	1	R	2
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
Atmospheric Emissions	Air Contaminants (N)		0	2	6	1-2	R	2
Accidental Releases	Mortality (N)	Solid streamer[a]; 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] Solid or Isopar filled streamers may be used during 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**
Sound				
Airguns	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter Presence	NS	3	-	-
Vessel Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	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.

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. Moisture droplets in the air refract light increasing illumination creating a glow around vessels at sea. In Newfoundland waters, 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. 2005a, 2006; Abgrall et al. 2008a,b, 2009). Occasionally, other Newfoundland seabirds (e.g., great 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. In Alaska, a species related to the dovekie, the crested auklet (*Aethia cristatella*), mass stranded on a crab fishing boat (Dick and Donaldson 1978). An estimated 1.5 tons of birds collided with or landed on the brightly lit boat at night. There are no known similar events involving large numbers of dovekies or any alcid species stranding on vessels in Newfoundland and Labrador waters.

To date, bird strandings offshore Newfoundland have consisted almost entirely of Leach's storm-petrel. This is not surprising given the huge numbers of this species in these waters coupled with their relative inability to become airborne after landing on a ship or platform. Numbers of strandings on seismic vessels have ranged from zero early in the season to tens of birds, mostly late in the season after fledging. On a Grand Banks seismic vessel, tens of birds in one night can be considered a "large scale stranding". The largest single stranding event observed by LGL biologists on seismic vessels was 46 birds, all of which were released alive (LGL Limited, unpublished data).

Monitoring of pelagic seabirds stranded due to light attraction on board seismic vessels has been conducted by LGL biologists during 16 seismic programs from 2004 to 2011 off both Newfoundland and Labrador. Seismic programs were initiated as early as 7 May and terminated as late as 8 November; however, most were conducted during the months of June to September. In total, 888 nights were monitored during these seismic programs. The number of nights per week with strandings and the number of individuals stranded per night was greatest from late August to mid-October. This period coincides with the fledging of Leach's storm-petrels from Newfoundland colonies. Young of this species fledge from Great Island (Witless Bay), Newfoundland, as early as 10 September but the majority fledge from mid-September to late October (Huntington et al. 1996). The mean fledging date is 25 September. Juveniles make up the majority of Leach's storm-petrels stranded due to light attraction near a colony off Scotland (Miles et al. 2010). However, in wintering areas adult Leach's storm-petrels may also strand because of light attraction (Rodríguez and Rodríguez 2009). Visibility during nights when storm-petrels stranded on seismic vessels off Newfoundland and Labrador was usually reduced due to fog, rain or overcast sky. This has been documented among other seabird species (Telfer et al. 1987; Black 2005). Strandings have also been noted to peak around the time of the new moon, i.e., when moonlight levels are lowest (Telfer et al. 1987; Rodríguez and Rodríguez 2009; Miles et al. 2010).

Birds may be attracted to light because of a preference for bioluminescent prey (Imber 1975) or because the red component of lights disrupt their magnetic orientation (Poot et al. 2008). 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.

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.). WesternGeco 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

<u>Sanitary/Domestic Wastes</u>

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.

<u>Air Emissions</u>

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.

<u>Presence of Vessels</u>

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. Seabirds may be attracted to the seismic, picket or supply vessel while prospecting for fish wastes associated with fishing vessels. Since there is little or no food made available by these vessels, seabirds are temporarily interested 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).

<u>Helicopters</u>

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

The potential effects of marine seismic activities on marine mammals and sea turtles have recently been reviewed for several 3D seismic projects in the Jeanne d'Arc Basin on the Grand Banks (e.g., LGL 2007a, 2008a, 2011a,b), Chevron's Labrador seismic EA (LGL 2010), 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

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 sea turtles and constitute one of the main issues 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 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.

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.

(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) reported 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. For a sub-adult Blainville's beaked whale, Pacini et al. (2011) reported a best hearing range of 40 to 50 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).

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. 2007a). 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 or possibly 25 kHz; baleen whales are said to constitute the "low-frequency" (LF) hearing group (Southall et al. 2007; Scholik-Schlomer 2012).

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.

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 will likely be readily audible to phocids.

Sea Turtles

Hearing in sea turtles occurs through a combination of bone and water conduction rather than air conduction (Lenhardt 1982; Lenhardt and Harkins 1983). 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 1,600 Hz for the species that have been tested (i.e., green, loggerhead, and Kemp's ridley sea turtles), with best hearing sensitivity ranging in frequencies from ~200 to 700 Hz (Ridgway et al. 1969; Bartol et al. 1999; Bartol and Ketten 2006; Ketten and Bartol 2006; Yudhana et al. 2010; Dow Piniak et al. 2012; Lavender et al. 2012). 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.

(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; Clark et al. 2009). 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. Through use of an analytical paradigm, Clark et al. (2009) found that of the large baleen whales, the North Atlantic right whale, may be most prone to communication masking due to commercial vessel traffic. They found that two commercial ships operating in the Stellwagen Bank National Marine Sanctuary, U.S. could cause an 84% reduction in the whale's communication space for at least 13.2 h a day. Gedamke (2011) suggested that blue and fin whale communication space may be reduced by 36 to 51% when seismic surveys are operating. Nieukirk et al. (2011) also suggested the potential of masking effects from seismic surveys on large whales in Fram Strait and the Greenland Sea. The biological repercussions of such a loss of communication space are unknown (Clark et al. 2009).

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 LGL's 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, 2011; Dunn and Hernandez 2009; Cerchio et al. 2011). However, there is one recent summary report indicating that calling fin whales distributed in one part of the North 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. (2009, 2010a,b, 2012) 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. 2009 a,b, 2010, 2011). In contrast, Di Iorio and Clark (2010) found that blue whales in the St. Lawrence Estuary *increased* their call rates 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, 2011; 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, 2011; 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. 2007b, 2009, 2011; Hanser et al. 2009; Holt et al. 2009; Castellote et al. 2010a,b, 2012; Di Iorio and Clark 2010). 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 2010). 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 (200 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 surveys.

(C) Disturbance by Seismic 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, 2011). 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).

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 2,678 in^3 array, and to a single 20 in^3 airgun with a (horizontal) source level of 227 dB re 1 $\mu Pa \cdot m_{p\text{-}p}$. 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. Studies examining the behavioral response of humpback whales off Eastern Australia are currently underway (Cato et al. 2011).

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. However, Moulton and Holst (2010) reported that humpback whales monitored during seismic surveys in the Northwest Atlantic had significantly lower sighting and were most often seen swimming away from the vessel during seismic periods compared with periods when airguns were silent.

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 (3,147 in^3 or 5,085 in^3) was operating vs. silent (Weir 2008a). There was also no significant difference in the mean CPA distance of the humpback sightings when airguns were on vs. off (3,050 m vs. 2,700 m, respectively). Cerchio et al. (2011) suggested that the breeding display of humpback whales off Angola may be disrupted by seismic sounds, as singing activity declined with increasing received levels.

It has been suggested that South 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. 2006a), 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. 2010a,b, 2012). 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). Similarly, Castellote et al. (2009, 2010a,b, 2012) reported that singing fin whales in the Mediterranean moved away from an operating airgun array and avoided the area of operations even for days after airgun activity had ceased. In addition, (Stone (2003) noted that fin/sei whales were less likely to remain submerged during periods of seismic shooting.

During seismic surveys in the Northwest 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. Castellote et al. (2009) reported that fin whales avoided their potential winter ground for an extended period of time (at least 10 days) after seismic operations in the Mediterranean Sea had ceased. 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 2011). The West 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 2011). 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 3,959 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; Barry et al. 2012).

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 2D 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. (2012) 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 2,250 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[4] 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 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 (~7,000 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 (~6,600 in^3), the results are less easily interpreted (Richardson et al. 2009). During both

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

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 (3,147 in^3 or 5,085 in^3) (Weir 2008a). Sample sizes were low, but CPA distances of dolphin groups were significantly larger when airguns were on (mean 1,080 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[5] 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 Northwest 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 another two small-array surveys 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.

