

**Environmental Assessment of HMDC's  
2D/3D/4D Seismic Projects  
2013-Life of Field  
Newfoundland Offshore Area**

**Prepared by**



**for**



**May 2013 (Revised February 2015)  
LGL Project No. SA1207**



**Environmental Assessment of HMDC's  
2D/3D/4D Seismic Projects  
2013-Life of Field  
Newfoundland Offshore Area**

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## List of Acronyms

CAPP	Canadian Association of Petroleum Producers
CEAA	Canadian Environmental Assessment Act
CFA	Crab Fishing Area
CIL	Cold Intermediate Layer
COSEWIC	Committee on the Status of Endangered Species in Canada
CPA	Closest Point of Approach
CPUE	Catch-per-unit-effort
CSEM	Controlled Source Electromagnetic
CWS	Canadian Wildlife Service
DFO	Department of Fisheries and Oceans Canada
EA	Environmental Assessment
EBSA	Ecologically and Biologically Significant Areas
ECSAS	Eastern Canadian Seabirds at Sea
EF	End of Field
EL	Exploration Licenses
EMCP	ExxonMobil Canada Properties Ltd.
ESRF	Environmental Studies Research Funds
FFAW	Fish, Food and Allied Workers
FLO	Fisheries Liaison Officer
FRCC	Fisheries Resource Conservation Council
GBS	Gravity Based Structure
HMDC	Hibernia Management and Development Company
HSE	Health, Safety and Environment
IBA	Important Bird Area
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IFMP	Integrated Fisheries Management Plan
L-DEO	Lamont-Doherty Earth Observatory of Columbia University
LF	Low Frequency
LOMA	Large Ocean Management Areas
MANMAR	Manual of Marine Weather Observing
MKI	Multi Klient Invest
MMO	Marine Mammal Observer
NAFO	North Atlantic Fisheries Organization
NL	Newfoundland and Labrador
NMFS	National Marine Fisheries Service
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
OPS	Operational Policy Statement

## List of Acronyms (Cont'd)

PAM	Passive Acoustic Monitoring
PBGB	Placentia Bay Grand Banks
PIROP	Programme intégré de recherches sur les oiseaux pélagiques
PL	Production Licenses
PTS	Permanent Threshold Shift
RA	Regulatory Area
RV	Research Vessel
SAR	Species at Risk
SARA	Species at Risk Act
SBO	Seabird Observer
SEL	Sound Exposure Levels
SPL	Sound Pressure Levels
SPOC	Single Point of Contact
SWSS	Sperm Whale Seismic Study
TTS	Temporary Threshold Shift
USFWS	United States Fish and Wildlife Services
VEC	Valued Ecosystem Component
VMS	Vessel Monitoring Systems
WREP	White Rose Extension Project

## Preface

This document is a revision of the original EA dated May 2013 (LGL 2013a). Revisions are based on addenda dated July and August 2013 (LGL 2013b,c) and changes to the Project Description dated July 2014 (LGL 2014), and associated HMDC responses to regulator comments. These HMDC reports and responses are available on the C-NLOPB website at [http://www.cnlopb.ca/env\\_active.shtml](http://www.cnlopb.ca/env_active.shtml) under the titles listed in the table below.

<b>Report Title</b>	<b>Date Posted on C-NLOPB Website</b>
EA Report	3 May 2013
EA Addendum	18 July 2013
EA Addendum Revised	22 August 2013
Proposed Changes to Project	9 July 2014
Response to Consolidated Comments	6 January 2015

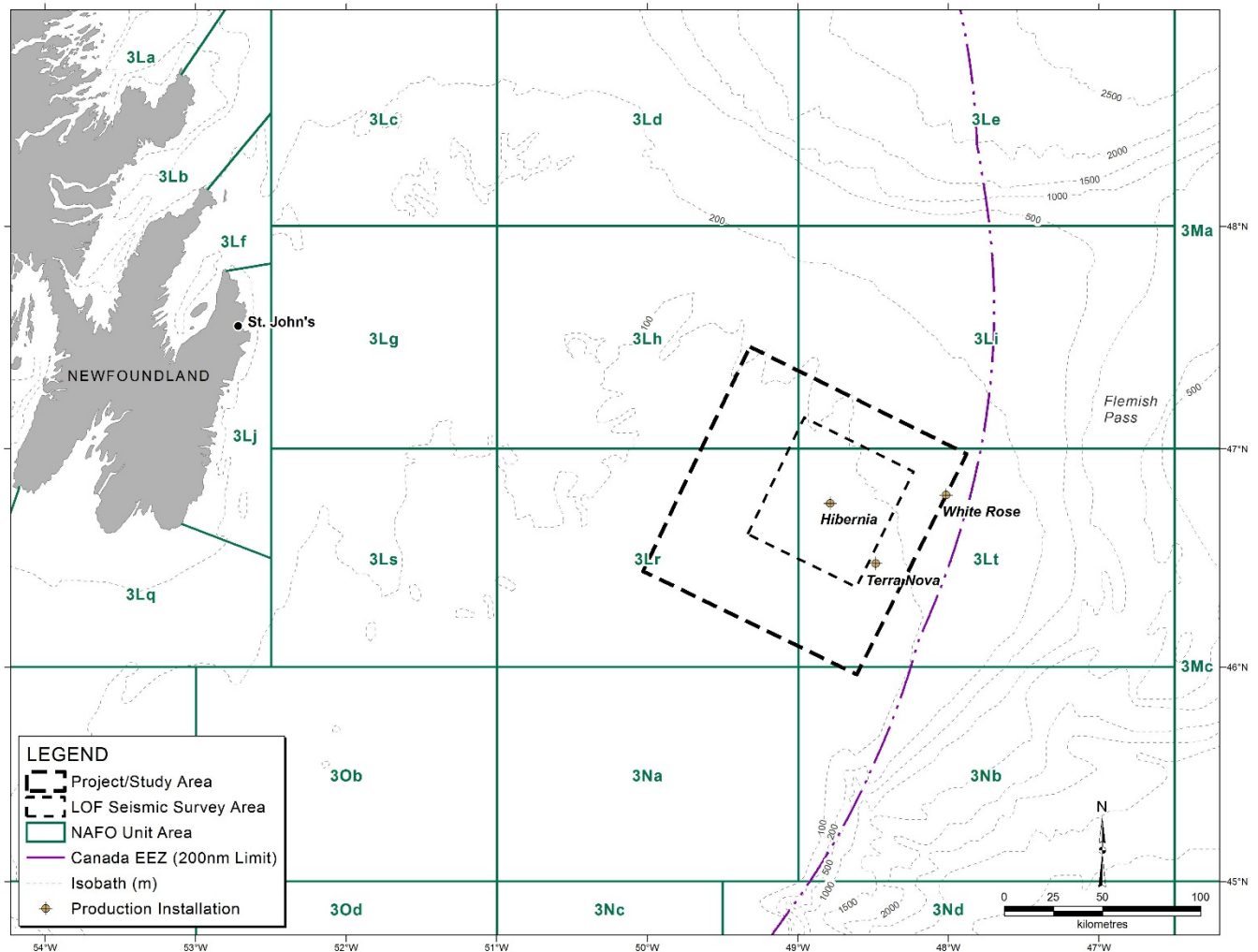
For future years, including the proposed 2015 survey, the EA will undergo updates or validations as required.

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## 1.0 Introduction

Hibernia Management and Development Company Ltd. (referred to here as HMDC, the Proponent or Operator) is proposing to conduct seismic surveys offshore Newfoundland in the region of the Jeanne d’Arc Basin (Figure 1.1). HMDC may conduct 2-D, 3-D or 4-D seismic surveys in one or more years within a 2013-life of field (LOF) timeframe. This constitutes “the Project” as assessed herein.



**Figure 1.1** HMDC Project/Study Area and the Proposed LOF Seismic Survey Area.

The HMDC Project Area and immediate surrounding area have been subject to numerous geophysical, drilling, and production EAs since the early 1980s. Each EA tended to build on the ones before. In assembling this EA, HMDC has attempted to produce a concise summary type document based on previous EAs while at the same time meeting the C-NLOPB Scoping Document in a comprehensive manner. Thus, repeated references are made to the most recent seismic EA (e.g., Husky Grand Banks Seismic EA-LGL 2012) for the general area which is appended in electronic form for the convenience of reviewers. While this EA covers 2013 to LOF, details on any post-2013 surveys will be provided in EA validation documents to be submitted to the C-NLOPB. For seismic projects conducted beyond 2014, this EA will be updated accordingly if it is determined the Project differs substantially from the activity assessed herein.

## 1.1 Relevant Legislation and Regulatory Approvals

This EA has been prepared in accordance with the C-NLOPB's requirements to support the issuance of an authorization; the process established by the C-NLOPB is similar to previous assessments conducted under the *Canadian Environmental Assessment Act (CEAA)*; a scoping document has been prepared by the C-NLOPB based on a project description filed by HMDC; these documents are available on the Board's website at [www.cnlopb.nl.ca](http://www.cnlopb.nl.ca).

Legislation relevant to the environmental aspects of the Project includes:

- *Canada-Newfoundland Atlantic Accord Implementation Act*
- *Oceans Act*
- *Fisheries Act*
- *Navigable Waters Act*
- *Canada Shipping Act*
- *Migratory Bird Convention Act*; and
- *Species at Risk Act (SARA)*

Specific guidelines issued by the C-NLOPB, the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (2012), are directly relevant to this undertaking.

The Board has formally delegated the responsibility of an acceptable environmental assessment report and any supporting documents to HMDC, the Project Proponent.

