Environmental Assessment of GXT's LabradorSPAN 2-D Seismic, Gravity and Magnetic Survey, 2013-2015

Prepared by

LGL LIMITED
environmental research associates

and

ION
GX TECHNOLOGY

March 2013
Project No. SA1199

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1.0 Introduction

This is an Environmental Assessment (EA) prepared by LGL Limited (LGL) and GX Technology Canada Ltd. (GXT) for GXT's proposed 2013 – 2015 2-Dimensional (2D) marine exploration program offshore Labrador and northern Newfoundland. The EA is designed to apply to the Project (i.e., all geophysical surveys - seismic, gravity and magnetic) conducted over the area of operations during a three-year period and intended to enable the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) to fulfill its responsibilities under Section 138 (1)(b) of the *Canada-Newfoundland Atlantic Accord Implementation Act* and Section 134(1)(b) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (Accord Acts). This EA has been guided by the Scoping Document prepared by the C-NLOPB, as well as by advice and information received and issues identified through various communications and consultations with other agencies, interest groups, stakeholders and beneficiaries.

The temporal scope of the Project is a three-year period (2013 to 2015) with seismic operations potentially occurring between June and November in any given year. The present document focuses primarily on the proposed 2-D seismic program which is anticipated to occur in 2013. It is currently uncertain if GXT will undertake seismic surveys offshore Labrador and northern Newfoundland during 2014 and 2015, as future surveys will depend on results of the initial survey and other factors. The geographic scope of the Project is the Project Area in any year shown in Figure 1.1. An example of a typical line layout that might be acquired in any one of the survey years is shown in Figure 1.2 (for illustrative purposes). Note that the Hawke Channel Fishery Closure Area (area in southern Study Area with dashed red-line border) is not a part of the Project Area.

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*. Pursuant to the Accord Acts, the C-NLOPB is responsible for seeking to identify the federal departments or agencies that may have expertise required in the completion of the assessment. Because seismic survey activities have the potential to affect seabirds, marine mammals, sea turtles, and fish and fisheries, Fisheries and Oceans Canada (DFO) and Environment Canada are the agencies that have most involvement in the EA process. Legislation that is relevant to the environmental aspects of the Project includes:

- *Canada-Newfoundland Atlantic Accord Implementation Act*
- *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*
- *Oceans Act*

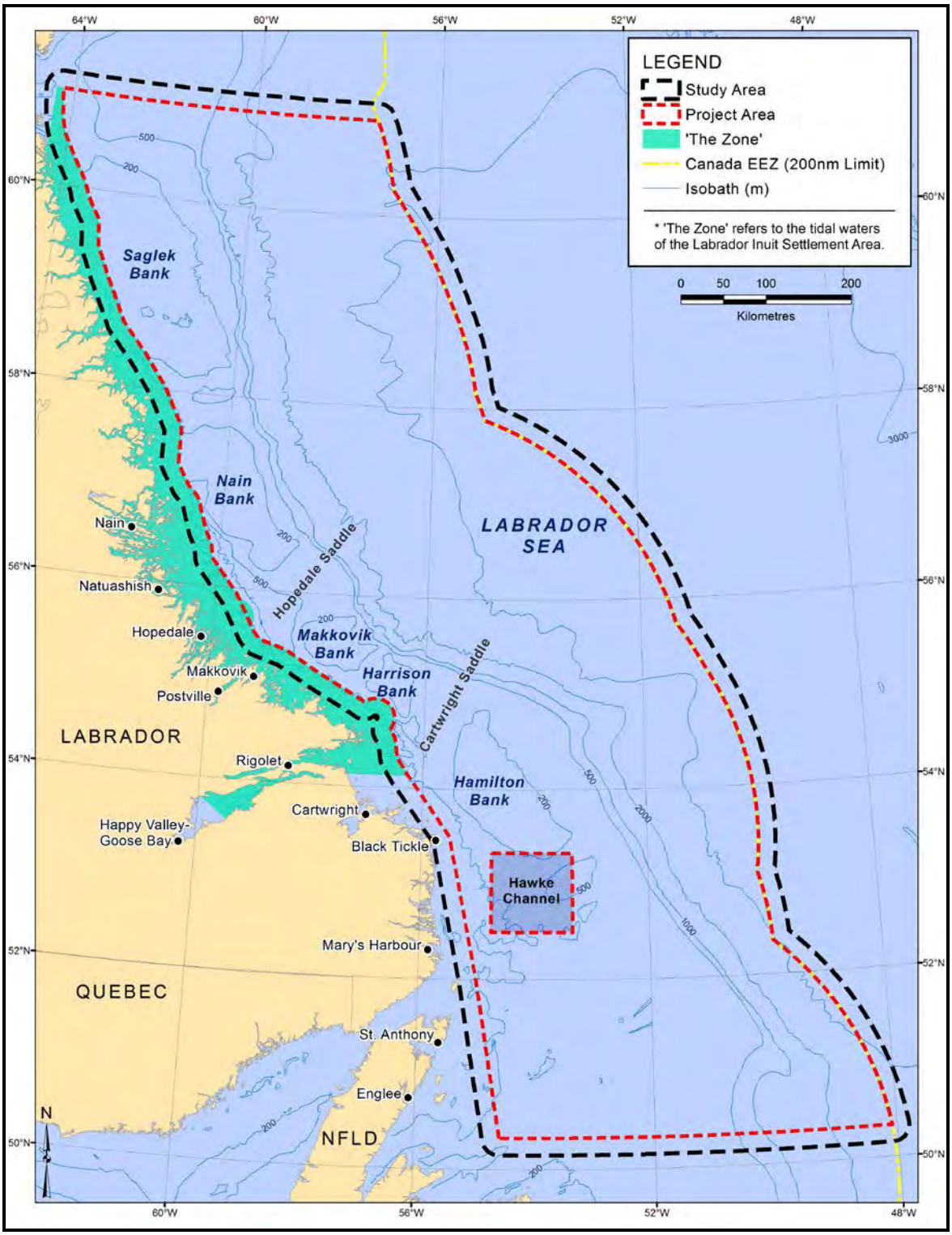

Figure 1.1 Locations of the Project Area and Study Area for GXT's LabradorSPAN Seismic Program(s), 2013 to 2015.

Figure 1.2 Representation of Typical LabradorSPAN Seismic Line Layout in Relation to the Project Area (darker blue), any Year, 2013 to 2015.

- *Fisheries Act*
- *Navigable Waters Act*
- *Canada Shipping Act*
- *Migratory Birds Convention Act*
- *Species at Risk Act*

GXT will follow guidelines issued by the C-NLOPB, the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (January 2012). It outlines mitigation and monitoring requirements for marine mammals and sea turtles for the program. The Project will also follow DFO's *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment,* and other advice received during the consultations for this Project.

1.2 The Proponent: GXT

GXT is a branch of ION Geophysical Corporation (ION), headquartered in Houston, Texas, a leading provider of geophysical technology, services and solutions for the global oil and gas industry. ION's ~1,000 employees operate from 23 offices in key petroleum centres throughout the United States, Canada, Latin America, Europe, Africa, Russia, China, and the Middle East. The company has a particular focus and experience working successfully in challenging environments including the Arctic, shallow/obstructed water and transition zones. It also has an established expertise in deep basin exploration seismic surveys (BasinSpans) using unique approaches to assess the prospectivity of large regional basins (see Objectives and Rationale, below)

ION's corporate capabilities range from seismic planning, data acquisition, processing and analysis to seismic equipment manufacture and software design. Other specific GXT capabilities include (for land and marine environments) 2D, 3D, and 4D seismic acquisition and data processing; multicomponent seismic processing; Ocean Bottom Cable (OBC) acquisition and processing; 3D Vertical Seismic Profiling (VSP) processing; noise removal and de-multiple technology; pre-stack velocity modeling; geophysical analyses; statics; PreSTM, PreSDM; azimuthal velocity analysis; and Reverse Time Migration (RTM).

1.3 Canada-Newfoundland and Labrador Benefits

An important aspect of the Canada-Newfoundland and Labrador Offshore Petroleum Board's mandate is the administration of provisions in the Accord Acts relating to industrial and employment benefits from the development of oil and gas resources in the Newfoundland and Labrador Offshore Area for Canada in general and for the Province of Newfoundland and Labrador in particular.

The Acts require that before any work or activity is authorized in the offshore area, a Canada-Newfoundland and Labrador Benefits Plan must be approved by the Board. In general terms, a benefits plan must describe a plan for the employment of Canadians and, in particular, members of the labour force of the province; and for providing manufacturers, consultants, contractors, and service companies in the province and other parts of Canada with a full and fair opportunity to participate on a competitive

basis in the supply of goods and services. GXT's Project Manager and Environmental Manager are both residents of NL and work from an office in St. John's. All contractors and sub-contractors working for GXT in NL must comply with the approved GXT Canadian-Newfoundland and Labrador Benefits Plan.

1.4 Contacts

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

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2.0 Project Description

In 2013, GXT is proposing to conduct a 2-Dimensional (2-D) single streamer marine geophysical survey to collect seismic, gravity, and magnetic data in open (ice-free) waters of the Labrador Shelf region, potentially starting as early as 1 June and concluding as late as 30 November. The survey is mainly focused on the Labrador Shelf and Slope (Figure 1.1). No acquisition or line turns will occur within the Nunatsiavut Zone (the Tidal Waters of the Labrador Inuit Settlement Area, as defined in the Labrador Inuit Land Claims Agreement). However, part of the survey is within the "Ocean Areas Adjacent to the Zone" (as defined in Part 6.1.1 of the Agreement).

The name of the Project is the "GXT 2013 – 2015 LabradorSPAN 2-D Seismic, Gravity and Magnetic Survey". The program is part of a larger Labrador Shelf / Southern Baffin Bay basin-wide Span investigation, part of which is also being permitted (for 2013) through the Greenland regulator (the Bureau of Minerals and Petroleum) for Greenland waters.

The timing of the survey and/or individual survey lines is subject to regulatory approvals, and such factors as weather and ice conditions, the location of fishing activities, and the timing of acquisition in Greenland. Any subsequent seismic survey conducted during 2014 and/or 2015 would also occur during the same temporal window of 1 June to 30 November with a maximum acquisition of 8,500 km in any one year.

2.1 Spatial and Temporal Boundaries

In terms of spatial boundaries, the Project Area is located on the Labrador Shelf and Slope between approximately 61° and 50.5°N (Figure 1.1). It is within Canada's Exclusive Economic Zone (EEZ) but does not enter the waters of Canada's Territorial Sea and does not include the Hawke Channel (area closed to mobile fishing gear) as shown on the maps in this report. As noted above, there will be no acquisition within the Nunatsiavut Zone, and acquisition lines will end 6 km short of the Zone boundary to ensure that line turns can be made without entering the Zone.

The Study Area includes the Project Area plus a 20 km buffer area around the Project Area (Figure 1.1) to account for the propagation of seismic survey sound that could potentially affect marine biota. Nearly all of the proposed 2013–2015 Project is within the Study Area used for the recent *Strategic Environmental Assessment Labrador Shelf Offshore Area* (Sikumuit 2008).

The temporal boundaries of the proposed Project encompass the 1 June to 30 November period in each year, potentially from 2013 to 2015.

2.2 Project Overview

The proposed Project is a ship-based seismic program commencing with a 2-D seismic, gravity and magnetic survey in 2013. During 2013, approximately 8500 line km will be permitted though less is

likely to be acquired. GXT typically permits more acquisition than it is usually possible to complete in large basin span programs to allow options in case some lines cannot be acquired (e.g. because of ice conditions). Additional seismic surveys may be conducted within the Project Area in 2014 and 2015 also with a maximum annual proposed acquisition of 8,500 km. The proposed 2-D program will use a conventional seismic ship, the M/V *Harrier Explorer* (described below) which will tow the sound source (airgun array) and a single streamer containing receiving hydrophones. The seismic vessel will also collect (passively) gravity and magnetic data at the same time, and it will have an echosounder for depth soundings. The support vessel will be the M/V *Polar Prince* (described below). Any seismic vessel operated during the Project will be approved for operation in Canadian waters by Transport Canada and the C-NLOPB.

Proposed mitigation procedures for this survey (detailed in Section 5.6) are based on a variety of sources, including:

- Discussions and advice received during consultations for this Project
- The C-NLOPB Scoping Document, and the Environmental Planning, Mitigation and Reporting guidance in Appendix 2 of the Board's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012)
- DFO's "Statement of Practice with respect to the Mitigation of Seismic Sound in the Marine Environment"
- National and international acts, regulations or conventions, such as the *Fisheries Act* and Regulations, *International Convention for the Prevention of Pollution from Ships* (MARPOL), and International Maritime Organization (IMO) standards.
- Other standards and guidance, such as the One Ocean Protocol for Seismic Survey Programs in Newfoundland and Labrador (2013), and the Joint Nature Conservation Committee (JNCC) guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys (2010)
- Industry best practices
- Expert judgement / experience from past surveys.

These mitigations include such procedures as close communications with fish harvesting interests, avoidance of active fishing areas, the use of a Single Point of Contact to help communications between the survey and fishers, the establishment of a Fishing Gear Compensation Program, ramp-up (i.e., soft start) of the airgun arrays, the use of two dedicated Marine Mammal Observers (MMOs) to monitor marine for mammals and turtles, to record seabird and other wildlife data and to implement shut downs of the seismic sound source array when required, and the use of at least two Fisheries Liaison Officers (FLOs), one provided by the FFAW and one representing Inuit/Nunatsiavut interests, to aid in coordination with fishing activities.

2.2.1 Objectives, Rationale and Alternatives

The planned program is a regional Basin Span survey to examine very deep geological formations in the Labrador Shelf region. GXT's Span surveys examine very broad and deep geological formations in and around basin areas using advanced geophysical techniques. They provide information on the geologic evolution, deep basin architecture, and the depositional and structural histories of an entire region. Surveying these ultra-deep formations allows for a better evaluation of the evolution of the geological basin areas, including identifying source rocks, migration pathways, and play types. These programs are not designed to identify specific or potential drilling locations.

The objective of the LabradorSPAN survey is to assist the understanding of the formation of the Labrador Basin area in order to further assess the petroleum system on a broad basin-level scale (a Basin Span survey). It will enhance the understanding of the area's hydrocarbon development and potential, and assist future exploration activities. This will be a significant resource for companies interested in the area's hydrocarbon potential and for future development and licensing opportunities.

GXT's surveys will enhance the understanding of the Labrador Shelf and Slope's hydrocarbon development and potential, and assist future exploration activities. Viable alternatives within the seismic program are essentially the choices between different contractors' ships and survey equipment that was evaluated though the bid process.

2.2.2 Project Scheduling

It is anticipated that annual seismic surveys will occur sometime within the period 1 June to 30 November from 2013 to 2015. The timing of the acquisition of specific lines within the Project Area in any year will depend on several factors, including commercial fish harvesting, the local weather, sea state, ice conditions in specific locations, and on the timing of Greenland parts of GXT's program.

2.2.3 Site Plans

In 2013, the proposed 2-D survey in Canadian waters (i.e., within Canada's EEZ) will be conducted within the Project Area shown in Figure 1.1. Water depths in the area range from approximately 100 m to 3,000 m. It is expected that in any program year a maximum of about 8,500 km could be acquired within the Newfoundland and Labrador offshore zone. These lines will be widely spaced (except where they cross in some locations), typically 50–100 km apart, ranging throughout much of the Project Area (Figure 1.2). The western limit of the Project Area is about 22 km (at its closest) from the Labrador mainland, though in most areas it is greater than this (30–50 km). The communities closest to the Project Area are approximately 40–50 km away. No portion of the survey will be acquired within Gilbert Bay, Nain Bight or Hamilton Inlet; survey lines will also remain outside of the Hawke Channel.

In addition to acquisition within the Newfoundland and Labrador sector, some of the lines in one or more years will extend into areas beyond the C-NLOPB's jurisdiction, (e.g., Greenland) and/or into international waters, beyond the EEZ boundary. Figure 1.2 provides an illustration of a typical LabradorSPAN line layout for any of the proposed survey years.

2.2.4 Personnel

The *Harrier Explorer* can accommodate 47 people. Personnel on seismic vessels typically include individuals from the Proponent (i.e., GXT), the vessel owner/operator (ship's officers and marine crew), and technical and scientific personnel from the main seismic contractor. The seismic vessel will also have FLOs and MMOs on board (see Section 5.6), as well as a GXT representative(s) who supervises Client Quality Control and Processing Quality Control. All project personnel will have all of the required certifications as specified by relevant Canadian legislation and the C-NLOPB. GXT's *Polar Prince,* the support vessel, can accommodate 52 people. Regular personnel for the survey will include ship's officers and marine crew.

2.2.5 Project Ships

A single conventional seismic ship will be used for data acquisition - the 81-m M/V Norwegian-built *Harrier Explorer*[1] - with part-time support, as needed, from the 73-m Canadian-built *Polar Prince,* for re-supply, crew changes and refueling. Although the survey is planned for ice-free waters, the *Polar Prince* is a medium-class icebreaker, which allows for more operational flexibility and safety in northern waters. Ship re-supply, re-fuelling and transfers of personnel will be offshore using the *Polar Prince* and, potentially the ports of Goose Bay, Cartwright, Hopedale and other ports in Labrador and Nuuk or other ports in South West Greenland. Although both ships have helidecks, no helicopter or other support vessel use is planned.

2.2.5.1 Seismic Vessel

The seismic vessel that will tow the sound source (airgun) array and hydrophone streamer is the Norwegian-built M/V *Harrier Explorer* (Figure 2.1). The specifications of the vessel are detailed below. The seismic ship will likely deploy a workboat to repair the streamer when necessary and will carry a Fast Rescue Craft.

[1] Although this is the planned vessel, it is possible that a different ship may need to be used in some years, given the realities of contract finalization and other considerations. If another vessel needs to be used instead as the seismic source ship, it will be equivalent in all respects related to environment and safety. This would not alter acquisition methods, mitigations or impact predictions.

Figure 2.1 Seismic Source Ship *Harrier Explorer.*

Call sign: 3EIE3
IMO number: 7807380
MMSI Number: 7807380
Owner: Harrier Navigation Company Ltd.
Operator: SeaBird Exploration
Classification: Research Vessel
Certification: DNV 01A1
Length overall: 81.26 m
Beam: 18.3 m
Draft: 5.8 m
Gross Tonnage: 4009 Tonnes
Net Tonnage: 996 Tonnes
Cruising Speed: 10.5 knots
Cruising Range: 23,000 nautical miles
Endurance: Cruising: 90 days; Seismic: 60 days
Accommodation: 47 persons

2.2.5.2 Support Vessel

The seismic ship will be accompanied by a support vessel, the M/V *Polar Prince* (Figure 2.2), formerly the Canadian Coast Guard Icebreaker Sir Humphrey Gilbert. It will have responsibilities for communications with other vessels (primarily fishing vessels) that may be operating in the area and for scouting ahead to look for hazards — particularly ice in and near the Project Area. Although the survey is planned for ice-free waters, the *Polar Prince* is a medium-class icebreaker, which allows for more operational flexibility and safety in northern waters. Its specifications are detailed below. Re-supply, re-fuelling and transfers of personnel will be done offshore using the *Polar Prince* and suitable area ports, such as Cartwright or Nuuk.

Figure 2.2 Project support ship *Polar Prince.*

Call sign: CFK 9552
IMO number: 5329566
MMSI Number: 316006460
Built: 1959
Major refit: 1985
Owner: GX Technology Canada Ltd.
Operator: GXT
Certification: Transport Canada Marine Safety & DNV 1A1 ICE-1A
Length: 67.06 m
Breadth: 15 m
Draft: 5 m
Gross Tonnage: 2152 Tonnes
Net Tonnage: 613 Tonnes
Cruising Speed: 11 knots
Max. Speed: 14.5 knots
Accommodation: 52 persons

It is also possible that the project might hire another smaller boat to assist with scouting operations (i.e., locating gear) in areas that might have active fisheries.

2.2.6 Seismic Energy Source Parameters

The seismic energy source will be an airgun array comprising individual airguns ranging in size from 100 to 250 in^3 each. The array will consist of four sub-arrays, with a total of 36 active airguns, totalling a discharge volume of 6300 in^3 (Figure 2.3). The airguns in the array are strategically arranged to direct most of the energy vertically downward rather than sideways (see Appendix C *in* LGL (2007) for a review of airgun sound characteristics).

The nominal firing pressure of the array will be 2000 pounds per square inch (psi). The shot interval will be one shot every 19 to 22 s. The source level of the array will be ~264.3 dB re 1 µPa (peak-peak broadband) or 242.3 dB re 1 μPa_{rms} (over 90% pulse duration). The array will be towed at a depth of 8–11 m. Figures 2.4 and 2.5 show the power and frequency output of the full array, respectively. The survey speed will be around 4.5 knots (8.3 km/h).

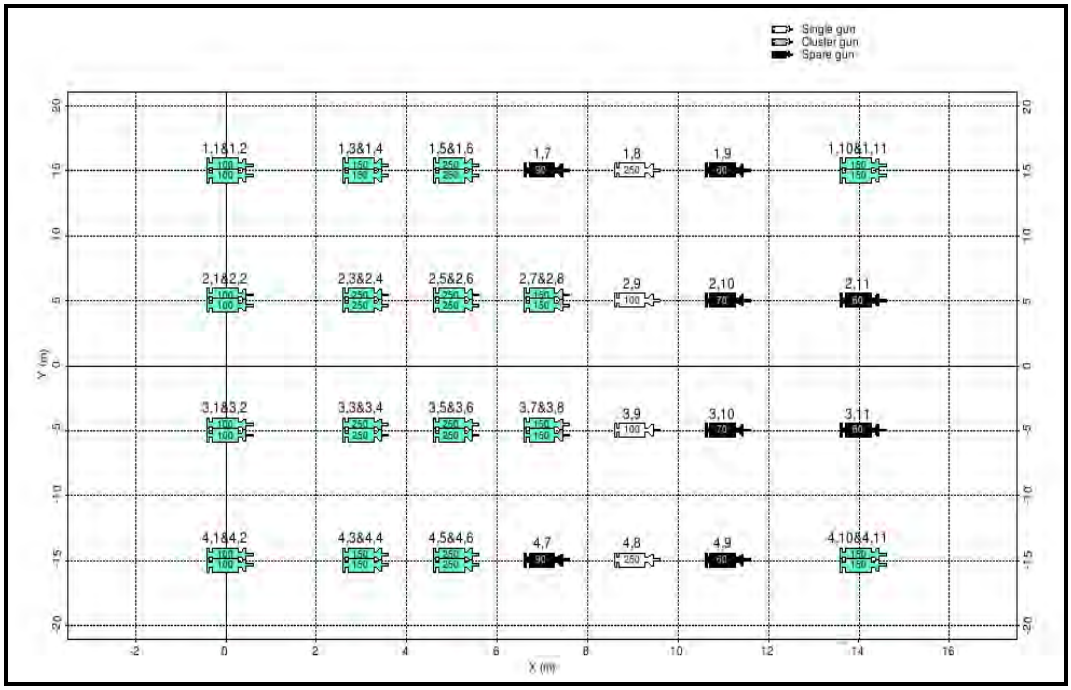


Figure 2.3 Array Geometry (layout) and Individual Volumes (in^3) of Airguns (airguns indicated in black will not be active).

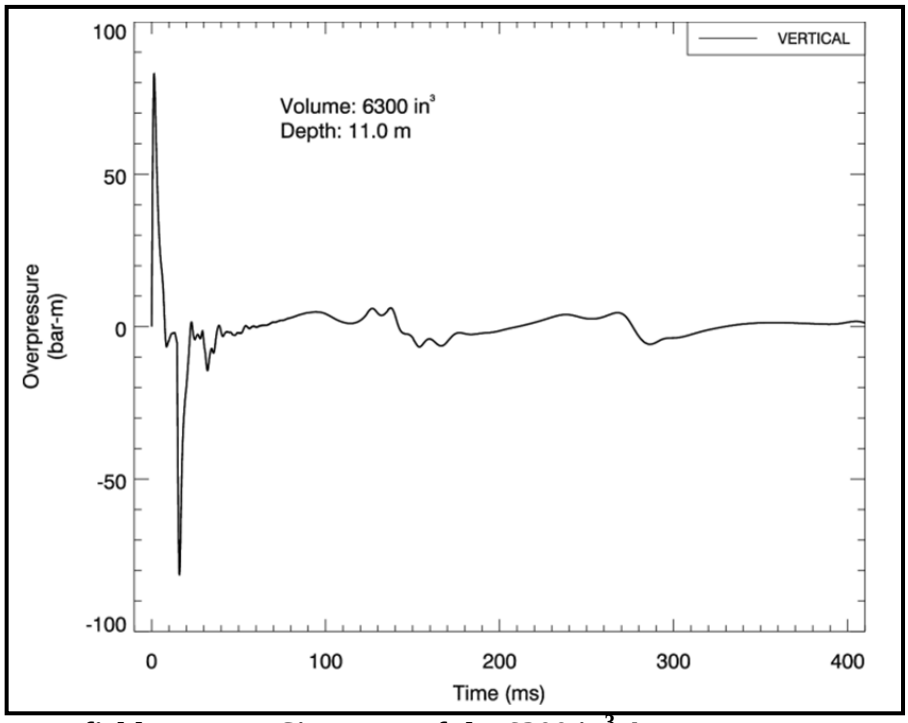


Figure 2.4 Far-field Pressure Signature of the 6300 in^3 Array.

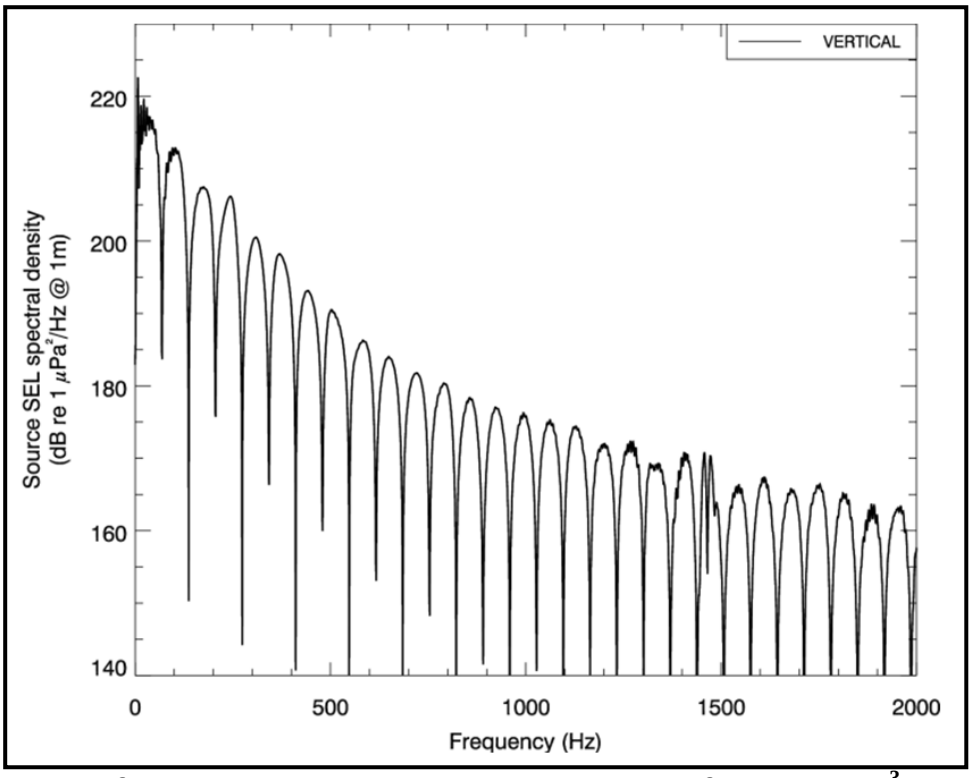


Figure 2.5 Far-field Frequency Spectrum (broadband) of the 6300 in^3 Array, including the Surface Ghost.

2.2.7 Seismic Streamer

The seismic ship will also tow a single seismic hydrophone cable (streamer) up to 9 km long, deployed near the ocean surface, at a depth of approximately 9–15 m. This is a passive listening device, which will receive the sound waves reflected from structures underneath the ocean floor and transfer the data to an on-board recording and processing system. The cable is a solid-core DigiSTREAMER Integrated Data Acquisition System manufactured by GXT parent company ION Geophysical. It will have DigiBird units (also manufactured by ION) attached at least every 300 m to maintain correct streamer depth and positioning.

The streamer will be made up of up to 90 Solid Active Streamer Sections, each 100 m in length. Streamer sections will contain a non-liquid fill to reduce self-noise properties and provide consistent buoyancy. The DigiSTREAMER technology performs better in cold weather where sentinel solid streamers may become stiff, leading to additional handling challenges. A stress-member chassis of non-magnetic Vectran® will provide high-tensile strength and predictable elongation for long tow configurations, such as that used for this survey.

2.2.8 Gravity and Magnetic Recorders

Gravity and magnetic data will be collected (passively) using an UltraSys™ marine gravity metre system consisted of a LaCoste and Romberg Marine Gravity metre, which has been modified by ZLS

Corporation to upgrade the optical beam position sensor to a capacitive inductance sensor. The metre has also been sealed with a dry nitrogen atmosphere to negate pressure differential and moisture effects.

2.2.9 Other Equipment

The seismic vessel is equipped with a Skipper GDS-101 echosounder. The downward-facing Skipper GDS-101 operates at a frequency of 38 kHz or 200 kHz and will be used to collect water depth information. For this Project, sound velocity profiles will also be acquired in the water column at various locations within the survey area. This is a routine practice during seismic programs. Sound velocity profiles allow for more accurate interpretation of the acoustic data (i.e., seismic pulses) recorded by the seismic streamer. These data are acquired with a small, passive device that will be deployed by the support vessel. The device measures pressure, temperature, and salinity, from which the speed of sound can be calculated.

2.2.10 Logistics and Support

As described above, the operations will consist of a single seismic ship, the *Harrier Explorer*, equipped with gravity and magnetic instruments and towing a sound source (airgun) array and a 9-km hydrophone streamer over widely spaced survey lines, working in ice-free marine areas. The project will also use a support ship, the *Polar Prince*, with icebreaking capabilities, as needed for re-supply, crew changes and refueling. The survey will follow planned pre-plot seismic lines to the extent possible, given possible local ice conditions.

The seismic lines will be acquired in the most efficient manner practical. Typically the vessel will have a 6-km run-in to the start of a seismic line and a 4 to 5 km run-out at the end of a seismic line. The ship will travel at approximately 8–9 km/hr when in data acquisition mode. The vessel will aim to operate continuously, though typically about 60% of the time is spent in production with the remainder of the time for line changes, standby (e.g. for weather, marine mammals), maintenance and/or other technical operations.

Crew changes will be every 4 to 5 weeks in the port of Goose Bay, Cartwright, Hopedale or other ports in in Labrador and/or the port of Nuuk and other ports in in South West Greenland, depending on the vessel location at the time . Refuelling logistics will be about every 4 weeks, and the transfers will take place offshore utilizing the *Polar Prince*, or in port.

No new shorebase facilities will be required for the Project for the 2-D seismic survey. Existing port infrastructure will be used for this Project

2.2.11 Discharges

Vessel discharges will not exceed those of standard vessel operations and will adhere to all applicable regulations. The main discharges include grey water (wastewater from washing, bathing, laundry, and food preparation), black water (human wastes), bilge water, deck drainage and discharges from machinery spaces. All discharges will comply with requirements in the International Convention for the

Prevention of Pollution of Ships, 1973, as modified by Protocol of 1978 (MARPOL 73/78) and its annexes. It is estimated that each vessel will generate 0.25 m^3 of black and grey water per day. Ground galley food waste can be discharged when a vessel is more than 3 miles offshore. Non ground galley food waste can be discharged when a vessel is more than 12 miles offshore.

2.2.12 Waste Management

Wastes produced from the seismic and support vessels, including hazardous and non-hazardous waste material, will be managed in accordance with MARPOL and with the vessel-specific waste management plans. SeaBird Exploration has a Garbage Management Plan in place for the *Harrier Explorer*, and there is a Waste Management Plan in place for the *Polar Prince*. All solid wastes will be sorted by type, compacted where practicable, and stored on board before disposal to an appropriate certified reception facility. Non-Toxic combustible material and waste oil from the vessels will be burned on-board in approved incinerators. The shipboard incinerators will have been examined and tested in accordance with the requirements of the shipboard incinerators IMO Res. MEPC 76(40) for disposing of ships-generated waste appended to the Guideline for the implementation of Annex V of MARPOL 73/78. . Sufficient and adequate facilities will be available on vessels to store solid wastes to the extent required. The contracted vessels policies and procedures will be reviewed against the GXT Plan. GXT's waste management plan will be filed with the C-NLOPB. Only ports with licensed waste contractors will be used for any waste returned from offshore. The Environmental Management Plan for SeaBird Exploration (the seismic vessel operator) is provided in Appendix 1. (Note that if a contractor plan is in conflict with commitments or requirements specific to this EA, the latter will take precedence.)

2.2.13 Air Emissions

The vessels will have an International Air Pollution Prevention Certificate issued under the provisions of the Protocol of 1997 as amended by resolution MEPC.176(58) in 2008, to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as the Convention). Air emissions will be those associated with standard operations for marine vessels in general, including the seismic vessel and support vessel. Vessels will only use diesel and gasoil with a sulphur content of no more than 1% (weight) following the *International Convention for the Prevention of Pollution from Ships* (MARPOL) Annex VI, for the North American Emission Control Area, which was implemented in Canada in August 2012 (see http://www.tc.gc.ca/eng/marinesafety/ bulletins-2012-03-eng.htm). It is expected that the ships will use ~1,000,000 L of fuel within Canadian waters per survey. There are no anticipated implications for the health and safety of workers on these vessels form air emissions.

2.2.14 Accidental Events

In the unlikely event of the accidental release of hydrocarbons during the Project, GXT and its seismic survey contractor will implement the measures outlined in its oil spill response plan which will be filed with the C-NLOPB. In addition, GXT has an Emergency Response Plan (Appendix 2) in place which bridges the emergency plans of all project entities and vessels to the local facilities and the Halifax Search and Rescue Region. The GXT representative onboard will represent GXT in all offshore Quality,

Health, Safety & Environment (QHSE) activities. The GXT Project Manager Dean Kennedy will represent GXT onshore from an office in St. John's.

2.3 Mitigation

Mitigation measures are referenced throughout the EA. The measures are described in detail in Section 5.6.

3.0 Physical Environment

The physical environment of the Study Area was described in in the Labrador Shelf Strategic Environmental Assessment (SEA) (Sikumiut 2008). A summary of the physical environment in the Study Area, based primarily on the Labrador Shelf SEA, is provided below with reference to weather, oceanography, and ice conditions, particularly during June to November.

3.1 Bathymetry

Water depth can affect the characteristics of received sound and thus is of relevance in the assessment of the effects of seismic energy on marine animals. The bathymetry in the Study Area is relatively complex with depths ranging from ~100 m to depths over 3,000 m, including continental shelves, slopes, and the abyssal plain. The Study Area is bounded on the northwest by Saglek Bank and the entrance to Hudson Strait, and in the south by the continental shelf waters of Newfoundland. Other major bathymetric features include Nain Bank, Makkovik Bank, Hamilton Bank, Harrison Bank, Hopedale Saddle, Cartwright Saddle, and the Labrador Marginal Trough.

3.2 Geology

Surficial and bedrock geology affect the characteristics of received sound and thus are of some relevance in the assessment of the effects of seismic energy on marine animals.

The surficial geology of the Labrador Shelf has been discussed in NORDCO (1982) and Josenhans et al. (1986) and has been summarized in the Labrador Shelf SEA. The bedrock geology of the Study Area is comprised primarily of Precambrian and Tertiary bedrock. The Precambrian bedrock dominates the seafloor on the inner shelf. Five surficial sedimentary formations are found in the Study Area and include till (Lower Till, Upper Till), proglacial and subglacial sediments (Qeovik Silt), and post glacial marine sediments (Makkaq Clay and Sioraq Silt and Gravel). Additional information on surficial sediments, as they relate to fish and fish habitat, is provided in Section 4.2.1.2.

3.3 Climate Conditions

3.3.1 Air Temperature

Data from the National Climate Data and Information Archive, Climate Normals and Averages for four land based weather stations near the Study Area—Hopedale, Cartwright, Battle Harbour (Loran; 1961-1990), and Nain (1971-2000) were used to calculate average air temperatures from June to November (Table 3.1). Air temperature means ranged from -5.1 to 12.3° C (Environment Canada 2013a), with coldest temperatures in Nain in November.

Table 3.1 Mean Daily Air Temperatures (°C) for the Period of June to November at Four Weather Stations along the Labrador Coast.

Weather Station	Mean Monthly Air Temperature (°C)					
	June	July	Aug	Sep	Oct	Nov
Nain (1971-2000)	6.2	10.1	10.7	7.0	1.1	-5.1
Hopedale (1961-1990)	6.0	10.3	10.6	7.0	1.9	-3.2
Cartwright (1961-1990)	8.0	12.3	11.9	8.1	2.9	-2.0
Battle Harbour (Loran)(1961-1990)	6.1	10.1	10.9	8.2	3.5	-0.8

Source: Environment Canada (2013a).

3.3.2 Wind

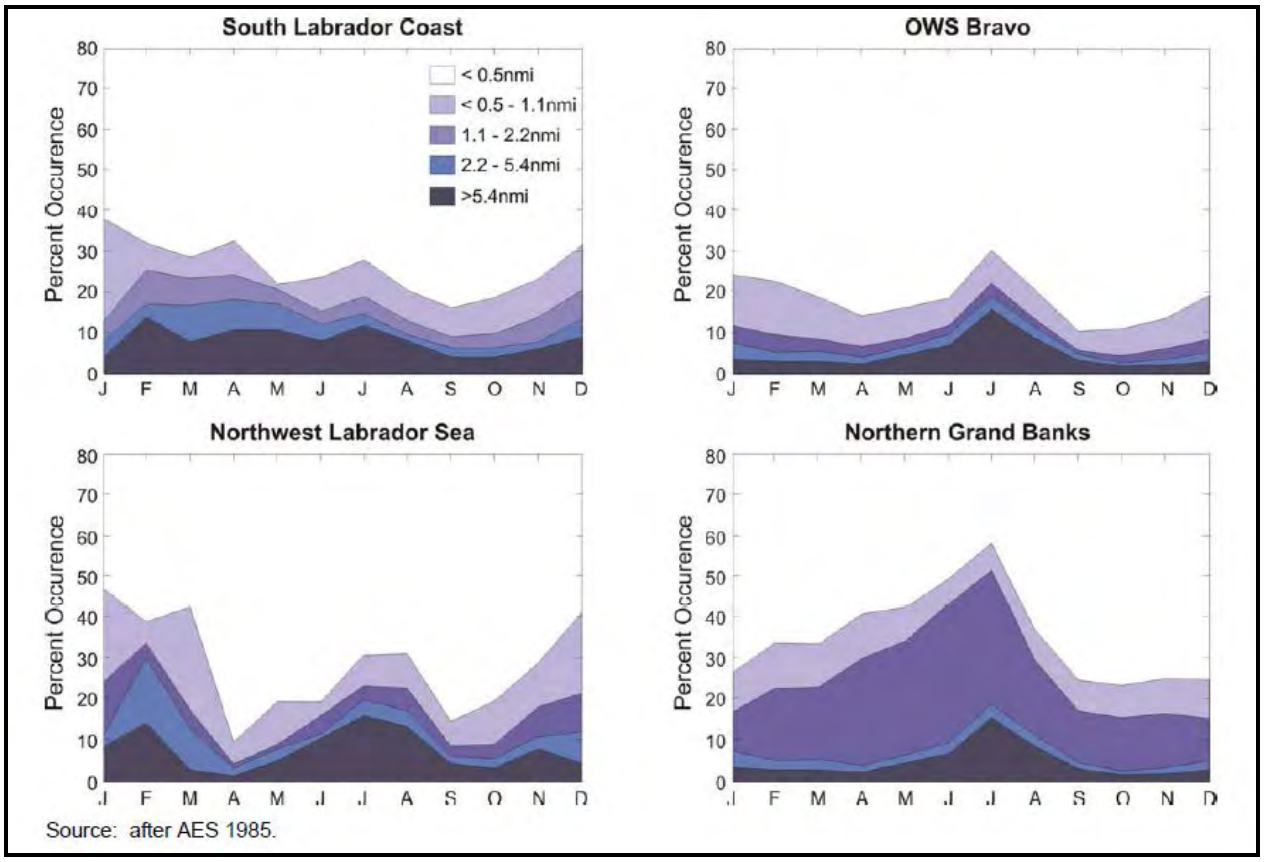
Wind speed is an important characteristic of the physical environment that can directly affect project activities. Within the Study Area, the lowest mean monthly wind speeds are experienced in July. MSC50 hindcast data from the Meteorological Service of Canada, taken from Section 3 of the Labrador Shelf Offshore Area SEA (Sikumiut 2008) are used here to describe wind speeds in the GXT Study Area. A series of nine grid point locations distributed north to south throughout the Study Area (see Figure 3.22 *in* Sikumiut 2008) were used. Mean monthly wind speeds for the period of June to November range from 4.97-9.54 m/s in the north and 5.96-10.53 in the south. July had the lowest mean wind speed at all nine locations, with wind speeds increasing through the fall and into the winter. Maximum monthly wind speeds of 28.69 m/s were recorded in November at grid point location 58° N, 59° W. The maximum wind speeds for July were 19.65 m/s at grid point location 53° N, 51° W.

3.3.3 Visibility

Shipping visibility categories (i.e., ranges of distances) are used here as an indicator of visibility conditions influenced by precipitation, fog and freezing spray. The ranges of shipping visibility are as follows:

- Visibility <0.5 nautical miles (nm);
- 0.5 –1.1 nm;
- 1.1 – 2.2 nm;
- 2.2 – 5.4 nm; and
- ≥ 5.4 nm.

Within the Study Area, annual visibility statistics for the South Labrador coast, Offshore Weather Station Bravo (OWS), and Northwest Labrador Sea, indicate more variable visibility during summer months (June-August), with higher percent occurrence of reduced visibility, and increased visibility through the fall to November (from Sikumiut (2008); Figure 3.1). In comparison to the northern Grand Banks, visibility conditions in the Study Area during June to November are much better.



Source: Sikumiut (2008).

Figure 3.1 Visibility Conditions based on Shipping Criteria.

3.4 Oceanography

3.4.1 Currents

The Labrador Current runs south along the Labrador coast originating in the Davis Strait with contributions from the warmer more saline waters of the West Greenland Current, and the cold, low salinity waters of the Baffin Island Current and Hudson Bay. In the middle of the Study Area, near Hamilton Bank, the Labrador Current branches into a smaller inshore and larger offshore stream (Lazier and Wright 1993). The minimum mean velocity, occurring in March/April is 3.1 cm s^{-1} and the maximum mean velocity, typically in October, is 35.1 cm s^{-1}. The steepest portion of the continental slope generally experiences stronger currents than over the continental shelf or areas farther offshore.

3.4.2 Waves

Wave conditions can potentially affect vessel operations for the Project; however, since wind conditions in the Study Area are relatively low during the summer and fall, usual wave conditions are also relatively minimal. Using 50 years of hindcast data from the same nine MSC50 grid locations as for the wind conditions (see above), the lowest monthly mean significant wave heights are experienced in July

increasing through the fall, peaking in December and January. At the most northern grid point (60° N, 61° W) the range of mean significant wave heights between June and November is 1.20-2.63 m and at the most southerly point (52° N, 51° W), 1.53-3.41 m. Maximum monthly significant wave heights recorded in the Study Area were up to 12.59 m in November (grid point 54° N, 53° W) and in July, maximum significant wave height reached 6.00 m at the most southerly station (grid point 52° N, 51° W).

3.5 Ice Conditions

3.5.1 Sea Ice

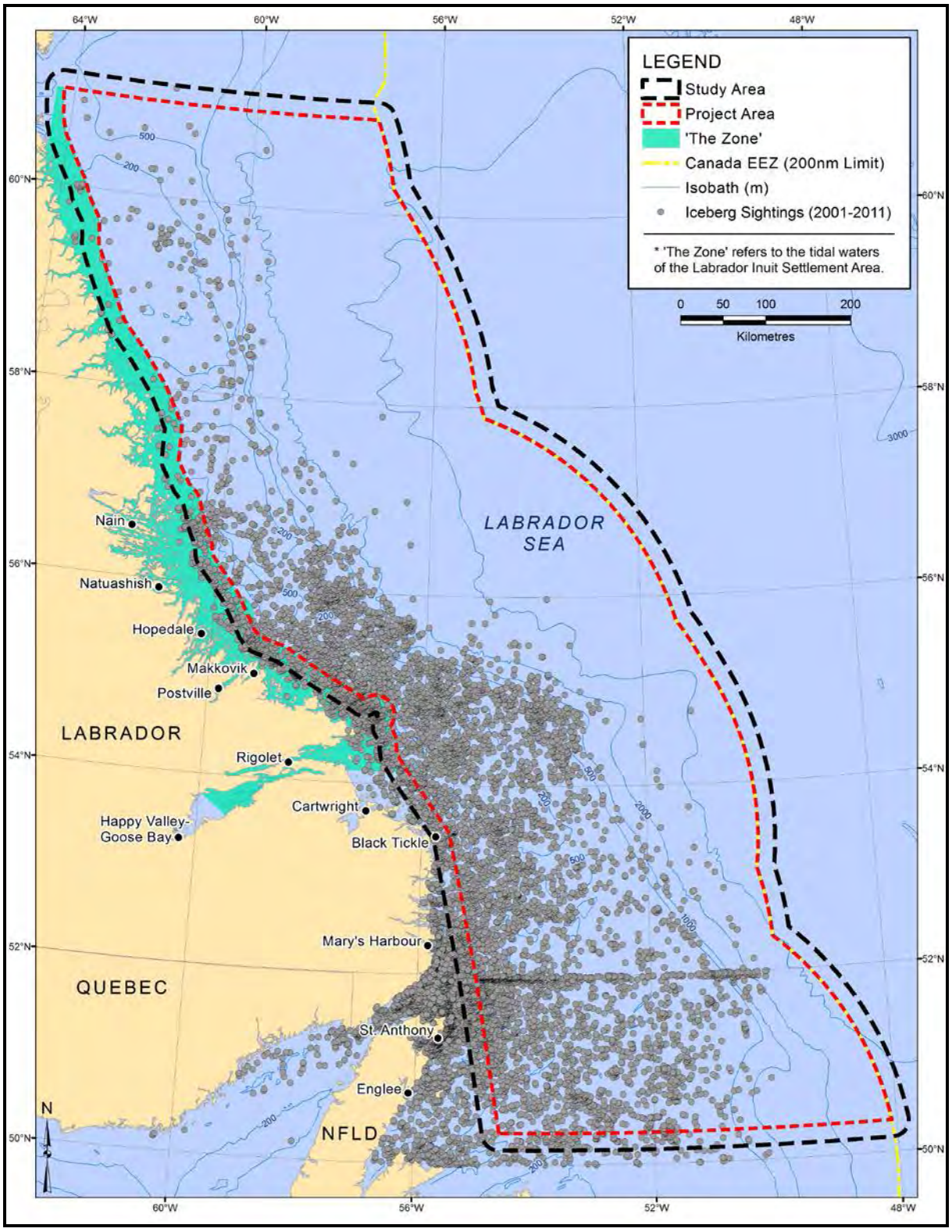
Ice conditions are an important component of the physical environment, directly affecting offshore activities in the area. The average start of the ice season in the Study Area is mid-November in the more northern areas and throughout December in the southern extent. Ice growth continues until early spring when ice retreat and break-up occurs. First signs of break-up occur around Notre Dame Bay in mid-March. The southern ice edge retreats to the Strait of Belle Isle by late-May and northward again to 55° N by late-June. More northern coastal regions see the end of ice season in late-July/early-August. The majority of the Study Area will be free of sea ice from late-June to November. In 1983, the drilling vessel *Petrel* observed some medium first-year ice in strips and patches in the area from 11 July to 17 August (LGL 2010).

3.5.2 Icebergs

Icebergs are well known for causing concern with regards to navigation and offshore activities along the coast of Newfoundland and Labrador. The major source, contributing ~90% of icebergs in Canadian waters (including the Study Area), are from glaciers on the west coast of Greenland (Environment Canada 2013b). Prevailing northwest winds and the strong Labrador Current, move icebergs south along the coast of Labrador from July to October. Miller and Hotzel (1984) estimated the number of icebergs crossing a series of transects on the Labrador Shelf at a rate of 6-15 icebergs km^{-1} per year with the total number if icebergs estimated at 1400-3000 per year. Data from the International Ice Patrol (IPP) Iceberg Sightings Database for the period of June to November, 2001-2011, show a total of 10,758 icebergs observed offshore Labrador (north of 50°N and west of 50°W; NSIDC 1995; Table 3.2; Figure 3.2).These observed sightings may not include all icebergs passing through offshore Labrador but indicate where they are most likely to occur in the area and relative abundance by month and year. Of the 10,758 icebergs observed during the June to November periods, most were sighted in June (45.0%) and July (23.3%). There is a great deal of interannual variation in the numbers of observed icebergs. For example, in 2005, during June to November, there were 36 icebergs whereas for that same time period in 2011, there were 3133 icebergs (Table 3.2). About 45% of the 10,758 icebergs recorded during June to November, 2001-2011, were classified as medium, large or very large size.

Table 3.2 Number of Icebergs Observed from June to November, 2001-2011, Offshore Labrador (north of 50°N and west of 50°W; IPP database).

Year	Month (Total No. of Icebergs)						Total	% of Total
	June	July	Aug	Sep	Oct	Nov		
2001	206	18	12	17	11	9	273	2.5
2002	251	115	162	56	46	30	660	6.1
2003	258	110	21	66	17	160	632	5.9
2004	23	8	10	72	8	12	133	1.2
2005	18	13	0	1	0	4	36	0.3
2006	1827	178	172	231	165	8	2581	24.0
2007	942	769	2	0	340	159	2212	20.6
2008	180	185	80	170	139	30	784	7.3
2009	2	30	11	0	3	135	181	1.7
2010	0	0	0	32	0	101	133	1.2
2011	1138	1085	344	443	110	13	3133	29.1
Total	**4845**	**2511**	**814**	**1088**	**839**	**661**	**10758**	
% of Total	**45.0**	**23.3**	**7.6**	**10.1**	**7.8**	**6.1**		



Source: IIP Iceberg Sightings Database.

Figure 3.2 Accumulated Iceberg Sightings for June to November, 2001-2011.

4.0 Biological Environment

4.1 Study Area Ecosystem

An ecosystem is an inter-related complex of physical, chemical, geological, and biological components that can be defined at many different scales, including a Project Area level (i.e., a deep ocean basin ecosystem) to a Regional Area ecosystem that is topographically and oceanographically complicated with shelves, slopes, and valleys and several major water masses and currents. Many important components of the ecosystem such as certain species and stages of fish, seabirds and marine mammals may be affected by the Project and these are discussed below.

4.2 Fish and Fish Habitat

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

4.2.1 Fish Habitat

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

4.2.1.1 Bathymetry

The bathymetry within the Study Area ranges from just under 100 m to more than 3,000 m (Figure 4.1). More than half of the Study Area is characterized by water depths exceeding 500 m. Only a small proportion of the Study Area is composed of areas where water depths are less than 200 m (e.g., Saglek Bank, Nain Bank, Makkovik Bank, Harrison Bank, Hamilton Bank). Essentially the entire portion of NAFO Division 3K that comprises a part of the Study Area has water depths greater than 200 m. The Hopedale Saddle and the Cartwright Saddle are the deep water areas between Nain Bank and Makkovik Bank, and Harrison Bank and Hamilton Bank, respectively (Figure 4.1).

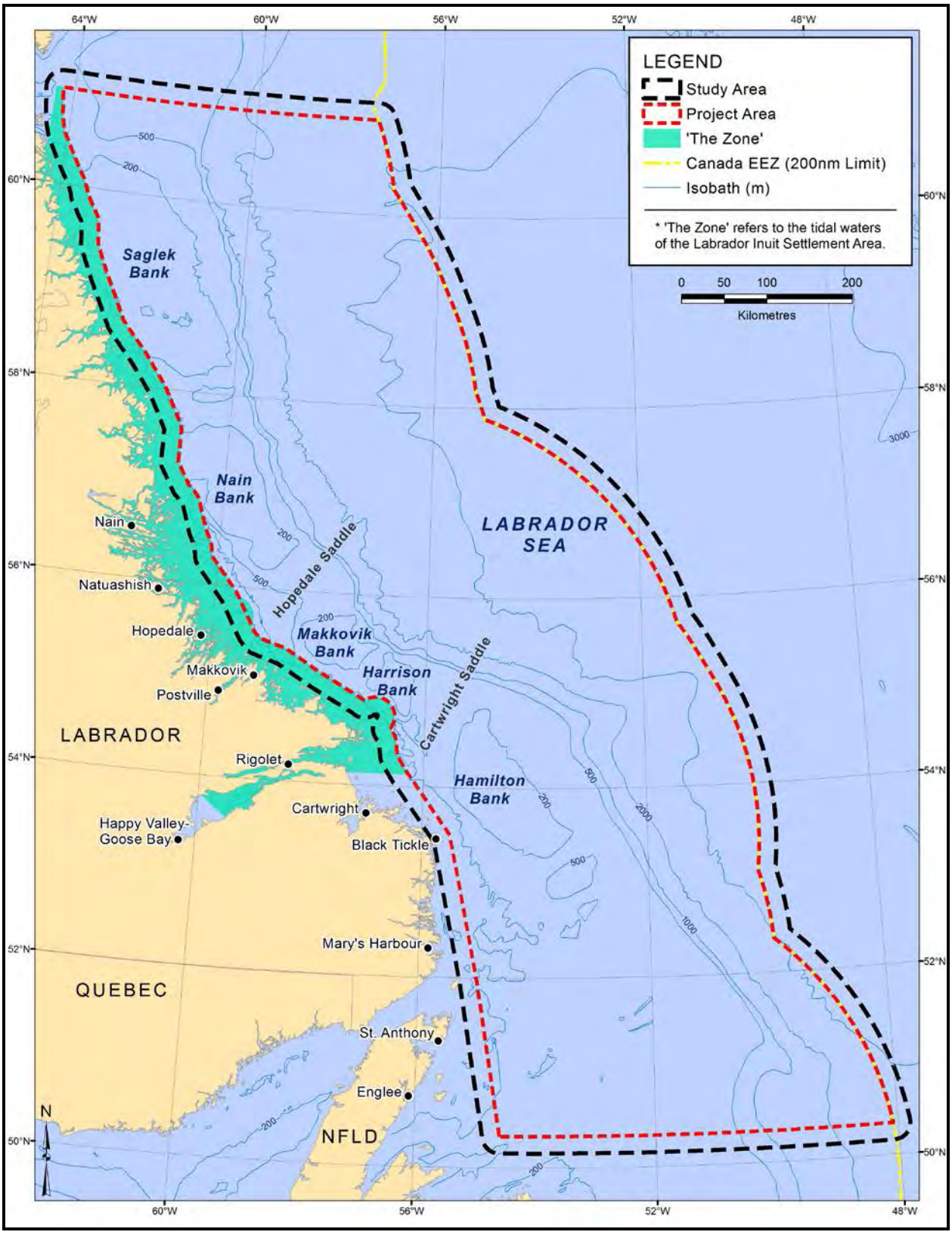


Figure 4.1 Bathymetric Features in the Study Area.

4.2.1.2 Surficial Sediment

The surficial geology of the Labrador Shelf has been discussed in NORDCO (1982) and Josenhans et al. (1986) and has been summarized in the Labrador Shelf SEA (Sikumiut 2008). The bedrock geology of the Study Area is composed primarily of Precambrian and Tertiary bedrock. The Precambrian bedrock dominates the seafloor on the inner shelf. Five surficial sedimentary formations are found in the Study Area and include till (Lower Till, Upper Till), proglacial and subglacial sediments (Qeovik Silt), and post glacial marine sediments (Makkaq Clay and Sioraq Silt and Gravel). Figure 3.1 in Sikumiut (2008) displays the offshore Labrador surficial sediment distribution by soil type between the 200 m and 1,000 m isobaths in part of the Study Area. These distributions are based on information from the Geological Survey of Canada. The four sediment classes displayed include clay, sand, silt and till.

4.2.1.3 Plankton

Plankton is composed of free-floating organisms that form the basis of the pelagic ecosystem. Members include bacteria, fungi, phytoplankton, and zooplankton (mostly invertebrates, but may also include fish eggs and larvae, termed ichthyoplankton). In simplest terms, phytoplankton (e.g., diatoms) produce carbon compounds through the utilization of sunlight, carbon dioxide, and nutrients (e.g., nitrogen, phosphorus, and silicon), a process called primary production. Herbaceous zooplankton (e.g., calanoid copepods, the dominant component of NW Atlantic zooplankton) feed on phytoplankton, a process called secondary production. The herbivores in turn are fed upon by predators (i.e., tertiary production) such as predacious zooplankton (e.g., chaetognaths, jellyfish, etc.), all of which may be grazed by higher predators including invertebrates, fishes, seabirds, sea turtles 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 marine biota tend to congregate for feeding.

The information on plankton of the Labrador Shelf has been reviewed extensively in the Labrador Shelf SEA (Sikumiut 2008) and is summarized briefly in the current section. Some of the key points concerning the various components of planktonic communities for the Labrador Shelf Area are highlighted below:

- Microbiota consisting of bacteria, mould, and yeast are ubiquitous in the marine environment, including Labrador Shelf waters. These microflora occupy a unique niche in marine ecosystems in that they serve as a food source as well as degrade organic matter (Bunch 1979). Typically, microflora are most abundant in the upper layers, and their numbers decrease with depth (Li and Harrison 2001);

- Phytoplankton distribution, productivity, and growth regulation in high-latitude ecosystems (e.g., Labrador Shelf) is a complex system with light, nutrients, and herbivore grazing being the principal factors limiting phytoplankton regulations (Harrison and Li 2008);

- The spring bloom of phytoplankton is the driving force of high-latitude marine ecosystem dynamics and its initiation in the Labrador Sea is strongly regionally dependent (Wu et al.

2008). The spring bloom in the southern Labrador Sea starts in March as a continuation of the bloom that commences on the Grand Banks and spreads northward. In the northern Labrador Sea, the spring bloom starts in early April with the bloom occurring earlier in both the north and south Labrador Sea areas as compared to the central Labrador Sea (Wu et al. 2008);

- Irradiance has been considered the limiting factor for development of the spring bloom; however, factors such as latitude, water column stratification, and freshwater inputs (ice melt, precipitation) are also important factors in Labrador Shelf waters (Wu et al. 2008);

- There also appears to be a fall bloom over shelf and slope regions in October for the Labrador Shelf area. Labrador Shelf waters display elevated chlorophyll biomass over most of the growing season from April through September – October (Cota et al. 2003);

- The role of sea-ice dynamics on the phytoplankton dynamics in the Labrador Shelf area is significant in that the marginal ice zones release freshwater via melting thereby strengthening stratification and affecting salinity and temperature distributions of the upper mixed layer. Retreat of the sea ice also influences the timing and magnitude of the phytoplankton bloom as well as penetration of light into the water column (Wu et al. 2007);

- The Labrador Shelf area is highly productive because of upwelling along the slopes of the offshore banks and channels and the outflow of nutrient rich water from the Hudson Strait (Drinkwater and Harding 2001; Breeze et al. 2002);

- The highest phytoplankton biomass (near surface) tends to be in the northern Labrador Sea area (Drinkwater and Harding 2001);

- There is the potential for both nitrate and silicate limitation in the Labrador Sea in summer, nitrate limitation in the central Labrador Sea, and a high probability that nutrients and irradiance may result in co-limitations during peak summer months, which affects the overall phytoplankton biomass (Harrison and Li 2008);

- Silicate concentrations are high and nitrate concentrations are low for both the Labrador Shelf and the shelf edge (AZMP 2007);

- Seasonal fluctuations in phytoplankton biomass into the Newfoundland and Labrador region are dominated by changes in the abundance of diatoms (DFO 2007a). The spring bloom trends to be dominated by diatoms while the fall bloom dominant species are flagellates and dinoflagellates (Buchanan and Foy 1980a,b; DFO 2007a);

- Chlorophyll concentrations were found to be higher near the coast and in bays as compared to further offshore. This may be attributed to nutrients associated with riverine input, tidal mixing, wind events, and localized upwelling (Buchanan and Foy 1980b);

- Zooplankton comprise the main link between primary production and higher-level organisms in the marine ecosystem. They transfer organic carbon from phytoplankton to fish, marine mammals, and birds higher in the food chain. Zooplankton are a food source for a broad spectrum of species and they contribute faecal matter and dead zooplankton to the benthic communities;

- Arctic water masses that influence the Labrador Current are dominated by calanoid copepods (*Calanus finmarchicus*, *Calanus glacialis*, and *Calanus hyperboreus*) and the cyclopoid *Oithona similis* (Huntley et al. 1983);

- 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 reproduction would be expected to occur in or around May in the northern and southern areas of the Labrador Sea with the central Labrador Sea lagging until sometime in June. The presence of stage I and II copepodites in the central Labrador Sea in October and November has suggested that there may be a second breeding period in late summer or early fall (Huntley et al. 1983) and that this aggregate is significantly smaller;

- The pre-adult *C. finmarchicus* develop in the surface waters over the summer and early autumn after which the majority migrates to deeper waters to enter a period of dormancy. This seasonal descent to deeper waters means that *C. finmarchicus* are largely absent from the Labrador shelf regions during winter months and then re-populate the shelf regions in the spring (Head and Pepin 2008); and,

- Sea ice biota are fauna and flora of all trophic levels that live in, on, or associated with sea ice during all or part of their life cycle. Some of these species become part of the plankton when the ice melts. Communities are found at the surface, interior, and bottom of the ice. There are different mechanisms for the formation of these communities depending on where the community is located within the ice (Horner et al. 1992).

The pattern and scale of long-term variability among Northwest Atlantic plankton communities based on continuous plankton recorder (CPR) data collected between 1958 and 2006 were recently investigated (Head and Pepin 2010; Pershing et al. 2010). A portion of the study area overlaps with the extreme southeast portion of the Project's Study Area. It was concluded that changes in the plankton community corresponded to changes in the physical environment suggesting that physical conditions are strong drivers of interannual variability in Northwest Atlantic Shelf ecosystems (Pershing et al. 2010). Head and Pepin (2010) showed that the increases in phytoplankton abundances in the shelf region in the early 1990s, primarily in winter, occurred along with increased contribution of Arctic-derived freshwater to the Newfoundland and Labrador Shelves. This increased influx of arctic water was also likely directly responsible for the increased abundances of the two arctic species *C. glacialis* and *C. hyperboreus*, and indirectly responsible for the decreased abundance of *C. finmarchius* because of changes in food composition.

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 seismic program. Planktonic stages of commercial invertebrates (e.g., crab) and fish (e.g., cod) that occur in the Study Area are described in the Labrador Shelf SEA (Sikumiut 2008) and in Section 4.2.2.3 related to reproduction in macroinvertebrates and fishes.

4.2.1.4 Benthos

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

The benthic invertebrate communities of the Labrador Shelf area are described in the Labrador Shelf SEA (Sikumiut 2008). There have been a limited number of benthic studies conducted in the waters off Labrador, particularly those deeper than 200 m, the depths most commonly found in the Study Area. The studies described in the Labrador Shelf SEA (Sikumiut 2008) largely concern benthic organisms and communities occurring in inshore waters shallower than 200 m and hence will be discussed briefly in the current section. An extensive literature search revealed no new studies completed in offshore Labrador waters since the Labrador Shelf SEA (Sikumiut 2008) was prepared.

Benthic invertebrate communities can be spatially variable because of physical habitat characteristics such as water depth, substrate type, currents, and sedimentation. The primary factors affecting the structure and function of such communities in high latitude communities are water mass differences, sediment characteristics, and ice scour (Carey 1991). The wide range of these characteristics within the Labrador Shelf 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. The benthic environment in the Study Area can be broken into two distributional zones (Carey 1991):

1. Continental shelf where the biomass is higher at the shelf edge, and
2. Upper Slopes where the biomass begins to decrease.

Stewart et al. (1985) surveyed benthic invertebrates at stations on the continental shelf and slope of southeastern Baffin Island, in Ungava Bay, and on the northern Labrador Shelf. Water depths ranged from 106 m to 970 m while bottom temperatures ranged from -0.7°C to 4.3°C. Stations deeper than 600 m had fine sand-silt substrate while shallower stations generally had a sand substrate. Stewart et al. (1985) identified 492 species of molluscs, echinoderms, crustaceans, and polychaetes. Many of the species were present in low abundances at a small number of stations. The data indicate that the groupings of the marine benthic organisms were more commonly associated with particular water masses and temperature distributions than substrate distributions.

Two stations examined by Stewart et al. (1985) were located on the northern Labrador shelf in water depths of 180 m (bottom temp. = 3.0°C; sand substrate) and 621 m (bottom temp. = 4.0C; silt and clay substrate). The dominant species, in terms of standing crop and abundance, at the shallower site were *Tachyrhynchus erosus* and *Macoma loveni* for molluscs, *Rhodine gracilior*, *Maldane sarsi*, and *Chaetozone setosa* for polychaetes, *Ophiura robusta* for echinoderms, and *Unciola leucopis* for crustaceans. The deeper site was dominated by *Yoldiella lucida*, *Thyasira gouldi*, and *Dentalium occidentale* for molluscs, *Glycera capitata*, *Ophelina cylindrocaudatus*, *Lumbrineris impatiens*, and an unidentified species for polychaetes, and *Amphipholis squamata* and *Amphiura fragilis* for echinoderms. The dominant crustaceans at the deeper site included *Ischyrocerus megacheir*, *Ampelisca gibba*, *Ampelisca amblyops*, *Haploops tubicola*, and *Byblis crassicornis*. At the shallower site, the water mass was influenced by mixing between the Labrador Current water and deeper, warmer Atlantic Intermediate water. The deeper site occurred under the Irminger Atlantic water mass.

Gilkinson (2012) provides summary data related to DFO research vessel trawl-caught benthos biomass in NAFO Divisions 2J3K between 2006 and 2010. Figure 1 in Gilkinson (2012) indicates that the trawl-caught benthos biomass during this period was dominated by sponges, sea anemones, snow crab and echinoderms. Sponge catches tended to be higher in 2J compared to 3K while sea anemone catch biomass was greater in 3K.

LGL analysis of DFO RV data for 2007-2011 also indicated that sponges were the benthos group accounting for highest catch weight. Other invertebrate benthos with relatively high catch weights included snow crab, sea anemones, basket stars, corals, basket stars and sea urchins, confirmation of what was reported in Gilkinson (2012).

Deep-water Corals

A variety of coral groups occur in Newfoundland and Labrador waters and include scleractinians (solitary stony corals), antipatharians (black wire corals), alcyonaceans (large and small gorgonians, soft corals), and pennatulaceans (sea pens) (Wareham and Edinger 2007; Wareham 2009). Corals are largely distributed along the edge of the continental shelf and slope off Newfoundland and Labrador (Edinger et al. 2007; Wareham and Edinger 2007). Typically, they are found in canyons and along the edges of channels (Breeze et al. 1997), deeper than 200 m. Soft corals are distributed in both shallow and deep waters, while horny and stony corals (hard corals) are restricted to deep water only in this region. Dense congregations of coral off Labrador are referred to as coral “forests” or “fields”. 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). The distribution of various corals, based on data collected by fisheries observers, along the northern and southern regions of the Labrador coast (Edinger et al. 2007; Wareham and Edinger 2007) are provided in Figures 4.13 and 4.14 of the Labrador Shelf SEA (Sikumiut 2008). In total, thirty species of corals were documented and comprising two antipatharians (black wire corals), 13 alcyonaceans (large gorgonians, small gorgonians, and soft corals), four scleractinians (solitary stony corals), and 11 pennatulaceans (sea pens). The authors noted that corals were more widely distributed on the continental edge and slope.

A recently published DFO technical report (Gilkinson and Edinger 2009) presents knowledge about 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). Their study area encompassed the continental shelf, edge, and slope ranging from Baffin Bay to the Grand Banks, including the Labrador Shelf (NAFO Divisions 2GHJ). Distributional maps were compiled by Wareham (2009) using DFO Newfoundland and Labrador Region Multispecies Surveys (2000 to 2007), DFO Arctic Multispecies Surveys (2006 to 2007), Northern Shrimp Survey (2005), and from Fisheries Observers aboard commercial fishing vessels (2004 to 2007). The maps provided by Wareham (2009) show the distribution of several coral groups occurring along the continental edge and slope from Baffin Bay to the Grand Banks. The groups profiled include antipatharians, alcyonaceans, scleractinians, and pennatulaceans. Six previously undocumented coral species, composed of one alcyonacean, two scleractinians, and three pennatulaceans, were identified in the Newfoundland and Labrador and Arctic Regions (Wareham 2009).

According to distribution maps included in Wareham (2009), there are numerous species of corals occurring within or adjacent to the Study Area. The species identified include large gorgonians (*Primnoa resedaeformis*, *Paragorgia arborea*, and *Paramuricea* spp.), small gorgonians (*Acanthogorgia armata*, *Acanella arbuscula*), and soft corals (*Anthomastus grandiflorus*, *Duva florida*, *Gersemia rubiformis*, and *Nephtheid* spp.). One scleractinian species (*Vaughanella margaritata*) and two pennatulacean species (*Anthoptilum grandiflorum* and unspecified sea pen species) are also noted to occur there. No antipatharian species were noted by Wareham (2009) to occur within this EA's Study Area. The majority of coral species were observed to occur on the continental slope, with the exception of several soft corals (*Gersemia rubiformis* and *Nephtheid* spp.) found distributed on the shelf. Map 1 in Wareham (2009) indicates a continuous coral distribution within the Study Area inside of the 1,000 m isobath, based on DFO RV survey catches. The area beyond 1,000 m was not sampled during the RV surveys.

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

4.2.2 Fish

In this EA, 'fish' includes macroinvertebrates that are targeted in the commercial fisheries and all fishes, targeted in the commercial fisheries or otherwise.

4.2.2.1 Macroinvertebrate and Fish Species Harvested during Commercial Fisheries

This section describes the principal macroinvertebrate and fish species that typically are harvested in the Study Area during commercial fisheries. These include both the targeted species (e.g., northern shrimp, snow crab, Greenland halibut (turbot), striped shrimp) as well as others caught incidentally.

Four species, northern shrimp, snow crab, Greenland halibut and striped shrimp, have dominated directed commercial landings data for the Study Area in recent years. Species are discussed in decreasing order of Study Area average annual catch weight for the 2005 to 20010 period (see Section 4.3). Some of the 'incidental catch' species (e.g., wolffish, Atlantic cod, American plaice) are also discussed in this section.

Northern Shrimp (Pandalus borealis)

The primary cold-water shrimp resource in the N Atlantic, the northern shrimp (*Pandalus borealis*) 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. Larger individuals generally occur in deeper waters. 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. Female shrimp also undergo a seasonal migration to shallow water where spawning occurs (DFO 2011a).

Northern shrimp are protandric hermaphrodites. They first mature as males, mate as males for one to several years and then change sex to spend the rest of their lives as mature females. Eggs are laid 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 feeding on planktonic organisms. Northern shrimp are known to live for more than eight years in some areas and are thought to begin to recruit to the fishery at age three, but may not be fully recruited until much later. Some northern populations exhibit slower rates of growth and maturation but greater longevity that results in larger maximum size (DFO 2011a).

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, cod, Atlantic halibut, skates, wolffishes and harp seals (*Phoca groenlandica*). Northern shrimp are vulnerable to these predators regardless of whether they have a soft shell or not (DFO 2011a).

In DFO RV surveys conducted in the Study Area between 2007 and 2011, northern shrimp accounted for the highest catch weight (~61 mt) (see Table 4.2 in Section 4.2.2.4). Shrimp were caught during the 2007-2011 RV surveys throughout the portion of the Study Area shallower than 500 m, the highest catches occurring off the northeastern Saglek Bank (2J), between Saglek Bank and Nain Bank (2GH), in Hopedale Saddle (2H), Cartwright Saddle (2G), offshore of Hamilton Bank (2G) and at the extreme southern part of the Study Area (3K) (see Figure 4.3 in Section 4.2.2.4).

In the Study Area commercial fishery conducted between 2005 and 2010, northern shrimp again accounted for the highest average annual catch weight (~88,000 mt) (see Table 4.5 in Section 4.3.2.2). Highest catches occurred in NAFO Divisions 2J3K portions of the Study Area and the locations of concentrated harvesting reflected the highest catch areas highlighted above for the RV surveys (see Figure 4.25 in Section 4.3.2.2). In his updates of northern shrimp assessments for NAFO Division 2G, Hopedale and Carwright Channels, Hawke Channel and Division 3K, Orr et al. (2011) concluded that the northern shrimp resource appears to be decreasing in the south but increasing in the north.

Snow Crab

The snow crab (*Chionoecetes opilio*), a decapod crustacean, occurs over a broad depth range in the NW Atlantic from Greenland south to the Gulf of Maine. Snow crab distribution is widespread and continuous in waters off Newfoundland and southern Labrador. Snow crabs undertake an ontogenetic migration from shallow cold areas with hard substrates to warmer deeper areas with soft substrates (DFO 2012a).

There are two fishery closure areas that occur in the Project Area: (1) Hawke Channel; and (2) Funk Island Deep (see Figure 4.11 in Section 4.3) and both were created to offer protection to snow crab (DFO, pers. comm. 2013). More details on these closure areas are provided in Section 4.7, Sensitive Areas.

The snow crab life cycle features a 12 to 15 week planktonic larval period, following spring hatching, involving several stages before settlement. Benthic juveniles of both sexes molt frequently, and at about 40 mm CW (~ 4 years of age) they may become sexually mature. Female crabs carry fertilized eggs for about two years (DFO 2012a).

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 2012a).

In DFO RV surveys conducted in the Study Area between 2007 and 2011, snow crab accounted for the thirteenth highest catch weight (~2.5 mt) (see Table 4.2 in Section 4.2.2.4). Snow crab total catch weight during the 2007-2011 RV surveys in the Study Area was relatively low (i.e., ~2.5 mt) and subsequently, was not mapped.

In the Study Area commercial fishery conducted between 2005 and 2010, this crab accounted for the second highest average annual catch weight (~8,500 mt) (see Table 4.5 in Section 4.3.2.2). Highest catches occurred in the western NAFO Division 3K portion of the Study Area, followed by the 2J portion in the inshore part of the Cartwright Channel and south of Hamilton Bank in the area of Hawke Channel. Most of the snow crab catches in the Study Area during the six-year period occurred at water depths >200 m and < 500 m (see Figure 4.34 in Section 4.3.2.2).

Snow crab landings in NAFO Div. 2H, 2J and 3K between 2008 and 2011 have decreased by 95%, 21% and 35%, respectively (DFO 2012a). Long-term recruitment prospects in all three NAFO Divisions are

unfavourable (DFO 2012a). Decreases in exploitable snow crab biomass in NAFO Div. 2HJ3K during recent years are also indicated in Mullowney et al. (2012).

Greenland Halibut (Turbot)

The Greenland halibut (*Reinhardtius hippoglossoides*), often referred to as turbot, is distributed throughout cold, deep waters of the Labrador Shelf, inhabiting the continental shelf and slope at depths of 200 to 600 m or more (Smidt 1969). High abundances of the species occur in the Hopedale, Cartwright, and Hawke Channels of mid- to southern Labrador (Bowering and Chumakov 1989). High abundances in shelf channels have been attributed to high concentrations of available prey, namely northern shrimp (Bowering 1983). Greenland halibut feed on a variety of species, including shrimp, small pelagic crustaceans, small fish (e.g., Arctic cod, capelin), larger fish (e.g., redfish, grenadier), and squid (DFO 2008b).

Greenland halibut inhabiting the continental shelf of Labrador are predominately immature (Bowering 1977, 1981, 1983; Zilanov et al. 1976; Bowering and Chumakov 1989). The majority of the adult population is distributed in the deep and warm N Atlantic waters (e.g., Davis Strait, between Greenland and Baffin Island) where spawning occurs in winter or early spring (Templeman 1973; Bowering 1983; Bowering and Brodie 1995). Larvae and juveniles are transported south by oceanic currents and colonize the deep channels of the Labrador banks (Bowering 1983; Bowering and Brodie 1995). In the Labrador Shelf area, Greenland halibut 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 DFO RV surveys conducted in the Study Area between 2007 and 2011, Greenland halibut accounted for the fourth highest catch weight (~32 mt) (see Table 4.2 in Section 4.2.2.4). Greenland halibut catches during the 2007-2011 RV surveys in the Study Area were highest in the central and southern parts, particularly inside of Nain Bank (2H), in the Cartwright Saddle (2J), and south of Hamilton Bank (2J3K). Greenland halibut were caught in areas with water depths ranging between <200 m to 1,000 m (see Figure 4.6 in Section 4.2.2.4).