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

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.

***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 μPa_{pk-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. 2006a). 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; Potter et al. 2007). Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the Northwest 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; D'Amico et al. 2009; Filadelfo et al. 2009; 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 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 (3,147 in^3 or 5,085 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 3,039 m vs. 2,594 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 $\mu Pa_{p\text{-}p}$ (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 1,839 m when the airgun array was in full operation (n = 612) vs. 1,960 m when all airguns were off (n = 66).

A detailed study of sperm whale reactions to seismic surveys was conducted 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 $\mu Pa_{pk\text{-}pk}$) 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 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. 2006b; 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 $\times$ 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 1,500 in^3. Subsequent monitoring work in the Canadian Beaufort Sea in 2001 to 2002, with a somewhat larger airgun system (24 airguns, 2,250 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 vessels than from 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 when 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 sighting 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, and little is known about the sound levels that will or will not elicit various types of behavioral reactions. There have been four directed studies that focused on short-term behavioural responses to single airguns of sea turtles in enclosures. 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.

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 1,500 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 2,000 psi [6] 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.

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 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 (2,678 in^3, 12 elements) operating in 100 to 120 m water depth, sea turtles may

[6] 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.

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.

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; 3,050 to 8,760 in^3) and small-source (up to six airguns or three GI guns; 75 to 1,350 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 5,085 and 3,147 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. 2006b). In contrast, DeRuiter and Larbi Doukara (2012) reported that 49 of 86 observed loggerhead turtles dove when close to an operating 13-airgun array in the Mediterranean Sea; they suggested that this diving behaviour was an avoidance response to the airguns sounds.

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 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 also 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. The 180 dB criterion for cetaceans is probably conservative for at least some species including bottlenose dolphin and beluga, i.e., lower than necessary to avoid temporary auditory impairment let along permanent auditory injury.

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 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 EAs and small-take authorizations, and NMFS is moving toward adoption of new procedures taking at least some of Southall et al. recommendations into account (Scholik-Schlomer 2012). 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; Le Prell 2012). 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. Extensive studies on terrestrial mammal hearing in air show that TTS can last from minutes or hours to (in cases of strong TTS) days. More limited data from odontocetes and pinnipeds show similar patterns (e.g., Mooney et al. 2009a,b; Finneran et al. 2010). However, 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, belugas, and finless porpoise. 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).

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, 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; Breitzke and Bohlen 2010; Laws 2012). 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. (2011) suggested that some baleen whales whose closest point of approach to a seismic vessel is 1 km or more could experience TTS.

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). 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*:** 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 and 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; Kastelein et al. 2011). Kastak et al. (2005) reported that the amount of threshold shift increased with increasing SEL in a California sea lion and harbour seal.

As with 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.

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. Similarly, Lenhardt (2002) exposed loggerhead turtles in a large net enclosure to airgun pulses. They noted TTS of >15 dB in one loggerhead turtle, with recovery occurring in two weeks. Turtles in the open sea might have moved away from an airgun operating at a fixed location, and in the more typical case of a towed airgun or airgun array, very few shots would occur at or around one location. Thus, exposure to underwater sound during net-enclosure experiments was not typical of that expected during an operational seismic survey.

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.

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. 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, 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).

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.

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. 2011). 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. In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into 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).

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.

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, numerous assumptions, and species differences. Also, data have been published susbsequent to Southall et al. (2007) indicating that, at least for non-pulse sounds, the "equal energy" model is not be entirely correct —TTS and presumably PTS thresholds may depend somewhat on the duration over which sound energy is accumulated, the frequency of the sound, whether or not there are gaps, and probably other factors (Ketten 1994, 2012). 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 discussion (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; Kastelein et al. 2011). 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. 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:

- Limited knowledge about noise-induced hearing damage in sea turtles and marine mammals (particularly baleen whales and pinnipeds);
- Seemingly greater susceptibility of certain species (e.g., harbour porpoise and harbour seal) to TTS and presumably also PTS; and
- 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

There is no evidence that seismic sound 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 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.

Sound-related processes that could potentially 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 high-powered sonar. The evidence for this remains circumstantial and would be associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys. However, Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. Additionally, 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, 8,490 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.

The monitoring and mitigation measures built into the planned work reduce any risk to beaked whales (and other species of cetaceans). Use of ramp-up procedures, in conjunction with the presumed natural tendency of beaked whales to avoid an approaching vessel, will reduce exposure.

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 nmi (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. 2007, 2009, 2011). 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. 2007). 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. 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-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.

Aside from stress, other types of physiological effects that might, in theory, be involved in beaked whale strandings upon exposure to naval sonar (Cox et al. 2006), such as resonance and gas bubble formation, have not been demonstrated and are not expected upon exposure to airgun pulses (see preceding subsection). If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of “the bends”, as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence that exposure to airgun pulses has this effect.

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.

Sound Effects – Summary

Based on the above review, marine mammals and sea turtles will likely exhibit certain behavioural reactions, including displacement from an area around a seismic source. 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}. As discussed above in "*Hearing Impairment Effects*", 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}. An additional criterion that is sometimes used in predicting "disturbance" impacts is 160 dB re 1 µPa; at this received level, some marine mammals exhibit behavioural effects in response to pulsed sound. There is ongoing debate about the appropriateness of all of these parameters for impact predictions and mitigation (see Appendix C in LGL 2007a).

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**
Sound				
Airguns	X	X	X	X
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Helicopter [b]	X	X	X	X
Vessel Presence				
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Helicopter Presence [b]	X	X	X	X
Vessel Lights				
Shore Facilities [c]				
Sanitary/Domestic Waste	X	X	X	X
Atmospheric Emissions	X	X	X	X
Garbage [a]				
Accidental Releases	X	X	X	X
Other Projects and Activities				
Oil and Gas Activities on the Grand Banks	X	X	X	X
Fisheries				
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.

For marine seismic programs in Newfoundland and Labrador, the C-NLOPB (2011) 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 and incorporated into the C-NLOPB guidelines that are a condition of project authorizations. 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)".

In the absence of site-specific acoustic modelling, the acoustic monitoring results in Austin and Carr (2005) have been used 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 3,090 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 5,123 m to 6,393 m. The distance of 6.5 km was used as a guide when estimating disturbance effects on marine mammals. It is recognized that the distances from airgun arrays where received sound levels exceed these noise criteria are dependent upon the configuration of a specific airgun array and site-specific variations in the environment that influence underwater sound propagation.

5.6.4.2 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 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, northern bottlenose 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.

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 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 not last very long. As per Table 5.11, the seismic 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* (>60 days in 2012), 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 was 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 were much 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. 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* (>60 days in 2012), 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 5.6.1) 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*.

<u>Baleen Whales</u>

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 (e.g., 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 baleen whale species, it is assumed that some 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 not last very long. As per Table 5.11, the seismic 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* (>60 days in 2012), in an area *<1 to 1-10 km*^{2}. Therefore, hearing impairment and/or physical effects on baleen whales would be *not significant* (Table 5.12).

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
Sound								
Airguns	Disturbance (N) Hearing Impairment (N) Physical Effects (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
Helicopter [b]	Disturbance (N)		0-1	1-2	1	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
Helicopter Presence [b]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Sanitary/Domestic Waste	Increased Food (N/P)	-	0-1	1	1	1-2	R	2
Atmospheric Emissions	Surface Contaminants (N)	-	0	1	6	1-2	R	2
Accidental Releases	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.

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 [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound				
Airguns	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Presence of Vessels				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter Presence	NS	3	-	-
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	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

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

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 km^2* or *101 to 1,000 km^2*. 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 temporary displacement 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 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 km^2* or *101 to 1,000 km^2*. 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 5.6.1) 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*.