## 1.2 The Operator

Headquartered in St. John's, Newfoundland and Labrador (NL), Hibernia Management and Development Company Ltd. (HMDC) was the first company to be involved in offshore oil production on the Grand Banks. HMDC is the management and operating company under Production Licenses (PL) for 1001 and 1005 and Exploration Licenses (EL) 1093. Most recent estimates of recoverable reserves for the Hibernia field are provided on the C-NLOPB website at [http://www.cnlopb.nl.ca/pdfs/estrr\\_hib.pdf](http://www.cnlopb.nl.ca/pdfs/estrr_hib.pdf).

Information on HMDC's commitment to Health, Safety and Environment (HSE) is provided at <http://www.hibernia.ca/she.html> some of which reads: "The principles of environmental responsibility and stewardship are integrated throughout the Hibernia organization and are reflected in every action and initiative. HMDC recognizes that environmental objectives, based on relevant scientific and socio-economic data, are best achieved by defining specific goals and developing appropriate standards through government consultation. Input from local communities is also essential in order to strike a balance between environmental needs and the technical and socio-economic demands of the project.

HMDC is applying some of the most stringent measures in the industry to prevent and clean up oil spills. All production, storage, off-loading and transportation systems have been designed to minimize the likelihood of any oil spills, large or small, and an effective Oil Spill Response Plan has been incorporated into the project's overall emergency response procedures.

In keeping with its commitment to community involvement, Hibernia continues to work closely with representatives of the Canada-Newfoundland and Labrador Offshore Petroleum Board and fishers and fish processors that represent Newfoundland and Labrador and Maritimes fishing interests on the Grand Banks."

One Ocean is the liaison organization established by the fishing and petroleum industries of Newfoundland and Labrador. Under the direction of an advisory board, One Ocean promotes mutual understanding between these two vital industries and their common marine environment.

### **1.3 Canada-Newfoundland and Labrador Benefits**

Consistent with the requirements of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* and the *Canada-Newfoundland Atlantic Accord Implementation Act*, HMDC is committed to enhancing the opportunities for Canadian and, in particular, Newfoundland and Labrador, participation.

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

## **1.4 Contacts**

The relevant HMDC contacts for this EA are provided below.

### **1.4.1 Executive Contact**

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### **1.4.2 Health, Environment & Safety Contact**

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### **1.4.3 Geophysical Operations Contact**

Geophysical contact, please direct inquiries to Jamie Long (as above).

## 2.0 Project Description

The official name of the Project is the 2D/3D/4D Seismic Projects, (2013-Remaining Life of Field) Newfoundland Offshore Area. The Project is located in an offshore area about 255 km east-southeast of St. John's, Newfoundland and Labrador (see Figure 1.1).

### 2.1 Spatial and Temporal Boundaries of the Project

The **Project Area** is defined as the area within which all routine project activities occur, including streamer and non-activated source array deployment and vessel turns (see Figure 1.1). A **LOF Seismic Survey Area** within the Project Area is defined as the area within which the sound source arrays may be active (for data acquisition and survey).

The **Study Area** is defined as the area within which any potential effects of the Project on the VECs, based on the scientific literature, could occur. The Study Area is the same as the "Affected Area" as originally defined by CEAA. Note that for this Project, the Study Area and the Project Area share the same boundary.

The **Regional Area** is loosely defined as the northern Grand Banks and Orphan Basin (e.g., to include the major Grand Banks developments such as Hibernia, Terra Nova, White Rose, and Hebron). This area is referred to when considering cumulative effects.

Detailed information on seismic surveys for each survey season during the Life of Field (LOF) will be provided prior to commencement of these surveys including a review of the EA to ensure all information is current and relevant, particularly with respect to Commercial Fisheries and Species at Risk (SAR).

The temporal boundaries include LOF wherein surveys may occur anytime between 1 May and 31 December.

### 2.2 Project Overview

The Proponent proposes, over the remaining life of the Hibernia field, to conduct marine geophysical programs within an approximate 4,035 km<sup>2</sup> area which is generally centered on the Hibernia GBS location (see Figure 1.1 – Project Area). The 2013 survey program was contained within a 702 km<sup>2</sup> area for the completion of a high quality 4-D monitor seismic survey.

In 2013, the Operator proposed to conduct a 4-D seismic survey starting as early as 1 May and concluding as late as 31 December. Four-D data acquisition simply means that successive 3-D survey data sets for the same area are interpreted to delineate changes in the reservoir over time. A typical application of this technique is using a previous 3-D data set and comparing it with a recently acquired 3-D survey to try and detect changes in, and hence, the behaviour of a reservoir in the production phase. This requires precise survey location control to ensure accurate comparison of the two seismic survey data sets.

The timing of surveys is subject to the Proponent's priorities and circumstances, weather and ice conditions, contractor availability and regulatory approvals. Any potential other seismic surveys conducted during subsequent seasons in 2014-LOF will also occur during the same temporal window of 1 May to 31 December.

The proposed future surveys could include 2-D, 3-D and 4-D programs. Traditional towed solid streamer technology was used in 2013. It is expected that a survey vessel will be available sometime in summer 2015. An EA Update will be submitted under separate cover to the C-NLOPB to cover proposed 2015 activities. If the surveys cannot be completed in 2015, they may be completed in subsequent years.

The seismic survey vessel(s) used during the Project will be approved for operation in Canadian waters and will be typical of the worldwide seismic fleet. In the case of either 2-D or 3-D surveys, the seismic survey ship will have air source arrays and multiple streamers (up to approximately 10 km in length). In 2013, the vessel towed a dual sound source and twelve seismic streamers of an approximate length of six kilometers. The streamer length to be considered in this EA is now increased from 8,100 m to 10,050 m (approx.) and the number of streamers to a maximum of 16. For the next seismic survey (now proposed for 2015), the streamer length may be upgraded to 10,000 m but the number of streamers will likely remain the same as the original Project Description (i.e., 12 streamers).

The C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012) will be used as the basis for the marine mammal monitoring and mitigation program for the seismic surveys. Dedicated marine mammal observers (MMOs) will monitor for marine mammals (and sea turtles if present) and implement mitigation measures (including those for stranded seabirds) as appropriate. A fisheries liaison officer (FLO) will be on board, as required, to ensure implementation of communication procedures intended to minimize conflict with the commercial fishery.

### **2.2.1 Objectives and Rationale**

The purpose of a seismic survey is to acquire data to assess the presence of geological structures suitable for the containment and accumulation of hydrocarbons and to determine the hydrocarbon characteristics.

In 2013, the seismic survey was intended to acquire high quality 4-D monitor survey data. The 4-D imaging will be used to monitor fluid and pressure changes in the reservoirs and also aid in optimization of future development well locations. The 4-D monitor seismic data will become part of the reservoir management plan.

### **2.2.2 Alternatives to the Project/Alternative Means within the Project**

The alternatives to the Project are:

1. To not explore for oil and gas offshore Newfoundland but pursue opportunities elsewhere in the world in order to assist in meeting market demand for petroleum products;

2. To not conduct seismic surveys prior to drilling; or
3. To not conduct surveys as part of reservoir management.

If the first alternative were selected, it would mean that the Proponent, government, and people of the province, East Coast region, and Canada would not benefit from the economic accruals of the Project in terms of wages, profits, taxes and royalties. The second and third alternatives are contrary to current best practice in the industry and would potentially waste significant resources drilling in the wrong locations.

Alternatives within the Project include the different contractors' vessels and equipment as described in the following Sections. These alternatives may be decided by the competitive bidding process.

### **2.2.3 Project Phases**

The Project may have a number of phases (the various survey types over time) depending upon the reservoir management plan. The actual timing of these within the temporal scope will be dependent on economic feasibility, seismic vessel availability and the interpretation of survey data from preceding phases.

### **2.2.4 Project Scheduling**

The first seismic survey occurred in summer 2013 and future programs may be conducted between May and December for the remaining life of the Hibernia oil field. For the 2013 survey, the intent was to commence data acquisition as a direct follow-on program to the 2013 Hebron Seismic Streamer Program.

### **2.2.5 Site Plans**

The Project Area proposed for the 2013-LOF seismic program is shown in Figure 1.1. Water depths in the Project Area range from <100 m to <200 m.

### **2.2.6 Project Components**

The components of a seismic survey include a seismic vessel; the towed seismic air source (s) array; the towed streamer (s) receiver array; and may also include a picket vessel; a logistics supply vessel; helicopter; and a shore base. Additionally, there may be an undershoot vessel for data acquisition in challenging areas or complex acquisition techniques. If required; the undershoot vessel would be equipped with a towed seismic air source (s) array and would not tow a seismic streamer array. The undershoot vessel seismic air source(s) array strength (volume) and configuration would be within the range of the primary equipment. If two source vessels are present, only one at a time would be active.

Survey parameters as they are presently known are provided in Table 2.1.

**Table 2.1 Known Seismic Survey Parameters.**

<b>General Information</b>	
Operating Company:	Hibernia Management & Development Company Ltd. (HMDC) and ExxonMobil Canada Properties Ltd., a partnership (EMCP)
Vessel Name(s):	TBD
Location:	See Figure 1.1 (above) and Table 2.2 (below)
Type of Survey:	2-D, 3-D, 4-D
Area:	Project Area = 15,261 km <sup>2</sup> Life of field Seismic Survey Area = 4,035 km <sup>2</sup>
Average line length (including 3 km run-out):	2013 4-D program was 18 km (may be about 28-38 km in 2015)
Line direction:	24.5° / 204.5° (may vary)
<b>Source Parameters</b>	
<b>Source type</b>	Bolt, Soder G or sleeve (steerable source preferred)
Number of active sources	2 (flip-flop)
Shot to shot interval	18.75 m (37.5 m per source) (may vary in subsequent years)
Total volume per source	3,000-6,000 cu inch
Source operating pressure	2,000 psi (may vary in subsequent years)
Source depth	6 m +/- 0.5 meters tolerance (may vary in subsequent years)
Output	Approximately 120 bar-meter peak-to-peak
<b>Streamer Parameters</b>	
<b>Streamer type</b>	Digital 24 bit (solid or gel-filled streamers required)
Number of active streamers	Up to 16 streamers (12 streamers on 8 streamer pre-plot in 2015)
Streamer separation	50 or 75 meters (may vary in subsequent years)
Active streamer length	Up to 10,050 meters
Steerable streamer device (REQUIRED)	DigiFin, Qfin, eBird, Nautilus or equivalent
Streamer depth	7-24 m +/- 1.0 m tolerance (TBC) (may vary in subsequent years)
Minimum line run-in distance	1.5 x active streamer length (unobstructed areas)

## 2.2.7 Personnel

A typical seismic vessel can accommodate approximately 50-100 personnel depending on size and capabilities of the contract vessel. Personnel on a seismic vessel includes individuals representing the Operator, the vessel owner/operator (ship's officers and marine crew), and technical and scientific personnel from the main seismic contractor. The seismic vessel will have a Fisheries Liaison Officer (FLO) and Marine Mammal Observers (MMO) on board, as well as an Operator representative (s). The representative serves as Client Quality Control, Navigation data Processing Quality Control, and HSE oversight. All project personnel will have all of the required certifications as specified by relevant Canadian legislation and the C-NLOPB.