In the Study Area commercial fishery conducted between 2005 and 2010, Greenland halibut accounted for the third highest average annual catch weight (~3,800 mt) (see Table 4.5 in Section 4.3.2.2). Locations with most concentrated commercial harvesting included off Saglek Bank (2G), off southeastern Nain Bank (2H), in the Cartwright Saddle area (2J), in deeper water to the east of Hamilton Bank (2J), and along the 1,000 m isobaths from 2J to 3K (see Figure 4.37 in Section 4.3.2.2).

Striped Shrimp *(Pandalus montagui)*

Striped shrimp are distributed from Davis Strait to the Bay of Fundy. As is the case with northern shrimp, the striped shrimp shows preferences for both depth and water temperature. It prefers slightly cooler water (-1 to 2°C) than the northern shrimp and is therefore more commonly distributed at

shallower depths (200-500 m). Striped shrimp also appear to prefer harder substrates than northern shrimp (DFO 2011a). Striped shrimp, primarily males and smaller females, migrate into the water column at night. This shrimp is an opportunistic feeder at or near the sea bottom and up in the water column. Striped shrimp are thought to live for five to eight years. As is the case with northern shrimp, striped shrimp is an important forage species (DFO 2011a).

Striped shrimp are also protandric hermaphrodites. They first mature as males, mate as males for one to several years and then change sex to spend the rest of their lives as mature females. Eggs are typically produced once a year in the late summer/fall and remain attached to the female until the following spring, when the female migrates to shallow coastal waters where hatching occurs. The larvae remain planktonic for three to four months, after which they settle to the bottom and begin the epibenthic portion of their life history (DFO 2011a).

In DFO RV surveys conducted in the Study Area between 2007 and 2011, striped shrimp total catch weight was relatively low (~4 mt) and subsequently was not mapped (see Table 4.2 in Section 4.2.2.4).

There is some directed fishery for the striped shrimp but most of its harvesting is as a result of by-catch in the northern shrimp fishery (DFO 2011a). In the Study Area commercial fishery conducted between 2005 and 2010, it accounted for the fourth highest average annual catch weight (~1,800 mt) (see Table 4.5 in Section 4.3.2.2). This is only about 2% of the commercial fishery average annual catch weight for northern shrimp in the Study Area during the same period (~88,000 mt). All striped shrimp catches occurred in the extreme northwestern corner of the Study Area, typically in areas with water depths ranging from 200 to 500 m (see Figure 4.40 in Section 4.3.2.2).

Wolffishes

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

In DFO RV surveys conducted in the Study Area between 2007 and 2011, wolffishes accounted for slightly more than 3.6 mt of total catch weight (see Table 4.2 in Section 4.2.2.4). In total, more than 4,200 individual wolffish were caught that five-year period, 78% of which were Atlantic wolfish. In terms of catch weight, northern wolffish and spotted wolffish accounted for about 78% of the total wolffish biomass caught during RV surveys in the Study Area between 2007 and 2011 (Table 4.2 in Section 4.2.2.4). However, considering their statuses under Schedule 1 of *SARA*, their harvest location distributions were mapped (see Figures 4.8 to 4.10 in Section 4.2.2.4). All three species were caught throughout the portion of Study Area surveyed.

Wolffishes were also incidentally harvested, but not landed, during directed commercial harvests within the Study Area.

Redfish

Redfish (*Sebastes* spp.) 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). 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).

The NW Atlantic redfish consist of a complex of three species identified as Acadian redfish (*S. fasciatus*), golden redfish (*S. marinus*), and deepwater redfish (*S. mentella*) (DFO 2012b). Acadian redfish and deepwater redfish both have *threatened* status under COSEWIC but no status under Schedule 1 of *SARA*. The redfish distribution in the NW Atlantic ranges from the Gulf of Maine, northwards off Nova Scotia and southern Newfoundland banks, in the Gulf of St. Lawrence, and along the continental slope and deep channels from the southwestern Grand Bank to areas as far north as Baffin Island. Redfish are also present in the area of Flemish Cap and west of Greenland.

The deepwater redfish and Acadian redfish, the two most important commercially-targeted species, are distributed according to a gradient in the NW Atlantic (DFO 2012b). The deepwater redfish is the dominant species in northern areas, such as Baffin Island and in Labrador waters, whereas Acadian redfish dominates in the Gulf of Maine and the basins and continental slope of the western Scotian Shelf (the latter known collectively as Unit 3). Their distribution overlaps in the Gulf of St. Lawrence (Unit 1), the Laurentian Channel (Unit 2), off Newfoundland (3LN, 3M, 3O), and south of the Labrador Sea (2J, 3K). In areas of distributional overlap, deepwater redfish generally occur in deeper water (350 – 500 m) than Acadian redfish (150 – 300 m).

Redfish are generally slow growing and long-lived fishes (DFO 2012b). 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.

Two biological stocks of *Sebastes* occurs in the Study Area: (1) the northern population of deepwater redfish (SA2+Div.3K); and (2) the Labrador Shelf population of Acadian redfish (SA2+Div.3K) (DFO 2012b). The Div.2J3K portion of the northern population of deepwater redfish stock is believed to be experiencing increased growth while the portion in the rest of SA 2 appears to be showing decreasing growth. The Labrador Shelf population of Acadian redfish appears to be growing throughout the Study Area (DFO 2012b).

In DFO RV surveys conducted in the Study Area between 2007 and 2011, deepwater redfish catch weight was second highest (~55 mt) (see Table 4.2 in Section 4.2.2.4). Deepwater redfish catches during the 2007-2011 RV surveys in the Study Area were highest along the 500-1,000 m isobath (see Figure 4.4 in Section 4.2.2.4).

In the Study Area commercial fishery conducted between 2005 and 2010, redfish accounted for the sixth highest average annual catch weight (~49 mt) (see Table 4.5 in Section 4.3.2.2), an extremely small proportion of the overall total catch weight in the Study Area during that period. Redfish catches were incidental in the commercial fishery.

Roughhead Grenadier

Although it does not have any status under Schedule 1 of *SARA*, the roughhead grenadier (*Macrourus berglax*) currently has *special concern* status under COSEWIC (COSEWIC 2007).

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

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

In DFO RV surveys conducted in the Study Area between 2007 and 2011, roughhead grenadier catch weight was the ninth highest (4 mt) (see Table 4.2 in Section 4.2.2.4).

This grenadier species is quickly becoming an important commercial fish in the NW Atlantic. Presently its fishery is unregulated since it is usually taken as bycatch in the Greenland halibut fishery. In the Study Area commercial fishery conducted between 2005 and 2010, roughhead grenadier accounted for the seventh highest average annual catch weight (~28 mt) (see Table 4.5 in Section 4.3.2.2).

American Plaice

The Newfoundland and Labrador population of American plaice (*Hippoglossoides platessoides*) currently has no status under Schedule 1 of *SARA* but it does have *threatened* status under COSEWIC (COSEWIC 2009b).

The American plaice is a bottom-dwelling flatfish that resides on both sides of the Atlantic (COSEWIC 2009b). American plaice that reside in the W Atlantic region range from the deep waters off Baffin

Island and western Hudson's Bay southward to the Gulf of Maine and Rhode Island (Scott and Scott 1988). In Newfoundland waters, plaice occur 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 approximately 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 2008f). 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 2008f) with the most intense spawning coincident with areas where the higher abundance of adults are found (Busby et al. 2007). Limited data in southern areas (e.g., Burgeo Bank, St. Pierre Bank and along the slopes of the Laurentian Channel and Hermitage Channel) indicate that spawning does occur in April and possibly other months (Ollerhead et al. 2004). In addition, spawning in southern areas (e.g., St. Pierre Bank) typically occurs in water temperatures of 2.7°C (Scott and Scott 1988). Large quantities of eggs are released and fertilized over a period of days on the seabed (Johnson 2004). Eggs are buoyant and drift into the upper water column, where they are widely dispersed, allowing for some intermingling of stocks. Intermingling of adults is minimal. Hatching time is temperature dependant, occurring in 11 to 14 days at temperatures of 5°C (Scott and Scott 1988). Larvae are 4 to 6 mm in length when they hatch and begin to settle to the seabed when they reach 18 to 34 mm in length and their body flattens (Fahay 1983).

In SA2 + Div. 3K, the American plaice stock declined to very low levels by the early 1990s. Total mortality has been decreasing in recent years but stock biomass remains at only 10% of the values seen in the 1980s (Morgan et al. 2013)

In DFO RV surveys conducted in the Study Area between 2007 and 2011, American plaice catch weight ranked eleventh (~3 mt) (see Table 4.2 in Section 4.2.2.4).

American plaice catches in the commercial fishery are incidental in other directed fisheries. During 2005-2010, the average annual catch weight for this flatfish was about 12 mt, ranking ninth overall (see Table 4.5 in Section 4.3.2.2).

Atlantic Cod

The NL population of Atlantic cod (*Gadus morhua*) has *endangered* status under COSEWIC but no status under Schedule 1 of *SARA*. Cod in the NL population inhabit waters ranging from immediately north of Cape Chidley on the northern tip of Labrador southeast to Grand Bank off eastern Newfoundland. For management purposes, cod in this population are treated as three separate stocks by

DFO: (1) northern Labrador cod (NAFO Divisions 2GH), (2) "northern cod" i.e., those found off southeastern Labrador, the Northeast Newfoundland Shelf, and the northern half of Grand Bank (NAFO Divisions 2J3KL, and (3) southern Grand Bank cod (NAFO Divisions 3NO). Cod in the Study Area are considered to be those of the northern Labrador (2GH) cod stock and the 'northern cod' (2J3KL). Cod in NAFO Subdiv. 0AB are part of the Arctic population and are also likely to occur in the Study Area. The following paragraphs provide an overall summary of the life history and ecology of Atlantic cod in Canadian waters, regardless of cod population or stock (Brattey et al. 2011).

The Atlantic cod is a demersal fish that inhabits cold (10 to 15°C) and very cold (less than 0 to 5°C) waters in coastal areas and in offshore waters overlying the continental shelf throughout the NW and NE Atlantic Ocean (COSEWIC 2003c). The species is found contiguously along the east coast of Canada from Baffin Island to Georges Bank. During the first few weeks of life, cod eggs and larvae are found in the upper 50 m of the water column. As juveniles, cod are settled on the bottom and tend to occur in nearshore habitats with vertical structure such as eelgrass (*Zostera marina*) and macroalgae. As adults, the habitat requirements of cod are increasingly diverse.

Atlantic cod typically spawn over a period of less than three months in water that may vary in depth from tens to hundreds of metres (COSEWIC 2003c). Cod are described as batch spawners because only a small percentage (5 to 25%) of the female's egg total is released at any given time during a three to six week period. There are two fishery closure areas that occur in the Project Area: (1) Hawke Channel; and (2) Funk Island Deep (see Figure 4.11 in Section 4.3) and both were created to offer protection to Atlantic cod (DFO, pers. comm. 2013). More details on these closure areas are provided in Section 4.7, Sensitive Areas. After hatching, larvae obtain nourishment from a yolk sac until they have reached a length of 1.5 to 2.0 mm. During the larval stage, the young feed on phytoplankton and small zooplankton in the upper 10 to 50 m of the water column. After the larval stage, the juveniles settle to the bottom where they appear to remain for a period of 1 to 4 years. These settlement areas are known to range from very shallow (<10 to 30 m) coastal waters to moderately deep (50 to 150 m) waters on offshore banks. After this settlement period, it is believed that the fish begin to undertake seasonal movements and migrations characteristic of adults.

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

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

Since the early 1970s, the northern Labrador cod stock (2GH) has been managed separately from southern Labrador cod (2J) because of differing characteristics (e.g., growth rates) of the stocks (ICNAF 1973). In addition, stock separation was influenced by over-fishing experienced in the 1960s, which affected the cod stock more in northern Labrador than in southern areas (Pinhorn 1976). According to COSEWIC (2003c), cod abundance in the inshore and offshore waters of Labrador and northeastern Newfoundland have declined by more than 99% since the 1960s and are currently at historical lows. Virtually no recovery of either abundance or age structure of offshore cod has been observed since the moratoria were imposed in the early 1990s and threats to persistence include fishing, predation by fish and seals, and natural and fishing-induced ecosystem changes. There is currently no directed fishery for cod in the Study Area, and only a relatively small quantity of cod by-catch is allowed. The stock remains at a low level (DFO 2005a).

Overall, the status of the 2J3KL cod stock has improved, particularly during 2004-2008. However, the improvements are limited to areas adjacent to the 3KL border and the central portion of the inshore. The stock has not increased across much of the historical geographic range (Brattey et al. 2011)

In DFO RV surveys conducted in the Study Area between 2007 and 2011, Atlantic cod catch weight ranked seventh (~5.5 mt) (see Table 4.2 in Section 4.2.2.4).

Atlantic cod catches in the commercial fishery are incidental in other directed fisheries. During 2005-2010, the average annual catch weight for this flatfish was about 1 mt, twelfth overall (see Table 4.5 in Section 4.3.2.2).

Roundnose Grenadier

Although it does not have any status under Schedule 1 of *SARA*, roundnose grenadier currently has *endangered* status under COSEWIC (COSEWIC 2008b).

Distributed in the NW Atlantic from Cape Hatteras to Greenland, the roundnose grenadier is a deepwater, demersal fish found in continental slope areas at depths of 200 to 2,000+ m (Atkinson 1995). This species is thought to undergo seasonal migrations with individuals in northeast Newfoundland waters occupying deeper water in winter and shallower water in late summer. Diurnal vertical migrations also occur that may carry them more than 1,000 m off the bottom (COSEWIC 2008b). The long-lived, late-maturing, slow-growing species has a low fecundity and is potentially vulnerable to overfishing (Devine and Haedrich 2008). The roundnose grenadier harvest has been under a moratorium in Canadian waters in NAFO Subareas 2 and 3 since the 1990s, but may be harvested as bycatch in other fisheries (Power 1999). Roundnose grenadier spawning grounds are largely unknown and suspected to be in waters deeper than 850 m. Spawning is believed to occur either in different areas throughout the NW Atlantic (COSEWIC 2008b) or predominately in Icelandic waters with the passive eggs and larvae carried to other areas in the NW Atlantic by currents (Scott and Scott 1988). The spawning time is uncertain, but believed to occur throughout the year with more intense spawning occurring during particular periods. These periods appear to vary between areas (Atkinson 1995). The roundnose grenadier feeds on a variety of small crustaceans and euphasiids, squid, and small fishes. This slow swimming species, in turn, is possibly consumed by other fishes (Scott and Scott 1988).

In DFO RV surveys conducted in the Study Area between 2007 and 2011, roundnose grenadier catch weight ranked seventeenth (~2 mt) (see Table 4.2 in Section 4.2.2.4).

Atlantic Salmon

Various populations of Atlantic salmon, all of which potentially pass through the Study Area during migration, have various status listings under COSEWIC, including *endangered*, *threatened* and *special concern*. No Atlantic salmon populations have status under Schedule 1 of *SARA*.

Atlantic salmon (*Salmo salar*) is an anadromous fish that lives in fresh water for the first two years of life before migrating to sea. It can spawn repeatedly, as opposed to most species of Pacific salmon (*Onchorhynchus* spp.), which typically die after one spawning (Schaffer 1974 *in* O'Connell et al. 2006; Flemming and Reynolds 2004 *in* O'Connell et al. 2006).

Atlantic salmon return to their natal rivers or tributaries for spawning. Both post-smolt (juvenile) and adult salmon migrate from NE North America in the spring and summer to waters off Labrador to overwinter. During these migrations, Atlantic salmon appear to transit the Study Area in early to mid-summer and late summer to fall (Reddin 2006). While at sea, adult salmon spend a considerable amount of time in the upper portion of the water column (Reddin 2006). Tagging studies of post-smolts indicate that they spend most of their time near the surface but at times dive deeply, likely in search of prey (Reddin et al. 2006).

While still in the river, post-smolts mainly eat aquatic insect larvae including caddisflies and blackflies. Adults at sea consume euphausiids, amphipods and fishes such as herring, capelin, small mackerel, sand lance and small cod. When salmon return to fresh water to spawn, they likely do not eat (Scott and Scott 1988). Causes of at-sea mortality of salmon are poorly understood (Reddin 2006) but it is known that they are prey for seals, sharks, pollock, and tuna (Scott and Scott 1988).

Commercial salmon harvesting ceased in 1998 although angling in freshwater and an Aboriginal subsistence fishery still occur (Reddin et al. 2006). The latter, which has seen landings increase from 16 metric tonnes (mt) in 2000 to 32 mt in 2005 and 2006, is undertaken by three groups consisting of the Nunatsiavut Government (formerly the Labrador Inuit Association or LIA), the Labrador Métis Nation, and the Innu Nation (Reddin et al. 2006). According to DFO (2008d), large salmon (maiden 2SW salmon) appear to be decreasing in Labrador similar to declines experienced in other areas of Eastern Canada and Europe (DFO 2008d). In 2007, there was no change in returns (<10%) of small and large salmon in SFA 1 compared to 2006. However, when compared to their respective previous 7 year means, small salmon returns were observed to increase while large salmon returns decreased (DFO 2008d).

Cusk

Although it does not have status under Schedule 1 of *SARA*, cusk currently has *threatened* status under COSEWIC (COSEWIC 2003d).

Cusk are solitary, slow-swimming groundfish that occur on both sides of the N Atlantic. In Canadian waters, this species is most common in the Gulf of Maine, Gulf of St. Lawrence and the southwestern Scotian Shelf (Scott and Scott 1988; COSEWIC 2003d). Although most common within a depth range of 128 to 144 m, some have been caught as deep as 600 m. Adult cusk prefer structured hard bottom habitat and a depth range of 400 to 600 m (DFO 2008e). The preferred habitat of juvenile cusk is not known (DFO 2008e). The diet of cusk is not well documented because their stomachs usually evert when they are brought to the surface. Studies have shown that in European waters, cusk feed on crab, molluscs, krill, cod, and halibut. Their diet is presumed to be the same in Canadian waters (Scott and Scott 1988).

American Eel

The American eel does not have status under Schedule 1 of *SARA* but does have *threatened* status under COSEWIC (COSEWIC 2006e).

The American eel is the W Atlantic representative of the worldwide genus *Anguilla*, whose members spawn in ocean waters, migrate to coastal and inland continental waters to grow, and then return to ocean spawning grounds to reproduce and die (Cairns et al. 2008). The historic Canadian range encompassed all accessible fresh water, estuaries and coastal marine waters connected to the Atlantic Ocean as far north as the mid-Labrador coast. Continental shelves are used by juvenile eels arriving from spawning grounds, and by silver eels, after several years in fresh water, returning to the spawning grounds. Spawning takes place in the Sargasso Sea, located south of Bermuda and east of the Bahamas.

Hatched larvae develop a leaf-like shape and are termed leptocephali (COSEWIC 2006e). American eel leptocephali drift westward towards the continental shelf, where they metamorphose into small, transparent glass eels, which have the serpentine shape of the adult form. As glass eels move into inshore waters, they develop pigmentation and become elvers. Elver arrival generally occurs in May and early June on the Atlantic coast of the Maritime Provinces. Some elvers remain in shallow protected salt water, some move into estuaries, and some move into fresh water. Elvers become yellow eels, which have a dark back and a yellowish belly. Sexual differentiation occurs during the yellow phase and appears to be controlled by environmental factors. Density appears to be the dominant influence, with high densities promoting the production of males. Females are dominant in many locations in Canada with the notable exceptions being the upper St. Lawrence River and Lake Ontario. When yellow eels reach a certain size, their bellies turn silver and they prepare for the spawning migration. Eels that occupy brackish and salt water tend to grow more rapidly than those in fresh water and thus return to spawning grounds at a younger age. Yellow eels in fresh water may continue to migrate for many years before returning to the spawning ground.

Newfoundland, including Labrador, is the most data-poor area of the American eel's Canadian range, and has no data sets that indicate abundance trends or absolute abundance at any life stage.

Arctic Cod

In Canadian waters, this distinctly arctic species, Arctic cod (*Boreogadus saida*), is found in the Beaufort Sea, the Arctic Archipelago, Hudson Bay, Baffin Bay, along the Labrador coast, eastern Newfoundland coast and the northern and eastern Grand Banks (DFO 2009a). Arctic cod can be encountered in a variety of water depths ranging from a few metres to 900+ m (DFO 2009a). Off northern Labrador, exploratory fishing ventures revealed that best catches using otter trawls were taken at depths of 100 to 250 m at bottom temperatures ranging from -1.4 to 0.6°C (DFO 2009a). Off southern Labrador and northern Newfoundland, catches were smaller and mainly taken at depths ranging from 200 to 300 m and at bottom temperatures of -1.2 to 3.6°C. During autumn the fish have been observed to congregate in large numbers and move into coastal waters. Temperatures ranging from of 0 to 4°C are believed to be optimal for Arctic cod survival although the species has been found in waters <0°C and frequently near drifting ice (DFO 2009a).

The stock structure of Arctic cod in the NW Atlantic is not known, but it is assumed that most of the adult stock(s) may reside on the northern Labrador shelf or even further north (Lilly et al. 1994). In northern Canadian waters, spawning is believed to occur in late autumn and winter under ice cover (DFO 2009a). Larvae may be transported with the Labrador Current south to the southern Labrador and NE Newfoundland shelves, where mainly one and two year old Arctic cod are found (Lilly et al. 1994).

The Arctic cod is generally of low commercial interest to Canadian fishermen because of its small size and relatively low abundance (Scott and Scott 1988; DFO 2009a); however, large numbers have been obtained off Labrador by Soviet trawlers as a bycatch in the offshore capelin fishery (DFO 2009a). The Arctic cod is an extremely important component of the Arctic food web (Lear 1983) and an important seasonal food supply for marine mammals, seabirds, and fishes that inhabit the area (Scott and Scott 1988). In turn, Arctic cod are the main consumers of plankton in the Arctic seas. Depending on age and body size, Arctic cod are known to feed on various stages of copepods and amphipods in addition to euphausiids, arrow worms (chaetognaths), and smaller members of their own kind (DFO 2009a).

Sand Lance

Sand lance (*Ammodytes* spp.) is a small planktivorous fish found on sandy seabeds. It is a pelagic species that forms varying sized dense schools feeding throughout the water column, but also spends a portion of each day buried in the sandy seabeds. It is found in the N Atlantic from Greenland to the Gulf of St. Lawrence and is typically found at depths of less than 100 m (Scott and Scott 1988; DFO 2004a). The species of sand lance present in the Labrador Shelf SEA Area is the northern sand lance (*A. dubius)*; however, there is speculation about whether there are one or two species of sand lance in the area covered by the Study Area (DFO 2004a). It is generally accepted that the offshore, northern species is *A. dubius* and the inshore species *A. americanus* (= *A. hexapterus*), but the characteristics of the two species overlap (DFO 2004a). It co-occurs over much of its range with the American sand lance (*A. americanus*) (Scott and Scott 1988). There is no information available regarding the time of spawning in the Study Area, but in general, sand lance spawn demersally during winter months in shallow waters (DFO 2004a). This species is not commercially fished, but is an important part of the marine food-web as it is a food source for marine mammals, seabirds, and several species of fish, including cod.

Arctic Char

Arctic char (*Salvelinus alpinus*) has a circumpolar distribution in the northern hemisphere. It is either anadromous or resident freshwater fish, with a higher predominance of resident fish further south, while anadromous populations are common in northerly regions. In Labrador, anadromous populations increase in frequency with latitude as they are replaced by sea-run brook char and Atlantic salmon in southern areas (DFO 2001).

Seaward migration for northern Labrador Arctic char commences with spring runoff and ice break-up in coastal rivers. Migrations consist of both first-time and repeat migrants with first time migrants being between two to seven years and 10 to 20 cm in length. Seaward migration for Arctic char is short and irregular, with both juveniles and adults spending only one to four months at sea before returning to fresh water. Ocean migrations are also spatially limited, with few Arctic char moving less than 100 km from home rivers, mostly along shore. The return migrations occur from July to September, with large, mature char returning first, followed by non-mature adults then juveniles (DFO 2007b).

Northern Labrador Arctic char mature at younger ages and smaller sizes than other char stocks from northern Canada (DFO 2001). Spawning takes place in the fall, commencing by mid-October, and occurs in either lakes or streams and is not dependent on any particular substrate. Females lay approximately 290 eggs per 100 g of body mass. Growth rates are slow during the freshwater stage of the life cycle, with the adult size-at-age being highly variable, dependent upon age of first sea migration and the number of migrations the char has taken. In Labrador, females begin to mature at approximately six years, with most individuals spawning at least once by the age of nine.

Arctic char are opportunistic predators while at sea, with diet varying over spatial areas. Sand lance, capelin, sculpins and hyperiid amphipods are the four main species of prey for Arctic char within Labrador Shelf waters (DFO 2001).

4.2.2.2 Macroinvertebrate and Fish Reproduction in the Study Area

Temporal and spatial reproduction specifics for macroinvertebrates and fishes that occur in the Study Area are provided in Table 4.1.

Table 4.1 Reproduction Specifics of Key Macroinvertebrate and Fish Species Known or 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
Greenland halibut	Spawning grounds extend from Davis Strait (south of 67°N) to south of Flemish Pass between 800 m and 2,000 m depth	Winter months	Uncertain
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 hundred of metres	March to June	10 to 12 weeks
Skates	Uncertain	Year-round	N/A
American plaice	Spawning generally occurs throughout the range the population inhabits.	April to May	12 to 16 weeks
Cusk	Uncertain	May to August	Presumed to be 4 to 16 weeks
Porbeagle shark	Very little known about the location of the pupping grounds	Mating in late summer and pupping during the winter	N/A
Wolffishes	Likely along the slope regions	September to November	Uncertain
Roundnose grenadier	Uncertain	Uncertain	Uncertain
Roughhead grenadier	Uncertain	Winter/early spring	Uncertain
Sand lance	Shallow waters	Winter	Uncertain
Capelin	Spawning generally on beaches or in deeper waters	Late June to early July	Several weeks
Atlantic salmon	Spawn in freshwater	October to November	Several weeks in freshwater
Arctic char	Spawn in freshwater	October to November	Several weeks in freshwater

4.2.2.3 Macroinvertebrates and Fishes Collected during DFO Research Vessel (RV) Surveys

DFO RV data collected during annual multi-species trawl surveys provide distributional information for species not discussed in the commercial fisheries as well as added information for commercial species.

Data collected during 2007 to 2011 spring and fall DFO RV surveys in the Study Area were analyzed, and catch weights and catch numbers of species/groups are presented in Table 4.2.

Northern shrimp accounted for 22.8% of the total 2007-2011 catch weight, followed by deepwater redfish (20.6%), shrimp (Natantia) (13.9%), Greenland halibut (turbot) (12.1%), sponges (6.4%), capelin (3.4%), Atlantic cod (2.1%), striped shrimp (1.5%), roughhead grenadier (1.5%), blue hake (1.2%), American plaice (1.1%) and Arctic cod (1.1%). All other species/groups account for less than 1% of the total 2007-2011 catch weight in the Study Area. The distribution of geo-referenced catch locations reported during the 2007 to 2011 DFO RV surveys within the Study Area are shown in Figure 4.2. Across all species caught during the 2007 to 2011 DFO RV surveys in the Study Area, total catch weight ranged from 45,332 kg in 2007 to 65,047 kg in 2008.

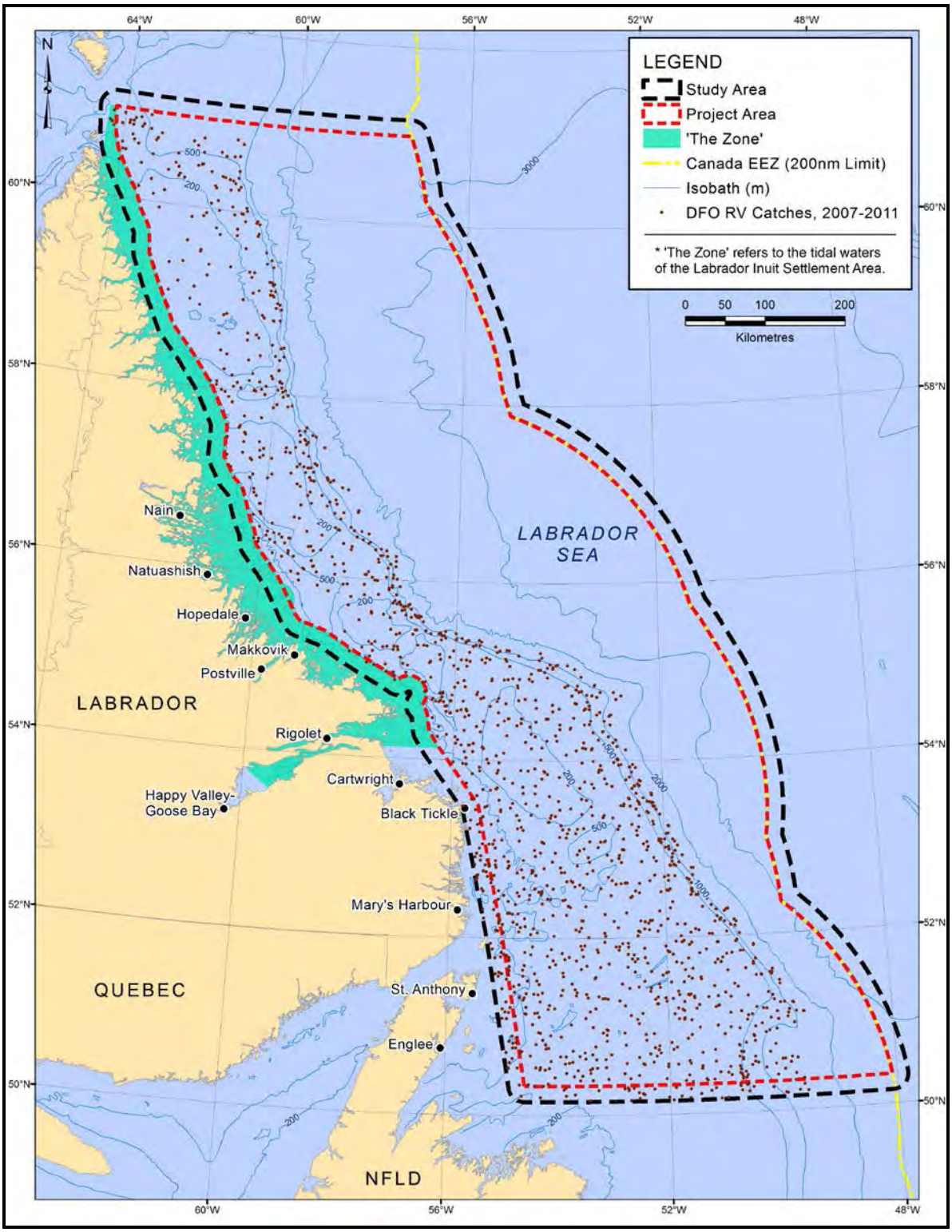
Spring surveys accounted for <15% of the total catch weight (Table 4.3). The average mean depths of catch during spring and fall surveys between 2007 and 2011 ranged from 141 m to 574 m, and 185 m to 1,295 m, respectively. The top five species/groups in terms of catch weight during the spring surveys, 2007-2011, were, in descending order, northern shrimp, deepwater redfish, shrimp (Natantia), Greenland halibut (turbot) and sponges. The top five species/groups in terms of catch weight during the fall surveys, 2007-2011, were, in descending order, deepwater redfish, shrimp (Natantia), Greenland halibut, northern shrimp and sponges (Table 4.3).

Table 4.2 Catch Weights and Numbers of Macroinvertebrates and Fishes Collected DFO RV Surveys within the Study Area, 2007-2011 Combined.

Species	Catch Weight (kg)	Catch Number
Northern shrimp (*Pandalus borealis*)	60,756	13,668,809
Deepwater redfish	54,908	463,479
Shrimp (Natantia)	37,071	n/a
Greenland Halibut (Turbot)	32,167	156,720
Sponges	17,120	n/a
Capelin	9,082	513,018
Atlantic Cod	5,468	7,533
Striped shrimp (*Pandalus montagui*)	4,010	906,134
Roughhead Grenadier	3,872	9,785
Blue Hake	3,297	21,539
American Plaice	3,006	16,725
Arctic Cod	2,897	157,837
Snow Crab	2,464	13,229
Sea Anemone	2,329	13,514
Jellyfish	2,251	80
Thorny Skate	1,914	6,472
Roundnose Grenadier	1,858	16,346
Basket Star (Gorgonocephalidae)	1,803	225

Species	Catch Weight (kg)	Catch Number
Northern Wolffish	1,754	396
Invertebrates	1,645	17
Longnose Eel	1,232	15,492
Shrimp (*Argis dentata*)	1,136	224,931
Spotted Wolffish	1,084	544
Lanternfish sp.	853	106,197
Witch Flounder	806	2,333
Atlantic (Striped) Wolffish	799	3,379
Marlin Spike	652	6,733
Vahl's Eelpout	603	14,601
Corals	572	n/a
Shanny	566	97,796
Eelpout (*Lycodes* sp.)	552	15,038
Spinytail Skate	524	98
Black Herring	522	364
Lumpfish	501	311
Snake Blenny	468	29,478
Eelpout (Zoarcidae)	423	13,913
Basket Star (*Gorgonocephalus arcticus*)	422	86
Sea Urchin (Echinoidea)	405	10,930
Greenland Shark	400	1
Mailed Sculpin	304	28,249
Northern Alligatorfish	298	27,741
Golden Redfish	275	372
Large Scale Tapirfish	270	355
Arctic Eelpout	214	1,126
Rigid Cushion Star	194	901
Jensen's Skate	187	60
Shrimp (*Eualus gaimardii belcheri*)	182	71,390
Black Dogfish	180	142
Shrimp (*Eualus macilentus*)	161	156,412
Shrimp (*Pasiphaea* sp.)	158	18,025
Moustache Sculpin	157	14,037
Shrimp (*Sabinea septemcarinata*)	156	44,324
Sea Urchin (*Strongylocentrotus* sp.)	151	13,962
Shrimp (*Pasiphaea multidentata*)	139	15,000
Sea Star (*Ctenodiscus* sp.)	134	9,277
Deepsea Cat Shark	132	76
Shrimp (*Lebbeus groenlandicus*)	127	27,805
Shrimp (*Pasiphaea tarda*)	115	11,719
Threebeard Rockling (*Gaidropsarus* sp.)	113	1,056
Threebeard Rockling (*Gaidropsarus ensis*)	113	1,105
Sea Urchin (*Strongylocentrotus droebachiensis*)	109	4,355
Atlantic Halibut	106	3
Octopus (Octopoda)	106	290
Octopus (Octopodidae)	105	244
Cusk	7	9
Spiny Dogfish	2	2
Overall Total	**266,386**	

Source: DFO RV Survey Data (2007-2011). Note: n/a denotes data unavailable.



Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.2 Distribution of All Species Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.

Table 4.3 Percentage Catch and Mean Catch Depth by Survey Season for Macroinvertebrates and Fishes Caught during DFO RV Surveys within the Study Area, 2007 to 2011 Combined.

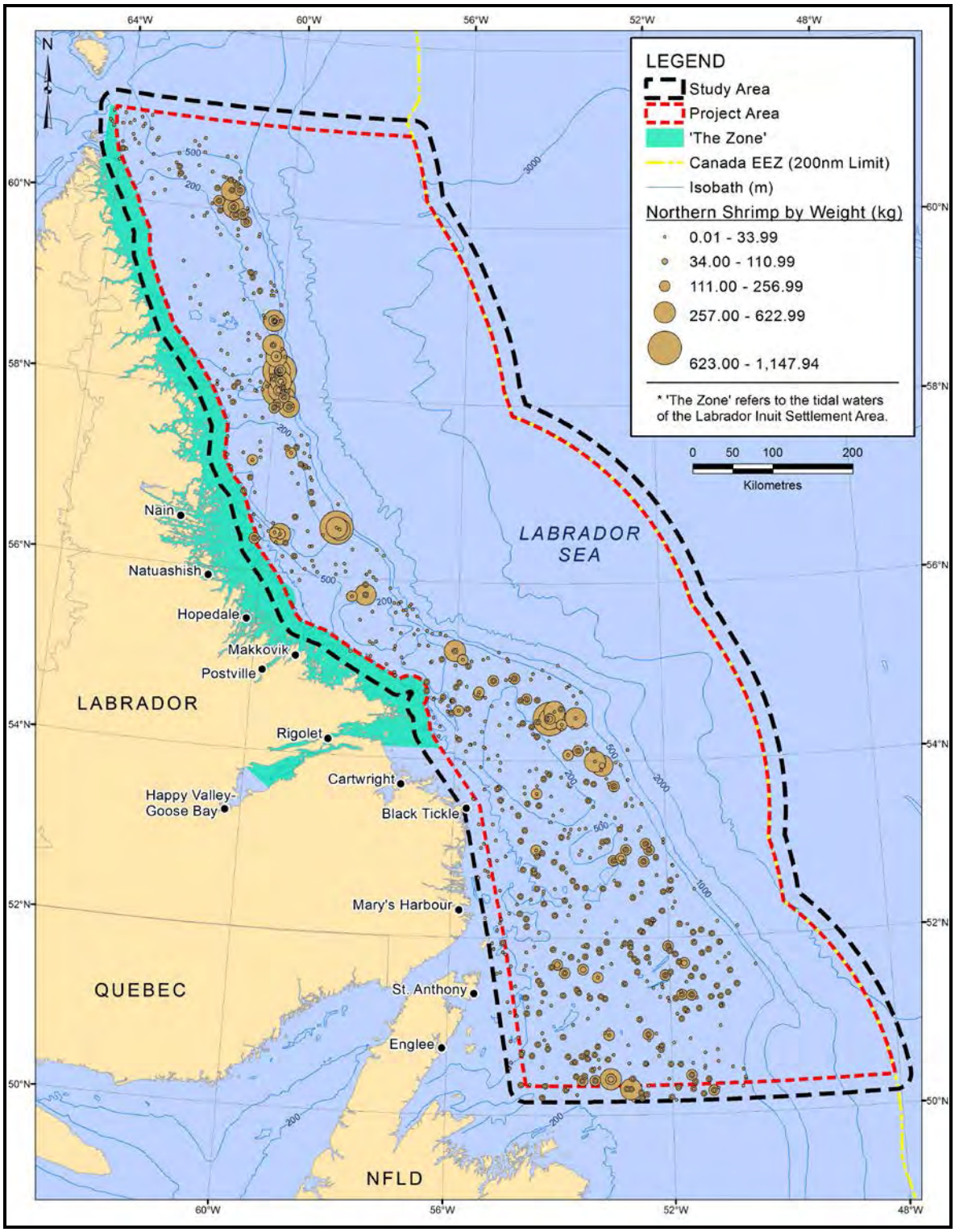
Species	Percentage Catch in Spring[1] Surveys (%)	Spring[1] Survey Mean Catch Depth (m)	Percentage Catch in Fall[2] Survey (%)	Fall[2] Survey Mean Catch Depth (m)
Shrimp (*Pandalus borealis*)	32	301	68	298
Deepwater redfish	8	369	92	377
Shrimp (Natantia)	< 1	164	> 99	443
Greenland Halibut (Turbot)	3	328	97	444
Sponges	25	297	75	453
Capelin	< 1	160	> 99	272
Atlantic Cod	3	253	97	285
Shrimp (*Pandalus montagui*)	61	235	39	209
Roughhead Grenadier	4	424	96	664
Blue Hake	< 1	489	> 99	924
American Plaice	9	263	91	322
Arctic Cod	31	223	69	236
Snow Crab	< 1	180	> 99	296
Sea Anemone	1	360	99	422
Jellyfish	5	359	95	682
Thorny Skate	12	318	88	329
Roundnose Grenadier	1	534	99	953
Basket Star (Gorgonocephalidae)	12	168	88	276
Northern Wolffish	3	405	97	532
Invertebrates	89	281	11	440
Longnose Eel	4	462	96	847
Shrimp (*Argis dentata*)	50	191	50	195
Spotted Wolffish	8	290	92	298
Lanternfish sp.	4	422	96	668
Witch Flounder	2	457	98	471
Atlantic (Striped) Wolffish	11	264	89	268
Marlin Spike	3	497	97	705
Vahl's Eelpout	6	311	94	334
Corals	71	306	29	610
Shanny	6	195	94	225
Eelpout (*Lycodes* sp.)	-	-	100	315
Spinytail Skate	4	297	96	859
Black Herring	-	-	100	1,257
Lumpfish	< 1	164	> 99	257
Snake Blenny	27	219	73	251
Eelpout (Zoarcidae)	31	213	69	364
Basket Star (*Gorgonocephalus arcticus*)	35	287	65	289
Sea Urchin (Echinoidea)	5	170	95	495
Greenland Shark	100	404	-	-
Mailed Sculpin	38	216	62	260
Northern Alligatorfish	21	238	79	276
Golden Redfish	13	344	87	382
Large Scale Tapirfish	-	-	100	916

Species	Percentage Catch in Spring[1] Surveys (%)	Spring[1] Survey Mean Catch Depth (m)	Percentage Catch in Fall[2] Survey (%)	Fall[2] Survey Mean Catch Depth (m)
Arctic Eelpout	22	241	78	214
Rigid Cushion Star	-	-	100	455
Jensen's Skate	-	-	100	1,061
Shrimp (*Eualus gaimardii belcheri*)	89	218	11	171
Black Dogfish	2	574	98	922
Shrimp (*Eualus macilentus*)	45	193	55	203
Shrimp (*Pasiphaea* sp.)	8	474	92	679
Moustache Sculpin	-	-	100	242
Shrimp (*Sabinea septemcarinata*)	41	187	59	209
Sea Urchin (*Strongylocentrotus* sp.)	2	141	98	262
Shrimp (*Pasiphaea multidentata*)	2	421	98	674
Sea Star (*Ctenodiscus* sp.)	-	-	100	412
Deepsea Cat Shark	-	-	100	1,295
Shrimp (*Lebbeus groenlandicus*)	9	185	91	221
Shrimp (*Pasiphaea tarda*)	28	484	72	875
Threebeard Rockling (*Gaidropsarus* sp.)	19	404	81	731
Threebeard Rockling (*Gaidropsarus ensis*)	-	-	100	642
Sea Urchin (*Strongylocentrotus droebachiensis*)	-	-	100	236
Atlantic Halibut	-	-	100	450
Octopus (Octopoda)	3	463	97	185
Octopus (Octopodidae)	1	410	99	187
Cusk	4	468	96	442
Spiny Dogfish	-	-	100	575

Source: DFO Research Vessel Survey Database (2007-2011).
Notes:
[1] July, August and September
[2] October and November

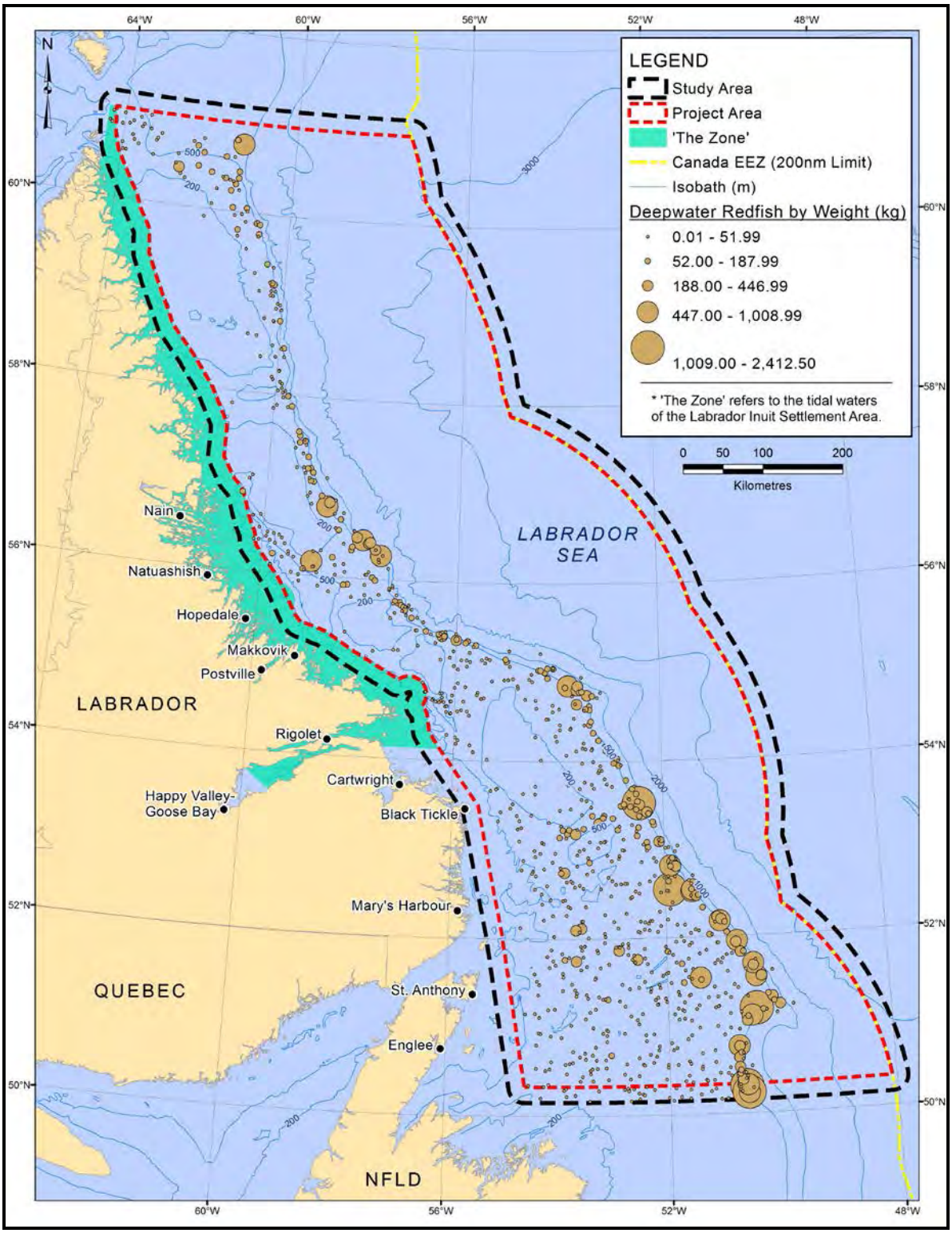
Figures 4.3 to 4.10 indicate DFO RV survey catch locations for northern shrimp, redfish, shrimp (Natantia), Greenland halibut, sponges and wolffishes during 2007 to 2011. The sizes of the circular symbols used in these figures are proportional to the catch weight range they represent for each species.

Species/groups that were caught predominantly during the spring RV surveys included various shrimps (i.e., *Pandalus montagui*, *Eualus gaimardii belcheri*) and corals. Species/groups that were caught in essentially equal amounts during both surveys included various shrimps (i.e., *Argis dentata*, *Eualus macilentus*, *Sabinea septemcarinata*). Most species/groups were caught predominantly during the fall RV surveys. The survey depth differences between spring and fall surveys likely account for some of the seasonal differences. The average mean depths of catch during spring and fall surveys between 2007 and 2011 ranged from 141 m to 574 m, and 185 m to 1,295 m, respectively (Table 4.3).



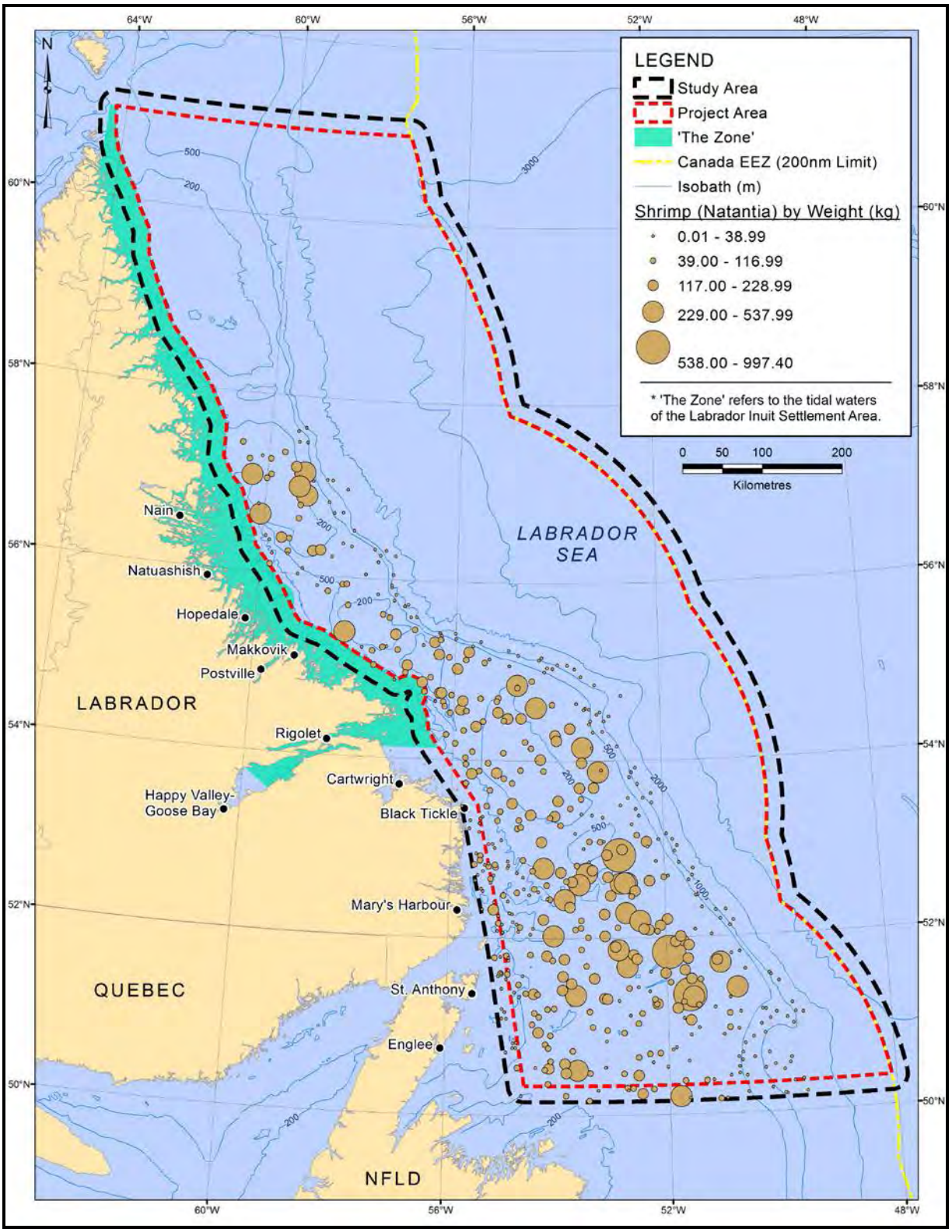
Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.3 Distribution of Northern Shrimp Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



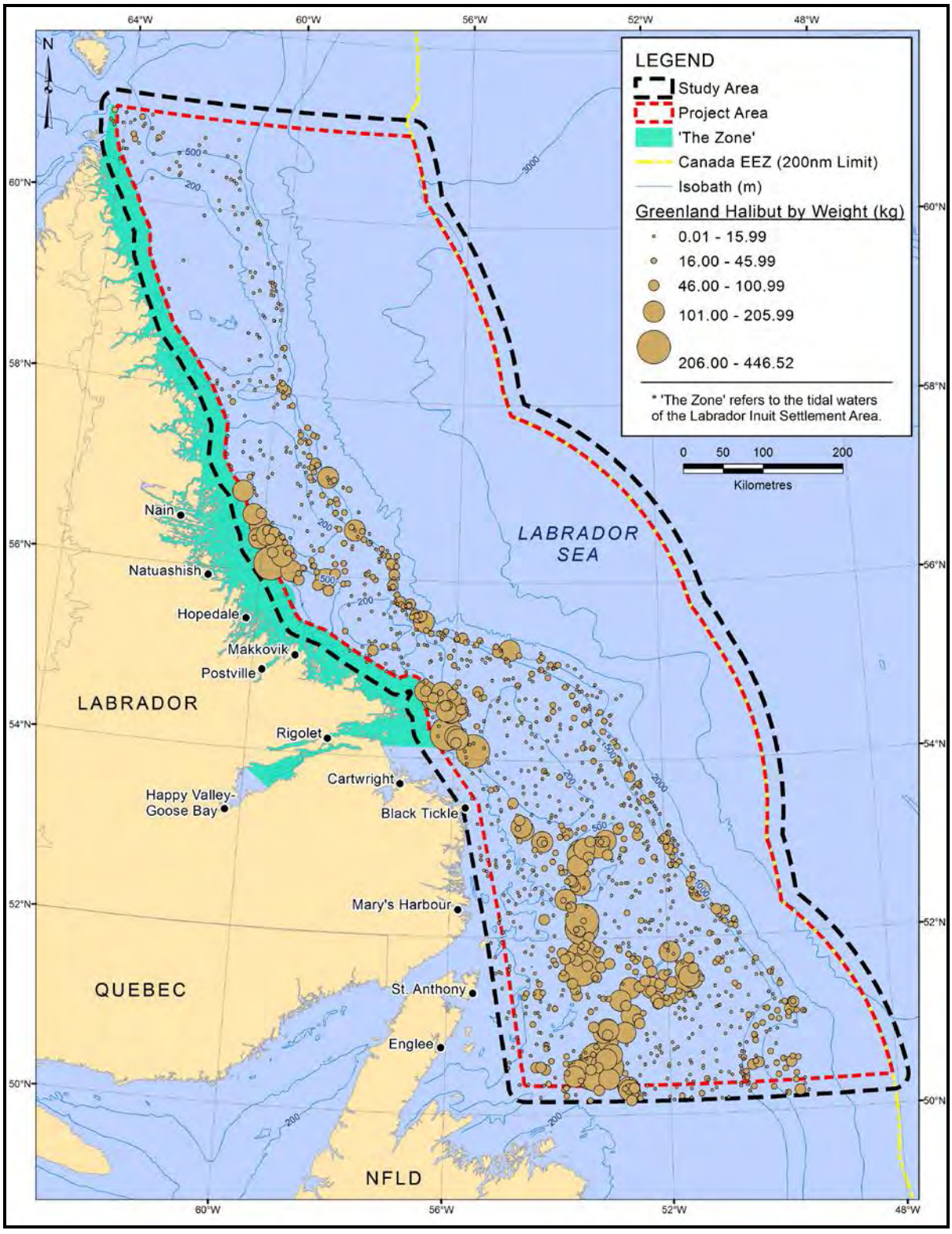
Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.4 Distribution of Deepwater Redfish Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



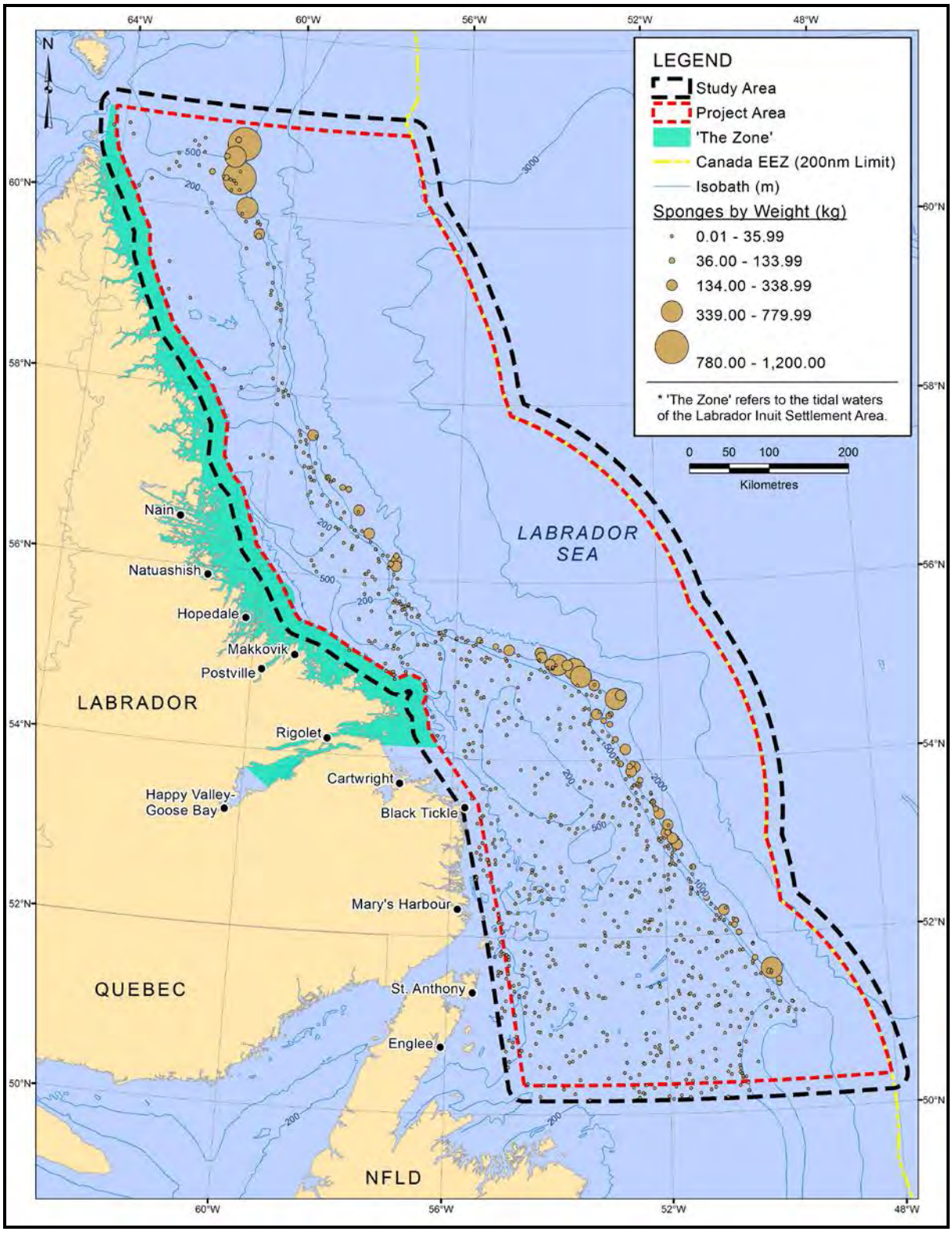
Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.5 Distribution of Shrimp (Natantia) Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



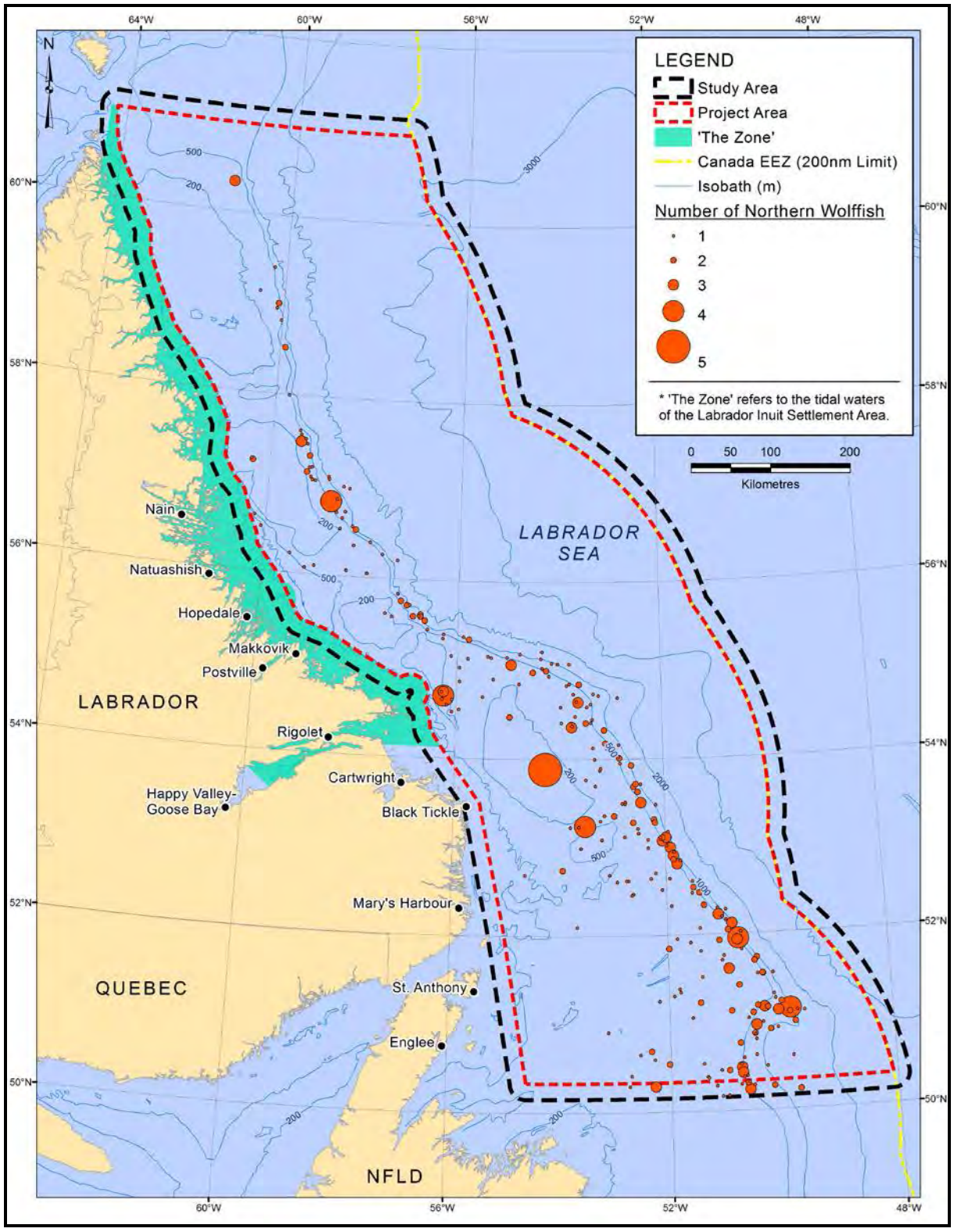
Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.6 Distribution of Greenland Halibut (turbot) Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



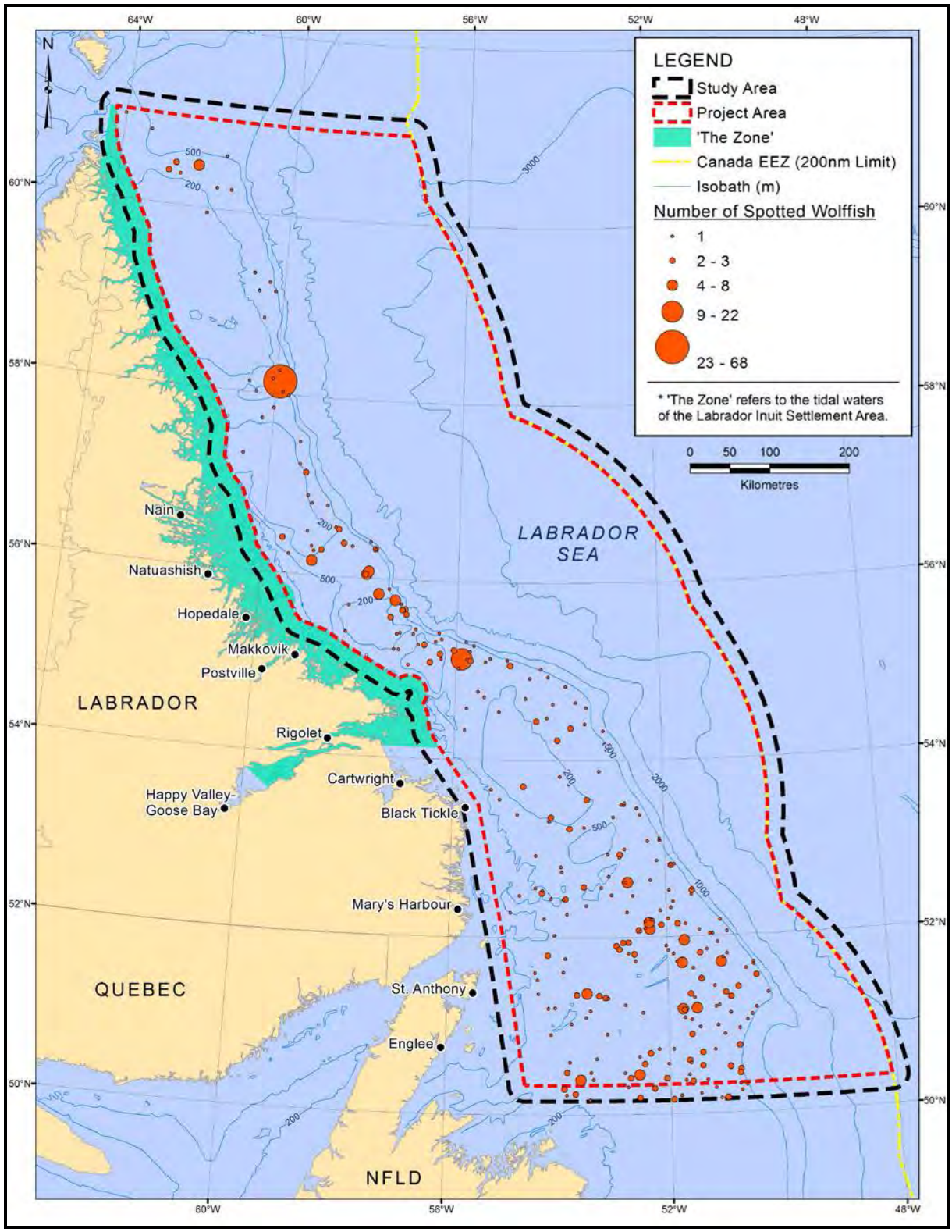
Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.7 Distribution of Sponge Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



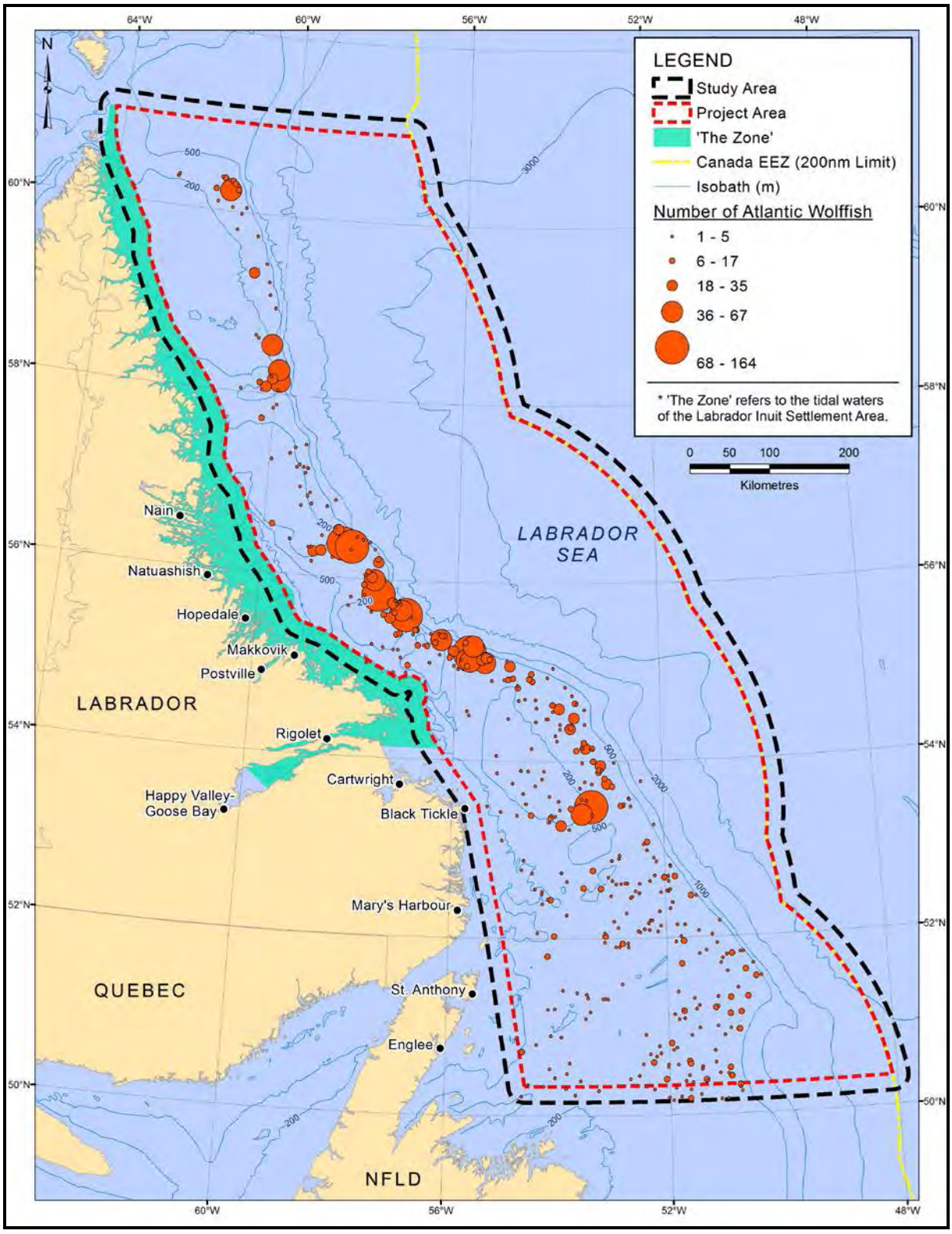
Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.8 Distribution of Northern Wolffish Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.9 Distribution of Spotted Wolffish Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.



Source: DFO Research Vessel Survey Database (2007-2011).

Figure 4.10 Distribution of Atlantic Wolffish Catch Locations during DFO RV Surveys in the Study Area, 2007-2011.

Catches at various mean depth ranges are also examined in this section. Table 4.4 presents total catch weights and predominant species caught within each mean depth range in the Study Area during the 2007 to 2011 period. Northern shrimp was caught primarily at depths ranging from 100 to 500m, deepwater redfish at depths ranging from 200 to 700 m, shrimp (Natantia) at depths ranging from 100 to 500 m, Greenland halibut at depths ranging greater than 300 m, and sponges at depths greater than 500 m.

Table 4.4 Total Catch Weights and Predominant Species Caught at Various Mean Catch Depth Ranges during DFO RV Surveys within the Study Area, 2007 to 2011 Combined.

Mean Catch Depth Range	Total Catch Weight (kg)	Predominant Species
<100	65	Sea Cucumber (Holothuroidea) (32%) Shrimp (Natantia) (12%) Basket Star (Gorgonocephalidae) (9%) Sea Urchin (Strongylocentrotus sp.) (9%) Arctic Cod (6%) Sea Urchin (Strongylocentrotus droebachiensis) (6%)
≥100 - <200	23,659	Shrimp (Natantia) (27%) Capelin (14%) Northern Shrimp (13%) Arctic Cod (6%) Basket Star (Gorgonocephalidae) (6%) Invertebrates (4%)
≥200 - <300	86,681	Northern Shrimp (48%) Shrimp (Natantia) (21%) Deepwater Redfish (6%)
≥300 - <400	52,557	Deepwater Redfish (23%) Northern Shrimp (22%) Shrimp (Natantia) (17%) Greenland Halibut (Turbot) (15%)
≥ 400 - <500	53,824	Deepwater Redfish (50%) Greenland Halibut (Turbot) (18%) Northern Shrimp (7%) Shrimp (Natantia) (6%)
≥500 - <600	19,465	Deepwater Redfish (47%) Greenland Halibut (20%) Sponges (7%)
≥600 - <700	4,114	Deepwater Redfish (38%) Greenland Halibut (Turbot) (16%) Roughhead Grenadier (10%) Blue Hake (6%)
≥700 - <800	1,200	Greenland Halibut (Turbot) (28%) Blue Hake (13%) Roughhead Grenadier (9%) Roundnose Grenadier (8%) Jellyfish (7%) Deepwater Redfish (6%)
≥800 - <900	4,136	Greenland Halibut (Turbot) (32%) Sponges (17%) Blue Hake (10%) Roundnose Grenadier (9%) Roughhead Grenadier (9%)

Mean Catch Depth Range	Total Catch Weight (kg)	Predominant Species
≥900 - <1,000	2,522	Greenland Halibut (Turbot) (29%) Roughhead Grenadier (18%) Roundnose Grenadier (15%) Blue Hake (13%)
≥1,000	21,821	Sponges (48%) Greenland Halibut (Turbot) (13%) Blue Hake (9%) Roughhead Grenadier (6%)

Source: DFO Research Vessel Survey Database (2007-2011).

Other Information:

- RV Data (2007-2011):
  - On average (based on catch weight): Fish (36.8%), Invertebrates (63.0%), Corals (0.2%)
    - Greatest catch in 2008; driven by higher northern shrimp catch than other survey years
  - % Total (based on catch weight): Summer (14.1%), Fall (85.9%)
    - Mean Depth: Summer (283 m), Fall (467 m)
    - Min Depth: Summer (126 m), Fall (110 m)
    - Max Depth: Summer (657 m), Fall (1,526 m)
  - Coral Mean Depth: Summer (306 m), Fall (612 m)
  - Sponge Mean Depth: Summer (297 m), Fall (453 m)

4.3 Fisheries

This section provides a description of the fisheries within the Study Area. Most of this section describes the commercial fishery in the Study Area between 2005 and 2010. Figure 4.11 shows the Study and Project areas in relation to regional fisheries management areas. As the figure indicates, the Study Area comprises portions of NAFO Divisions 2G, 2H, 2J and 3K. Three fishery closure areas are also identified in Figure 4.11. Two of them, Hawke Channel and Funk Island Deep, occur either entirely or partially within the southern part of the Project Area. The third fishery closure area, Cabot Island-Funk Island, is located immediately south of the Study Area. All three are described further in Section 4.7 on Sensitive Areas.

This section also briefly describes any recreational fisheries, traditional fisheries and aquaculture activity in the Study Area. The biological characteristics and status of the principal commercial and other marine species, including prey for commercial species, were described in the preceding Section 4.2.

4.3.1 Data Sources

The fisheries data analyses use DFO Newfoundland Region (Newfoundland and Labrador), Maritimes Region (New Brunswick and Nova Scotia Atlantic coasts), Gulf Region (Prince Edward Island, and New Brunswick and Nova Scotia Gulf coasts), and Quebec Region (Gulf and St. Lawrence River) georeferenced catch and effort datasets. The DFO datasets record domestic harvest and foreign harvest landed in Canada. The time period used for analyses was 2005 to 2010. Landings data for years after 2010 were not available at the time of writing.

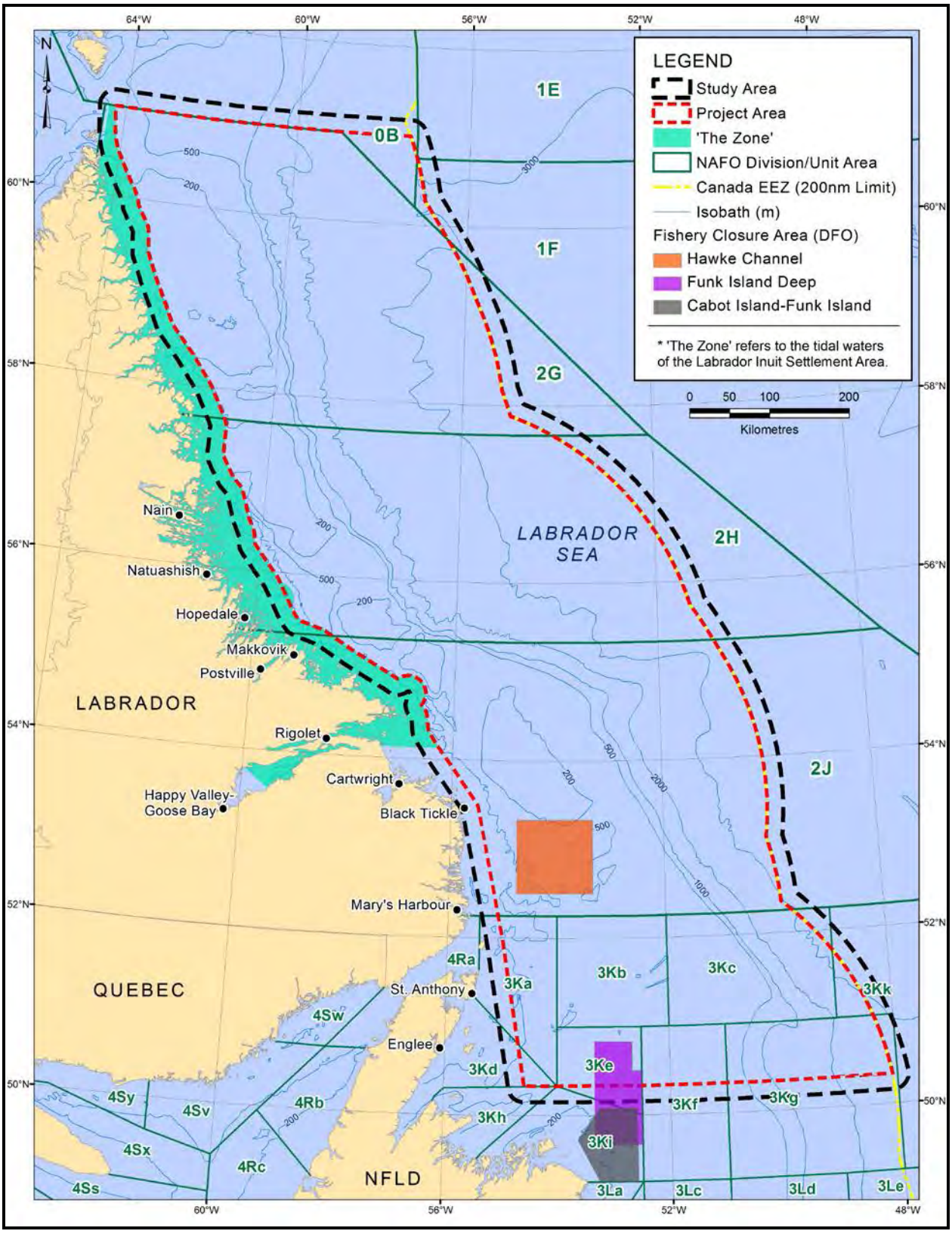


Figure 4.11 Study Area, Project Area and Closure Areas in relation to Regional Fisheries Management Areas (NAFO Divisions and Unit Areas).