<u>Seals</u>

Seals are not expected to be abundant within the Study Area, particularly in the time period when seismic 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 a few 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 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 km*^{2}. 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 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 temporary 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 vessel would be ensonified periodically for a duration of *<1 month* or *1 to 12 months*. As per Table 5.11, the seismic 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).

5.6.4.3 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 or PTS.

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 "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 cool water temperatures likely preclude species other than leatherbacks from occurring there. If sea turtles did occur near the seismic 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).

Prey Species: Leatherback sea turtles are expected to feed primarily on jellyfish. It is unknown how jellyfish react to seismic 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*.

5.6.4.4 Effects of Helicopter Overflights

A crew change may occur via helicopter if the seismic program is longer than five to six weeks. The 2012 seismic program is anticipated to be >60 days in duration. However, crew changes may be conducted in port. Helicopters will maintain a regulated flight altitude above sea level unless it is necessary to fly lower for safety reasons.

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).

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
Sound								
Airguns	Hearing Impairment (N) Physical Effects (N) 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
Helicopter [b]	Disturbance (N)		0-1	1-2	1	1	R	2
Vessel Lights								
Vessel Presence								
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
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
Sanitary/Domestic Waste	Increased Food (N/P)	-	0-1	1	1	1-2	R	2
Atmospheric Emissions	Surface Contaminants (N)	-	0	1	6	1-2	R	2
Accidental Releases	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*) 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 [a]	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
Sound				
Airguns	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter Presence	NS	3	-	-
Vessel Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	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.

<u>Sea Turtles</u>

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).

5.6.4.5 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 (>60 days in 2012). It is anticipated that a supply ship will also be on site occasionally. 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), this risk is minimal (Laist et al. 2001; Vanderlaan and Taggart 2007). Marine mammal responses to ships are presumably mostly 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 (2007a). 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 any 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).

5.6.4.6 Effects of Accidental Releases

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with WesternGeco's policy, and handling and reporting procedures. If fluid-filled streamers are used in surveys in 2012 to 2015, 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 release 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).

5.6.4.7 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* and therefore *not significant* (Tables 5.11 to 5.14).

5.6.5 Effects of the Project on Species at Risk (SAR)

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 4.12, *SARA* species of relevance to the Study Area include:

- Spotted and northern wolffish, and white shark;
- Ivory gull;
- Blue and North Atlantic right whale; and
- Leatherback sea turtle.

Species not currently designated (see Table 4.12) 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 2015), 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.

The mitigation measure of ramping up the airgun array (over a 30 min period) is expected to minimize the potential for effects on white sharks and wolffishes. As per the detailed effects assessment contained in Section 5.6.1, physical effects of the Project on the various life stages of the white shark and two wolffish species will range from *negligible* to *low* for a duration of *<1 month* to *1-12 months* over 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).

Ivory gull foraging behaviour would not likely expose it to underwater sound, and this species is unlikely to occur in the Study Area, particularly during the time when seismic surveys are likely to being conducted. Furthermore, ivory gulls are not known to be prone to stranding on vessels. The mitigation measures of monitoring the seismic vessel and releasing stranded birds (in the unlikely event that an ivory gull did strand on the vessel) and ramping up the airgun array will minimize the potential for effects on this species. As per the detailed effects assessment in Section 5.6.3, the predicted effects of the Project on ivory gulls will be *negligible*. Therefore, the predicted effects of the Project on ivory gulls are predicted to be *not significant.*

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 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 also available (ALTRT 2006). No critical habitat in the Study Area has 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 5.6.4, the predicted effects of the Project on blue whales, right whales and leatherback sea turtles will range from *negligible* to *low* for a duration of *<1 month* to *1-12 months* over an area of *<1* to *101-1,000* km^2 (Table 5.16). Based on these criteria, the predicted effects of the Project on blue whales, right whales and leatherback sea turtles are predicted to be *not significant* (Table 5.17).

In summary and based upon the preceding discussion, potential effects of WesternGeco's proposed 2D and 3D seismic programs are not expected to contravene the prohibitions of *SARA* (Sections 32(1), 33, 58(1)).

Table 5.15 Potential Interactions Between the Project and Species at Risk VEC.

Valued Ecosystem Components: Species at Risk					
Project Activities	**White Shark**	**Wolffishes**	**Ivory Gull**	**Blue and Right Whales**	**Leatherback Sea Turtle**
Sound					
Airguns	X	X	X	X	X
Seismic Vessel	X	X	X	X	X
Supply Vessel	X	X	X	X	X
Picket Vessel	X	X	X	X	X
Geohazard Vessel	X	X	X	X	X
Helicopter [b]			X	X	X
Vessel Lights	X	X	X		
Vessel Presence					
Seismic Vessel			X	X	X
Supply Vessel			X	X	X
Picket Vessel			X	X	X
Geohazard Vessel			X	X	X
Sanitary/ Domestic Waste	X	X	X	X	X
Atmospheric Emissions	X	X	X	X	X
Garbage [a]					
Helicopter Presence			X	X	X
Shore Facilities [c]					
Accidental Releases	X	X	X	X	X
Other Projects and Activities					
Oil and Gas Activities on Grand Banks	X	X	X	X	X
Fisheries	X	X	X	X	X
Marine Transportation	X	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.

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
Sound								
Seismic Array	Disturbance Hearing Impairment (N); Physical Effects (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
Helicopter [c]	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Vessel Presence								
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
Helicopter Presence [c]	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
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
Atmospheric Emissions	Surface contaminants (N)	-	0	1	6	1-2	R	2
Accidental Releases	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 = 101-1,000 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] 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 Geophysical Program on the Species at Risk VEC.

Valued Ecosystem Component: Species At Risk				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood [a]**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Sound				
Airguns	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Vessel Lights	NS	3	-	-
Helicopter Presence	NS	3	-	-
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	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.

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 WesternGeco seismic program activities in the Project Area.

It is also necessary to assess cumulative effects from other non-Project activities that are occurring or planned for the Regional Area. These activities may include:

- Commercial and research survey fishing;
- Vessel traffic (e.g., transportation, defense, yachts);
- Hunting (e.g., seabirds, seals); and
- Offshore oil and gas industry.

Fishing has been discussed and assessed in detail in Section 5.6.2. 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. The seismic surveying will also spatially and temporally avoid DFO research vessels during multi-species trawl surveys. Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to 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 low and *not significant*.

The vast majority of hunting of seabirds (mostly murres) in Newfoundland and Labrador waters occurs near shore from small boats. Also, it is predicted that no murres will suffer mortality from the Project's routine activities. 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, and the Project will not cause mortality to seals even in the event of an accidental spill of petroleum hydrocarbons.

Potential offshore oil and gas industry activities in the Regional Area (as per the C-NLOPB public registry, www.cnlopb.nl.ca) include:

- Multi Klient Invest ASA (MKI) 2D seismic program on Northeast Newfoundland Shelf (i.e., Labrador Basin, Orphan Basin, Flemish Pass, Jeanne d'Arc Basin), 2012-2017 (2012 surveying planned);
- Statoil 3D/2D geophysical program including geohazard and electromagnetic surveys in Jeanne d'Arc and Central Ridge/Flemish Pass Basins, 2011-2019 (2012 surveying planned);
- Husky's seismic and geohazard program in the Jeanne d'Arc Basin/Flemish Pass, 2012-2020 (2012 surveying planned);
- Investcan Energy Corporation 2D/3D seismic program including geohazard and VSP surveys on Labrador Shelf, 2010-2017;
- Chevron Canada Resources 3D/2D seismic program including geohazard survey in offshore Labrador, 2010-2017;
- Chevron Canada Resources 3D and/or 2D seismic program including geohazard survey in the North Grand Banks Region, 2011-2017;
- Statoil exploration, appraisal, and delineation drilling program in Jeanne d'Arc Basin area, 2008-2016;
- Suncor exploration drilling in Jeanne d'Arc Basin, 2009-2017;
- Husky White Rose new drill centre construction and operations program, 2008-2015; and
- Husky exploration and delineation drilling program in Jeanne d'Arc Basin, 2008-2017.