## 2.2.8 Seismic Vessel

Vessel specifics will be provided in subsequent document submissions once the contractors are selected. The selected ship(s) will be a fully equipped, modern vessel suited to the environment and task. There may be a primary seismic vessel plus a secondary source vessel (i.e., undershoot vessel); both vessels will not activate their sound sources simultaneously.



## **2.2.9 Seismic Energy Source Parameters**

A typical 2-D, 3-D or 4-D survey sound source consists of one or two air source arrays, 3,000 to 6,000 in<sup>3</sup> in total volumes, which operate at towed depths between 6 m and 15 m. The air source operates on compressed air at pressures 1,800 to 2,500 psi, and produce approximate peak-to-peak pressures 100 to 180 bar-m.

The 2013 4-D survey sound source consisted of two air source arrays, with sufficient volume to output up to 120 bar-meters peak to peak. The air source operated at a towed depth of approximately six meters. The air sources will be operated with compressed air at a pressure of approximately 2,000 psi. While towing the survey lines, the two air source arrays were discharged alternately, one each 18.75 meters down the line or approximately every six seconds.

The proposed 2015 4-D survey sound source will consist of two air source arrays, with sufficient volume to output approximately 120 bar-meters peak-to-peak (see Table 2.1) to match the previous survey. The air source will operate at a towed depth of approximately six meters. The air sources will be operated with compressed air at a pressure of approximately 2,000 psi. While towing the survey lines, the two air source arrays are discharged alternately, one each approximately every 18.75 meters down the line. The 2015 program will be described in a 2015 EA Update/Validation. Seismic air source array specifications may vary in subsequent years.

## **2.2.10 Seismic Survey Receivers**

The 2013 4-D seismic survey used 12 towed streamers with a length of 6,000 m and deployed at a depth of approximately seven to 24 meters. The streamers were separated by 50 or 75 meters. The streamers incorporated solid flotation to minimize the environmental impact in the case of breaks or tears.

The 2015 4-D seismic survey will use 12 towed streamers with an active length of approximately 6,000 m and deployed at a depth of approximately 15 to 25 meters (see Table 2.1). The streamers will be separated by 75 meters. The streamers will be solid or gel-filled to minimize the environmental impact in the case of breaks or tears. Lead-in and stretch Sections may contain limited amounts of isopar. Streamer configurations may vary in subsequent years. In subsequent surveys, 2-D, 3-D, and 4-D seismic surveys may use up to 16 towed streamers with an approximate length of up to 10,050 m and deployed at depths ranging from five to 30 m. Streamer equipment specifications will be provided when program designs are complete. The 2015 program will be described in a 2015 EA Update/Validation. Streamer configurations may vary in subsequent years.

## **2.2.11 Logistics/Support**

Details of logistical operations to support the Project will largely depend on the contracted seismic acquisition company. The seismic vessel will use shorebase facilities in St. John's, NL for initial clearance into Canadian waters and exit from Canadian waters at the end of the survey. Re-supply of

the seismic vessel during the survey will be accomplished with a chartered supply vessel from the Port of St. John's.

A picket vessel will be used to scout ahead for hazards and for interacting and communicating with other users of the area about the survey and associated trailing gear, and assist in working with fishers in the area (if any). A supply vessel will provide a means for towing the seismic vessel in the case of a loss of propulsion. This will avoid a major loss of equipment and potential environmental damage.

Due to varying weather conditions, the contractor will likely use a supply vessel for crew changes rather than a helicopter. However, it is possible the seismic vessel may use a helicopter for crew changes. Helicopters can also be used in case of medical and other emergencies and for minor re-supply.

The seismic contractor will use existing shorebase facilities in St. John's whenever necessary and a dedicated shore-based representative or contact person will be located in St. John's for the duration of the Project.

#### **2.2.12 Waste Management**

Waste will be managed consistent with applicable regulations and industry best practices in offshore Newfoundland.

#### **2.2.13 Air Emissions**

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

#### **2.2.14 Accidental Events**

In the unlikely event of the accidental release of hydrocarbons during the Project, the Operator 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, the Operator has emergency response plans in place which will be bridged with the seismic contractor's response plans prior to commencement of the seismic program.

### **2.3 Mitigations**

Guidance provided in the C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012) will be used as the basis for the management and mitigation of environmental risks associated with the project. These guidelines recommend that operators implement the mitigations listed in the Fisheries and Oceans Canada *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*. Mitigations used will be consistent with the most current version of the DFO Statement. Marine mammal sightings data will be provided to DFO.

The DFO Statement recommends the use of a marine mammal observer (MMO) to continuously observe, for a minimum of 30 minutes, a 500 m safety zone (centered on the air source array) prior to start up and to ramp-up the array gradually over a 20 minute period beginning with the activation of a single source element. Further, it recommends the ramp-up be delayed if a cetacean, sea turtle or *Species at Risk Act* (SARA) listed (Schedule 1) marine mammal is detected within the safety zone. In addition, the air source array will be shut down any time a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of the SARA is observed in the safety zone. In periods of low visibility (i.e., very heavy fog and/or night time), the seismic operator will utilize the additional mitigation technique of passive acoustic monitoring in areas of critical habitat for endangered or threatened cetaceans or where a cetacean may be significantly and adversely affected as identified through the EA process and as prescribed in the Statement of Canadian Practice. Sightings data will be provided to DFO (J. Lawson).

A Canadian Wildlife Service (CWS) permit will also be obtained to enable the MMO to salvage and release seabirds which may strand on the seismic vessel. A seabird salvage log will be maintained to record all seabird interactions as per the permit conditions. Handling of stranded, oiled and non-oiled birds will be in accordance with the CWS Bird Handling Permit and relevant CWS protocols. A pelagic seabird monitoring program will be instituted by the MMO (s) generally consistent with the protocols contained in Gjerdrum et al. (2012). Strandings data will be provided to CWS.

To mitigate risks to fishers and fishing gear, a fisheries liaison officer (FLO) will be utilized as needed to assess risks prior to departure; to recommend mitigations while at sea; and to communicate directly with fishers as needed. Meetings will also be held with the fishing industry to share details of the project; to assess the likelihood of fishing activity in the area; and to address any concerns or issues identified.

## 2.4 Project Site Information

Project location is in the offshore Newfoundland area (see Figure 1.1).

The seismic Project Area is approximately 15,261 km<sup>2</sup> in size and generally centered upon the Hibernia gravity based structure (GBS) (charted position 46 45.01N, 48 46.9W) (Table 2.2). For the present Project, the Study Area has the same boundaries as the Project Area to accommodate all ship turning, holding, and streamer and non-activated source array deployment (see Figure 1.1; Table 2.2). The Project and Study Areas also include the area which is the focus of any and all HMDC future seismic programs until end of field (EF) (i.e., the LOF Seismic Survey Area, see Figure 1.1; Table 2.2). The LOF Seismic Survey Area is 4,035 km<sup>2</sup> in area and is the area within which sound source activation will be confined.

The Project/Study Areas are contained inside the North Atlantic Fisheries Organization (NAFO) 3Lh, i, r, t Unit Areas, in an area generally referred to as the Jeanne d'Arc Basin.

**Table 2.2 Area Coordinates. See also Figure 1.1.**

		WGS84 UTM 22N		WGS84 (unprojected)	
Boundary_Block	Corner	Easting (m)	Northing (m)	Latitude (DD)	Longitude (DD)
LOF Seismic Survey Area	NE	710844	5197280	46.895577	-48.231988
LOF Seismic Survey Area	SE	683660	5137689	46.367839	-48.612217
LOF Seismic Survey Area	SW	627615	5163253	46.610700	-49.333473
LOF Seismic Survey Area	NW	654800	5222847	47.140926	-48.958437
Project/Study Area	NE	737337	5207185	46.975646	-47.879508
Project/Study Area	SE	685271	5092997	45.965522	-48.608779
Project/Study Area	SW	574629	5143442	46.440423	-50.028464
Project/Study Area	NW	626695	5257634	47.459821	-49.319025

#### **2.4.1 Environmental Features**

HMDC and other operators have been conducting seismic surveys in and around the Jeanne d’Arc Basin for many years and are thoroughly familiar with local conditions of weather, sea state, and ice. In addition, they are supported by state of the art weather and ice observation and forecasting.

The physical and biological environments of the general area have been described in a number of recent EAs for the northern Grand Banks (LGL 2011a,b; 2012; and others). A summary of the physical and biological environments, based on the previous EAs plus any new information is provided in the following Sections (Sections 3.0 and 4.0, respectively).