The DFO data are georeferenced in two ways: by latitude and longitude (degrees and minutes) of the gear set location, and by the Unit Area in which the catch was harvested. While much of the harvest carries the latitude and longitude information, virtually all the data carry a Unit Area designation. Georeferencing by latitude and longitude allows the mapping of specific harvesting locations. Areas farther from shore, fished generally by larger boats, tend to have a greater proportion of their catch georeferenced, while those closer to shore have less. Also, certain inshore species (e.g., lobster) are not georeferenced, while the GPS coordinates of the harvesting locations of deep water species (e.g., snow crab) are usually reported.

The Unit Area (UA) designation allows all the harvesting data to be tabulated according to these fisheries management sub-zones. It is important to note that some of the UAs occur only partially within the boundaries of the Study Area. For these Unit Areas, the harvesting locations occurring outside of the Study Area were excluded from analysis for the detailed overview of the 2005 to 2010 fishing seasons.

The maps in the sections that follow show harvesting locations, based on the latitude and longitude (lat/long) data, as dark points. (The data coordinates given are those recorded in the vessel's fishing log, and is reported in the DFO datasets by degree and minute of latitude and longitude; thus the position should be accurate within approximately 925 m (0.5 nm) of the reported coordinates.) The points are not "weighted" by quantity of harvest, but show where fishing effort was recorded. Such location data have been groundtruthed with fishers in many consultations for past assessments and for fisheries planning. They have proven to be particularly useful for Operators in understanding the likely location of gear concentrations and timing of fisheries in order to eliminate or minimize potential mutual interference. Similar maps were also presented to area fisheries organizations during the consultations for this EA and were found to be a good representation of fishing areas and patterns.

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

Fisheries consultations were conducted with representatives of the Torngat Joint Fisheries Board of the Torngat Wildlife, Plants and Fisheries Secretariat (for Nunatsiavut); the Torngat Fish Producers Co-operative Society; the Labrador Fisherman's Union Shrimp Company; the Fish, Food and Allied Workers union (FFAW); the Association of Seafood Producers (ASP), the Canadian Association of Prawn Producers (CAPP); and DFO all of which represent fishers or manage harvesting in the Project Area; and with One Ocean. The consultations gather information about area fisheries and to determine any issues or concerns to be considered in the EA, as well as to discuss communications, mitigations and other solutions aimed at eliminating or minimizing potential impacts on the fisheries. Other sources

consulted for this assessment include DFO species management plans, stock status reports, and the C-NLOPB SEA reports (e.g., Labrador Shelf SEA) (see Consultation Report, Appendix 3).

4.3.2 Overview

This section provides an overview of the commercial fisheries within and/or adjacent to the Project Area and Study Area. The first part provides the historical context. The second part of this overview provides similar recent information for the georeferenced (lat/long) data specifically recorded within the Study Area and Project Area for 2005 to 2010, and maps the locations of these fisheries for that period. This section also provides more detailed information on the principal regional fisheries.

4.3.2.1 Historical Fisheries

Commercial fish harvesting in many parts of Newfoundland and Labrador has changed considerably over the last two decades, shifting from a groundfish-based industry to primarily crustacean harvesting. In the early 1990s, a harvesting moratorium was imposed on several commercially important groundfish species and directed fisheries for Atlantic cod and other groundfish were no longer permitted in most areas.

The Study Area fisheries were not exceptions to this trend (Sikumiut 2008; LGL 2010). After large groundfish catches in NAFO Divisions 2GHJ and 3K in the 1970s and 1980s, the fishery was considerably reduced in the early 1990s at the time of the moratorium. Since then, much lower quotas have been allowed, varying over the years based in scientific advice and other considerations. Overall, the Study Area groundfish fishery has become greatly reduced while the invertebrate fisheries have grown substantially in importance. Invertebrate catches, most notably northern shrimp, have become increasingly important within the Study Area, particularly since the mid-1990s. In the late 1980s, the fisheries largely targeted northern shrimp, Atlantic cod, and Greenland halibut (turbot). Northern shrimp and Greenland halibut remain important target species in 2010; however, snow crab has replaced Atlantic cod as a principal species. Today, there is no directed fishery for Atlantic cod, and only a modest by-catch is allowed.

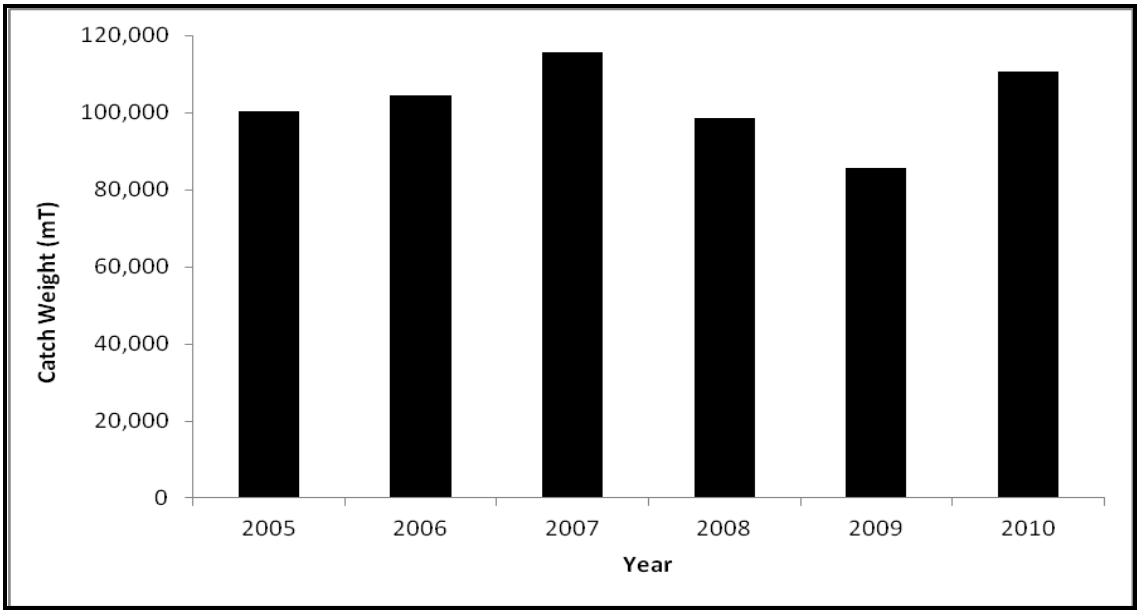
4.3.2.2 Study Area Commercial Fisheries 2005 to 2010

The 2005 to 2010 domestic harvests recorded from within the Study Area are shown in Table 4.5. As indicated, the principal fisheries (by quantity of harvest) within the Study Area are for northern shrimp (86.1%), snow crab (8.3%), and Greenland halibut (turbot) (3.7%). These same three species accounted for more than 98% combined average annual catch value during the same period. The total annual commercial fisheries catch weights of all species during June to November, 2005-2010 combined, are indicated in Figure 4.12.

Table 4.5 Average Annual Commercial Catch Weights and Values in the Study Area, 2005 to 2010.

Species	Quantity (mt)	% of Total	Value ($)	% of Total
Northern Shrimp	87,976	86.1	146,411,845	79.2
Snow Crab	8,455	8.3	25,867,059	14.0
Greenland Halibut (Turbot)	3,820	3.7	9,027,301	4.9
Striped shrimp (*Pandalus montagui*)	1,803	1.8	3,590,319	1.9
Mackerel	51	0.1	16,556	< 0.1
Redfish	49	< 0.1	27,280	< 0.1
Roughhead Grenadier	28	< 0.1	10,713	< 0.1
Witch Flounder	25	< 0.1	14,248	< 0.1
American Plaice	12	< 0.1	8,352	< 0.1
Skate	6	< 0.1	1,542	< 0.1
Capelin	5	< 0.1	558	< 0.1
Atlantic Cod	1	< 0.1	870	< 0.1
White Hake	0.3	< 0.1	208	< 0.1
Haddock	0.2	< 0.1	159	< 0.1
Atlantic Halibut	0.2	< 0.1	1,032	< 0.1
Icelandic Scallops	0.2	< 0.1	211	< 0.1
Flounder sp.	0.1	< 0.1	148	< 0.1
Yellowtail Flounder	<0.1	< 0.1	14	< 0.1
Monkfish	<0.1	< 0.1	5	< 0.1
Totals	**102,233**	**100.0**	**184,978,419**	**100.0**

Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).



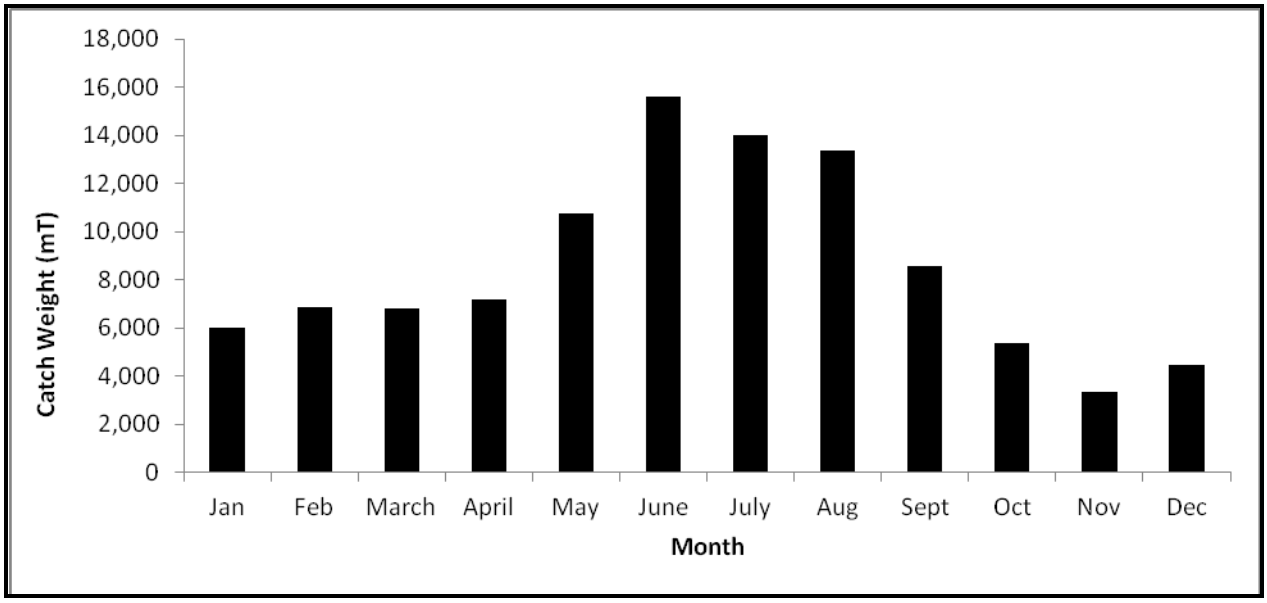
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.12 Total Annual Commercial Fishery Catch Weights in the Study Area, All Species, 2005-2010.

Monthly Timing of the Harvest

Monthly timing of commercial harvesting of all species within the Study Area for 2005 to 2010 is indicated in Figure 4.13.

Overall catch weight was highest May to September and lowest during late fall and winter. However, the timing of the harvests can vary from year to year with resource availability, fisheries management plans, and enterprise harvesting strategies.



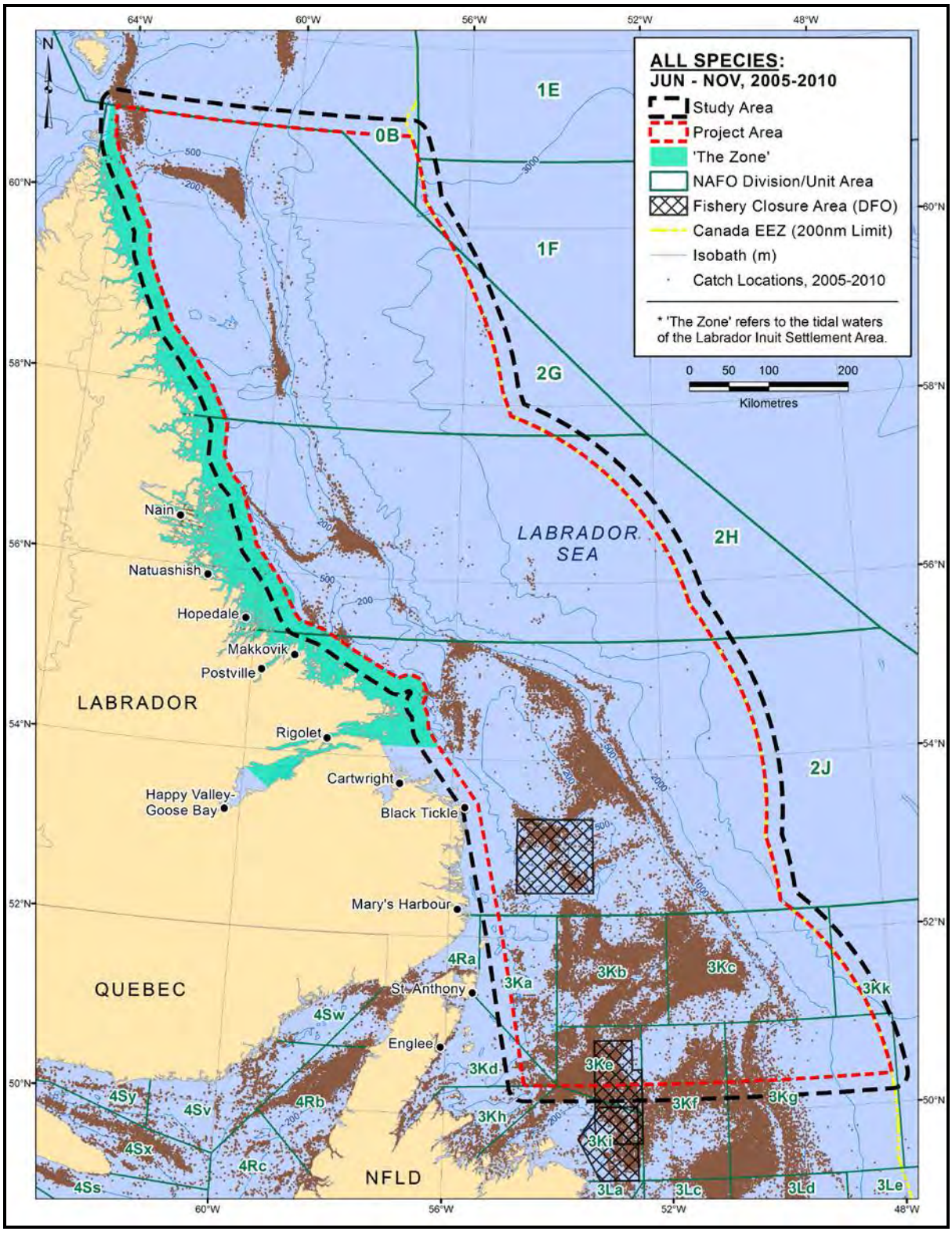
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.13 Average Monthly Commercial Fishery Catch Weights in the Study Area, All Species, 2005-2010.

2005 to 2010 Domestic Harvesting Locations

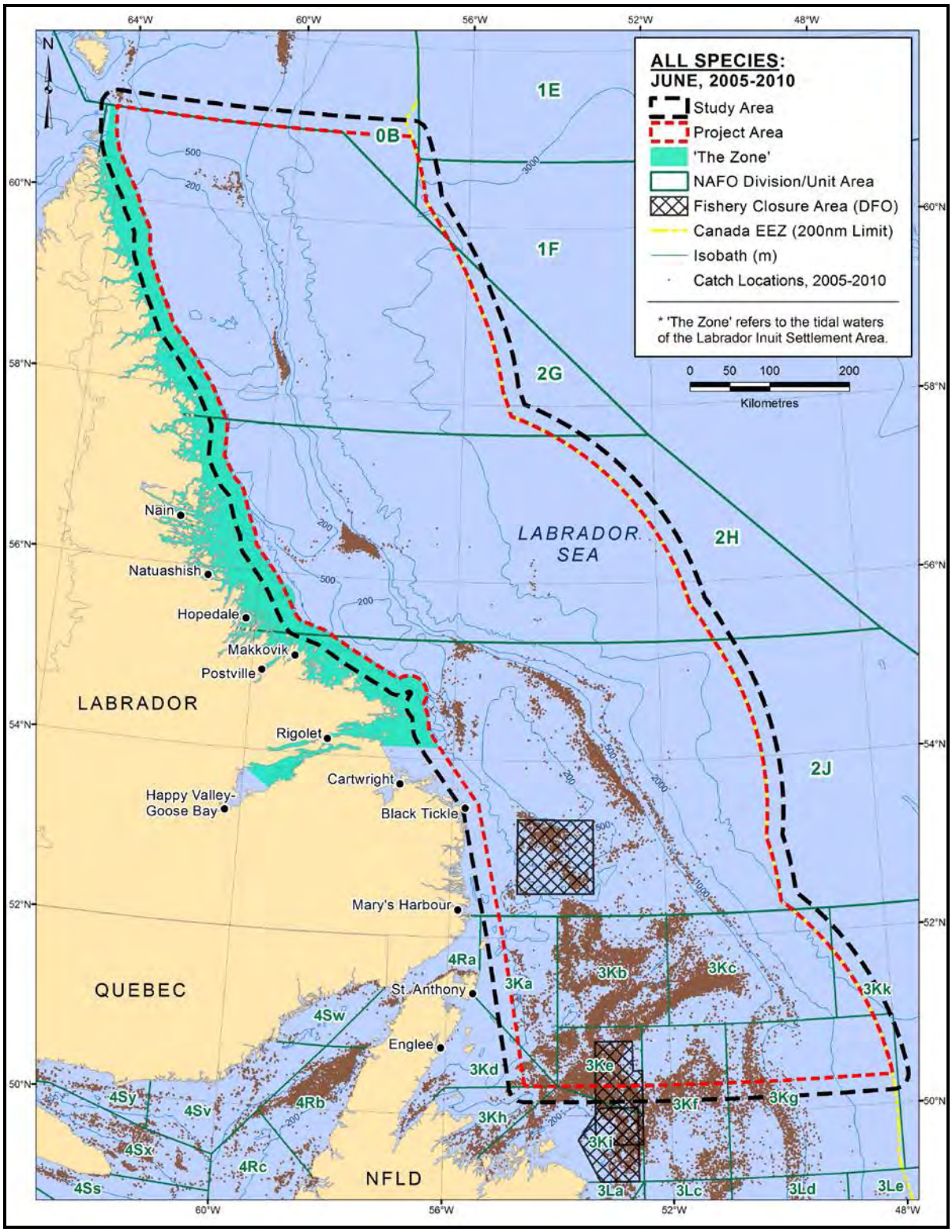
Figure 4.14 indicates georeferenced harvesting locations in relation to the Study and Project Areas for all species, June-November, 2005 to 2010 combined. As Figure 4.14 indicates, most of the fish harvesting occurs in the southern part of the Study and Project areas. A comparison with fisheries maps in the Labrador Shelf SEA (Sikumiut 2008) indicates that most of these locations are highly consistent from year to year.

Figures 4.15 to 4.20 provide domestic harvesting locations of all species by month, 2005-2010 combined.



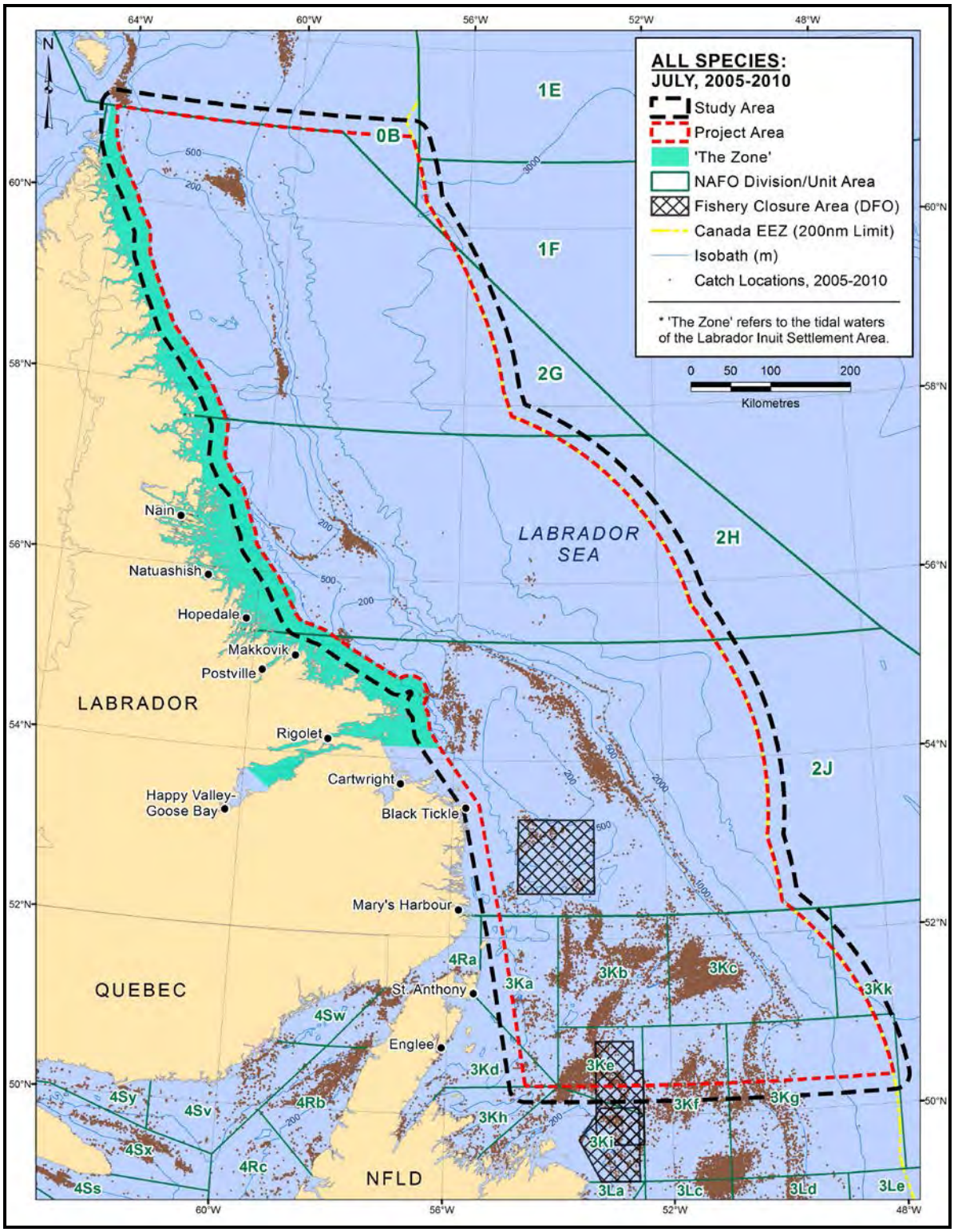
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.14 Distribution of Commercial Fishery Harvest Locations, All Species, June to November, 2005-2010 Combined.



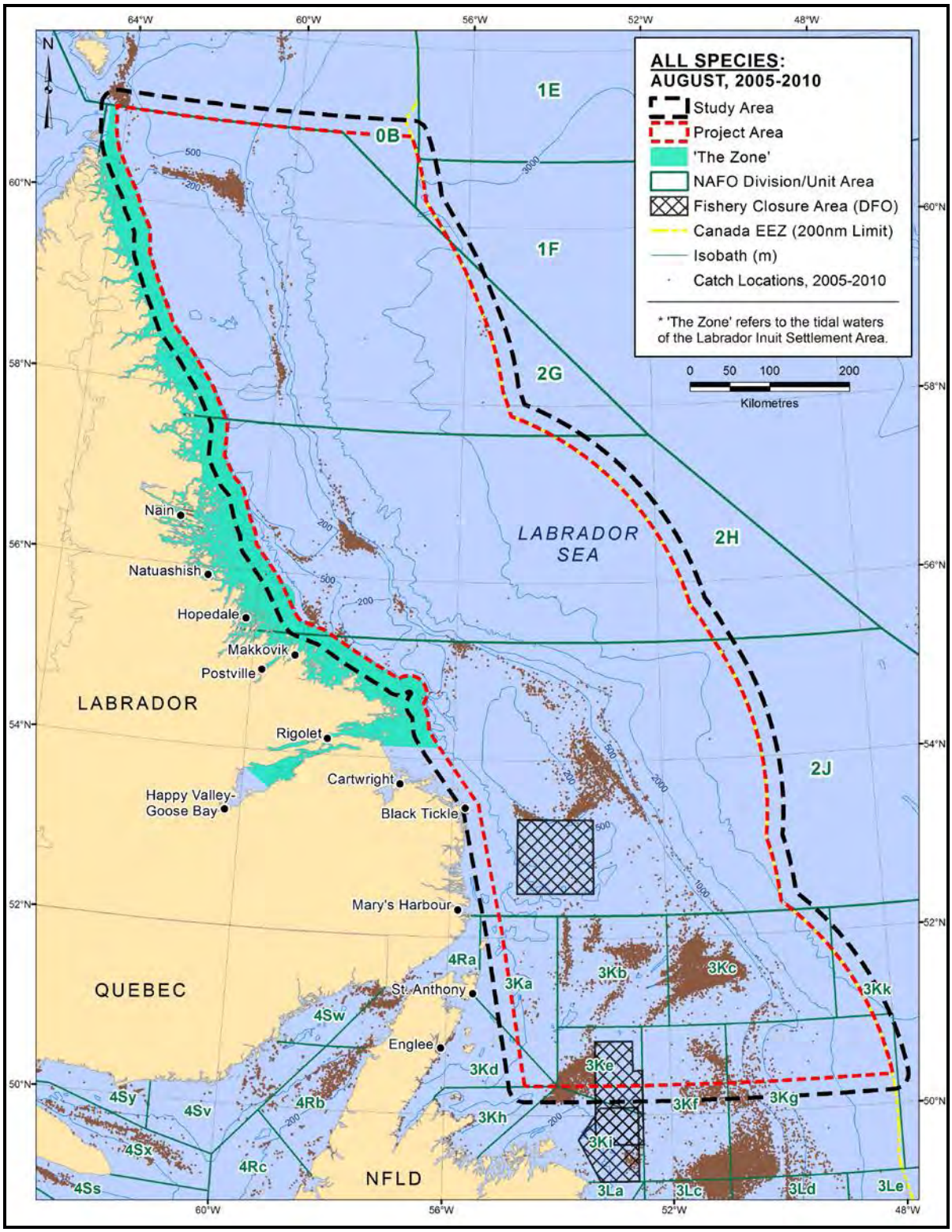
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.15 Domestic Harvesting Locations, All Species, June, 2005-2010 Combined.



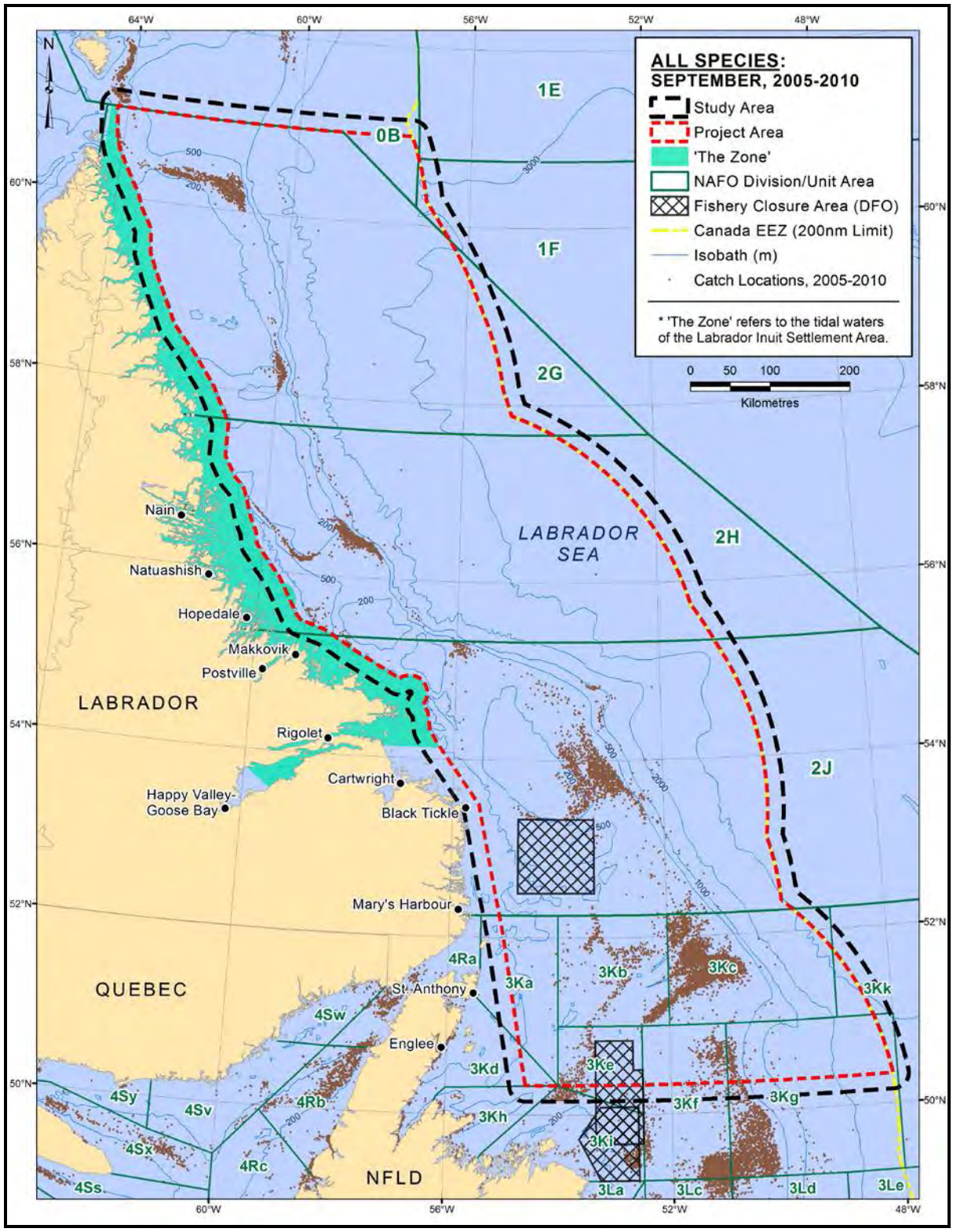
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.16 Domestic Harvesting Locations, All Species, July, 2005-2010 Combined.



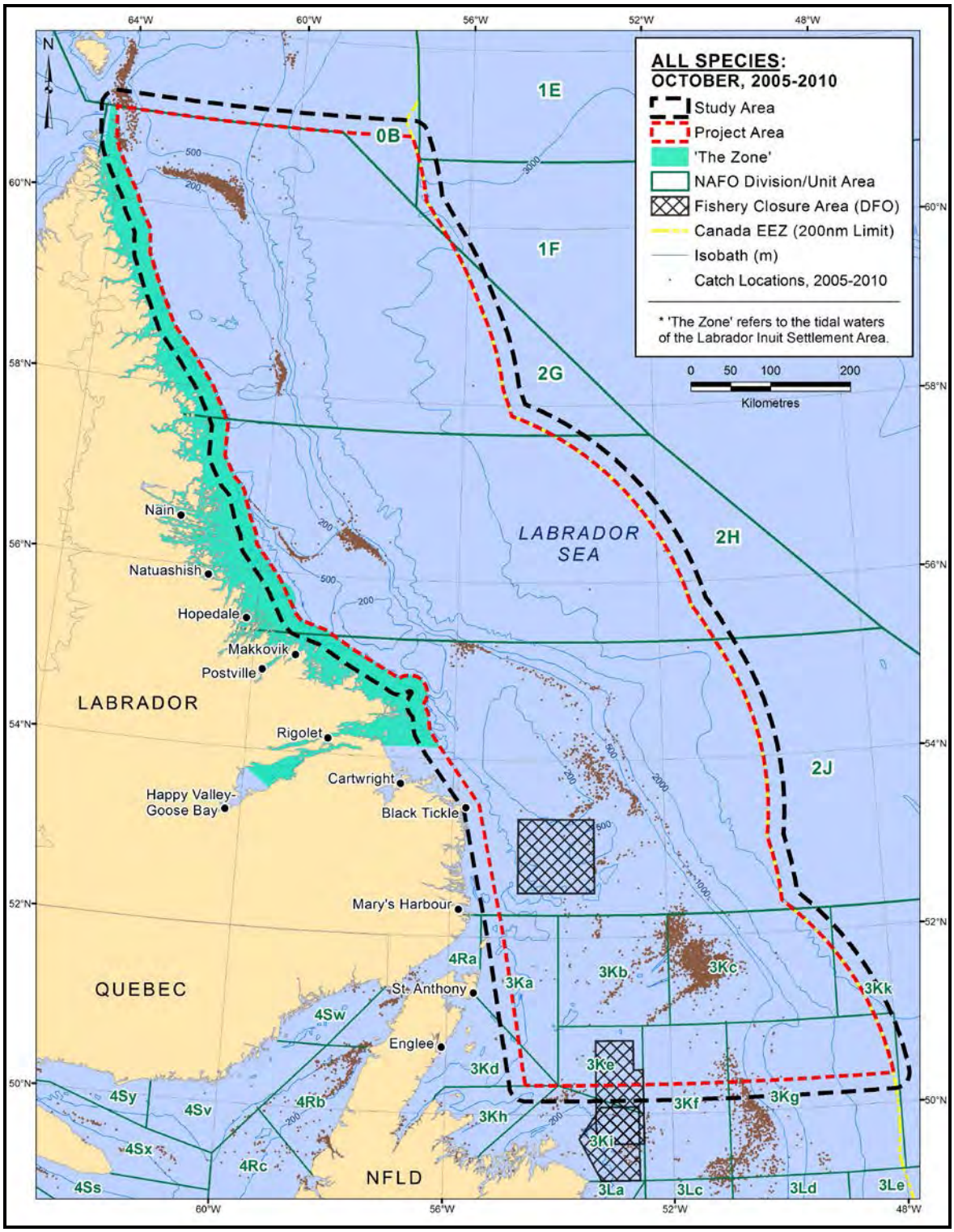
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.17 Domestic Harvesting Locations, All Species, August, 2005-2010 Combined.



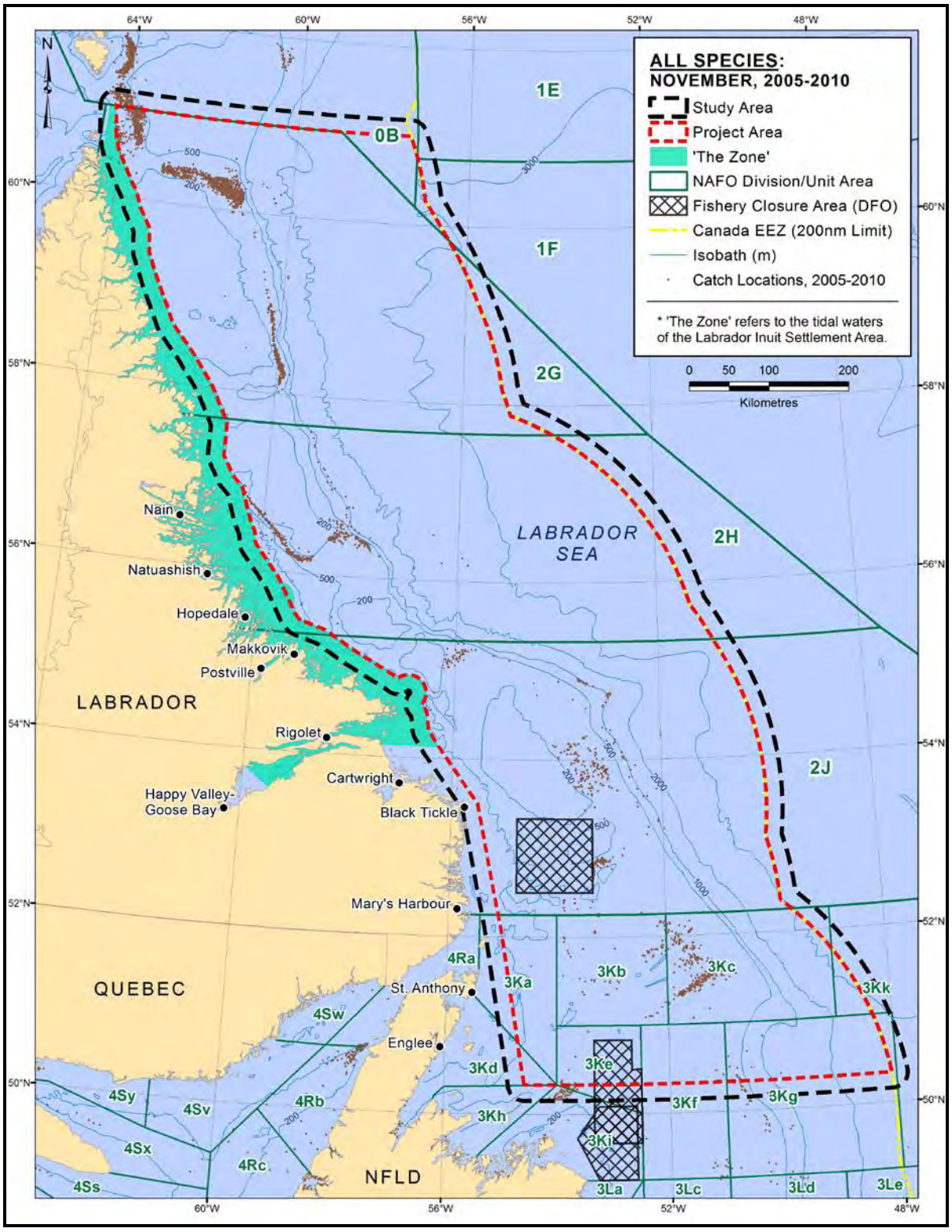
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.18 Domestic Harvesting Locations, All Species, September, 2005-2010 Combined.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.19 Domestic Harvesting Locations, All Species, October, 2005-2010 Combined.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.20 Domestic Harvesting Locations, All Species, November, 2005-2010 Combined. Fishing Gear

For the most part, the fishing gear used in the Study Area in 2005 to 2010 reflects the species being exploited (Table 4.6). Shrimp trawls target northern shrimp, crab pots target snow crab, and gillnets harvest Greenland halibut. Shrimp trawl, a mobile gear, accounted for almost 96% of the total catch weight of all species in the Study Area, between June and November, 2005-2010. The fixed gears (pots and gillnets) accounted for slightly more than 4% of the total catch weight. Fishing gear descriptions are provided in Section 4.10.2.3 of the Labrador Shelf SEA (Sikumiut 2008).

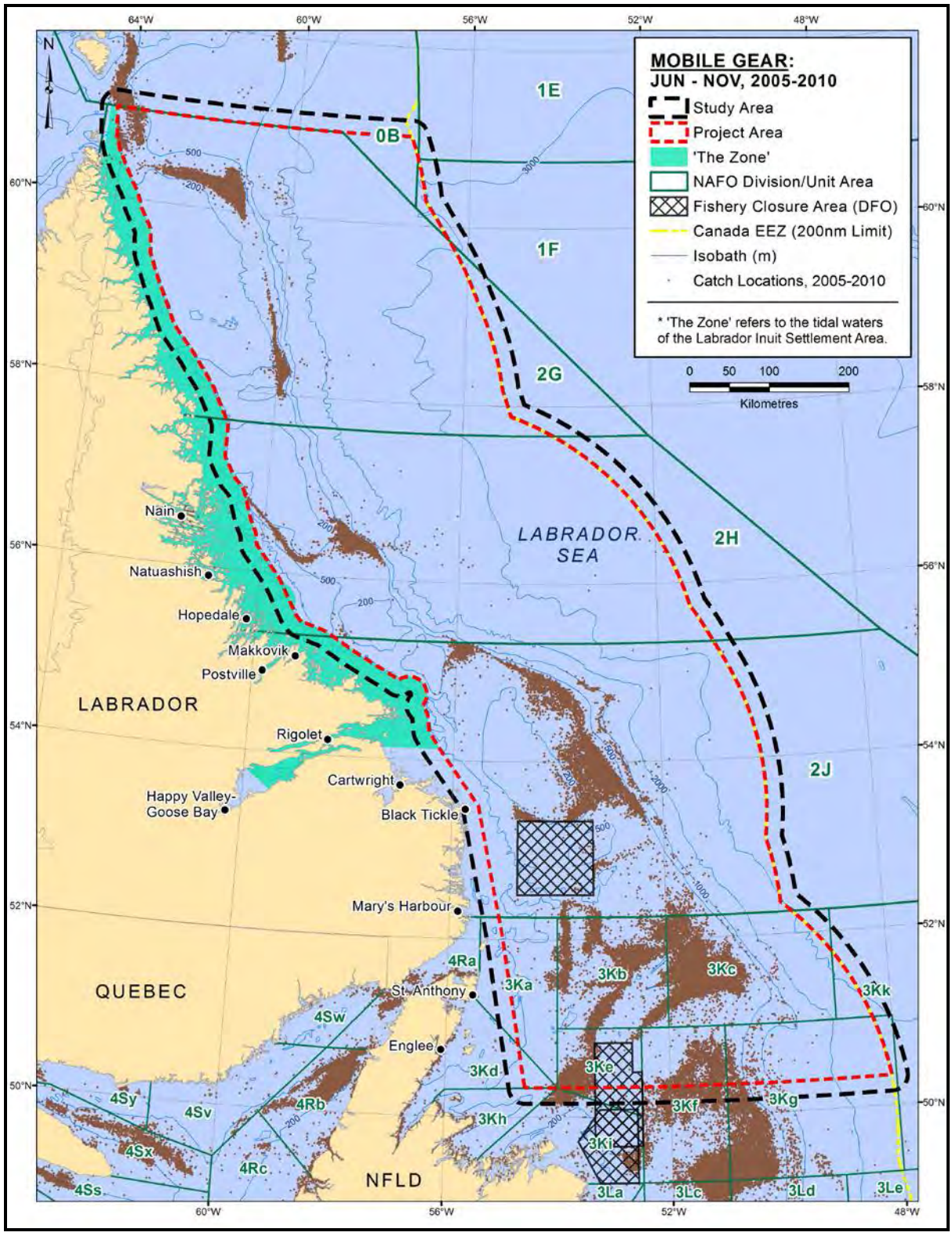
In general, the fixed gears have greater potential for interacting with Project activities than mobile gears, because they use submerged lines attached to buoys at the ocean surface, which can be easily snagged by towed seismic gear, causing damage to both the fishing gear and to the seismic streamer. They are often placed in one location for several days, are difficult to detect and may be set out over long distances in the water.

Figures 4.21 and 4.22 show locations of mobile and fix gear harvesting locations during 2005 to 2010 combined.

Table 4.6 Average Annual Commercial Catch Weights in the Study Area for Fixed and Mobile Gear, June to November, 2005 to 2010, Combined.

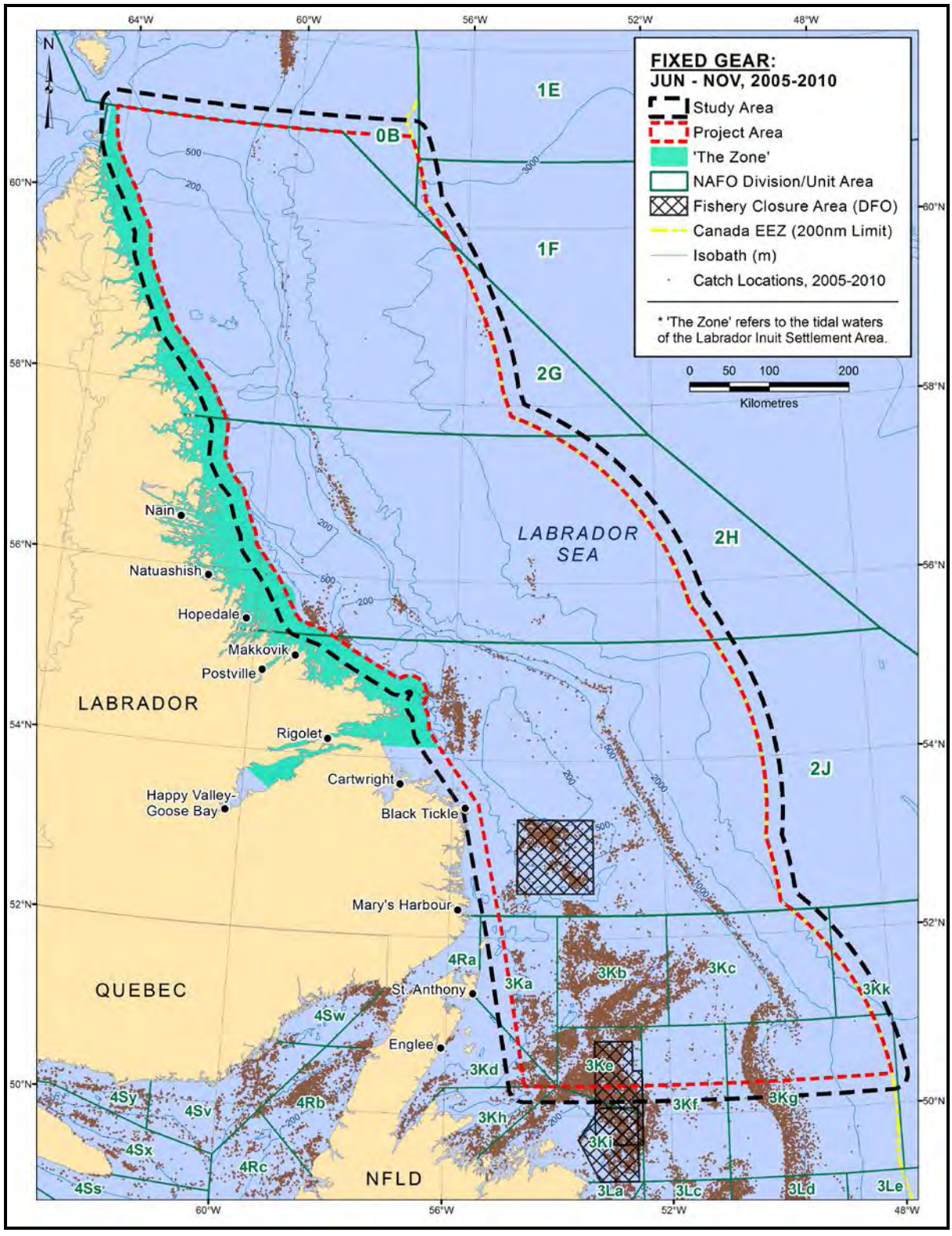
Species	Fixed Gear (mt)	% of Total	Mobile Gear (mt)	% of Total
Northern Shrimp	0	0	87,976	95.6
Snow Crab	8,455	83.0	0	0
Greenland Halibut (Turbot)	1,692	16.6	2,127	2.3
Striped shrimp (*Pandalus montagui*)	0	0	1,803	2.0
Mackerel	0	0	51	0.1
Redfish	8	0.1	41	<0.1
Roughhead Grenadier	26	0.3	2	<0.1
Witch Flounder	2	<0.1	23	<0.1
American Plaice	1	<0.1	12	<0.1
Skate	6	0.1	0.1	<0.1
Capelin	0	0	5	<0.1
Atlantic Cod	0.2	<0.1	1	<0.1
White Hake	0.3	<0.1	0	0
Haddock	0.2	<0.1	0	0
Atlantic Halibut	0.1	<0.1	<0.1	<0.1
Icelandic Scallops	0	0	0.2	<0.1
Flounder sp.	0	0	0.1	<0.1
Yellowtail Flounder	<0.1	<0.1	0	0
Monkfish	<0.1	<0.1	0	0
Totals	**10,191**	**100.0**	**92,042**	**100.0**

Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.21 Mobile Gear Harvesting Locations, June-November, 2005 to 2010 Combined.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.22 Fixed Gear Harvesting Locations, June-November, 2005 to 2010 Combined. Principal Fisheries

The following section provides information on the principal Study Area fisheries as identified through the DFO commercial landings database, previous EAs (LGL 2010; Stantec 2010), and the Labrador Shelf SEA (Sikumiut 2008).

Northern Shrimp

The fishery for northern shrimp off the coast of Labrador began in the mid-1970s, primarily in the Hopedale and Cartwright Channels, before expanding north and south through the 1980s (DFO 2008a). Hopedale and Cartwright Channels occur in Shrimp Fishing Area (SFA) 5 (DFO 2008a); the Study Area includes all of SFA 4 and 5 and most of SFA 6 (Figure 4.23) Northern shrimp has been the major fishery in the Project Area and Study Area over the last two decades, by both quantity and value. Total annual catch weights for northern shrimp in the Study Area between 2005 and 2010 are indicated in Figure 4.24, averaging at about 88,000 mt per year. Figure 4.25 shows the northern shrimp harvesting locations for June to November, 2005 to 2010, combined. The average northern shrimp harvests by month for the 2005 to 2010 period for the Study Area are shown in Figure 4.26. It indicates that June to September was the period during which the highest catches were made.

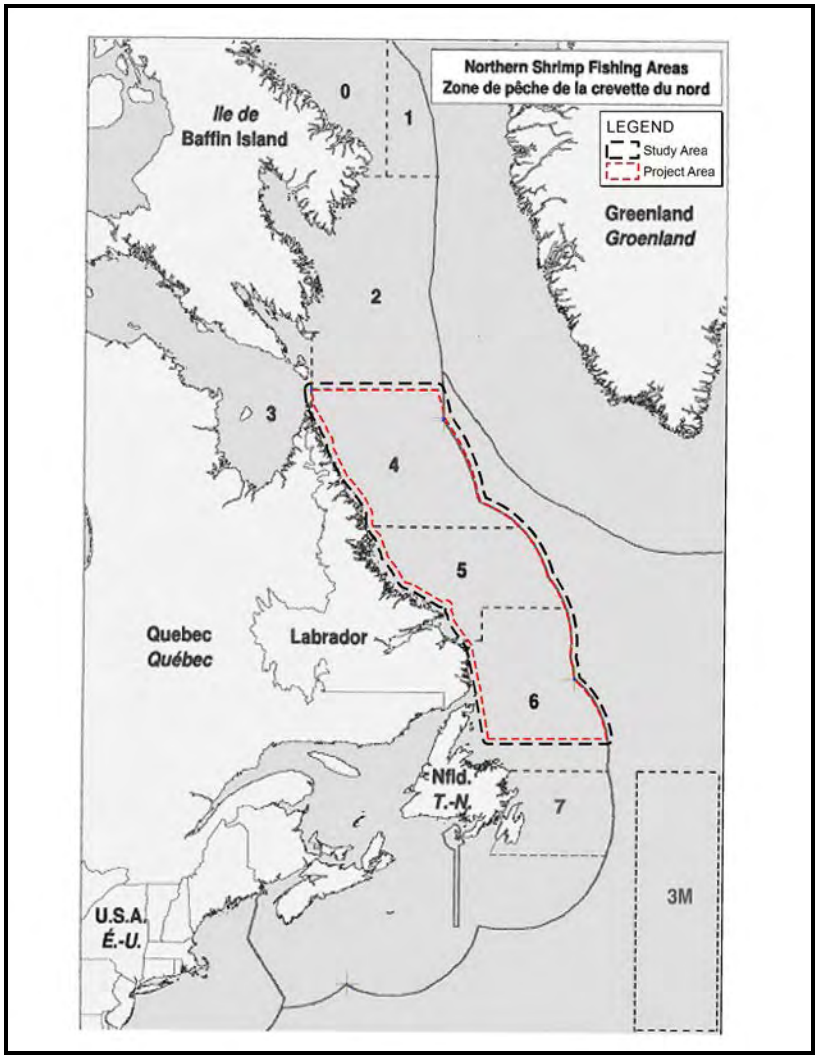
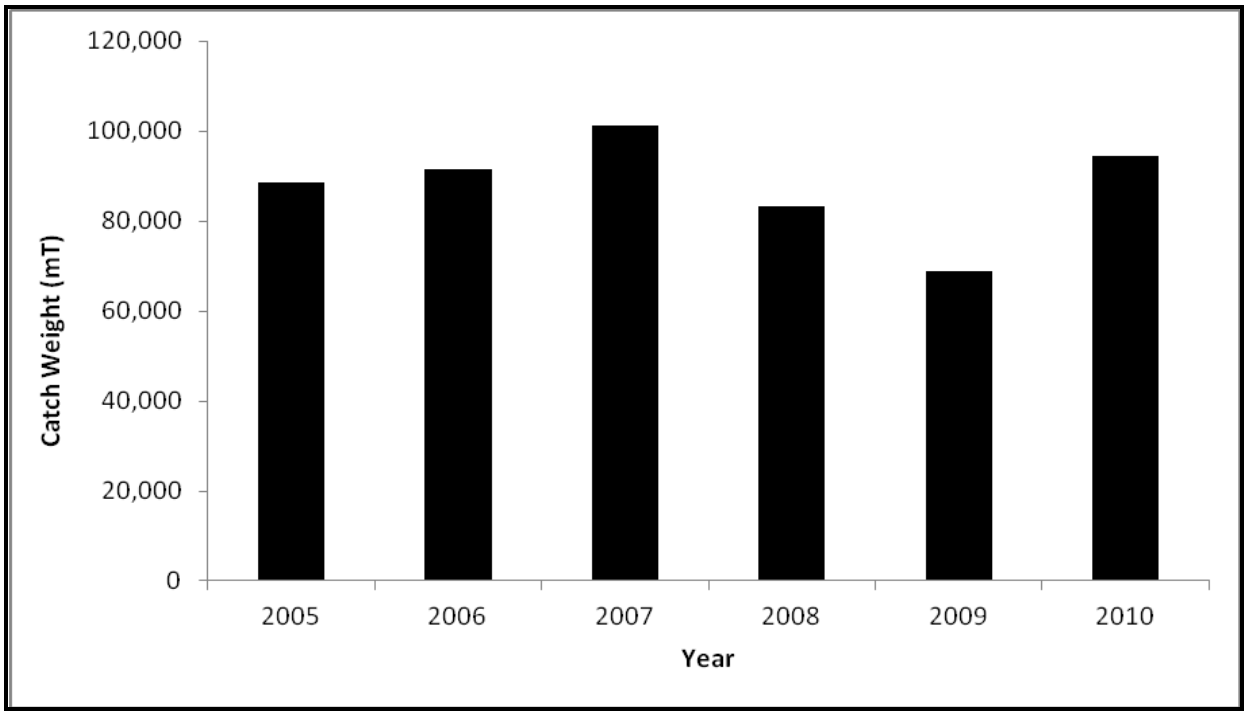
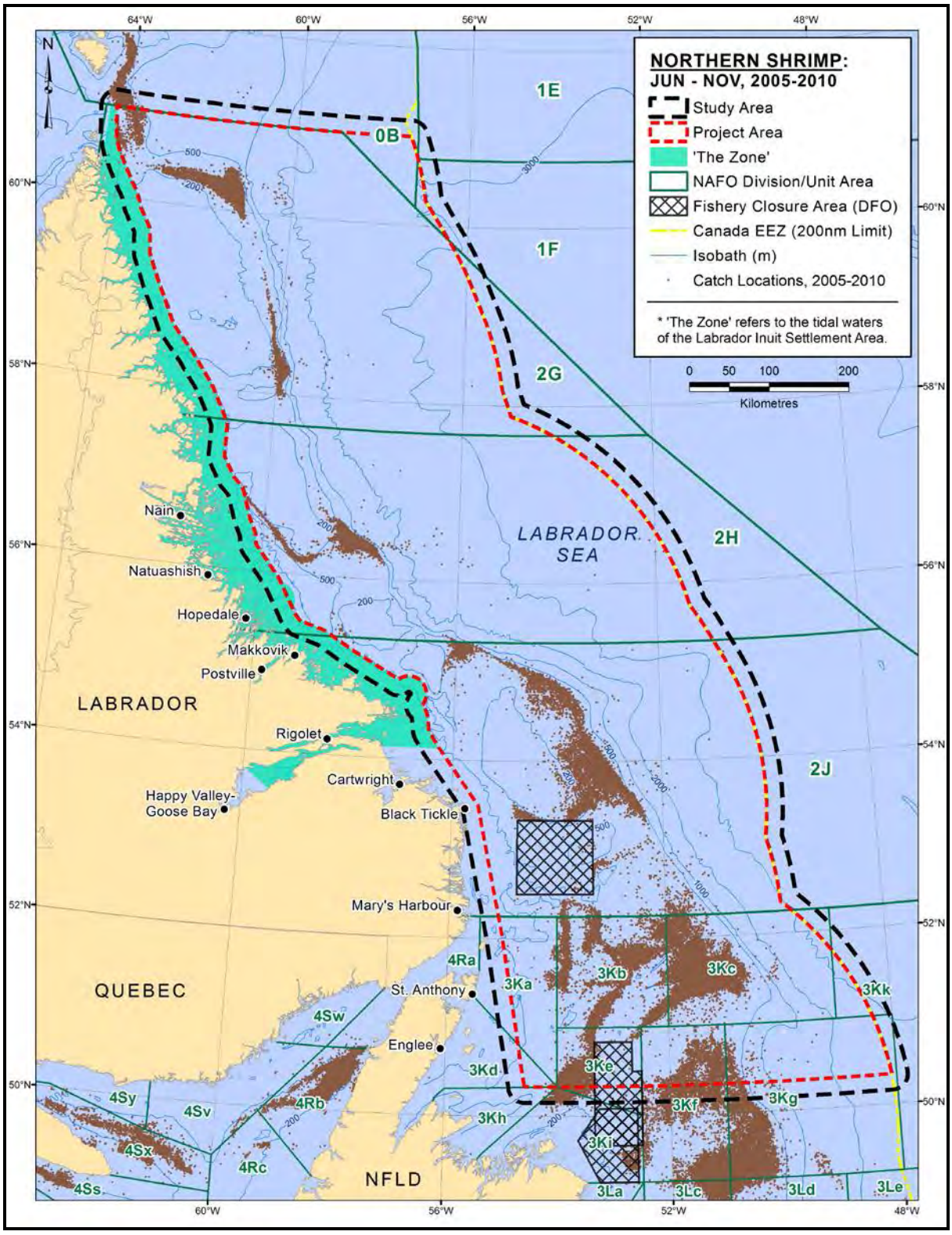


Figure 4.23 Shrimp Fishing Areas (SFAs) in Relation to the Project and Study Areas.



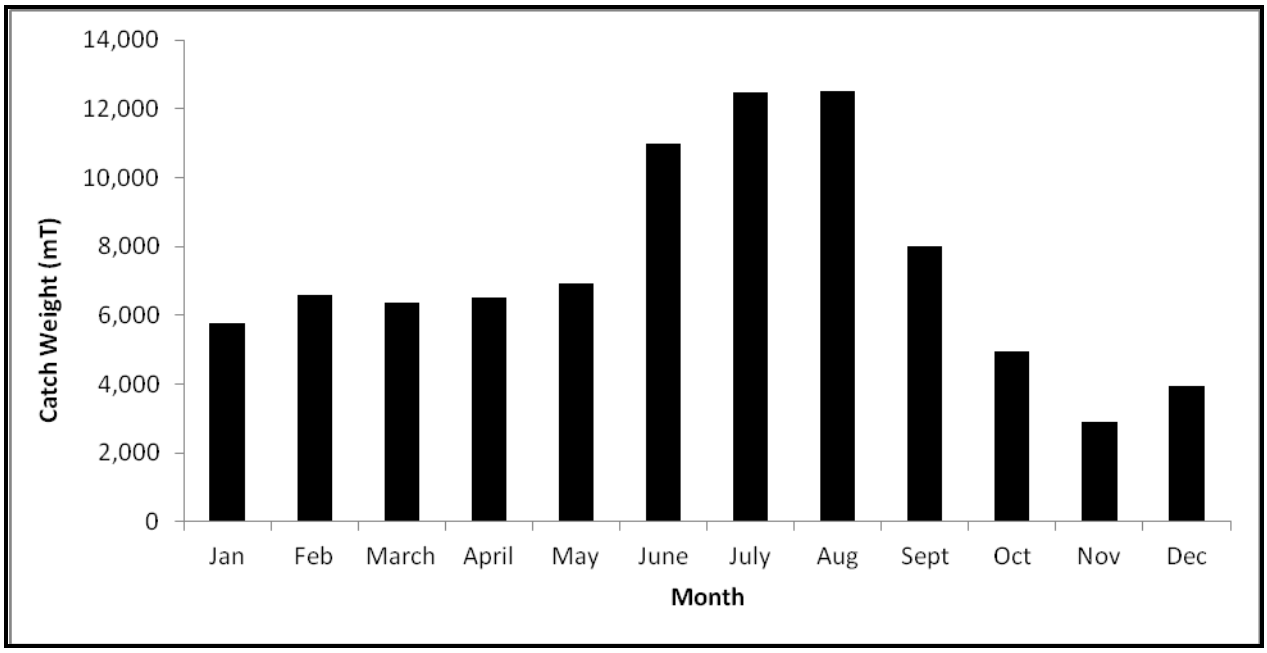
Source: DFO commercial landings database, All Atlantic Regions, 2005 to 2010.

Figure 4.24 Total Annual Catch Weights for Northern Shrimp, 2005-2010.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

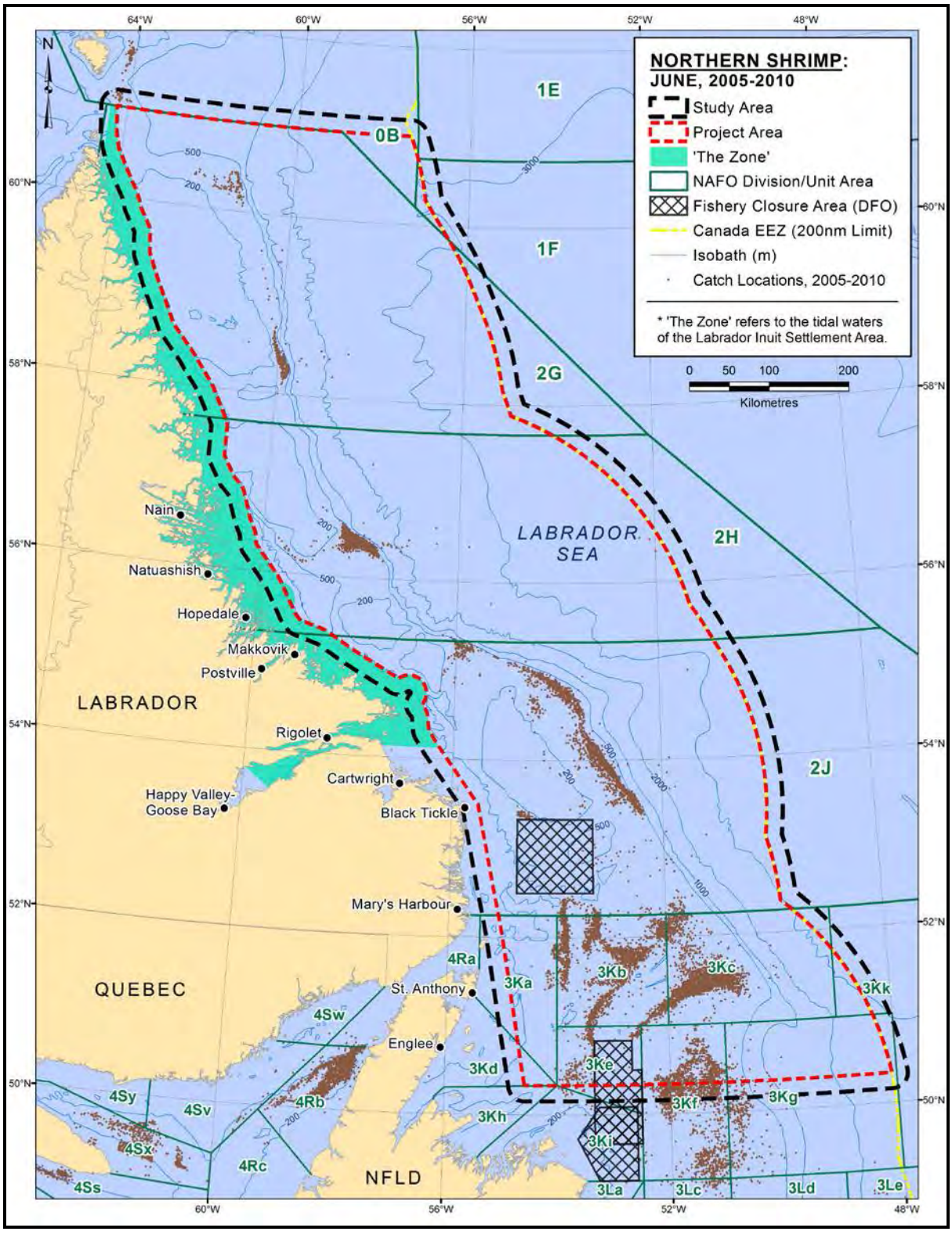
Figure 4.25 Domestic Harvesting Locations, Northern Shrimp, June to November, 2005-2010 Combined.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

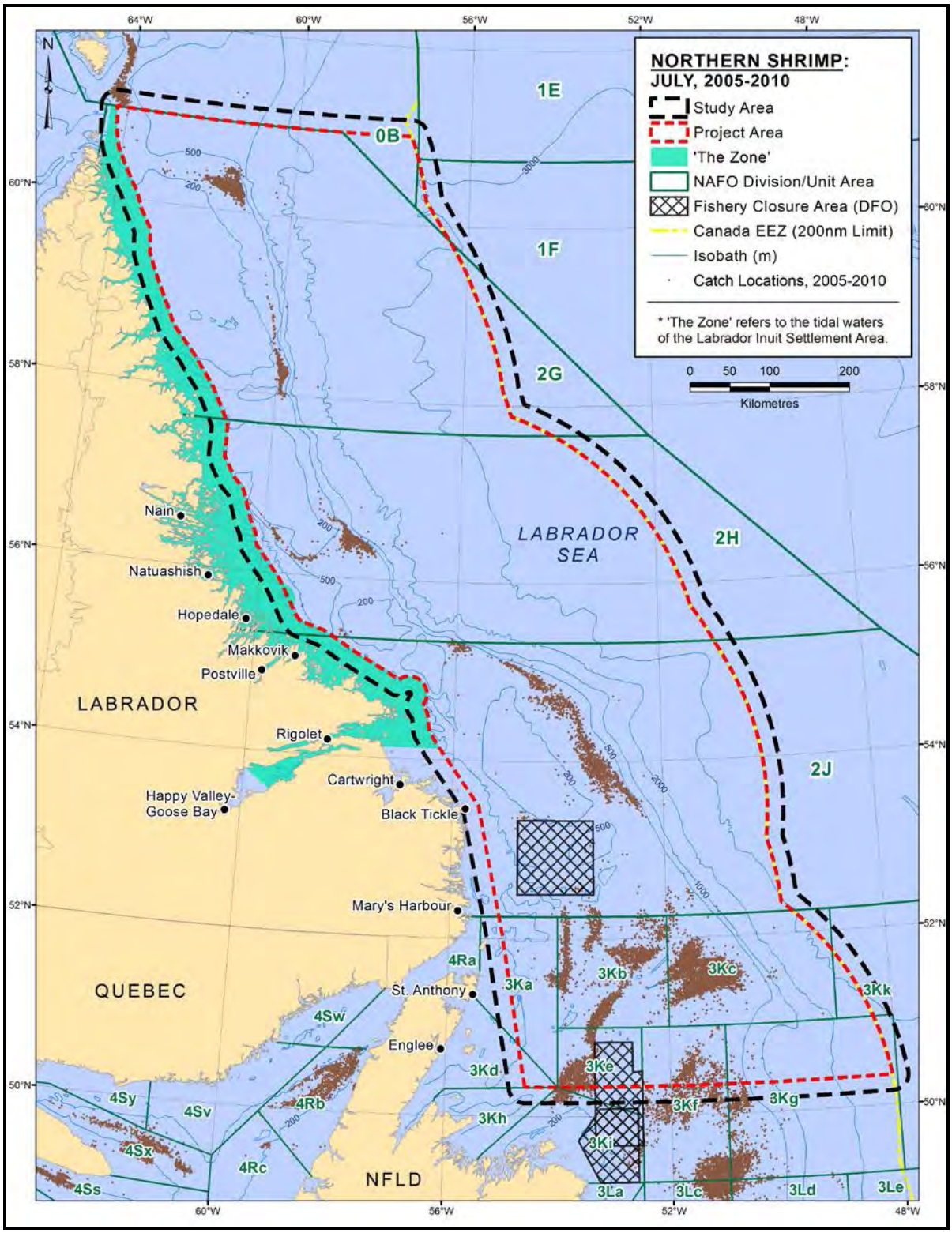
Figure 4.26 Average Monthly Catch Weights for Northern Shrimp in the Study Area, 2005-2010.

Figures 4.27 to 4.32 illustrate the distribution of northern shrimp harvesting locations for each month between June and November, 2005-2010 combined.



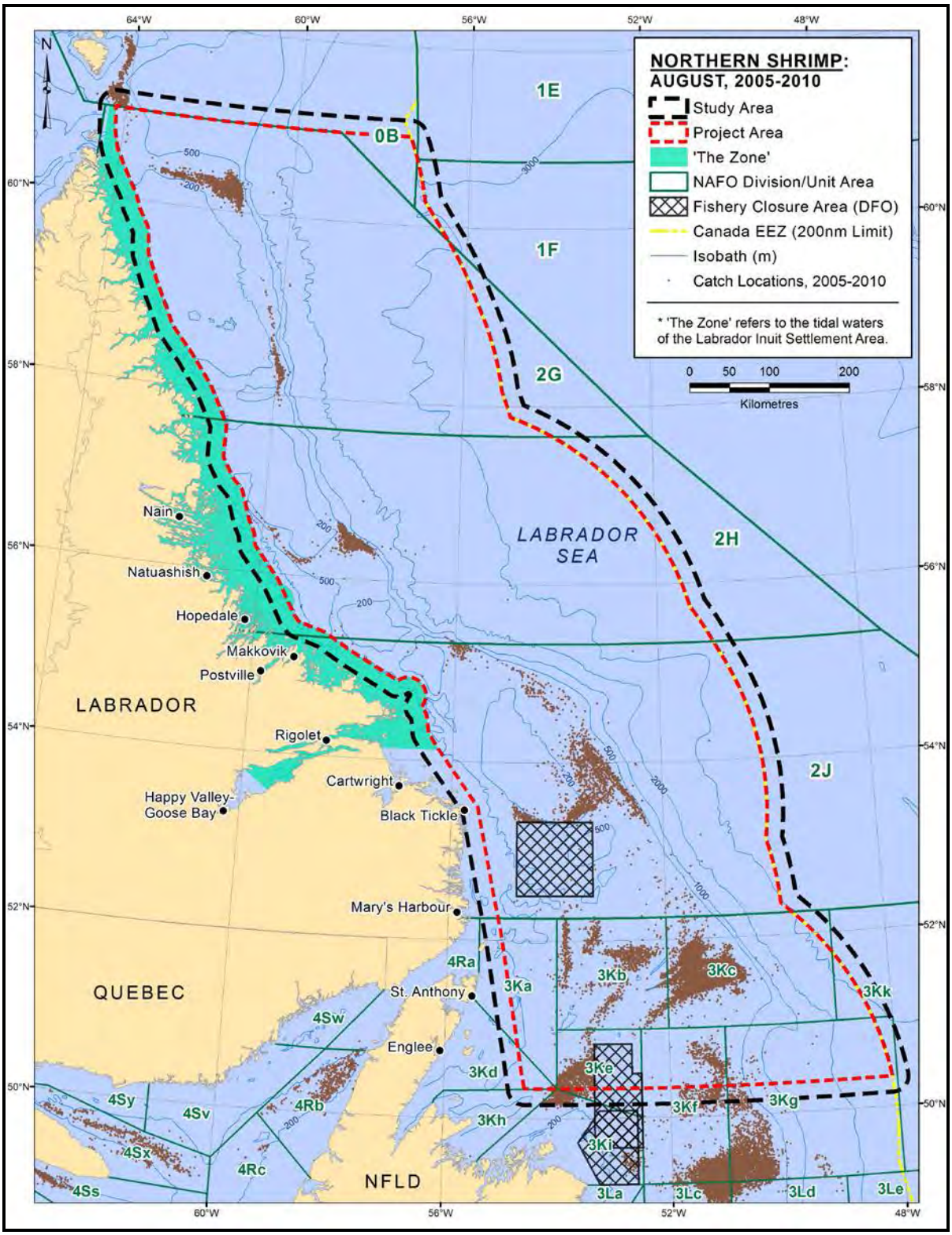
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.27 Domestic Harvesting Locations, Northern Shrimp, June, 2005-2010 Combined.



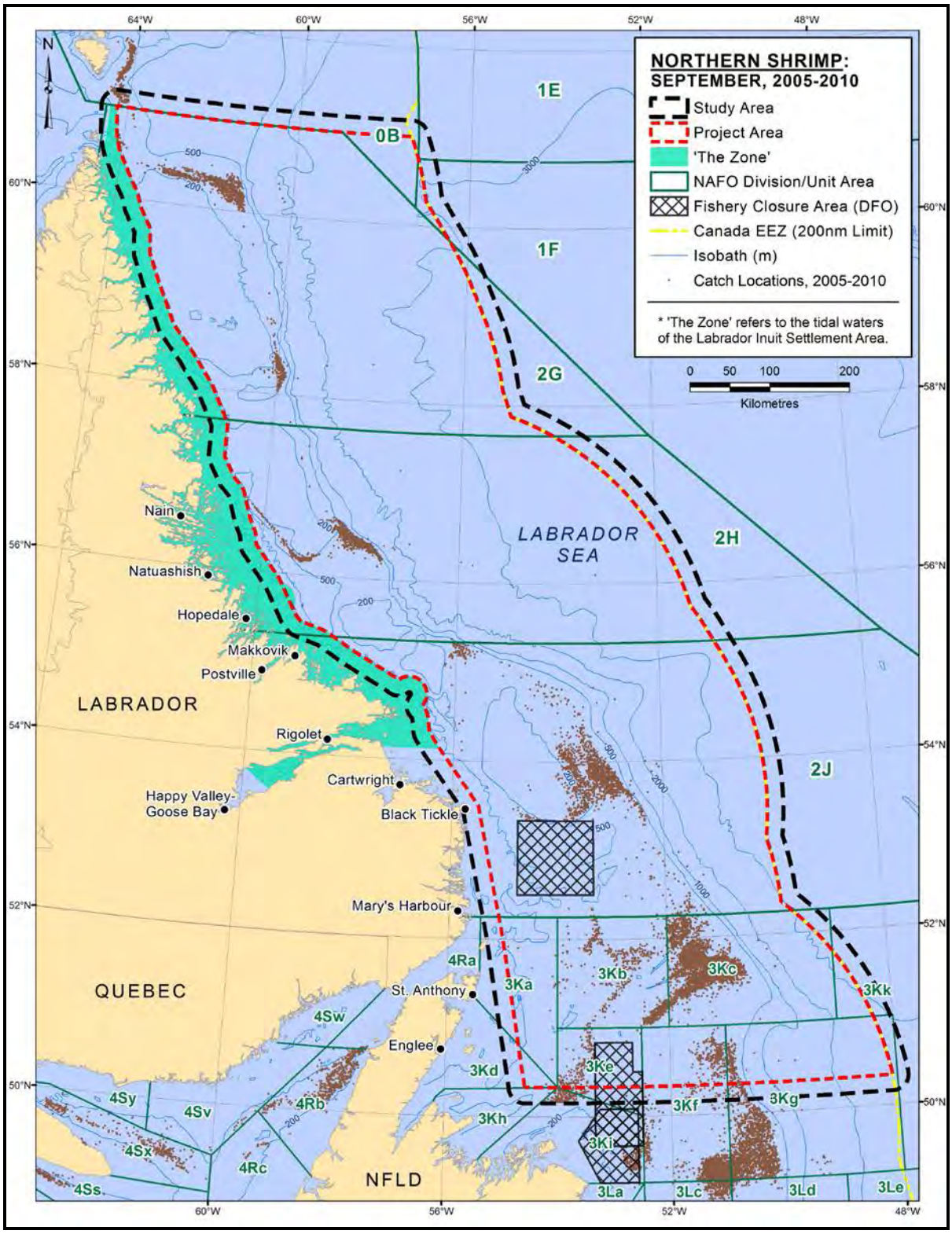
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.28 Domestic Harvesting Locations, Northern Shrimp, July, 2005-2010 Combined.