While the above list suggests potential for many programs to run concurrently it should be noted that the East Coast operators tend to coordinate their logistics. As a result, based on historical levels of activities, there typically would be no more than two or three drill rigs and two or three seismic programs operating off Newfoundland and Labrador during any one season.

In addition, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. A fourth development (Hebron) is anticipated to commence installation in 2012. The existing developments fall inside of the boundaries of WesternGeco's Study Area but do not create the same levels of underwater noise as seismic, geohazard, or VSP programs. 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 other seismic programs proposed for 2012 (e.g., Statoil, Husky, MKI). Different seismic programs could potentially be operating in close proximity. During these periods, marine mammals may be exposed to noise from each of the seismic survey programs. It will be in the interests of the different parties for good coordination between programs in order to provide sufficient buffers and to minimize acoustic interference. 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 activity of seismic programs (2013-2015) in the area will be assessed in the EA update process. Uncertainty due to the large identified Study Area will be reduced as specific survey designs (covering smaller area) become available.

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 geophysical programs, the current scientific prediction is it that *no significant residual effects* will result.

5.8 Mitigations and Follow-up

Project mitigations are summarized in the text provided below and in Table 5.18. WesternGeco and contractors will adhere to mitigations detailed in Appendix 2 of the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB, February 2011) including those in 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. Fishing gear may only be retrieved from the water by the gear owner (i.e., fishing license owner). This includes buoys, radar reflectors, ropes, nets, pots, etc., associated with fishing gear and/or activity. If gear contact is made during seismic operations it should not be retrieved or retained by the seismic vessel. There are conditions that may warrant gear being retrieved or retained if it becomes entangled with seismic gear; however, further clarification on rules and regulations regarding fishing gear should be directed to the Conservation and Protection Division of Fisheries and Oceans Canada (NL Region). WesternGeco 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 • Request input from fishing captains through FFAW PIL regarding streamer deploying and testing plan. • 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 any 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 • Use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations.
Injury (mortality) to stranded seabirds	• Daily monitoring of vessel • Handling and release protocols • Minimize lighting if safe
Exposure to hydrocarbons	• adherence to International Convention for the Prevention of Pollution from Ships (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:

- Timely and clear 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).

WesternGeco 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. WesternGeco commits to ongoing communications with other operators with active seismic programs within the general vicinity of its seismic 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 shutdown 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 WesternGeco that a CWS *Migratory Bird Handling Permit* will be required, and this will be secured as it has been done in the past. In the unlikely event that marine mammals, turtles or birds are injured or killed by Project equipment or accidental releases 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. As per the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2011), monitoring protocols for marine mammals and sea turtles will be consistent with those developed by LGL and outlined in Moulton and Mactavish (2004). Seabird data collection protocols will be consistent with those provided by CWS in Wilhelm et al. (n.d.). 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. WesternGeco's geophysical 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 [a]**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Sound				
Airguns	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Vessel Presence				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Vessel Lights	NS	3	-	-
Helicopter Presence	NS	3	-	-
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	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.

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APPENDICES

A. Seabird Summary Tables

B. Persons Consulted

C. SPOC (and FLO) Protocols, Procedures and Reporting Forms

Appendix A. Seabird Summary Tables

Table A.1 Average densities of seabirds by month recorded during 10-minute seabird counts on the Orphan Basin, 14 May to 24 September 2005.

	Average Densities (number of individuals per km²) per 10-minute Observation Period					
	May	**June**	**July**	**August**	**September**	**All Months Combined**
No. of 10-minute Observation Periods	113	157	45	135	71	521
Total Area Surveyed (km²)	42.1	63.3	16.1	51.8	30.8	204.1
Species						
Northern Fulmar	30.12	4.75	3.27	4.23	16.14	11.54
Greater Shearwater	1.17	4.23	35.37	21.15	9.18	11.32
Leach's Storm-Petrel	5.14	7.74	5.48	10.23	6.31	7.43
Great Black-backed Gull	0.24	0.08	0.00	4.14	12.07	2.79
Dovekie	1.25	1.21	0.00	0.04	0.00	0.65
Thick-billed Murre	0.61	0.74	0.00	0.00	0.00	0.36
Black-legged Kittiwake	1.07	0.27	0.06	0.06	0.03	0.34
Herring Gull	0.43	0.05	0.00	0.22	0.07	0.18
Sooty Shearwater	0.00	0.12	0.05	0.17	0.38	0.14
Long-tailed Jaeger	0.25	0.06	0.00	0.00	0.00	0.07
Red Phalarope	0.20	0.01	0.00	0.00	0.00	0.05
Unidentified murre	0.03	0.04	0.00	0.10	0.00	0.05
Common Murre	0.05	0.06	0.14	0.00	0.00	0.04
Pomarine Jaeger	0.03	0.00	0.00	0.02	0.04	0.02
Lesser Black-backed Gull	0.00	0.04	0.00	0.00	0.03	0.02
Manx Shearwater	0.00	0.02	0.00	0.00	0.00	0.01
South Polar Skua	0.00	0.00	0.06	0.00	0.03	0.01
Unidentified skua	0.00	0.00	0.00	0.02	0.03	0.01
Parasitic Jaeger	0.03	0.00	0.00	0.00	0.04	0.01
Unidentified jaeger	0.00	0.00	0.00	0.03	0.00	0.01
Glaucous Gull	0.02	0.00	0.00	0.00	0.00	0.01
Sabine's Gull	0.03	0.00	0.00	0.00	0.00	0.01
Arctic Tern	0.00	0.02	0.00	0.00	0.00	0.01
Atlantic Puffin	0.02	0.00	0.06	0.00	0.00	0.01
All Species	1.27	0.61	1.39	1.27	1.39	1.10

Source: Moulton et al. 2006.

Table A.2 Average densities (± standard deviation) of seabirds by month recorded during 10-minute seabird counts on the Orphan Basin, August (*n* = 53 counts) and September (*n* = 33 counts) 2006.

Species	Average Densities - number of individuals per km^2 (±SD) - of 10-minute Tasker Counts		
	August	**September**	**All**
Greater Shearwater	11.78 (±24.67)	2.43 (±5.88)	8.20 (±20.15)
Leach's Storm-Petrel	6.01 (±5.79)	6.26 (±7.13)	6.11 (±6.30)
Black-legged Kittiwake	1.42 (±2.73)	7.81 (±21.89)	3.87 (±13.95)
Northern Fulmar	2.34 (±4.72)	5.75 (±6.09)	3.65 (±5.51)
Great Black-backed Gull	0.25 (±0.95)	2.37 (±6.56)	1.06 (±4.23)
Sooty Shearwater	0.35 (±0.74)	1.06 (±2.21)	0.63 (±1.52)
Pomarine Jaeger	0.07 (±0.28)	0.18 (±0.82)	0.11 (±0.55)
Great Skua	0.11 (±0.31)	0.12 (±0.50)	0.11 (±0.39)
Arctic Tern	0.09 (±0.46)	0.07 (±0.40)	0.08 (±0.43)
Atlantic Puffin	0.15 (±0.91)	0.07 (±0.49)	0.08 (±0.77)
Long-tailed Jaeger	0.12 (±0.38)	0	0.07 (±0.30)
Parasitic Jaeger	0.02 (±0.18)	0.13 (±0.50)	0.07 (±0.34)
Lesser Black-backed Gull	0.04 (±0.21)	0	0.03 (±0.17)
Dovekie	0	0.05 (±0.31)	0.02 (±0.19)
Common Murre	0.03 (±0.22)	0	0.02 (±0.18)
South Polar Skua	0.03 (±0.21)	0	0.02 (±0.16)
skua sp.	0.04 (±0.19)	0	0.02 (±0.15)
Wilson's Storm-Petrel	0.03 (±0.21)	0	0.02 (±0.16)
Herring Gull	0	0.03 (±0.18)	0.01 (±0.11)
Northern Gannet	0.02 (±0.16)	0	0.01 (±0.13)
All Species	**22.89** (±25.15)	**26.35** (±22.89)	**24.22** (±24.23)

Source: Abgrall et al. 2008b.