#### **2.4.2 Physical Environment and Effects on the Project**

A description of the general physical environment of the area is contained in recent EAs for the northern Grand Banks (e.g., LGL 2011a,b; LGL 2012) and is summarized in Section 3.0. The survey will be conducted in water depths ranging from <100 m to <200 m. The scheduling seismic surveys during a period (May to December) when NW Atlantic operating conditions (e.g., temperatures, wind, wave, and ice conditions) are generally better than the January-April period, should lessen any effects of the environment on the Project.

A summary of expected effects of the physical environment on the Project, based on information in previous EAs, as well as any new information, are provided in Section 5.5.

### **2.4.3 Fish and Fish Habitat**

The fish species that inhabit the Project Area are typical of the Grand Banks at Project depths. The species (e.g., invertebrates) and habitats that support them have been discussed in detail in previous EAs for the Jeanne d'Arc Basin. These components of the ecosystem are summarized in Section 4.0, based on previous EAs and other relevant documents.

### **2.4.4 Species at Risk**

The Project Area is not known to contain any sensitive areas or critical habitats for species listed on Schedule 1 of the *Species at Risk Act (SARA)* (see Section 4.7). Seven species listed as *threatened* or *endangered* on Schedule 1 including the blue whale, North Atlantic right whale, leatherback sea turtle, Ivory Gull, two wolffish species and white shark, while rare, may possibly occur in the Project Area. The potential effects on these species and those currently considered *threatened* or *endangered* by the Committee on the Status of Endangered Species in Canada (COSEWIC) which may occur in the Study Area are discussed in Section 5.6.5.

## **2.5 Other Users**

### **2.5.1 Commercial Fisheries**

The Project Area supports a variety of commercial fisheries as described in Section 4.2.4 based on latest available DFO geo-referenced catch data (2010). Some of the most important fisheries in and adjacent to the Project Area include those for northern shrimp, snow crab, and Greenland halibut.

### **2.5.2 Navigable Waters**

In addition to foreign and domestic fisheries vessels, potential users of the navigable waters in the Grand Banks regional area may include cargo and passenger vessels, recreational, aboriginal/subsistence vessels, other oil industry-related vessels, transport and military vessels, and other commercial ships.

### **2.5.3 Consultations**

During the course of the assessment, HMDC consulted with stakeholders with an interest in the Project. Consultations with the fishing industry were undertaken through the established One Ocean mechanism and the Fish, Food and Allied Workers (FFAW), and directly with other relevant fishing interests as necessary. Those consulted and the results of those consultations are presented in Section 5.1.1.

## **2.6 Effects of the Project on the Environment**

The proposed Project will be similar to many other programs routinely conducted offshore Newfoundland and elsewhere in eastern Canada, and is not expected to produce any adverse significant environmental effects on the marine environment in or adjacent to the Project Area. Nonetheless,

potential environmental effects are examined in detail with focus on the commercial fishery, SARA species, marine mammals, and cumulative effects from interactions with other users of the area, particularly any other seismic programs. Accidental events (such as an unplanned hydrocarbon release) associated with Project activities are also assessed in this EA.

### **2.6.1 Assessment Boundaries**

The assessment boundaries for the Project are shown in Figure 1.1. Consideration was given to the Regional Area (i.e., the Grand Banks) when analyzing cumulative effects as this is the area of current and anticipated future oil industry activities for the duration of the Project. The temporal boundaries for the proposed Project are 2013 to LOF, with the timing of seismic surveys between 1 May and 31 December within any particular year.

### **2.6.2 Valued Ecosystem Components**

As is common practice on the East Coast and as recommended in the Scoping Document (C-NLOPB 2013), a valued ecosystem component (VEC) approach was used in this EA. The VECs include:

- Fish and fish habitat;
- Commercial fisheries;
- Marine birds;
- Marine mammals and sea turtles; and
- Species at Risk and sensitive areas.

### **2.6.3 Environmental Mitigation and Monitoring**

As noted previously, MMO (s) will be on board the vessel (s) to provide proper identification of marine mammals and species at risk for mitigation purposes and to collect opportunistic data on marine mammal behaviour and distribution with and without air sources operating. Information on marine bird occurrence and distribution will be collected during the seismic surveys, and the MMO will also conduct stranded bird handling according to CWS protocols.

Plans will be developed to avoid or lessen any potential effects on the commercial fishery. These plans will include mitigations such as good communications (e.g., fishery broadcast notifications), the presence of a dedicated FLO on the vessel, avoidance of areas during times of heavy fixed gear use, and a fishing gear damage compensation program.

## 3.0 Physical Environment

A detailed description of the physical environment on the Grand Banks and the edge of the Continental Shelf as prepared by Oceans Ltd. is provided in LGL (2012) (electronic copy appended). A brief summary abridged directly from LGL (2012) follows below.

### 3.1 Climatology

The Jeanne d'Arc Basin experiences weather conditions typical of a marine environment with the surrounding waters having a moderating effect on temperature. In general, marine climates experience cooler summers and milder winters than continental climates and have a narrower annual temperature range. Furthermore, a marine climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and significant amounts of precipitation.

The climate of the Jeanne d'Arc Basin is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in and steered by the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes and arises due to the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence is considerably stronger in the winter months (i.e., January-March) than during the summer months (July-September) due to an increase in the south to north temperature gradient.

The data sources to describe the climatology of the Jeanne d'Arc Basin came from four main sources: (1) the International Comprehensive Ocean-Atmosphere Data Set (ICOADS); (2) rig observations (MANMAR); (3) the MSC50 N Atlantic wind and wave climatology database; and (4) the National Hurricane Centre's best-track data set. These are described in detail in LGL (2012). In addition, Colbourne et al. (2012) described regional conditions for 2011 based on a large number of oceanographic stations.

Wind and wave statistics were compiled using MANMAR data from several offshore platforms located in the region. The location, period of observation and anemometer height for each of these stations is presented in Table 3.1. Note: The Glomar Grand Banks and the GSF Grand Banks are the same platform under different names at the time of the observations.

Wave statistics were also compiled from wave data measured on the White Rose field. The White Rose data set from October 2003 to December 2010 has been split due to the change in measuring equipment from a TRYAXIS directional waverider buoy to a Datawell Directional Waverider Buoy in August 2007.

**Table 3.1 Locations of MANMAR Observations.**

	<b>Latitude</b>	<b>Longitude</b>	<b>Anemometer Height</b>	<b>Period</b>
<b>Sea Rose FPSO</b>	46.8°N	48.0°W	42	August 02, 2007 – September 30, 2011
<b>Terra Nova FPSO</b>	46.4°N	48.4°W	50	August 12, 2007 - September 30, 2011
<b>Glomar Grand Banks</b>	46.5°N	48.4°W	82.5	December 31, 1998 - July 02, 2000
<b>GSF Grand Banks</b>	46.7°N	48.0°W	82.5	August 01, 2007 - September 30, 2011
<b>Henry Goodrich</b>	46.4°N	48.6°W	95	February 23, 2000 - September 30, 2011
<b>Hibernia</b>	46.7°N	48.7°W	139	January 01, 1999 - September 30, 2011

Source: LGL (2012).

### 3.1.1 Wind

Wind in the Regional Area is discussed in detail in Section 3.1.3 of LGL (2012). Some relevant excerpts are provided below.

The Hibernia area experiences predominately southwest to west flow throughout the year. There is a strong annual cycle in the wind direction. West to northwest winds which are prevalent during the winter months begin to shift counter-clockwise during March and April resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominately westerly again by late fall and into winter. Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season.

In addition to mid-latitude low pressure systems crossing the Grand Banks, tropical cyclones often move northward out of the influence of the warm waters south of the Gulf Stream, passing near the Island of Newfoundland. Once the cyclones move over colder waters they lose their source of latent heat energy and often begin to transform into a fast-moving and rapidly developing extratropical cyclone producing large waves and sometimes hurricane force winds.

Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season. Mean wind speeds for all data sets peak during the month of January (Table 3.2).

Wind speed typically increases with increasing heights above sea level. Statistics provided in Table 3.2 are presented in order of increasing height, with the MSC50 data set being the lowest and the Hibernia Platform being the highest. The anemometer heights for each platform are found in Table 3.1 in Section 3.1.2.3 of LGL (2012) (appended). Statistics for each anemometer level are presented to give a better idea of winds at varying levels above sea level.



Monthly wind roses along with histograms of the frequency distributions of wind speeds can be found in Appendix 1 of LGL (2012) (appended). Wind speeds are much lower in the summer than in winter.

At three locations in the Hibernia region, light winds (0.5 to  $\leq 5.7$  m/s) occur about 30% of the time, moderate about 37% (5.7 to  $\leq 9.8$  m/s), strong (9.8 to  $\leq 17$  m/s) about 30%, and gale to storm (17.0 to 32.4 m/s) about 3% of the time (see Figures 3.6 to 3.8 in LGL 2012).

**Table 3.2 Mean Wind Speed (m/s) Statistics.**

	MSC50 Grid Point 10636	MSC50 Grid Point 11809	MSC50 Grid Point 11818	ICOADS	Sea Rose FPSO	Terra Nova FPSO	Glomar Grand Banks	GSF Grand Banks	Henry Goodrich	Hibernia
<b>January</b>	11.0	11.1	11.3	14.1	12.8	13.8	12.9	13.2	15.5	16.1
<b>February</b>	10.9	11.0	11.1	13.7	12.1	13.6	11.9	12.8	15.4	15.6
<b>March</b>	9.8	9.9	10.0	12.6	11.0	12.2	11.9	12.1	14.0	14.5
<b>April</b>	8.3	8.4	8.4	11.8	10.3	11.6	11.4	12.0	13.0	13.6
<b>May</b>	7.0	7.1	7.1	10.4	8.9	10.5	9.7	10.9	11.8	12.2
<b>June</b>	6.5	6.6	6.6	10.2	8.6	9.8	9.4	9.8	11.6	11.7
<b>July</b>	6.0	6.2	6.1	9.9	8.4	9.6	9.5	9.6	11.0	11.4
<b>August</b>	6.3	6.5	6.4	9.2	10.3	9.2	8.4	8.8	9.7	10.6
<b>September</b>	7.5	7.6	7.6	10.4	10.7	10.5	10.3	9.7	10.8	11.7
<b>October</b>	8.8	8.9	8.9	11.8	12.5	11.7	12.8	10.2	12.3	13.3
<b>November</b>	9.5	9.6	9.7	12.4	12.7	12.3	11.0	11.5	13.0	13.7
<b>December</b>	10.6	10.7	10.8	14.0	13.9	14.5	12.6	13.4	14.7	15.9

Source: LGL (2012).