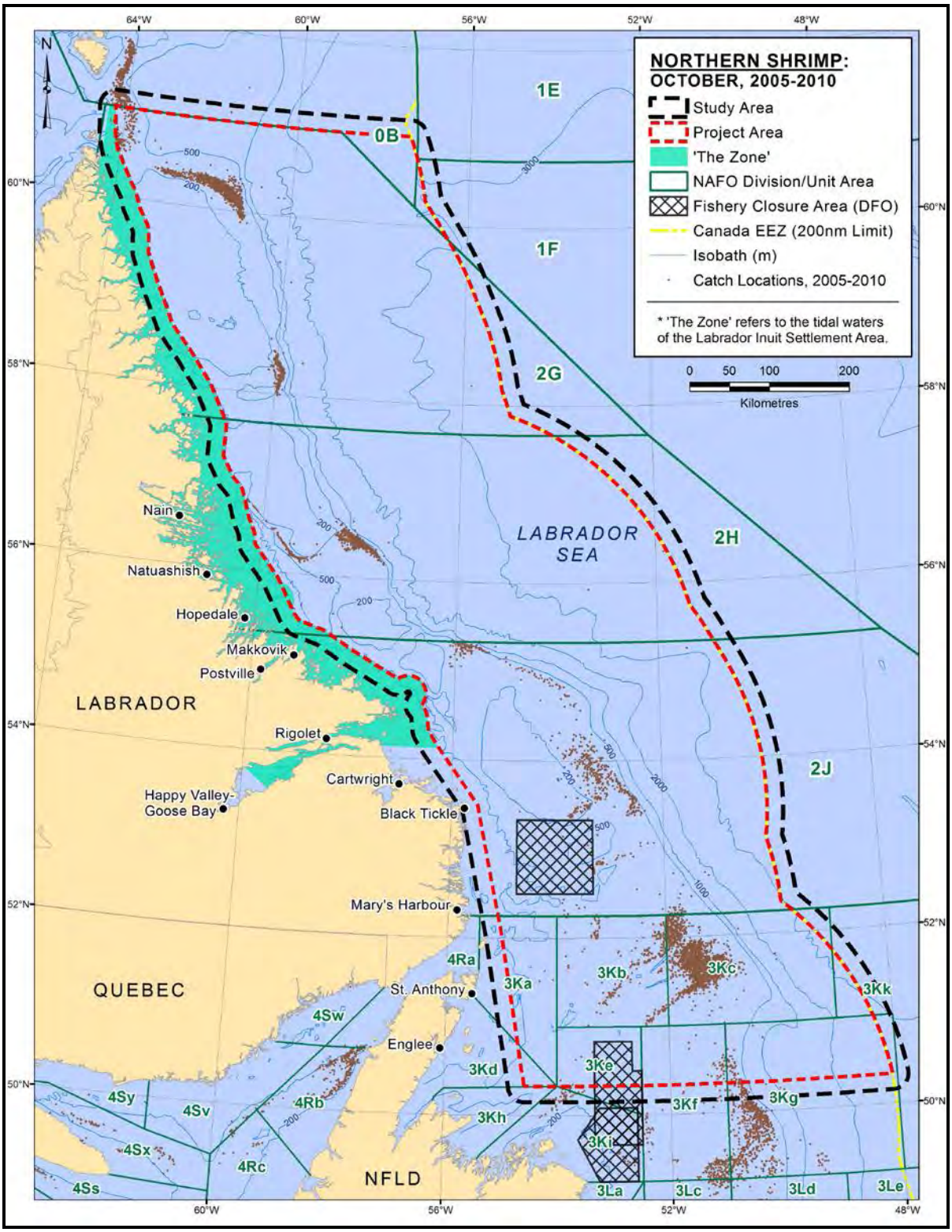
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.29 Domestic Harvesting Locations, Northern Shrimp, August, 2005-2010 Combined.



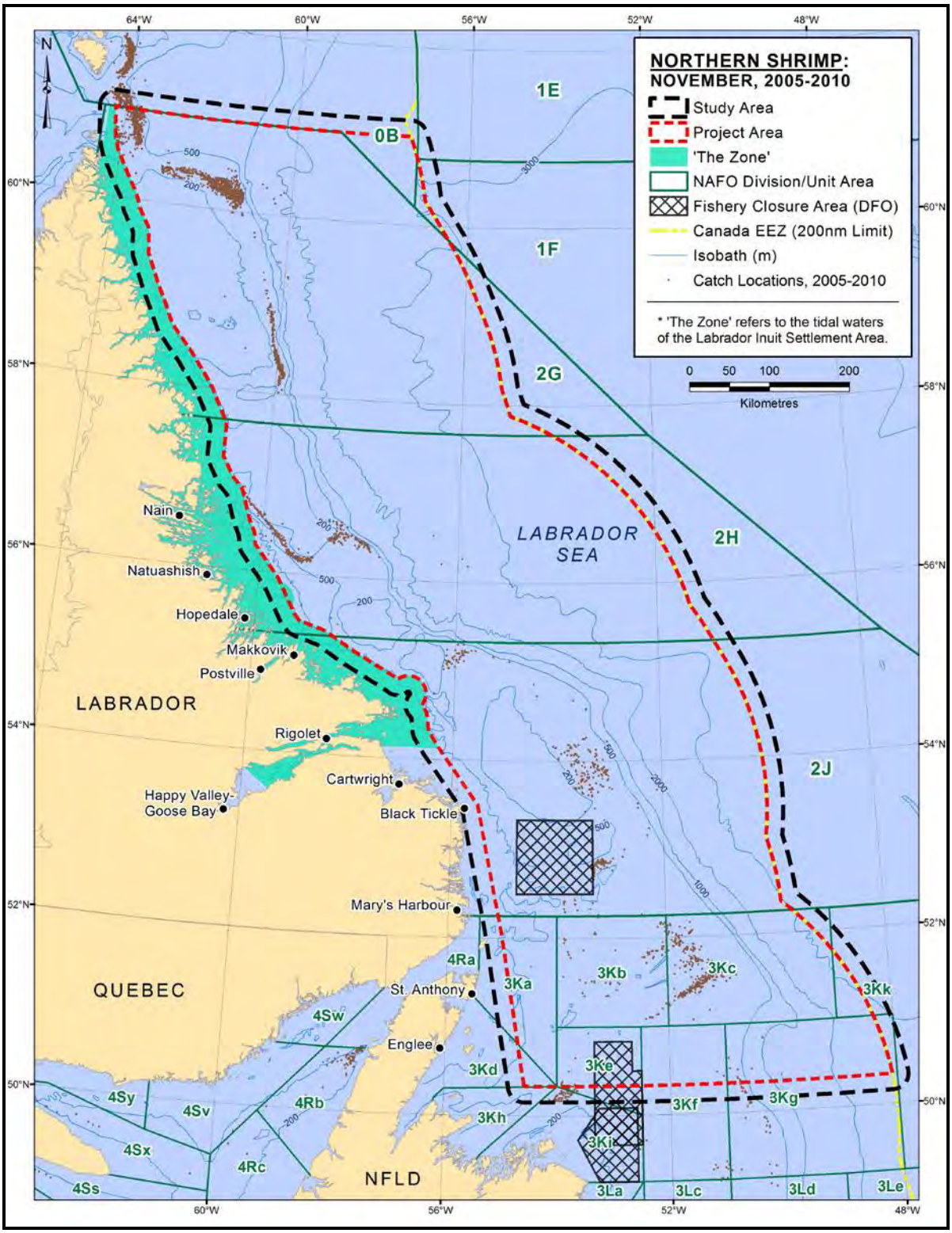
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.30 Domestic Harvesting Locations, Northern Shrimp, September, 2005-2010 Combined.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.31 Domestic Harvesting Locations, Northern Shrimp, October, 2005-2010 Combined.

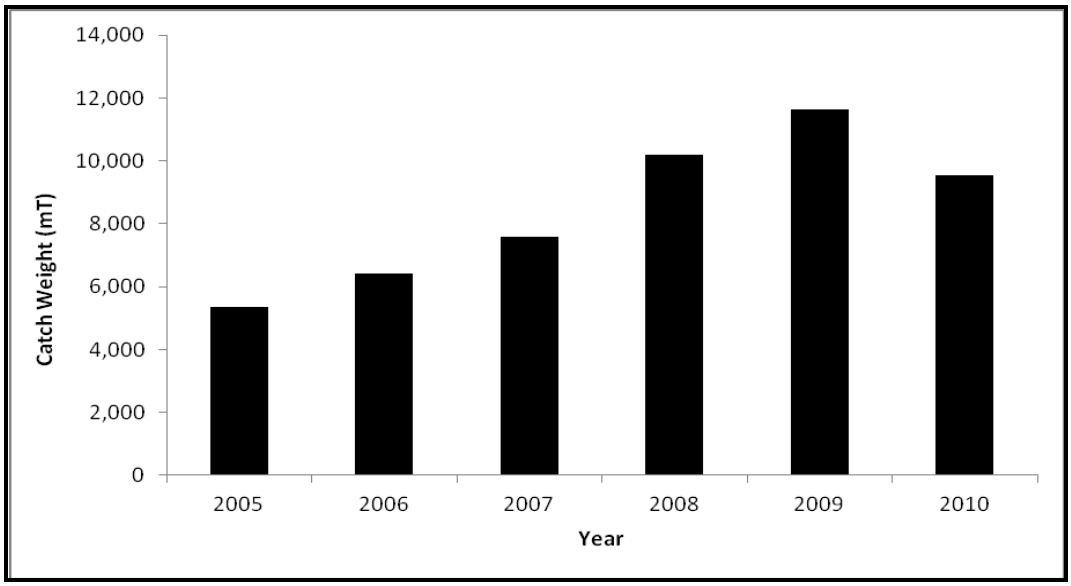


Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.32 Domestic Harvesting Locations, Northern Shrimp, November, 2005-2010 Combined.

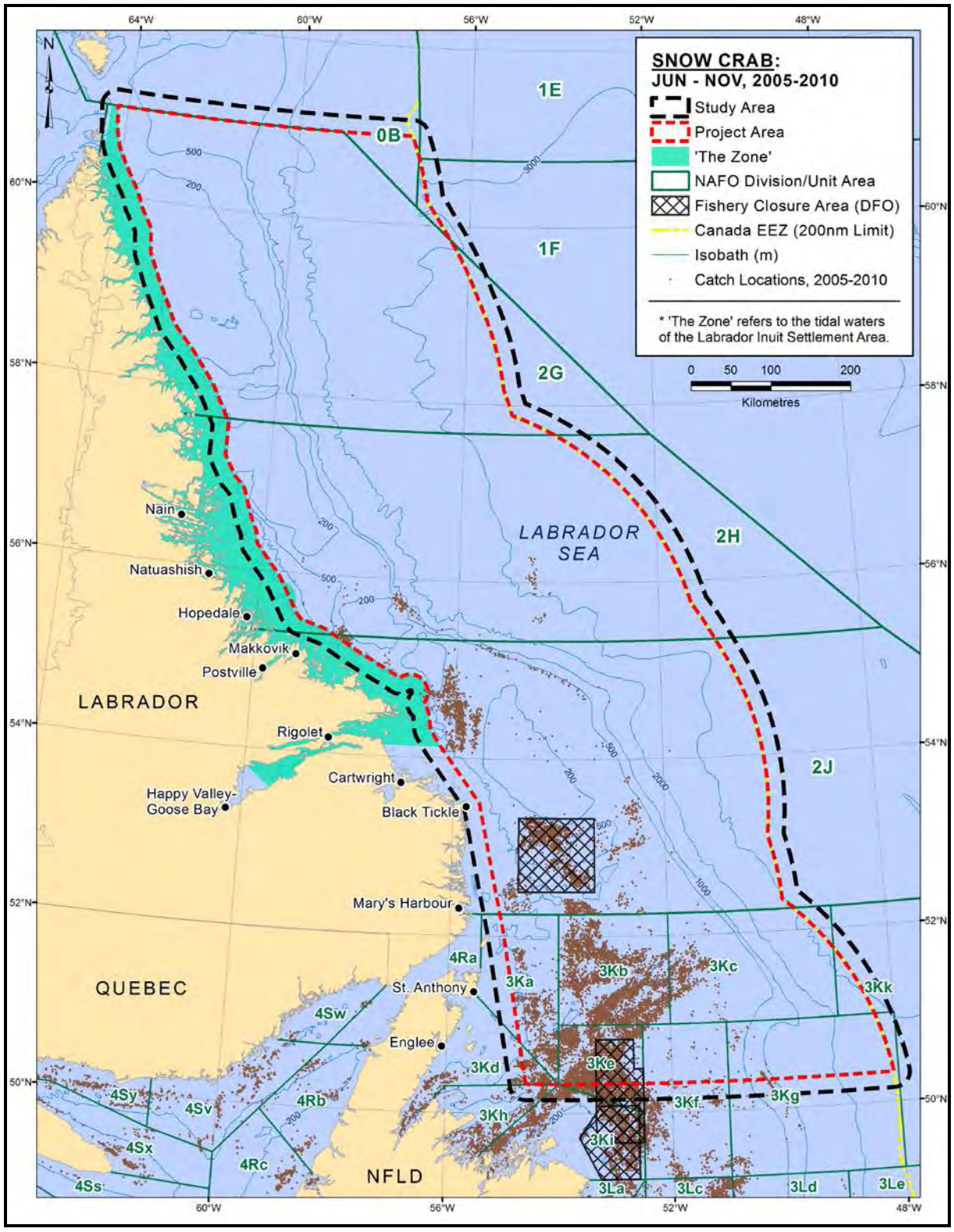
Snow Crab

Snow crab is the second most important commercial species in the Study Area by both quantity and value. Total annual catch weights for snow crab in the Study Area between 2005 and 2010 are indicated in Figure 4.33. Figure 4.34 shows the snow crab harvesting locations for 2005-2010 combined. The average snow crab harvests by month for the 2005 to 2010 period in the Study Area are shown in Figure 4.35. May and June were the two months during which most of the snow crab was caught.



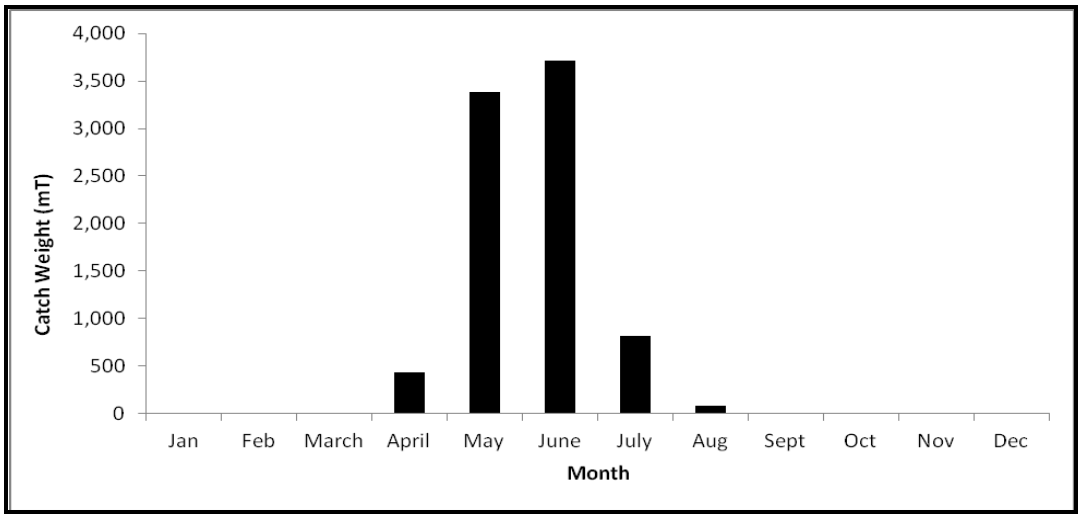
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.33 Total Annual Catch Weights for Snow Crab in the Study Area, 2005-2010.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.34 Domestic Harvesting Locations, Snow Crab, June to November, 2005-2010 Combined.

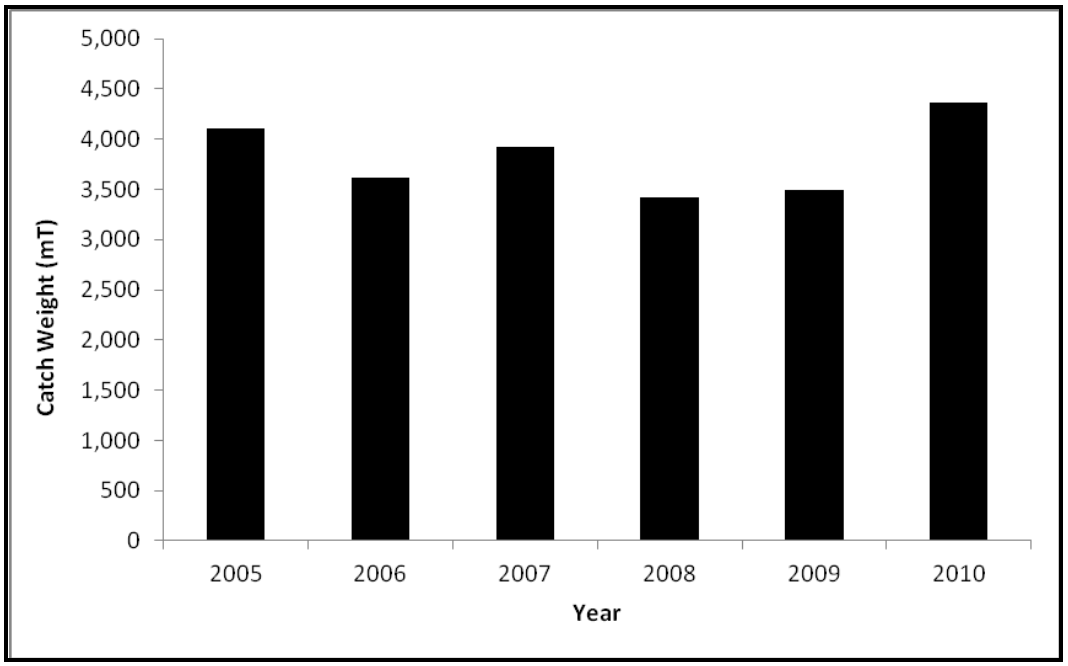


Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.35 Average Monthly Catch Weights for Snow Crab in the Study Area, 2005-2010.

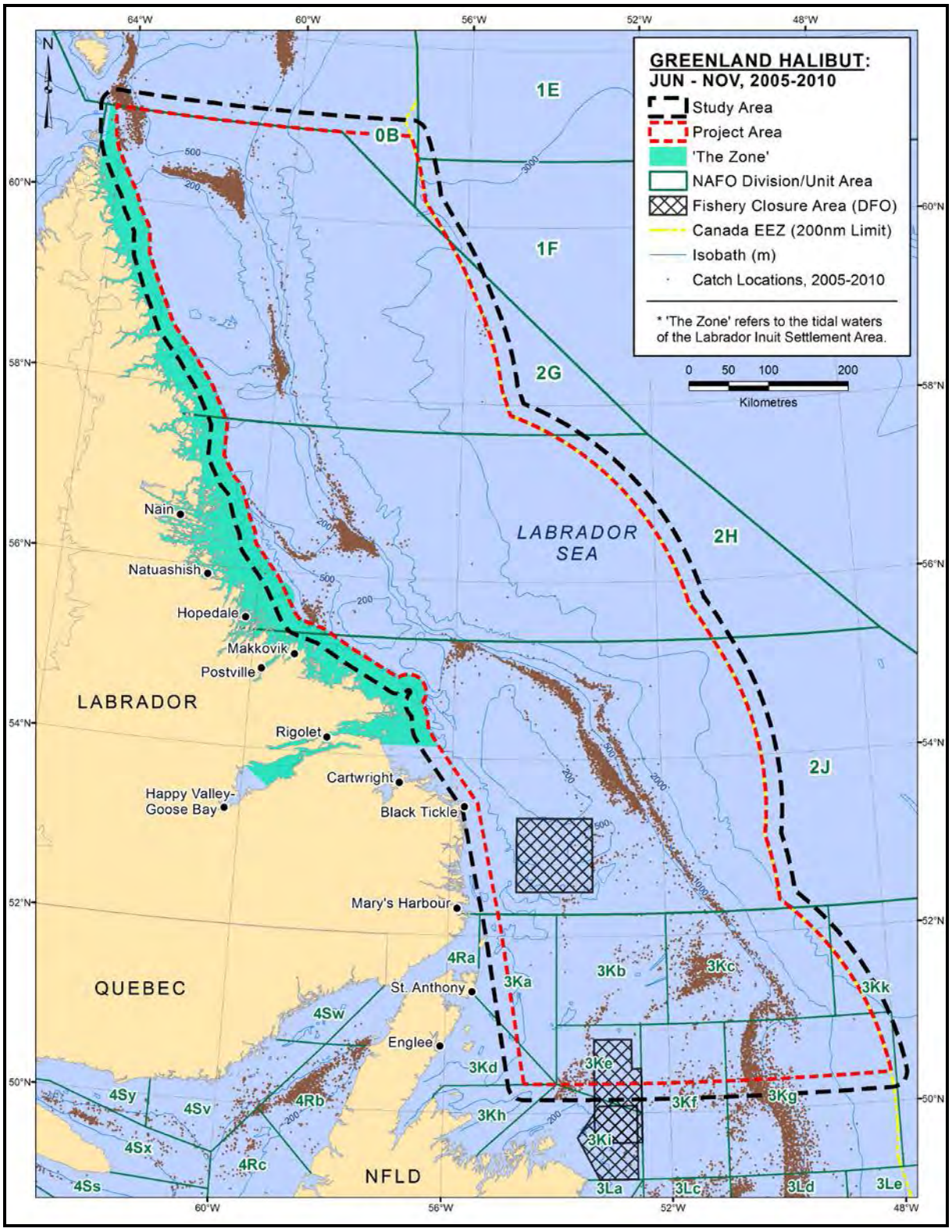
Greenland Halibut (Turbot)

Although its total catch weight is small, Greenland halibut (turbot) made up the largest part of groundfish catches in the Study Area from 2005 to 2010. Total annual catch weights for Greenland halibut in the Study Area between 2005 and 2010 are indicated in Figure 4.36. Figure 4.37 shows the Greenland halibut harvesting locations for 2005-2010 combined. The average Greenland halibut harvests by month for the 2005 to 2010 period in the Study Area are shown in Figure 4.38.



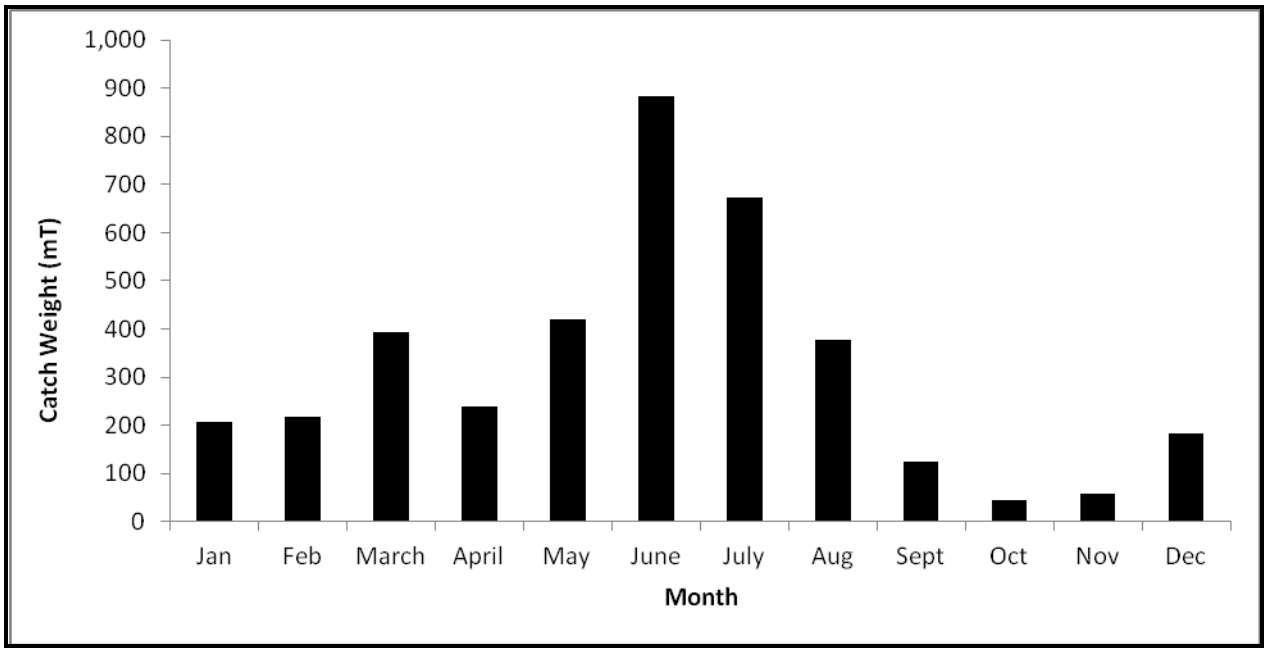
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.36 Total Annual Catch Weights for Greenland Halibut (turbot) in the Study Area, 2005-2010.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.37 Domestic Harvesting Locations, Greenland Halibut (turbot), June to November, 2005-2010 Combined.

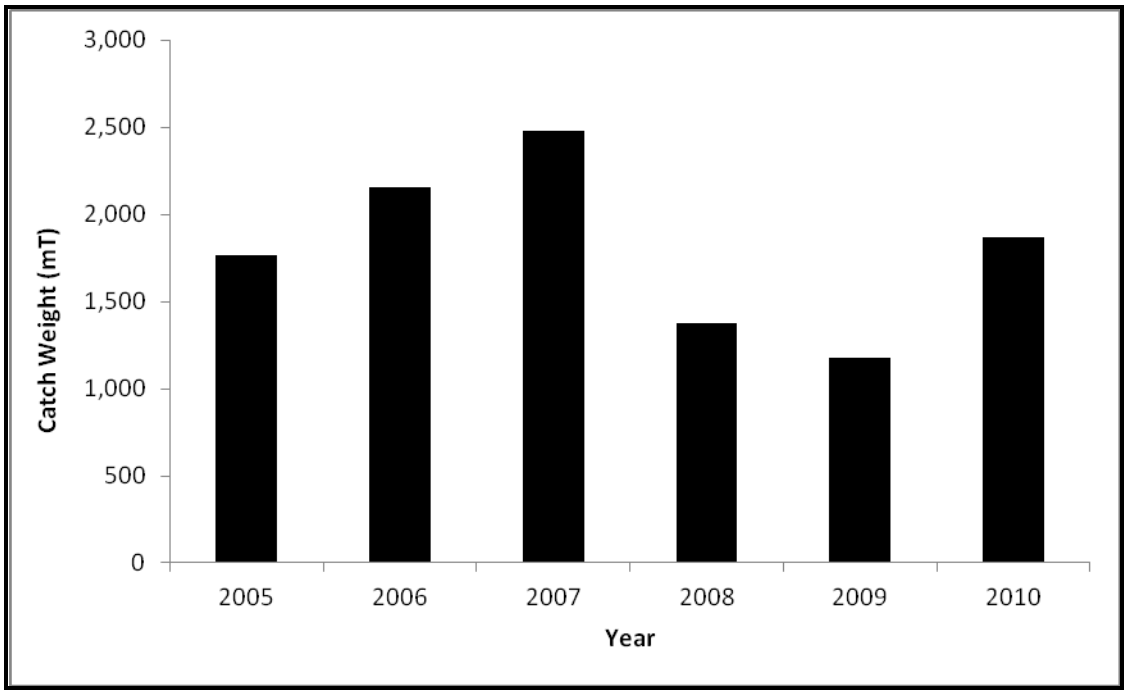


Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.38 Average Monthly Catch Weights for Greenland Halibut (turbot) in the Study Area, 2005-2010.

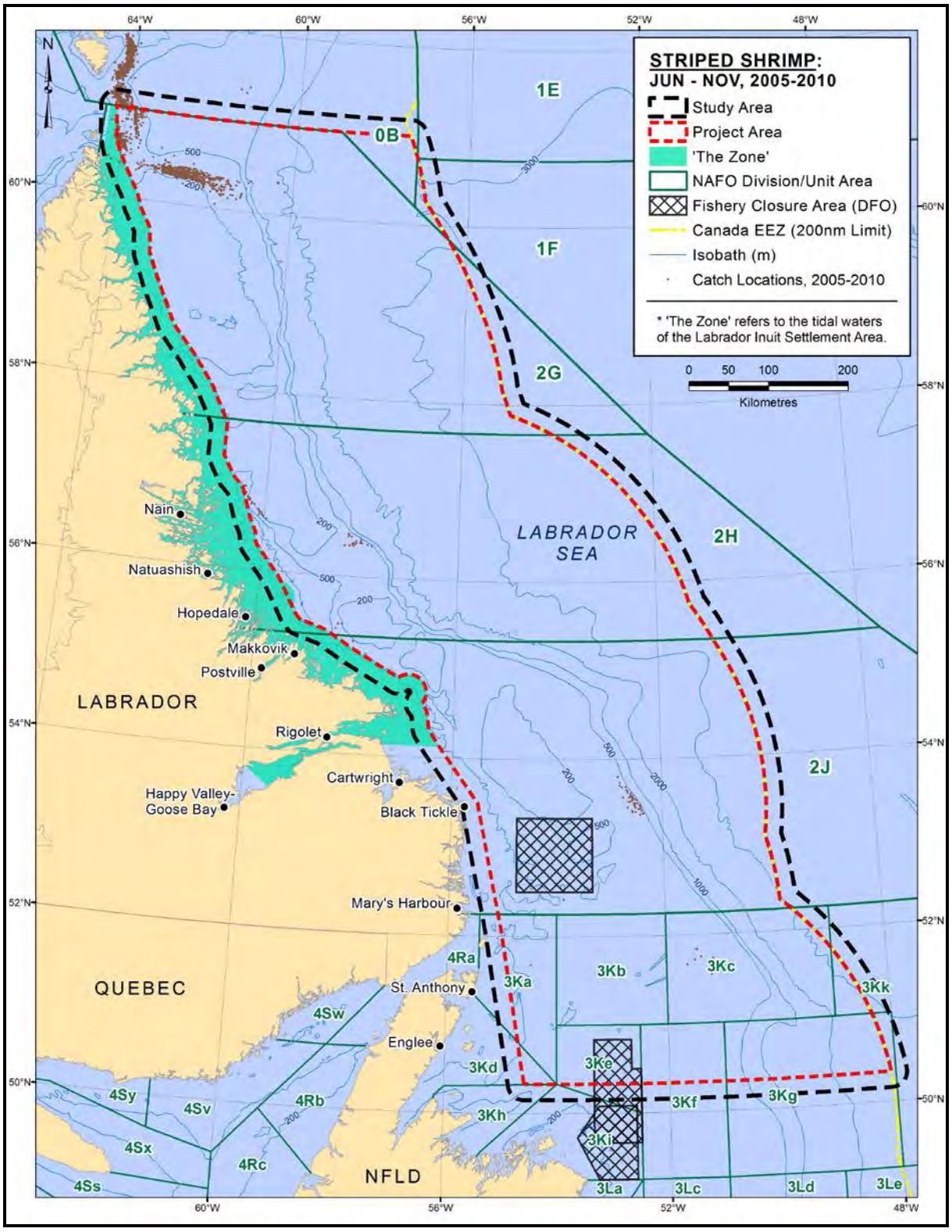
Striped Shrimp

Despite its relatively small average annual catch weight in the Study Area between 2005 and 2010, striped shrimp catch value over that time exceeded $3.5 million. Although there is some directed fishery for this shrimp, most is harvested as by-catch in the northern shrimp fishery (DFO 2011a). Total annual catch weights for striped shrimp in the Study Area between 2005 and 2010 are indicated in Figure 4.39. As the graph illustrates, there was considerable variability in total catch weight during that time. As Figure 4.40 shows catches were primarily in the most northern part of the Study Area. The average striped shrimp harvests by month for the 2005 to 2010 period in the Study Area are shown in Figure 4.41. As illustrated by the graph, August to December was the primary harvesting period for this species during the six-year period.



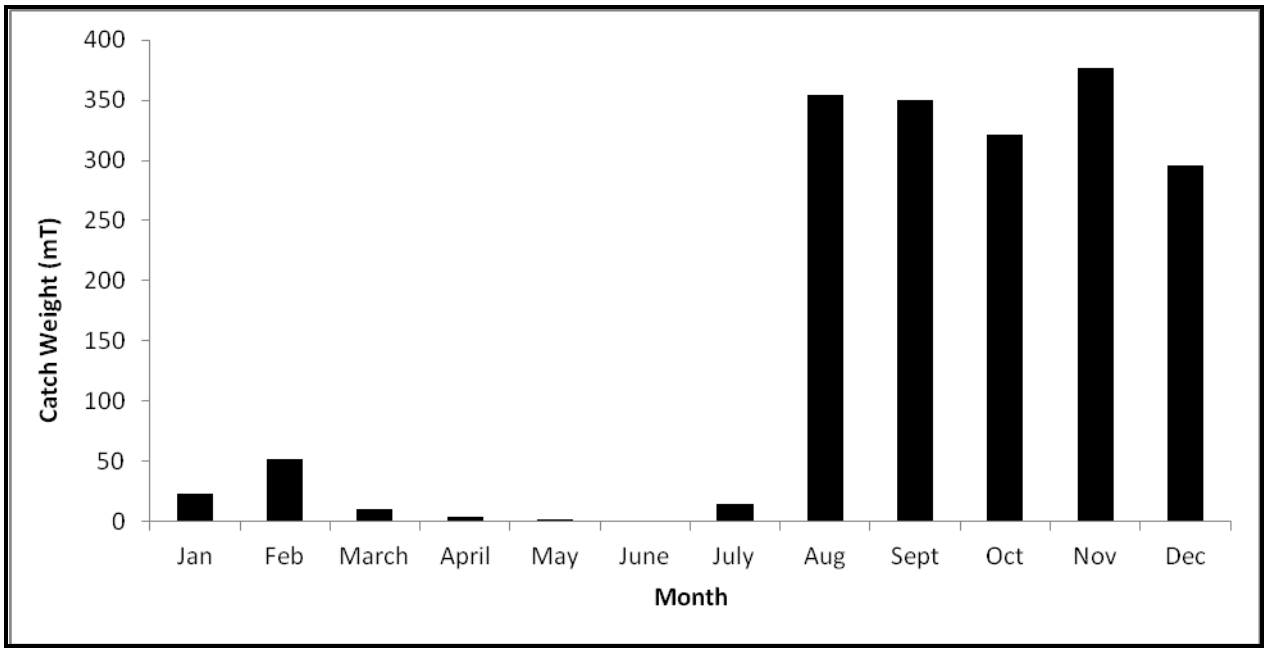
Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.39 Total Annual Catch Weights for Striped Shrimp, 2005-2010.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.40 Domestic Harvesting Locations, Striped Shrimp, June to November, 2005-2010 Combined.



Source: DFO commercial landings database, All Atlantic Regions (2005 to 2010).

Figure 4.41 Average Monthly Catch Weights for Striped Shrimp in the Study Area, 2005-2010.

4.3.3 Industry and DFO Research Vessel Surveys

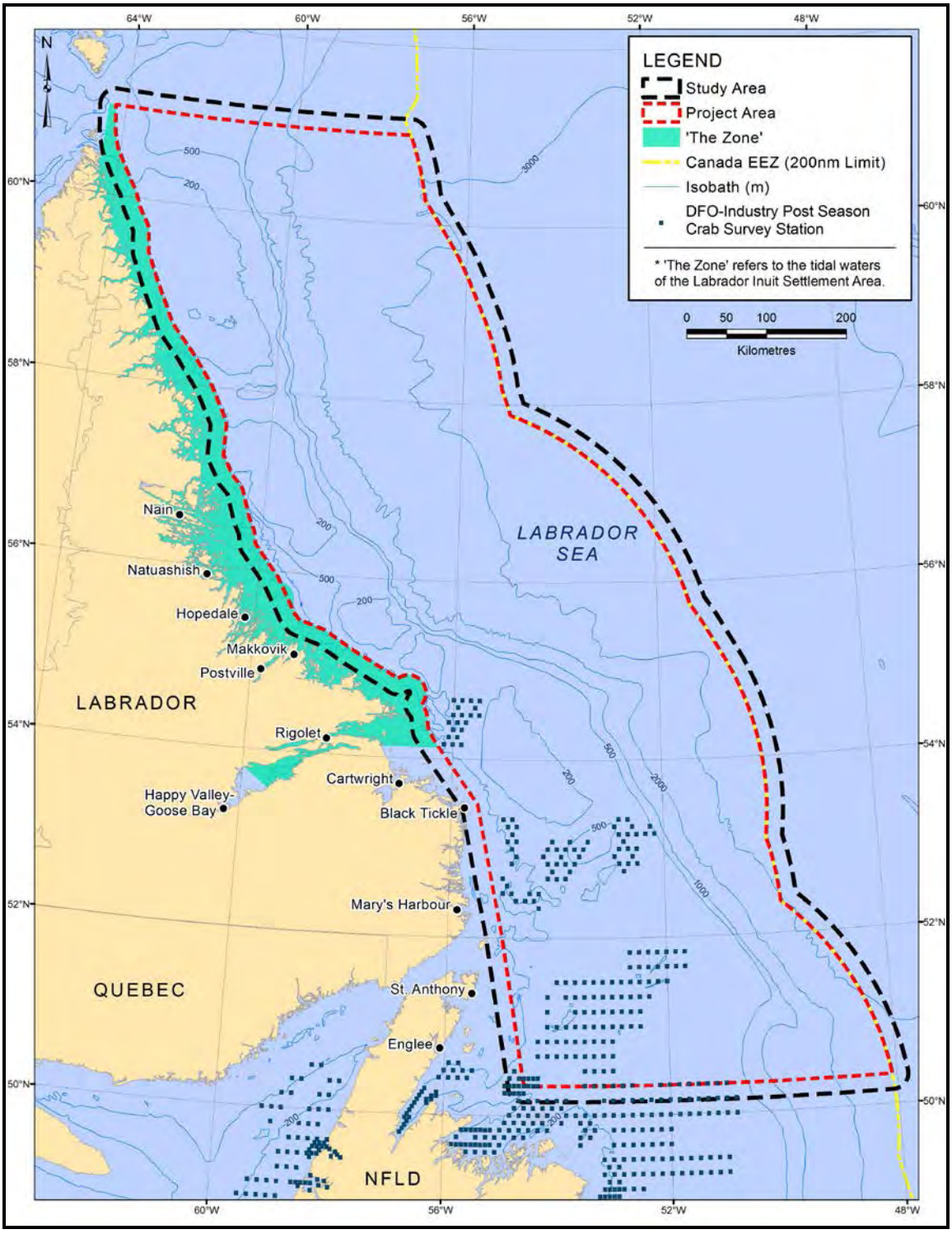
Fisheries research surveys conducted by DFO, and sometimes by the fishing industry, are important to the commercial fisheries to determine stock status, as well as for scientific investigation. In any year, there may be overlap between the Study Area and DFO research surveys in NAFO Divisions 2HJ3K, depending on the timing in a particular year.

The tentative timing of DFO RV surveys in the Study Area in 2013 is indicated in the following table (Table 4.7) (G. Sheppard, DFO, pers. comm., 2013). According to DFO, research surveys are likely to occur in the Study area for most of October, a portion of November, and perhaps in early December.

Table 4.7 Tentative Timing of DFO Research Vessel Surveys in the Study Area, 2013.

NAFO Division	Start Date	End Date
2H	4 October	15 October
2H+2J	16 October	29 October
2J+3K	30 October	12 November
3K	13 November	26 November
3K+3L Deep	27 November	10 December

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 before it is completed. The set locations are determined by DFO and do not change from year to year. Many of the northern stations fall within GXT's Study Area. Research station locations in relation to the Project Area and Study Area are shown in Figure 4.42.



Source: DFO (2013).

Figure 4.42 Locations of DFO-Industry Collaborative Post-Season Snow Crab Trap Survey Stations in Relation to the Project and Study Areas.

4.3.4 Traditional and Aboriginal Fisheries

According to the Labrador Shelf SEA (Sikumiut 2008), Labrador waters are used extensively by local aboriginal peoples for traditional hunting and fishing. The activities are spread widely throughout the region and vary by season. The aboriginal people consider these activities as part of their culture and history and concerns were expressed in the public consultation sessions during the completion of the SEA report and through the process of collecting traditional knowledge over the impact that operations and/or accidental events may have on them. Some of the activities and issues that were highlighted for the SEA Area are:

- Fishing: the area is used extensively for fishing. Species noted were crab, rock cod (= Greenland cod), Atlantic cod, Arctic char, sculpin, mussels, clams, wrinkles, and sea urchins;
- Traditional uses such as egging and berry picking are conducted on the islands in coastal areas;
- Harlequin Duck, a *threatened* species migrates through the area;
- Ducks and geese are also hunted in the area; and,
- Traditional activities are well dispersed throughout the Labrador Shelf Area.

Though not specified by the Labrador Shelf SEA (Sikumiut 2008), it is likely that most of these activities occur in inshore waters landward of the Project and Study Areas.

The traditional, or country food, harvesting activities occurring in the Labrador Shelf SEA Area are described in Section 4.10.6 of the Labrador Shelf SEA (Sikumiut 2008) and include the harvest of invertebrate and fish (marine and anadromous) species and the hunting of seabirds, waterfowl, and marine mammals, particularly seals.

Inuit have the right to harvest fish, wildlife, and plants throughout the Labrador Inuit Settlement Area at all times of the year up to their full level of needs for food, social and ceremonial (FSC) purposes (Nunatsiavut 2009). Inuit are able to take as many fish as they need for their FSC purposes unless a total allowable harvest is established by the federal Minister of Fisheries for conservation purposes.

If a total allowable harvest is set for a species or stock of fish, the Nunatsiavut Government will recommend an Inuit domestic harvest level for that species or stock (Nunatsiavut 2009). The domestic harvest level will be the amount that Inuit need for their FSC purposes, and will come from information that is being collected from Inuit about their fishing, hunting and gathering activities. The Nunatsiavut Government's recommendation must be accepted by the federal Minister of Fisheries unless it cannot be supported by information.

When an Inuit domestic harvest level is established for a species or stock of fish, Inuit will be able to harvest up to the Inuit domestic harvest level for that species or stock (Nunatsiavut 2009). If necessary, the Inuit domestic harvest level will be divided amongst individuals or families by the Nunatsiavut Government. The FSC species harvested are not listed by Nunatsiavut (2009); however, the Labrador Métis Nation, which has similar rights for FSC purposes, provides the harvesting regulations

for several species on their website (LMN 2009). Species harvested for FSC purposes include Atlantic salmon, Arctic char, trout, herring, smelt, scallop, and whelk. Several seal species are hunted and include harp, grey, ringed, bearded, and hooded. Some examples of the birds harvested include geese, eiders, and gull eggs. Various regulations exist for the harvest of different species for FSC use. Smelt, for example, can only be harvested by angling and harvest limits are restricted to the amount required for FSC purposes. The species can be harvested year-round in tidal waters from Hamilton Inlet to Battle Harbour.

FSC or subsistence fisheries for Atlantic salmon and Arctic char occurring in Labrador waters are described by Reddin et al. (2008). From 1999 to 2005, a FSC or subsistence fishery of 10 mt was available for members of the Labrador Inuit Association (now known as the Nunatsiavut Government) in the north as well as the Lake Melville area, both located in SFA 1. The Innu Nation also fish for salmon in Lake Melville from the community of Sheshatshiu and on the north coast from the community of Natuashish. They generally restrict themselves to harvests of around 3 mt. Beginning in 2000 and continuing into 2005, residents of Labrador were able to fish in the sea for brook trout and Arctic char with a permitted bycatch of four salmon. In 2004 to 2005, members of the Labrador Métis Nation (LMN) on the south coast of Labrador negotiated a subsistence fishery of 10 mt with DFO in the area between Fish Cove Point and Cape St. Charles, located in SFA 2. The total landings in the four fisheries for FSC or subsistence purposes, including the bycatch of salmon in the resident trout fishery, were 26 mt in 2007, which was a slight decline from the 2006 landings. Landings for 2008 subsistence harvest were unavailable when DFO (2009b) was prepared. The Arctic char food fishery has a higher harvest than the Atlantic salmon food fishery harvest (DFO 2009b); however, the total number of char (and trout) landed in Labrador is unknown because there is no reporting system for fish caught either through the ice in the winter and spring or by recreational fishing in the summer (Reddin et al. 2008). The total landings of Arctic char were also unavailable (DFO 2009b). The recreational groundfish fishery for NAFO Div. 2J3KL has allocated a quota for FSC purposes for the Labrador Metis Nation and Innu in recent years. In 2008, the FSC quota was 10 mt.

The harvesting of country food can take many forms and today has incorporated many modern methods according to the Labrador Shelf SEA. The use of traditional ecological knowledge derived from generations of harvesting helps to identify the locale and timing of harvest activities that are tied to a particular target species' migrations and resource use. A variety of nets, traps and jigs are used to harvest fish, typically from inshore motor boats. Marine mammals are hunted with the assistance of boats and snowmobiles. Birds are hunted with rifles from land and water with the use of snowmobiles and boats.

Traditionally, the outer edge of the landfast ice, the "sina", was usually the most productive zone accessible to Inuit hunters. In the Nain and Hopedale areas, coastal islands shield the landfast ice from environmental impacts and the ice is subsequently locked in place, providing an extension of hunting and trapping areas up to 30 km from the coast (VBNC 1997 *in* the Labrador Shelf SEA (Sikumiut 2008)). For residents of Postville, smelt and capelin were caught only during spawning time. Smelt are only caught near the head of the bays. Bay capelin spawn on inside beaches, while outside capelin spawn on the beaches along the coast (Brice-Bennett 1977 *in* the Labrador Shelf SEA (Sikumiut 2008)). Salmon arrived on the coast in late June/early July and are caught using traps, nets, or jigged. The

importance of cod varied along the coast (Brice-Bennett 1977 *in* the Labrador Shelf SEA (Sikumiut 2008)).

Ringed seals are hunted near their breathing holes or in open water. After the break-up of ice in mid June, harp seals are hunted or netted as they enter the bays (VBNC 1997 *in* the Labrador Shelf SEA (Sikumiut 2008)). Traditionally, char were speared as they migrated up the rivers. Char and salmon were also caught by net along the coast. In the spring, ice fishing camps can be found at the heads of bays (e.g., Anaktalak Bay).

Information on country harvesting in Labrador was collected by traditional knowledge interviews, during public consultation meetings, and from literature sources for the Labrador Shelf SEA. Using this information, the authors identified important country food and harvest areas. None of the areas identified occurred in offshore waters, including those within the Study Area. Rather, the areas identified for many of the species discussed (capelin, various seal species, harbour porpoise, Atlantic white-sided dolphins, polar bears, and migratory birds) highlighted the importance of coastal waters (e.g., "The Zone" see Section 4.7) for traditional harvesting in Labrador. The seismic survey activities will not enter this area.

4.3.5 Recreational Fisheries

Arctic char and Atlantic salmon were suggested to be important non-commercial species targeted by recreational fisheries in the Labrador Shelf Area (see the Labrador Shelf SEA (Sikumiut 2008)). Recreational fisheries directed at brook trout (*Salvelinus fontinalis*) also occur in Labrador waters. These three anadromous species are typically harvested in freshwater or coastal marine waters, outside of the Study Area. Subsistence fisheries also occur for Atlantic salmon and Arctic char in Labrador waters.

Small recreational fisheries for Atlantic cod occur in Labrador Shelf waters with the majority of catches occurring within NAFO Division 2J according to the Labrador Shelf SEA (Sikumiut 2008).

4.3.6 Aquaculture

At present, there is no approved aquaculture site in the Labrador Shelf area, including within the Study Area.

4.4 Seabirds and Migratory Birds

The Labrador Sea is rich in breeding and migratory seabirds. There are 32 species of marine birds occurring regularly on the Labrador coast and the north coast of Newfoundland (Table 4.8). Among the countless islands along these coastlines, some provide suitable nesting conditions for colonies of various gull species, Arctic and Common Tern, Common Eider and auks (Razorbill, Thick-billed Murre, Common Murre, Atlantic Puffin and Black Guillemot). There are five main concentrations of nesting auks, along these coastlines: (1) offshore islands south east of Nain, (2) Quaker Hat Island near Cape Harrison, and (3) Gannet Islands and Bird Island Groswater Bay/Table Bay, (4) Wadham Islands, and

(5) Funk Island (Figure 4.43). These five island groups support almost 660,000 pairs of breeding seabirds. More than 40% of the North American breeding population of Razorbill nests on the mid-Labrador coast alone. The Gannet Islands (including the Gannet Cluster) off Hamilton Inlet, the largest breeding seabird nesting colony in Labrador, supports more than 91,000 pairs of nesting seabirds in the summer (Table 4.9). The Wadham Islands and Funk Island, not far south of the Study Area, host over 430,000 pairs of seabirds that travel great distances on foraging sorties. Colonies of terns (Arctic and Common) and gulls (Herring, Great Black-backed, Ring-billed and Glaucous) and nesting Common Eider are scattered along most of the Labrador coast and the north coast of Newfoundland.

Large numbers of Great Shearwater and Sooty Shearwater migrate from breeding islands in the South Atlantic to spend the summer in the offshore waters Newfoundland and Labrador. Three species of jaeger (Long-tailed, Pomarine and Parasitic) and two species of phalarope (Red and Red-necked) migrate through Newfoundland and Labrador offshore waters between Arctic breeding grounds and mid-latitude wintering grounds. Many of the 3.8 million Thick-billed Murres and up to 10 million Dovekies breeding in the eastern Canadian Arctic and Greenland winter in the Labrador Sea or cross it on the way to the Grand Banks and other parts of southern Atlantic Canada. Large numbers of sub-adults of Northern Fulmar and Black-legged Kittiwake from breeding colonies in the eastern Arctic and Europe spend the early parts of their lives in the Labrador Sea.

Offshore Labrador is a known wintering area for the Ivory Gull, a species designated as Endangered on Schedule 1 of *SARA*, COSEWIC and the Newfoundland and Labrador *Endangered Species Act*. Harlequin Ducks moult and stage at some sites along the Labrador coast and around islands off the Labrador coast. This species is designated Special Concern on Schedule 1 of *SARA* and by COSEWIC. Some sections of coastal Labrador and the waters around some of its offshore islands are moulting and staging areas for Harlequin Duck and Barrow's Goldeneye, both listed on Schedule 1 of *SARA*. Details on these species are located in Section 4.6 on Species at Risk. Shorebirds and other species found on the coast but not in the Study Area are not discussed in detail this report (see the Labrador Shelf SEA for information on coastal species).

Table 4.8 Monthly Occurrence and Abundance of Pelagic Seabirds in Offshore Labrador and Northern Newfoundland.

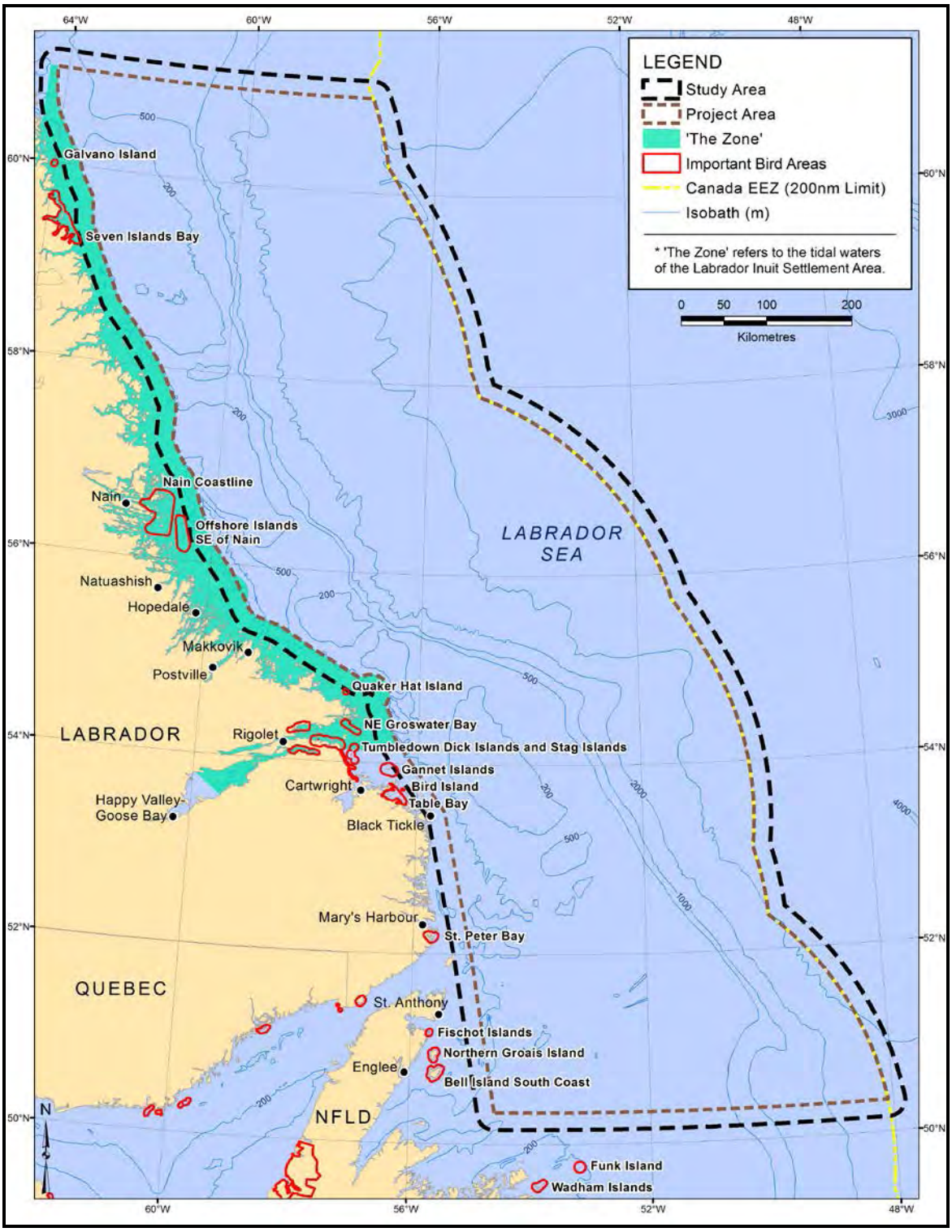
Species	Scientific Name	Abundance[1]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Northern Fulmar	*Fulmarus glacialis*	Common	■	■	■	■	■	■	■	■	■	■	■	■
Great Shearwater	*Puffinus gravis*	Common					■	■	■	■	■	■		
Sooty Shearwater	*Puffinus griseus*	Uncommon					■	■	■	■	■	■		
Manx Shearwater	*Puffinus puffinus*	Scarce					■	■	■	■	■	■		
Leach's Storm-Petrel*	*Oceanodroma leucorhoa*	Uncommon				■	■	■	■	■	■	■		
Northern Gannet	*Morus bassanus*	Uncommon				■	■	■	■	■	■	■		
Red-necked Phalarope*	*Phalaropus lobatus*	Uncommon					■	■	■	■	■	■		
Red Phalarope	*Phalaropus fulicarius*	Common					■	■	■	■	■	■		
Ring-billed Gull*	*Larus delawarensis*	Uncommon				■	■	■	■	■	■	■		
Herring Gull*	*Larus argentatus*	Common			■	■	■	■	■	■	■	■	■	■
Iceland Gull	*Larus glaucoides*	Common	■	■	■	■	■					■	■	■
Glaucous Gull*	*Larus hyperboreus*	Common	■	■	■	■	■	■	■	■	■	■	■	■
Great Black-backed Gull*	*Larus marinus*	Common			■	■	■	■	■	■	■	■	■	■
Black-legged Kittiwake*	*Rissa tridactyla*	Common	■	■	■	■	■	■	■	■	■	■	■	■
Ivory Gull	*Pagophila eburnea*	Scarce	■	■	■	■	■						■	■
Common Tern*	*Sterna hirundo*	Common					■	■	■	■	■	■		
Arctic Tern*	*Sterna paradisaea*	Common					■	■	■	■	■	■		
Great Skua	*Stercorarius skua*	Scarce					■	■	■	■	■	■		
Pomarine Jaeger	*Stercorarius pomarinus*	Uncommon					■	■	■	■	■	■		
Parasitic Jaeger	*Stercorarius parasiticus*	Uncommon					■	■	■	■	■	■		
Long-tailed Jaeger	*Stercorarius longicaudus*	Uncommon					■	■	■	■	■	■		
Dovekie	*Alle alle*	Common	■	■	■	■	■	■			■	■	■	■
Common Murre*	*Uria aalge*	Common				■	■	■	■	■	■	■	■	■
Thick-billed Murre*	*Uria lomvia*	Common	■	■	■	■	■	■	■	■	■	■	■	■
Razorbill*	*Alca torda*	Common				■	■	■	■	■	■	■	■	■
Black Guillemot*	*Cepphus grylle*	Common	■	■	■	■	■	■	■	■	■	■	■	■
Atlantic Puffin*	*Fratercula arctica*	Common				■	■	■	■	■	■	■	■	■

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

Notes: Shaded fields indicate the months when species may be expected.

* Breeds on the mid-Labrador coast and Wadham Islands.

[1] Common = likely present daily in moderate to high numbers; Uncommon = likely present daily in small numbers; Scarce = likely present regularly in very small numbers; Rare = usually absent, individuals occasionally present.



Source: Bird Studies Canada and The Canadian Nature Federation (2004). Important Bird Areas of Canada Database. Port Rowan, Ontario: Bird Studies Canada. Full metadata: http://birdmap.bsc-eoc.org/maps/metadata/caniba_poly.xml

Figure 4.43 Important Bird Areas of the Labrador coast and Northern Newfoundland.

Table 4.9 Breeding Pairs of Pelagic Seabirds at Important Bird Areas.

Species	Number of Nesting Pairs								
	Southeast of Nain	**Quaker Hat**	**Northeast Groswater Bay**	**Gannet Islands**	**Bird Island**	**Northern Groais Island**	**Wadham Islands**	**Funk Island**	**Total**
Northern Fulmar	-	-	-	16	-			13	29
Leach's Storm-Petrel	-	-	10	20	present		10,000		10,030+
Northern Gannet								6,075	6,075
Herring Gull	-	-	present		-			500	500+
Glaucous Gull	350	-	-	-	-				350
Great Black-backed Gull	-	-	100	120	20			100	340
Black-legged Kittiwake	-	4[a]	-	113	-	2,400		810	3,323
Common Murre	2,260	-[a]	2,060[a]	36,702[a]	3,100			396,000	440,122
Thick-billed Murre	8,000	126[a]	365[a]	1,897[a]	present			250	10,767+
Razorbill	815	-[a]	3,714[a]	14,329[a]	1,530		30	200	10,638
Black Guillemot	341	-	present	110	-		25		476+
Atlantic Puffin	12,240	-[a]	17,404[a]	38,666[a]	8,070		15,950	2,000	176,855
Totals	**24,006**	**130**	**23,653+**	**91,973**	**12,720+**	**2,400**	**26,005**	**405,948**	**659,505**

Source: Important Bird Areas of Canada (www.ibacanada.ca); [a] CWS unpublished data.

4.4.1 Important Bird Areas for Seabirds

Important Bird Areas (IBAs) form a network composed of sites that are important to the natural diversity of Canadian bird species and are critical for the long-term viability of naturally occurring bird populations. The Canadian IBA program was launched in 1996 by BirdLife International partners Canadian Nature Federation (now Nature Canada) and Bird Studies Canada (www.ibacanada.ca). The goal of the IBA program is to ensure the conservation of sites through the development and implementation of conservation plans in partnership with local stakeholders for priority IBAs. There are 19 IBAs along the Labrador coast and the north coast of Newfoundland north of 49°N (Figure 4.43, Table 4.10). The Study Area overlaps small portions of the Seven Islands Bay, Quaker Hat and Gannet Islands IBAs. Fourteen IBAs are important for waterfowl (see the Labrador Shelf SEA for details on coastal waterfowl). Eight of the 19 IBAs were designated as IBAs because of significant numbers of nesting seabirds (Table 4.8). These eight IBAs contain almost 660,000 pairs of breeding seabirds of 11 species. The Gannet Islands contain the largest seabird colony on the coast of Labrador with 14,329 pairs of Razorbill (about 33% of the North American breeding population), 38,666 pairs of Atlantic Puffin, and 36,702 pairs of Common Murre (Table 4.8).

4.4.2 Distribution and Abundance

There are few data on the seabirds of the Labrador northern Newfoundland coastlines. The seabird colonies at The Gannet Islands and Funk Island are exceptions. There is updated information on the numbers of nesting murres on four of the islands in the IBA southeast of Nain (Wilhelm and Duffy 2009). Pelagic seabird abundance data in the Labrador Sea and off northern Newfoundland are available from Canadian Wildlife Service (CWS) programme intégré de recherches sur les oiseaux pélagiques (PIROP) shipboard surveys from 1967 to 1994 (Lock et al. 1994). The more recent (2006 to 2009) CWS Eastern Canadian Seabirds at Sea (ECSAS) survey program sampled only a small portion of the Study Area (Fifield et al. 2009), however PIROP sampled most of the area. Both programs sampled only small portions of the Study Area during the winter and spring, when much of the Study Area is ice covered.

Seabird abundance (all species combined) derived from PIROP during January to March was 1.0 to 99.99 birds/linear km in most of the 15'N x 30'W blocks that have been surveyed far offshore in the Study Area off the Labrador Coast and off northern Newfoundland (Lock et al. 1994). Seabird abundance closer to shore in the Study Area was 0.10 to 9.99 birds/linear km category in most blocks. In one block off the Northeast Newfoundland Shelf over 100 birds/linear km were recorded. During April to June, abundance also ranged from 1.0 to 99.99 birds/linear km in most blocks. However, abundance averaged over 100 birds/km in one block far off the shelf. During July to September, abundance averaged 1.0 to 99.99 birds/linear km over much of the Study Area. A few survey blocks at the Labrador Shelf edge and beyond showed an abundance of >100 birds/linear km. October to December data are available for only a small portion of the Study Area but abundance in most survey blocks fell in the 1.0 to 99.99 birds/linear km range. Over 100 birds/linear km were recorded in a few blocks at or beyond the continental shelf edge. Northern Fulmar, Black-legged Kittiwake and murres made up most of the birds during these surveys. However, shearwater species made a large contribution

from June to August and Dovekie was a large component during October and November (Lock et al. 1994).

Table 4.10 Important Birds Areas of the Labrador Coast and North Coast of Newfoundland (49ºN to 61ºN).

Name	Location	Vulnerable Species or Congregations
Galvano Island	59.99°N, 64.01°W	Nesting Common Eider.
Seven Islands Bay	59.40°N, 63.65°W	Premoulting staging Harlequin Duck, nesting Common Eider.
Nain Coastline	56.50°N, 61.08°W	Moulting Surf Scoter.
Offshore Islands Southeast of Nain	56.42°N, 60.58°W	Nesting Razorbill, Atlantic Puffin and murres.
Quaker Hat Island	54.75°N, 57.33°W	Nesting Razorbill and murres.
Goose Brook, Hamilton Inlet	54.30°N, 58.25°W	Staging Canada Goose.
Northeast Groswater Bay	54.40°N, 57.30°W	Nesting Razorbill, Atlantic Puffin and murres.
South Groswater Bay Coastline	54.20°N, 57.58°W	Migrating Black Scoter, nesting Common Eider.
The Backway, Rigolet	54.11°N, 58.14°W	Moulting Surf Scoter.
Tumbledown Dick Islands and Stag Islands	54.08°N, 57.18°W	Moulting Harlequin Duck.
Cape Porcupine	53.31°N, 57.04°W	Staging Surf Scoter.
Gannet Islands	53.97°N, 56.53°W	Nesting Razorbill, Atlantic Puffin, Common Murre; moulting Harlequin Duck.
Table Bay, Cartwright	53.66°N, 56.40°W	Nesting Common Eider.
Bird Island, Cartwright	53.75°N, 56.09°W	Nesting Atlantic Puffin, Common Murre and Razorbill.
St. Peter Bay	52.19°N, 55.69°W	Premoulting staging Harlequin Duck, moulting Common Eider.
Fischot Islands	51.17°N, 55.68°W	Wintering Common Eider.
Northern Groais Island	50.94°N, 55.60°W	Nesting Black-legged Kittiwake, wintering Common Eider.
Wadham Islands and adjacent marine area	49.56°N, 53.84°W	Nesting Atlantic Puffin, Black Guillemot, Leach's Storm-Petrel, Razorbill; wintering Common Eider
Funk Island	49.76°N, 53.18°W	Nesting murres, Northern Gannet, Atlantic Puffin, Black-legged Kittiwake, large gulls, Razorbill, Northern Fulmar.

Source: www.ibacanada.ca.

During the ECSAS surveys, seabird density (all species combined) during March to April ranged from 3.3 to 20.3 birds/km^2 in the four 1°N x 1°W blocks that were surveyed in the Study Area (Fifield et al. 2009). During May to August density ranged from 1.5 to 48.8 birds/km^2 in most of the survey blocks. During September and October density was 4.9 to 46.7 birds/km^2. From November to February density ranged from 3.7 to 45.1 4.9 birds/km^2 in most blocks. The majority of the bird species recorded during these surveys off Labrador and northern Newfoundland were Northern Fulmar, Black-legged Kittiwake, murres and Dovekie in all seasons (Fifield et al. 2009).

Analysis of ECSAS and PIROP data collected in fall in Subarctic and Arctic areas identified two seabird concentrations in the Labrador Sea (McKinnon et al. 2009). One of these concentrations occurs in late September and October at the eastern limit of Hudson Strait, which is consistent with Mallory and Fontaine's (2004) findings. A density of 38.8 birds/km^2 was recorded east of Resolution Island on 22 September. Another peak in density of a mean of 58.7 birds/km^2 and a maximum of 132 birds/km^2 was observed off the northeastern tip of Ungava Bay on 21 October, consisting mostly of large groups of birds resting on the surface. The other concentration area was off the mid-Labrador coast (roughly 54° to 59° N) in late October with a maximum density of 63 birds/km^2 on 23 October, due mostly to large flocks of flying birds.

4.4.2.1 Anatidae (Ducks, Geese and Swans)

The Labrador and northern Newfoundland coasts are important areas for sea ducks (tribe Mergini). The largest nesting colonies of Common Eider in Newfoundland and Labrador occur in the area of Table Bay to Groswater Bay with a secondary concentration in Nain Bight, reflecting a level of productivity also noted for breeding seabirds. Published estimates of numbers are rare and conservative because aerial surveys generally underestimate true population size. Nevertheless probably more than 10,000 pairs of Common Eiders nest in the Hamilton Inlet area (Lock 1986; Lock et al. 1994). Less is known of the moulting distribution of these stocks although large numbers of males (~ 9,000) were recorded moulting in the mouth of Table Bay in July 1989 (Goudie et al. 1994) and more than 5,000 St. Peter Bay in 1998 (IBA site data). Other moult aggregations are likely localized in the Labrador coastal area. Surf, Black and White-winged Scoters breed in interior Labrador and by mid-summer relatively large aggregations moult in Hamilton Inlet and Nain Bight. Sites such as Backway off Lake Melville and Nain Bight typify traditional sites where large groupings of males and non-breeders aggregate annually to complete the feather moult. By early fall (after mid-September), numbers of eiders north of Hamilton Inlet have diminished considerably, suggesting some redistribution (Lidster et al. 1993). Common Goldeneye, Barrow's Goldeneye and Red-breasted Merganser moult in coastal areas of Labrador in smaller aggregations (generally hundreds). Barrow's Goldeneye and Harlequin Duck, both listed on Schedule 1 of *SARA* as Special Concern, are discussed in more detail in Section 4.6, Species at Risk.

4.4.2.2 Procellariidae (Fulmars, Shearwaters and Petrels)

Four species from this family occur regularly in the Study Area: Northern Fulmar, Great Shearwater, Sooty Shearwater and Manx Shearwater. Northern Fulmar has a circumpolar distribution with the centre of breeding abundance in the North Atlantic, including the Canadian Arctic, Greenland, Iceland and northeast Europe and Scandinavia. Very few nest on the coast of Newfoundland and Labrador (Lock et al. 1994). Sixteen pairs are known to breed on Gannet Islands and 13 pairs on Funk Island (Table 4.9). However, it is a common year around resident in eastern Newfoundland and Labrador waters outside of the pack ice (Lock et al. 1994). Banding records show that Northern Fulmars from breeding colonies in the Canadian Arctic, Greenland, and the British Isles regularly winter in Newfoundland and Labrador waters (Brown 1986; Lock et al. 1994). Five adult Northern Fulmars fitted with satellite transmitters at Cape Vera, Devon Island, Nunavut, during the breeding season spent most of December to March in the Labrador Sea between 50ºN and 55ºN (Mallory et al. 2008). This shows the importance of the Labrador Sea as a wintering area for the species. However, the summer

populations off eastern Newfoundland and Labrador are thought to be composed of sub-adults from breeding colonies in Greenland and the Eastern Atlantic. In offshore areas, Northern Fulmar has been recorded in all months of the year in densities from < 1 to > 100 individuals per linear km (Brown 1986).

Great Shearwater breeds in the South Atlantic, mainly on the Tristan da Cunha Island and Gough Island. The adults are present at the breeding sites from October to April. They spend the non-breeding season (April to October) in the N Atlantic. A significant percentage of the total world population migrates to eastern Newfoundland and Labrador for the annual moult from June through August (Lock et al. 1994). Great Shearwater can be expected at sea off the Labrador and northern Newfoundland coasts from June to October with the largest concentrations (10 to 100 individuals/linear km) occurring along the continental shelf edge (Brown 1986). Sooty Shearwater has a similar distribution to Great Shearwater in that it nests in the Southern Hemisphere and some of the population flies to the Northern Hemisphere during the summer. Sooty Shearwater usually occurs among the more numerous Great Shearwater in Newfoundland and Labrador and during the same time period.

Most of the world population of Manx Shearwater breeds on islands in northeast Atlantic (Iceland, Scotland, Ireland, England and France) and The Azores and Canary Islands. It winters in the Southwest Atlantic off eastern South America (Godfrey 1986). The small population of Manx Shearwater present in Atlantic Canada during the summer months is probably a combination of Newfoundland breeders from Middle Lawn Island (Burin Peninsula) and non-breeding sub-adults and migrants from European breeding colonies (Lee and Haney 1996). Manx Shearwater is scarce along the Labrador coast, with sightings north to 57°N.

4.4.2.3 Hydrobatidae (Storm-Petrels)

Leach's Storm-Petrel is the only species of the family Hydrobatidae occurring regularly off the Labrador coast. Leach's Storm-Petrel is a widespread and abundant species occurring in both the Atlantic and Pacific oceans. In the Atlantic it breeds in northwest Europe (Iceland, Scotland and Norway) and in North America from southeast Labrador to Massachusetts (Huntington et al. 1996). The centre of breeding in eastern North America is the Avalon Peninsula, Newfoundland where close to four million pairs nest (Lock et al. 1994). It is a scarce breeder in Labrador with ≥ 30 pairs known to breed along the mid-Labrador coast (Table 4.9). Leach's Storm-Petrel is scarce in Labrador waters with 0 to >1 individual per linear km recorded during on Hamilton Bank and none north of 55° N, but is more abundant closer to the large colonies of the Avalon Peninsula (Brown 1986).

4.4.2.4 Sulidae (Gannets and Boobies)

Northern Gannet breeds in the North Atlantic in Quebec, Newfoundland, Iceland, Faeroe Islands and British Isles. It winters along the coast from New Jersey to the Gulf of Mexico and British Isles to the Azores Islands. Three of the five major gannet colonies in North America are located in Newfoundland at Cape St. Mary's, Baccalieu Island and Funk Island. Despite its name the Gannet Islands has never had a Northern Gannet nesting colony, nor are there colonies anywhere else along the Labrador coast. Gannets feed on small to medium size fish and squid over shelf waters, avoiding deep water beyond the

continental slope. It occurs regularly in small numbers on Hamilton Bank in April to October (Brown 1986).

4.4.2.5 Phalaropodinae (Phalaropes)

The Red-necked and Red Phalaropes occur in the marine environment of the Labrador coast during migration. Both species migrate through Newfoundland and Labrador offshore waters en route between wintering areas in the South Atlantic and breeding grounds in the Arctic and sub-Arctic. The Red-necked Phalarope nests on fresh water ponds in Labrador as far south as Groswater Bay (Godfrey 1986). In migration phalaropes are known to congregate in areas of upwelling and oceanographic fronts in the Labrador Sea, particularly along the continental shelf slope (Orr et al. 1982; Lock et al. 1994). Both species of phalarope are probably widespread at sea off the Labrador coast in the period late May to October, with areas of concentration possible at the continental shelf edge, particularly during the southward migration from July to September.

4.4.2.6 Laridae (Gulls and Terns)

Herring, Ring-billed, Great Black-backed, Glaucous, Iceland and Ivory Gulls, and Black-legged Kittiwake occur regularly in Labrador and northern Newfoundland waters. Herring and Great Black-backed Gull are common and widespread breeders along the entire coast. They are absent from areas of dense pack ice during winter. Ring-billed Gull nests locally in small colonies on the coastlines north to Voisey's Bay. Glaucous Gull is a northern species breeding south along the Labrador coast to 55°30'N. It winters at sea, particularly among pack ice and near the ice edge south to the Carolinas. Iceland Gull breeds north of Labrador, with Baffin Island being the centre of abundance. The species winters commonly south to Newfoundland and the Gulf of St. Lawrence. Ivory Gull is listed on *SARA* Schedule 1 as endangered. See Section 4.6 for details. In North America Ivory Gull breeds in the high Arctic and winters on sea ice between 50°N and 64°N (Godfrey 1986; Haney and MacDonald 1995). Precise estimates of the numbers wintering off the Labrador coast are not available, but the wintering population involves birds from the Canadian Arctic, Greenland and Franz Josef Land (Tuck 1971; Gilg et al. 2010). It was never a very common bird. Small, but significant numbers of Ivory Gull are probably present on the sea ice off the Labrador coast and probably off northern Newfoundland, including the Study Area, between December and May. Black-legged Kittiwake is a true sea gull, spending all its life at sea except when it has to nest on coastal islands. It is a common resident in Newfoundland and Labrador waters, remaining outside of the main pack ice in winter. In Newfoundland and Labrador, it breeds in large colonies, mainly on the Avalon Peninsula. Black-legged Kittiwake breeds in surprisingly small numbers on the Labrador coast. The only individuals breeding on the Labrador coast are those at The Gannet Islands and a new, small colony at Quaker Hat. Large numbers of birds migrate to the Labrador Sea and Newfoundland waters to winter (Lock et al. 1994). Stable isotope analyses and tagging with global location sensors have confirmed that many of these birds originate from breeding colonies in the Canadian Arctic and Greenland (González-Solís et al. 2011; Frederiksen et al. 2012). Sub-adult kittiwakes summer at sea away from breeding colonies. Kittiwake is common on shelf waters of Labrador and northern Newfoundland away from solid pack ice throughout the year (Brown 1986).

Arctic and Common Terns are the only species of tern occurring in offshore Labrador and offshore northern Newfoundland. Arctic Tern is circumpolar, breeding in both the sub-Arctic and high Arctic. Its breeding range extends south along the Atlantic coast to Maine. It migrates at sea between South Atlantic wintering grounds and North Atlantic breeding areas. Common Tern breeds in temperate and sub-Arctic North America and Eurasia. In eastern North America, it winters from South Carolina and southward. It is a common breeder both inland and in littoral waters of Newfoundland and Labrador. Both species are locally common at breeding sites along the coasts of Labrador and northern Newfoundland. Common Tern reaches its northern limit of breeding at about 56°40'N. Common Tern migrates near shore whereas Arctic Tern migrates both inshore and offshore. Terns are fairly common on the Labrador and northern Newfoundland coastlines from late May to early September.