Table A.3 Average densities (± standard deviation) of seabirds recorded during 10-minute seabird counts during on the Orphan Basin, 23 July to 6 September (*n* = 97 counts) 2007.

Species	**Average Densities - number of individuals per km^2 (±SD) - of 10-minute Tasker Counts**
Leach's Storm-Petrel	4.34 (±3.23)
Greater Shearwater	2.42 (±3.47)
Northern Fulmar	1.67 (±1.95)
Sooty Shearwater	0.19 (±0.49)
Common Murre	0.09 (±0.46)
Great Black-backed Gull	0.05 (±0.32)
Northern Gannet	0.03 (±0.23)
Long-tailed Jaeger	0.03 (±0.22)
Thick-billed Murre	0.03 (±0.26)
Dovekie	0.02 (±0.20)
Red Phalarope	0.01 (±0.10)
Manx Shearwater	0.01 (±0.01)
unidentified murre	0.01 (±0.10)
Black-legged Kittiwake	0.01 (±0.09)
Lesser Black-backed Gull	0.01 (±0.09)
All Species	**8.87** (±6.38)

Source: Abgrall et al. 2008b.

Table A.4 Average densities of seabirds by week recorded during 10-minute seabird counts in the Jeanne d'Arc Basin and adjacent areas, 1 October to 8 November 2005, arranged in order of decreasing density.

	Average Density (number of individuals per km²) per 10-minute Observation Period						
Species	**1-7 October**	**8-14 October**	**15-21 October**	**22-28 October**	**29 Oct. - 4 Nov.**	**5-8 November**	**All weeks combined**
Northern Fulmar	3.07	25.57	4.35	34.17	10.00	10.77	14.72
Dovekie	1.53	5.07	10.14	13.58	7.07	4.16	7.09
Black-legged Kittiwake	1.16	8.38	11.76	8.97	4.29	5.78	6.57
Thick-billed Murre	0	1.86	5.01	4.16	7.41	9.58	4.11
Greater Shearwater	11.82	1.71	0.45	0	0	0	2.87
Atlantic Puffin	0.86	1.73	2.37	1.34	1.65	0.51	1.46
Common Murre	1.05	0.88	1.52	0.83	0.05	0.20	0.81
Great Black-backed Gull	0.25	1.59	0.65	0.67	0.51	0.46	0.68
Leach's Storm-Petrel	1.02	0.39	0.46	0.54	0.04	0	0.47
Sooty Shearwater	0.19	1.03	0.50	0.61	0	0	0.40
Glaucous Gull	0	0	0.06	0.50	0.04	0.48	0.16
Herring Gull	0.04	0.05	0.00	0.06	0.20	0.76	0.13
Pomarine Jaeger	0.21	0	0	0	0	0	0.04
Jaeger sp.	0.08	0	0	0.07	0	0	0.03
Murre sp.	0	0.05	0.04	0.08	0	0	0.03
Northern Gannet	0.07	0	0	0	0.09	0	0.03
Razorbill	0.14	0	0	0	0	0	0.03
Iceland Gull	0	0	0	0	0.05	0.09	0.02
Lesser Black-backed Gull	0	0.12	0	0	0	0	0.02
Parasitic Jaeger	0	0.05	0	0.04	0	0	0.02
Red Phalarope	0.07	0	0	0.04	0	0	0.02
Skua sp.	0	0.05	0.05	0	0	0	0.02
Great Skua	0	0	0.05	0	0	0	0.01
Manx Shearwater	0	0	0	0.04	0	0	0.01
South Polar Skua	0.03	0	0	0	0	0	0.01
All species	**21.70**	**48.55**	**37.40**	**65.71**	**31.39**	**32.79**	**39.76**

Source: Abgrall et al. 2008a.

Table A.5 Average densities of seabirds by week recorded during 10-minute seabird counts in the Jeanne d'Arc Basin, 9 July to 16 August 2006.

Species	Average Density (number of individuals per km²) per 10-minute Observation Period						
	9-16 July	**17-23 July**	**24-30 July**	**31 July - 6 August**	**7-13 August**	**14-16 August**	**All Weeks Combined**
Greater Shearwater	2.54	7.04	4.33	8.90	1.57	0.62	5.06
Leach's Storm-Petrel	1.15	0.17	0.24	0.41	0.42	0.10	0.60
Northern Fulmar	0.15	0.05	0.05	0	0	0.05	0.07
Sooty Shearwater	0.07	0	0.05	0.02	0.03	0	0.04
Atlantic Puffin	0.12	0	0	0	0	0	0.03
South Polar Skua	0	0	0.05	0.05	0	0	0.02
Common Murre	0.08	0	0	0	0	0	0.02
Skua sp.	0	0	0.05	0	0	0	0.01
Red Phalarope	0	0	0.10	0	0	0	0.01
Pomarine Jaeger	0	0	0.05	0	0.03	0	0.01
Northern Gannet	0	0	0	0.02	0	0	0.01
Murre sp.	0	0.05	0	0.03	0	0	0.01
Manx Shearwater	0.02	0	0	0.03	0	0	0.01
Great Black-backed Gull	0	0	0	0	0	0.03	0.01
Dovekie	0	0	0	0.03	0	0	0.01
Black-legged Kittiwake	0	0	0	0	0	0.05	0.01
All Species	**4.14**	**7.32**	**4.91**	**9.49**	**2.03**	**0.85**	**5.93**

Source: Abgrall et al. 2008a.

Table A.6 Average Densities of seabirds bi-monthly recorded during 10-minute seabird counts in the Jeanne d'Arc Basin and adjacent areas, 21 May to 29 September 2008.

Species	Average Density (number of individuals per km²) per 10-minute Observation Period									
	21-31 May	**1-15 June**	**16-20 June**	**1-15 July**	**16-31 July**	**1-15 August**	**16-31 August**	**1-15 September**	**16-29 September**	**Grand Total**
Greater Shearwater	0.05	2.11	15.07	26.65	19.93	24.27	9.81	9.04	3.18	11.92
Sooty Shearwater	0	0.33	1.04	0.25	0.1	0.07	0.53	6.06	3.98	1.65
Northern Fulmar	0.08	0.18	3.54	0.15	0.26	0.57	1.02	1.41	3.03	1.24
All murres	1.1	0.25	0.46	0.31	0.29	0.02	0.88	1.61	3.57	1.02
Leach's Storm-Petrel	0.22	0.13	0.21	0.21	0.97	0.57	0.49	1.49	2.92	0.9
Common Murre	0.72	0.09	0.28	0.31	0.24	0	0	1.51	3.42	0.84
Unidentified Murre	0.38	0.12	0.18	0	0.03	0.02	0.88	0.08	0.15	0.18
Great Black-backed Gull	0	0	0	0	0	0	0.03	0.55	0.52	0.15
Atlantic Puffin	0	0.02	0.13	0.14	0.02	0	0	0.02	0.59	0.11
Manx Shearwater	0	0	0.06	0.14	0.21	0.07	0	0	0	0.05
Pomarine Jaeger	0	0	0	0	0	0.02	0.06	0.12	0.14	0.04
South Polar Skua	0	0	0	0.14	0.03	0.03	0.06	0.04	0	0.03
Great Skua	0	0	0	0.03	0	0	0.03	0.06	0.04	0.02
Northern Gannet	0	0	0	0	0	0	0.16	0.03	0	0.02
Dovekie	0.03	0	0.02	0	0	0	0	0	0.07	0.02
Black-legged Kittiwake	0	0.02	0.07	0	0	0	0.03	0.03	0.02	0.02
Thick-billed Murre	0	0.04	0	0	0.03	0	0	0.02	0	0.01
Red Phalarope	0	0	0	0	0	0	0	0.05	0	0.01
Long-tailed Jaeger	0	0	0	0	0	0	0	0.03	0.02	0.01
Unidentified phalarope	0	0	0	0	0	0	0	0.03	0	0.005
Parasitic Jaeger	0	0	0	0	0	0	0	0.005	0.02	0.003
Wilson's Storm-Petrel	0	0	0	0	0	0	0	0.02	0	0.003
Herring Gull	0	0	0	0	0	0	0	0.02	0	0.002
Unidentified Skua	0	0	0	0	0	0	0.03	0	0	0.002
Unidentified Jaeger	0.03	0	0	0	0	0	0	0	0.02	0.002
Lesser Black-backed Gull	0	0	0	0	0	0	0	0	0.02	0.002
Arctic Tern	0	0	0	0	0	0	0	0	0.02	0.002
All Birds	**1.51**	**3.03**	**20.6**	**31.03**	**21.82**	**25.63**	**13.14**	**20.59**	**18.12**	**17.23**