Note: Anemometer heights provided in Table 3.1.

Monthly maximum wind speeds for each of the available data sets are presented in Table 3.3. Rapidly deepening storm systems known as weather bombs (intense low-pressure systems with a central pressure that falls 24 millibars or more in a 24-hour period) frequently cross the Grand Banks. These storm systems typically develop in the warm waters of Cape Hatteras and move northeast across the Grand Banks. Wind speeds of 49.4 m/s and 52.5 m/s from the southwest were recorded by the Hibernia Platform and the Henry Goodrich anemometers respectively, at 21Z on February 11<sup>th</sup>, 2003. During this storm, a low pressure developing off Cape Hatteras on February 10<sup>th</sup>, 2003 rapidly deepened to 949 mb as it tracked northeast across the Avalon Peninsula around 18Z on February 11<sup>th</sup>, 2003. Another storm, following a similar track to the February 10<sup>th</sup>, 2003 storm passed over the area on October 15, 2009. During this event, the low pressure deepened from 1,002 mb at 00Z October 14<sup>th</sup>, to 963 mb as it lay northeast of the Avalon on October 15<sup>th</sup>. A wind speed of 43.7 m/s was recorded by the Sea Rose FPSO at 00Z and 03Z October 15, 2009.

**Table 3.3 Maximum Wind Speed (m/s) Statistics.**

	<b>MSC50 Grid Point 10636</b>	<b>MSC50 Grid Point 11809</b>	<b>MSC50 Grid Point 11818</b>	<b>ICOADS</b>	<b>Sea Rose FPSO</b>	<b>Terra Nova FPSO</b>	<b>Glomar Grand Banks</b>	<b>GSF Grand Banks</b>	<b>Henry Goodrich</b>	<b>Hibernia</b>
<b>January</b>	28.8	28.1	28.8	43.7	25.7	31.9	30.9	37.6	44.2	43.2
<b>February</b>	32.3	31.9	30.5	49.4	29.8	34.0	26.8	31.4	52.5	49.4
<b>March</b>	27.6	29.7	31.7	38.0	23.7	29.8	23.7	28.8	32.9	37.6
<b>April</b>	25.0	24.4	25.4	36.0	24.7	26.8	26.8	33.4	35.0	37.6
<b>May</b>	22.1	22.8	23.5	33.9	21.6	25.2	22.1	25.7	32.9	32.4
<b>June</b>	23.1	23.6	23.7	35.5	18.5	24.2	21.1	27.3	31.4	35.5
<b>July</b>	20.5	17.9	19.8	31.9	18.0	23.2	20.1	25.2	28.3	31.9
<b>August</b>	30.5	27.8	30.1	36.0	33.4	29.8	25.7	26.2	30.9	41.2
<b>September</b>	24.0	28.1	25.8	43.2	30.9	34.5	29.3	27.8	35.0	43.2
<b>October</b>	27.6	27.8	27.0	44.8	43.7	31.9	32.9	30.9	33.4	44.8
<b>November</b>	27.4	27.1	27.9	38.1	25.2	28.3	25.7	25.2	37.6	38.1
<b>December</b>	30.0	30.1	29.2	39.6	24.7	37.6	27.3	29.3	39.6	39.1

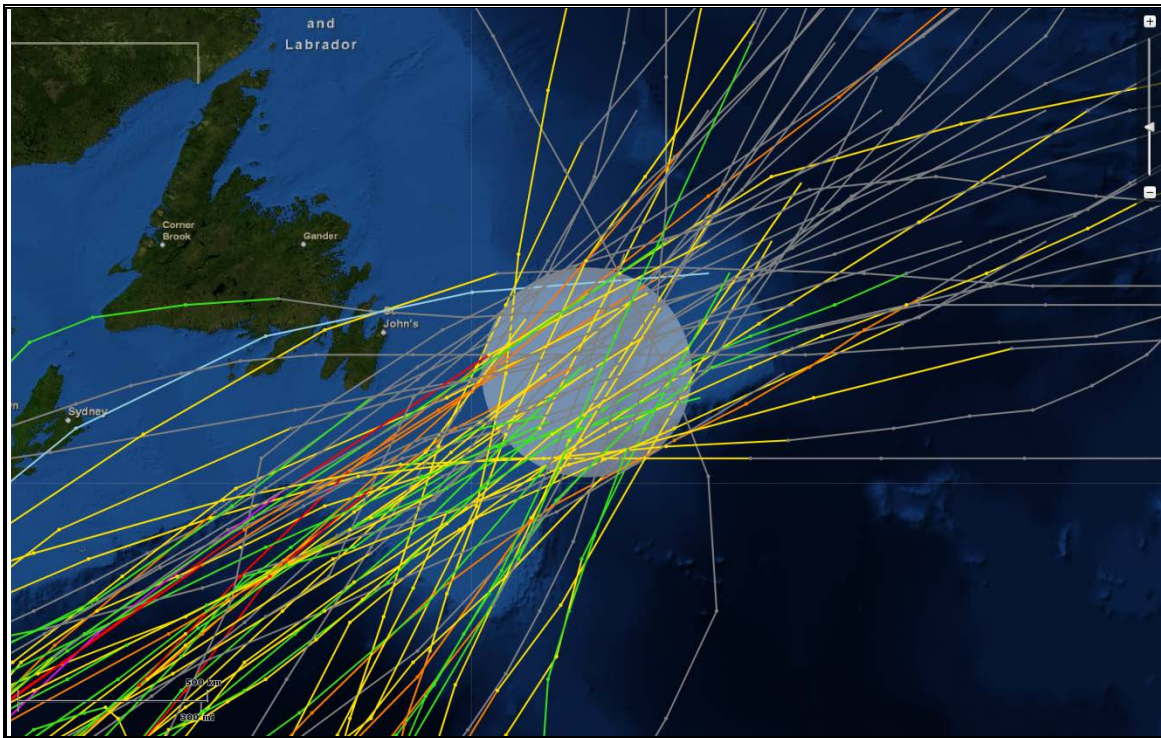
Source: LGL (2012).

Note: Anemometer heights provided in Table 3.1.

### **3.1.1.1 Tropical Systems**

The hurricane season in the N Atlantic basin normally extends from June through November, although tropical storm systems occasionally occur outside this period. While the strongest winds typically occur during the winter months and are associated with mid-latitude low pressure systems, storm force winds may occur at any time of the year as a result of tropical systems. Once formed, a tropical storm or hurricane will maintain its energy as long as a sufficient supply of warm, moist air is available. Tropical storms and hurricanes obtain their energy from the latent heat of vapourization that is released during the condensation process. These systems typically move east to west over the warm water of the tropics. However, some of these systems turn northward and make their way towards Newfoundland and the Project Area. Since the capacity of the air to hold water vapour is dependent on temperature, the hurricanes begin to lose their tropical characteristics as they move northward over the colder ocean waters. By the time these weakening cyclones reach Newfoundland, they are usually embedded into a mid-latitude low and their tropical characteristics are usually lost.

Since 1960, 39 tropical systems have passed over the Regional Area. Their tracks over the Regional Area are shown in Figure 3.1.



Source: LGL (2012).

**Figure 3.1 Storm Tracks of Tropical Systems Passing within 200 nm of 46°55'N, 47°52.5'W (1960 to 2010).**

### 3.1.2 Waves

Waves are discussed in detail in Section 3.1.4 of LGL (2012). Some relevant excerpts are provided below.

The main parameters for describing wave conditions are the significant wave height, the maximum wave height, the peak spectral period, and the characteristic period. The significant wave height is defined as the average height of the 1/3 highest waves, and its value roughly approximates the characteristic height observed visually. The maximum height is the greatest vertical distance between a wave crest and adjacent trough. The spectral peak period is the period of the waves with the largest energy levels, and the characteristic period is the period of the 1/3 highest waves. The characteristic period is the wave period reported in ship observations, and the spectral period is reported in the MSC50 data set.

A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell groups. A swell is a wave system not produced by the local wind blowing at the time of observation and may have been generated within the local weather system, or from within distant weather systems. The former situation typically arises when a front, trough, or ridge crosses the point of concern, resulting in a marked shift in wind direction. Swells generated in this manner are usually of low period. Swells generated by distant weather systems may propagate in the direction of the winds that originally formed to the vicinity of the observation area. These swells may travel for

thousands of miles before dying away. As the swell advances, its crest becomes rounded and its surface smooth. As a result of the latter process, swell energy may propagate through a point from more than one direction at a particular time.

The wave climate of the Grand Banks is dominated by extra-tropical storms, primarily during October through March; however, severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area. They are still capable of producing storm force winds and high waves.

Significant wave heights on the Grand Banks peak during the winter months with the majority of data sources peaking in January. The lowest significant wave heights occur in the summer with July month the lowest mean monthly significant wave height. Significant wave height statistics are provided in Tables 3.4 and 3.5 below.

Combined significant wave heights of 10.5 m or more occurred in each month between September and April in the MSC50 data, with the highest waves occurring during the month of February. The highest combined significant wave heights of 14.7 m and 12.0 m in the Terra Nova and Hibernia data sets, respectively, occurred during the February 11, 2003 storm event mentioned previously.