4.4.2.7 Stercorariidae (Skuas and Jaegers)

One skua and three species of jaeger occur regularly along the coasts of Labrador and northern Newfoundland. Great Skua breeds in the Northeast Atlantic in Iceland, Faeroe Islands, Scotland and Norway, and winters farther south, but remains north of the equator. In Atlantic Canada, it is a summer visitor and spring and fall migrant. Very low densities of Great Skuas probably occur where there are concentrations of shearwaters, the target species from which they steal food. The three species of jaeger, Pomarine, Parasitic and Long-tailed, have circumpolar distributions, breeding in the low and high Arctic. They winter at sea near the equator. All three species migrate through the Study Area in spring and late summer/early fall. A few Parasitic Jaegers nest in Labrador north of 58°N (Godfrey 1986). In general jaegers are in offshore waters of Labrador and northern Newfoundland from mid-May to October. They are never numerous but are widespread in low densities, usually occurring where there are concentrations of other seabird species.

4.4.2.8 Alcidae (Murres, Guillemots, Puffins, Razorbill and Dovekie)

There are six species of the Alcidae in eastern North America and all of them have a significant role in the ecosystem of the Labrador and northern Newfoundland coastlines. Common Murre breeds in the North Pacific and North Atlantic Oceans. In the Atlantic it breeds in northern Europe, including Iceland and Greenland, and in the Northwest Atlantic from Labrador to Nova Scotia. Large colonies exist in northeastern Newfoundland, including Funk Island. Common Murre breeds in large colonies on the mid-Labrador coast with a total of 47,000 pairs at five main colonies (Table 4.9). This species reaches the northern limit of its breeding range in eastern North America at colonies on a group of islands near Nain at 56°42'N. Murres are most numerous offshore in the Study Area after the flightless fledglings and breeding adults abandon nesting colonies in late summer until the adults return inshore to the colonies in spring. Fledgling Common Murres leave the nesting ledges at the Gannet Islands and head to sea with parents, soon to be temporarily flightless, around 9-13 August (Birkhead and Nettleship 1987). Tagging with geolocators has shown that adults departing the Gannets Islands nesting colony are present in the southern third of the Study Area during fall migration (August to October) (Montevecchi et al. 2012). A further geolocator study found that in winter (November to February) some adults from this colony are present in the southern quarter of the Study Area (McFarlane Tranquilla et al. 2013). Some adults from Newfoundland nesting colonies (i.e., Funk Island, Witless Bay) winter in the southeast corner of the Study Area.

Thick-billed Murre breeds in the Arctic, North Atlantic and North Pacific oceans. In eastern North America it breeds mainly in the Arctic. On the Labrador and northern Newfoundland coast Thick-billed Murre is outnumbered by Common Murre during the breeding season (Table 4.9). It is estimated that up to four million Thick-billed Murres winter in Newfoundland and Labrador waters (Lock et al. 1994). Fledglings and adults leave the Gannet Islands nesting colony and head offshore in mid-August (Tuck 1961). Flightless fledglings and adults departing colonies in the farther north reach the Labrador Sea in September and begin a swimming, southward migration in the Labrador Current (Gaston 1982, Orr and Ward 1982). Birds tagged with geolocators at nesting colonies on the Minaret Islands (off Baffin Island) and Coates Island (Hudson Bay) were south of 62°N by 6 September (Gaston et al. 2011). Many reach Newfoundland waters by November. First-year and two year old birds reach Newfoundland in large numbers in November and December. Tagging Thick-billed Murres with geolocators showed that birds wintering (November to February) in the Study Area originate from nesting colonies on Prince Leopold Island, Minaret Islands and Coats Island in Nunavut, Digges Islands in northern Quebec, and the Gannet Islands in Labrador (McFarlane Tranquilla et al. 2013). Band returns show that the Newfoundland wintering population originates from breeding colonies not just in the Canadian Arctic (Hudson Strait and Lancaster Sound), but west Greenland and Iceland as well (Lock et al. 1994). Thick-billed Murre is present year round off the Labrador coast. In winter this species may be common along the eastern edge of the pack ice.

Razorbill breeds in the North Atlantic from northern Europe, including Iceland and Greenland, to the mid-Labrador coast and south to Maine. About 43% (18,526 pairs) of the North American breeding population of Razorbill nests on the mid-section of Labrador coast (Table 4.9). Most of these (14,329 pairs) are on The Gannet Islands (CWS unpubl. data). Razorbills depart the Gannet Islands colony from early August to early September and migrate south along the Labrador and eastern Newfoundland coasts (Lavers et al. 2009). A few are found off southern Labrador into November and December. Razorbill numbers in eastern Newfoundland waters peak from mid-October to mid-November (Chapdelaine 1997), however, the majority winter from southern Newfoundland to the Gulf of Maine (Lavers et al. 2009). Razorbills are present in Labrador shelf waters from April to November.

Atlantic Puffin breeds in the North Atlantic on the British Isles, Norway, Iceland, Greenland, Newfoundland and Labrador, and south to Maine. In Canada, the centre of breeding abundance is in southeast Newfoundland. The more than 82,000 pairs breeding on the mid-Labrador coasts represent about 20% of the North American breeding population. In North America Atlantic Puffins winter mainly off southern Newfoundland and Nova Scotia. Atlantic Puffin is present off the Labrador and northern Newfoundland coasts from May to November.

Black Guillemot breeds on both sides of the Atlantic, north into Arctic waters. It nests in numerous small colonies on coastal headlands and many small rocky islands. Population size estimates are difficult to achieve because the eggs are laid in inaccessible rock crevices. Black Guillemot is partially migratory but remains as far north as there is open water. Unlike the other members of the Alcidae, it feeds near shore and is rarely found more than a few kilometres from shore or pack ice. Black Guillemot is a year round resident on the coast of Labrador.

Dovekie breeds mainly in Greenland, Iceland, and northern Norway, and winters at sea in the North Atlantic south to New Jersey and France. Many of the ten million pairs of Dovekie breeding in Greenland winter in Newfoundland and Labrador. Dovekies feed on small invertebrates often associated with shelf breaks or ice edges. Gjerdrum et al. (2008) found strong correlations between abundances of copepods (*Calanus* spp.) and Dovekie at shelf edges off northeast Newfoundland in spring 2006. The abundant Dovekie is common near ice and in open offshore waters of the Labrador coast from September to May.

4.4.3 Prey and Foraging Strategy

Seabirds in the Study Area employ a variety of foraging strategies and feed on a variety of prey species (Table 4.11). Many of the shearwaters, storm-petrels, gulls, and phalaropes capture their food by seizing it from the surface, either while flying or resting on the surface. Gannets and terns search for prey from the air, then plunge dive to capture the prey item. Members of the auk family (Alcidae) dive from a resting position on the surface and actively pursue their prey underwater. Consequently, they spend most of their time on or under the ocean's surface. Diving depth and time also varies by species. Some species such as terns and phalaropes specialize in foraging in shallow depths at the surface, while at the opposite end of the range, species such as alcids and loons dive to great depths (i.e., 20 to 50 m). Larger species of seabirds feed on capelin, sand lance, and short-finned squid, crustaceans, or offal, whereas smaller species such as phalaropes and Dovekie feed primarily on copepods, amphipods, and other zooplankton (Table 4.11).

4.4.3.1 Procellariidae (Fulmar and Shearwaters)

Northern Fulmar and the four species of shearwaters that are expected to occur in the Regional 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, dipping head under the water, or diving under the water. Shearwaters are also capable of diving a short distance under the surface up to 10 m but usually less (Brown et al. 1981). They may do this flying low over the water and then plunging into the water with enough force to get them below the surface for a few seconds or dive from a sitting position.

4.4.3.2 Hydrobatidae (Storm-Petrels)

Leach's and Wilson's Storm-Petrel feed at night primarily on small, vertically-migrating, mesopelagic animals including myctophid fish, decapods and amphipods (Steele and Montevecchi 1994; Hedd and Montevecchi 2006). These storm-petrels usually feed while on the wing, picking small food items from the surface of the water.

4.4.3.3 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 and their heads probably rarely go beneath the surface.

Table 4.11 Foraging Strategy, Prey, Time with Head under Water and Dive Depth 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
Great Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Sooty Shearwater	Fish, zooplankton, cephalopods, crustaceans, offal	Shallow plunging, surface feeding	Brief	1-10
Manx Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Hydrobatidae				
Leach's Storm-Petrel	Fish, crustaceans	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 (1977); Nettleship and Birkhead (1985); Lock et al. (1994); Gaston and Jones (1998).

4.4.3.4 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 rarely is the entire body 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 spotting prey from the wing then dropping to water 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 rests on the water.

4.4.3.5 Stercorariidae (Skuas and Jaegers) 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. As a result of this life history they are less numerous than species from which they steal food. 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.

4.4.3.6 Alcidae (Dovekie, Murres, Razorbill and Atlantic Puffin)

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

4.5 Marine Mammals and Sea Turtles

4.5.1 Marine Mammals

A total of 21 marine mammals, including 14 cetaceans, six seals, and the polar bear, occur in the Study Area (Table 4.12). Table 4.12 presents the temporal and spatial distribution, habitat and relevant *SARA* and COSEWIC designations for each species. Most marine mammals use the Project Area seasonally, and the region represents important foraging and breeding areas for many.

An additional three species may very occasionally enter the Project Area and/or were historically abundant on the Labrador Shelf, including the bowhead whale (*Baleana mysticetus*), North Atlantic right whale (*Eubalaena glacialis*), and Atlantic walrus (*Odobenus rosmarus rosmarus*). Although thought to be historically common throughout the Strait of Belle Isle and Labrador Sea, bowhead whales now only rarely range as far south as the northern coast of Labrador as a result of depletion during industrial whaling (COSEWIC 2009a). Individuals occurring in northern Labrador likely represent either the Davis Strait or Hudson Bay stocks of the eastern Canada-west Greenland population; they are considered *special concern* by COSEWIC, but have no status under *SARA*.

North Atlantic right whales, considered *endangered* on Schedule 1 of *SARA* and by COSEWIC, became severely depleted by commercial whalers and are thought to have once ranged into coastal Labrador. However, no sightings have occurred in the last hundred years in the Strait of Belle Isle historical whaling area, despite evidence from bones in Red Bay, Labrador that they were once harvested in the region (COSEWIC 2003a; Brown et al. 2009). Currently, North Atlantic right whales are primarily found in Canadian waters in Roseway Basin on the Scotian Shelf and the Bay of Fundy during late summer and fall before migrating south along the eastern United States to wintering grounds in the southeast United States (COSEWIC 2003a; Brown et al. 2009).

Atlantic walrus are considered *extirpated* from Nova Scotia to Labrador, where they historically occurred (COSEWIC 2006a). Currently they are found in the eastern Canadian Arctic, where they are designated as *special concern* under COSEWIC; they are considered rare south of Hebron-Okak Bay on the Labrador coast (COSEWIC 2006a).

Thus, the available information suggests that it is very unlikely that any of these three species occur in the Project Area. In addition, five sightings of Risso's dolphin (*Grampus griseus*) were made in the Study Area from 1990 to 2003 based on the DFO cetacean sightings database. This species is considered *not at risk* by COSEWIC and it has no status under *SARA*. It is very rare offshore Labrador and is not expected to occur in the Study Area.

There is relatively little information on the occurrence and abundance of marine mammals on the Labrador Shelf. Previous environmental assessments (e.g., Canning and Pitt 2007; LGL 2010) and the Labrador Shelf SEA provide summaries of marine mammal species and previously available sighting data for the Project Area and offshore Labrador waters. Canning and Pitt (2007) summarized population estimates for marine mammals that may occur in the White Rose area of the Jeanne d'Arc Basin located

southeast of the Labrador Project Area; most of these species and populations presumably overlap with those found in the Project Area.

Table 4.12 Marine Mammals Known or Expected to Occur in the Labrador Shelf Study Area.

Species (Scientific Name)	Study Area		Habitat	*SARA* Status[a]	COSEWIC Status[b]
	Occurrence	Season			
Baleen Whales (Mysticetes)					
Humpback whale (*Megaptera novaengliae*)	Common	Year-round, but mostly May-Oct.	Coastal & banks	Schedule 3: Special Concern	NAR
Blue whale (*Balaenoptera musculus*)	Rare	Year-round, but mostly spring	Coastal & pelagic	Schedule 1: Endangered	E
Fin whale (*Balaenoptera physalus*)	Common	Year-round, but mostly summer	Slope & pelagic	Schedule 1: Special Concern	SC
Sei whale (*Balaenoptera borealis*)	Uncommon	May-Sept.	Offshore & pelagic	NS	DD
Minke whale (*Balaenoptera acutorostrata*)	Common	Year-round, but mostly May-Oct.	Shelf, banks & coastal	NS	NAR
Toothed Whales (Odontocetes)					
Sperm whale (*Physeter macrocephalus*)	Uncommon	Year-round, but mostly summer	Palagic, slope & canyons	NS	NAR; LPC
Northern bottlenose whale (*Hyperoodon ampullatus*)[c]	Common	Year-round?	Palagic, slope & canyons	Schedule 1: Endangered	E
Sowerby's beaked whale (*Mesoplodon bidens*)	Rare	Summer?	Palagic, slope & canyons	Schedule 1: Special Concern	SC
Beluga whale (*Delphinapterus leucas*)[d]	Rare	Winter or Summer?	Coastal & ice edge	NS	E
Killer whale (*Orcinus orca*)	Uncommon	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
White-beaked dolphin (*Lagenorhynchus albirostris*)	Common	Year-round, but mostly June-Sept.	Shelf	NS	NAR
Harbour porpoise (*Phocoena phocoena*)	Uncommon	Year-round, but mostly spring-fall	Shelf, coastal	Schedule 2: Threatened	SC
True Seals (Phocids)					
Harbor seal (*Phoca vitulina*)	Uncommon	Year-round	Coastal	NS	NAR
Harp seal (*Pagophilius groenlandicus*)	Common	Year-round, but mostly winter-spring	Pack ice & pelagic	NS	NC; MPC
Hooded Seal (*Cystophora cristata*)	Common	Year-round, but mostly winter-early spring	Pack ice & pelagic	NS	NAR; MPC
Bearded Seal (*Erignathus barbatus*)	Uncommon	Year-round	Coastal, shallow & ice edge	NS	DD; MPC
Grey seal (*Halichoerus grypus*)	Rare	Summer?	Coastal & shelf	NS	NAR
Ringed Seal (*Phoca hispida*)	Common	Winter-spring?	Landfast ice with snow cover	NS	NAR; HPC
Polar Bear					
Polar Bear (*Ursus maritimus*)	Uncommon	Winter-summer	Coastal & pack ice	Schedule 1: Special Concern	SC

Note: ? indicates uncertainty.
[a] Species designation under the Species at Risk Act (Government of Canada 2012); NS = No Status.
[b] Species designation under COSEWIC (COSEWIC 2013); E = Endangered, SC = Special Concern, DD = Data Deficient, NAR = Not at Risk, NC = Not Considered, LPC = Low-priority Candidate, MPC = Mid-priority Candidate, HPC = High-priority Candidate.
[c] Refers to the Scotian Shelf population, but it is unclear to which population animals in the Project Area belong. The Davis Strait-Baffin Bay-Labrador Sea population has no status under *SARA* but is considered *special concern* under COSEWIC.
[d] Population affiliation is unclear, but individuals presumably represent the Ungava Bay and/or Eastern Hudson Bay populations (DFO 2005b).

Opportunistic sightings are available, but there have been few systematic surveys of marine mammals offshore of Labrador. LGL Limited conducted aerial surveys for marine mammals and seabirds in the southern Labrador Sea offshore and coastal areas as one component of the Offshore Labrador Biological Studies (OLABS) from 1981 to 1982 (McLaren et al. 1982). Seasonal surveys ranged from the Makkovik Bank in the north to Cape Freels in the south (between 56ºN and 49.15ºN and west to 52ºW). A number of marine mammal species were observed during the OLABS surveys in the southern Labrador Sea, including:

- Minke whale
- Fin whale
- Humpback whale
- Sperm whale
- Northern bottlenose whale (tentatively identified)
- Beluga whale
- Atlantic (long-finned) pilot whale
- Killer whale
- Atlantic white-sided dolphin
- White-beaked dolphin
- Habour porpoise
- Harbour seal
- Harp seal
- Bearded seal
- Hooded seal

Humpback whales were the most abundant of the baleen whale species observed, while pilot whales and unidentified dolphins were the most common toothed whales recorded. A high density of harp seals (~60,000 seals) was recorded, all in late winter to early spring (McLaren et al. 1982).

Marine mammal monitoring was also conducted by Geophysical Survey Inc. (GSI) during 2004 and 2005 geophysical surveys over the Labrador Shelf. Fisheries Liaison Officers (FLOs) served as Marine Mammal Observers (MMOs) during the surveys. From late July to early October 2004, there were 22 cetacean sightings totaling ~260 individuals and pilot whales were the most frequently observed species (as described in Canning and Pitt 2007). From mid-June to mid-October 2005, FLOs recorded 63 cetacean sightings of ~297 individuals and pilot whales were again the most frequently recorded species (as described in Canning and Pitt 2007). Recorded species from the 2004 and 2005 surveys included:

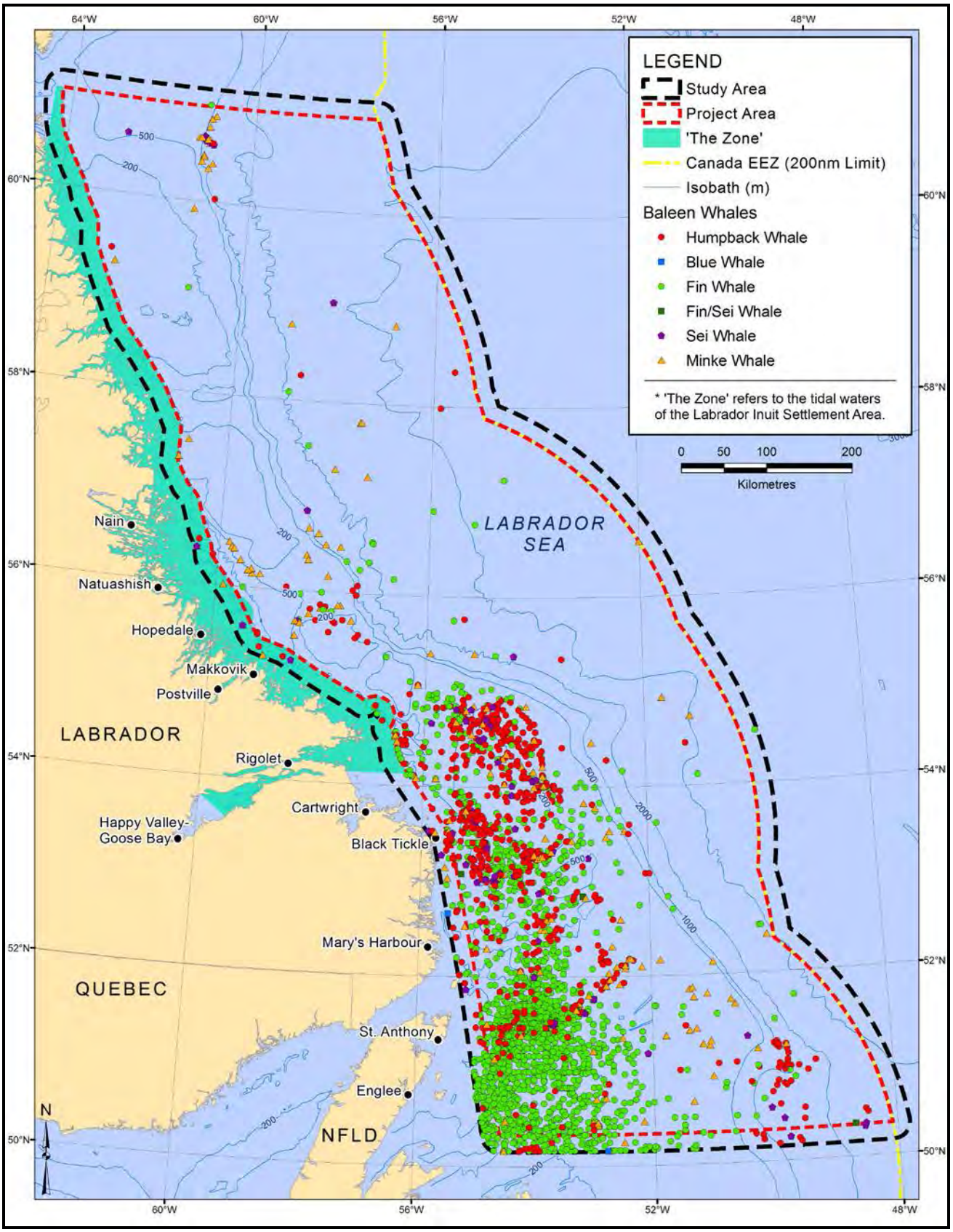
- Humpback whale
- Fin whale
- Minke whale
- Sperm whale
- Pilot whale
- Killer whale
- Atlantic white-sided dolphin

- White-beaked dolphin
- Harbour porpoise
- Unidentified dolphin
- Unidentified whale

Lawson and Gosselin (2009) provided preliminary minimum abundance estimates, without the application of correction factors, for the most frequently sighted cetacean species detected during aerial surveys from Nova Scotia to Labrador during the summer of 2007. A total of 741,699 km^2 were surveyed off southern and eastern Newfoundland and off Labrador from 17 July to 24 August 2007, yielding a total of 584 cetacean sightings or a density of 0.0008 sightings/km^2. There were 19 sightings along the Labrador coast, but these were too few to obtain reliable abundance estimates in the Labrador stratum. However, the authors note that marine fauna were generally reported later in 2007 than in previous years, suggesting that lower densities of animals than usual may have been encountered during the Labrador portion of the survey. During 5,363 km of on-effort trackline in Labrador, there were sightings of beluga whale, common dolphin, fin whale, minke whale, northern bottlenose whale, pilot whale, white-sided dolphin, unidentified large whale, and unidentified dolphin. There were a total of four or less sightings of each species. The spatial distribution of sightings by species was not provided, so it is unclear how animals were distributed with respect to the location of the Project Area, distance to shore, or water depth.

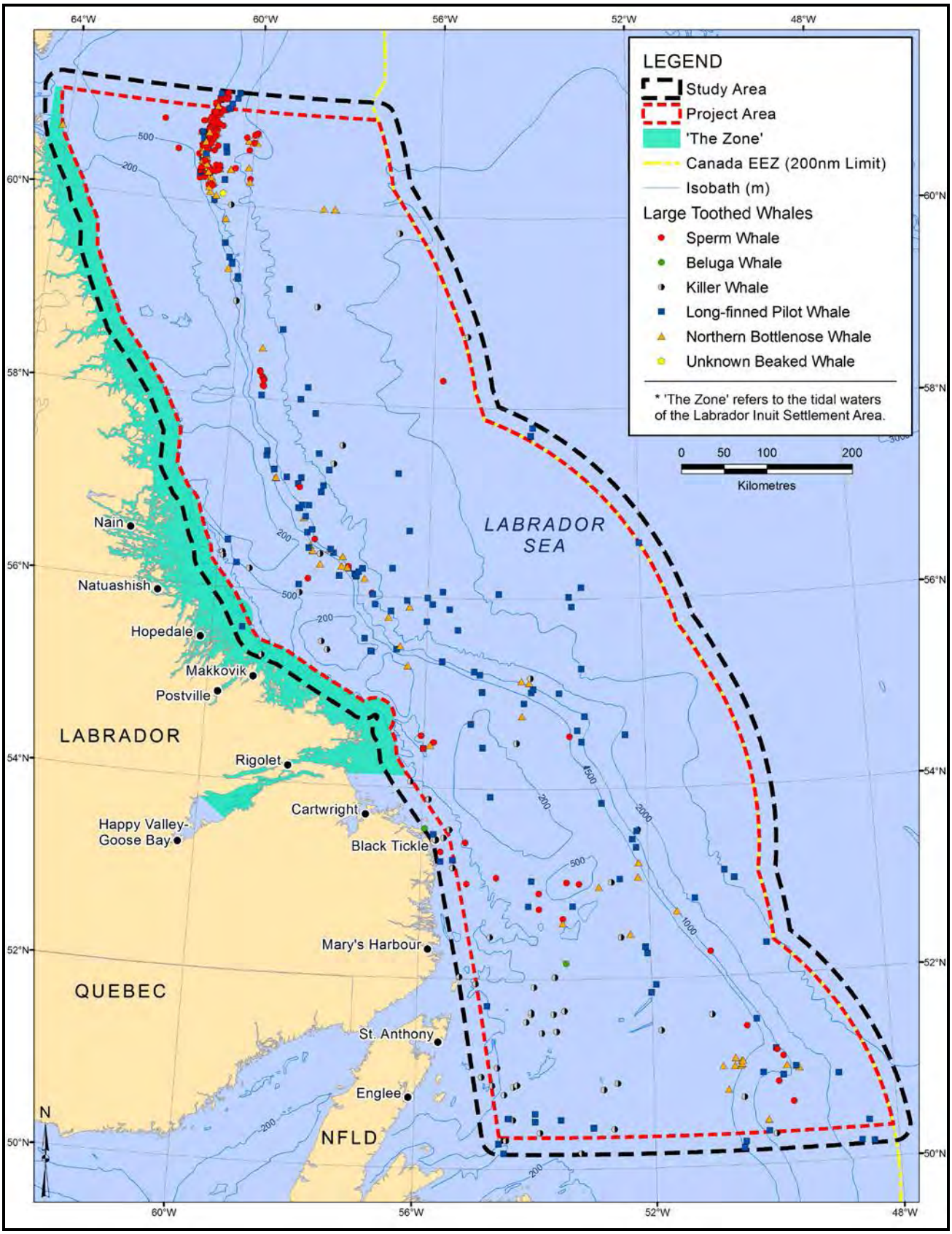
Earlier versions of a cetacean sightings database compiled by DFO in St. John's were summarized in Canning and Pitt (2007) and the Labrador Shelf SEA. The following summary provides an updated review of these data. A large database of cetacean sightings in Newfoundland and Labrador waters has been compiled by DFO in St. John's (J. Lawson, DFO Research Scientist, pers. comm. 2013) 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 provide fine-scale descriptions or predictions of abundance or distribution. The summary of sightings below combines the data sources described above as well as historical and recently added sightings from commercial whaling, fisheries observers, and the general public. Within the Study Area, sighting dates ranged from 1894 to 2007 and included baleen whales (Figure 4.44), toothed whales (Figure 4.45), and delphinids and porpoises (Figure 4.46); sightings are summarized in Table 4.13. A number of *caveats* should be noted when considering the DFO cetacean sightings data, including:

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),



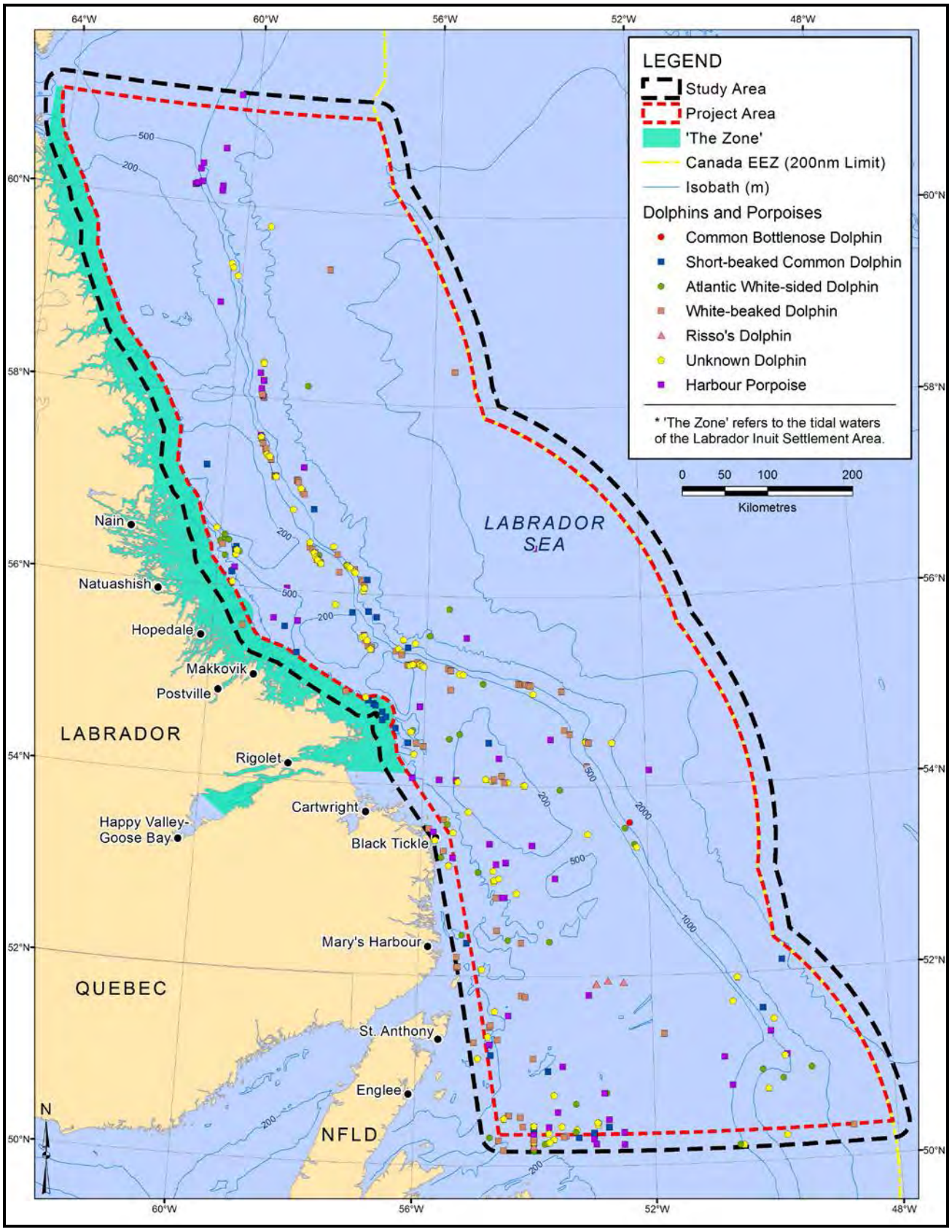
Source: DFO cetacean sightings database, see text for description of data and *caveats* associated with these data.

Figure 4.44 Baleen Whale Sightings in the Study Area.



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

Figure 4.45 Toothed Whale Sightings in the Study Area.



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

Figure 4.46 Delphinid and Porpoise Sightings in the Study Area.

Table 4.13 Cetacean Records that Occurred within the Offshore Labrador Study Area, Dating from 1894 to 2007.

Species	Number of Sightings	Minimum Number of Individuals	Months Sighted
Mysticetes			
Fin whale	251	948	May to Dec
Humpback whale	1004	7995	April to Jan
Minke whale	191	392	April to Jan
Sei whale	66	169	May to Dec
Blue whale	2	2	July to Aug
Odontocetes			July, Aug, Oct
Sperm whale	169	546	June, July to Oct
Northern bottlenose whale	116	564	April to Dec
Killer whale	63	523	March to Dec
Pilot whale	162	3029	Jan to Dec
Common dolphin	37	605	July to Sept, Nov
Atlantic white-sided dolphin	48	621	June to Dec
White-beaked dolphin	119	801	July to Nov
Unidentified dolphin	110	720	Jan, June to Nov
Harbour Porpoise	46	269	July to Dec
Other			
Unidentified large whale	133	633	April to Dec
Unidentified small whale	7	25	May, Aug, Oct, Nov
Unidentified whale	104	597	Feb, April to Dec

Source: DFO (see text for description and *caveats* associated with these data).

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.

Baleen Whales (Mysticetes)

Five species of baleen whales occur in the Project Area, including the *SARA*-listed blue whale (*endangered*, Schedule 1) and fin whale (*special concern*, Schedule 1) described in the Species at Risk section (Section 4.6). Although some individuals may be present in offshore waters of Newfoundland and Labrador year-round, most baleen whale species presumably migrate to lower latitudes during winter months.

Blue Whale

The Atlantic population of blue whale is discussed in Section 4.6 on Species at Risk. The blue whale is currently designated as *endangered* under Schedule 1 of *SARA* and by COSEWIC (see Table 4.15 in Section 4.6).

Fin Whale

The Atlantic population of fin whale is discussed in Section 4.6. The fin whale is currently designated as *special concern* under Schedule 1 of *SARA* and by COSEWIC (see Table 4.15 in Section 4.6).

Humpback Whale

The humpback whale is cosmopolitan in distribution and is most common over the continental shelf and in coastal areas (Jefferson et al. 2008). There are an estimated 11,570 individuals in the N Atlantic (Stevick et al. 2003). In eastern Canada, humpback whales are listed as *special concern* under Schedule 3 of *SARA* and are considered *not at risk* by COSEWIC. Humpback whales migrate annually from high-latitude summer foraging areas to Caribbean breeding grounds in the winter. Primary feeding areas in the N Atlantic have been described using genetic and individual identification data as the Gulf of Maine, eastern Canada, west Greenland, and the NE Atlantic (Stevick et al. 2006). Humpback whales are common over the banks and nearshore areas of Newfoundland and Labrador from June through September, sometimes forming large aggregations to feed primarily on spawning capelin, sand lance, and krill. During aerial surveys in August 1980, Hay (1982) estimated a density of 0.0282 humpbacks per n.mi.^{2} (0.0082 humpbacks per km^2) or a total of ~214 animals in an area offshore of central Labrador. The Labrador Shelf SEA (Sikumiut 2008) suggests that primary feeding areas for humpbacks are likely found along the shoreline from Hudson Strait to the southern coast of Newfoundland; this is supported by extensive sightings (n = 1004) over the continental shelf in the Study Area, especially off southern Labrador from July through November, based on the DFO cetacean sightings database (Figure 4.44). During surveys of sub-Arctic North Atlantic waters, humpback whales were sighted off Labrador and the east coast of Newfoundland (Compton et al. 2007). Clapham et al. (1993) noted 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. Based on the DFO cetacean sightings database, the humpback whale was the most frequently sighted cetacean within the Study Area.

Sei Whale

Sei whale distribution is poorly known, but it occurs in all oceans and it appears to prefer mid-latitude temperate waters (Jefferson et al. 2008). There is no current population estimate for the N Atlantic, but 1,400 to 2,250 individuals were estimated to use the NW Atlantic based on catch data collected during commercial whaling (COSEWIC 2003b). In the Canadian Atlantic, sei whales have no status under *SARA* and are considered *data deficient* by COSEWIC. Sei whales appear to prefer offshore, pelagic, deep areas that are often associated with the shelf edge, and feed primarily on copepods (COSEWIC 2003b).

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). However, there are numerous observations in the region according to the Labrador Shelf SEA, and there were 66 sightings of sei whales in the Study Area based on the DFO cetacean sightings database (Figure 4.44). Most sightings were made during August through October within the 500-m isopleth off southern Labrador, but some sightings were made in deeper water farther offshore. According to Prieto et al. (2010), the Labrador Sea appears to be an important feeding area for sei whales from the NE Atlantic. One sei whale that was tagged in the Azores during 2005 (Olsen et al. 2009) and seven individuals that were tagged in the Azores during 2008–2009 travelled to the Labrador Sea, where they spent extended periods of time on the northern shelf, presumably to feed (Prieto et al. 2010).

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). There are four populations recognized in the N Atlantic, including the Canadian east coast, west Greenland, central N Atlantic, and NE Atlantic stocks (Donovan 1991). There are an estimated 8,987 individuals in the Canadian east coast stock, which ranges from the Gulf of Mexico to the western half of Davis Strait (Waring et al. 2011). Minke whales have no status under *SARA* and are considered *not at risk* in the Atlantic by COSEWIC. 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 typically remaining as late as October and November; however, some may stay through the winter (see Labrador Shelf SEA (Sikumiut 2008)). Minke whale sightings are common in the Study Area; according to the DFO cetacean sightings database, there were 189 sightings from April to December and two sightings during January (Figure 4.44). During August–September surveys of sub-Arctic North Atlantic waters, minke whales were sighted in the Strait of Belle Isle and off the east coast of Newfoundland (Compton et al. 2007). Minke whales were also sighted four times in the Labrador stratum during DFO's 2007 aerial survey (Lawson and Gosselin 2009). In a study off northern Newfoundland and southern Labrador, Perkins and Whitehead (1977) most frequently observed minkes occurring singly, but groups of up to five individuals were also often encountered. 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).

Toothed Whales (Odontocetes)

Nine species of toothed whales occur in the Project Area (see Table 4.12), ranging from the largest of odontocetes, the sperm whale, (~18 m for an adult male; Reeves and Whitehead 1997) to one of the smallest, the harbour porpoise (~1.6 m for an average adult (COSEWIC 2006b)). Many of these species seem to be present in the Labrador Sea only seasonally, but there is generally little information on the distribution and abundance of these species. The northern bottlenose whale (Scotian Shelf population) is designated as *endangered* on Schedule 1 of *SARA*, Sowerby's beaked whale is considered of *special concern* (Schedule 1), and the harbour porpoise is considered as *threatened* (Schedule 2); all are described in detail in Section 4.6. In addition, the beluga whale is considered *endangered*, the killer

whale is considered *special concern*, and the sperm whale is designated as a *low priority candidate species* by COSEWIC, but none are designated under *SARA* (all are described in Section 4.6).

Northern Bottlenose Whale

Northern bottlenose whale is discussed in Section 4.6 on Species at Risk. The Scotian Shelf population of northern bottlenose whale is designated *endangered* under Schedule 1 of *SARA* and by COSEWIC (see Table 4.15 in Section 4.6). The Davis Strait-Baffin Bay-Labrador Sea population has no status under *SARA* but is considered of *special conern* by COSEWIC. It is unclear whether northern bottlenose whales occurring in the Study Area belong to the Davis Strait population, Scotian Shelf population, or both.

Sowerby's Beaked Whale

Sowerby's beaked whale is discussed in Section 4.6 on Species at Risk. Sowerby's beaked whale is considered as *special concern* under Schedule 1 of *SARA* and by COSEWIC (see Table 4.15 in Section 4.6).

Harbour Porpoise

Harbour porpoises occur in continental shelf regions of the northern hemisphere; in the NW Atlantic, they occur from Baffin Island to New England (Jefferson et al. 2008). There are at least three populations recognized in the NW Atlantic: eastern Newfoundland and Labrador, the Gulf of St. Lawrence, and the Gulf of Maine/Bay of Fundy (Palka et al. 1996). There are currently no range-wide population estimates for eastern Canada, largely due to a lack of any estimates for the Newfoundland and Labrador sub-population (COSEWIC 2006b).

In the Atlantic, harbour porpoises are considered *threatened* (Schedule 2) on *SARA* and of *special concern* by COSEWIC (see Table 4.15 in Section 4.6). 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 from the driftnet fishery also indicate that harbour porpoises occur over the continental shelf and as far north as Nain and the Labrador Sea (Stenson et al. 2011). Harbour porpoises were also regularly reported as bycatch in waters >2000 m deep in the Labrador Sea (Stenson et al. 2011). Harbour porpoises have also been sighted along the 1,000 m depth contour on the Canadian side of Davis Strait between 58ºN to 61º15'N (COSEWIC 2006b). In general, harbour porpoises are primarily observed over continental shelves and in areas with coastal fronts or upwelling that concentrate small schooling fish, although sightings also occasionally occur in deeper waters (Read 1999). Bycaught porpoises in Newfoundland appear to primarily consume capelin, Atlantic herring, sand lance, and lantern fish (COSEWIC 2006b). Harbour porpoises typically occur singly or in small groups of up to three individuals, occasionally occurring in larger groups (COSEWIC 2006b). The Labrador Shelf SEA indicates that harbour porpoises are most likely to occur in the Labrador Sea from spring to fall. There were 46 harbour porpoise sightings in the

Study Area during May through December in the DFO cetacean sightings database, with some sightings in water >2,000 m deep (Figure 4.46).

Beluga Whale

Belugas occurring in offshore Labrador waters are likely members of either the Ungava Bay or eastern Hudson Bay populations (COSEWIC 2004). Both populations are small; the Ungava Bay population is too small to estimate and might have been *extirpated* while the eastern Hudson Bay population includes ~2000 individuals (COSEWIC 2004). Both populations are designated as *endangered* by COSEWIC and neither is currently designated on Schedule 1 of *SARA* (see Table 4.15 in Section 4.6).

Beluga whales have a circumpolar distribution, being found in Arctic waters of Alaska, Canada, Greenland, Russia, and Norway (Jefferson et al. 2008). Based on distinct summer distributions and genetic isolation, seven populations are recognized in Canada with animals occurring offshore of Labrador likely representing either the Ungava Bay or eastern Hudson Bay populations (COSEWIC 2004). Both populations are small; the Ungava Bay population is too small to estimate and might have been *extirpated* while the eastern Hudson Bay population includes ~2000 individuals (COSEWIC 2004). Although they have no status under *SARA*, the Ungava Bay and Eastern Hudson Bay populations of belugas are currently considered *endangered* by COSEWIC.

Belugas were considered common in northern Labrador coastal waters during summer months until the 1950s, but are now considered scarce and are reported occasionally each summer (COSEWIC 2004). However, two satellite-tagged individuals from the eastern Hudson Bay population were tracked to positions near Nain, Labrador in January (Lewis et al. 2003 *in* COSEWIC 2004), and DFO (2005b) suggests that eastern Hudson Bay animals overwinter along the Labrador coast. Beluga whales migrate between open-water overwintering areas to spring and summer calving and foraging areas, typically close to river estuaries or located in offshore areas. In the fall, they may forage intensively in deep-water areas offshore, eating a variety of fish and invertebrates (COSEWIC 2004). There were four beluga whale sightings (of 89 individuals) during a summer 2007 aerial survey offshore of Labrador (Lawson and Gosselin 2009). The DFO cetacean sightings database has two records of beluga within the southwestern portion of the Study Area, one in July and one in September (Figure 4.45).

Killer Whale

Killer whales have a cosmopolitan distribution and occur in all oceans from polar pack ice to the equator, but they appear to be most common in coastal areas of higher latitudes (Jefferson et al. 2008). Killer whales offshore of Labrador and eastern Newfoundland are likely members of the NW Atlantic/ eastern Arctic population, which is categorized as *special concern* by COSEWIC but has no status under *SARA* (see Table 4.15 in Section 4.6). The number of killer whales in the NW Atlantic/eastern Arctic population is unknown (COSEWIC 2008c), 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). 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. While sightings are also more common in coastal areas than offshore (Lawson et al. 2007), it is unclear whether this due to higher observer effort nearshore or a true representation of killer whale distribution. Based on the DFO cetacean sightings database, there have been 63 killer whale sightings in the Study Area from March to December, with most sightings occurring during July–September (Figure 4.45).

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). 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. Waring et al. (2009) reported an estimate of 4,804 animals for the U.S. Atlantic; no updates have been made to this estimate by Waring et al. (2012). Sperm whales have no status under *SARA* and are designated *not at risk* by COSEWIC. However, they are a *low priority candidate* species under COSEWIC (see Table 4.15 in Section 4.6). Large aggregations or small groups of females and juveniles occur in tropical and sub-tropical regions, but males are most common singly or in small same-sex groups occurring at higher latitudes (Whitehead 2003). Since males tend to range further north, sperm whales encountered in the Labrador Sea 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 are most likely to occur in deep water and high relief areas offshore of Labrador during summer months. They were the most frequently sighted toothed whale in the Study Area, based on the DFO cetacean sightings database; there were 172 sperm whale sightings, most occurring from July to October (Figure 4.45).

Long-finned Pilot Whale

The long-finned pilot whale is widespread in the N Atlantic and considered an abundant year-round resident of Newfoundland and Labrador (Nelson and Lien 1996). Although the total number of long-finned pilot whales off the east coast of the U.S. and Canada is uncertain, an estimated 12,619 individuals occur in the NW Atlantic (Waring et al. 2011). During an August 1980 aerial survey, Hay (1982) estimated a density of 0.0606 animals per n.mi.^{2} offshore of central Labrador. In the DFO cetacean sightings database, long-finned pilot whales were one of the most commonly identified toothed whales within the Study Area (n = 162), occurring year-round, but with most sightings occurring during

July and August (Figure 4.45). There were also three pilot whale sightings during a summer 2007 aerial survey in the Labrador stratum (Lawson and Gosselin 2009).

Long-finned pilot whales have no status under *SARA* and are considered *not at risk* by COSEWIC. Pilot whales studied near Nova Scotia have an average group size of 20 individuals, but groups range 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 are a primary prey item in Newfoundland, but they also consume other cephalopods and fish (Nelson and Lien 1996).

Atlantic White-sided Dolphin

Atlantic white-sided dolphins occur in temperate and sub-Arctic regions of the N Atlantic (Jefferson et al. 2008). There may be at least three distinct stocks in the N Atlantic, including the Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea areas, which combined are estimated to total ~23,390 animals in the NW Atlantic (Waring et al. 2011); however, their abundance off Labrador and eastern Newfoundland is unknown. Atlantic white-sided dolphins have no status under *SARA* and are considered *not at risk* by COSEWIC. Atlantic white-sided dolphins occur regularly from spring to fall in offshore areas of Newfoundland and Labrador, but less is known of their winter distribution. Sightings in the N Atlantic seem to coincide with the 100-m depth contour and areas of high relief (see Labrador SEA (Sikumiut 2008)). Based on bycatch data from 1965–2001, white-sided dolphins were the most frequently caught species in the Labrador Sea during July–October; spring bycatch rates were much lower (Stenson et al. 2011). There were 48 sightings in the DFO cetacean sightings database in the Study Area from June through December (Figure 4.46). There was a single August sighting during a summer 2007 aerial survey offshore of Labrador (Lawson and Gosselin 2009). 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, averaging 52.4 (Weinrich et al. 2001).

White-beaked Dolphin

White-beaked dolphins have a more northerly distribution than most dolphin species, occurring in cold temperate and sub-Arctic waters of the N Atlantic (Jefferson et al. 2008). Waring et al. (2009) estimated a total of 2003 individuals in the N Atlantic; this total was not updated by Waring et al. (2011). It is unknown how many occur off Labrador and northeastern Newfoundland, but based on ship-board surveys undertaken in the summer of 1982, Alling and Whitehead (1987) provided an abundance estimate of 3486 white-beaked dolphins for Labrador. White-beaked dolphins have no status under *SARA* and are considered *not at risk* by COSEWIC. According to the Labrador Shelf SEA, sightings of white-beaked dolphins are generally common in the Study Area. In the DFO cetacean sightings database, 119 sightings were made in the Study Area from July through November, but especially during August (Figure 4.46), although none were seen during a summer 2007 aerial survey offshore of Labrador (Lawson and Gosselin 2009). 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).

Short-beaked Common Dolphin

The short-beaked common dolphin is widely distributed over the continental shelf in temperate, tropical and subtropical regions (Jefferson et al. 2008). An estimated 120,743 individuals reside in the NW Atlantic (Waring et al. 2011), but an unknown number are found in eastern Canada (Gaskin 1992). Short-beaked common dolphins form groups ranging in size from several dozens to over 10,000, often moving rapidly and displaying many aerial behaviours such as porpoising and bowriding (Jefferson et al. 2008). They are found in a variety of habitats, ranging from 100 to 2,000 m deep, but appear to prefer areas with high seafloor relief (Selzer and Payne 1988) and are often associated with features of the Gulf Stream (Hamazaki 2002). The abundance and distribution of short-beaked common dolphins also coincides with peaks in abundance of mackerel, butterfish and squid (Selzer and Payne 1988). Gaskin (1992) indicated that common dolphins can be abundant off the coast of Nova Scotia and Newfoundland for a few months during the summer. There were 37 sightings of common dolphins reported in the DFO cetacean sightings database in the Study Area, mainly during July to September (Figure 4.46).

True Seals (Phocids)

Six species of seals occur in the Project Area (see Table 4.13). None of these species are designated under *SARA*. However, harp, hooded and bearded seals are considered *mid priority candidate species*. Ringed seal is considered a *high priority candidate species* by COSEWIC; these four species are summarized in Section 4.6.

Ringed Seal

Ringed seals are an ice-associated seal with a circumpolar distribution throughout the Arctic, occurring in areas with seasonal ice cover (Jefferson et al. 2008). They occasionally range as far south as northern Newfoundland. There is limited abundance information for ringed seals due to difficulties in accurately surveying ringed seals, but there are an estimated 1.3 million individuals in an area that includes the eastern Canadian Arctic, Labrador Sea, and west Greenland (NAMMCO n.d.). Ringed seals are the most abundant seal species in northern Labrador and are considered common throughout their range (Stenson 1994). Ringed seals have no status under *SARA* and are considered *not at risk* by COSEWIC, although they are currently a *high priority candidate* species (see Table 4.15 in Section 4.6). Ringed seals prefer annual landfast ice with extensive snow cover, but also occur in offshore pack ice; pupping occurs in late winter to early spring using snow lairs built above the ice next to a breathing hole (Smith and Stirling 1975). Moulting occurs on the ice following the spring breeding season until ice breakup, and intensive feeding occurs from late July through October in pelagic areas or among pack ice (Smith and Hammill 1981 *in* the Labrador Shelf SEA (Sikumiut 2008)). Ringed seals eat a variety of crustaceans, as well as Arctic cod, capelin, and sand lance (NAMMCO n.d.).

Harp Seal

Harp seals occur in the N Atlantic and Arctic oceans, from the Gulf of St. Lawrence to Russia (Jefferson et al. 2008). They are considered the most abundant seal in the NW Atlantic. Based on survey data, the population size for eastern Canada was estimated at 8.3 million harp seals for 2008 (DFO 2012c). Since reproductive rates declined after 2008, the population size for 2012 was estimated to be 7.7 million (DFO 2012c). COSEWIC has not yet considered the status of harp seals, but they are a *mid priority candidate* species with no status under *SARA* (see Table 4.15 in Section 4.6). Harp seals are common during spring off northeast Newfoundland and southern Labrador where they congregate to breed and pup on the pack ice; the majority of the NW Atlantic population uses this region while the small remainder uses the Gulf of St. Lawrence (Lavigne and Kovacs 1988). Harp seals migrate to Arctic and Greenland waters during summer, while offshore areas of southern Labrador and eastern Newfoundland appear to be major wintering areas (Stenson and Sjare 1997; Lacoste and Stenson 2000). Off 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 N Atlantic, ranging from Nova Scotia to the high Arctic in Canada (Jefferson et al. 2008). There are an estimated 593,500 individuals in the Canadian Atlantic, the majority of which (~535,800 animals) whelp and breed in the pack ice off northeast Newfoundland/southern Labrador in late winter-early spring (Hammill and Stenson 2006). Hooded seals have no status under *SARA* and are considered *not at risk* by COSEWIC; however, they are currently a *mid priority candidate* species. Four primary pupping and mating areas occur in the N Atlantic and include northeast Newfoundland/southern Labrador, the Gulf of St. Lawrence, Davis Strait, and northeast Greenland (Jefferson et al. 2008). Hooded seals aggregate in eastern Greenland to moult during early summer before dispersing to Davis Strait or the Greenland Sea for late summer and fall (see Hammill and Stenson 2006). Less is known about winter distribution, although there have been winter sightings on the Grand Banks; recent telemetry data suggests that hooded seals move along the continental shelf edge after leaving Greenland moulting grounds to Davis Strait and Baffin Bay followed by southerly migrations into the Labrador Sea during winter (Andersen et al. 2009). Hooded seals consume benthic invertebrates like shrimp, Greenland halibut, redfish, Arctic cod, and squid (Hammill and Stenson 2000).

Bearded Seal

The bearded seal is an ice-affiliated seal occurring throughout Arctic regions, mainly over the continental shelf and areas with moving ice or ice leads (Jefferson et al. 2008). An estimated 190,000 bearded seals may exist within the Canadian Arctic (Cleator 1996), but no estimates are available for Labrador waters. Bearded seals have no status under *SARA* and are considered *data deficient* by COSEWIC; however, they are a *mid priority candidate* species (see Table 4.15 in Section 4.6). Although they may remain in or near sea ice year-round, bearded seals are considered more pelagic during summer and fall (Laidre et al. 2008). There is little information on the distribution or movements of bearded seals in Labrador, but they appear to be found at low densities along the entire coast and

more common in northern portions (Stenson 1994; Cleator 1996). Bearded seals are benthic feeders, consuming a variety of crustaceans, mollusks, and some benthic fishes like sculpins, flatfish, and cod (see Labrador Shelf SEA for additional detail).

Harbour Seal

Although generally restricted to nearshore areas, the harbour seal has a widespread distribution in the northern hemisphere (Jefferson et al. 2008). Ranging from the U.S. east coast to Baffin Island and western Greenland, Waring et al. (2009) estimated that there were 99,340 individuals in the N Atlantic. However, as this estimate is based on survey data from 2001, it is deemed unreliable, and no current abundance estimate is available (Waring et al. 2011). There are few quantitative estimates of abundance for Labrador, but Sjare et al. (2005) suggest that areas along the coast south of Cartwright likely support the highest densities. In addition, little distribution information exists for harbour seals along the Labrador coast. Hunters have indicated the following areas contain concentrations of harbour seals: Paradise River, Double Mer Lake, an area near Cape Harrison north of Groswater Bay, bays near Hopedale, Sandy Island area near Natuashish, and river mouths and estuaries around Nain (Sjare et al. 2005). Harbour seals are likely year-round residents, occurring at low densities near coastal areas. Fish, shrimp, and squid are consumed by harbour seals in Newfoundland and Labrador, particularly cod, sand lance, capelin, and herring (Sjare et al. 2005). Harbour seals have no status under *SARA* and are considered *not at risk* by COSEWIC.

Grey Seal

Grey seals inhabit cold temperate to sub-Arctic regions of the N Atlantic, ranging in Canada from Nova Scotia to Labrador (Jefferson et al. 2008). An estimated ~300,000 grey seals occur in the NW Atlantic, with the majority breeding and moulting on Sable Island, south of Nova Scotia, over the winter and spring, respectively (Thomas et al. 2007). An unknown number range into eastern Newfoundland and Labrador. Grey seals have no status under *SARA* and are considered *not at risk* by COSEWIC. 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 presumably move northward, ranging occasionally into Labrador waters, from July to September (Stobo et al. 1990).

Polar Bear

The polar bear is discussed in Section 4.6, Species at Risk. The polar bear is listed as a species of *special concern* under Schedule 1 of *SARA*, and it is considered as *special concern* by COSEWIC (see Table 4.15 in Section 4.6).

4.5.2 Sea Turtles

Sea turtles are likely not common within the Labrador Sea, but three species could potentially occur within the Project Area. Table 4.14 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*; the loggerhead sea turtle is designated as *endangered* by COSEWIC, but it has no status under *SARA* (see Table 4.15 in Section 4.6; see Section 4.6, Species at Risk for profile).

The loggerhead sea turtle has no status under *SARA*, but it is designated as *endangered* by COSEWIC. There are no current population estimates for loggerhead turtles in Atlantic Canada (DFO 2010a). However, it is the most common sea turtle in North American waters, but rarely ventures as far north as Labrador (Spotila 2004), as it prefers water between 20–25°C (DFO 2010a). Adults can migrate considerable distances between near-equatorial nesting areas and temperate foraging areas (Hawkes et al. 2007). Loggerhads appear to move with the Gulf Stream into eastern Canada waters during summer, especially the Scotian Shelf, Georges Bank and Grand Banks from July through October (Smith 2001, 2002 *in* Brazner and McMillan 2008; Javitech 2002, 2003 *in* Brazner and McMillan 2008). In the NW Atlantic, thousands of mostly immature loggerheads have been bycaught in the Canadian pelagic longline fishery since 1999 (Brazner and McMillan 2008). While foraging at sea, loggerheads likely consume gelatinous zooplankton and squid (Spotila 2004).

Table 4.14 Sea Turtles Potentially Occurring in the Labrador Shelf Study Area.

Species	Project Area		*SARA* Status[a]	COSEWIC Status[b]	Activities	Habitat
	Occurrence	Timing				
Leatherback sea turtle	Rare	June to Nov	Schedule 1: Endangered	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

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

Kemp's Ridley sea turtle has no status under *SARA* and has not been considered by COSEWIC. The Kemp's Ridley sea turtle is restricted in its 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 off Labrador.

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). The information provided in this section is current as of March 2013 on the websites for *SARA* (http://www.sararegistry.gc.ca/default_e.cfm) and COSEWIC (http://www.cosepac.gc.ca/index.htm).

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. Nonetheless, attention must be paid to all of the *SARA*-listed species because of their sensitivities to perturbation and the potential for status upgrades. 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 4.15 in Section 4.6 of this EA. Atlantic wolffish (*Anarhichas lupus*), the Atlantic population of fin whales (*Balaenoptera physalus*), Sowerby's beaked whale (*Mesoplodon bidens*), polar bear (*Ursus maritimus*), Harlequin Ducks, and Barrow's Goldeneye are designated as *special concern* on Schedule 1 (Table 4.15). 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 4.15 as *endangered*, *threatened* or species of *special concern* under COSEWIC. Other non-*SARA* listed marine species that potentially occur in the Study Area and are listed by COSEWIC as *candidate species* are also included in Table 4.15.

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 Project Area: (1) the leatherback sea turtle (ALTRT 2006); (2) the spotted wolffish (Kulka et al. 2008), (3) the northern wolffish (Kulka et al. 2008), (4) the blue whale (Beauchamp et al. 2009), and (5) the Scotian Shelf population of the northern bottlenose whale (DFO 2010b). A recovery strategy has also been proposed for the Ivory Gull (Environment Canada 2013c). In addition, management plans have been prepared for the Atlantic wolffish (Kulka et al. 2008), Harlequin Duck (Environment Canada 2007), and Barrow's Goldeneye (Environment Canada 2013d); all currently designated as *special concern* on Schedule 1.

GXT will monitor *SARA* issues through 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. GXT will continue to exercise due caution to minimize impacts on these species during all of its operations. GXT also understands that other marine species might be designated as *endangered* or *threatened* on Schedule 1 during the course of the Project (2013-2015), and will continue to monitor any status changes.

Species profiles and any related special or sensitive habitats are described in the following sections.

Table 4.15 *SARA* Schedule 1 and COSEWIC-listed Marine Species that Potentially Occur in the Study Area.

Species		***SARA* Schedule 1**			**COSEWIC**			
Common Name	**Scientific Name**	***Endangered***	***Threatened***	***Special Concern***	***Endangered***	***Threatened***	***Special Concern***	***Candidate Species***
Blue whale	*Balaenoptera musculus*	X			X			
Northern bottlenose whale (Scotian Shelf population)	*Hyperoodon ampullatus*	X			X			
Leatherback sea turtle	*Dermochelys coriacea*	X			X			
Ivory gull	*Pagophila eburnea*	X			X			
White shark	*Carcharodon carcharias*	X			X			
Northern wolffish	*Anarhichas denticulatus*		X			X		
Spotted wolffish	*Anarhichas minor*		X			X		
Atlantic wolffish	*Anarhichas lupus*			X			X	
Fin whale (Atlantic population)	*Balaenoptera physalus*			X			X	
Sowerby's beaked whale	*Misoplodon bidens*			X			X	
Polar bear	*Ursus maritimus*			X			X	
Harlequin Duck	*Histrionicus histrionicus*			X			X	
Barrow's Goldeneye	*Bucephala islandica*			X			X	
Loggerhead sea turtle	*Caretta caretta*				X			
Atlantic cod (NL[a] population)	*Gadus morhua*				X			
Porbeagle shark	*Lamna nasus*				X			
Roundnose grenadier	*Coryphaenoides rupestris*				X			
Atlantic salmon (various populations)	*Salmo salar*				X	X	X	
Beluga (Eastern Hudson Bay population)	*Delphinapterus leucas*				X			
Beluga (Ungava Bay population)	*Delphinapterus leucas*				X			
Cusk	*Brosme brosme*				X			
American plaice (NL[a] population)	*Hippoglossoides platessoides*					X		
American eel	*Anguilla rostrata*					X		
Acadian redfish	*Sebastes fasciatus*					X		
Deepwater redfish	*Sebastes mentella*					X		
Northern bottlenose whale (Davis Strait-Baffin Bay-Labrador Sea population)	*Mesoplodon bidens*						X	

Species		*SARA* Schedule 1			COSEWIC			
Common Name	**Scientific Name**	***Endangered***	***Threatened***	***Special Concern***	***Endangered***	***Threatened***	***Special Concern***	***Candidate Species***
Harbour porpoise	*Phocoena phocoena*						X	
Killer whale (NW Atlantic/E Arctic populations)	*Orcinus orca*						X	
Blue shark	*Prionace glauca*						X	
Roughhead grenadier	*Macrourus berglax*						X	
Spiny dogfish	*Squalus acanthias*						X	
Ringed seal	*Phoca hispida*							High priority
Lumpfish	*Cyclopterus lumpus*							High priority
Hooded seal	*Cystophora cristata*							Mid priority
Harp seal	*Phoca groenlandica*							Mid priority
Bearded seal	*Erignathus barbatus*							Mid priority
Spinytail skate	*Bathyraja spinicauda*							Mid priority
Pollock	*Pollachius virens*							Mid priority
Greenland shark	*Somniosus microcephalus*							Mid priority
Sperm whale	*Physeter macrocephalus*							Low priority

Sources: *SARA* website (http://www.sararegistry.gc.ca/default_e.cfm) (as of March 2013); COSEWIC website (http://www.cosepac.gc.ca/index.htm) (as of March 2013).

[a]Newfoundland and Labrador.

4.6.1 Profiles of *SARA* Schedule 1 Species/Populations

Only those species/populations that are listed under *SARA* Schedule 1 as *endangered*, *threatened* or *special concern* are profiled in detail in this section. Other marine animals listed in Table 4.15 are described in Section 4.0, Biological Environment.

4.6.1.1 Blue Whale

The blue whale has a cosmopolitan distribution, but tends to be more frequently observed in deep water than in coastal environments (Jefferson et al. 2008). Blue whales became severely depleted during industrial whaling and still occur at relatively low densities in the N Atlantic. The Atlantic population of blue whales is considered *endangered* on *SARA* Schedule 1 and by COSEWIC. Blue whales likely number in the low hundreds in the NW Atlantic (COSEWIC 2002); the recovery strategy for blue whales in the NW Atlantic notes a long-term recovery goal of 1,000 mature individuals through the achievement of three 5-year objectives (Beauchamp et al. 2009). No Critical Habitat was identified. Blue whales have been sighted only sporadically off the Labrador coast (COSEWIC 2002). However, resightings of an individual support one proposed hypothesis that blue whales from eastern Canada migrate in the spring to Davis Strait (COSEWIC 2002). According to the Labrador Shelf SEA, there have been rare sightings of blue whales off Labrador, although this may at least partially be attributable to poor observer coverage in the Project Area. In the DFO cetacean sightings database, there were only two records of blue whales in the southwestern portion of the Study Area (Figure 4.44), but there is also likely reduced effort offshore of Labrador. Blue whales feed primarily on krill and their distribution is often associated with areas of upwelling or shelf edges where their prey may concentrate. The Labrador Shelf SEA suggests that blue whales are likely to occur on the Labrador Shelf in late winter and spring, but have been sighted in the region year-round.

4.6.1.2 Northern Bottlenose Whale

The distribution of northern bottlenose whales is restricted to the N Atlantic, primarily in deep, offshore areas with two regions of concentration: the Gully and adjacent submarine canyons on the eastern Scotian Shelf, and Davis Strait off northern Labrador (Reeves et al. 1993). Throughout their range, including Labrador, northern bottlenose whales were harvested extensively during industrial whaling, which likely greatly reduced total numbers (COSEWIC 2011). The total abundance of northern bottlenose whales in the N Atlantic is unknown. However, Whitehead and Wimmer (2005) estimated that ~163 individuals comprise the Scotian Shelf population; the most recent estimate is ~164 individuals (COSEWIC 2011). The size of the Baffin Bay-Davis Strait-Labrador Sea population is uncertain (COSEWIC 2011; Whitehead and Hooker 2012). The encounter rate during boat surveys was 0.03 encounters/h for the Labrador-Davis Strait population and 0.50 for the Gully (COSEWIC 2012 *as cited in* Whitehead and Hooker 2012).

The Scotian Shelf population is designated *endangered* under Schedule 1 of *SARA* (COSEWIC 2011). The recovery goal for this population it to "achieve a stable or increasing population and to maintain, at a minimum, current distribution" (DFO 2010b). The Davis Strait population has no status under *SARA* but is considered *special concern* by COSEWIC (2011). The Labrador population is considered to occur in the area year-round, with mating and births occurring from April to June, with a peak in April

(Benjaminsen 1972 *in* COSEWIC 2011). The calving season of the Scotian Shelf population peaks in August (Whitehead et al. 1997). No matches of photoidentified individuals have been made between the Scotian Shelf and the Baffin-Labrador populations (COSEWIC 2011), and nuclear and mitochondrial markers revealed very little interchange between these two populations (Dalebout et al. 2006). Occurring primarily in deep waters over canyons and the shelf edge, whales tagged on the Scotian Shelf routinely dove to depths over 800 m and remained submerged for over an hour (Hooker and Baird 1999). Foraging apparently occurs at depth, primarily on deep-water squid and fish (COSEWIC 2011).

Northern bottlenose whales are likely to occur at low densities, but year-round, throughout the deep, offshore waters of the Labrador Sea (see Labrador Shelf SEA). However, it is unclear to which population animals occurring in Labrador and Newfoundland, including the Study Area, belong (DFO 2011b). Based on the DFO cetacean sightings database, 116 groups of northern bottlenose whales have been sighted in the deeper waters and near the shelf break of the Study Area from April to December (Figure 4.45). There was also one northern bottlenose whale sighting (of a single animal) during a summer 2007 aerial survey offshore of Labrador (Lawson and Gosselin 2009; see Section 4.5).

4.6.1.3 Leatherback Sea Turtle

The largest and most widely ranging of sea turtles, the leatherback sea turtle, ranges from sub-polar and cool temperate foraging grounds to tropical and sub-tropical nesting areas in all of the world's oceans (Spotila 2004). Exhibiting wide-ranging oceanic movements, leatherbacks occur in pelagic regions of the N Atlantic to forage on gelatinous zooplankton (Hays et al. 2006). There are an estimated 34,000 to 94,000 leatherback adults in the North Atlantic (TEWG 2007), but there is no current estimate of the number of leatherbacks using eastern Canada waters (COSEWIC 2012). Nonetheless, James et al. (2006) suggested that Canadian waters support high densities of leatherbacks during the summer and fall, and that the Canadian waters should be considered critical foraging habitat for this species. Three primary habitats, likely used as foraging areas by leatherback turtles in Atlantic Canada, were identified using satellite tracking data: (1) the area near Georges Bank, (2) southeastern Gulf of St. Lawrence and waters east of Cape Breton, and (3) waters south and east of Burin Peninsula, Newfoundland (DFO 2011c). Leatherback sea turtles forage on jellyfish, such as lion's mane and moon jellyfish, in Atlantic Canadian waters; they consume an average of 330 kg wet mass of jellyfish per day (Heaslip et al. 2012).

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 observations occurring from ~July to October, with a peak in August and September (Goff and Lien 1988). Most sea turtles migrate southward by mid-October (James et al. 2007; Sherrill-Mix et al. 2008). James et al. (2006) noted that increasing sea surface temperatures in Canadian waters result in a significant increase in turtle sightings. DFO Newfoundland Region has maintained a database of leatherback turtle sightings and entanglements in Newfoundland and Labrador (J. Lawson, DFO Research Scientist, pers. comm.), but records for Labrador are rare; there is only one record in the DFO database of a leatherback turtle sighting in the Study Area off Labrador, at a latitude of 53ºN. Threlfall (1978) reported on the first record of a leatherback turtle from Labrador off Nain at 56º45'N.

4.6.1.4 Ivory Gull

Ivory Gull is designated *endangered* on Schedule 1 of *SARA*. The Ivory Gull nests at sites in the High Arctic. There are small, scattered colonies in the Canadian Arctic, Greenland, Spitsbergen and the northern islands and archipelagos of Russia in the Kara Sea. The current status of the global Ivory Gull population is poorly known. It is rare on a global scale with fewer than 14,000 pairs (COSEWIC 2006). The Canadian Arctic supports a significant but declining population of Ivory Gull. The Canadian breeding population was estimated at 2,400 individuals in the early 1980s (Thomas and MacDonald 1987). Extensive surveys of historic breeding sites and adjacent breeding habitat in 2002 and 2003 and interviews with Inuit residents indicate the breeding population in Canada has declined by 80% (Gilchrist and Mallory 2005). Currently, the Canadian breeding population is estimated at approximately 500 to 600 individuals, based on surveys conducted between 2002 and 2005. Reasons for the apparent decline of the Canadian breeding population are uncertain. The winter range of the Ivory Gull in the Northwest Atlantic is among sea ice from the Davis Strait south to about 50º to the Labrador Sea (Orr and Parsons 1982). In some years, this includes the Strait of Belle Isle, and northern Gulf of St. Lawrence, the east coast of Newfoundland particularly the Northern Peninsula of Newfoundland, and the Lower North Shore of Québec (COSEWIC 2006). The population that winters off the Labrador and northern Newfoundland coasts include Ivory Gulls breeding in the eastern Canadian Arctic, Greenland and Franz Josef Land, based upon banding recoveries and satellite transmitters (Tuck 1971, Gilg et al. 2010). Ten adult Ivory Gulls banded in early April 1964 and 1966 in the Labrador Sea were recovered shot in Greenland 2 to 17 years later (Lyngs 2003).

A recent marine bird survey conducted within the pack ice off the coast of Newfoundland and Labrador in March 2004 observed few Ivory Gulls (0.02 per 10 min watch), compared with 1978, when Ivory Gulls were commonly observed at that time of year in this region (0.69 per 10 min. watch; Stenhouse and Wells, unpubl. data *in* COSEWIC 2006). During the OLABS program in 1981 to 1982, twelve Ivory Gulls were observed on Makkovik Bank during 16-18 April 1981 (McLaren et al. 1983). Most of 150 Ivory Gulls recorded during surveys conducted off Labrador and northeast Newfoundland in the time period of 16-21 February 1982 were located on Makkovik and Hamilton Banks. In general, Ivory Gulls were observed where ice cover ranged from 26% to 75% especially at or near the edge of pack ice. Ivory Gull is known as ‘ice partridge’ to some residents of coastal Labrador and northern Newfoundland, indicating a regular presence in the winter months. The diet of Ivory Gull includes lanternfish and Arctic cod, crustaceans and carrion (Mallory et al. 2008). Ivory Gull are sometimes observed scavenging byproducts of the Newfoundland and Labrador seal hunt during late winter and spring.

Ivory Gull is probably present in globally significant numbers in the Study Area when pack ice is present or near the Study Area from December to April or May.

4.6.1.5 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 western N

Atlantic, Mediterranean Sea, southern Africa, southern Australia, New Zealand, and the eastern N 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 NE 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 NW 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 N 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 an orca preying on a white shark (*SARA* website accessed January 2012).

4.6.1.6 Wolffishes

Three species of wolffish (i.e., northern, spotted, and Atlantic) are the only fishes currently listed under Schedule 1 of *SARA*. Both the northern and spotted wolffishes are currently listed as *threatened* on Schedule 1 of *SARA* and under COSEWIC. The Atlantic wolffish is currently considered as *special concern* on Schedule 1 of *SARA* and under COSEWIC. A recovery strategy for northern and spotted wolffishes and a management plan for Atlantic wolffish were recently published (Kulka et al. 2008).

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 NE 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 2007-2011, 396 northern wolffish were caught, 97% of which were taken during the fall survey times (see Tables 4.2 and 4.3 in Section 4.2.2.4). Most of the northern wolfish were caught in the southern part of the Study Area at a variety of depths (see Figure 4.8 in Section 4.2.2.4).

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 2007-2011, 544 spotted wolffish were caught, 92% of which were taken during the fall survey times see Tables 4.2 and 4.3 in Section 4.2.2.4. Northern wolfish catches were most concentrated in the central and southern parts of the Study Area (see Figure 4.9 in Section 4.2.2.4).

Atlantic Wolffish

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

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

During DFO RV surveys conducted in the Study Area during 2007-2011, 3,379 Atlantic wolffish were caught, 89% of which were taken during the fall survey times see Tables 4.2 and 4.3 in Section 4.2.2.4. Atlantic wolfish catches were most concentrated in the central and northern parts of the Study Area (see Figure 4.10 in Section 4.2.2.4).

4.6.1.7 Fin Whale

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; the current best estimate for the western N Atlantic is 3,985 individuals (Waring et al. 2011). They are designated as *special concern* on Schedule 1 of *SARA* and by COSEWIC. Fin whales continue to regularly occur in Newfoundland and Labrador waters, particularly during summer months (Labrador Shelf SEA). Fin whales within the Labrador Shelf area mainly occur nearshore (COSEWIC 2005). Based on the DFO cetacean sightings database, fin whales have been sighted throughout the Study Area from May to December; however, the greatest number of observations occurred in the southwestern portion of the Study Area within the 500-m isopleth during July to September (Figure 4.44). There was also a single fin whale sighting offshore of Labrador during a summer 2007 aerial survey (Lawson and Gosselin 2009; see Section 4.5). 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). Fin whales may stay on the Labrador shelf year-round or migrate to warmer mid-latitude waters, but little information on winter habitat is currently available.

4.6.1.8 Sowerby's Beaked Whale

The Sowerby's beaked whale is designated as *special concern* (Schedule 1) under *SARA* and by COSEWIC. It is a small beaked whale found only in the N Atlantic, primarily in deep, offshore temperate to subarctic waters (COSEWIC 2006d). It is the most northerly distributed of the *Mesoplodon* spp., with all but one record occurring in the NW Atlantic between New England and Labrador (MacLeod 2000; MacLeod et al. 2006). COSEWIC (2006d) notes that mesoplodonts observed in Davis Strait during summer 2003 were likely Sowerby's beaked whales. There are an unknown number of Sowerby's beaked whales in the N Atlantic, but they are only rarely encountered offshore of eastern Newfoundland and Labrador. They are most often observed in deep water, along the shelf edge and slope. One sighting of four individuals was made during a seismic survey in Orphan Basin in 2005 (Moulton et al. 2006a). There were no sightings within the Study Area of Sowerby's beaked whale from the DFO cetacean sightings database. It is unclear if Sowerby's beaked whales are uncommon or poorly surveyed because of their deep-diving behaviour, small size, and offshore habitat. Observations most frequently occur during the summer, but observer effort is considerably increased during this season in offshore areas northeast of Newfoundland and Labrador (COSEWIC 2006d). Based on analysis of stomach contents, they appear to prefer mid- to deep-water fish and squid (MacLeod et al. 2003). Despite the paucity of confirmed sightings, Sowerby's beaked whales may occur in low densities in deep areas offshore of Labrador.

4.6.1.9 Polar Bear

The polar bear has a circumpolar distribution in the Arctic Ocean, and ranges from Newfoundland to Ellesmere Island in eastern Canada (Jefferson et al. 2008). Thirteen sub-populations are recognized, including the Davis Strait population that ranges from southern Baffin Island, Davis Strait, southwestern Greenland, along Labrador, and to northeastern Newfoundland (COSEWIC 2008a). Within Canada, Greenland, and Alaska, there are an estimated 15,500 individuals (COSEWIC 2008a), including ~2,100 bears in the Davis Strait population (Peacock et al. 2006 *in* COSEWIC 2008a). Polar bears are designated as *special concern* under Schedule 1 of *SARA* and by COSEWIC. Polar bears are generally more common in northern Labrador, particularly on pack ice during winter and spring, but were perhaps more common historically in southern Labrador prior to human encroachment and harvest (see Labrador Shelf SEA). However, elders from Nain, Labrador have indicated an increase in polar bears as well as a shoreward shift in distribution in recent years, potentially as a response to climate change (COSEWIC 2008a). Ringed seals are the primary prey of polar bears, and the polar bear's distribution is closely associated with that of seals. Polar bears are found in sea ice areas along the coast from early winter until breakup in late spring, when they retreat to coastal areas until sea ice returns in the fall. Pregnant females excavate dens in the late fall, typically close to the coast, and cubs are born between November and January (COSEWIC 2008a).