Source: Abgrall et al. 2009.

Appendix B. Persons Consulted

The following agencies, managers and fishing industry participants were consulted for WesternGeco's proposed 2012 seismic program:

Fisheries and Oceans Canada

Jason Kelly, Co-ordinator, Environmental Assessment & Major Projects, Oceans, Habitat & Species at Risk Branch

Environment Canada (Environmental Protection Branch)

Glenn Troke, EA Co-ordinator

Jerry Pulchan, EA Analyst

Nature NL (and member organizations)

Dr. Len Zedel, Nature NL

One Ocean

Maureen Murphy, Director of Operations

Fish, Food and Allied Workers Union (FFAW)

Robyn Saunders-Lee, Petroleum Industry Liaison

Gerard Chidley, Independent Fish Harvester

Association of Seafood Producers

E. Derek Butler, Executive Director

Ocean Choice International

Rick Ellis, Fleet Manager

Icewater Seafoods

Michael O'Connor, Fish Harvesting Consultant

Tom Osbourne, Plant Manager, Arnold's Cove

<u>Clearwater Seafoods Limited Partnership</u>

Catherine Boyd, Manager, Corporate Affairs

<u>Newfound Resources Ltd. (NRL)</u>

Brian MacNamara, President

Captain Carl Hillier, Skipper of the *Newfoundland Pioneer*

Jeff Simms, Operations Manager

<u>Groundfish Enterprise Allocation Council (Ottawa)</u>

Bruce Chapman, Executive Director

Appendix C. SPOC (and FLO) Protocols, Procedures and Reporting Forms

Commercial Fisheries

The Environmental Assessment (EA) for offshore petroleum exploration projects document past and anticipated fishing in the general area of the projects, though fishing and fishing gear could occur almost anywhere. The document should be consulted closely.

The main threat of conflict with seismic survey activities is usually from fixed fishing gear (e.g. crab pots and gillnets) and the presence of fishing vessels in the seismic acquisition area. DFO / industry science surveys are another area where avoidance may be required; this will also be described in the EA.

It should be noted that fishers are not required to move fishing gear from the exploration work area. All gear in the path of the petroleum exploration work should be avoided and other clear areas pursued instead. If obstructing fishing gear is located by the seismic or scout vessel, the exact positions, and name or CFV number on the gear, should be recorded and relayed to the Fisheries Liaison Officer (FLO) and the Single Point of Contact (SPOC). At sea the FLO, and on land the SPOC, will try to contact the gear owners (based on the name or CFV information). The FLO and SPOC will attempt to determine the plans / schedule of the gear owner with respect to that gear, and will encourage the owner to communicate with the seismic vessel / FLO at sea, and to shift the gear in question into a different area the next time it is hauled, though this may not result in any significant change of location.

Operational Responsibilities, Protocols and Communications

Fisheries Liaison Officer (FLO)

(See C-NLOPB Guidelines; program operated by the Fish, Food and Allied Workers Union, (FFAWU), contact Robyn Saunders-Lee at 709-576-7276.)

The aims of the FLO program are to ensure fisheries-industry led monitoring / observer coverage of petroleum exploration programs, to provide operational planning / information exchange to help prevent at-sea conflicts with fishing activities. It also aims to build and maintain trust between the petroleum and fisheries industries, and to provide the fishing industry and the operator with feedback about environmental and fisheries issues.

The FLO's primary responsibility is as a representative of the fishing industry on board the seismic vessel. As such, his/her first duty is to monitor and safeguard the fishing industry's interests. Specific activities include:

- Observe activities which may affect the fisheries industry
- Help identify, avoid and resolve possible fisheries issues / conflicts, e.g.
  - Make radio contact with any fishing boats in the area and stay in touch generally
  - Help identify / locate any fishing gear in and near the current exploration area so it can be avoided
  - Determine gear type, layout, fishing plans (when in area, when leaving)
  - Advise bridge about best course of action to avoid gear / fishing activities
  - Inform fishers nearby about the petroleum exploration activities

  - Serve as initial contact in case of any gear damage; help to identify gear owners if encountered; verify gear damage.
- Provide offshore personnel with other relevant information and briefings
- Monitor response to emergency situations or drills
- Attend regular operations briefings
- Attend safety meetings, as requested
- Keep a daily log of all activities and observances, and report on any special issues/concerns to groups noted below
- Complete a written summary report following each rotation. Provide summary reports to the FFAWU, the Operator (and other fishing associations as requested by the Operator) and Single Point of Contact (SPOC, i.e. Canning & Pitt Inc), detailing sightings, environmental issues and fishing vessel traffic.

To the extent it does not interfere with their main duties listed above, and subject to prior approval by the Operator & FFAWU:

- Assist with other routine operations
- Undertake special projects as identified by the operator, in consultation with FFAWU.

Usual Qualifications of FLOs

FLOs should be familiar with the area's fisheries and industry, and undergo required training:

- Marine Radio Operators Certificate
- basic First Aid Certificate
- a valid Marine Emergency Duties (MED) Certificate that includes A1 Basic Safety, B1 Survival craft, B2 Marine Firefighting
- a valid mariners/seafarers medical certificate (health certification)
- a Workplace Hazardous Materials Information System (WHMIS) certificate (training may also be provided during mobilization)
- a passport (as a contingency)
- Helicopter Underwater Egress Training (HUET) and Helicopter Underwater Emergency Breathing Apparatus (HUEBA) training if helicopter transits are required.

Single Point of Contact (SPOC)

(See C-NLOPB Guidelines; operated by Canning & Pitt Inc., contact: R. Pitt or S. Canning at survey@canpitt.ca or 709-738-0133 or fax 709-753-4471.)

The SPOC's primary responsibilities are to serve as a liaison between the commercial fishing industry and the petroleum industry during marine projects. It provides the fishing industry with a "single point" (by way of a broadcast toll-free phone number included in Notices to Shipping) if there are issues, questions or incidents related to any offshore petroleum industry exploration activities.

With regards to a specific operator/project the SPOC's primary responsibilities are 1. to be available to fishers as a single liaison point about the project, 2. to respond to any gear damage incidents (or possible incidents) with a report initiated by either the seismic vessel, scout boat or a fisher. The SPOC will also investigate and follow through with reporting on these incidents. 3. to assess the validity of claim incidents and recommend payment based on the best evidence available, and 4. to provide appropriate standardized forms to the FLO / fishers for reporting and claims.

If requested, the SPOC will also file Notices to Shipping for the seismic vessel and assist the Operator and the FFAWU with the provision of FLO services and logistics.