**Table 3.4 Combined Significant Wave Height Statistics (m).**

	<b>MSC50 Grid Point 10636</b>	<b>MSC50 Grid Point 11809</b>	<b>MSC50 Grid Point 11818</b>	<b>Terra Nova FPSO</b>	<b>White Rose (2003- 2007)</b>	<b>White Rose (2007- 2010)</b>	<b>Glomar Grand Banks</b>	<b>GSF Grand Banks</b>	<b>Henry Goodrich</b>	<b>Hibernia</b>
<b>January</b>	4.1	4.2	4.3	4.1	4.9	4.2	3.7	3.3	4.2	4.0
<b>February</b>	3.9	3.9	4.0	3.8	4.5	3.8	3.1	3.8	4.0	3.7
<b>March</b>	3.4	3.4	3.5	3.4	4.3	3.2	2.7	3.2	3.4	3.2
<b>April</b>	2.8	2.8	2.9	2.6	2.7	2.5	2.6	2.7	2.7	2.5
<b>May</b>	2.2	2.2	2.3	2.2	2.6	2.4	1.9	2.2	2.1	2.1
<b>June</b>	1.9	1.9	1.9	1.8	2.6	1.9	1.5	1.9	1.8	1.9
<b>July</b>	1.7	1.7	1.7	1.5	2.4	1.6	1.6	1.7	1.6	1.6
<b>August</b>	1.8	1.8	1.8	1.8	2.3	1.9	1.8	1.8	1.7	1.8
<b>September</b>	2.4	2.4	2.4	2.3	2.8	2.3	2.8	2.3	2.3	2.3
<b>October</b>	3.0	3.0	3.0	3.0	3.8	3.1	3.5	2.9	2.9	3.0
<b>November</b>	3.4	3.4	3.4	3.1	3.8	3.0	3.0	2.9	3.2	3.0
<b>December</b>	4.0	4.0	4.1	3.8	4.2	4.2	3.5	4.1	3.7	3.7

Source: LGL (2012).

**Table 3.5 Maximum Combined Significant Wave Height Statistics (m).**

	<b>MSC50 Grid Point 10636</b>	<b>MSC50 Grid Point 11809</b>	<b>MSC50 Grid Point 11818</b>	<b>Terra Nova FPSO</b>	<b>White Rose (2003- 2007)</b>	<b>White Rose (2007- 2010)</b>	<b>Glomar Grand Banks</b>	<b>GSF Grand Banks</b>	<b>Henry Goodrich</b>	<b>Hibernia</b>
<b>January</b>	13.0	12.6	13.3	12.5	12.2	11.8	9.0	10.0	12.0	11.5
<b>February</b>	14.6	14.9	15.5	14.7	11.9	10.2	6.5	10.6	14.1	12.0
<b>March</b>	11.7	11.1	11.5	9.7	12.8	8.8	5.0	8.7	9.0	9.4
<b>April</b>	10.8	10.9	10.6	8.6	11.0	5.7	7.5	5.7	8.0	7.6
<b>May</b>	10.1	10.4	10.9	6.4	10.9	6.6	4.6	6.3	6.5	6.6
<b>June</b>	9.9	10.0	10.5	6.5	9.2	5.6	3.5	4.8	7.0	6.7
<b>July</b>	6.2	6.2	6.6	4.1	8.5	3.5	3.0	3.8	9.0	5.0
<b>August</b>	9.5	8.5	9.2	8.0	9.3	7.3	4.0	6.7	8.0	8.0
<b>September</b>	11.2	12.9	12.5	12.6	11.1	12.9	10.0	7.2	10.5	9.5
<b>October</b>	12.1	11.9	12.6	10.6	12.2	9.5	9.0	7.2	10.5	11.0
<b>November</b>	11.5	11.4	12.0	10.2	11.2	9.4	6.3	8.5	9.5	9.7
<b>December</b>	13.9	13.3	14.1	11.7	11.1	11.1	8.5	9.9	10.0	10.0

Source: LGL (2012).

While maximum significant wave heights tend to peak during the winter months, a tropical system could pass through the area and produce wave heights during any month.

On an annual basis, wave heights range from 0 to  $\leq 3.0$  m about 61% of the time, from 3.0 to  $\leq 6.0$  about 33% of the time, and from 6.0 to  $\leq 8.0$  m about 6% of the time (see Figures 3.16 to 3.19 in LGL 2012).

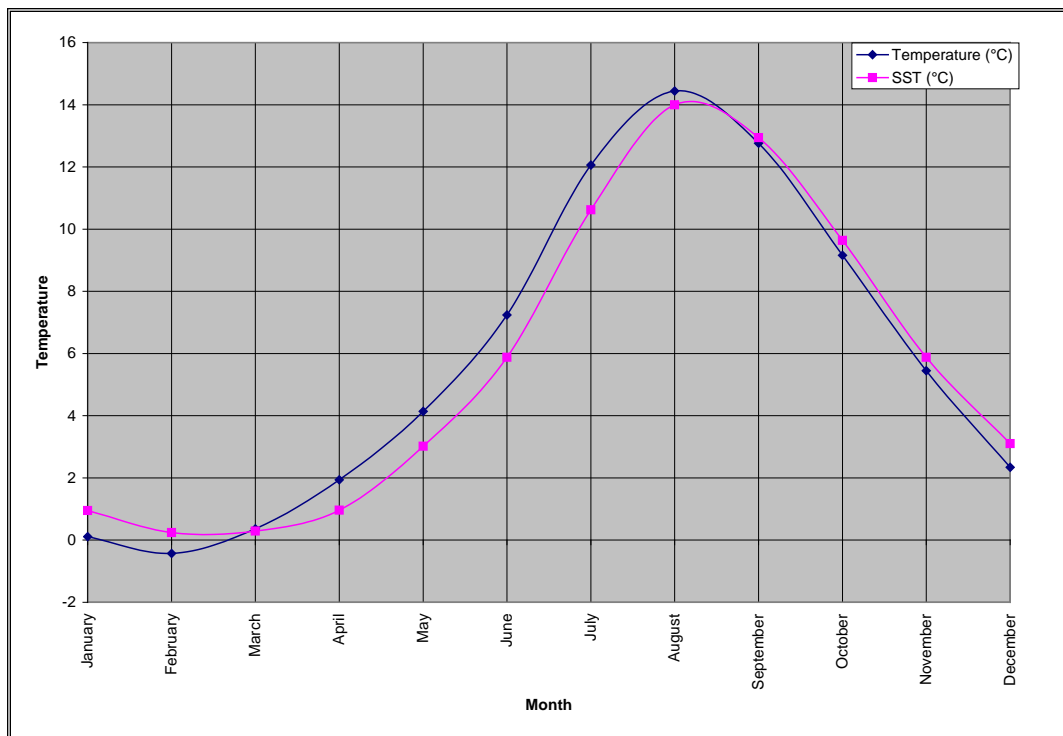
### 3.1.3 Weather Variables

Weather variables are discussed in Section 3.1.5 of LGL (2012) and briefly summarized below.

#### 3.1.3.1 Temperature

The moderating influence of the ocean serves to limit both the diurnal and the annual temperature variation on the Grand Banks. Diurnal temperature variations due to the day/night cycles are small. Short-term, random temperature changes are due mainly to a change of air mass following a warm or cold frontal passage. In general, air mass temperature contrasts across frontal zones are greater during the winter than during the summer season.

Mean air and sea temperatures for the area (1980-2010) are shown in Figure 3.2. Air temperatures over the NW Atlantic in 2011 decreased from the above normal temperatures but still remained somewhat above normal (Colbourne et al. 2012).



Source: ICOADS Data Set (1980-2010) in LGL (2012).

**Figure 3.2 Monthly Mean Air and Sea Surface Temperature for the ICOADS Region.**

### 3.1.3.2 Visibility

Visibility is defined as the greatest distance at which objects of suitable dimensions can be seen and identified. Horizontal visibility may be reduced by any of the following phenomena, either alone or in combination:

- Fog
- Mist
- Haze
- Smoke
- Liquid Precipitation (e.g., drizzle)
- Freezing Precipitation (e.g., freezing rain)
- Frozen Precipitation (e.g., snow)
- Blowing Snow

During the winter months, the main obstruction is snow; however, mist and fog may also reduce visibilities at times. As spring approaches, the amount of visibility reduction attributed to snow decreases. As the air temperature increases, so does the occurrence of advection fog. Advection fog forms when warm moist air moves over cooler waters. By April, the sea surface temperature south of Newfoundland is cooler than the surrounding air. As warm moist air from the south moves over the colder sea surface, the air cools and its ability to hold moisture decreases. The air will continue to cool until it becomes saturated and the moisture condenses to form fog. The presence of advection fog increases from April through July. The month of July has the highest percentage of obscuration to visibility, most of which is in the form of advection fog, although frontal fog can also contribute to the reduction in visibility. In August the temperature difference between the air and the sea begins to

narrow and by September, the air temperature begins to fall below the sea surface temperature. As the air temperature drops, the occurrence of fog decreases. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low-pressure systems. Fog is the main cause of the reduced visibilities in autumn and snow is the main cause of reduced visibilities in the winter. September and October have the lowest occurrence of reduced visibility since the air temperature has, on average, decreased below the sea surface temperature and it is not yet cold enough for snow.

Fog also occurs in the Jeanne d'Arc Basin as relatively warm rain falls through cooler air beneath a frontal surface. Typically, the base of the cloud layer lowers as the air becomes saturated and condensation occurs. If the cloud base reaches the surface, frontal fog occurs. Most frequently, frontal fog occurs ahead of a warm front associated with a frontal disturbance. As the front moves through, clearing of the fog may occur but frequently, frontal fog gives way to advection fog in the warm sector of a low pressure system. Typically, fog clears as drier air is advected into the region from continental source regions to the west.

### **3.1.3.3 Precipitation**

The frequency of precipitation type for each region was calculated by Oceans Ltd. using data from the ICOADS data set, with each occurrence counting as one event. Precipitation statistics for these regions may be low due a fair weather bias. That is, ships tend to either avoid regions of inclement weather, or simply do not report during these events.