4.6.1.10 Harlequin Duck

The eastern North American population of Harlequin Duck is designated *special concern* by COSEWIC and is listed as such on Schedule 1 of *SARA*. This species nests along clear, swiftly flowing streams in eastern Siberia, Alaska, Yukon, and Mackenzie District of the Northwest Territories south to Idaho and Oregon, and in eastern North America from northern Québec, Labrador, and western Newfoundland to northern New Brunswick (Robertson and Goudie 1999). In Labrador it nests from Navchak Bay to Hopedale, in watersheds between Hopedale and Groswater Bay, and watersheds along the Churchill River (Robertson and Goudie 1999). During winter the western North American population is distributed along coastlines from the Aleutian Islands to Oregon (Robertson and Goudie 1999). More than half of the eastern North America population winters along coasts from Maine southward to Maryland, whereas the remainder and winter in southwestern Greenland (Robertson and Goudie 1999). Breeding pairs south of Hamilton Inlet appear to moult along the Labrador coast at sites such as the Gannet Islands off Table Bay, Tumbledown Dick Island and Stag Islands in Groswater Bay, and St. Peter's Bay in southern Labrador, whereas many of the pairs breeding north of Hamilton Inlet stage along the adjacent coastline and cross the Study Area in late June to mid-July to moult and over-winter in southwestern Greenland (Chubbs et al. 2008; Trimper et al. 2008). The number of Harlequins moulting at the Gannet Islands increased from 180 to 248 from 1999 to 2003 (Trimper et al. 2008). At Tumbledown Dick Islands and Stag Islands about 50 and 60 moulting individuals have been counted (Gilliland et al. 2002). A total of 28 have moulted around the islands in the Northeast Groswater Bay IBA (Robertson et al. 2002). Around the islands in the St. Peter Bay 30 to 72 moulting individuals have been counted (Trimper et al. 2008). A total of 159 moulting individuals have been counted at the north shore of Northern Groais Island (Gilliland et al. 2002). As with other sea ducks, the Harlequin Duck has delayed maturation, low annual production, variable breeding success, and is long-lived (Goudie et al. 1994, Robertson and Goudie 1999, Thomas and Robert 2001). These traits make populations susceptible to negative impacts when adult mortality is high, such as may occur in concentrated moulting or wintering birds coming in contact with an oil spill. In addition, strong natal philopatry to wintering areas impedes recolonization of habitat where birds have been extirpated (Robertson et al. 2000). A management plan has been finalized for the eastern population of this species (Environment Canada 2007).

4.6.1.11 Barrow's Goldeneye

The population of Barrow's Goldeneye in eastern North America is designated *special concern* by COSEWIC and is listed on Schedule 1 of *SARA*. Unlike the Common Goldeneye, it has a restricted distribution. The Barrow's Goldeneye breeds in Iceland, the interiors of Alaska, the Yukon, British Columbia, and Alberta, but the breeding grounds of the eastern North American have only recently been identified (Laurentian Highlands of east-central Quebec) (Eadie et al. 2000). There are unconfirmed reports that this species has nested in Labrador. On the breeding ground Barrow's Goldeneye nests around freshwater lakes and ponds where it feeds mostly on aquatic insects. It winters along the Pacific coast of Alaska and British Columbia and in eastern North America is found in scattered areas of the coastlines of Atlantic Canada and the eastern U.S., with the largest concentrations along the St. Lawrence Estuary (Eadie et al. 2000, Robert et al. 2002). Wintering birds have not been found along the Labrador coastline (Eadie et al. 2000). During winter it feeds over hard substrates primarily on mollusks. In the eastern North American population, the data on the moult migration of males are few,

but most males appear to migrate to protected bays and inlets along the east coast of Hudson Bay, Ungava Bay and the Labrador coast, and the remainder to freshwater lakes in northern Quebec (Savard and Dupuis 1999, Robert et al. 2000). Moulting birds along the Labrador coast are mainly found from Makkovik to Ramah Bay (including Nain Bight, Hebron Fjord, and Primo Inlet) but also at Cape White Handkerchief, Rowsell Bay (Savard and Dupuis 1999, Robert et al. 2000; 2002). Males arrive in these moulting areas from mid-June to the end of July and depart from mid-September to late October, with peak numbers in August (Robert et al. 2002). This species has low lifetime reproductive but is long-lived and has high adult survival, so population is size is sensitive to adult mortality (Eadie et al. 2000). The species has a small global population size and there is little information on the breeding, moulting, and critical wintering areas of the eastern North American population. A management plan has been finalized for the eastern population of this species (Environment Canada 2013d).

4.7 Sensitive Areas

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

Provincial parks are administered under the *Provincial Parks Act* (1970), while sensitive areas such as ecological reserves are administered under the provincial *Wilderness and Ecological Reserves Act* (1980). National parks are administered under the *National Parks Act* (2000) and National Marine Conservation Areas (NCMAs) is established under the *Canada National Marine Conservation Areas Act (2002)*. Marine Protected Areas (MPAs) are administered under the *Oceans Act* (1996) which includes *Gilbert Bay Marine Protected Regulations* (2005) outlining the regulations applicable to Gilbert Bay, a marine protected area within Labrador coastal waters.

Sensitive areas that occur at least partially within the Study and/or Project Areas include the following (based on Husky EA (Stantec 2010)) (Figure 4.47):

- Hawke Channel Fishery Closure Area;
- Funk Island Deep Fishery Closure Area;
- Coral Protection Zone;

- Nain Bight Candidate National Marine Conservation Area (NMCA);
- Hamilton Inlet Candidate National Marine Conservation Area (NMCA); and
- The Zone.

Sensitive areas that occur proximate to the Study Area include the following (based on Husky EA (Stantec 2010)) (Figure 4.47):

- Cabot Island Funk Island Fishery Closure Area;
- Gilbert Bay Marine Protected Area (MPA);
- Battle Harbour National Historic Site (NHS);
- Gannett Islands Ecological Reserve;
- Fourteen (14) Important Bird Areas (IBAs);
- Torngat Mountains National Park;
- Mealy Mountains National Park (proposed); and
- Eagle River Waterway Provincial Park (proposed).

As noted in the Labrador Shelf SEA (Sikumiut 2008), the banks and channels of the Labrador Shelf are relatively high in terms of productivity and species diversity. It should also be noted that important areas within the Study Area, though not specifically designated, may be important areas for corals, spawning, nursing, rearing, and/or migratory areas, and areas of traditional harvesting activities.

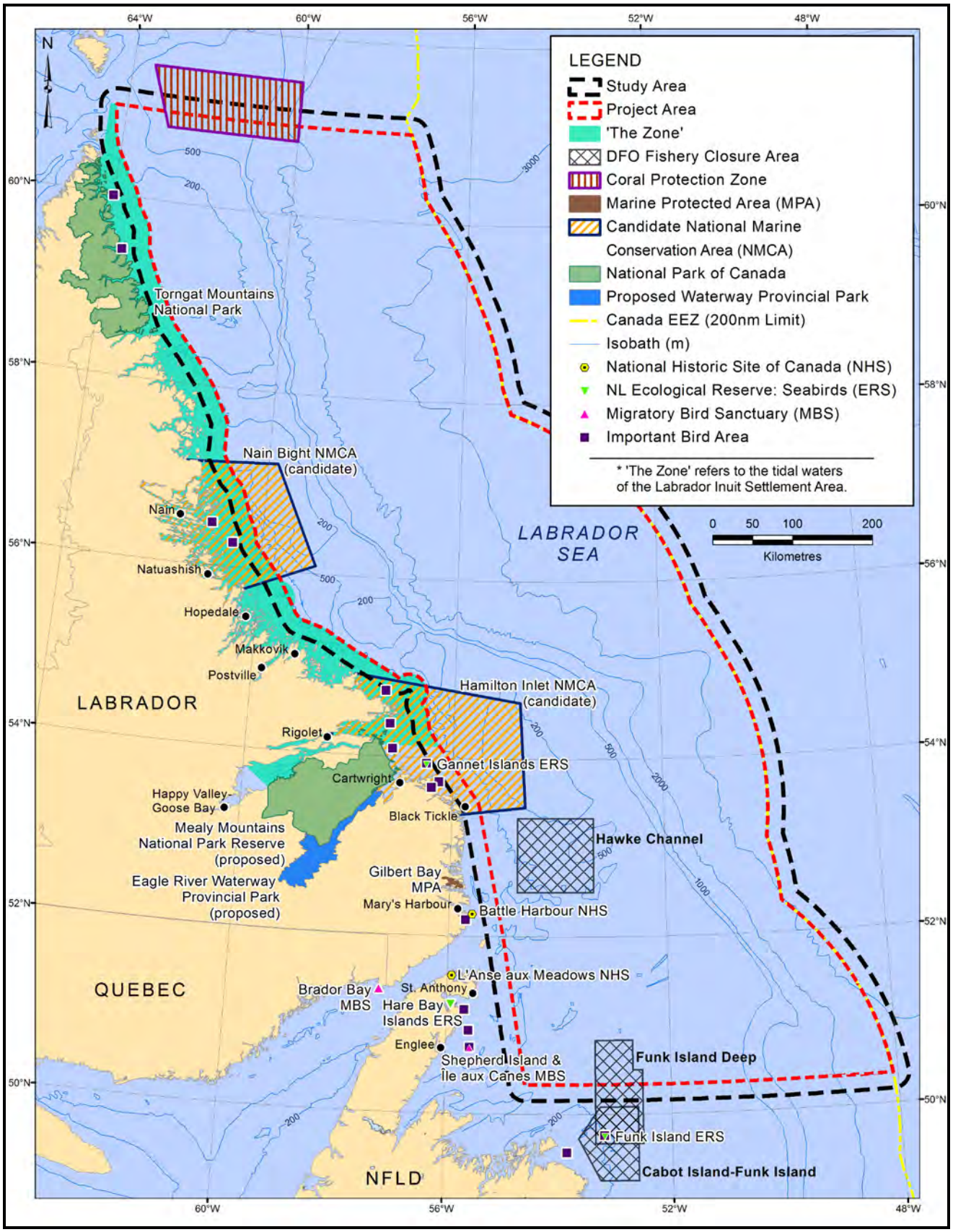


Figure 4.47 Sensitive Areas Overlapping or Proximate to the Project and/or Study Areas.

Table 4.16 provides information on each of the sensitive areas identified above.

Table 4.16 Sensitive Areas Overlapping or Proximate to the Project and/or Study Areas

Sensitive Area	Description
Overlapping Project and/or Study Area	
Funk Island Deep Fishery Closure Area	It's general purpose is to protect Atlantic cod and snow crab, and their habitats by reducing bottom damage by bottom contact gear. Approximately half of this closure area overlaps with the southern Study Area. It has an area of 7,923 km^2. This area was closed by DFO to gillnet fishing year-round since 2002. This area was closed by DFO to inshore shrimp trawling year-round since 2005. This area has voluntary closure to large vessel shrimp fleet.
Coral Protection Zone	A portion of this area overlaps with both the Project Area and the Study Area The focus of this area is coral. This area is a voluntary fishery closure area.
Nain Bight Candidate National Marine Conservation Area	This candidate area extends seaward from Nain to include part of Nain Bank, and has substantial overlap with the Study and Project Areas. There is increased biological productivity in the area. There is diverse and abundant avifauna, including numerous alcid species, Eider Ducks and Harlequin Ducks.
Hamilton Inlet Candidate National Marine Conservation Area	This candidate area extends seaward from Nain to include part of Nain Bank, and has substantial overlap with the Study and Project Areas. There is increased biological productivity in the area. There is diverse and abundant avifauna, including numerous alcid species, Eider Ducks and Harlequin Ducks.
The Zone	The Study Area extends 14 km into the Zone. The Zone was established under the *Labrador Inuit Land Claims Agreement* (2005). It encompasses 48,690 km^2 of ocean extending to the limit of Canada's territorial sea (Government of Newfoundland and Labrador 2012). A co-management board (The Torngat Joint Fisheries Board) appointed by the Government of Canada, Government of Newfoundland and Labrador, and the Nunatsiavut Government will be established as the primary body for making recommendations to governments on the conservation and management of fish in this area. The provincial and federal governments will retain the overall responsibility for the conservation and management of the fishery in this area. Within the Zone, Labrador Inuit will have the right to harvest fish and marine mammals for Inuit food, social and ceremonial purposes.

Sensitive Area	Description
	If conservation requires that fishing by Inuit be limited, the limits will be set by the federal minister based on a recommendation of the Nunatsiavut Government. Inuit will be guaranteed a percentage of new or additional commercial fishing licences for specified species within and in waters adjacent to the Zone.
Proximate to Study and Project Area	
Hawke Channel Fishery Closure Area	Although surrounded by the Project Area, the Hawke Channel Fishery Closure Area does not overlap with the Project Area. It's general purpose is to address impacts of trawls and gillnets on snow crab and Atlantic cod. It has an area of 8,575 km^2. Initially only 1,372 km^2 in 2002 but expanded in 2003. This area was closed by DFO to gillnet fishing and trawling year-round since 2002.
Cabot Island-Funk Island Fishery Closure Area	The Cabot Island-Funk Island Fishery Closure Area is at least 28 km from the Project Area. It has an area of 5,741 km^2. This area is closed to otter trawling between 1 May and 30 November
Gilbert Bay Marine Protected Area	The Gilbert Bay MPA is 39 km from the Project Area. This MPA has an area of 47 km^2. This MPA was designated in 2005. The focus of this MPA is a resident population of Atlantic cod that is genetically distinct from other Labrador cod.
Battle Harbour National Historic Site	The Battle Harbour National Historic Site is 34 km from the Project Area. Mercantile saltfish premises first established here in 1770s developed into a thriving community that was known as the 'Capital of Labrador'.
Gannett Islands Ecological Reserve	The Gannett Islands Ecological Reserve is 22 km from the Project Area. It is the largest razorbill colony in North America and largest seabird colony in Labrador
Important Bird Areas	The closest IBA to the Project Area is 19 km away. There are 14 IBAs in the vicinity of the Study Area. See Section 4.4 for details.
Torngat Mountains National Park	The Torngat Mountains National Park is 22 km from the Project Area.
Mealy Mountains National Park (proposed)	The proposed Mealy Mountains National Park is 53 km from the Project Area.
Eagle River Waterway Provincial Park (proposed)	The proposed Eagle River Waterway Provincial Park is 91 km from the Project Area.

5.0 Effects Assessment

Two general types of effects are considered in this document:

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

Methods of effects assessment used here are comparable to those used in recent east coast offshore seismic (e.g., LGL 2007, 2010) and drilling EAs (e.g., LGL 2006). These documents conform to the (now repealed) *Canadian Environmental Assessment Act* (*CEAA*) of 1992 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).

5.1 Scoping

The C-NLOPB provided a draft (dated 29 January 2013) and a final (dated 26 March 2013) Scoping Document for the Project which outlined the factors to be considered in the assessment. In addition, various stakeholders were contacted for input (see below, Section5.2). 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 MKI Labrador EIS (RPS 2011), the Chevron Labrador seismic EA (LGL 2010), the Labrador Shelf infill-extension seismic EA (Canning and Pitt 2007), and the Labrador Shelf SEA (Sikumiut 2008). Reviews of present state of knowledge on the effects of seismic as well as the biological setting of the Study Area were also conducted.

5.2 Consultations

5.2.1 GXT Consultation Policy and Approach

GXT's policy for consultation on marine seismic projects is to consult (primarily through in-person meetings) with relevant agencies, stakeholders and rights-holders (e.g. beneficiaries) during the pre-survey and the survey stages. GXT will initiate meetings and respond to requests for meetings with the interested groups throughout this period. After the survey is complete GXT will conduct follow-up discussions. The same approach would be followed before, during and after any survey work for 2014 and 2015. In summary, each year GXT will meet

- Before the survey is permitted: to provide Project information, gather information about area fisheries, determine issues or concerns, discuss communications and mitigations.
- After the survey is permitted, during the survey activities: To report on the progress of the survey, to determine if any survey-related issues have come up, and to discuss solutions if they have.
- After the survey is complete: To provide an up-date on the Project, hear if there were any issues, and to present results of the MMO and FLO reports.

The in-person meetings include the direct participation of GXT's Project Manager and Environmental Manager, and other issue-specific personnel support as needed.

GXT has applied this consultation approach in several previous surveys in the Canadian Beaufort Sea since 2006 within the Inuvialuit Settlement Region (ISR), where screenings are conducted by both the National Energy Board (NEB) and the ISR's Environmental Impact Screening Committee (EISC). In those areas there has been a high level of agency and community-level support for GXT's approach and follow-up.

5.2.2 Program Consultations 2013

During the in-person consultation and other meetings, GXT representatives (Project Manager and Environmental Manager) presented PowerPoints with details about ION/GXT, the project and why and how it is done. The presentations included maps of the proposed 2013 survey lines and the Project and Study Areas as well as several maps showing fish-harvesting locations (key species) in relation to those lines. GXT also recorded information about commercial fish harvesting details, including Traditional Environmental/Ecological Knowledge (TEK) related to the Project from participants Area, as well as any issues, concerns and advice about mitigations (particularly avoiding concurrent fisheries) and communications. Questions were invited at all times. Information packages and/or brochures (see Appendix 3) were provided before or at the meetings (including additional copies for wider distribution), as were coordinates for locating the full Project Description through the C-NLOPB Registry.

In-person meetings were also proposed to all relevant agencies and groups, but most of these preferred communications by telephone and/or email. In these cases, information packages were sent and comments / advice invited. (In some cases agencies contacted declined to comment on the initial information and subsequent/follow-up invitations to provide advice or comments).

GXT was assisted in the first round of consultations by Sikumiut Environmental Management Ltd., LGL Ltd. and/or Canning & Pitt Associates Inc.

As has been the case for other seismic project assessments in the Newfoundland and Labrador sector, the most consistent issue raised during the consultations was the commercial fisheries – specifically ensuring that the survey does not interfere with or otherwise impact harvesting success (Section 4.3 describes the important fisheries in the Study and Project Areas). Consequently, fish harvester groups and agencies were a key focus of the consultations.

Fisheries-related consultations and contacts (in person, by telephone and/or by email) were conducted with representatives of the following groups / agencies:

- Nunatsiavut Government, Department of Lands and Natural Resources – in person
- Torngat Joint Fisheries Board of the Torngat Wildlife, Plants and Fisheries Secretariat (for Nunatsiavut) – in person (GXT was invited to the Secretariat quarterly meeting where all members and staff were present) / email

- Torngat Fish Producers Co-operative Society – in person
- Fish, Food and Allied Workers Union (FFAW) and fleet representatives – in person / email / telephone
- Labrador Fisherman's Union Shrimp Company – telephone / emails
- Association of Seafood Producers (ASP) –emails
- Canadian Association of Prawn Producers (CAPP) - emails
- Groundfish Enterprise Allocation Council - emails
- Fisheries and Oceans Canada (DFO) - emails
- Ocean Choice International (OCI) - emails
- Groundfish Enterprise Allocation Council (GEAC) Ottawa - emails
- Clearwater Seafoods - emails
- Icewater Fisheries - emails
- Newfound Resources Ltd. (NRL) - emails
- One Ocean - in person / emails

All of these groups (except One Ocean) represent fishers or harvesting companies, or manage harvesting operations in the Project Area. Fisheries information was also presented and comments invited at public meetings in Labrador. At the FFAW's request, local fishing interests in communities where fishers are represented by the union (the adjacent communities on the Island of Newfoundland and Southern Labrador, primarily) were to be consulted by them and information/comments passed on to GXT. Specific information provided during the discussions about the fisheries has been incorporated in Section 4.3, Fisheries of this EA.

Other groups consulted about the proposed Project included:

- Sivunivut Inuit Community Corporation, North West River – in person
- Nature Newfoundland and Labrador (NNL) (and various member organizations) – telephone / email
- Environment Canada (EC) – emails
- Town of Happy Valley - Goose Bay (Deputy Mayor) – email / in person
- Community meeting in Happy Valley-Goose Bay – in person
- Community Meeting in North West River – in person
- Community Meeting in Nain – in person.

Further in-person meetings are planned (in April, following GXT's continuing consultation approach) with the following:

- Nunatsiavut Government – additional meetings with Department of Lands and Natural Resources personnel and others as requested
- Nain – follow-up meetings
- Makkovik - community
- Hopedale - community

- Postville - community
- Cartwright – community
- Mary's Harbour / Port Hope Simpson - community
- Other groups that might request a meeting.

Collectively, these consultations and discussions have been intended to provide information about the Project, to gather information about area fisheries and to determine any issues or concerns to be considered in the EA and continuing Project planning, as well as to discuss communications, mitigations and other solutions aimed at eliminating or minimizing potential impacts on the environment. (See Consultation Report documents, Appendix 3; this also contains copies of representative information packages provided as well as public announcements and posters used for the public sessions.)

In addition to the consultations initiated by GXT, in late January the Nunatsiavut Government, the FFAW, One Ocean, Fisheries and Oceans Canada, Environment Canada, Transport Canada, Health Canada, the Department of National Defence, Natural Resources Canada, the NL Department of Environment and Conservation, the NL Department of Fisheries and Aquaculture, and the NL Department of Natural Resources were informed of the Project by the C-NLOPB, and the detailed Project Description was provided to them as well as the draft EA Scoping Document for comment. (See Public Registry http://www.cnlopb.nl.ca/environment/gxtc.shtml.)

5.2.3 Issues Identified

As noted above, the dominant concern of most groups consulted was avoiding impacts on the commercial fisheries (fish and fish harvesting); other issues related to protecting other aspects of the marine environment in the area, such as marine mammals and seabirds, and special areas. There were also questions raised about economic opportunities (benefits) that the Project might provide. The following presents (in bullet form) the main issues raised, which are then addressed in the Assessment sections of this EA (Sections 5.8.4 to 5.8.8), as are specific mitigation plans to address these concerns and issues (Section 5.6):

- Physical interference with fishing activities caused by the ships and towed seismic gear (especially with fixed gear fisheries for snow crab and Greenland halibut/turbot)
- Effects on fish behaviour from Project sound, especially the array (scaring fish away from fishing gear, reducing catch success – all commercial species)
- Damage to fixed fishing gear (crab pots, Greenland halibut/turbot nets, caused by the Project ships or streamer)
- Physical effects on key commercial fisheries species from the sound of the array (especially snow crab, shrimp and groundfish)
- Representation of interests (Aboriginal and commercial harvesting) at sea during the Project
- Ensuring adequate on-going communications and information exchange during the survey
- Physical and behavioural effects on marine mammals and sea turtles
- Effects on seabirds, especially related to vessel stranding

- Pollution (water quality, air emissions and spill prevention and response)
- Species at Risk (*SARA* and COSEWIC)
- Other potential marine hazards / vessel traffic.

Further details are presented in Appendix 3.

5.2.4 Follow-Up

As described above, GXT will conduct follow-up discussions with all interested groups during and after the survey. This would include reporting on the progress of the survey, monitoring the effectiveness of the mitigations., determining if any survey-related issues have/had come up and (post survey) to present monitoring results.

5.3 Valued Ecosystem Components

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

VECs include the following groups:

- rare or at risk species or habitats (as defined by COSEWIC and *SARA*);
- species or habitats that are unique to an area, or are valued for their aesthetic properties;
- species that are harvested by people (e.g., commercial fish species); and
- species that have at least some potential to be affected by the Project.

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

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

- **Fish and Fish Habitat** with emphasis on the three principal commercial species: (1) northern shrimp, (2) snow crab, and (3) Greenland halibut (turbot), and *SARA* species (e.g., wolffishes). It is recognized that there are many other fish species, commercial or prey species, that could be considered but it is LGL's professional opinion that this suite of species captures all of the relevant issues concerning the potential effects of seismic surveys on important invertebrate and fish populations of the Project Area.

- **Fisheries** (primarily commercial harvesting) were the most referenced VEC of concern during consultations. While they are directly linked to the fish VEC above in that an impact on fish could affect fishery success for that species, the greater concern expressed was interference with fishing, either through the sound produced by the array (scaring fish from fishing gear) or interference with fixed fishing gear (caused by the ships or the seismic streamer). All fisheries are considered where relevant (i.e., commercial, subsistence /

ceremonial, recreational). The commercial fishery is a universally acknowledged important element in the society, culture, economic and aesthetic environment of Newfoundland and Labrador. Also included in this VEC are research surveys (which are conducted using types of fishing gear), both those conducted by DFO and those conducted by industry. 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 Labrador Shelf area hosts large populations during all seasons. They are important socially, culturally, economically, aesthetically, ecologically and scientifically. This VEC is of 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 concern from both a public and scientific perspective, at local, national and international scales.

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

- **Species at Risk** are those designated as *endangered* or *threatened* on Schedule 1 of *SARA*. In addition, species listed as *special concern* have been considered here as well. All species at risk in Newfoundland and Labrador offshore waters are captured in the VECs listed above. However, because of their special status, they are also discussed separately.

5.4 Boundaries

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

5.4.1 Temporal

The temporal boundaries of the Project are 1 June to 30 November in 2013. In subsequent years (2014 and 2015), seismic surveys may also occur within the period 1 June to 30 November.

5.4.2 Project Area

The 'Project Area' is defined as the area within the C-NLOPB jurisdiction where seismic data could be acquired. This includes the area around the outer perimeter of the data acquisition area to accommodate the ships' turning radii (see Figure 1.1). The coordinates of the Project Area (WGS84, unprojected geographic coordinates) are presented in Table 5.1. The western boundary of the Project Area is 6 km offshore of The Zone.

Table 5.1 Coordinates of the Project Area Corners (WGS84, unprojected geographic coordinates).

Project Area 'Corner'	WGS84 (Decimal Degrees)	
	Latitude	Longitude
NE *	61.00000	-57.38344
SE *	50.33333	-48.08269
SW	50.33333	-54.58333
NW **	61.00000	-64.25286

Notes:

* coincident with Canada EEZ administrative boundary

** coincident with northern (NE) tip of 'The Zone'

5.4.3 Affected Area

The 'Affected Area' varies according to the specific vertical and horizontal distributions and sensitivities of the VECs of interest and is defined as that area within which effects (physical or important behavioural ones) have been reported to occur.

5.4.4 Study Area

An area larger than (i.e., 20 km beyond) the Project Area that encompasses any potential effects (including those from accidental events) reported in the literature.

5.4.5 Regional Area

The regional boundary is the boundary as defined in the Labrador Shelf SEA Area and is retained here for consistency. An exception to this boundary is the inclusion of the major Grand Banks developments when considering cumulative effects.

5.5 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.

5.5.1 Identification and Evaluation of Effects

Interaction matrices were prepared that identify all possible Project activities which could interact with any of the VECs. The interaction matrices are used only to identify potential interactions; they make no assumptions about the potential effects of the interactions. Interactions were then evaluated for their potential to cause effects. In instances where the potential for an effect of an interaction was deemed impossible or extremely remote, these interactions were not considered further. In this way, the assessment could focus on key issues and the more substantive environmental effects.

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

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

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

5.5.2 Classifying Anticipated Environmental Effects

The concept of classifying environmental effects simply means determining whether they are negative or positive. The following includes some of the key factors that are considered for determining negative environmental effects, most of which are included in 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, including economic well-being, such as fishing income.

5.5.3 Mitigation

Where needed, mitigation measures appropriate for each effect predicted in the matrix were identified (Section 5.6) and the effects of various Project activities were then evaluated assuming that appropriate mitigation measures are applied. Residual effects predictions were made taking into consideration these mitigations.

5.5.4 Evaluation Criteria for Assessing Environmental Effects

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

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

Magnitude describes the nature and extent of the environmental effect for each activity. Geographic extent refers to the specific area (km^2) affected by the Project activity, which may vary depending on the activity and the relevant VEC. Duration and frequency describe how long and how often a project activity and/or environmental effect will occur. Reversibility refers to the ability of a VEC to return to an equal or improved condition at the end of the Project. The ecological, socio-cultural and economic context describes the current status of the area affected by the Project in terms of existing environmental effects. The Study Area is not considered to be strongly affected by human activities.

Magnitude was defined as:

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

High	Affects more than 25 percent of individuals in the affected area (e.g., geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 3.

Definitions of magnitude used in this EA have been used previously in numerous offshore oil-related environmental assessments under CEAA. These include assessments of the Chevron Labrador Shelf seismic EA (LGL 2010), Labrador Shelf infill-extension EA (Canning and Pitt 2007), the White Rose Oilfield Comprehensive Study (Husky 2000), the Husky Jeanne d'Arc Basin exploration drilling EAs and update (LGL 2002, 2005a, 2006), the Husky Jeanne d'Arc Basin 3-D seismic EA and update (LGL 2005b; Moulton et al. 2006b), the StatoilHydro Jeanne d'Arc Basin area seismic and geohazard program EA (LGL 2008), and the ConocoPhillips Laurentian Sub-Basin exploration drilling EA and supplement (Buchanan et al. 2006; LGL 2009a), and seismic EA (LGL 2009b).

Durations are defined as:

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

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

5.5.5 Cumulative Effects

The cumulative effects assessment is consistent with the principles provided in the CEAA "Cumulative Effects Practitioner's Guide" (Hegmann et al. 1999) and the CEA Agency Operational Policy Statement on addressing cumulative effects (CEA Agency 2007). Projects and activities considered in the cumulative effects assessment included other human activities in Newfoundland and Labrador offshore waters, with emphasis on the Regional Area of the Labrador Shelf area.

- Survey program within-project cumulative impacts. For the most part, and unless otherwise indicated, within-project cumulative effects are fully integrated within this assessment. Note that the seismic lines for this program will be long and widely spaced (50-100 km apart) with occasional crossing points, effectively resulting in 'one time' exposures of biota and fishing grounds to maximum energy from the discharging airguns.
- 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). On the Labrador Shelf area for 2013, there are no current plans for seismic or drilling programs as of the time of submission of this EA (C-NLOPB, pers. comm., 18 March 2013; C-NLOPB Public Registry, accessed 24 March 2013). The amount and timing and locations of other seismic operations and potential drilling

programs in and near the Study Area in 2014 and 2015 are not currently available, but would be considered for future years' operations, if they occur.
- Commercial fisheries;
- Marine transportation (tankers, cargo ships, supply vessels, naval vessels, fishing vessel transits, etc.); and
- Hunting activities (marine birds and seals).

5.5.6 Integrated Residual Environmental Effects

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

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

The last of these points considers all residual environmental effects, including project and other-project cumulative environmental effects. As such, this represents an integrated residual environmental effects evaluation.

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

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

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

5.5.7 Significance Rating

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

> *Having a high magnitude; or medium magnitude for a duration of greater than one year and over a geographic extent greater than 100 km^2*

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

5.5.8 Level of Confidence

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

5.5.9 Determination of Whether Predicted Environmental Effects are Likely to Occur

As per other EAs (e.g., LGL 2010), the following criteria for the evaluation of the likelihood of any predicted significant effects are used.

- probability of occurrence; and
- scientific certainty.

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

5.5.10 Follow-up Monitoring

Because any effects of the Project on the environment will be relatively short-term and transitory, there is no need to conduct follow-up monitoring. However, there will be some monitoring (described below in the Mitigations sections) during the course of the Project, and if these observations indicate evidence of an anticipated effect on a VEC or an accidental release of fuel, then the need for follow up monitoring and other actions will be assessed in consultation with the C-NLOPB.

5.6 Mitigation Measures

The effects assessments that follow in this chapter (in Sections 5.8 - 5.11) consider the potential effects of the LabradorSPAN Project in light of the specific mitigation measures that will be applied for this Project in this environment. The purpose of these measures is to eliminate or reduce the potential impacts that might affect the area VECs (as identified in Section 5.3). GXT recognizes that the careful and thorough implementation of, and adherence to, these measures will be critical for ensuring that the Project does not result in unacceptable environmental consequences.

This section details the various measures that will be established and applied for this Project. Many of these are specially tailored to this program, while others are founded in regulations, guidelines, or "best environmental practices". Collectively, they are based on or take guidance from several sources, including:

- Discussions and advice received during consultations for this Project (Section 5.2 and Appendix 3), and for other relevant EAs
- The C-NLOPB Scoping Documents, and the Environmental Planning, Mitigation and Reporting guidance in Appendix 2 of the Board's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012)

- DFO's *Statement of Practice with respect to the Mitigation of Seismic Sound in the Marine Environment*
- National and international acts, regulations or conventions, such as the *Fisheries Act* and Regulations, *International Convention for the Prevention of Pollution from Ships* (MARPOL), and International Maritime Organization (IMO) standards.
- Other standards and guidance, such as the One Ocean *Protocol for Seismic Survey Programs in Newfoundland and Labrador* (2013), and the Joint Nature Conservation Committee (JNCC) *Guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys* (2010)
- Industry best practices
- Expert judgement / experience from past surveys.

The mitigations that follow are organized under principal categories (i.e. Survey Layout and Location; Communications and Liaison; Fisheries Avoidance; Fishing Gear Damage Program; Marine Mammal / Wildlife Protection; Pollution Prevention and Emergency Response). Because several of the specific mitigation plans listed under these categories mitigate potential effects on more than one VEC (e.g. seismic array ramp-up/soft start can warn away marine mammals and fish), the relevant VECs are noted for each of the measures. Table 7.2 then summarizes these measures, organized by VEC.

These measures will be adhered to in each survey year, with adjustments as necessary based on monitoring and follow-up.

1. Survey Layout and Location
(Fish; Fisheries; Marine Mammals/Sea Turtles; Seabirds; Cumulative Effects)

The layout of GXT's Basin Span surveys (see typical line pre-plots presented in Figure 1.2), with very long and widely spaced lines - typically several hundred kilometres long and 50 to 100 km apart except where they cross in some locations, means that in most areas (fishing grounds and wildlife habitat) there will be only a one-time exposures to project activities, unlike most 2D or 3D seismic surveys. With the seismic ship travelling at ~9 km hour, for any given location, the survey will be 10 - 20 km away within a few hours and will not return there, except for the crossing points, which will likely be separated by several days or even weeks in timing. Typically, only parts of a few of the lines would pass over any key fishing ground in any program year.

The western limit of the Project Area is about 22 km away at its closest point of approach to the more sensitive coastal areas, though for most lines the distance will be greater than this (30–50 km). The survey will not enter the Nunatsiavut Zone (the Tidal Waters of the Labrador Inuit Settlement Area), or within identified sensitive areas such as Gilbert Bay, Nain Bight and Hamilton Inlet, or the Hawke Channel, which is a highly concentrated fixed-gear fishing area.

2. Communications and Liaison
(Fisheries; Science Surveys, Effects of the Environment on the Project; Other Marine Users)

Consultations and discussions for this Project have indicate that frequent, timely and effective communications with fishing industry organizations / participants must be a central part of the fisheries mitigations for the survey. This will work 1.to ensure that the seismic program does not operate in the area of active fisheries, and 2. to allow the survey to plan its acquisition and proceed in the most efficient way possible in light of concurrent fishing locations.

Information Exchange. Detailed and up-to-date information about the fisheries likely to be active in specific parts of the Project Area at specific times.

Maps of past fish harvesting activities (see Section 4.3 of this EA) are a valuable planning tool, but exact times and locations change somewhat from year to year. To be accurate, the information flow about current fishing activities will need to be a continuing process that is updated as fishing seasons open and close and as quotas are taken. This information will be accessed through continuing information exchanges with the relevant fishing organizations on a regular basis, including through the mechanisms described below, such as the FFAW Petroleum Information Liaison person, the FLOs, direct contacts with representatives of the Labrador fisheries organizations, and with DFO (for fisheries survey/research information). Operational details of these communications will be finalized with the relevant organizations as the fishing season information and plans are known.

Ten/Five Survey Outlook. Plans of where the seismic ship will be working in the next 10 days will be sent by GXT to fishing organizations and/or fishers every 5 days.

The GXT 10-day plan will indicate expected seismic survey locations, in light of expected fishing locations, Item 1, above) and various other factors (e.g. acquisition priorities, ice). These will be issued from the ship every 5 days, so that fisheries interests have an opportunity to respond if any of the planned acquisition raises concerns about a potential fisheries conflict, and so that this can be addressed. In discussions with the Torngat Fisheries Co-Op, for instance, it was agreed that the most effective means of doing this for their membership is to email the plans to the Co-Op office (Happy Valley – Goose Bay) and they will distribute the information to their members and coordinate any responses back to GXT. Issuing the 10-day plans every 5 days will also take into account the reality that the survey plans often have to change (e.g. because of weather, repairs, changing ice conditions).

Fisheries Liaison Officers (FLOs). The survey will place FLOs on board the seismic ship, to communicate with fishing vessels at sea, and relay information to shore as needed (at least two FLOs - a FFAW representative and a representative of Inuit/Nunatsiavut interests). The FLOs are the primary at-sea liaison between the commercial fishing industry and the seismic survey program. In past seismic surveys FLOs have been very effective for "real time" communications, and to assist the vessel in planning activities in light of current fisheries and fishing gear locations.

As described in the One Ocean Protocol document, "the FLO is tasked with identifying potential at-sea conflicts between fishing and petroleum operations". His/her duties include radio contact with fishing boats in the area, informing fishers nearby about the seismic program (including providing coordinates of planned

survey lines), helping to identify fishing plans (when in area, when leaving) and any fishing gear in and near the seismic survey program area so it can be avoided, advising on best course of action to avoid gear and/or other fishing activities, providing information about changes in relevant fisheries, and sending daily reports. The FLO roles and duties - based on past practice, and the One Ocean Protocol document (Section 4.6 FLO Operational Responsibilities, Protocols and Communications) - will include the following:

- Stationed on the project seismic vessel, observe activities which may affect the fishing industry and petroleum operations;
- Initiate and maintain radio contact with fishing boats in the area and ensure all communication with fishing vessels is conducted via the FLO;
- Inform fishers nearby about the seismic survey program and provide coordinates and relevant spatial and temporal details;
- Help identify/locate any fishing gear in and near the seismic survey program 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 and/or fishing activities;
- Serve as initial contact if damaged gear is encountered, verify damage, help identify owners and file an incident report;
- Regularly discuss/convey fisheries related aspects including changes in relevant fisheries, status of species quotas and closures with the onboard Client Representative;
- Report to and confer with the onboard Client Representative regarding operational situations;
- Attend regular operations briefings;
- Attend safety meetings and participate in all relevant Health Safety and Environment (HSE) initiatives and procedures as requested;
- Complete and submit a daily report (electronic/hardcopy) including all observations, communications and meetings attended to the onboard Client Representative;
- Other duties as identified and approved through consultation with the Operator and Service Provider.

The FLO The One Ocean Protocol document also notes that the FFAW/One Ocean Petroleum Industry Liaison (see below) usually prepares a Summary Report on fishing activity for the FLO, including Vessel Monitoring System (VMS) data (see below) before departure on the seismic ship, and continues to provide data to the FLO while on board the seismic vessel on an as-needed basis throughout the program. (See www.oneocean.ca/pdf/2013%20Seismic%20Protocol%20Document.pdf.)

The FLO would also assist if there are any gear damage incidents, as detailed below (Fishing Gear Damage Program).

Single Point of Contact (SPOC.) The role of the sore-based SPOC (as noted in the CNLOPB Guidelines) is also to facilitate communication between the Project and other marine users, and particularly with fisheries. It has become a standard and effective mitigation for seismic surveys over many years. Typical services provided are

- Documenting the locations of known vessels for seismic survey operators; provide current information about the locations of seismic activities and fishing activities.
- Regularly update survey vessels on expected locations of fishing activities in their operating areas
- Assisting with updates to the seismic vessels about changes in relevant fisheries, the progress of species quotas and closures
- Maintaining additional contact with fishers known to be in active survey areas, directly or through the Fisheries Liaison Officers (FLOs), the FFAW, other fishing organizations (such as the Torngat Co-op), and One Ocean
- Providing information directly to fishers when requested via email or a toll-free phone line maintained for this purpose, based on the best-available data provided to them by the survey
- Attempting to identify (from CFV id numbers, etc.) any gear located in the water or involved in an incident, as requested by the survey operator
- Providing survey information to fisheries groups and organizations as required.
- Providing initial contacts (via email and/or the toll free phone number) for any gear damage or loss claims, for the survey's fishing gear compensation program.

SPOC contact information will be broadcast in the Coast Guard Notices to Shipping and communicated to fishers through their organizations. The SPOC will also have duties if there are any gear damage incidents, as detailed below (Fishing Gear Damage Program).

FFAW / One Ocean Petroleum Industry Liaison Contacts. As an initiative of One Ocean (whose mission is to be the medium for information exchange regarding industry operational activities between the fishing and petroleum industries in Newfoundland and Labrador), an arrangement was undertaken for the employment of a Petroleum Industry Liaison (PIL) at the FFAW. The principle objective of the PIL is to ensure the views and concerns of fish harvesters are considered by the offshore petroleum industry and regulators during the development, review and execution of exploration, development and production activities. As such, the PIL is the main contact for petroleum related activities at the FFAW. GXT will utilize the PIL the key contact for communications between the Project and FFAW-represented fishing interests.

VMS Data. GXT will use VMS data (as available) to understand and help avoid fishing locations and monitor other area marine activities, for logistics and safety. The One Ocean Protocol notes (Section 3.3) that "One Ocean and Fisheries and Oceans Canada (DFO) have an arrangement to provide Vessel Monitoring System (VMS) information to petroleum company members of One Ocean. The VMS program at DFO Newfoundland Region provides a satellite based, near real time, positional tracking system of fishing vessels within the Canadian Exclusive Economic Zone (EEZ), as well as foreign and domestic vessels in the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area outside the 200 nautical mile limit. The ability to access current fisheries data (location of activity) is an important component in the development of operational plans for offshore petroleum related activities. The VMS data generated by DFO consists of coordinates only and does not divulge information of a confidential or sensitive nature." GXT has requested (through One Ocean) that the Project have access to these data.

Notices to Shipping. As a standard procedure and requirement, GXT will file and update NotShips with Canadian Coast Guard Radio / ECAREG advising marine interests of the seismic survey's general operating area for the period covered by the Notice. The Notices will include contact information (email and toll-free phone number) for the survey's Fishing Gear Damage program (see below).

Survey Start-Up Sessions (Project Ships' Crews). GXT places a strong emphasis on informing the at-sea Project personnel on each ship before the survey begins, through several presentation modules, about the environmental issues and concerns in the area in which they will be working, GXT's environmental commitments and regulatory requirements, safety, emergency response, the duties and authority of the MMOs and the FLOs, and the cultural importance and legal status of Aboriginal interests in the area. These sessions will include showing the Canadian Association of Petroleum Producers "Fishery Liaison Officer Video" about the importance of FLO participation in offshore Newfoundland and Labrador exploration activities, as recommended in the One Ocean Protocol. The FLOs, MMOs and GXT Environmental Manager will be present at these meetings.

Communications Follow-Up. As stated in the Consultations section (Section 5.2), GXT will continue to consult with fisheries (and other) groups before and during the survey (with the active participation of GXT Managers) and will also conduct follow-up discussions with all interested groups after the survey. This would include reporting on the progress of the survey, monitoring the effectiveness of the mitigations and whether any survey-related issues had come up, and (after survey) to present monitoring results.

Other Notifications / Communication. GXT will also follow several procedures / vehicles to facilitate excellent communications for the survey, including the following:

- GXT will employ the latest technology in at-sea communications with and between the survey ships (VHF, HF, Satellite telephone and internet, VMS).
- GXT will provide information (the NotShip text) to the CBC Fisheries Broadcast.
- As advised during its Labrador consultations GXT will provide information to the OKâlaKatiget Society (OK) radio system to be used to notify fisher sailing from coastal communities about the location of the survey ships and GXT's plans. The Society provides a regional, native communication service for the people on the North Coast and the Lake Melville regions of Labrador.
- GXT will also issue a Newsletter (by email) during the survey to interests and any others who request to be added to the distribution list. This will provide information and updates about the Project. The newsletter will provide direct contact (telephone and email addresses) to the responsible GXT Managers.
- GXT will also establish a Project-specific web site to supplement the Newsletter and post recent information and Project contact details.
- At the request of the FFAW, GXT has also supplied photographs (from different points of view) of the planned survey vessels so that fishers at sea have a better chance to identify them if they are in the area.

Further details of the communications plans will be developed during GXT's continuing discussions with fisheries representatives.

3. Fisheries Avoidance (Fisheries; Science Surveys)

Avoiding Fishing Areas. GXT will avoid active fishing areas during the seismic survey. Specifically GXT will monitor the location of fishing activities and plan its work away from those grounds when fishing is active there. The communications protocols and methods described above will be the key means for GXT to have the information to plan around and away from fish harvesting. Continuing contact between the Project and fishing group representatives, the on-board FLOs, the SPOC, DFO and the FFAW PIL will be essential for this process.

GXT understands that fish harvesters are not required to move their vessels or gear from the seismic survey program area and will not be told to do so; this information will be clearly communicated at the start-up meetings (described above).

No Gear Deployment Enroute to Survey Area. GXT will not deploy is array or streamer in NL waters during transits to the survey area. In addition, the FLOs will advise the vessel en-route to the area ensure fishing gear is avoided by the ships during transits.

Avoidance of Fisheries Science Surveys. 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. For previous NL surveys a temporal and spatial separation plan has been was been implemented (on DFO advice) to ensure that seismic operations did not interfere with the research survey. The procedures, which GXT will follow, involve adequate "quiet time" before the research vessel arrived at its survey location. The avoidance protocol includes a 30 km (16 nm) spatial separation and a seven day pre-research survey temporal separation.

Use of Scout Vessel. If there is a possibility of the survey program working in areas adjacent to active fishing, GXT will use a vessel (the program support ship or and additional smaller vessel) to scout ahead, usually along the planned route of a survey line, to make sure there are no fishing boats or gear in the area. Information about any sightings or radio communications will be relayed back to the survey ship and the FLOs.

Monitoring and Follow-up. As described above, GXT in discussions with relevant groups and mechanisms (such as the FLOs), will continue to monitor the effectiveness of the mitigations during the survey, and consider the results before subsequent year programs.

4. Fishing Gear Damage Program (Fisheries)

Fishing Gear Damage or Loss Compensation Program. A compensation Program will be made available by GXT which is consistent with C-NLOPB guidelines and past practices. This program covers any damage to fishing gear (or vessels) caused by the survey vessels or survey gear, and includes the value of any harvest lost as a direct result of an incident. The Notices to Shipping filed by the vessels for survey work and for transits to and from the survey area will also inform fishers that they may contact the SPOC toll free by telephone or email if they believe that they have sustained survey-related gear

damage. This information will also be communicated through other means (e.g. the Newsletter, contact through fisheries organizations).

The SPOC will follow through with any claim received, in communication with GXT, the FLOs and the relevant fisheries organization. For responding to a claim, GXT will follow procedures (which have been employed successfully in the past by other Operators) similar to those outlined in the One Ocean Protocol document.

Damage or Loss Incident Response. The One Ocean Protocol (Section 4.8 and 4.9) describes responses to a gear conflict to be followed on board a Project ship. GXT will have such procedures in place and will respond to them and any subsequent compensation claim. More specifically, in case of an observed or reported incident, one of the FLOs will follow the following procedures:

- If personnel on board the GXT seismic and/or scout vessel observe fishing gear (abandoned, adrift or active) it should be communicated to the FLO. Gear should not be touched / retrieved by project personnel as it is illegal for anyone but the gear owner to move the gear;
- If the support/scout vessel makes the observation, personnel should record exact positions and name or Canadian Fishing Vessel (CFV) number on the gear (buoy/highflyer) and report it to the FLO;
- The FLO will communicate with fishing vessels in the vicinity in an attempt to identify the gear owner;
- If the CFV number is known, the FLO or the SPOC may be able to identify and contact the owner;
- If identification and contact with the gear owner is successful, the FLO will attempt to determine the plans/schedule of the gear owner with respect to the gear and will encourage the owner to communicate with the FLO at sea;
- If it is not possible to contact the gear owner the survey ship should attempt to work in another area and return to the location at a later time;
- The FLO will record the information in the daily report and submit it to the on-board Client representative.
- If there is any indication a project vessel or its equipment made contact with fishing gear it should be communicated to the FLO immediately;
- The FLO will contact the on-board Client Representative and vessel Master as soon as possible after discovery of the incident;
- The FLO will take all reasonable action to prevent any further or continuing damage;
- If possible, photograph the gear or gear debris in the water and after recovery;
- If necessary, secure and retain any of the gear debris;
- Record the incident in the Daily Report;
- File a Fishing Gear Incident Report and give it to the on-board GXT Client Representative;
- Any contact with fishing gear must be reported immediately even if no damage to the gear has occurred.

Appendix F of the One Ocean Protocol document contains an incident reporting form which meets the requirements of the C-NLOPB Guidelines in assessing a claim. GXT understands that all such incidents

must be reported to the C-NLOPB, which maintains a 24-hour answering service at 709-682-4426 for this purpose (709-778-1400 during working hours). Reports on contacts with fishing gear will include the exact time and location of initial contact, loss of contact and a description of any identifying markings on the gear. Incidents will be reported to GXT (Project Manager and Environmental Manager) by their onboard Client Representative; GXT will then report it to the C-NLOPB following the Board's incident reporting guidelines and/or any other requirements.

5. Marine Mammal / Wildlife Protection (Marine Mammals, Sea Turtles, Seabirds, Fish)

The following marine mammal and sea turtle related measures are based on the Statement of Canadian Practice which are also contained in the C-NLOPB Guidelines.

Use of a Safety Zone. The survey will establish (MMOs) a safety zone which is a circle with a radius of at least 500 m as measured from the center of the air source array. It will be used and at for all times the safety zone is visible when the array is operating and before operations during the pre-start up watch

Pre-Start Up Watch. A qualified Marine Mammal Observer will continuously observe the safety zone for a minimum period of 30 minutes before array start up and maintain a regular watch of the safety zone at all other times the array is active. The array ramp up can only start (or restarting if the array has been inactive for more than 30 minutes) if the full extent of the safety zone is visible and no cetacean, sea turtle or other marine mammal listed as endangered or threatened on Schedule 1 of the *Species at Risk Act* has been seen for at least 30 minutes.

Ramp-Up / Soft Start. If array activation is permitted (based on the pre-watch) a gradual ramp-up (slow increase in power) of the air source array may take place over a minimum of 20 minutes beginning with the activation of a single source element of the air source array, preferably the smallest source element in terms of energy output, and a gradual activation of additional source elements of the air source array will follow until the operating level is reached.

Shut-down of Array. The air source array will be shut down immediately if any of the following is observed by the Marine Mammal Observer in the safety zone:

a) a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; or
b) any other marine mammal or sea turtle that has been identified in an environmental assessment process as a species for which there could be significant adverse effects.

Line Changes and Maintenance Shut-Downs. When seismic surveying (data collection) ceases during line changes, for maintenance or for other operational reasons, the air source array(s) will be

a) shut down completely; or
b) reduced to a single source element.

If the air source array(s) is reduced to a single source element visual monitoring of the safety zone and shut-down requirements will be maintained, but ramp-up procedures will not be required when seismic surveying resumes.

Operations in Low Visibility. If the full extent of the safety zone is not visible, and the array has been inactive for more than 30 minutes, pre-watch, ramp up and acquisition will not commence until visibility conditions allow.

Seabird Strandings. Any seabirds (most likely Leach's Storm-Petrel) that become stranded on the vessels 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. Char dine (CWS) (n.d.). It is understood by GXT that a CWS *Migratory Bird Handling Permit* will likely be required. GXT will request the ships to minimize lighting on board to the extent that it does not affect safety.

Wildlife Data Collection. Marine mammal / sea turtle observations will be made during ramp-ups and during data acquisition periods, and at other times on an opportunistic basis. This will include observations about marine mammal responses and behaviour to the ships and/or the array. Seabird surveys, i.e., standardized counts, will be conducted throughout the seismic program from the seismic vessel by MMOs experienced in the identification of seabirds at sea. Protocols modified and approved for use from ships at sea by Environment Canada as outlined in the Eastern Canada Seabirds at Sea (ECSAS) Standardized Protocol for Pelagic Seabird Surveys from Moving and Stationary Platforms will be utilized (Gjerdrum et al. 2012). A schedule of conducting seabird surveys (likely three times per day) at widely spaced intervals will be followed. Surveys can only be conducted when visibility is >300 m and adequate light conditions permit positive species identification. Data will be collected by a qualified environmental observer(s) (MMO) and FLOs.

Reporting. A monitoring report will be submitted to the C-NLOPB within one year after completion of the surveys as per the C-NLOPB *Guidelines*. In the unlikely event that marine mammals, turtles or birds are injured or killed by Project equipment or accidental spills of fuel, a report will immediately be filed with C-NLOPB and the need for follow-up monitoring assessed.

6. Pollution Prevention / Emergency Response (Fisheries, Marine Mammals, Sea Turtles, Seabirds, Fish, Cumulative Effects)

Waste Management. As described in the Project Description sections of this EA, wastes produced from the vessels, including hazardous and non-hazardous waste material, will be managed in accordance with MARPOL and with the vessel-specific waste management plans. SeaBird Exploration has a Garbage Management Plan in place for the *Harrier Explorer*, and there is a Waste Management Plan in place for the *Polar Prince*. All solid wastes will be sorted by type, compacted where practicable, and stored on board before disposal to an appropriate certified reception facility. Non-Toxic combustible material and waste oil from the vessels will be burned on-board in approved incinerators. The shipboard incinerators will have been examined and tested in accordance with the requirements for shipboard incinerators IMO Res. MEPC 76(40) for disposing of ships-generated waste appended to the Guideline for the implementation of Annex V of MARPOL 73/78. Sufficient and adequate facilities will be available on vessels to store solid wastes generated. The contracted vessels policies and procedures will be reviewed

against the GXT waste management plan, which will be filed with the C-NLOPB. Only ports with licensed waste contractors will be used for any waste returned from offshore. The Environmental Management Plan for SeaBird Exploration (the seismic vessel operator) is provided in Appendix 1.

Discharge Prevention and Management. Vessel discharges will not exceed those of standard vessel operations and will adhere to all applicable regulations. The main discharges include grey water (wastewater from washing, bathing, laundry, and food preparation), black water (human wastes), bilge water, deck drainage and discharges from machinery spaces. All discharges will comply with requirements in the International Convention for the Prevention of Pollution of Ships, 1973, as modified by Protocol of 1978 (MARPOL 73/78) and its annexes. Ground galley food waste can be discharged when a vessel is more than 3 miles offshore. Non ground galley food waste can be discharged when a vessel is more than 12 miles offshore.

Air Emission Control. The vessels will have an International Air Pollution Prevention Certificate issued under the provisions of the Protocol of 1997 as amended by resolution MEPC.176(58) in 2008, to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as the Convention). Air emissions will be those associated with standard operations for marine vessels in general, including the seismic vessel and support vessel. Vessels will only use diesel and gasoil with a sulphur content of no more than 1% (weight) following the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI, for the North American Emission Control Area, which was implemented in Canada in August 2012 (see http://www.tc.gc.ca/eng/marinesafety/ bulletins-2012-03-eng.htm).

Response to Accidental Events. In the unlikely event of the accidental release of hydrocarbons during the Project, GXT and its seismic survey contractor will implement the measures outlined in the Shipboard Oil Pollution Emergency Plans (SOPEPs) which will be filed with the C-NLOPB. In addition, GXT has an Emergency Response Plan (Appendix 2) in place which bridges the emergency plans of all project entities and vessels to the local facilities and the Halifax Search and Rescue Region. The GXT representative onboard will represent GXT in all offshore Quality, Health, Safety & Environment (QHSE) activities. The GXT Project Manager (Dean Kennedy) will represent GXT onshore from an office in St. John's.

The SOPEPs are designed to assist the ships' personnel in dealing with an unexpected discharge of oil. The primary purpose is to set in motion the necessary actions to stop or minimize the discharge of oil and to mitigate its effects. Effective planning ensures that the necessary actions are taken in a structured, logical and timely manner. The primary objectives of this Plan are to prevent oil pollution, to stop or minimize oil outflow when damage to the ship occurs, to stop or minimize oil outflow when an operational spill occurs, and to help contain / clean-up a spill. The ships also carry Spill Kits which typically contain such equipment as

- Air operated pump
- Polypropylene Scoops
- Swabs, Shovels, Brooms with handle
- Bags with absorbent
- Absorbent sheets

- Absorbent bond
- Guard bond
- Plastic drums
- Plastic garbage bin
- Plastic bags
- Rubber gloves and boots
- Chemical protective suits

In the event of the spill, the two ships would work and use their gear together to respond to and contain the released hydrocarbons.

Use of Solid Core Streamer. GXT will use a solid core streamer, manufactured by parent-company ION, so streamer floatation fluid will not cause a leakage hazard.

The following summarizes these mitigations organized by potential effect on VECs (Table 5.2).

Table 5.2 Summary of Mitigations Measures by Potential Effect.

Potential Effects	Primary Mitigations
Interference with fishing vessels / mobile and fixed gear fisheries	• Upfront communications, liaison and planning to avoid fishing activity • Continuing communications throughout the program • FLOs • SPOC • Advisories and communications • VMS data • Avoidance • Start-up meetings on ships
Fishing gear damage	• Upfront communications, liaison and planning to avoid fishing gear • Use of scout vessel • SPOC • Advisories and communications • FLOs • Compensation program • Reporting and documentation • Start-up meetings on ships
Interference with shipping	• Advisories and at-sea communications • FLOs (fishing vessels) • Use of scout vessel • SPOC (fishing vessels) • VMS data
Interference with DFO/FFAW research program	• Communications and scheduling • Avoidance
Temporary or permanent hearing damage/disturbance to marine animals	• Pre-watch of safety zone • Delay start-up if marine mammals or sea turtles are within 500 m • Ramp-up of airguns • Shutdown of airgun arrays for *endangered* or *threatened* marine mammals and sea turtles within 500 m • Use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations

Potential Effects	Primary Mitigations
Temporary or permanent hearing damage/ disturbance to Species at Risk or other key habitats	• Pre-watch of safety zone • Delay start-up if marine mammals or sea turtles are within 500 m • ramp-up of airguns • Shutdown of airgun arrays for *endangered* or *threatened* marine mammals and sea turtles within 500 m • Use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations. [No critical habitat has been identified in or near the Study Area.]
Injury (mortality) to stranded seabirds	• Daily monitoring of vessel • Handling and release protocols • Minimize lighting if safe
Seabird oiling	• Adherence to MARPOL • Spill contingency and response plans • Use of solid streamer

5.7 Effects of the Environment on the Project

The physical environment of the Project Area is described in Section 3.0 and the Labrador Shelf SEA (Sikumiut 2008) and the reader is referred to these sources to assist in determining the effects on the Project. Furthermore, safety issues are assessed in some detail during the permitting and program application processes. Nonetheless, effects on the Project are important to consider, at least on a high level, because they may sometimes lead to effects on the environment.

Given the Project time frame of June to November for seismic operations and the requirement of a seismic survey to avoid periods and locations of sea ice, sea ice should have no effect on the Project. Icebergs in the early summer may cause some survey delays if survey lines have to be altered to avoid them. Most physical environmental constraints on seismic surveys are those imposed by wind and wave. The Project scheduling avoids the most continuous extreme weather conditions and GXT's contractors will be thoroughly familiar with east coast operating conditions. As a prediction of the effects of the environment on the Project, GXT will likely use an estimate of 20% weather-related down time for the Project for planning purposes. 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.

There are also expected to be effects on the Project because of the commercial fisheries activities expected in the Project Area. These will require that the seismic ship avoid certain zones within the Project Area at certain times, when harvesting is active, especially when fishing gear is in the water. The effects on the Project will be minimized through advanced planning and good communications, as described in the Mitigation measures (Section 5.6).

Effects of the biological environment on the Project are unlikely, other than for array shutdowns if required when marine mammals enter the Safety Zone.

Collectively, these potential effects cannot be considered to cause a significant effect on the Project otherwise the Project would not be acceptable to the Proponent.

5.8 Effects of the Project on the Environment

This effects assessment is organized so that issues generic to any type of ship activity in Labrador Shelf waters such as fisheries vessels, DFO research vessels, military ships, marine transporters, or the proposed seismic surveys are discussed first. A detailed effects assessment then follows, which focuses on the effects of noise (primarily on marine mammals, fish and fisheries) and the towed seismic streamer (primarily on fishing gear), which is the major distinction between the effects of seismic surveys versus those of other marine vessels. The applicable mitigation measures (detailed in Section 5.6) are also noted for the relevant activity. The detailed assessment includes the generic effects in the ratings and predictions tables but does not discuss these generic issues in any detail.

5.8.1 Generic Activities - Air Quality

The air emissions from project activities will be those from the Project vessels engines and generators, and vessel incinerators, all of which will be within the range of emissions from typical marine vessels on the east coast such as fishing, research, or offshore supply vessels. As such, there will be no particular or unique health or safety concerns associated with project emissions.

Given that the Project will use sulphur content (no more than 1%) fuel (following Canadian 2012 ECA regulations) and that it will add negligible air emissions (relative to total NW Atlantic ship traffic) to a windy oceanic environment there will be no measureable adverse effect on air quality or human health in the Project Area.

5.8.2 Generic Activities - Marine Use

Project-related traffic will include one seismic survey vessel and one support vessel. The survey and support vessels will operate within the Project Area (see Figure 1.1), except when transiting to or from the survey area. The support vessel will operate occasionally to and from the Project Area for re-provisioning.

Other ships operating in the area could include freighters, tankers, fishing vessels, research vessels, naval vessels, and private yachts. Mitigations (detailed in Section 5.6) will minimize potential conflicts and any adverse effects with other vessels; these include:

- At sea communications (VHF, HF, Satellite, radar etc.);
- Utilization of Fisheries Liaison Officers (FLOs) for advice and coordination in regard to avoiding fishing vessels and fishing gear;
- Support / scout vessel to alert other vessels of towed gear in water;
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast;
- Compensation program in the event any project vessels damage fishing gear; and
- Single Point of Contact (SPOC).GXT will also coordinate with DFO, St. John's, to avoid any potential conflicts with research vessels that may be operating in the area.

Given the expected vessel density conditions and mitigations described above, there should be *negligible* adverse effects on other marine users of the Project Area.

5.8.3 Generic Activities - Waste Handling

Waste generated by the Project will be that generated by a total maximum of ~100 personnel on a two vessels. Waste will include:

- Gray/black water;
- Galley waste; and
- Solid waste.

As described in Section 5.6 vessel discharges will not exceed those of standard vessel operations and will adhere as a minimum to all applicable regulations and applicable international standards. The main discharges include grey water (wastewater from washing, bathing, laundry, and food preparation), black water (human wastes), bilge water, deck drainage and discharges from machinery spaces. Wastes produced from the seismic and support vessels, including hazardous and non-hazardous waste material, will be managed in accordance with MARPOL and with the vessel specific waste management plans.

Waste produced by the Project will handled and treated appropriately and therefore have *negligible* effect on the environment in the Study Area.

5.8.4 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 5.3), the *negligible* residual effects are predicted to be *not significant*. The 2013 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, no further reference to the 'fish habitat' component of the Fish and Fish Habitat VEC is made in this assessment section. Ichthyoplankton, invertebrate eggs and larvae, and macrobenthos are considered as part of the 'fish' component of the Fish and Fish Habitat VEC.

Table 5.3 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 [c]**	**Pelagic Fish**	**Groundfish**
Vessel Lights		X				X	
Sanitary/Domestic Waste	X	X		X		X	
Air Emissions	X	X		X		X	
Garbage [a]						X	
Sound							
Airgun Array		X	X	X	X	X	X
Seismic Vessel						X	
Support Vessel						X	
Echosounder			X	X	X	X	X

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 [c]**	**Pelagic Fish**	**Groundfish**
Presence of Vessels							
Seismic Vessel							
Support Vessel							
Shore Facilities [b]							
Accidental Spills	X	X		X		X	
Other Projects and Activities							
Oil and Gas Activities on Labrador Shelf	X	X	X	X	X	X	X
Oil and Gas Activities on Grand Banks	X	X	X	X	X	X	X
Fisheries	X	X	X	X	X	X	X
Marine Transportation	X	X		X		X	

[a] Not applicable as garbage will be brought ashore.
[b] There will not be any new onshore facilities. Existing infrastructure will be used.
[c] Juveniles are young fish that have left the plankton and are often found closely associated with substrates.

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

5.8.4.1 Sound

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

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

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).

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 400–1,500 Hz for the squid *Sepiotheutis lessoniana* and 400–1,000 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).

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 2004b). 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 crabs; 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 μPa_{0-p}. Statocysts were removed and preserved, but at the time of publication, results of the statocyst analyses were not available. No squid or cuttlefish mortalities were reported as a result of these exposures.

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

Stress indicators in the haemolymph of adult male snow crabs were monitored immediately after exposure of the animals to seismic survey sound (Christian et al. 2003, 2004) and at various intervals after exposure. No significant acute or chronic differences were found between exposed and unexposed animals in which various stress indicators (e.g., proteins, enzymes, and 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 include Payne et al. (2008); Popper (2009); Popper and Hastings (2009a,b). These papers consider various sources of anthropogenic sound, including seismic airguns.

Fertilized capelin (*Mallotus villosus*) eggs and monkfish (*Lophius americanus*) larvae were exposed to seismic airgun sound and subsequently examined and monitored for possible effects of the exposure (Payne et al. 2009). The laboratory exposure studies involved a single airgun. Approximate received SPLs measured in the capelin egg and monkfish larvae exposures were 199 to 205 dB re 1 μPa_{p-p} and 205 dB re 1 μPa_{p-p}, respectively. The capelin eggs were exposed to either 10 or 20 airgun discharges, and the monkfish larvae were exposed to either 10 or 30 discharges. No statistical differences in mortality/morbidity between control and exposed subjects were found at 1 to 4 days post-exposure in any of the exposure trials for either the capelin eggs or the monkfish larvae.

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

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

Saetre and Ona (1996) applied a "worst-case scenario" mathematical model to investigate the effects of seismic sound on fish eggs and larvae. They concluded that mortality rates caused by exposure to seismic airgun sound are so low compared to the natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

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

Popper et al. (2005) tested the hearing sensitivity of three Mackenzie River fish species after exposure to five discharges from a seismic airgun. The mean received peak SPL was 205 to 209 dB re 1 µPa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1 $\mu Pa^2 \cdot s$ per discharge. While the broad whitefish (*Coregonus nasus*) showed no Temporary Threshold Shift (TTS) as a result

of the exposure, adult northern pike (*Esox lucius*; a *hearing generalist*), and lake chub (*Couesius plumbeus*; *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). Considerable uncertainty is associated with this estimation of the source level.

Behavioural Effects

Invertebrates

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

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

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

Caged brown shrimp *Crangon crangon* reared under different acoustical conditions exhibited differences in aggressive behaviour and feeding rate (Lagardère 1982). Those exposed to a continuous sound

source showed more aggression and less feeding behaviour. It should be noted that behavioural responses by caged animals may differ from behavioural responses of animals in the wild.

McCauley et al. (2000a,b) provided the first evidence of the behavioural response of southern calamari squid *Sepioteuthis australis* exposed to seismic survey sound. McCauley et al. (2000a, b) reported on the exposure of caged cephalopods (50 squid and two cuttlefish) to sound from a single 20 in^3 airgun. The cephalopods were exposed to both stationary and mobile sound sources. The two-run total exposure times during the three trials ranged from 69 to 119 min. at a firing rate of once every 10 to 15 seconds. The maximum SPL was >200 dB re 1 μPa_{0-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.

A review of the scientific literature related to the potential effects of seismic sound on invertebrate fisheries is included in Section 5.7.5, Fisheries VEC.

Fishes

Pearson et al. (1992) investigated the effects of seismic airgun sound on the behaviour of captive rockfishes *Sebastes* sp. exposed to the sound of a single stationary airgun at a variety of distances. The airgun used in the study had a source SPL at 1 m of 223 dB re 1 µPa at 1 $m_{0\text{-}p}$, and measured received SPLs ranged from 137 to 206 dB re 1 $\mu Pa_{0\text{-}p}$. The authors reported that rockfishes reacted to the airgun sounds by exhibiting varying degrees of startle and alarm responses, depending on the species of rockfish and the received SPL. Startle responses were observed at a minimum received SPL of 200 dB re 1 $\mu Pa_{0\text{-}p}$, and alarm responses occurred at a minimum received SPL of 177 dB re 1 $\mu Pa_{0\text{-}p}$. Other observed behavioural changes included the tightening of schools, downward distributional shift, and random movement and orientation. Some fishes ascended in the water column and commenced to mill (i.e., "eddy") at increased speed, while others descended to the bottom of the enclosure and remained motionless. Pre-exposure behaviour was 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 $m_{0\text{-}p}$. The shot interval was 25 seconds, and exposure durations ranged from 4.6 to 12 hours. Horizontal distributions did not appear to change as a result of exposure to seismic discharge, but there was some indication of a downward shift in the vertical distribution. The catch rates during experimental fishing did not differ significantly between pre- and post-seismic fishing periods.

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

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

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

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

A review of the scientific literature related to the potential effects of seismic sound on finfish fisheries is included in Section 5.8.5, Fisheries VEC.

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. 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.

Sound Exposure Effects Assessment

The reader should first refer to the interaction table (Table 5.3) to determine if there are any interactions with project activities, secondly to the assessment table (Table 5.4) which contains ratings for magnitude, extent, and duration, and thirdly to the significance predictions table (Table 5.5).

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 focus by selecting (1) the strongest sound source, in this case the airgun array, and (2) several species that are representative of the different types of sensitivities and 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 (post-larval snow crabs remain on bottom, post-larval cod occur in the water column, and larvae of both snow crab and cod are planktonic in upper water column), (2) motility of the animal (post-larval snow crabs much less motile than post-larval cod, and larvae of both are essentially passive drifters), (3) absence or presence of a swim bladder (i.e., auditory sensitivity) (snow crabs without swimbladder and cod with swimbladder), and (4) reproductive strategy (snow crabs carry fertilized eggs at the bottom until larval hatch, and cod eggs are planktonic).

Potential impacts on other marine invertebrate and fish species are inferred from the assessment using snow crab and Atlantic cod. Potential interactions between the proposed Project activities and the Fish and Fish Habitat VEC are shown in Table 5.3.

Table 5.4 Assessment of Effects of Project Activities on the Fish and Fish Habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Vessel Lights	Neutral effect		0					
Sanitary/Domestic Waste	Pathological effects (N); Contamination (N)	Treatment; adherence to regulations and conventions	0-1	1	1	2	R	2
Air Emissions	Pathological effects (N); Contamination (N)	Use of low-sulpher fuel; Equipment maintenance	0	1	6	2	R	2
Sound								
Airgun Array	Disturbance (N)	Ramp-up of array; Spatial or temporal avoidance	1	1-3	6	2	R	2
Airgun Array	Physical effects (N)	Ramp-up of array; Spatial or temporal avoidance	1	1	6	2	R	2
Seismic Vessel	Disturbance (N)	Spatial or temporal avoidance	0-1	1	6	2	R	2
Support Vessel	Disturbance (N)	Spatial or temporal avoidance	0-1	1	6	2	R	2
Echosounder	Disturbance (N)	Spatial or temporal avoidance	0-1	1	6	1	R	2
Presence of Vessels								
Seismic Vessel	Disturbance (N)							
Support Vessel	Disturbance (N)							
Accidental Releases	Pathological effects (N); Contamination (N)	Solid streamer [a]; Spill response	0-1	1-2	1	1	R	2

[a] A solid streamer will be used for all seismic surveys

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 5.5 Significance of Potential Residual Environmental Effects of Project Activities on the Fish and Fish Habitat VEC.

Valued Ecosystem Component: Fish and Fish Habitat				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood[a]**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Lights	NS	2-3	-	-
Sanitary/Domestic Waste	NS	2-3	-	-
Air Emissions	NS	2-3	-	-
Sound				
Airgun Array	NS	2-3	-	-
Seismic Vessel	NS	2-3	-	-
Support Vessel	NS	2-3	-	-
Echosounder	NS	2-3	-	-
Presence of Vessels				
Seismic Vessel	-	-	-	-
Support Vessel	-	-	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

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

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

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

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

As already indicated in this section, although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain. Available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range. Considering the typical source levels associated with commercial seismic airgun arrays, close proximity to the source would result in exposure to very high sound pressure levels. While egg and larval stages are not able to actively escape such an exposure scenario, juvenile and adult cod would most likely avoid it. Developing embryos, juvenile and adult snow crab are benthic and generally far enough from the sound source to receive energy levels well below levels that may have impact. In the case of eggs and larvae, it is likely that the numbers negatively affected by exposure to seismic sound would be negligible when compared to those succumbing to natural mortality (Saetre and Ona 1996). 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 100 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.

Note that the seismic lines for this program will be long and widely spaced (50-100 km apart) with occasional crossing points, effectively resulting in 'one time' exposures of biota and fishing grounds to maximum energy from the discharging airguns.

As indicated in Table 5.4, 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 5.5)

5.8.4.2 Other Project Activities

Vessel Lights

As indicated in Table 5.3, there are potential interactions between vessel lights and certain components of the Fish and Fish Habitat VEC. However, other than the relatively neutral effect of attraction of certain species/life stages to the upper water column at night, there will be *negligible* effects of vessel lights on this VEC (Table 5.4). 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 5.5).

Sanitary/Domestic Waste

As indicated in Table 5.3, there are potential interactions between sanitary/domestic waste and certain components of the Fish and Fish Habitat VEC. After application of mitigation measures, including treatment of the waste, the residual effects of sanitary/domestic waste on the Fish and Fish Habitat VEC are predicted to be *negligible to low* in magnitude for a duration of *1-12 months* over an area of *<1 km*^{2} (Table 5.4). Based on these criteria ratings, the *reversible* residual effects of *infrequen*t exposure to sanitary/domestic waste associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.5).

Air Emissions

As indicated in Table 5.3, there are potential interactions between atmospheric emissions and certain components of the Fish and Fish Habitat VEC that occur near surface. Considering that the amount of atmospheric emissions produced during the proposed seismic program will rapidly disperse to

undetectable levels and that low sulpher content fuel (no more than 1%) will be used, the residual effects of exposure to them on the Fish and Fish Habitat VEC are predicted to be *negligible* (Table 5.4). 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 5.5).

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

As indicated in Table 5.3, 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 indicated mitigations in place, the residual effects of an accidental release associated with the GXT'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 5.4). 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 5.5).

5.8.5 Fisheries VEC

The potential interactions of Project activities and the Fisheries VEC are indicated in Table 5.6. Traditional fisheries, recreational fisheries, DFO and joint DFO/Industry Research Surveys were included in the assessment of the Fisheries VEC.

Table 5.6 Potential Interactions of Project Activities and the Fisheries VEC.

Valued Ecosystem Component: Fisheries			
Project Activities	**Mobile Invertebrates and Fishes (fixed [e.g., gillnet] and mobile gear [e.g., trawls])**	**Sedentary Benthic Invertebrates (fixed gear [e.g., crab pots])**	**Research Surveys (mobile gear-trawls; fixed gear-crab pots)**
Vessel Lights			
Sanitary/Domestic Waste	X	X	X
Air Emissions			
Garbage [a]			
Sound			
Airgun Array	X	X	X
Seismic Vessel	X	X	X
Support vessel	X	X	X
Echosounder	X		X
Presence of Vessels			
Seismic Vessel	X	X	X
Support Vessel	X	X	X
Shore Facilities [b]			
Accidental Spills	X	X	X
Other Projects and Activities			
Oil and Gas Activities on the Labrador Shelf	X	X	X
Oil and Gas Activities on the Grand Banks			
Marine Transportation	X	X	X

[a] Not applicable as garbage will be brought ashore.
[b] There will not be any new onshore facilities. Existing infrastructure will be used.

Behavioural changes in commercial species in relation to catchability as a result of exposure to airgun sound, and conflict with harvesting activities and fishing gear (primarily the streamer) were raised as potential issues during the consultations and issues scoping for this assessment (see Section 5.2; Appendix 3). 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 may result in tainting (or perceived tainting) thus affecting product quality and marketing.

The following sections assess the potential effects of Project activities on the Fisheries VEC.

5.8.5.1 Sound

As indicated in the description of commercial fisheries in Section 4.3, there has been substantial harvesting within the Study Area between 2005 and 2010. Northern shrimp accounted for most of the commercial harvest within the Study Area during that period, followed by snow crab, Greenland halibut

(turbot), striped shrimp and numerous other species that combined accounted for only about 0.1% of the total catch weight during that six-year period.

The potential for impacts on fish harvesting will, therefore, depend on the location and timing of the surveying activities in relation to these fishing areas when they are active, and the type of fishing gear used in any given location and season. If the survey work is situated away from these fishing areas or occur at different times, 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).

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 below. 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.

The following two sections provide a review of the scientific literature related to the potential effects of exposure to seismic sound on fisheries for invertebrate and finfish species.

Invertebrate Fisheries

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

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

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

that lobster catch rates were affected by seismic surveys. They also noted that due to natural variability and fishing pressure, a large effect on lobster would be required to make any link to effect of seismic.

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 $\mu Pa_{0\text{-}p}$ and 178 dB re 1 $\mu Pa_{0\text{-}p}$, 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. 2012). 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 $\mu Pa_{0\text{-}p}$. 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 $\mu Pa_{0\text{-}p}$. 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 echosounder 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 $\mu Pa_{0\text{-}p}$. 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).

Mitigations

In consideration of these issues, Section 5.6 of this EA details numerous measures and mechanisms identified through several sources (such as consultations with fishing industry representatives and the C-NLOPB Guidelines) that GXT will apply for mitigating potential impacts from sound on fisheries activities, such as communication and information exchange, the use of FLOs and SPOC, and avoiding active fishing areas.