Other usual activities include

- Updates to the FLO/ seismic vessel about known changes in relevant fisheries, the progress of species quotas and closures.
- Identifying (from CFV ID numbers, etc) owners of any gear located in the seismic project area or involved in an incident, as requested by an operator
- Contacting fishers identified in the seismic project areas (e.g. if gear is identified in the area) and ascertaining their plans and activities, as required
- Communicating directly with fishers when requested via Canning & Pitt's toll-free line (which it maintains for this purpose), based on the best-available data provided to Canning & Pitt Associates, Inc. by the seismic vessels
- With the agreement of the seismic vessel involved, update other vessels on the general location of seismic survey activities in their area
- Provide exploration project information to relevant fisheries groups and organizations as required.

SPOC Communications

1. Canning & Pitt maintains a toll-free phone line for incident reporting and information. This number is in contact with Canning & Pitt Inc. or its message service 24 hours a day. The number is 1-877-884-FISH (3474).

2. Canning & Pitt Inc. maintains a single point e-mail address for the purpose of the seismic project. E-mail to this address is broadcast to key contacts at Canning & Pitt Inc, facilitating a faster response time. This address is "survey@canpitt.ca." This is the e-mail that should be used for all communications from the seismic ship.
3. Canning & Pitt Inc. will contact and exchange information with relevant fish harvesters and harvester groups (e.g. the FFAWU) and with the federal Department of Fisheries and Oceans, as necessary, as required / requested during the seismic activities.

4. As Single Point of Contact for this project, Canning & Pitt Inc. will provide information to the C-NLOPB, as required, including copies of reports of active fishing areas, upon request, and informing C-NLOPB of claims and any proposed settlement.

5. If requested, Canning & Pitt Inc. will provide liaison between the operator and the FLO Program/FFAWU to help ensure that qualified FLOs are available when needed.

Information from Vessels / Operators (for SPOC)

Canning & Pitt requires the following information from vessel operators in order to perform its work (send to survey@canpitt.ca):

- Relevant vessel contact information and a designated contact person (e.g. Party Chief / Captain)

- The outer boundaries of each survey area (on a chart if feasible) and in latitude and longitude coordinates; also - if possible - a chart showing all activities (e.g. survey lines) with appropriate identification.

- Information on any changes to the expected survey area (i.e. outside the area posted under the current Notice to Shipping)

FLO Supply / Crew Change

Contacts re: FLO Supply – Robyn Saunders-Lee, FFAWU, 709-576-7276.

As noted, if requested, Canning & Pitt Inc. will assist in these matters between the operator and the FFAW's FLO Program. Canning & Pitt Inc. should be sent the co-ordinates (phone / email) of the appropriate project contact person for crew-changes, etc. Contact Canning & Pitt Inc. at survey@canpitt.ca or 709-738-0133 / fax 709-753-4471.

Notices to Shipping

As noted above, if requested, Canning & Pitt Inc. will file Notices to Shipping to the Canadian Coast Guard for broadcast on Coast Guard Radio and via ECAREG, on behalf of the vessel/platform (with information supplied by the vessel), and periodically check CCG Radio for currency of notices.

If the SPOC is filing the NotShips, the relevant information (work area and other project particulars) should be sent to them (survey@canpitt.ca) 48 hours before the Notice is to take effect. This is normally sent to the SPOC by the Captain/Master or by the Party Chief. The SPOC will provide a copy of the Notice back to the ship when it is filed.

All Notices filed for seismic vessels will identify the operating area of each vessel and will identify Canning & Pitt as the point of contact for submitting gear and vessel damage claims relating to seismic projects, and will supply contact information (toll-free phone number). This information will be contained in announcements through CCG Radio's Notices to Shipping (for mariners and fishers).

Note: Although Canning & Pitt will relay Notices to Shipping to the Canadian Coast Guard on the vessel's behalf, it is the ultimate responsibility of the vessel to ensure that these Notices are filed and that accurate information is filed.

The recommended tag line for Notices is "... Fishers who believe they have had gear damage as a result of operations are advised to contact Canning & Pitt Associates toll free at 1-877-884-3474."

Position Reports

The SPOC requires at least twice-daily position updates for the seismic vessel, e-mailed to Canning & Pitt Inc. (survey@canpitt.ca). Usually this is provided by the agency handling position reports for the Project, e.g. Stratos, Blue Sky. If a fishing gear incident occurs, the SPOC will likely request more detailed positions report for the period in question.

Sighting and Reporting Fishing Gear or Possible Gear

Any observation of gear at sea (abandoned or fishing) should be communicated to the FLO, and the FLO should report this in the FLO's daily log (summarized in the weekly report) including its type, condition and position. Any and all contact with fishing gear (or possible gear) should be treated as an Incident, and the protocols described in the following sections should be followed.

Normally, floating debris including apparently abandoned fishing gear should not be touched / retrieved by project personnel, unless it is necessary to remove gear that is clearly detached and lost (e.g. a drifting highflyer) because it poses a specific risk to the seismic project if not moved. Otherwise no fishing gear (including all active gear) should be touched by scout or seismic vessel personnel. However, its location and description should be reported to the FLO for inclusion in the daily log.

As noted above, the SPOC may be able to identify (from CFV id numbers, etc) owners of any gear sighted in the survey area. If this is required, contact them directly via survey@canpitt.ca with the relevant information.

Reports of Activities

In addition to completing any Gear Contact report forms (described in the following sections), the FLO will keep daily logs (compiled as weekly reports). These should be sent directly to the SPOC (survey@canpitt.ca) each week, as well as to the Client and/or Operator, and to the FFAW.
In addition to other relevant information about the project and area fisheries, the logs should supply adequate details of all fisheries-related contacts and sightings (including radio contacts with fishers), and should include the following:

- time of sighting / contact
- gear type and quantity, if known
- location (lat & long)
- owner, if known
- condition of gear, whether it has been abandoned or adrift
- type of contact made (radio, sighting, info from scout boat)
- any potential damage caused by the contact.

Incidents

This describes handling of commercial fisheries related gear incidents/accidents (i.e. contacts with fishing gear). A "contact" with fishing gear (or suspected fishing gear) means a physical contact, rather than an observation (see above).

Any and all contacts with fishing gear (including retrieval of abandoned or adrift gear), should be reported to the SPOC and the C-NLOPB using the incident Report form provided, according to the protocols described below.

Incidents Recorded by Seismic Vessel

The following are the procedures to be followed by project personnel / FLO if there is any indication on board the vessel (e.g. debris on streamer, direct contact from fisher) that the seismic ship, scout boat or a seismic streamer (or other equipment) may have made contact with fishing gear.

Gear Contacts: The *C-NLOPB Guidelines* (April 2004, Section 4.2 and Appendix 2) state that "contact with fishing gear must … be reported immediately. The Board maintains a 24- hour answering service at (709) 778-1400 for this purpose. Direct contact may be made at (709) 682-4426." This guideline requires that all fishing gear contacts by a seismic vessel be reported to the Board (observe a maximum within 24 hours), even if no damage to the gear has occurred. Suspected/ possible contacts with gear should also be reported.

The Gear Contact Procedures (below) should be followed if there is any indication that the vessel (including a scout/guard vessel) or the seismic streamer (or other equipment) may have made contact with fishing gear (e.g. visual observation, ropes or other debris caught on the streamer or acoustic array), and a report prepared and filed as soon as possible.

The report is usually prepared by a person on the ship making contact who has first-hand knowledge of the event, preferably the FLO. The facts as known are recorded on the form and should be sent to survey@canpitt and to the Operator.

The SPOC's role is then to relay the report to the Board as quickly as possible, to follow up with the report, to identify the gear owners, and to investigate any related claim of damage made by a fisher. Reports of follow-up activities will be prepared and filed with the Board and the other parties.

Incidents Reported to SPOC

The following are the procedures to be followed by the SPOC (Canning & Pitt Inc.) if they are contacted by a fisher about an incident (e.g. via their broadcast toll-free number).