The frequency of precipitation type (Table 3.6) shows that annually, precipitation occurs 22.0% of the time within the ICOADS region. Winter has the highest frequency of precipitation with 34.8% of the observations reporting precipitation. Snow accounts for the majority of precipitation during the winter months, accounting for 58.6% of the occurrences of winter precipitation. Summer has the lowest frequency of precipitation with a total frequency of occurrence of 12.9%. Snow has been reported in each month from August to May; however, this is may be due to coding error rather than the actual presence of snow.

The percentage of occurrences of freezing precipitation data was also calculated from the ICOADS data set. Freezing precipitation occurs when rain or drizzle aloft enters negative air temperatures near the surface and becomes super-cooled so that the droplets freeze upon impact with the surface. This situation typically arises ahead of a warm front extending from low pressure systems passing west of the area. The frequency of freezing precipitation was slightly higher in the winter months than during the spring. No freezing precipitation occurred during summer and autumn.

Thunderstorms occur relatively infrequently over the Study Area though they may occur in any month of the year. Spring has the least number of thunderstorms occurring only 0.02% of the time while summer has the highest frequency of thunder storms with 0.12%. It should be noted that hail only occurs in the presence of severe thunderstorms, yet in Table 3.6, the frequency of hail is higher than the frequency of thunderstorms during the months of November to February. This may be due to observer

inexperience, classifying what should be ice pellets (formed through entirely different atmospheric processes) as hail or mistyping what should have been “Thunderstorm without Hail – Code 95” as “Thunderstorm with Hail – Code 96” in the original Manmar data.

**Table 3.6 Percent Frequency (%) Distribution of Precipitation.**

	<b>Rain / Drizzle</b>	<b>Freezing Rain / Drizzle</b>	<b>Rain / Snow Mixed</b>	<b>Snow</b>	<b>Thunder Storm</b>	<b>Hail</b>	<b>Total</b>
<b>January</b>	13.0	0.5	0.6	23.5	0.0	0.2	37.9
<b>February</b>	10.3	0.8	0.4	22.4	0.0	0.1	34.0
<b>March</b>	11.6	0.9	0.3	14.3	0.0	0.0	27.0
<b>April</b>	13.1	0.2	0.2	4.8	0.0	0.0	18.3
<b>May</b>	14.1	0.0	0.1	1.0	0.0	0.0	15.2
<b>June</b>	13.3	0.0	0.0	0.0	0.1	0.0	13.4
<b>July</b>	10.9	0.0	0.0	0.0	0.1	0.0	11.0
<b>August</b>	14.0	0.0	0.0	0.1	0.2	0.0	14.4
<b>September</b>	15.5	0.0	0.0	0.1	0.1	0.0	15.6
<b>October</b>	20.2	0.0	0.1	1.1	0.1	0.1	21.6
<b>November</b>	19.3	0.0	0.4	5.7	0.0	0.2	25.7
<b>December</b>	16.0	0.1	0.5	15.4	0.0	0.3	32.3
<b>Winter</b>	13.2	0.5	0.5	20.4	0.0	0.2	34.8
<b>Spring</b>	13.0	0.3	0.2	6.3	0.0	0.0	19.9
<b>Summer</b>	12.7	0.0	0.0	0.0	0.1	0.0	12.9
<b>Autumn</b>	18.4	0.0	0.2	2.3	0.1	0.1	21.0
<b>Total</b>	14.3	0.2	0.2	7.2	0.1	0.1	22.0

Source: LGL (2012).

#### **3.1.3.4 Sea Spray Vessel Icing**

Potential sea spray icing conditions start within the Project Area during the month of November with a frequency of icing potential of just 0.4%. As the temperature falls throughout the winter, the percentage of occurrence of icing increases to a maximum of 29.4% in February. Extreme sea spray icing conditions were calculated to occur 1.0% of the time during February. Icing potential decreases rapidly after February in response to warming air and sea surface temperatures, and by June the frequency of icing conditions is 0.0%.

## **3.2 Wind and Wave Extreme Value Analyses**

The wind and wave extreme values analyses are contained in Section 3.2 of LGL (2012) (appended).



## 3.3 Physical Oceanography

### 3.3.1 General Circulation

Water circulation and current data were described in detail by Oceans Ltd. in Section 3.3 of LGL (2012). Some information relevant to surface towed and bottom mounted seismic operations is provided in this Section.

The regional oceanic circulation on the Grand Banks and surrounding areas is governed by the bathymetric features of the continental shelf (Figure 3.3). A major characteristic of ocean currents is their tendency to follow local and regional underwater bathymetry.

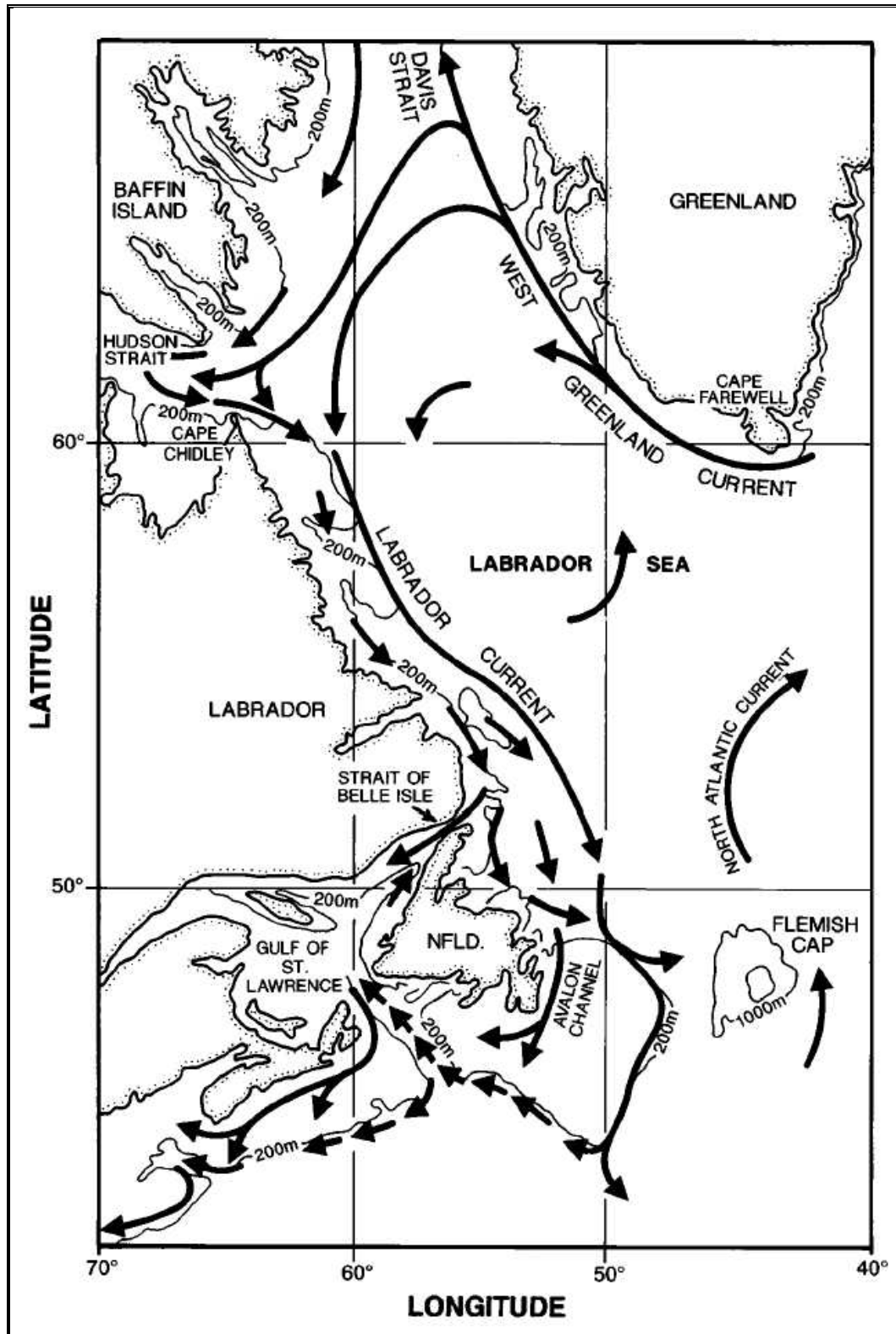
The Grand Banks–Flemish Cap bathymetric features exert a major influence on the regional oceanic circulation. The shape of the banks and channels steers the flow of the Labrador Current. The Labrador Current is comprised of two main streams; an inshore stream near the coast, and a more intense offshore stream over the shelf break between the 400 and 1,200 m isobaths (Lazier and Wright 1993). There is some exchange between these two streams which occurs in the channels and saddles that separate the banks offshore Labrador and Newfoundland. The inshore branch of the Labrador Current flows through the Avalon Channel, while the offshore branch flows along the northern slope of the Grand Banks. This branch of the Labrador Current divides east of 48°W, resulting in part of the branch flowing to the east around Flemish Cap and the other flowing south around the eastern edge of the Grand Banks and through Flemish Pass (Figure 3.3).

The general circulation and mean currents on the Grand Banks are well understood from geostrophic calculations, drifter data, current modeling, and direct measurements. The variabilities are becoming more understood as the quantity of data collected on the Grand Banks increases.

Oceans Ltd. (in LGL 2012) analyzed currents in the Regional Area in what they called Subarea 1. Subarea 1 is the shallow Section of the Grand Banks where Terra Nova and Hibernia are located. There have been continuous current measurements at Terra Nova since 1999. The measurements are at 20 m below the surface, mid-depth and 10 m above bottom. There are also some measurements in the boundary layer at approximately 1 m above bottom. These current measurements are representatives of the Study Area because the bathymetry is relatively flat. Tables 3.7 to 3.9 present the mean speeds, velocities and the maximum speeds by month for a 10-year period between 1999 and 2009.