Assessment of the Effects of Seismic Survey Sound

The degree of overlap between fishing activity and seismic activity that could occur during the 2013 season is unknown at the moment, but will be determined prior to the commencement of the seismic surveys (see Communication mitigations, Section 5.6). 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. Note that the seismic lines for this program will be long and widely spaced (50-100 km apart) with occasional crossing points, effectively resulting in 'one time' exposures of biota and fishing grounds to maximum energy from the discharging airguns. With application of the mitigations discussed above, effects of seismic survey sound on the Fisheries VEC are predicted to be a *negligible* to *low* magnitude during *1-12 months* over an area of *<1* to *11-100 km^2* (Table 5.7). Based

on these criteria ratings, the *reversible* residual effects of seismic survey sound on the Fisheries VEC are predicted to be *not significant* (Tables 5.8).

Table 5.7 Assessment of Effects of Project Activities on the Fisheries VEC.

Valued Ecosystem Component: Fisheries								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Sanitary/Domestic Waste	Disturbance (N); Effect on catch rate (N)	Treatment; containment	0-1	1	1	2	R	2
Sound								
Airgun Array	Disturbance (N) Effect on catch rate (N)	Spatial or temporal avoidance; communication	0-1	1-3	6	2	R	2
Seismic Vessel	Disturbance (N); Effect on catch rate (N)	Spatial or temporal avoidance; communication	0	1	6	2	R	2
Support vessel	Disturbance (N); Effect on catch rate (N)	Spatial or temporal avoidance; communication	0	1	6	2	R	2
Echosounder	Disturbance (N); Effect on catch rate (N)	Spatial or temporal avoidance; communication	0-1	1	6	2	R	2
Presence of Vessels								
Seismic Vessel	Conflict with gear (N)	Spatial or temporal avoidance; FLOs; SPOC damage/loss compensation	0-1	1	6	2	R	2
Support Vessel	Conflict with gear (N)	Spatial or temporal avoidance ; FLOs; SPOC; damage/loss compensation	0-1	1	6	2	R	2
Accidental Spills	Taint (N); Perceived taint (N)	Solid streamer [a] Preventative protocols; Response plan; Communication	0-1	1-2	1	1	R	2

[a] A solid streamer will be used for all seismic surveys

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

Table 5.8 Significance of Potential Residual Environmental Effects on the Fisheries VEC.

Valued Ecosystem Component: Fisheries				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood [a]**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Lights	-	-	-	-
Sanitary/Domestic Waste	NS	3	-	-
Air Emissions	-	-	-	-
Garbage	-	-	-	-
Sound				
Airgun Array	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Support vessel	NS	3	-	-
Echosounder		2-3		
Presence of Vessels				
Seismic Vessel and Streamers	NS	3	-	-
Support Vessel	NS	3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

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

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

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

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

Vessel Presence (including streamers)

Commercial fish harvesting activities occur throughout the June 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 they are deployed concurrently with seismic survey operations. During seismic surveying, operations will be conducted continuously for 20-90 days. Because of the length of the streamers being towed behind it, the manoeuvrability of a seismic vessel is restricted and other mobile 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. There will typically be no deployment of streamer outside the Project Area and there will be no array testing outside that area. The only circumstance under which the streamer would be deployed

outside the Project Area in severe weather conditions. Sometimes retrieval of the streamer might not be possible and the seismic vessel may have to stay on the same heading for a couple days for the safety of the vessel and streamer.

When gear conflict events occur that damage gear or result in gear loss due to the survey, they will be assessed and compensation will be paid for both gear and catch losses attributable to the seismic survey, as described below.

Mitigations

Section 5.6 of this EA details the measures and mechanisms identified that GXT will apply for mitigating potential impacts of the presence of the vessels and the towed seismic gear on fisheries activities, such as communication and information exchange, the use of FLOs and SPOC, avoiding active fishing areas, providing for gear damage compensation.

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 Fisheries VEC are predicted to be a *negligible* to *low* magnitude during *1-12 months* over an area of *<1* to *11-100 km*^{2} (Table 5.7). Based on these criteria ratings, the *reversible* residual effects of vessel presence during the seismic program on the Fisheries VEC are predicted to be *not significant* (Tables 5.8).

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 section 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*.

Accidental Releases

In the event of an accidental release of hydrocarbons (e.g., 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 an actual or perceived tissue tainting. The streamers to be used are solid-core so streamer floatation fluid will not be an issue. 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 and in Section 5.6, the effect of accidental hydrocarbon releases on the Fisheries VEC is predicted have a *negligible* to *low* magnitude during

<1 month over an area of *<1* to *1-10 km*^{2} (Table 5.7). Based on these criteria ratings, the *reversible* residual effect of accidental releases on the Fisheries VEC during the seismic program is predicted to be *not significant* (Tables 5.8).

5.8.6 Marine Birds VEC

There are three main potential types of impacts to seabirds from offshore seismic exploration: (1) attraction to ship lights at night, (2) underwater sound from airgun arrays, and (3) accidental release of fuel. Potential interactions between the Project and seabirds are shown in Table 5.9.

Table 5.9 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]	
Sound	
Airgun Array	X
Seismic Vessel	X
Support Vessel	X
Echosounder	X
Presence of Vessels	
Seismic Vessel	X
Support Vessel	X
Shore Facilities [b]	
Accidental Spills	X
Other Projects and Activities	
Oil And Gas Activities on Labrador Shelf	X
Oil And Gas Activities on Grand Banks	X
Fisheries	X
Marine Transportation	X

[a] Not applicable as garbage will be brought ashore.
[b] There will not be any new onshore facilities. Existing infrastructure will be used.

5.8.6.1 Vessel Lights

Nocturnally-active seabirds can be attracted to artificial lighting at night. This includes lights at coastal lighthouses and vessels at sea (Montevecchi et al. 1999). Seabirds as well as migrating landbirds have been attracted to lights on offshore oil and gas platforms, especially during foggy or overcast conditions (Montevecchi 2006). Several studies of seabird attraction to artificial lighting on offshore and coastal structures and vessels have been conducted (see Husky 2012 for a review). The birds may become injured by flying directly into the source of light or the ship infrastructure (Dick and Donaldson 1978; Telfer et al. 1987; Black 2005; Russell 2005; Poot et al. 2008; Rodríguez and Rodríguez 2009). However, most mortality occurs because these birds enter the partially enclosed areas of ships. On seismic vessels, stranded birds are often found on streamer and airgun decks, where they are unable to find their way out (LGL, unpubl. data). They mill about until exhausted and drop to the deck, after

which they succumb to dehydration, starvation, exhaustion, or hypothermia. The latter occurs as a result of falling into the drip trays under winches used to deploy streamers or airgun hoses, where they come into contact with hydraulic fluid or streamer fluid. Birds may be attracted to artificial lighting from a distance of up to 5 km in the case of offshore oil/gas installations with 30 kW of lighting (Poot et al. 2008).

Attraction to artificial lighting and attendant grounding appears to be widespread among procellariiform seabird species (i.e., petrels, shearwaters, prions, storm-petrels, and diving-petrels (Pelecanoididae) (but not albatrosses Diomedeidae), having been observed in more than 20 species (Imber 1975; Reed et al. 1985; Telfer et al. 1987; Le Corre et al. 2002; Black 2005; Montevecchi 2006; Abgrall et al. 2008b; Rodríguez and Rodríguez 2009; Miles et al. 2010; Howell 2012). Leach's Storm-Petrel is the seabird most often attracted to lights at night in Newfoundland and Labrador waters.

Small colonies of nesting Leach's Storm-Petrels occur in Newfoundland not too distant from the Study Area (see Figure 4.43 and Table 4.8 in Section 4.4) and small numbers of storm-petrels forage offshore. Leach's Storm-Petrels are present in Labrador and northern Newfoundland waters from April to October. The period of greatest risk of attraction to offshore lights is thought to be September when adults and newly fledged chicks are dispersing from nesting colonies and moving to offshore wintering grounds (Williams and Chardine n.d.). Young-of-the-year birds appear to be more susceptible to light attraction than are adults, but the extent of storm-petrel susceptibility is unclear. Leach's Storm-Petrel and other birds stranding have regularly occurred on previous seismic and controlled source electromagnetic surveys in Newfoundland waters (Moulton et al. 2005, 2006b; Lang et al. 2006; Lang and Moulton 2008; Abgrall et al. 2008a). Storm-petrels have been also reported to land on drill rigs in Newfoundland waters during summer (e.g., 52 birds in three weeks on the Terra Nova drill rig; U. Williams, Petro-Canada, pers. comm.). A detailed review of the issue is contained in the White Rose Extension Project EA (Husky 2012).

Mitigation measures to rescue stranded storm-petrels on board the seismic vessel will be the responsibility of the MMO. As noted in Section 5.6, 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 Petro-Canada (now Suncor) on proper procedure and handling of stranded storm-petrel (Williams and Chardine, n.d.). GXT acknowledges that a Federal *Migratory Bird Salvage Permit* will be required. Deck lighting can be minimized (if it is safe and practical to do so) to reduce the likelihood of stranding. 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. Mitigation and monitoring for stranded birds will reduce effects of attraction to lights to a *low* magnitude, over a geographic extent of *1-10 km^2*, and for a duration of *1-12 months* (Table 5.10). Thus, effects are predicted to be *not significant* (Table 5.11).

5.8.6.2 Sanitary/Domestic Waste

Sanitary waste generated by the vessels will be macerated before subsurface discharge, following requirements described in Section 5.6. 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 are predicted to be negligible to low magnitude within 1- 10 km^2 area, for a duration of 1-12 months (Table 5.10). Thus, effects are predicted to be not significant (Table 5.11).

Table 5.10 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**
Vessel Lights	Attraction (N)	Reduce lighting (if possible)	1	2	2-3	2	R	1
Sanitary/Domestic Waste	Increased Food (N/P)	Treatment / containment	0-1	1	1	2	R	1
Air Emissions	Air Contaminants (N)	Low sulphur fuel (1%)	0	1	6	2	R	1
Sound								
Airgun Array	Disturbance (N)		0-1	1-2	6	2	R	1
Airgun Array	Physical Effects (N)	Ramp-up	0-1	1	6	2	R	1
Seismic Vessel	Disturbance (N)		0-1	1	6	2	R	1
Support Vessel	Disturbance (N)		0	1	6	2	R	1
Echosounder	Disturbance (N)		0-1	1	6	2	R	1
Presence of Vessels								
Seismic Vessel	Disturbance (N)	Stranding protocol	0	2	6	2	R	1
Support Vessel	Disturbance (N)	Stranding protocol	0	2	6	2	R	1
Accidental Spills	Mortality (N)	Solid streamer[a]; Spill Response	1	1-2	1	1	R	1

Key:

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

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

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

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

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

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

[a] A solid streamer will be used for all seismic surveys.

Table 5.11 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 (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – physical effects	NS	3	-	-
Array – behavioural effects	NS	3	-	-
Seismic Vessel	NS	3	-	-
Support Vessel	NS	3	-	-
Echosounder	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Support Vessel	NS	3	-	-
Accidental Spills	NS	2	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

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

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

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

5.8.6.3 Air Emissions

Although atmospheric emissions could, in theory, affect the health of some resident marine seabirds, the effects will be *negligible*, because emissions of potentially harmful materials will be small (especially using low 1% sulphur fuel) 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.

5.8.6.4 Sound

The effects of underwater sound on birds have not been well studied. Birds have good hearing abilities in air (Fay 1988), but much of what is believed about their hearing ability under water is inferred from mammals. Hearing thresholds (the minimum sound pressure levels at which a sound can be detected) in birds are probably higher in water than in air, as is the case with humans (Dooling and Therrien 2012). In addition, the frequency of best hearing underwater in birds is probably lower in water than air, as it is

with humans. However, birds' feather coverings may affect hearing. The muscles attached to the feather shafts contract during dives, forming a waterproof seal that probably prevents water from entering the auditory meatus.

Only one study has examined the effects of underwater seismic surveys on birds. Observations of free-ranging moulting Long-tailed Ducks (*Clangula hyemalis*) in the Beaufort Sea showed little effect on the ducks' 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.

Most species of seabirds that are expected to occur in the Study Area feed at the surface or at less than one metre below the surface of the ocean (see Table 4.10 in Section 4.4). Northern Gannet plunge dives to a depth of 10 m. They are under the surface for a few seconds during each dive so would have minimal exposure to underwater sound. Great Shearwater, Sooty Shearwater, and Manx Shearwater feed mainly at the surface but also chase prey briefly beneath the surface down to a depth of two to ten metres (Brown et al. 1978, 1981).

The Alcidae are one group of birds that spends considerable time under water at various depths to hunt for food and require a significant length of time to secure food (see Table 4.10 in Section 4.4). This group includes Dovekie, Common Murre, Thick-billed Murre, Razorbill and Atlantic Puffin. From a resting position on the water, they dive under the surface in search of small fish and invertebrates. Alcids use their wings to propel their bodies rapidly through the water. All are capable of reaching considerable depths and spending considerable time under water (Gaston and Jones 1998). An average duration of dive times for the five species of *Alcidae* is 25 to 40 seconds reaching an average depth of 20 to 60 m, but murres are capable of diving to 120 m and have been recorded underwater for up to 202 seconds (Gaston and Jones 1998).

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

The effects of underwater sounds on Alcidae are unknown. Sounds are probably not important to Alcidae in securing food. However, all six species are quite vocal at breeding sites indicating auditory capabilities are important in that part of their life cycle. The 'laughing call' of the Thick-billed Murre is shown to cover a frequency range of 1.0 to 4.0 kHz (Gaston and Jones 1998). While supporting data on actual effects are few, it is predicted that there will be *no significant effects* (Table 5.11) on seabirds from the sound because the magnitude of the effect (if it occurs) will be *negligible* to *low*, the geographic extent will be small (probably < *1 km²* to *1-10 km²*), and duration will be *1-12 months* (Table 5.10).

5.8.6.5 Presence of Vessels

The seismic vessel and support vessel 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 or support vessel while prospecting for fish wastes associated with fishing vessels. Since there is little or no food made available by these vessels seabird have a short term interest in the vessels and soon go elsewhere in search of food. Seabirds sitting on the water in the path of these vessels can move out of the way. The physical presence of the vessels will have a *negligible* effect that is *not significant* on seabirds (Tables 5.10 and 5.11).

5.8.6.6 Accidental Spills

The primary accidental event associated with the seismic program that could have environmental consequences of concern is the unintentional release of fuel from project vessels. [Only solid streamers will be used.] All fuel handling and reporting procedures on board will be consistent with GXT's policy, and handling and reporting procedures. A fuel spill may occur from the seismic ship and/or the support vessel—both vessels will use marine gas oil. Marine gas oil is a light fuel that persists in the environment for much shorter periods than does crude oil or heavy fuel oils such as Bunker C. In cold water, only about 50% of the spilled gas oil would remain on the water surface after 12 hours (Smith and McIntyre 1971). Thus, a spill of gas oil would not persist for long periods on the water surface. About half of the oil lost from the surface is dispersed in the water column and about half is lost to evaporation (Birchard and Nancarrow 1986). Once in the water column, the half-life of diesel at 0º to 2ºC may be more than 10 days (Gearing and Gearing 1982). Any spills would likely be small and quickly dispersed by wind, wave, and ship's propeller action. The effects of hydrocarbon spills on seabirds were reviewed in Husky (2012) and are not repeated in detail here.

The reported effects of hydrocarbon spills on seabirds vary with species, type of hydrocarbon, weather conditions, time of year and duration of the spill (Gorsline et al. 1981). Exposure to oil causes thermal and buoyancy deficiencies that typically lead to the deaths of affected marine birds. Although some may survive these immediate effects, long-term physiological changes may eventually result in death (Ainley et al. 1981; Burridge and Kane 1985; Frink and White 1990; Fry 1990). For some individual birds, oiling has not had lethal or marked sublethal effects. Among oiled, colour-banded Herring Gulls and Lesser Black-backed Gulls (*Larus fuscus*), most survived and cleaned themselves with a few weeks of oiling, some bred successfully and survived up to 20 years after oiling (Camphuysen 2011).

Exposure to fuel under calm conditions may harm or kill individual birds. Potential spills will likely be small and evaporation and dispersion rapid (particularly given the fuel type). Spill response plans (SOPEPs) and equipment will be in place. Effects of a small accidental spill on seabirds would be *low* magnitude, over a duration of *<1 month*, in an area *<1 km^2 to 1–10 km^2* and effects are judged to be *not significant* (Tables 5.10 and 5.11).

Waters off the southeast coast of Newfoundland are a major junction for international marine traffic destined for Canadian and U.S. ports. Analyses of the oil involved in bird strandings show that wastes are composed of mixtures of bunker C and marine diesel, indicating origins in the engine room bilges of

ocean-going ships (Lock and Deneault 2000). The illegal discharge of oily bilge water off the southeast coast of Newfoundland is a chronic problem (Wiese and Ryan 1999, 2003). GXT project vessels will not engage in the illegal discharge of oily bilge water.

5.8.7 Marine Mammals and Sea Turtles VEC

The potential effects of marine seismic activities on marine mammals and sea turtles have previously been reviewed in the Labrador Shelf SEA and a recent seismic EA for the Labrador Shelf (LGL 2010—Section 5.7.7), as well as for several 3-D seismic projects in the Jeanne d'Arc Basin on the Grand Banks (e.g., LGL 2005b—Section 6.5.12; LGL 2007—Section 5.6.6; LGL 2008—Section 5.6.4), and other reviews (e.g., Richardson et al. 1995; Gordon et al. 2004; Stone and Tasker 2006; Southall et al. 2007; Abgrall et al. 2008b). The following review is based largely on these documents with new and relevant literature included.

5.8.7.1 Effects of Seismic Sound

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

To assess the potential effects of the proposed seismic survey on marine mammals and sea turtles in the Labrador Sea 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.

Categories of Noise Effects

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

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioural response, i.e., the mammals may tolerate it, either without or with some deleterious effects (e.g., masking, stress);
3. The noise may elicit behavioural reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviours (detectable only by statistical analysis) to active avoidance reactions;

4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any anthropogenic noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, intermittent airgun 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.

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 few data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales. Nonetheless, Ridgway and Carden (2001) reported on the hearing sensitivity of a neonate sperm whale, and there are now several studies on the hearing thresholds of beaked whales. Cook et al. (2006) report that a stranded Gervais' beaked whale showed evoked potentials from 5 to 80 kHz, with best sensitivity at 80 kHz. In another study, Finneran et al. (2009) found that an adult Gervais' beaked whale had a similar upper cutoff of 80 to 90 kHz. For a sub-adult Blainville's beaked whale, Pacini et al. (2011) reported the best hearing range to be 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).

The Skipper GDS-101 echosounder onboard the proposed seismic vessel operates at a frequency of 38 kHz, 50 kHz or 200 kHz. The two lower frequencies will be audible to odontocetes, but the higher frequency will not likely be detectable by odontocetes.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioural and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpback whales, with components >24 kHz (Au et al. 2006). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000; Parks et al. 2007b). Although humpbacks and minke whales may have some auditory sensitivity to frequencies above 22 kHz (Berta et al. 2009), for baleen whales as a group, the functional hearing range is thought to be about 7 Hz to 22 kHz or possibly 25 kHz; baleen whales are said to constitute the "low-frequency" 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.

The echosounder proposed for use operates at frequencies that are likely too high to be detected by baleen whales.

Pinnipeds

Underwater audiograms have been obtained for several species of phocids, otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002, 2009). The functional hearing range for pinnipeds in water is considered to extend from 75 Hz to 75 kHz (Southall et al. 2007). Compared to odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, better auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

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

Sound pulses from the airgun arrays and pings at lower frequencies from the echosounder will likely be readily audible to phocids.

Polar Bears

Data on the specific hearing capabilities of polar bears are limited. A recent study of the in-air hearing of polar bears suggested that medium- and some high-frequency sounds may be audible to polar bears, with best hearing sensitivity between 11.2 and 22.5 kHz (Nachtigall et al. 2007).

Sea Turtles

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

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 or echolocation 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 (e.g., Au 2008). Through use of an analytical paradigm, Clark et al. (2009) found that of the large baleen whales, the endangered North Atlantic right whale, may be most prone to communication masking due to commercial vessel traffic. They found that two commercial ships 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 up to 36 to 51% when seismic surveys are operating. Nieukirk et al. (2012) and Blackwell et al. (2013) also suggested the potential of masking effects from seismic surveys on large whales. The biological repercussions of 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 our experience. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011), 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, 2012; Smultea et al. 2004; Holst et al. 2005a,b, 2006, 2011; Dunn and Hernandez 2009; Cerchio et al. 2011; Klinck et al. 2012). However, there is one summary report indicating that calling fin whales distributed in one part of the N Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that preliminary paper whether the whales ceased calling because of masking, or whether this was a behavioural response not directly involving masking. 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 lower call detection rates (Blackwell et al. 2013). In contrast, Di Iorio and Clark (2009) found evidence of *increased* calling by blue whales in the St. Lawrence Estuary during operations by a lower-energy seismic source—a sparker. 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}.

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

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or to shift their peak frequencies in response to strong sound signals, or otherwise modify their vocal behaviour in response to increased noise (Dahlheim 1987; Au 1993; reviewed in Richardson et al. 1995:233*ff*, 364*ff*; Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007a, 2009, 2011; Hanser et al. 2009; Holt et al. 2009; Di Iorio and Clark 2010; McKenna 2011; Castellote et al. 2012; Melcón et al. 2012; Risch et al. 2012). It is not known how often these types of responses occur upon exposure to airgun sounds. 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.

Pinnipeds have their 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.

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

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; Ellison et al. 2012). 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). The U.S. National Marine Fisheries Service (NMFS) is currently moving toward adoption of new procedures taking at least some of the Southall et al. recommendations into account (Scholik-Schlomer 2012; NMFS 2013). 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 (Stone and Tasker 2006; Weir 2008a), strong avoidance reactions by several species of mysticetes have been observed at ranges up to 6 to 8 km and occasionally as far as 20 to 30 km from the source vessel when large arrays of airguns were used. Experiments with a single airgun of 20 to 100 in^3 showed that bowhead, humpback and grey whales all showed localized avoidance of the airgun (Malme et al. 1984, 1985, 1986, 1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b).

Studies of gray, 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 sections provide more details on the documented responses of particular species and groups of baleen whales to marine seismic operations.

Humpback Whales: Responses of humpback whales to seismic surveys have been studied during migration, on the summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998, 2000a) studied the responses of migrating humpback whales off western Australia to a full-scale seismic survey with a 16 airgun 2678 in^3 array, and to a single 20 in^3 airgun with a (horizontal) source level of 227 dB re 1 $\mu Pa \cdot m_{p-p}$. They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program, although localized displacement varied with pod

composition, behaviour, and received sound levels. Observations were made from the seismic vessel, from which the maximum viewing distance was 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 behavioural response of humpback whales off Eastern Australia are currently underway (Cato et al. 2011, 2012).

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 during seismic surveys in the Northwest Atlantic that used 24–32 airguns with a total volume of up to 5085 in^3, humpback whales had significantly lower sighting rates and were most often seen swimming away from the vessel during seismic periods compared with periods when airguns were silent. In addition, humpbacks were, on average, seen 200 m farther from the vessel during seismic operations compared to periods when the array was silent (Moulton and Holst 2010).

Among wintering humpback whales off Angola (n = 52 useable groups), there were no significant differences in encounter rates (sightings/hr) when a 24 airgun array (3147 in^3 or 5085 in^3) was operating vs. silent (Weir 2008a). There was also no significant difference in the mean CPA distance of the humpback sightings when airguns were on vs. off (3050 m vs. 2700 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 S Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004). The evidence for this was circumstantial and subject to alternative explanations (IAGC 2004). Also, the evidence was not consistent with subsequent results from the same area of Brazil (Parente et al. 2006), or with direct studies of humpbacks exposed to seismic surveys in other areas and seasons (see above). After allowance for data from subsequent years, there was "no observable direct correlation" between strandings and seismic surveys (IWC 2007, p. 236).

Rorquals: Blue, sei, fin, and minke whales (all of which are members of the genus *Balaenoptera*) often have been seen in areas ensonified by airgun pulses (Stone 2003; MacLean and Haley 2004; Stone and

Tasker 2006), 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. 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 (p = 0.0057; 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 ($p <$ 0.05; Stone and Tasker 2006). Similarly, Castellote et al. (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) reported that minke whales have occasionally been observed to approach 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; Robertson et al. 2011).

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 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. (2012) 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 2012). In addition, the W Pacific grey whale population did not seem affected by a seismic survey in its feeding ground (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 2012). 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; Moulton and Miller 2005; 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; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance. Studies that have reported cases of small toothed whales close to the operating airguns include Duncan (1985), Arnold (1996), Stone (2003), and Holst et al. (2006). When a 3959 in^3, 18 airgun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when a large array of airguns is firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away, or to 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; Barry et al. 2010; Moulton and Holst 2010).

The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea in summer found that sighting rates of belugas were significantly lower at distances 10 to 20 km compared with 20 to 30 km from an operating airgun array (Miller et al. 2005). The low number of beluga sightings by marine mammal observers on the vessel

seemed to confirm there was a strong avoidance response to the 2250 in^3 airgun array. More recent seismic monitoring studies in the same area have confirmed that the apparent displacement effect on belugas extended farther than has been shown for other small odontocetes exposed to airgun pulses (e.g., Harris et al. 2007). Narwhals are also known to be sensitive to human activities and to react at long distances from vessels (Finley et al. 1990); however, there have been no studies on the effects of seismic vessels on narwhals. However, Heide-Jørgensen et al. (2013) reported on three ice entrapments of narwhals in Baffin Bay subsequent to seismic surveys in the area. They suggested that airgun sounds may have delayed the migration timing of narwhals, thereby increasing the risk of entrapments in the ice; however, there was no direct evidence to support this.

Goold (1996a,b,c) studied the effects on common dolphins of 2-D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1 km radius from the airguns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area and were not attributable to seismic surveys (Goold 1996a,b,c).

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[2] 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 various other areas show similar patterns. A summary of vessel-based monitoring data from the Gulf of Mexico during 2003 to 2008 showed that delphinids were generally seen farther from the vessel during seismic than during non-seismic periods (based on Barkaszi et al. 2009, excluding sperm whales). Similarly, during two NSF-funded Lamont-Doherty Earth Observatory of Columbia University (L-DEO) seismic surveys that used a large 20 airgun array (~7000 in^3), sighting rates of delphinids were lower and initial sighting distances were farther away from

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

the vessel during seismic than non-seismic periods (Smultea et al. 2004; Holst et al. 2005a, 2006; Richardson et al. 2009). Monitoring results during a seismic survey in the southeast Caribbean showed that the mean CPA of delphinids during seismic operations was 991 m during seismic operations vs. with 172 m when the airguns were not operational (Smultea et al. 2004). Surprisingly, nearly all acoustic detections via a towed passive acoustic monitoring (PAM) array, including both delphinids and sperm whales, were made when the airguns were operating (Smultea et al. 2004). Although the number of sightings during monitoring of a seismic survey off the Yucatán Peninsula, Mexico, was small (*n* = 19), the results showed that the mean CPA distance of delphinids during seismic operations there was 472 m during seismic operations vs. with 178 m when the airguns were silent (Holst et al. 2005a). The acoustic detection rates were nearly five times higher during non-seismic compared with seismic operations (Holst et al. 2005a).

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

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

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

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

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

both surveys was small. Results from two small-array surveys in southeast Alaska were even more variable (MacLean and Koski 2005; Smultea and Holst 2008).

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).

Captive bottlenose dolphins and beluga whales exhibited changes in behaviour when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002, 2005). Finneran et al. (2002) exposed a captive bottlenose dolphin and beluga to single impulses from a water gun (80 in^3). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviours were exhibited by captive bottlenose dolphins and a beluga exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviours in captive, trained marine mammals exposed to single transient sounds may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound before exhibiting the aversive behaviours mentioned above.

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

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 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 very few 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) and/or change their behaviour in response to vessel noise (e.g., Pirotta et al. 2012). They may dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales, which also are often quite long (Baird et al. 2006; Tyack et al. 2006b). In any event, it seems 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. In fact, during seismic surveys in the Northwest Atlantic, a group of Sowerby's beaked whales and two groups of unidentified beaked whales traveled towards the vessel when the airguns were active (Moulton and Holst 2010). Also, northern bottlenose whales sometimes are quite tolerant of slow-moving vessels not emitting airgun pulses (Reeves et al. 1993; Hooker et al. 2001). Detections (acoustic or visual) of northern bottlenose whales have been made from seismic vessels during recent seismic surveys in the Northwest Atlantic during periods with and without airgun operations (Potter et al. 2007; Moulton and Miller 2005; Moulton and Holst 2010). Three of four groups of northern bottlenose whales sighted during seismic operations in the Northwest Atlantic swam towards the vessel while the airguns were active (Moulton and Holst 2010). Visual and acoustic studies elsewhere 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 (Laurinolli and Cochrane 2005; Simard et al. 2005).

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" section, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries or other physiological effects may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. No conclusive link has been established between seismic surveys and beaked whale strandings. There was a stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) in September 2002 when the R/V *Maurice Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002; Hildebrand 2005). However, NMFS did not establish a cause and effect relationship between this stranding and the seismic survey activities (Hogarth 2002). Cox et al. (2006) noted the "lack of knowledge regarding the temporal and spatial correlation between the [stranding] and the sound source". Hildebrand (2005) illustrated the approximate temporal-spatial

relationships between the stranding and the *Ewing*'s tracks, but the time of the stranding was not known with sufficient precision for accurate determination of the CPA distance of the whales to the *Ewing*. Another stranding of Cuvier's beaked whales in the Galápagos occurred during a seismic survey in April 2000; however "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry [ed.] 2002).

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

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

More extensive data from vessel-based monitoring programs in U.K. waters and eastern Canada and Angola suggest that sperm whales in those areas show little evidence of avoidance or behavioural disruption in the presence of operating seismic vessels (Stone 2003; Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010). Among sperm whales off Angola (n = 96 useable groups), there were no significant differences in encounter rates (sightings/h) when a 24 airgun array (3147 in^3 or 5085 in^3) was operating vs. silent (Weir 2008a). There was also no significant difference in the CPA distances of the sperm whale sightings when airguns were on vs. off (means 3039 m vs. 2594 m, respectively). Encounter rate tended to increase over the 10 month duration of the seismic survey. 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 show considerable tolerance of seismic surveys by at least some sperm whales. Also, a study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa_{p-p} (Madsen et al. 2002).

Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behaviour of sperm whales (McCall Howard 1999). Sightings of sperm whales by observers on seismic vessels operating in the Gulf of Mexico during 2003 to 2008 were at very similar average distances regardless of the airgun operating conditions (Barkaszi et al. 2009). For example, the mean

sighting distance was 1839 m when the airgun array was in full operation (n = 612) vs. 1960 m when all airguns were off (n = 66).

A detailed study of sperm whale reactions to seismic surveys has been done recently in the Gulf of Mexico — the Sperm Whale Seismic Study or SWSS (Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). During SWSS, D-tags (Johnson and Tyack 2003) were used to record the movement and acoustic exposure of eight foraging sperm whales before, during, and after controlled exposures to sound from airgun arrays (Jochens et al. 2008; Miller et al. 2009). Whales were exposed to maximum received sound levels of 111 to 147 dB re 1 μPa_{rms} (131 to 162 dB re 1 μPa_{pk-pk}) at ranges of about 1.4 to 12.8 km from the sound source (Miller et al. 2009). Although the tagged whales showed no discernible horizontal avoidance, some whales showed changes in diving and foraging behaviour during full-array exposure, possibly indicative of subtle negative effects on foraging (Jochens et al. 2008; Miller et al. 2009; Tyack 2009). Two indications of foraging that they studied were oscillations in pitch and occurrence of echolocation buzzes, both of which tend to occur when a sperm whale closes in on prey. "Oscillations in pitch generated by swimming movements during foraging dives were on average 6% lower during exposure than during the immediately following post-exposure period, with all 7 foraging whales exhibiting less pitching (p = 0.014). Buzz rates, a proxy for attempts to capture prey, were 19% lower during exposure…" (Miller et al. 2009). Although the latter difference was not statistically significant (p = 0.141), the percentage difference in buzz rate during exposure vs. post-exposure conditions appeared to be strongly correlated with airgun-whale distance (Miller et al. 2009: Fig. 5; Tyack 2009).

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

There are very few specific data on responses of beaked whales to seismic surveys, but it seems likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars; if they ever do so in response to seismic survey noise is unknown. Northern bottlenose whales seem to continue to call when exposed to pulses from distant seismic vessels.

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

For delphinids, and possibly 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 2008. Pinnipeds exposed to seismic surveys have also been observed during seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of pinnipeds exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or to habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

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

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behaviour modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array" (Arnold 1996). In Puget Sound, sighting distances for harbour seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmek 1998). Bain and Williams (2006) also stated that their small sample of harbour seals and sea lions tended to orient and/or move away upon exposure to sounds from a large airgun array.

Monitoring work in the Alaskan Beaufort Sea during 1996 to 2001 provided considerable information regarding the behaviour of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). Those seismic projects usually involved arrays of 6 to 16 airguns with total volumes of 560 to 1500 in^3. Subsequent monitoring work in the Canadian Beaufort Sea in 2001 to 2002, with a somewhat larger airgun system (24 airguns, 2250 in^3), provided similar results (Miller et al. 2005). The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings averaged somewhat farther away from the seismic vessel when the airguns were operating than when they were not (Moulton and Lawson 2002). Also, seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997. However, the avoidance movements were relatively small, on the order of 100 m to (at most) a few hundreds of metres, and many seals remained within 100 to 200 m of the trackline as the operating airgun array passed by.

The operation of the airgun array had minor and variable effects on the behaviour of seals visible at the surface within a few hundred metres of the airguns (Moulton and Lawson 2002). The behavioural data indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behaviours, e.g., "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

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

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

were greater from source than monitoring vessels at locations with received sound levels <120 dB_{rms} (Haley et al. 2010). In the Beaufort Sea, sighting rates for seals exposed to received sound levels ≥160 dB_{rms} were also significantly higher from monitoring than from seismic source vessels, and sighting rates were significantly higher from source vessels in areas exposed to <120 compared to ≥160 dB_{rms} (Savarese et al. 2010). In addition, seals tended to stay farther away and swam away from source vessels more frequently than from monitoring vessels when received sound levels were ≥160 dB_{rms}. These observations are indicative of a tendency for phocid seals to exhibit localized avoidance of the seismic source vessel when airguns are firing (Funk et al. 2010). Over the three years, seal sightings rates were greater from monitoring than source vessels at locations with received sound levels ≥160 and 159–120 dB_{rms}, whereas seal sighting rates were greater from source than monitoring vessels at locations with received sound levels were <120 dB_{rms}, suggesting that seals may be reacting to active airguns by moving away from the source vessel.

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

Polar Bear

Airgun effects on polar bears have not been studied. However, polar bears observed on the ice would be largely unaffected by underwater sound. Sound levels received by polar bears in the water would be attenuated because polar bears generally swim with their heads above water and do not dive much below the surface where received levels of airgun sounds are reduced near the surface.

Sea Turtles

There have been far fewer studies of the effects of airgun noise (or indeed any type of noise) on sea turtles. Four studies have focused on short-term behavioural responses of sea turtles in enclosures to single airguns. However, comparisons of results among studies are difficult because experimental designs and reporting procedures have varied greatly, and only one of the studies provided specific information about the levels of the airgun pulses received by the turtles. Although responses of free-ranging sea turtles to seismic surveys are now being reported, we are not aware of any directed studies on responses of free-ranging sea turtles to seismic sounds or on the long-term effects of seismic or other sounds on sea turtles.

The most recent of the studies of caged sea turtles exposed to airgun pulses was a study by McCauley et al. (2000a,b) off western Australia. This is apparently the only such study in which received sound levels were estimated carefully. The authors exposed caged green and loggerhead sea turtles (one of each) to pulses from an approaching and then receding 20 in^3 airgun operating at 1500 psi and 5 m airgun depth. The single airgun fired every 10 s. There were two trials separated by two days; the first

trial involved ~2 h of airgun exposure and the second ~1 h. The results from the two trials showed that, above a received level of 166 dB re 1 μPa_{rms}, the turtles noticeably increased their swim speed relative to periods when no airguns were operating. The behaviour of the sea turtles became more erratic when received levels exceeded 175 dB re 1 μPa_{rms}. The authors suggested that the erratic behaviour exhibited by the caged sea turtles would likely, in unrestrained turtles, be expressed as an avoidance response (McCauley et al. 2000a,b).

O'Hara and Wilcox (1990) tested the reactions to airguns by loggerhead sea turtles held in a 300 x 45 m area of a canal in Florida with a bottom depth of 10 m. Nine turtles were tested at different times. The sound source consisted of one 10 in^3 airgun plus two 0.8 in^3 "poppers" operating at 2000 psi [4] and airgun depth of 2 m for prolonged periods of 20 to 36 h 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; firing rate was one shot every 5 to 6 s. Ten turtles were tested individually, and seven of these were retested several days later. The airgun was initially discharged when the turtles were near the center of the enclosure and the subsequent movements of the turtles were documented. The turtles exhibited avoidance during the first presentation of airgun sounds at a mean range of 24 m, but the avoidance response waned quickly. Additional trials conducted on the same turtles several days later did not show statistically significant avoidance reactions. However, there was an indication of slight initial avoidance followed by rapid waning of the avoidance response which the authors described as "habituation." Their auditory study indicated that exposure to the airgun pulses may have resulted in TTS (discussed earlier). Reduced hearing sensitivity may also have contributed to the waning response upon continued exposure. Based on physiological measurements, there was some evidence of increased stress in the sea turtles, but this stress could also have resulted from handling of the turtles.

Once again, inconsistencies in reporting procedures and experimental design prevent direct comparison of this study with either McCauley et al. (2000a,b) or O'Hara and Wilcox (1990). Moein et al. (1994) stated, without further details, that "three different decibel levels (175, 177, 179) were utilised" during each test. These sound levels probably are received levels in dB re 1 μPa, and probably relate to the initial exposure distance (mean 24 m), but these details were not specified. Also, it was not specified

[4] 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.

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.

Lenhardt (2002) exposed captive loggerhead sea turtles while underwater to seismic airgun (Bolt 600) sounds in a large net enclosure. At received levels of 151–161 dB, turtles were found to increase swimming speeds. Similar to the McCauley et al. studies (2000a,b--see above), near a received level of ~175 dB, an avoidance reaction was common in initial trials, but habituation then appeared to occur. A TTS of over 15 dB was found in one animal, with recovery two weeks later. Lenhardt (2002) suggested that exposure of sea turtles to airguns at water depths >10 m may result in exposure to more energy in the low frequencies with unknown biological effects.

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, 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 (2678 in^3, 12 elements) operating in 100 to 120 m water depth, sea turtles may exhibit behavioural changes at approximately 2 km and avoidance around 1 km. These estimates are subject to great variation, depending on the seismic source and local propagation conditions.

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

Related studies involving stimuli other than airguns may also be relevant.

1) Two loggerhead turtles resting on the bottom of shallow tanks responded repeatedly to low-frequency (20 to 80 Hz) tones by becoming active and swimming to the surface. They remained at the surface or only slightly submerged for the remainder of the 1 min trial (Lenhardt 1994). Although no detailed data on sound levels at the bottom vs. surface were reported, the surfacing response probably reduced the levels of underwater sound to which the turtles were exposed.
2) In a separate study, a loggerhead and a Kemp's Ridley sea turtle responded similarly when 1 s vibratory stimuli at 250 or 500 Hz were applied to the head for 1 s (Lenhardt et al. 1983). There appeared to be rapid habituation to these vibratory stimuli.
3) Turtles in tanks showed agitated behaviour when exposed to simulated boat noise and recordings from the U.S. Navy's Low Frequency Active (LFA) sonar (Samuel et al. 2005, 2006).

The tones and vibratory stimuli used in these studies were quite different from airgun pulses. However, it is possible that resting sea turtles may exhibit a similar "alarm" response, possibly including surfacing

or alternatively diving, when exposed to any audible noise, regardless of whether it is a pulsed sound or tone.

Data on sea turtle behaviour near airgun operations have also been collected during marine mammal and sea turtle monitoring and mitigation programs associated with various seismic operations around the world. Results suggest it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. During six large-source (10 to 20 airguns; 3050 to 8760 in^3) and small-source (up to six airguns or three GI guns; 75 to 1350 in^3) surveys conducted by L-DEO during 2003 to 2005, the mean 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 turtle 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 of 5085 and 3147 in^3 were used during the seismic program. Sea turtles were seen closer to the seismic source and sighting rates were twice as high during non-seismic vs. seismic periods (Weir 2007). However, there was no significant difference in the median distance of turtle sightings from the array during non-seismic vs. seismic periods (means of 743 m [n = 112] and 779 m [n = 57]). Off northeastern Brazil, 46 sea turtles were seen during 2028 h of marine mammal mitigation and monitoring of seismic exploration using 4 to 8 GI airguns, no evidence of adverse impacts on sea turtles from seismic operations was apparent (Parente et al. 2006). In contrast, DeRuiter and Doukara (2012) reported that loggerhead sea turtles in the Mediterranean responded to shots from a 13 airgun array by diving; of 86 turtles that were visually tracked, 57% dove at or before their CPA, and six or more dove immediately following an airgun shot.

The paucity of data precludes specific predictions as to how free-ranging sea turtles respond to seismic sounds. The possible responses could include one or more of the following: (1) avoidance of the entire seismic survey area to the extent that the turtles move to less preferred habitat; (2) avoidance of the immediate area around the active seismic vessel, i.e., local avoidance of the source vessel but not the general area; and/or (3) no appreciable avoidance, although short-term behavioural reactions are likely.

The potential alteration of a migration route might have negative impacts. However, it is not known whether the alteration would ever be on a sufficient geographic scale, or be sufficiently prolonged, to

prevent turtles from reaching an important destination. Again, this is not a likely possibility in the circumstances of the present project.

Avoidance of a preferred foraging area because of seismic survey noise may prevent sea turtles from obtaining preferred prey species and hence could impact their nutritional status. However, it is highly unlikely that sea turtles would completely avoid a large area along a migration route. Available evidence suggests that the zone of avoidance around seismic sources is not likely to exceed a few kilometres (McCauley et al. 2000b). Avoidance reactions on that scale could prevent sea turtles from using an important coastal area or bay if there was a prolonged seismic operation in the area. Sea turtles might be excluded from the area for the duration of the seismic operation, or they might remain but exhibit abnormal behavioural patterns (e.g., lingering at the surface where received sound levels are lower). Whether those that were displaced would return quickly after the seismic operation ended is unknown. Again, this is not a likely possibility in the circumstances of the present project, since operations will be in offshore areas that are not known or expected to be preferred foraging habitat.

The results of experiments and monitoring studies on responses of marine mammals and fish to seismic surveys show that behavioural responses are possible, depending on species, time of year, activity of the animal, and other unknown factors. The same species may show different kinds of responses at different times of year or even on different days (Richardson et al. 1995). It is reasonable to expect similar variability in the case of sea turtles exposed to airgun sounds. For example, sea turtles of different ages have very different sizes, behaviour, feeding habits, and preferred water depths. Nothing specific is known about the ways in which these factors may be related to airgun sound effects on sea turtles. However, it is reasonable to expect lesser effects in young turtles concentrated near the surface (where levels of airgun sounds are attenuated) as compared with older turtles that spend more time at depth where airgun sounds are generally stronger.

In summary, most studies have been conducted in shallow water, enclosed areas and thus are not directly applicable to the Project Area. The limited available data indicate that sea turtles will hear airgun sounds. Based on available data, it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. Seismic operations in or near areas where turtles concentrate are likely to have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Labrador Sea, including the Project Area, is not a breeding area for sea turtles and it is not known or thought to be an important feeding area, and thus high concentrations of sea turtles are unlikely.

Hearing Impairment Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. 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., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Current U.S. NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). Those criteria

have been used in establishing the safety (=shut-down) radii planned for numerous seismic surveys conducted under U.S. jurisdiction. Those criteria have been used in establishing the safety (=power-down) zones for seismic surveys in some parts of Canada. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause TTS in marine mammals. As discussed below, the 180 dB criterion for cetaceans is probably quite conservative (i.e., lower than necessary to avoid auditory injury), for at least some species including bottlenose dolphin and beluga.

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published by Southall et al. (2007). Those recommendations have not, as of early 2013, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain EISs and small-take authorizations, and NMFS is moving toward adoption of new procedures taking at least some of the Southall et al. recommendations into account (Scholik-Schlomer 2012).

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 sections 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. 2010a). 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 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). The following summarizes some of the key results on odontocetes.

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

The assumption that, in marine mammals, the occurrence and magnitude of TTS is a function of cumulative acoustic energy (SEL) is probably an oversimplification (Finneran 2012). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Mooney et al. 2009a; Finneran and Schlundt 2010, 2011; Finneran et al. 2010a,b; Finneran 2012). Kastak et al. (2005) reported preliminary evidence from pinnipeds that, for prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer, i.e., the results were not fully consistent with an equal-energy model to predict TTS onset. Mooney et al. (2009a) showed this in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130 to 178 dB re 1 μPa for periods of 1.88 to 30 min. Higher SELs were required to induce a given TTS if exposure duration was short rather than if it was longer. Exposure of the aforementioned bottlenose dolphin to a sequence of brief sonar signals showed that, with those brief (but non-impulse) sounds, the received energy (SEL) necessary to elicit TTS was higher than was the case with exposure to the more prolonged octave-band noise (Mooney et al. 2009b). Those authors concluded that, when using (non-impulse) acoustic signals of duration ~0.5 s, SEL must be at least 210 to 214 dB re 1 $\mu Pa^2 \cdot s$ to induce TTS in the bottlenose dolphin. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140 to 160 dB re 1 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration.

On the other hand, the TTS threshold for odontocetes exposed to a single impulse from a watergun (Finneran et al. 2002) appeared to be somewhat lower than for exposure to non-impulse sound. This was expected, based on evidence from terrestrial mammals showing that broadband pulsed sounds with rapid rise times have greater auditory effect than do non-impulse sounds (Southall et al. 2007). The received energy level of a single seismic pulse that caused the onset of mild TTS in the beluga, as

measured without frequency weighting, was ~186 dB re 1 $\mu Pa^2 \cdot s$ or 186 dB SEL (Finneran et al. 2002).[5] The rms level of an airgun pulse (in dB re 1 µPa measured over the duration of the pulse) is typically 10 to 15 dB higher than the SEL for the same pulse when received within a few kilometres of the airguns. Thus, a single airgun pulse might need to have a received level of ~196 to 201 dB re 1 μPa_{rms} in order to produce brief, mild TTS. Exposure to several strong seismic pulses that each has a flat-weighted received level near 190 dB_{rms} (175 to 180 dB SEL) could result in cumulative exposure of ~186 dB SEL (flat-weighted) or ~183 dB SEL (M_{mf}-weighted), and thus slight TTS in a small odontocete. That assumes that the TTS threshold upon exposure to multiple pulses is (to a first approximation) a function of the total received pulse energy, without allowance for any recovery between pulses. However, recent data have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). For example, Finneran et al. (2011) reported no measurable TTS in bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of ~195 dB re 1 $\mu Pa^2 \cdot s$.

The conclusion that the TTS threshold is higher for non-impulse sound than for impulse sound is somewhat speculative. The available TTS data for a beluga exposed to impulse sound are extremely limited, and the TTS data from the beluga and bottlenose dolphin exposed to non-pulse sound pertain to sounds at 3 kHz and above. Follow-on work has shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012).

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

Insofar as we are aware, there are no published data confirming that the auditory effect of a sequence of airgun pulses received by an odontocete is a function of their cumulative energy. Southall et al. (2007) consider that to be a reasonable, but probably somewhat precautionary, assumption. It is precautionary because, based on data from terrestrial mammals, one would expect that a given energy exposure would have somewhat less effect if separated into discrete pulses, with potential opportunity for partial auditory recovery between pulses. However, as yet there has been little study of the rate of recovery from TTS in marine mammals, and in humans and other terrestrial mammals the available data on recovery are quite variable. Southall et al. (2007) concluded that—until relevant data on recovery are

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

available from marine mammals—it is appropriate not to allow for any assumed recovery during the intervals between pulses within a pulse sequence.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, 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 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 CPA 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). This assumes that the ramp-up (soft-start) procedure is used when commencing airgun operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As discussed earlier, single-airgun experiments with bowhead, grey, and humpback whales show that those species do tend to move away when a single airgun starts firing nearby, which simulates the onset of a ramp-up.[6]

Pinnipeds: In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels of ~178 and 183 dB re 1 μPa_{rms} and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, initial evidence from more prolonged (non-pulse and pulse) exposures suggested that some pinnipeds (harbour seals in particular) incur TTS at

[6] Three species of baleen whales that have been exposed to the onset of pulses from single airguns showed avoidance, specifically *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]. 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.

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. They noted that, for non-impulse sound, doubling the exposure duration from 25 to 50 min (i.e., a +3 dB change in SEL) had a greater effect on TTS than an increase of 15 dB (95 vs. 80 dB) in exposure level. Mean threshold shifts ranged from 2.9 to 12.2 dB, with full recovery within 24 h (Kastak et al. 2005). Kastak et al. (2005) suggested that, for non-impulse sound, SELs resulting in TTS onset in three species of pinnipeds may range from 183 to 206 dB re 1 $\mu Pa^2 \cdot s$, depending on the absolute hearing sensitivity.

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

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

Sea Turtles: Few studies have directly investigated hearing or noise-induced hearing loss in sea turtles. Moein et al. (1994) studied the effect of sound pulses from a single airgun of unspecified size on loggerhead sea turtles. Apparent TTS was observed after exposure to a few hundred airgun pulses at distances no more than 65 m. The hearing capabilities had returned to "normal" when the turtles were re-tested two weeks later. Studies with terrestrial reptiles have also demonstrated that exposure to impulse noise can cause hearing loss. For example, desert tortoises (*Gopherus agassizii*) exhibited TTS after exposure to repeated high-intensity sonic booms (Bowles et al. 1999). Recovery from these temporary hearing losses was usually rapid (<1 h), which suggested that tortoises can tolerate these exposures without permanent injury (Bowles et al. 1999). However, there are no data to indicate whether or not there are any plausible situations in which exposure to repeated airgun pulses at close range could cause permanent hearing impairment in sea turtles.

Turtles in the area of seismic operations prior to start-up may not have time to move out of the area even if standard ramp-up (=soft-start) procedures are in effect. It has been proposed that sea turtles require a longer ramp-up period because of their relatively slow swimming speeds (Eckert 2000). However, it is unclear at what distance from a seismic source sea turtles will sustain hearing impairment, and whether there would ever be a possibility of exposure to sufficiently high levels for a sufficiently long period to cause irreversible hearing damage.

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

Most cetaceans show some degree of avoidance of seismic vessels operating an airgun array (see above). It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. TTS would be more likely in any odontocetes that bow- or wake-ride or otherwise linger near the airguns. However, while bow- or wake-riding, odontocetes would be at the surface and thus not exposed to strong sound pulses given the pressure-release and Lloyd Mirror effects at the surface. But if bow- or wake-riding animals were to dive intermittently near airguns, they would be exposed to strong sound pulses, possibly repeatedly.

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

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

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels >180 dB re 1 μPa_{rms}. The corresponding limit for pinnipeds has been set by NMFS at 190 dB, although the HESS Team (HESS 1999) recommended a 180 dB limit for pinnipeds in California. The 180 and 190 dB re 1 μPa_{rms} levels have not been considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above, data that are now available imply that TTS is unlikely to occur in various odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses in which the strongest pulse has a received level substantially exceeding 190 dB re 1 μPa_{rms}. On the other hand, for the harbour seal, harbour porpoise, and perhaps some other species, TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 190 dB re 1 μPa_{rms}. That criterion corresponds to a single pulse SEL of 175 to 180 dB re 1 $\mu Pa^2 \cdot s$ in typical conditions, whereas TTS is suspected to be possible in harbour seals and harbour porpoises with a cumulative SEL of ~171 and ~164 dB re 1 $\mu Pa^2 \cdot s$, respectively.

It has been shown that most large whales and many smaller odontocetes (especially the harbour porpoise) show at least localized avoidance of ships and/or seismic operations (see above). Even when avoidance is limited to the area within a few hundred metres of an airgun array, that should usually be sufficient to avoid the possibility of TTS based on what is currently known about thresholds for TTS onset in cetaceans. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans near the airguns at the time of startup to move away

from the seismic source and to avoid being exposed to the full acoustic output of the airgun array (see above). Thus, most baleen whales likely will not be exposed to high levels of airgun sounds provided the ramp-up procedure is applied. Likewise, many odontocetes close to the trackline are likely to move away before the sounds from an approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for baleen whales or odontocetes that show avoidance of ships or airguns to be close enough to an airgun array to experience TTS. In the event that a few individual cetaceans did incur TTS through exposure to strong airgun sounds, this is a temporary and reversible phenomenon unless the exposure exceeds the TTS-onset threshold by a sufficient amount for PTS to be incurred (see below). If TTS but not PTS were incurred, it would most likely be mild, in which case recovery is expected to be quick (probably within minutes).

Polar Bear: There are no available data on TTS in polar bears. However, TTS is considered unlikely to occur in polar bears if they are swimming with their head above the water surface or on land, given pressure release effects at the water's surface.

Sea Turtles: There have been few studies that have directly investigated hearing or noise-induced hearing loss in sea turtles. The apparent occurrence of TTS in loggerhead turtles exposed to many pulses from a single airgun ≤65 m away (Moein et al. 1994) suggests that sounds from an airgun array could cause at least temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs. There is also the possibility of permanent hearing damage to turtles close to the airguns. However, there are few data on temporary hearing loss and no data on permanent hearing loss in sea turtles exposed to airgun pulses.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter 1985). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. Rise time is the interval required for sound pressure to increase from the baseline pressure to peak pressure.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal or sea turtle, even with large arrays of airguns. However, given the likelihood that some animals close to an airgun array might incur at least mild TTS (see above), there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 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). The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002, 2005; Nachtigall et al. 2003, 2004). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995; Southall et al. 2007). However, there is special concern about strong sounds whose pulses have very rapid rise times. In terrestrial mammals, there are situations when pulses with rapid rise times (e.g., from explosions) can result in PTS even though their peak levels are only a few dB higher than the level causing slight TTS. The rise time of airgun pulses is fast, but not as fast as that of an explosion.

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

- exposure to single very intense sound;
- fast rise time from baseline to peak pressure;
- repetitive exposure to intense sounds that individually cause TTS but not PTS; and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

More recently, Southall et al. (2007) estimated that received levels would need to exceed the TTS threshold by at least 15 dB, on an SEL basis, for there to be risk of PTS. Thus, for cetaceans exposed to a sequence of sound pulses, they estimated 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.

Sound impulse duration, peak amplitude, rise time, number of pulses, and inter-pulse interval are the main factors thought to determine the onset and extent of PTS. Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

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

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

It is unlikely that an odontocete would remain close enough to a large airgun array long enough to incur PTS. There is some concern about bow-riding odontocetes, but for animals at or near the surface, auditory effects are reduced by Lloyd's mirror and surface release effects. The presence of the vessel between the airgun array and bow-riding odontocetes could also, in some but probably not all cases reduce the levels received by bow-riding animals (e.g., Gabriele and Kipple 2009). The TTS (and thus PTS) thresholds of baleen whales are unknown but, as an interim measure, assumed to be no lower than those of odontocetes. Also, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. The TTS

(and thus PTS) thresholds of some pinnipeds (e.g., harbour seal) as well as the harbour porpoise may be lower (Kastak et al. 2005; Southall et al. 2007; Lucke et al. 2009; Kastelein et al. 2011, 2012). If so, TTS and potentially PTS may extend to a somewhat greater distance for those animals. Again, Lloyd's mirror and surface release effects will ameliorate the effects for animals at or near the surface.

In theory, a reduction in hearing sensitivity, either temporary or permanent, may be harmful for sea turtles. However, very little is known about the role of sound perception in the sea turtle's normal activities. Hence, it is not possible to estimate how much of a problem it would be for a turtle to have either temporary or permanent hearing impairment. It is noted above that sea turtles are unlikely to use passive reception of acoustic signals to detect the hunting sonar of killer whales, because the echo-location signals of killer whales are likely inaudible to sea turtles. Hearing is also unlikely to play a major role in their navigation. However, hearing impairment, either temporary or permanent, might inhibit a turtle's ability to avoid injury from vessels, because they may not hear them in time to move out of their way. In any event, sea turtles are unlikely to be at great risk of hearing impairment.

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

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

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

Physical and Non-Auditory Physiological Effects

Strandings and Mortality

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

strandings with high-intensity sound events and found that deep-diving odontocetes, primarily beaked whales, were by far the predominant (95%) cetaceans associated with these events, with 2% mysticete whales (minke). However, as summarized below, there is no definitive evidence that airguns can lead to injury, strandings, or mortality even for marine mammals in close proximity to large airgun arrays.

Specific sound-related processes that may lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behaviour (such as a change in diving behaviour that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioural change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioural response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007; Kvadsheim et al. 2012).

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

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys. 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, 8490 in^3 array in the general area. The evidence linking the stranding to the seismic survey was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam echosounder at the same time, but this had

much less potential than the aforementioned naval sonars to affect beaked whales, given its downward-directed beams, much shorter pulse durations, and lower duty cycle. Nonetheless, the Gulf of California incident plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar suggest a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand 2005).

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

Non-auditory Physiological Effects

Based on evidence from terrestrial mammals and humans, sound is a potential source of stress (Wright and Kuczaj 2007; Wright et al. 2007a,b, 2009, 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. 2007a,b). Hatch and Fristrup (2009) suggested that problems associated with chronic noise may compromise physiological function, and may decrease the use of biologically important areas. 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 (e.g., McCauley et al. 2000a:62*ff*; Nieukirk et al. 2012) but not of some others.

Available data on potential stress-related impacts of anthropogenic noise on marine mammals are extremely limited, and additional research on this topic is needed. Nonetheless, 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. In addition, Rolland et al. (2012) suggested that ship noise causes increased stress in right whales; they showed that baseline levels of stress-related faecal hormone metabolites decreased in North Atlantic right whales with a 6 dB decrease in underwater noise from vessels.

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, polar bears, 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 5.12.

Table 5.12 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**	**Polar Bears**	**Sea Turtles**
Vessel Lights					
Sanitary/ Domestic Waste	X	X	X	X	X
Air Emissions	X	X	X	X	X
Garbage [a]					
Sound					
Seismic Vessel	X	X	X	X	X
Seismic Array	X	X	X	X	X
Support Vessel	X	X	X	X	X
Echosounder	X	X	X	X	X
Presence of Vessels					
Seismic Vessel	X	X	X	X	X
Support Vessel	X	X	X	X	X
Shore Facilities [b]	X	X	X	X	X
Accidental Spills	X	X	X	X	X
Other Projects and Activities					
Oil and Gas Activities on the Labrador Shelf	X	X	X	X	X
Oil and Gas Activities on the 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] There will not be any new onshore facilities. Existing infrastructure will be used.

Sound Criteria for Assessing Impacts

Impact zones for marine mammals are commonly defined by the areas within which specific received sound level thresholds are exceeded. The U.S NMFS (1995, 2000) has concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 μPa_{rms}. The corresponding limit for seals has been set at 190 dB re 1 μPa_{rms}. These sound levels are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS, one cannot be certain that there will be no injurious effects, auditory or otherwise, to marine mammals. For over a decade, it has been common for marine seismic surveys conducted in some areas of U.S. jurisdiction and in some areas of Canada (Canadian Beaufort Sea and on the Scotian Shelf), to include a "shutdown" requirement for cetaceans based on the distance from the airgun array at which the received level of underwater sounds is expected to diminish below 180 dB re 1 μPa_{rms}. An additional criterion that is often used in predicting "disturbance" impacts is 160 dB re 1 µPa; at this received level, some marine mammals exhibit behavioural effects. There is ongoing debate about the appropriateness of these parameters for impact predictions and mitigation (see Appendix C in LGL 2007a).

For marine seismic programs in Newfoundland and Labrador, the C-NLOPB (2012) recommends that seismic operators follow the "*Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*" (hereafter referred to as the *Statement*) issued by the DFO. The *Statement* does not include noise criteria as part of the recommended mitigation measures, rather it defines (see Point 6.a) a safety zone as "a circle with a radius of at least 500 metres as measured from the centre of the air source array (s)".

Assessment of Effects of Sound on Marine Mammal VEC

The marine mammal effects assessment is summarized in Table 5.13 and discussed in detail below.

Table 5.13 Assessment of Effects on the Marine Mammal VEC.

Valued Ecosystem Components: Marine Mammals								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Sanitary/Domestic Waste	Increased Food (N/P)	Treatment; containment	0-1	1	1	2	R	1
Air Emissions	Surface Contaminants (N)	Low sulphur fuel	0	1	6	2	R	1
Sound								
Airgun Array	Hearing Impairment (N) Physical Effects (N)	Pre-watch; Ramp-up; Delay Start; Shutdown[a]	0-1	1-2	6	2	R	1
Airgun Array	Disturbance (N)	Pre-watch; Ramp-up; Delay Start;	1	3-4	6	2	R	1

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**
		Shutdown[a]						
Seismic Vessel	Disturbance (N)		0-1	1-2	6	2	R	1
Support Vessel	Disturbance (N)		0-1	1-2	6	2	R	1
Echosounder	Disturbance (N)		0-1	1	6	2	R	1
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0-1	1	6	2	R	1
Support Vessel	Disturbance (N)		0-1	1	6	2	R	1
Accidental Spills	Injury/Mortality (N)	Solid streamer[b]; Spill Response	1	1-2	1	1	R	1

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] Solid or Isopar filled streamers may be used during the survey, depending on the seismic contractor.

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* Schedule 1 and that may occur in and near the Project Area (i.e., northern bottlenose whale, Sowerby's beaked whale). Beluga whales, killer whales, and harbour porpoises, all with special status by COSEWIC (the harbour porpoise is also listed as *threatened* under Schedule 2 of *SARA*), 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 (see Appendix C in LGL 2007).

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 GXT's Project activities. The mitigation measure of ramping-up the airgun array (over a 30 min period) should allow whales close to the airguns to move away before the sounds become sufficiently strong to have 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 reduced potential for toothed whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". As per Table 5.13, GXT's seismic program is predicted to have *negligible* to *low* hearing impairment/physical effects on toothed whales, over a duration of *1 to 12 months*, in an area *<1 km^2* to *1-10 km^2*. Therefore, hearing impairment and/or physical effects on toothed whales are judged to be *not significant* (Table 5.14).

Table 5.14 Significance of Potential Residual Environmental Effects of the Proposed Seismic Program on the Marine Mammal VEC.

Valued Ecosystem Component: Marine Mammals				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – hearing/physical effects	NS	2	-	-
Array – behavioural effects	NS	3	-	-
Seismic Vessel	NS	3	-	-
Support Vessel	NS	3	-	-
Echosounder	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Support Vessel	NS	3	-	-
Accidental Spills	NS	3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

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

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

Disturbance Effects: Based on the above review, there could be behavioural effects on some species of toothed whales within the Project Area. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. Based on available literature, a 160 dB re 1 μPa_{rms} sound

level is used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. This is likely a conservative criterion since some toothed whale species:

- have been observed in other areas relatively close to an active seismic source where received sound levels are greater than 160 dB; and
- individuals which may be temporarily displaced from an area will not be significantly impacted by this displacement.

It is uncertain how many toothed whales may occur in the Study Area at various times of the year. The Study Area is not known to be an important feeding or breeding areas for toothed whales (however, there has been little research to verify this). As per Table 5.13, disturbance effects from Project activity noise on toothed whales would likely be *low*, over *1 to 12 months*, in an area of *11 - 100* or *101 - 1,000 km^2*. Therefore, potential effects related to disturbance, are judged to be *not significant* for toothed whales (Table 5.14).

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 Sections 5.7.5 and 5.7.6) and over a small portion of a whale's foraging range within the Project Area. Potential effects of reduced prey availability on toothed whales are predicted to be *negligible*.

Baleen Whales

Baleen whales are thought to be sensitive to low-frequency sounds such as those that contribute most of the energy in seismic pulses. Species of most concern are those that are designated under *SARA* Schedule 1 and that may occur in and near the Project Area (i.e., blue and fin 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 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 should allow any whales close to the airguns to move away before the sounds become sufficiently strong to have 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 reduced potential for baleen whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". As per Table 5.13, GXT's seismic program is predicted to have *negligible to low* hearing impairment effects on baleen whales, over a duration of *1 to 12 months*, in an area *<1 km^2* to *1–10 km^2*. Therefore, hearing impairment and/or physical effects on baleen whales are judged to be *not significant* (Table 5.14).

Disturbance Effects: Based on the above review, there could be behavioural effects on some species of baleen whales within and near the Project 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 scale of impact at *11–100 km^2* to *101–1,000 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 displacement from an area constitutes a significant impact for baleen whales in the Project Area.

It is uncertain how many baleen whales may occur in the Study Area during the period when seismic activity is most likely to occur (June to November). The Project Area is not known to be an important feeding or breeding area for baleen whales. As per Table 5.13, disturbance effects on species of baleen whales would likely be *low*, over a duration of *1 to 12 months*, in an area of *11–100 km^2* to *101–1,000 km^2*. Therefore, effects related to disturbance, are judged to be *not significant* for baleen whales (Table 5.14).

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 Sections 5.7.5 and 5.7.6) 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 judged to be *negligible*.

Seals

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, hooded, and ringed seals are expected to have a more northerly distribution during the main survey period (June to November), although they could be moving through the Study Area. Grey and harbour seals are likely not very abundant 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 (although some are COSEWIC *candidate species*, see Section 4.6).

Hearing Impairment and Physical Effects: Given that seals typically avoid the immediate area around a seismic array, seals are unlikely to 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 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 reduced 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 5.13, GXT's seismic program is predicted to have *negligible to low* hearing impairment and/or physical effects on seals, over a duration of *1 to 12 months*, in an area *<1 km^2* to *1–10 km^2*. Therefore, hearing impairment and physical effects on seals are judged to be *not significant* (Table 5.14).

Disturbance Effects: Based on the above review, there could be behavioural effects on seals within and near the Project Area. Known effects include changes in diving behaviour and localized avoidance of the seismic vessel. It is uncertain how many seals may occur in the Project Area during the period when seismic operations will occur (June to November). There are no available criteria for assessing the sound level most likely to elicit avoidance reactions in seals. It is noteworthy that seals have been sighted inside the radius thought to cause TTS (190 dB) in other areas. A 160 dB re 1 μPa_{rms} sound level has been conservatively used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. Therefore, the area where displacement may occur would have likely a scale of potential effect at *11–100 km^2*. This estimated area around the seismic vessel would be ensonified periodically for a duration of *1 to 12 months*. As per Table 5.13, GXT's proposed seismic program is predicted to have *low* disturbance effects on seals. Therefore, effects related to disturbance, are judged to be *not significant* for seals (Table 5.14).

Polar Bears

Airgun effects on polar bears have not been studied. However, polar bears on the ice would be unaffected by underwater sound. Sound levels received by polar bears in the water would be attenuated because polar bears generally swim with their heads out of the water or at the surface and polar bears do not dive much below 4.5 m. Received levels of airgun sounds are reduced near the surface because of the pressure release effect at the water's surface (Greene and Richardson 1988; Richardson et al. 1995). Measurements of the in-air hearing of polar bears suggest bears have best hearing sensitivity for sounds with frequencies between 11.2 to 22.5 kHz (Nachtigall et al. 2007). Their hearing is presumably adapted for in-air hearing, and—even when submerged—they may not be very sensitive to underwater sound. It is unlikely that many polar bears will be encountered during the proposed seismic program, given that operations will likely occur during ice-free periods. Given the small number of polar bears involved, effects of seismic sound sources on polar bear hearing are predicted to be *negligible*. Similarly, effects of seismic sources on polar bear behaviour are predicted to be low in an area of *11–100 km^2* (Table 5.13). No significant effects are expected (Table 5.14).

Prey Species: It is unlikely that seals (polar bear's primary prey) will be impacted by seismic activities to a degree that inhibits the foraging success of seals. If seals exhibit avoidance of the seismic ship it will likely be transitory in nature (see above) and over a small portion of a seal's foraging range within the seismic area. Potential impacts of reduced prey availability are predicted to be *negligible*.

Assessment of Effects of Sound on Sea Turtle VEC

The effects assessment for sea turtles is summarized in Table 5.15.

Hearing Impairment and Physical Effects: Based on available data, it is possible that sea turtles might exhibit temporary hearing loss if the turtles are close to the airguns (Moulton and Richardson 2000). However, there is not enough information on sea turtle temporary hearing loss and no data on permanent hearing loss to reach any definitive conclusions about received sound levels that trigger TTS. Also, it is likely that sea turtles will exhibit behavioural reactions or avoidance within an area of unknown size around a seismic vessel. The mitigation measure of ramping-up the airgun array over a 30 min period should permit sea turtles close to the airguns to move away before the sounds become sufficiently strong

to have any potential for hearing impairment. Also, ramp-up will not commence if a sea turtle is sighted within the 500 m safety zone, and the airgun array will be shutdown if a sea turtle is sighted within the safety zone.

Table 5.15 Assessment of Effects on the Sea Turtle VEC.

Valued Ecosystem Components: Sea Turtles								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Sanitary/Domestic Waste	Increased Food (N/P)	Treatment; containment	0-1	1	1	2	R	1
Air Emissions	Surface Contaminants (N)	Low sulphur fuel	0	1	6	2	R	1
Sound								
Airgun Array	Hearing Impairment (N); Physical Effects (N)	Pre-watch; Ramp-up; Delay Start; Shutdown[a]	0-1	1-2	6	2	R	1
Airgun Array	Disturbance (N)	Pre-watch; Ramp-up; Delay Start; Shutdown[a]	1	3	6	2	R	1
Seismic Vessel	Disturbance (N)		0-1	1-2	6	2	R	1
Support Vessel	Disturbance (N)		0-1	1-2	6	2	R	1
Echosounder	Disturbance (N)		0-1	1	6	2	R	1
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0-1	1	6	2	R	1
Support Vessel	Disturbance (N)		0-1	1	6	2	R	1
Accidental Spills	Injury/Mortality (N)	Solid Streamers[b]; Spill Response	1	1-2	1	1	R	1

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] Solid or Isopar filled streamers may be used during the survey, depending on the seismic contractor.

It is very unlikely that many sea turtles will occur in the Study Area. Therefore, there is likely limited potential for sea turtles to be close enough to an array to experience hearing impairment. If some turtles did experience TTS, the effects would likely be quite "temporary". As per Table 5.15, GXT's seismic program is predicted to have *negligible* to *low* physical effects on sea turtles, over a duration of *1 to 12 months*, in an area *<1 to 1–10 km²*. Therefore, auditory and physical effects on sea turtles are judged to be *not significant* (Table 5.16).

Table 5.16 Significance of Potential Residual Environmental Effects of the Proposed Seismic Program on the Sea Turtle VEC.

Valued Ecosystem Component: Sea Turtles				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – hearing/physical effects	NS	2	-	-
Array – behavioural effects	NS	3	-	-
Seismic Vessel	NS	3	-	-
Support Vessel	NS	3	-	-
Echosounder	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Support Vessel	NS	3	-	-
Accidental Spills	NS	2	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km² (4 or greater rating).

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

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

Disturbance Effects: It is possible that sea turtles will occur in the Project Area, although the cooler water temperatures likely preclude some species from occurring there. 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 *11–100 km²*. As per Table 5.15, GXT's seismic program is predicted to have *low* disturbance effects on sea turtles, over a duration of *1 to 12 months*, in an area *11–*

100 km^2. Therefore, effects related to disturbance, are judged to be *not significant* for sea turtles (Table 5.16).

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

5.8.7.2 Effects of Presence of Vessels

During the proposed seismic program, there will be one seismic ship at all times and a support vessel on site during most of the program. 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 support vessel), this risk is likely to be minimal (e.g., Laist et al. 2001; Vanderlaan and Taggart 2007; Gende et al. 2011; Wiley et al. 2011). Marine mammal responses to ships are presumably responses to noise, but visual or other cues are also likely involved. Marine mammal response (or lack thereof) to ships and boats (pre-1995 studies) are summarized in Richardson et al. (1995), p. 252 to 274. More recent studies are described in Husky (2012). Marine mammal responses to the presence of vessels are variable. Seals often show considerable tolerance to vessels. Like seals, polar bears exhibit variable responses to boats. Some seem to approach vessels while others exhibit avoidance (e.g., Harwood et al. 2005). Toothed whales sometimes show no avoidance reactions and occasionally approach them; however, some species are displaced by vessels. Baleen whales often interrupt their normal behaviour and swim rapidly away from vessels that have strong or rapidly changing noise, especially when a vessel heads directly towards a whale. Stationary vessels or slow-moving, "non-aggressive" vessels typically elicit very little response from baleen whales.

To the best of our knowledge, there are few systematic studies on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound. Hazel et al. (2007) evaluated behavioural responses of green turtles to a research vessel approaching at slow,

moderate, or fast speeds (4, 11, and 19 km/h, respectively). Proportionately fewer turtles fled from the approaching vessel as speed increased, and turtles that fled from moderate to fast approaches did so at significantly shorter distances from the vessel than those that fled from slow approaches. The authors concluded 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 support vessel.

Sea turtles may also become entangled with seismic gear (e.g., cables, buoys, streamers, etc.) or collide with the vessel (Pendoley 1997; Ketos Ecology 2007; Weir 2007; Hazel et al. 2007). Entanglement of sea turtles with marine debris, fishing gear, dredging operations, and equipment operations are a documented occurrence and of elevated concern for sea turtles. Turtles can become wrapped around cables, lines, nets, or other objects suspended in the water column and become injured or fatally wounded, drowned, or suffocated (e.g., Lutcavage et al. 1997; NMFS 2007). Seismic personnel have

reported that sea turtles (number unspecified) became fatally entrapped between gaps in tail-buoys associated with industrial seismic vessel gear deployed off West Africa in 2003 (Weir 2007). With dedicated monitoring by trained biological observers, no incidents of entanglements of sea turtles with this gear have been documented in over 40,000 n.mi. (74,000 km) of 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.

However, the Labrador Shelf, including the Project Area, is not a breeding area for sea turtles and it is not known or thought to be an important feeding area, and thus it is not expected that high concentrations of sea turtles could potentially be physically affected.

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*, in an area *1–10 km^2*. Therefore, effects related to the presence of vessels, are judged to be *not significant* for marine mammals and sea turtles (Figures 5.13 to 5.16).

5.8.7.3 Effects of Accidental Spills

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with GXT's policy, and handling and reporting procedures. A fuel spill may occur from the seismic ship and/or the support vessel. 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 Section 11.4.3 of Husky (2012) 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 but effects are primarily believed to be sublethal (Husky 2012). Effects of a small accidental spill on marine mammals or sea turtles would be *low*, over a duration of *<1 month*, in an area *<1 km^2 to 1–10 km^2* and are judged to be *not significant* (Figures 5.13 to 5.16).

5.8.7.4 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 the support vessel. Any effects from these interactions are predicted to be *negligible* (Figures 5.13 to 5.16).

5.8.8 Effects of the Project on Species at Risk

A biological overview of all species considered at risk under *SARA* and/or by COSEWIC 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 4.14, *SARA* species of relevance to the Study Area include:

- white shark; northern, spotted, and Atlantic wolffish;
- Ivory Gull, Harlequin Duck, and Barrow's Goldeneye;
- blue, northern bottlenose, Sowerby's beaked, and fin whale; polar bear; and
- leatherback sea turtle.

Species not currently designated 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 Species at Risk VEC here but have been assessed in the relevant VEC in Sections 5.8.4 (Fish), 5.8.6 (Marine Birds) and 5.8.7 (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 (2013 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 Environment Canada. Potential interactions between the Project and SAR are shown in Table 5.17.

As per the detailed effects assessment contained in Section 5.8.4 and shown again in Tables 5.4 to 5.5, physical effects of the Project on the various life stages of wolffishes and the white shark will range from *negligible* to *low* over a duration of *1-12 months*, within an area of *<1 km*^{2} (Table 5.18). Behavioural effects may extend out to a larger area but are still predicted to be *not significant* (Table 5.19). The mitigation measure of ramping up the airgun array (over a 30 min period) is expected to minimize the potential for impacts on wolffishes and the white shark.

As per the detailed effects assessment in Section 5.8.6, the predicted effect of the Project on the Ivory Gull, Harlequin Duck, and Barrow's Goldeneye is *not significant.* These species are unlikely to occur in the Study Area, particularly during the summer when seismic surveys are likely to be conducted. In addition, the foraging behaviour (and location of foraging areas) would not likely expose them to underwater sound from the Project (Tables 5.18 and 5.19). Furthermore, these bird species are not known to be prone to stranding on vessels. The mitigation measure of monitoring the seismic vessel and releasing stranded birds and ramping up the airgun array will minimize the potential for impacts on these species.