In some cases, the SPOC will be contacted directly by a fisher claiming possible seismic survey-related gear loss or damage. In these cases, the SPOC will first investigate independently, but may request details of locations, timing and activities from the vessel and/or FLO. When completed, the SPOC will provide their investigation report (and recommendations) to the Operator, the claimant, the Board, and the relevant fisheries organization (e.g. the FFAWU) and other parties directly involved.

When contacted by a fisher about a possible gear damage / loss incident, the SPOC will follow the following procedures.

1. Record the particulars about the incident by phone – fisher name and contact numbers, location of gear, date of incident (or date set), type and amount of gear, other vessels nearby.

2. Forward a Damage Report Form for Fishers (using a format acceptable to the C-NLOPB) to the claimant to be completed and returned as soon as possible.

3. If no incident has been reported by a petroleum seismic vessel in the same general area, conduct a preliminary investigation of the location and dates to determine (to the extent possible) if the incident was related to an seismic vessel, and/or which operator might potentially have been involved.

4. If it appears possible that the incident was the result of seismic operations, notify the C-NLOPB of the possible incident, and notify the likely seismic operator(s) of the incident.

5. Conduct a full investigation of the incident. This will usually involve obtaining more detailed position reports and other information from seismic ships in the area.

6. Report on the findings and the recommendations to the C-NLOPB and the seismic operator (if relevant).

Gear Contact/Conflict Procedures and Form

Recording / Reporting Procedures for Fishing Gear & Vessel Contact Incidents

This outlines the steps personnel (usually the FLO) on board the seismic vessel will take in the event of a suspected conflict / contact with fishing gear/vessel.
Recording Incident Information

If you have any indication that the vessel or the seismic streamer (or other equipment) may have made contact with fishing gear (e.g. visual observation, ropes or other debris caught on the streamer or acoustic array), you should, as soon as feasible:

1. take all reasonable action to prevent any further or continuing damage
2. note how the incident was discovered and by whom
3. note exact time, location, sea conditions, and any other pertinent information about the discovery of the event
4. record any fisher/fishing vessel identification number (e.g. a Canadian FishingVessel/CFV number painted on a buoy, or a crab pot licence tag)
5. if possible, photograph the gear or gear debris in the water and after recovery
6. secure and retain any of the suspected gear debris, if this is possible and Feasible
7. note what the seismic vessel had been doing before discovering the incident, and retain any data on the ship's positions during the preceding 24 hours
8. note any other vessels that you are aware of in your vicinity before/during discovering the incident.

The Gear Incident Report form that should be filed is attached. You may also add any additional information if you feel it is relevant.

Reporting an Incident

(1) As soon as possible after an incident (or a suspected incident) has occurred, notify the Client's representative on board the seismic vessel, and Canning & Pitt Associates, Inc. at

Tel: 709-738-0133
Fax: 709-753-4471
or E-mail: or survey@canpitt.ca.

As the C-NLOPB Guidelines state, any incident should be reported immediately to the 24-hour answering service at (709) 778-1400 or to the duty officer at (709) 682 4426; or else notify (at least within 24 hrs) EYoung@cnlopb.nl.ca at the C-NLOPB, e.g. directly from the seismic vessel via E-mail. The initial report should be sent immediately when completed to the SPOC (Canning & Pitt Inc) and to the Operator. The SPOC will then report it to the Board. It should include the information described in Items 3 and 4 above.

(2) As soon as feasible thereafter (within 48 hours), e-mail the full report and any photos of the incident (using the Incident Report form) to Canning & Pitt Associates. (Canning & Pitt will relay this to the Board after reviewing it for completeness).

(3) If possible, retain any gear debris until it can be transported to shore and turned over to Canning & Pitt Associates, Inc.

Sighting or Moving Fixed Fishing Gear

If the seismic vessel sights any evidence of fixed fishing gear (e.g. "highflyer" with radar reflector affixed to a large buoy; three buoys together) which the vessel believes may be located on or close to one of the project activities (e.g. on or near a survey line), the following procedure is recommended.

1. If possible, the seismic vessel should observe and record any identification number (e.g. the CFV number) painted on the buoy or highflyer.

2. The seismic vessel should attempt to hail (via VHF radio) any fishing vessels which may be in the vicinity. If a fishing vessel can be reached, report the type, location and - if known - the CFV numbers marked on the gear and ask the skipper of that vessel for any information which might allow the seismic vessel to identify the owner. (Note: It is not legal for any one but the gear owner to move the gear.)

3. If the CFV number is known, Canning & Pitt may be able to identify the owner of the gear; contact them at 709-738-0133.

4. If it is not possible to contact the gear owner, the seismic vessel should attempt to work in another area and return to the first location at a later time.

Gear Incident Report Form[7]
(for Seismic Vessels)

To be completed and filed (see "Gear Contact/Conflict Procedures") in case of any fishing gear contact incident, whether or not the fishing gear was damaged.

Seismic Vessel Name:

Did fishing gear appear to be damaged by the contact? Y N

1. Person completing Report:

Position

E-mail/Phone No: /

2. Date of incident:

Time of incident/discovery: /

Location of the incident Lat: Long:

(If known)

3. Name of fishing vessel:

CFV No (on gear/buoy):

Vessel Skipper/Owner:

Address:

[7] Extra space for completing form removed for purposes of this EA.

Telephone/Fax No:

/

4. Wind / weather / visibility / sea state at time of incident or discovery:

5. Describe the type and quantity gear recovered (including any identifying marks / numbers, etc):

6. Describe what the seismic vessel was doing at the time of the incident:

7. Describe what the fishing vessel was doing at the time of the incident:

8. Draw a sketch/diagram showing the position of the seismic vessel/gear in relation to the gear, fishing vessel, etc.:

9. Describe any measures the seismic vessel took to recover gear, or to stop or limit the damage or loss:

10. Names of any other vessels in the area at the time of the incident (if known):

11. Describes steps taken to notify fishing vessel or others:

12. Other pertinent information / remarks (use extra sheets if necessary):

Fishing Gear Damage Report [8]
(For Fishing Industry Participants)

To be completed by claimant or representative

Date of Report: ________________________________

1. Person completing this Report: ____

Position ____

Telephone/Fax No: ______________________ / ______________________

Address: ____

____

2. Skipper at time of incident: ____

Telephone/Fax No: ______________________ / ______________________

Address: ____

____

3. Name of fishing vessel: ____

CFV No: ____

Vessel Owner: ____

Owner Address: ____

____

[8] Extra space for completing form removed for purposes of this EA.

4. Licence or Permit holder's name ______________________________
(of gear and/or vessel involved)

Licence / Permit Held (+ No.) ______________________________

Telephone/Fax No: ______________ / ______________

Address: ______________________________

____

5. Person who will be making the claim for this incident: ______________________________

Date of loss/damage (or when discovered):______________________________

Time of the incident (or when discovered):______________________________

Location of the incident or discovery:______________________________

Lat: ____________ Long: ____________

Original set/deployed positions of the gear:

Start: Lat: ____________ Long: ____________

End: Lat: ____________ Long: ____________

Date gear was set, before the incident:______________________________

Time gear was set, before the incident:______________________________

Other vessels fishing in the area (if known):

Type of fishery (gear, vessel) and species being fished:

How was the incident discovered:

Describe the damage that occurred (quantity and gear components damaged or lost; nature of the damage):

Draw a sketch/diagram showing the position of your gear (and show relation to the vessel which caused the damage, if known) (use separate sheet if necessary):

Any other information about how the incident occurred (use separate sheet if necessary):

Vessel and operator / company responsible for the loss/ or damage (if known or suspected):

Reason for believing this vessel / operator was responsible:

I certify that the above information is, to the best of my knowledge, full and accurate in every detail.

Signed by: Date:

Please fax, e-mail or mail to:

Canning & Pitt Associates, Inc.
PO Box 21461, St. John's, Newfoundland, Canada, A1A 5G2
Fax: 709-753-4471

Tel: (toll-free) 1-877-884-3474
E-mail: survey@canpitt.ca