Based on available information, the blue whale, Sowerby's beaked whale, and leatherback sea turtle are not expected to occur regularly in the Study Area. It is extremely unlikely that a North Atlantic right whale would occur in the Study Area. Northern bottlenose whales, designated as *endangered* (Scotian Shelf population), are expected to occur regularly in the Study Area during summer months and perhaps also at other times of the year. The polar bear, designated as *special concern*, also occurs in the Study Area primarily during the winter and spring. There are finalized recovery strategies for leatherback sea turtles (ALTRT 2006), blue whales in Atlantic Canada (Beauchamp et al. 2009), the Scotian Shelf population of northern bottlenose whales (DFO 2010b), and North Atlantic right whales for which critical habitat has also been designated (Brown et al. 2009). Mitigation and monitoring designed to minimize potential effects of airgun array noise on *SARA*-listed marine mammals and sea turtles will include those detailed in Section 5.6. These include

- prewatch of the safety zone before the array is activated;

- ramp-up of the airgun array over a 30 min period;
- monitoring by MMO(s) 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 5.8.7, the Project is predicted to have *no significant effect* (hearing impairment/physical or behavioural) on SAR marine mammals and sea turtles (Table 5.14 and 5.16, respectively).

In summary, potential effects of the proposed 2-D seismic program are not expected to contravene the prohibitions of *SARA* (Sections 32(1), 33, 58(1)).

Table 5.17 Potential Interactions between the Project and Species At Risk VEC.

Valued Ecosystem Components: Species at Risk				
Project Activities	**Wolffishes, White Shark**	**Ivory Gull, Harlequin Duck, Barrow's Goldeneye**	**Blue, Northern Bottlenose, Sowerby's Beaked, and Fin Whales, Polar Bear**	**Leatherback Sea Turtle**
Vessel Lights	X	X		
Sanitary/ Domestic Waste	X	X	X	X
Air Emissions	X	X	X	X
Garbage [a]				
Sound				
Airgun Array	X	X	X	X
Seismic Vessel	X	X	X	X
Support Vessel	X	X	X	X
Echosounder	X	X	X	X
Presence of Vessels				
Seismic Vessel		X	X	X
Support Vessel		X	X	X
Shore Facilities [b]				
Accidental Spills	X	X	X	X
Other Projects and Activities				
Oil and Gas Activities on Labrador Shelf	X	X	X	X
Oil and Gas Activities on Grand Banks	X	X	X	X
Fisheries	X	X	X	X
Marine Transportation	X	X	X	X

[a] Not applicable as garbage will be brought ashore.
[b] There will not be any new onshore facilities. Existing infrastructure will be used.

Table 5.18 Assessment of Effects on the Species at Risk VEC.

Valued Ecosystem Component: Species At Risk								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Vessel Lights	Attraction (N); mortality (N)	Turn off non-essential lighting; release protocols for seabirds	0-2	1-2	2-3	2	R	1-2
Sanitary/Domestic Waste	Increased Food (N/P)	-	0-1	1	6	2	R	1
Air Emissions	Surface Contaminants (N)	-	0	1	6	2	R	1
Sound								
Airgun Array	Hearing Impairment (N) Physical Effects (N)	Ramp-up; Delay Start[a]; Shutdown [b]	0-1	1-2	6	2	R	1
Airgun Array	Disturbance (N)	Ramp-up; Delay Start[a]; Shutdown [b]	0-1	3-4	6	2	R	1
Seismic Vessel	Disturbance (N)		0-1	1-2	6	2	R	1
Support Vessel	Disturbance (N)		0-1	1-2	6	2	R	1
Echosounder	Disturbance (N)		0-1	1-2	6	2	R	1
Presence of Vessels								
Seismic Vessel	Disturbance (N)		0-1	1	6	2	R	1
Support Vessel	Disturbance (N)		0-1	1	6	2	R	1
Accidental Spills	Injury/Mortality (N)	Solid Streamer[c]; Spill Response	1-2	1-3	1	1-2	R	1

Key:

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

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

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

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

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

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

[a] Ramp-up will be delayed if any marine mammal or sea turtle is sighted within the 500 m safety zone.
[b] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[c] Solid or Isopar filled streamers may be used during the survey, depending on the seismic contractor.

Table 5.19 Significance of Potential Residual Environmental Effects of the Proposed Seismic Program on the Species At Risk VEC.

Valued Ecosystem Component: Species At Risk				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – hearing/physical effects	NS	2	-	-
Array – behavioural effects	NS	3	-	-
Seismic Vessel	NS	3	-	-
Support Vessel	NS	3	-	-
Echosounder	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Support Vessel	NS	3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

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

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

6.0 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 GXT seismic survey activities in the Project Area.

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

- Fishing (e.g., commercial, traditional, recreational);
- Vessel traffic (e.g., transportation, defense, recreational vessels);
- Hunting (e.g., seabirds, seals); and
- Offshore oil and gas industry.

Commercial fishing has been discussed and assessed in detail in Section 5.8.5. Commercial fishing activities, by their nature, cause mortality and disturbance to fish populations and may cause incidental mortalities or disturbance to seabirds, marine mammals, and sea turtles. It is predicted that the seismic surveys will not cause any mortality to these VECs (with the potential exception of small numbers of storm-petrels) and thus, there will be no or negligible cumulative effect from mortalities. There is some potential for cumulative effect from disturbance (e.g., fishing vessel noise) but there will be directed attempts by both industries to mitigate effects and to avoid each other's active areas and times. Any gear damage attributable to the Project will be compensated and thus any effects will be *not significant*.

Shipping activity in the Labrador Sea involves vessels travelling to, from Labrador ports, and to other ports in the province and vessels that are travelling through the zone mostly to and from ports in the Canadian High Arctic (see Labrador Shelf SEA; Sikumiut 2008). Shipping is mostly seasonal, beginning in June when ice conditions permit and ending in November at the onset of winter. There are exceptions; for example, the offshore fishing activities and freighters travelling between Greenland and eastern North American ports continue throughout the year. The shipping of concentrated ore from the mining operations in Voisey's Bay also continues during the winter months at the rate of one vessel trip every three weeks on average. The Canadian Coast Guard operates Marine Communications and Traffic Services centres in St. Anthony and Happy Valley-Goose Bay. It records the activities of vessels that are 500 gross tonnage and greater. In 2006, it recorded 624 vessel trips in the area and in 2007 recorded 608 vessel trips to November 2007. According to the Canadian Coast Guard, this may not necessarily a complete listing especially for vessels that travel non-stop through the zone.

The Labrador traffic relevant to the Study Area during the shipping season involves scheduled ferry and freight services as follows (Labrador Shelf SEA, with updates):

- Ferry services from Happy Valley-Goose Bay to Black Tickle and northern Labrador communities to Nain. The *MV Northern Ranger* begins operations in early June and ends by mid-November. Services include passengers and freight. The schedule is on a five-day cycle (Monday to Friday) to the northern ports and a three-day cycle to the southern ports (Friday to Sunday).

- Ferry services between Charlottetown, Norman Bay, William's Harbour and Port Hope Simpson. The *MV Marine Eagle* begins operations in early June and ends by mid-November. Services include passengers and freight. It alternates between ports on a daily operation except Sunday.
- Freight services by the *MV Sir Robert Bond* to northern Labrador as needed.

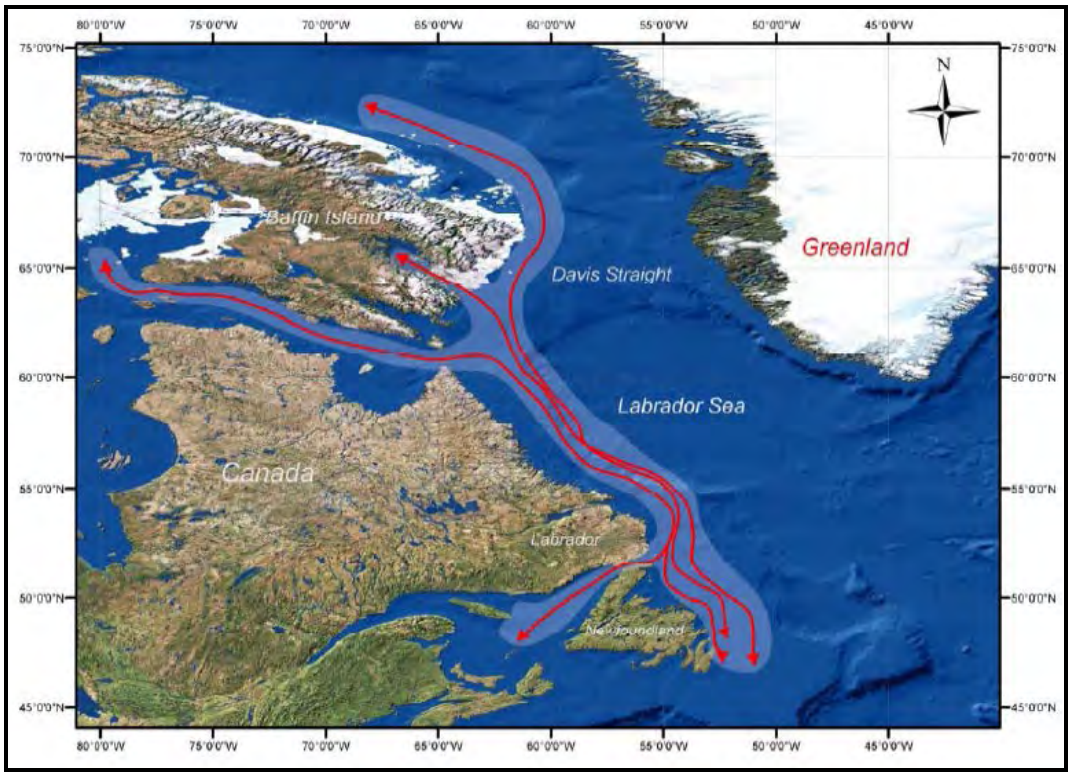
Oil tankers operate regularly during the shipping season, delivering fuel to ports along the Labrador coast (Labrador Shelf SEA). Oil companies such as Imperial Oil Ltd., Ultramar, Irving and Petro-Nav supply various types of fuels to Labrador and the far north. Tankers operated by several companies transport these fuels. Coastal Shipping Ltd., a subsidiary of the Woodward Group, operates four tankers, with two of these dedicated to supplying fuel to Labrador communities and two supplying the Canadian Arctic. Groupe Desgagnes in Quebec, Algoma Tankers in Ontario and Rigel Shipping in New Brunswick are tanker-operating companies that transport fuel to Labrador and ports in the far north. General routing to the Arctic through the Labrador Sea is shown in Figure 6.1.

Other vessels transport cargo to various community and industry projects in Labrador and farther north (Labrador Shelf SEA). These shipping companies include Miller's Shipping in St. John's, Berkshire Shipping in Arnold's Cove, Davis Shipping in Wesleyville, McKeil Marine Limited in Hamilton, Ontario, and Groupe Ocean in Quebec. These companies also provide barge towing services that carry heavy construction equipment and supplies to remote areas.

The mining operations in Voisey's Bay have approximately 20 vessel trips per year to the mine wharf site in Edward's Cove, Anaktalak Bay (Labrador Shelf SEA). It involves the transport of ore to other processing plants in Canada and the supply of fuel and general freight to the site. The Labrador Inuit Development Corporation (LIDC) operates an anorthosite mine in Ten Mile Bay near Nain. A portion of the ore is shipped to Hopedale by Barge while the larger amount is exported directly to Italy by cargo ship, which is usually one vessel trip per year.

Shipping is likely to have an effect on the behaviour of fish and marine mammals. Seismic noise will contribute a minor percentage to the overall noise generated by other vessel sources, and will be of temporary and short duration in most areas. Two additional ships, travelling at slow speeds, is also not likely to add much traffic congestion. Ships may need to divert around the immediate seismic survey area, but this will not prevent or impede the passage of either vessel as the *Shipping Act* and standard navigation rules will apply.

Analyses of the oil involved in bird strandings in the region show that wastes are composed of mixtures of bunker C and marine diesel, indicating origins in the engine room bilges of ocean-going ships (Lock and Deneault 2000). The illegal discharge of oily bilge water off the southeast coast of Newfoundland is a chronic problem (Wiese and Ryan 1999, 2003) and may also be an issue off Labrador. Vessels chartered by GXT will not engage in the illegal discharge of oily bilge water. It is expected that the additional effects of seismic noise or vessel discharge with existing shipping effects are *not significant*. It is also possible that some species habituate to ship noise.



Source: Labrador Shelf SEA.

Figure 6.1 Shipping Transportation to the Canadian Arctic through the Labrador Sea.

The vast majority of hunting of seabirds (mostly murres) in Newfoundland and Labrador waters occurs near shore from small boats and thus, there is little or no potential for cumulative effects on this VEC. Similarly, most, if not all, seal hunting would occur outside of the Project Area in the Gulf of St. Lawrence or off northeast Newfoundland.

Offshore oil and gas industry projects listed on the C-NLOPB public registry (www.C-NLOPB.nl.ca as viewed 20 March 2013) for offshore Labrador include:

- Husky Energy 2-D and 3-D seismic, vertical seismic profiling (VSP), and geohazard surveys offshore Labrador, 2010 to 2017;
- Investcan Energy Corporation 2-D and 3-D seismic, vertical seismic profiling (VSP), and geohazard surveys offshore Labrador, 2010 to 2017;
- Chevron Canada Resources 2-D and 3-D seismic, and geohazard surveys offshore Labrador, 2011 to 2017; and
- Multi Klient Invest 2-D seismic surveys offshore Labrador, 2011-2013.

If offshore operations are conducted in separate survey areas, it is expected that the overall impacts of each project would be independent and as predicted. In addition, multiple seismic and drilling programs are proposed or ongoing in the Jeanne d'Arc Basin, Orphan Basin, Flemish Pass, or offshore of Newfoundland's west coast in the Gulf of St. Lawrence. Also, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. While the existing developments are all several hundred kilometres outside the boundaries of the

proposed Project Area, they are within the range of activities that have occurred on the Grand Banks over the last 10 years. However, offshore oil and gas activity on the Grand Banks should be far enough away to avoid any disturbance effects. Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and are predicted to be *not significant*.

All vessels (supply vessels, fishing vessels, cargo vessels and seismic vessels) and offshore rigs on the east coast, including Labrador, have navigation and warning lights. In some instances, work areas are lit by floodlights. As discussed in the preceding paragraphs, some seabirds may be attracted to these lights and, consequently, become stranded on support vessels, drill rigs, or other offshore structures. However, cumulative effects are not expected to exceed those expected for individual vessels in the area. There will be *no significant* cumulative effects of lights on marine birds triggered by the exploration program.

7.0 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 8.1. GXT's seismic program is predicted to have *no significant effects* on VECs.

Table 7.1 Significance of Potential Residual Environmental Effects of the Proposed Seismic Program on VECs in the Study Area.

Valued Ecosystem Component: Fish and Fish Habitat, Fisheries, Birds, Turtles, Marine Mammals, Species at Risk				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood (Significant Effect Only)**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Vessel Presence/Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Air Emissions	NS	3	-	-
Sound				
Array – physical effects	NS	2-3	-	-
Array – behavioural effects	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Support Vessel	NS	3	-	-
Echosounder	NS	3	-	-
Presence of Vessels				
Seismic Vessel and Streamer	NS	3	-	-
Support Vessel	NS	3	-	-
Accidental Spills	NS	2-3	-	-

Key:

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

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

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

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

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List of Appendices

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Appendix 3. Consultation Reports

A. Labrador – Nunatsiavut Consultation Report (GXT / Sikimuit Environmental Management)

B. Other Consultations (GXT – Canning & Pitt Associates)

Appendix 1. Environmental Management Plan

Environmental management plan

Identification: **MA-0016**	Version: **2.0**
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a. Introduction

The objective of this plan is to document the implementation of the SeaBird Environmental Management System (EMS) derived from the Health, Safety and Environmental Management System (HSE MS) manual. This Environmental Management Plan (EMP) documents the plans and activities that will guide the Company's ISO 14001 compliant EMS.

Continual improvement towards sustainability is the key underlying principle of responsible environmental management; and it is the cornerstone of the Company EMS. By establishing measureable goals and monitoring the effectiveness of the system to deliver those goals we complete the 'continuous improvement' cycle as defined in ISO 14001.

b. Custodian and Purpose

Company Environmental Management Plan (hereafter referred to as 'EMP') is controlled by the Company's HSSEQ Group. The EMP is disseminated using the SeaArc document management system.

The objective of the EMP is to document the implementation of the principles, goals and requirements of the Company Health, safety and environmental policy in conformance to ISO 14001.

c. Scope and Application

The scope of the EMP is seismic operations. The EMP may be supplemented by specific project plans where required.

1. Executive summary

Good environmental management is based on the known science but there are clearly uncertainties and complexities that are not entirely understood. Therefore, the precautionary principle is widely adopted to mitigate the limitations of scientific knowledge. Beyond the limitations of science there are also expectations imposed by public perception of the environment. The public concept of environmental risk is not entirely physical but influenced by social concerns: and issues may need to be resolved in an inclusive way, through mediation and negotiation between the stakeholders.

Continual improvement towards sustainability is the key underlying principle of our environmental management. SeaBird Managers recognize and accept their responsibilities and accountability for minimising the impact of our operations on the environment using the systems established in the Company's HSE MS.

This plan explains the effort made by Company to implement an effective environmental management system as part of the Health, Safety, Security, Environmental and Quality (HSSEQ) planning process (according to the principles of ISO 14001). These include the requirement to obey rules and regulations and the need for continual improvement. The EMP is an open-ended dynamic list of objectives and targets for the company to achieve. It details the current arrangements to achieve these targets and outlines the possible methods for changes to be made, based on sources of input.

Continual improvement is taken forward through objectives and targets. These have been set and will be regularly reviewed to ensure that the EMS remains relevant to the Company's needs. Continual improvement will be made through capital projects to improve the environmental systems aboard the vessels; and through initiatives to cumulatively reduce impacts over time.

1.1. Environmental definitions

Management System Definitions

ISO Definitions

2. Environmental management system

The HSE MS manual defines the structure of the Environmental Management System (EMS) in detail. Key parts of this structure are shown here to establish the background to the EMP.

2.1. Environmental impacts

An environmental impacts assessment has been created for the company's operations. It is the responsibility of the management Representative to ensure that it is accurate. For this to occur the main elements of the EMS are coordinated through the Management Representative while as many functions as possible are automated or semi-automated to assist in the movement and analysis of information.

The Environmental aspects file is situated in SeaArc in management System, section 4.2.

2.2. Register of legislation

A register of legislation has been created and cross-referenced to the Environmental aspects and impacts so there is a ready-reference between legislation and relevant impacts. The register is attached to the *Environmental impacts* and can be reached at the link shown above.

2.3. Objectives and targets

The Company EMP is a written plan designed to deliver the Company's objectives and targets.

Each survey has a Project Plan developed to meet the HSSEQ objectives and targets. These may come from the client; national legislation; local community; company; industry; or other third party, as agreed. The site plan will include:

- Environmental objectives
- Resources available
- The technology to be used in product or process improvement

Company objectives are established to conform to the Health, safety and environmental policy. These objectives are reviewed and updated by management and guide the creation of company and vessel targets.

Annual company HSSEQ targets are set that include environmental targets for the company.

A set of vessel targets are set for the vessels and these include environmental targets relating to drills and contingency planning. Each vessel records the consumption of Marine Gasoil (MGO) and the consumption of refrigerant gasses. These data are sent into the office. During 2010 these data will be benchmarked so that in future reduction targets can be set. Using source deployment booms has been identified as a method of reducing fuel consumption and it may be possible to upgrade engines to more efficient modes.

In addition, project-specific environmental improvement targets may be set to address objectives, as discussed above.

Specific office site or department environmental improvement plans and targets are established based on environmental aspects and impacts and what is possible, given the limited control over some aspects.

2.4. Organisation and responsibility

Organisation charts are established that show the relationships between personnel functions. These are managed within the Quality Assurance (QA) management system. The charts are stored in section 3.1 Organisational structure and responsibilities of the MS. The HSSEQ group chart shows the reporting and advisory relationships of the EMS Management Representative (MR). The MR is designated to be the Senior HSSEQ Advisor who reports directly to the VP HSSEQ.

Job descriptions are located in section 3.3 Resources of the MS. These include relevant environmental responsibilities. In addition, written procedures, work instructions, etc and vessel's preventative maintenance system (PMS) TM-Master define specific task responsibilities.

2.5. Communications

The Company has an established a communications process for receiving, documenting and responding to internal and external communications from interested parties regarding environmental effects and management. The procedure operates under the ISO 9001 based, Quality management System (QMS).

Communications received about environmental matters from an external source will be copied to the Senior HSSEQ Advisor and VP HSSEQ. A response will be made by the appropriate manager. Consultation may take place with environmental; or legal; or operations experts as decided by the VP HSSEQ.

If a non-conformance of the EMS is indicated it will be taken forward under the nonconformity procedure. Nonconformities that could impact the EMS are identified as such on the forms and these like all nonconformities will be reviewed by the HSSEQ group.

2.6. Procedures and contingency planning

Procedures, Work Instructions and contingency planning are in place and the structure of the system is outlined in the HSE MS Manual. The elements involved in the EMP are outlined in the following sections.

3. Vessel management system

Each vessel operates a comprehensive environmental management system based on the protection of the environment from emissions created by the vessel. The environmental aspects have been evaluated and the following measures designed to minimise that impact.

3.1. Waste management

3.1.1 Waste management plans

The Waste Management Plan is located in SeaArc. It complies with international marine pollution prevention (MARPOL) requirements to ensure that all waste whether incinerated, stored or disposed is recorded.

Suitable identified (named and/or colour-coded) containers are installed around each vessel to allow segregation of waste at source. The crew assigned to collecting and dealing with waste also check waste segregation, where not already done at source, as a check and control measure.

Failures in the segregation process are likely to be recorded in the 'Observation Card' system or 'incident reporting system' depending on the potential severity. These SeaNet-based systems provide a means to record management system failures and opportunities for improvement.

Waste segregation is also practiced in shore-based offices, where identified waste segregation containers are used. Recycling facilities for this waste is via local authority run collection and processing services.

3.1.2 Garbage record book

Each vessel maintains a Garbage Record Book/Log to record the day to day details of garbage management including types, volumes (before and after incineration) and if there were any deficiencies that might adversely impact the environment. Special waste is disposed ashore, usually via registered handling companies or by return to registered companies, such as the manufacturer.

The garbage record is usually under the control of the Chief Officer.

3.1.3 Ballast water management plans

Each vessel operates a Ballast Water Management Plan to ensure that organisms whether flora or fauna are not transferred between sea areas.

3.1.4 Oil record book

Each vessel operates an Oil Record Book/Log. This book records all activity connected to fuel oil, lubrication oil, recycled oil and waste oil. It shows exchange on and off the vessel and transfer of oil around the vessel. It is under the control of the Chief Engineer.

3.2. Emissions to atmosphere

Permissible maritime emissions to the atmosphere are mandated by the International Maritime Organisation (IMO) in MARPOL annex VI.

Each vessel holds an International Air Pollution Prevention certificate (IAPP). This regulates the permissible emissions into the air from the vessel. These emissions are primarily from engine exhausts and incineration. To minimize environmental impact all vessels operate using Marine Gasoil (MGO) (has the least sulphur oxide (SOx) content for marine propulsion engines). SOx content (as part of overall fuel quality) is defined when requesting fuel oil and samples of delivered fuel are sent for independent checks for each fuel shipment received aboard vessels'. Percentage of SOx emissions from our ships will be progressively reduced where supplies permit, as part of vessel annual targets for greenhouse gas reduction.

Progressive reductions in nitrogen oxide (NOx) emissions and particulate matter from marine engine exhausts have been agreed for the medium-term future by the IMO. Company will plan to implement these ahead of any deadline.

Fuel use records are collected aboard vessels and transmitted to the office on a weekly basis. These data provide means to monitor vessel CO_2 emissions using independently supplied and approved calculation. These data are recorded in SeaNet reporting.

NB. The Oil Record Book/Log maintained aboard each vessel provides evidence of compliance, as all fuel oil shipments on and off the vessel are certified in this record.

3.3. Emissions to sea

3.3.1 Water

Water types are identified aboard each vessel into type. Pipes, valves and containers are identified (generally by colour-coding or tagging/marking) to minimize possibility for error. Overboard discharge valves are identified and locked-out from accidental operation, whenever discharge is not permitted.

Water types are identified as:

- Potable (drinking water)
- Ballast/bilge (potentially contaminated)
- Sea water
- Sewage
- Grey water (showers, sinks, etc)

Sewage: There is a system aboard each vessel to contain and process sewage according to regulated standards. It can only be discharged to the sea under controlled and regulated conditions.

Grey water: To reduce the impact of any grey water discharge the optimum environmentally-friendly detergents are supplied aboard vessels. Refer to purchasing process in Quality MS manual for further details.

Oily-water separators are used to remove oil from potentially contaminated water, such as bilge water, before discharge overboard. Oily-water separators are independently certified that they reduce oil content to a maximum of 15 parts per million. Discharges are recorded in the Oil Record Book, including details such as time, amount and vessel position.

3.3.2 Food

Food can be discharged at sea according to MARPOL conditions. Food maceration (where the food waste is ground down to significantly reduce the size of pieces) is in place on most vessels.

3.3.3 Seismic equipment

Towed seismic equipment is connected together with variously wire ropes, Kevlar ropes, stainless-steel shackles, etc. This equipment is routinely checked and changed out as required. There is always the possibility that equipment may break. These situations are reviewed and likely loss situations and critical equipment failure (significant environmental impact) are addressed and secondary recovery systems (such as safety lanyards, secondary ropes, radar reflectors, lights, positioning beacons, etc) are used to minimize the risk of loss.

3.4. Local nature conservation

In certain remote areas logistic support facilities may be reduced or non-existent. In this situation the client usually has an established local presence that will assist with vessel support as required. This minimises our exposure to impacting on the local population and natural environment ashore.

We may establish a shore support organization comprising one or two Company personnel or third party contracted personnel. These activities use established offices and hotels making marginal impact on the local natural environment.

Any impact will be determined during the planning phase of each survey and action taken as required. Refer to Environmental Impact Assessment and survey Project Plans.

3.5. Seismic source noise and marine nuisance

The impact on marine fauna of anthropogenic (human-created) noise from the seismic energy source is of concern in the industry and to the wider public. Research on this complicated scientific subject is ongoing. Particularly because there is uncertainty about the effect of this noise, it remains (after mitigation), as a significant environmental risk: refer to the ‘Environmental Impact Register’ (EIR) for details.

3.5.1 Seismic source soft start

The Joint Nature Conservancy Council (JNCC) of the UK established the first set guidelines for working in areas containing marine mammals. These guidelines have been amended and updated and are the basis of guidelines used around the world today.

Since there are a number of guidelines with variations from the JNCC guidelines, it was decided by the International Association of Geophysical Contractors (IAGC) to establish a common set of minimum guidelines for protection of whales. The majority of the seismic industry uses these as a norm (where no other guidelines are implemented). Company commits to applying the IAGC guidelines as a minimum. These include an observation period and a soft-start (ramp-up) of the seismic source.

In practice, a 'soft start' or 'ramp-up' of the seismic source is always made and this is the primary mechanism for mitigating the effects of the sound source. The soft-start is intended to provide a warning to marine fauna of the increasing noise which allows time for any species that may be sensitive to the noise to move away.

Parameters including the time taken for soft-start will be established for each project and details included in the relevant Project Plan.

3.5.2 Marine mammal observation

Include in the JNCC and IAGC guidelines for soft start is a requirement to make a 'pre-start' observation of the sea area surrounding the seismic source to watch out for those species identified in planning. Personnel will be trained before undertaking this task.

Often, dedicated and externally trained (third party supplied) Marine Mammal Observers* (MMO) may be used aboard vessels to make visual monitoring of the survey area to help ensure that species of concern are seen. These Observers work with vessel personnel to ensure that the requisite actions are taken and reports made about any sightings.

*NB. MMOs may be termed Marine Fauna Observer (MFO) to recognize that turtle species and other fauna including birds may be included in specific monitoring programmes. The term 'MMO' is generally taken to include monitoring of any fauna identified in the planning (Project Plan) process.

3.5.3 Passive acoustic monitoring systems

Soft-start described above is used as part of mitigation for many whale and dolphin species (as listed in the planning for the survey). Passive Acoustic Monitoring (PAM) systems may also be used aboard vessels as part of the cetacean monitoring/mitigation requirements. PAM systems can be used at night and in periods of low visibility such as fog.

These systems operate by towing an array of hydrophones behind the source vessel. These systems require animals to be making sounds (vocalising) and therefore will not always 'hear' animals. PAM systems are still generally under development and rely on interpretation based on operator experience and bespoke computer software.

3.6. Local impact of survey activities

The presence of seismic survey vessels in an area can adversely affect fishing and leisure activity such as diving and sightseeing. These groups (stakeholders) are consulted during the planning stage for surveys whenever possible or as required by the controlling authority. Plans may be established to minimize adverse impacts between seismic and local activities. Fisheries Liaison Officers (FLO); navy representatives; government department representatives; environmental observers; etc, can be stationed aboard vessels on the survey area to assist in liaison and cooperation with local stakeholders.

Where fishing and leisure activity is more regional in nature, then suitable general navigation warnings are broadcast to maximize knowledge of planned activities across a larger area. Additional measures will be determined during the planning phase of each survey, then implemented and updated as required. Refer to relevant Environmental Impact Assessment and survey Project Plans.

The logistical presence of seismic survey support activities ashore is normally very slight. Vessels operate out of established sea ports and personnel use commercial hotels and personnel travel to and from the closest airport taking scheduled flights. Local purchase vendors and commercial companies may be used where possible for 'top-up' supplies or small-scale fabrication. These activities inject moderate amounts of money into the local economy which is unlikely to distort local markets due to the small amounts involved.

3.7. Packaging

Company product is repackaged in the original supplied blank data boxes or data transferred electronically with no packaging.

Ship's consumable supplies arrive in manufacturer's packaging and this is either returned to supplier in port, disposed at in-port authorized facility or incinerated aboard the vessel when offshore.

Equipment such as: streamer levelers, streamer recovery devices, streamer sections, source umbilical cables, etc are usually returned in the original packaging. This is generally retained for reuse when equipment is returned for repair or credit.

3.8. Storage

Potential pollutants such as oils; chemicals; batteries; contaminated medical supplies; volatile organic compounds; compressed gasses; etc are stored with due regard to hazards created by their use, accidental spillage, proximity to ignition and fire sources and their potential involvement in fire incidents. Chemicals are not decanted unless suitable containers are available and these are suitably identified with their contents.

Refer to vessel safety and emergency plans; vessel risk assessments; operating procedures and checklists.

Appropriate operating procedures, environmental contingency procedures and record-keeping are maintained for each vessel; manned support site and office site. These processes operate predominantly within the SeaNet system.

4. Office management system

Each office operates an environmental management system based on the statutory responsibility and company best-practice for protection of the environment. The environmental aspects have been evaluated and the following measures designed to minimise that impact.

4.1. Purchasing

The supply of chemicals to the vessels has been identified as the primary source of environmental impact and the most suitable supplier has been engaged.

The process of identification of other suppliers that can have a significant impact on the products that the Company uses is yet to be undertaken. Further action on the supplier chain may be identified in targets and plans going forward.

The HSSEQ Group may be consulted for advice and where appropriate to audit the supplier before or during use.

4.2. Resources

4.2.1 Waste management

Waste management complies with national requirements to ensure that all waste is disposed appropriately.

Waste is recycled, as far as local facilities allow and Company provides suitable identified containers at points of use for collecting this waste.

Batteries are collected in identified containers. These are special waste and will be disposed of via the local national facilities (where these exist).

Used electronic devices are taken to the sites' Information Systems (IS) department. Where the IS department does not have representation at the site, they will be contacted to advise about suitable disposal.

4.2.2 Water

Water supply is generally part of the leased facility and cannot be easily monitored.

Despite the lack of means to measure its use, care is taken to advise staff through awareness training and reminder signs to stop unnecessary use of this resource.

4.2.3 Food

Food waste is collected separately and where there are facilities to recycle, these are used.

4.3. Consumables

4.3.1 Packaging

Company do not produce product from the administration offices apart from bid and contract information. These are normally specially consigned to be delivered to the client by courier. Therefore, reuse of packaging is not a significant contributor to the EMS.

4.3.2 Paper

The majority of use of paper is in printers. A supply of single-sided use paper is kept in printing areas for use as 'scratch' paper.

Targets for the reduction of paper use, such as by double-sided printing will be established as part of the continual improvement process.

4.3.3 Plastic cups

Minimisation of the use of plastic cups will be a locally-controlled aim where the site decides that this is the best environmental and practical solution.

5. Monitoring

5.1.1 Collecting data

Vessels comply with ISM Code requirements to keep records of waste emissions to the sea and to land. This data is also sent ashore weekly in a weekly report to the office. Additional environmental data is submitted in weekly reports. These weekly reports are completed to Sunday midnight and uploaded to each vessel's SeaNet site. These records are then available to management and therefore, electronic copies are 'permanently' (Control of records procedure) retained due to the robust Data includes records of fuel use and waste emissions.

5.1.2 Analysing data

Useful comparison of these data is difficult due to the variability of factors that impact the results. The work patterns of the vessels are hardly ever the same (different in-water set-ups to tow; different operational speed due to survey configuration; variable weather and currents; size and frequency of source array; number of personnel aboard; etc). Therefore, general operational parameters and guidelines have been set for the vessels and data is collected. Specific monitoring and reduction programmes will be developed once benchmark standards have been set.

Non-conformity reports may be created where the EMP is not being complied with.

General records made as a result of activities such as, meeting reports; observations cards; toolbox logs; Risk Assessments; Management of Change; etc may also indicate factors. These are all recorded in the SeaNet system and available to managers and advisors for review.

The Senior HSSEQ Advisor and HSSEQ Group are tasked with analysing the various established monitoring inputs. They will also review actual working practice aboard the vessels during audits and general operations.

6. Audit

Vessels and company sites will be audited as part of the EMS to a standard that includes the aims of the ISM Code requirements and those of the ISO 14001 programme.

A schedule of HSSEQ audits has been established for 2010, in addition to the existing programme of ISM Code audits and various external audits. This programme requires that all vessels are audited annually and reports created.

7. Review

Review is in place to allow problems or developments that do not match planned or budgeted schedule to be addressed. It will also provide input into the ongoing environmental management programme to identify environmental aspects and impacts.

Before the annual management review of the HSSEQ system, the Senior HSSEQ Advisor will instigate a review of the EMP and create a report to be presented to senior management.

Appendix 2. Emergency Response Plan

Contact MCTS Center
Happy Valley-Goose Bay (VOK)
1 709-896-2252
1 709-896-8455 fax

ion
GX TECHNOLOGY

<u>All Project Vessels Contact MCTS Happy Valley-Goose Bay (VOK)</u>

Twice Daily

By: GMDSS OR Phone: 1 709-896-2252

If Contact Is Not Made 1 hour After The Scheduled Time

Then MCTS Happy Valley-Goose Bay Contact GXT

Dean Kennedy 1 709-682-2336
OR
Tim Dudley 1 832 344-6755

GXT conduct a Communications Search for the Vessel Until contact is Established

If contact cannot be make with the Vessel then Activate
Halifax SRR
1 800 563 2444
1 902 427 8200

GX TECHNOLOGY

VESSEL MASTER ORDERS MEDICAL EVACUATION

Vessel Contact Halifax SRR

1 800 563 2444
1 902 427 8200

OPTPION ONE

SAR HELICOPTER

Vessel to Transit Within Helicopter Range

OPTION TWO

Vessel Transit to Nearest Port with airport facilities

Conduct Company Emergency Call Outs

All PROJECT VESSELS

FIRE
COLLISION
BLACKOUT
ABANDON SHIP
STEERING LOSS
ADVERSE WEATER
MAN OVERBOARD
POLLUTION

CAPTAIN Contact HALIFAX SRR

1 800 563 2444

1 902 427 8200

Follow Vessel Emergency Response ISM Manuals

Conduct Company Call Out Plans

GX TECHNOLOGY

POLLUTION

Follow Vessel Specific Maritime ISM Contingencies Pollution Manual

IF SOURCE IS OIL REFER TO:

SHIPBOARD OIL POLLUTION EMERGENCY PLAN

Vessel Specific Marine Operation Procedures

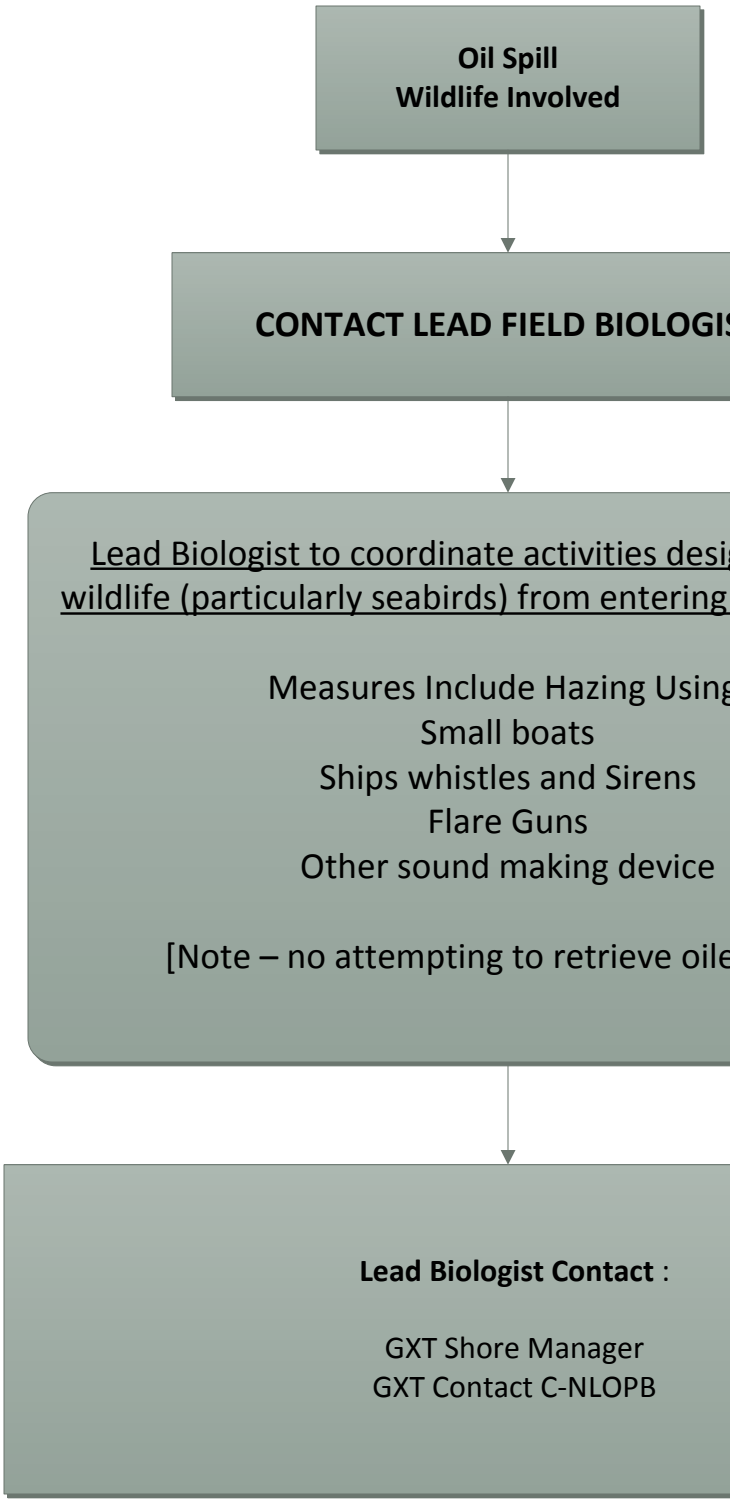
CONTACT Halifax SRR

1 800 563 2444
1 902 427 8200

CONTACT

GXT Management
Vessel Owners/Operators
C-NLOPB

Follow Office SOPEP Manual/Procedures for Vessel Oil Spills


Oil Spill
Wildlife Involved
CONTACT LEAD FIELD BIOLOGIST
Lead Biologist to coordinate activities designed to keep wildlife (particularly seabirds) from entering the oiled area.
Measures Include Hazing Using:
Small boats
Ships whistles and Sirens
Flare Guns
Other sound making device
[Note – no attempting to retrieve oiled birds]
Lead Biologist Contact :
GXT Shore Manager
GXT Contact C-NLOPB

ion
GX TECHNOLOGY

HARVESTER ENCOUNTER

Master / FLOs / GXT Representative PROCEDURES

(1) STOP production and move away from Harvester

(2) Record how the Harvester was noticed / how contact was made and by whom

(3) Record exact time, location, sea conditions, and any other pertinent information about the event

(4) If the FLOs are able to communicate with the Harvester, identity who it is and whether there are any other Harvesters in the area.

(5) Note what the seismic vessel had been doing before the encounter

(6) Note any other vessels that you are aware of in your vicinity before/during the encounter.

Note: FLOs To Communicate with Harvester where possible

Vessel Contact GXT

GXT Project Manager Contact

GXT Management
C-NLOPB

Appendix 3. Consultation Reports

A. Labrador – Nunatsiavut Consultation Report (GXT / Sikimuit Environmental Management)

B. Other Consultations (GXT – Canning & Pitt Associates)

Appendix 3A.

Labrador – Nunatsiavut Consultation Report (GXT / Sikimuit Environmental Management)

Labrador Consultations
LabradorSPAN Offshore Seismic Operations 2013

Submitted to:

GX Technology Canada Ltd.

Submitted by:

Sikumiut Environmental Management Ltd.
P.O. Box 39089, St. John's, NL
A1E 5Y7

March 2013

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Appendices

Appendix A Attendees at 2013 LabradorSPAN Seismic Operations Agency and Public Consultation Meetings
Appendix B Communications

1.0 CONTEXT

The 2013 Labrador Shelf Seismic Operations agency and public consultation meetings were held on behalf of GX Technology (GXT) with support from Sikumiut Environmental Management Ltd. (SEM). The 2013 consultation process was set for March 19-21st with meetings planned for three communities; Happy Valley-Goose Bay (HV-GB) and North West River (NWR) in the Lake Melville area of Labrador, and Nain on the north coast of Labrador. Meetings were scheduled for both stakeholders (i.e., Torngat Wildlife and Fisheries Board, Nunatsiavut Government, Torngat Fish Producers Co-operative Society Ltd., Sivunivut Corporation Inc.) as well as public sessions. These consultations represent the beginning of the public consultation efforts; GXT intends to hold additional sessions on the north and south coasts of Labrador following the Easter break as part of their continuing consultation policy and approach.

2.0 CONSULTATION PROCESS

Dean Kennedy, GXT Project Manager, along with Robert Pitt, GXT Environmental Manager were present for all of the meetings. Crystal Kehoe of SEM coordinated meeting logistics and facilitated the meetings.

2.1 Communications

The public promotion processes of the meetings were as follows:

- Notice of meetings were e-mailed to community leaders, town councils, fishers, government fisheries officials and others;
- Personal telephone calls were made to town councils, town governments and fisheries associations;
- A CBC announcement was made on the Labrador Morning Show, The Fisherman's Broadcast and the news service from Corner Brook; and
- Public Meeting Notifications were placed in The Labradorian and Northern Pen newspapers online.

Attendance at the individual meetings ranged from one to 11 persons for a total of 27 persons which included government officials and concerned local residents (meeting attendance is documented in Appendix A).

Each meeting was opened with a brief introduction and an explanation for the consultations. A MS PowerPoint presentation was shown regarding marine seismic operations in general, the specific seismic lines planned for the 2013 season, and the timeframes in which the lines

would be acquired, as well as several maps showing fish-harvesting locations (key species) in relation to the 2013 lines. GXT/SEM also recorded information about commercial fish harvesting details related to the Project Area. GXT/SEM also record any issues and concerns, and advice about mitigations (particularly avoiding concurrent fisheries) and communications. Meeting participants were provided with the Project Information Brochure (Appendix B) including extra copies for wider distribution. The meeting was open to questions and discussion during and after the presentation.

3.0 ISSUE IDENTIFICATION

Notes from each meeting are contained herein while the following summarizes the main areas of concern.

The sensitivity of the area in relation to the commercial fishery resources such as crab, shrimp and turbot was raised at all of the meetings. It was mentioned on more than one occasion that many would prefer no seismic activity in these areas during relevant fishing seasons.

The effect of seismic sound on fish and other animal populations (i.e., seals, whales) is a concern.

Compensation for damage to the fishery and fishing gear were discussed at most meetings.

Community benefits particularly in the context of port services and employment is an important consideration.

There was also concern about the possibility of pollution from an “oil or gas spill” during the operations.

In addition, there was discussion about the purpose of the Project, how it was to be conducted and the use of the seismic data obtained. All persons who attended the meetings were very interested in the project and posed various questions and comments. They were interested in being kept informed on the project and any future plans for development.

3.1 Fisheries

The commercial fisheries were discussed and attendees indicated the importance of that industry to the entire coast of Labrador. The commercial fisheries are still relatively new and in the process of being built up. GXT managers showed slides of maps showing the fishing locations using data provided by Fisheries and Oceans Canada (DFO). A general recommendation from most attendees was complete avoidance of the active fishing areas during fishing season. Detailed discussion about specific management measures to address

these concerns focused on selecting the right timing for the operations; using observers on board the seismic ship; gear avoidance protocols; noise protocols (staying away from active areas where harvesting might be affected by the seismic array sound); and other operational requirements to avoid conflicts. Central to implementing successful management and avoidance measures will be effective on-going communications before and during the fisheries. There was considerable discussion about this with some participants and details to be incorporated within the Project mitigation / communication plan were identified. GXT agreed that each of these fishery considerations will be written into the Environmental Assessment (EA).

As this was only the beginning of the consultations, it was stated by several participants that going into the coastal communities would be beneficial (i.e., Makkovik, Rigolet, Hopedale, Postville). The fisheries are important for these communities and they will want to be consulted. It was explained that additional consultations were planned (for April) in these communities before the survey occurred. In addition, it was suggested that the south coast communities would want to be consulted as well (i.e., Cartwright, Mary's Harbour). It was explained that as Cartwright was a possibility as a service port, these communities would be included in future consultations.

3.1.1 Possible Impact on Crab Fishery

It was noted more than once that during the 2011 crab season fishers believed that seismic operations may have impacted the success of the crab fishery. People felt that the catch was affected and the gear itself was snagged and dragged away on the seismic equipment. The experience of crab fishers is that there was good fishing in an area prior to seismic activity and poor catches occurred after the ship had passed through the area and persisted into the following year. A comment was made that waters were warmer than usual last year which would contribute to some decrease in crab stocks; however there were also comments that the cod stocks seem to be increasing and according to fishers, increased cod means decreased crab stocks. The fishers located on marine charts the areas fished for crab. The crab season can begin around mid July and end around the end of July or into August, depending on catch rate. It was indicated that the Torngat Fish Co-op would provide fishing positions once they were determined. It was also stated that in a previous seismic survey a seismic ship "ordered" fishers to move their gear to make way for the seismic ship. They noted that they would not do that again.

GXT managers noted that they would have a full Gear Damage Compensation Program in place for the survey (which would include compensation for lost catch), with well-publicized toll-free phone number and an email address for fishers to contact GXT and/or make a claim. GXT also noted that it understands very well that it cannot tell fishers to move their gear (or touch their gear) and that the fisheries take precedence under the *Fisheries Act.*

Torngat Fisheries Co-op stated that areas 2H/2J used to be for crab fishing but that pocket dried up and fishers have now moved south to 54° 40'. They also noted that they could have as many as 11 boats fishing snow crab and turbot this year.

3.1.2 Possible Impact on Turbot Fishery

It was stated by some attendees that when a seismic ship is in an area it affects the turbot in that they are moving more. Fishers find the turbot are caught more in the head ropes of their nets as opposed to the bottom where they are usually caught. It was noted that there did not appear to be a change in catch but rather that the turbot appear to be moving more (more active) when a seismic vessel is in the area.

There is a split season for turbot fishing. About 75% occurs in June and the remainder in August. There is a new communal quota of 190 metric tones for area 2+3K. Most turbot fishing occurs within about 20 km of Makkovik as the turbot processing plant is located in that community.

3.1.3 Possible Impact on Shrimp Fishery

It was noted that during the 2011 shrimp season fishers believed that seismic operations may have impacted the success of the shrimp fishery. The experience of shrimp fishers is that there was good fishing in an area prior to seismic activity and poor catches occurred after the ship had passed through the area and persisted through the remainder of the fishing season. However, the following year's catch seemed to be better. The shrimp fishery occurs from about mid-August to mid-October, especially in Area 5. Only one Nunatsiavut beneficiary owns a fishing vessel and the rest need to lease. This means that most of the shrimp fishery depends on fishing vessel availability.

3.2 Seismic Activity and the Nunatsiavut Zone

Proposed seismic lines range from north east Newfoundland to the northern tip of Labrador (2013) and across to Greenland (2013). The seismic surveys would not enter the Nunatsiavut Zone or Hawke Channel. In fact, the lines would terminate about 6 km outside of the Zone to give room for the vessel to turn and not enter the Zone at all. Questions were raised about why these areas were being avoided and whether there was interest in them. It was explained that due to permitting timelines, 2013 survey lines would not enter the Zone or Hawke Channel. However, GXT also explained that there is definite interest in these areas but that they have often been avoided in the past due to perceived restrictions or uncertainties about the process that would be required. GXT is hoping to begin communications for entering the Zone in 2014 but a separate EA along with additional meetings would need to be arranged.

The Sivunivut Corporation Inc. chairperson mentioned that if work was to go ahead and enter the Nunatsiavut Zone, a Permit to Access would be required. However, since the Land Claims Agreement has only recently been adapted, it would be reasonable to think that this is possible. GXT stated that even if no development was to take place within the Zone, it would be still beneficial to survey the area to have a complete understanding of the Labrador Basin.

3.3 Concerns with Noise and the Environment

Some participants were interested and concerned with the amount of noise created by the seismic array. Due to this particular survey having to go deeper into the earth, the noise of the array would need to be somewhat louder than some previous surveys. Concerns were raised regarding where the sound goes and how the sound affects the fish and other wildlife. It was described that while this array arrangement was slightly louder, the array did not fire as many times in one area. For this survey, the array activates about every 20 seconds while the typical array is fired every 8-10 seconds. The aim is for the sound to go straight down and in this configuration, about 80% reaches the bottom; the other 20% does spread more horizontally. In addition, the lines for this survey will be further apart than a typical configuration which means the vessel would only be in a given area once or maybe twice where the lines intersect.

There were inquiries about the effects that the seismic sounds had on fish, and specifically whether dead fish were seen after the ship passed. In response it was explained that seismic programs have been carried out in Newfoundland and Labrador waters in the past and that dead fish had never been reported by fisheries or other observers, and no measurable negative effects on fish stocks. It has been reported that fish, especially the free swimming fin fish, tend to move away from array noise, which protects them from physical harm but might affect catchability. It was explained that the physical effects on fish could be studied n a lab and that experiments examining physical impacts (e.g., on otoliths, swim bladders and eggs, etc.) have indicated that unless the animal was directly under an array (i.e., within a metre or so), there would be little to no physical effect. However, the behavioral effects are more difficult to demonstrate in a laboratory and currently they are not as well understood, though new studies are being planned in the NL waters. It was questioned whether this type of seismic work could be used to further studies of behavioral effects and what the long term trends would be around seismic surveys. It was explained that while GXT would be more than interested in assisting with this type of study, it would not be economically viable and could be considered a conflict of interest to conduct this type of study on its own. GXT stated that the Environmental Studies Research Fund (ESRF), along with other organizations, have funded these types of studies in the past and similar ones should be conducted for the Labrador Sea.

When it comes to whales and other mammals, the Canadian standard (in the Statement of Canadian Practice, DFO) is to use a Safety Shutdown Zone of 500 m from the centre of the array; this means that the array will not be started or will be shut down if active, if a marine mammal or sea turtle comes within that area. However, GXT has shutdown up to 1.5 km away for known feeding/critical habitat areas. This is why Marine Mammal Observers (MMOs) are very important as they have full authority for shutdowns when whales and other mammals are observed.

There was also concern regarding any issues for seals. There had been observations of seal carcasses washing up on shore for no apparent reason. In addition, there is a concern of decreased harp seal numbers due to increased noise in Lake Melville. GXT noted that the seismic vessel also serves as a research platform for bird and marine biologists (the MMOs) to

collect wildlife data for the areas. GXT was also asked if they might be able to provide space for a biologist on one of the vessels as a platform for some independent research on Labrador mammal populations; GXT said that they would have to investigate the space availability, and that this might be possible.

3.4 Other Issues / Questions

The participants asked about the need for more seismic data since this was already conducted in the seventies and it was thought that any oil that had been identified had already been discovered. It was explained that previous exploration provided insufficient data and that seismic technology has increased dramatically and interpretation has changed. The differences would be great from any information that had been collected in the past and that more information is needed. In particular, GXT explained that their proposed survey was a basin span which was quite different in its objectives and design from other surveys. Basin spans look deeper and at different structure than typical seismic surveys, in order to develop an understanding of wide geological structures at the basin level.

One comment was that “oil development off the coast of Newfoundland and Labrador is a disaster waiting to happen”. The concern was that while it seems fine for this project, do the people of Labrador want to say go ahead and drill for oil? It was explained that there are and will be many defined processes and several opportunities for input between this seismic exploration stage and any further exploration and any actual development stage. It was also explained that GXT does not benefit from any oil discovered. The profits they make are from the data itself, not from its subsequent use by petroleum companies.

It was discussed that the seismic operations involves chartering a ship and crew that is equipped and dedicated to this purpose. Local benefits will involve hiring observers and other support services. It was brought up at more than one meeting as to whether local residents would be able to work upon the vessels. It was explained that job postings would be sent to Labrador. Since GXT owns the support ship (the *Polar Prince*) it also crews it through a crewing company. In the past, in the Inuvialuit Settlement Region in Canada’s western Arctic, for example, two Inuvialuit had been hired for permanent (not Project-related) positions on that ship.

The seismic study could take place from within the period June to November. In regards to the timing it was further explained that the completion of the EA is now critical to getting the project approved and starting the process to acquire seismic ships.

A representative of the Town of Happy Valley – Goose Bay (Deputy Mayor) attending one of the meetings noted that the Council had received our information about the Project and fully supported it.

The following information was provided to questions from the attendees:

- There has been no tangling or entrapment of marine mammals in seismic arrays.
- Constant communications with any fishing vessels in the area helps to avoid fishing gear.
- All vessel garbage is self-contained and there is no dumping allowed; similar to the coastal vessels.
- Any liquid wastes will be fully treated before release following MARPOL requirements, and non-toxic waste will be incinerated following MARPOL regulations.
- This survey will use a solid-core streamer, which means that if a streamer breaks there is nothing to leak into the waters.
- The cable behind the boat sits approximately 8 to 12 m deep, depending on the area and is 9 km long.
- Explosives were used in the past and sometimes gave good results but were detrimental to the environment, and especially harmful to fish. Explosives have now been replaced with sound technology in marine areas, which has significantly reduced environmental effects.
- Although this survey should not be conducted during ice season, small icebergs and other such obstacles can be avoided without affecting the survey. The availability of the support ship, which is an icebreaker, will be a good safety measure.
- The survey results are similar to a picture of a cliff face which shows all of the lines of rock, and from this information, potentially where oil could be found. Since the sound goes up to 40 km deep, it looks below the sea floor and would not be useful for mapping the sea floor.
- GXT currently has an in-depth orientation session explaining all the environmental commitments and requirements for all people on board the vessel and will include the fisheries as an important component.
- The possibility of Nain and Cartwright as service ports were highlighted.

3.5 Information Sharing and Communications Processes

Sharing fisheries and seismic ship location information and communications coordinated through various mechanisms and Fisheries Liaison Officers (FLOs) were seen as very helpful and necessary, as was the use of the scout boat to locate fishing activities and communicate with fishers.

3.6 Public Consultations

Many individuals thanked and complimented the company for engaging in public consultation. The process is seen as an important avenue to iron out issues of concern and to engage with the fishery.

4.0 CONCLUSION

The meetings were successful and well received though the public sessions were not highly attended. Generally, the attendees appreciated the information sharing that is part of the public consultation process and were clear on what they identify as potential challenges between the seismic operations and the crab, turbot and shrimp fisheries. The presentation helped fishers understand the length of time the seismic vessel would be in an area, the speed at which it moves, the role of the supply and scout boats and the various ways the seismic ship can be in communication with fishing vessels. As for the comments relating to complete avoidance of the fishing areas during fishing season, GXT expressed that it would like to stay away from the fishing gear as much as the fishers want them to stay away. This is especially true for areas of fixed gear. The seismic equipment is very expensive and ideally must avoid any entanglement.

In addition, GXT determined that a good part of the communication plan would be to present an advanced line plan (e.g., a two week plan) and then when the time came closer, a three day work plan. The advance plan could give the fishers a chance to determine where they would be and give any feedback to assist in determining the final three day work plan, with the aim of avoiding the active fishing areas. Also, it was determined that it could be important to have an additional scout ship during June to August depending on where the survey ship will be.

GXT intends to continue its consultation efforts in other north coast communities and in southern Labrador in the coming weeks. A follow up consultation report on those activities will follow.

GXT also noted its intention to convene other meetings with the groups during and after the survey.

APPENDIX A

Attendees at 2013 LabradorSPAN Seismic Operations Consultation Meetings

Attendees at 2013 LabradorSPAN Seismic Operations Agency and Public Consultation Meetings

(Crystal Kehoe of SEM also attended all meetings)

Happy Valley-Goose Bay

Torngat Joint Fisheries Board Presenters: Robert Pitt, GXT Environmental Manager; Dean Kennedy, GXT Project Manager

Jamie Snook, Torngat Wildlife, Plants and Fisheries Secretariat
Aaron Dale, Torngat Wildlife, Plants and Fisheries Secretariat
Beverly White, Torngat Wildlife, Plants and Fisheries Secretariat
Julie Whalen, Torngat Wildlife, Plants and Fisheries Secretariat
Phonse Pittman, Torngat Joint Fisheries Board
David Bonnell, Torngat Joint Fisheries Board
John Mercer, Torngat Joint Fisheries Board
Keith Watts, Torngat Joint Fisheries Board
Craig Taylor, Torngat Joint Fisheries Board
Eric Andersen, Torngat Joint Fisheries Board
Stanley Oliver, Torngat Joint Fisheries Board / Deputy Mayor of Happy Valley – Goose Bay

Nunatsiavut Government Presenters: Robert Pitt, GXT Environmental Manager; Dean Kennedy, GXT Project Manager

Carl McLean Deputy Minister of Lands and Development, Nunatsiavut Government

Public Meeting Presenters: Robert Pitt, GXT Environmental Manager; Dean Kennedy, GXT Project Manager

Gordon Rendell Nunatsiavut Group of Companies

Torngat Fish Producers Co-operative Society Ltd. Presenters: Robert Pitt, GXT Environmental Manager; Dean Kennedy, GXT Project Manager

Keith Watts – General Manager
Ronald Johnson – Assistant General Manager

North West River (NWR)

Sivunivut Corporation Inc. Presenter: Robert Pitt, GXT Environmental Manager

Ed Tuttauk – Chairperson of Sivunivut Corporation Inc.

Ernie McLean – Mayor of NWR

Rose Ford - Sivunivut Program Coordinator

Ralph Lyall - Town Councilor

Jamie Jackman - Sivunivut Community Researcher

Scott Neilson – Heritage Research Analyst and researcher with MUN

Robin Goodfellow Baikie - Town Councilor

North West River

Public Meeting

Ed Tuttauk – Chairperson of Sivunivut Corporation Inc.

Note: No presentation was made since the single attendee had been at the Sivunivut meeting.

Nain

Public Meeting. Presenters: Robert Pitt, GXT Environmental Manager;
Dean Kennedy, GXT Project Manager

Joe Dicker – Nunatsiavut Government

Gus Dicker – SEM

Ron Webb – SEM

John Terriak - carver

APPENDIX B

Communications

GX Technology Canada Ltd. (GXT) is proposing to conduct a marine 2D (two-dimensional) seismic survey offshore north-eastern Canada, in the Labrador Sea area between 2013 - 2015, within the regulatory jurisdiction of the C-NLOPB.

GX Technology is being assisted by Sikumiut Environmental Management Ltd. (Sikumiut) for these consultations. GXT is here today to share information about the 2013 project with you, and to listen to your comments and advice to help make sure we do it right.

GXT believes in meeting with local interests before, during and after a project. This is the first of several meetings we hope to have with you. We will come back to tell interested groups how things are going and to find out if any issues have come up. We will also return after the survey to report on how things went (e.g. to present wildlife monitoring results, fisheries liaison results).

Thank you for taking the time to meet with us today and sharing your thoughts.

Proposed 2D Seismic Survey, Offshore Labrador Shelf

GX TECHNOLOGY

GX Technology Canada Ltd.
An ION company
www.iongeo.com

GX Technology Canada Ltd.

(GXT)

PROJECT DESCRIPTION

GXT is proposing to conduct an offshore two-dimensional (2D) seismic survey along the Labrador Shelf between 2013 and 2015.

The survey will use a seismic ship, MV *Harrier Explorer,* and a support ship, the GXT-owned *Polar Prince* (formerly the CCG/DFO icebreaker *Sir Humphrey Gilbert)*. It will tow a seismic sound source array and a 9-km long hydrophone (listening) streamer / cable.

No work will occur within the Nunatsiavut Zone (the Tidal Waters of the Labrador Inuit Settlement Area, as defined in the Labrador Inuit Land Claims Agreement). Part of the survey is within the "Ocean Areas Adjacent to the Zone" (as defined in Part 6.1.1 of the Agreement) (see map).

GXT plans to include biological and resource experts (Marine Mammal Observers / Fisheries Liaison Officers) to represent and assist with marine mammal, seabird and fisheries matters, and Nunatsiavut interests. These will include Inuit / Nunatsiavut representatives on the seismic ship.

SCHEDULE OF THE WORK

The survey season is June through mid-November, depending on ice, local weather conditions, and other marine activities (e.g. fish harvesting).

OBJECTIVE OF THE WORK

The proposed project is a regional Basin Span survey designed to provide a better understanding of the offshore geology of the Northern Labrador Shelf, and to use this information to identify new petroleum exploration opportunities. GXT's Basin Span programs are different from other surveys because they look very deep to understand broad regional structures. This unique information will be used to determine the regional extent of geological formations not previously known through conventional methods.

OPERATING SCHEDULE

The seismic ship will be at sea and work continuously (24-hour operations when possible) during the survey. Unlike most surveys, GXT's Span programs activate the airguns only about half as often as other 2D seismic programs to allow time to listen for the very deep sound echos. Crew changes will be made via port call, probably at Cartwright, usually every 6 – 8 weeks.

YOUR ENVIRONMENT

GX Technology Canada Ltd. (GXT) is preparing an Environmental Assessment of potential effects on the surrounding environment. Your input during these meetings is an important way for us to understand your concerns and to help us address them.

The main sensitivities identified in the project area include fisheries, marine mammals, fish species, and resident breeding and migrant birds.

GXT has had a lot of experience working in other sensitive areas in the north without any spills, or impacts on marine wildlife. We want to continue to work in partnership with you, to keep our good record and improve opportunities for local people.

PROTECTION & MITIGATION

As it has in other areas, GXT will continue to apply a comprehensive set of precautions and mitigation measures to prevent or reduce the likelihood of affecting the fisheries, wildlife and the environment in general. These measures will be similar to those GXT has used successfully in the past in several northern and Arctic regions, such as the Canadian Beaufort Sea (most years since 2006), with additional measures specific to the Labrador Shelf area.

To reduce potential effects on fisheries, GXT will stay out of the Hawke Channel area, avoid active fishing, plan activities away from key species areas during key seasons, avoid fisheries research surveys, and maintain close consultation / information exchange with fishing groups during the survey.

Onboard Inuit and other Fisheries Liaison Officers will provide dedicated marine radio contacts for fishing vessels that might be in the vicinity of the survey vessel to help identify and avoid gear locations, discuss potential interactions and find solutions, and provide guidance to the Bridge.

GXT, through its on-shore managers and on-board representatives, will also communicate with appropriate fisheries organizations to inform them of planned survey activities and to help ensure good information exchange with fisheries participants.

Relevant information about the survey will be publicized using established communications mechanisms, such as the Coast Guard Notices to Shipping and CBC Radio's Fisheries Broadcast, as well as direct communications between the survey vessel and fishing boats via marine radio at sea.

To avoid or reduce potential impacts on marine mammals (particularly whales) GXT will follow the 'Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment' developed by DFO (Fisheries and Oceans Canada, 2004). This document is available on the internet at http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismic-sismique/index_e.asp

The Statement of Canadian Practice was created to formalize and standardize the mitigation measures to be used in Canada with respect to the conduct of seismic surveys in the marine environment.

Other environmental protection measures include waste management, grey / black water disposal methods, reduction of air emissions, and emergency (spill) response plans, procedures and drills, that meet and exceed national and international standards (e.g. MARPOL).

GXT also meets with all project crew before project start-up to make sure they know and respect all of our environmental commitments and requirements.

THANK YOU FOR YOUR INTEREST

Please contact us if you have any further concerns or other information.

Robert Pitt, GXT - Environmental Manager
rpitt@gxt.com 709-682-3342

Dean Kennedy, GXT - Project Manager
dkennedt@gxt.com 709-682-2336

Crystal Kehoe, Sikumuit - Consultation Support
crystal.kehoe@sikumiut.ca 709-754-0499 (ext. 211)

Sikumiut
Environmental
Management Ltd.

Sikumiut
Avatiligijingita
Kamajingit

NOTICE

Public Consultation Meetings
GX Technology Canada Ltd
Proposed 2D marine Labrador Shelf Offshore Seismic Program

As part of its consultation program, GX Technology Canada Ltd. (GXT) will hold public meetings to provide information and discuss its proposed seismic project with local beneficiaries, stakeholders and other interested people. The project is a 2 dimensional (2D) seismic survey using a single seismic ship in the marine areas off the Labrador Shelf. The survey lines do not enter the Nunatsiavut Marine Zone. The work is planned for June to November over a two or three year period, starting in 2013. Similar surveys have been conducted in the offshore Labrador area in recent years and local Labrador Inuit observers were placed on the vessels involved.

Initial community meetings will be held in Happy Valley – Goose Bay, North West River and Nain. The time of meetings in other Labrador communities will be announced later.

Scheduled Meetings:

Happy Valley – Goose Bay	March 19, 2013 - 7:00 PM	Labrador Friendship Centre
North West River	March 20, 2013 - 7:00 PM	North West River Community Centre
Nain	March 21, 2013 - 7:00 PM	Nunatsiavut Government Office

Everyone Welcome. Contact for consultations:

Crystal Kehoe Sikumiut Environmental Management Ltd.
E-mail: Crystal.Kehoe@sikumiut.ca
Telephone (709) 754-0499 x211

NOTICE

Public Consultation Meetings

GX Technology Canada Ltd's proposed 2D marine seismic program, offshore Labrador Shelf

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E-mail: Crystal.Kehoe@sikumiut.ca
Telephone (709) 754-0499 x211

Sikumiut

ion
GX TECHNOLOGY

6122085

FOR RADIO

Re: Consultation Meetings for GXT Offshore Seismic Project

As part of its consultation program, GX Technology Canada Ltd. (GXT) will hold public meetings to provide information and discuss a proposed offshore seismic survey. The project is a 2 dimensional program using a single seismic ship in marine areas off the Labrador Shelf. The work is planned for June to November over a two or three year period, starting in 2013. Similar surveys have been conducted in the offshore Labrador area in recent years and local Labrador Inuit observers were placed on the vessels involved. Initial community meetings will be held in Happy Valley – Goose Bay, North West River and Nain. The time of meetings in other Labrador communities will be announced later.

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Everyone welcome.

Appendix 3B.

Other Consultations
(GXT – Canning & Pitt Associates)

Report on Agency and Industry Consultations for the GX Technology Canada Ltd. 2013 – 2015 LabradorSPAN 2D Seismic, Gravity and Magnetic Survey

During preparation of the environmental assessment (EA) for the GX Technology Canada Ltd. 2013 – 2015 LabradorSPAN 2D Seismic, Gravity and Magnetic Survey, consultations were undertaken with relevant government agencies, representatives of the fishing industry and other interest groups. The purposes of these consultations were to describe the proposed seismic program, identify any issues and concerns, and gather additional information relevant to the EA. (Note that Nunatsiavut consultations were undertaken separately.)

A short description of the proposed program (see attached), including a Project Area location map and species harvesting location maps which included the specific lines proposed for 2013, were sent to the relevant agencies and industry stakeholder groups in February 2013. They were asked to review this information and invited to meet with GXT representatives. If they did not consider a meeting was necessary, they were asked to provide any comments they might have on the proposed activities and to indicate whether or not they would like more information and/or to discuss the survey by telephone. Two separate follow-up emails were sent in March to those who had not replied, as well as telephone calls in several cases. The majority of those contacted indicated that they did not think that an in-person meeting was needed and provided their comments by email and/or telephone. Several of these agencies (e.g. the FFAW, DFO, EC) were informed of the Project in late January through the C-NLOPB process, and provided with the Project Description and draft EA Scoping Document for any comments.

Specifically the following agencies, stakeholders and interest groups were contacted for consultation about the proposed 2012-2015 seismic program:

- 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
- Canadian Association of Prawn Producers (CAPP), Ottawa
- Clearwater Seafoods
- Icewater Fisheries
- Newfound Resources Ltd. (NRL)
- Labrador Fishermen's Union Shrimp Company Limited

Response and Comments from Stakeholders

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 GXT representatives and their consultants. Managers noted that they had reviewed the project and provided relevant comments to the C-NLOPB.

Nature Newfoundland and Labrador (NNL)

Nature NL's representative asked questions about how the proponent would be controlling the sound speed profile, about the types of probes that would be used, and about any other active bottom profiling instruments that would be used – e.g. Doppler in particular, which emits high frequency sound. (GXT informed the representative by email no Doppler profiling will be done.)

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 GXT representatives, a number of general issues and specific concerns were noted and discussed.

Following a presentation of GXT's proposed 2013 program, there was a general discussion of established consultative procedures and protocols for seismic surveys as outlined and described in two recently completed documents: "One Ocean Protocol for Consultation Meetings: Recommendations for the Fishing and Petroleum Industries in Newfoundland and Labrador": and the "One Ocean Protocol for Seismic Survey Programs in Newfoundland and Labrador". One Ocean's Managing Director noted that these documents had been developed and agreed by One Ocean's Working Group which includes representatives from both industries, and that these documents can serve to assist and guide pre-survey consultations, to manage fish harvesting and seismic vessel

interactions and communications during survey operations, as well as describing appropriate fisheries-related mitigative measures based on lessons learned over the past decade or so.

It was agreed that the FFAW's Petroleum Industry Liaison manager would consult with relevant fleet sectors and note their concerns about and expectations for the survey and pass them on. If there was then a need for GXT to meet with these groups or any of the local-area fishing groups, they would let GXT know.

Fishers said they were concerned about possible interactions between harvesting activities and survey operations, especially in the southern section of the proposed Project Area; potential outcomes included gear conflicts and the potential for seismic noise to affect fishing success. The key species at issue were snow crab, shrimp and turbot. It was noted that fisheries in this general area have been "troubled" by a number of environmental factors and are presently "under pressure". Thus, there is a strong perception that survey activities might further affect fish catches if a seismic vessel was in the general vicinity. Concern was also raised about potential negative effects on the post-season crab survey.

It was indicated that avoidance of active fishing areas by the survey, and good communications and information flow between both industries during the survey, would be the best way to minimize impacts. It was also recommended that GXT personnel follow the applicable protocols in the One Ocean document for seismic surveys which, as noted above, were developed in conjunction with FFAW. It was also expected that a FFAW FLO will be on board at all times with exclusive fisheries duties. It was also recommended that GXT work with One Ocean to obtain fishing vessel position data from DFO's Vessel Management System during the survey period.

At the request of the FFAW, GXT also supplied photographs (from different points of view) of the planned survey vessels so that fishers at sea have a better chance to identify them if they are in the area.

Labrador Fishermen's Union Shrimp Company Limited (LFUSC Limited)

LFUSC Limited's General Manager did not have any specific comments about how the proposed seismic survey operations might affect established fishing activities, and expected that fish harvesters would be the ones best qualified to provide an informed discussion on this matter. He noted that most of the firm's shrimp quota is harvested by its partner company, MV Osprey Limited, based in North Sydney.

He also noted that LFUSC Limited along with several other Labrador-based offshore shrimp licence holders are now part of an industry association group called the Northern Coalition. These licence holders were once part of the Canadian Association of Prawn Producers, but decided to form their own organization a few years ago.

LFUSC Limited's General Manager said he would forward the GXT survey information along to Mr. Scott Nichols, fleet manager for MV Osprey Ltd., and also to Ms Rosalind Walsh of the Northern

Coalition for their review and comment. (GXT will continue its consultation with this group as the survey window approaches.)

Ocean Choice International

OCI's Fleet Manager stated that there would very likely be some interactions between his company's shrimp harvesting operations (and those of other licence holders) during the survey period if there was overlap (time, location), and noted that he had forwarded the information on to the offshore group, i.e. CAPP (Canadian Association of Prawn Producers), for their comment.

Other Fishing Industry Stakeholders

Other groups / stakeholders who responded did not indicate that they had any specific comments. To date, there has been no response from the ASP, Clearwater Seafoods, Newfound Resources, or Icewater Fisheries.

Persons Consulted

The following agencies, managers and fishing industry participants were consulted for GXT's 2013 offshore Labrador 2D seismic program:

Fisheries and Oceans Canada

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

Shawna Powell, Environmental Assessment & Major Projects, Oceans, Habitat & Species at Risk Branch

Environment Canada (Environmental Protection Branch)

Glenn Troke, EA Co-ordinator

Nature NL (and member organizations)

Dr. Len Zedel, Nature NL

One Ocean

Maureen Murphy, Director of Operations

Fish, Food and Allied Workers Union (FFAW)

Johan Joensen, Petroleum Industry Liaison

Labrador Fishermen's Union Shrimp Company Limited

Gilbert Linstead, General Manager, Lanse au Loup

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

Clearwater Seafoods Limited Partnership

Catherine Boyd, Manager, Corporate Affairs

Newfound Resources Ltd. (NRL)

Brian MacNamara, President

Groundfish Enterprise Allocation Council (Ottawa)

Bruce Chapman, Executive Director

C***anadian Association of Prawn Producers (CAPP)***

Bruce Chapman, Executive Director

Sample Information Package, Other Consultations (email distribution)

GXT Labrador Span Seismic Survey 2013- 2015

Seismic GX Technology Canada Ltd. is proposing to conduct marine geophysical survey to collect seismic, gravity and magnetic data in open (ice-free) waters in and near the Labrador Shelf within the period June – November, potentially in 2013, 2014 and 2015. The proposed survey area is shown on the attached location map. The actual lines to be surveyed will be different each year.

The proposed program will be configured as a conventional a two-dimensional (2D) (single streamer) operation, with a single seismic ship towing a single compressed air sound source array (6300 cu. in., at ~11 m depth) and one 9-km long passive solid-core hydrophone streamer deployed at a 9 to 15 m depth. The gravity and magnetic data will be collected at the same time using an on-board passive measurement system.

The program is designed a regional Basin Span survey to examine very deep geological formations under the Labrador Shelf and Slope, between approximately 61 degrees and 50.5 degrees North Latitude (see Map). It is expected that in any program year a maximum of about 8500 line km could be acquired within the indicated Project Area. These lines will be widely spaced (except where they cross in some locations), typically 50 km – 100 km apart. No portion of the survey will be acquired within Gilbert Bay, Nain Bight, Hamilton Inlet, the Hawke Channel or the Nunatsiavut Zone (the Tidal Waters of the Labrador Inuit Settlement Area). Although the proposed survey window is between June and November, the timing of specific lines in any year will depend on factors such as local weather, sea state, ice conditions in specific locations, and/or local commercial fish harvesting.

The seismic ship is the 81–m *Harrier Explorer* (or an equivalent vessel, depending on the year), with part-time support as needed, from the 73-m *Polar Prince* (the former CCG icebreaker *Sir Humphrey Gilbert*). Re-supply, re-fuelling and transfers of personnel will be offshore using the Polar Prince and/or suitable area ports, such as Goose Bay or Nuuk, Greenland.

The full Project Description is attached for your reference, and I am also sending you maps showing the location of key species harvested offshore Labrador during the proposed survey window, June to November. These maps are for the year 2010, but the EA will also be providing historical catch and effort data information.

When you have had an opportunity to review this information, please let us know if you have any comments or concerns, or if you and other managers would like to receive additional information about GX Technology Canada Ltd.'s proposed 2013-2015 survey Program.

If you would like to meet with the Proponent to discuss the proposed survey further, company representatives would be very pleased to do so anytime in the next week or so. Please let us know as soon as you can if you would like to meet with them.

Also Included:

1. Key Fisheries maps showing proposed 2013 survey lines

2. Full Project Description as filed with the C-NLOPB and available on the Public Registry (http://www.cnlopb.nl.ca/pdfs/gxtc/projdesc.pdf)