Table 3.7 shows that the mean speeds at 20 m below the surface range between 11.4 cm/s in April to 17.5 cm/s in September. The maximum speed was 79.9 cm/s in September 2001. Due to the high degree of current variability, the mean velocities ranged from 2.1 cm/s in June to 7.4 cm/s in January.

The currents speeds were slightly lower at mid-depth and at 10 m above bottom. At mid-depth the mean speeds ranged from 8.7 cm/s in August to 11.4 cm/s in February, and the mean velocities ranged between 1.4 cm/s and 3.7 cm/s. The maximum speed was 73.6 cm/s in September 1999 during the passage of Hurricane Gert. At 10 m above the bottom the mean speeds ranged between 7.0 cm/s in June to 11.9 cm/s in January. The mean velocities ranged between 1.0 cm/s and 3.6 cm/s. The maximum speed was 48.1 cm/s in March, 2005.



Source: Colbourne et al. (1997).

**Figure 3.3 Major Ocean Circulation Features in the NW Atlantic.**

**Table 3.7 Near-surface Currents at Terra Nova.**

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Maximum Speed (cm/s)	Year of Speed
January	16.2	7.4	57.0	2009
February	14.3	4.2	59.0	2003
March	13.1	4.2	51.5	2007
April	11.4	2.5	41.0	2001
May	12.7	4.0	57.2	2003
June	13.2	2.1	52.5	2001
July	14.4	3.0	52.4	2006
August	14.8	2.6	60.4	2001
September	17.5	3.6	79.9	2001
October	16.7	5.9	61.8	2004
November	14.3	6.7	56.3	2000
December	15.6	5.0	71.5	2006

Source: LGL (2012).

**Table 3.8 Mid-depth Current at Terra Nova.**

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Maximum Speed (cm/s)	Year of Speed
January	10.5	3.3	43.5	2006
February	11.4	2.5	47.0	2005
March	10.3	3.2	40.9	2005
April	9.5	1.4	37.0	2000
May	8.6	2.3	33.7	2006
June	9.1	2.4	34.8	2004
July	9.0	2.2	38.0	2006
August	8.7	2.0	39.2	2004
September	9.8	2.6	73.6	1999
October	11.2	3.7	53.4	2006
November	10.0	3.0	58.4	2003
December	9.8	2.7	44.1	2006

Source: LGL (2012).

**Table 3.9 Near-bottom Currents at Terra Nova.**

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Maximum Speed (cm/s)	Year of Speed
January	11.9	3.6	36.1	2001
February	11.4	2.5	45.6	2005
March	11.1	2.7	48.1	2005
April	8.7	1.8	29.2	2008
May	7.4	2.0	27.7	2000
June	7.0	1.3	25.9	2000
July	8.2	2.0	30.4	2000
August	8.8	1.0	26.8	2008
September	10.1	1.0	45.1	1999
October	10.6	1.4	40.8	2000
November	9.3	1.5	29.0	2006
December	11.3	1.5	43.9	2006

Source: LGL (2012).

### 3.3.2 Water Mass Structure

The water structure on the north-eastern Section of the Grand Banks of Newfoundland is characterized by the presence of three identifiable features (as described by Oceans Ltd. in Section 3.3 in LGL 2012).

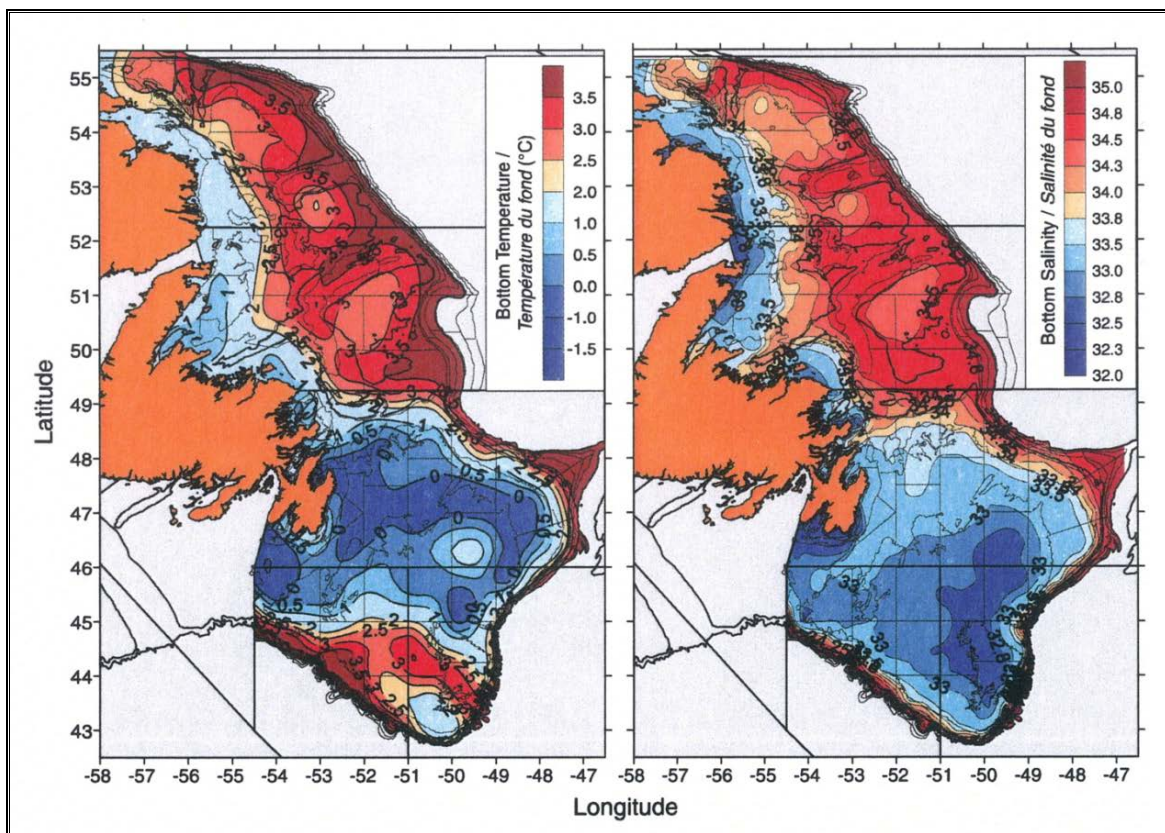
The first identifiable feature is the surface layer which is exposed to interaction with the atmosphere, and experiences temperature variations from subzero values in January and February to above 15°C in summer and early fall. Salinity at this layer is strongly impacted by wave action and local precipitations. Considering that a water mass is a body of water which retains its well defined physical properties, over a long time period, the surface layer of variable temperature and salinity is usually left out of a water mass analysis for a particular region. During the summer, the stratified surface layer can extend to a depth of 40 m or more. In winter, the stratification in the surface layer disappears and becomes well mixed due to atmospheric cooling and intense mixing processes from wave action.

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

of water which occupies the entire water column. In 2011, the area of the CIL on the Grand Bank was the second lowest on record (Colbourne et al. 2012).

Bottom temperature and salinity maps were produced by Colbourne et al. (2007) by trawl-mounted CTD data from approximately 700 fishing tows during the fall of 2005. These maps are presented in Figure 3.4 shows the presence of the CIL near bottom in the Study and Regional areas.

A third element is the sharp density boundary near the Shelf break which separates the water on the shelf from the warmer, more saline water of the Continental Slope. The water over the Slope is the Labrador Sea water which is formed in the Labrador Sea as a result of the deep convection processes that take place during severe winters. The Labrador Sea has temperatures between 2°C to 4°C and salinities between 34.8‰ to 35‰.



Source: Colbourne et al. (2007).

**Figure 3.4 Bottom Temperature and Salinity Maps Derived for the Trawl-mounted CTD Data.**

### 3.4 Sea Ice and Icebergs

Sea ice and icebergs of the Regional Area are described in Section 3.4 of LGL (2012).

### **3.4.1 Sea Ice**

The annual sea ice extent on the Newfoundland and Labrador shelf was below normal for the 16<sup>th</sup> consecutive year (Colbourne et al. 2012). A weekly analysis of the Canadian Ice Service's 30-Year Frequency of Presence of Sea Ice over the area shows that the Study Area may be affected by sea ice beginning the week of January 22 and lasting until the week beginning April 30 (analysis by Oceans Ltd. in LGL 2012 appended). This timing is outside the temporal boundary of the HMDC project and thus is not discussed further.

### **3.4.2 Icebergs**

An analysis has been performed by Oceans Ltd. for Husky Energy to determine the threat posed by icebergs in Husky's 2012-2020 Seismic Project Area (see LGL 2012 appended) which encompasses the proposed HMDC Project Area defined in the present EA. The International Ice Patrol Iceberg Sightings Database from 1974 to 2009 was used as the primary data source in this analysis; (NSIDC 1995) shows the number of iceberg sightings from 1974 to 2009.

A monthly analysis shows that icebergs have been spotted within the region from January to August, October and December; however, they are most prominent during the month of April (see Table 3.5.3 and Figure 3.5.1 in LGL 2012). This peak is prior to the start of the Project in any given year. However, May has the second highest frequency and approximately 40% of the icebergs may be present in the area during the Project's time window of May through December. With respect to size, the most prominent icebergs are small, accounting for 28.7% of observed icebergs within the region. Large icebergs occur 9.8% of the time.

Colbourne et al. 2012 reports that in 2011: "Only three icebergs were detected south of 48°N on the Northern Grand Bank, compared to one in 2010, substantially fewer than the 1981-2010 mean of 767."

## **4.0 Biological and Socio-economic Environments**

The biological and socio-economic environments in and near the Study Area have been described in a number of exploration and drilling EAs and associated amendments for Jeanne d'Arc (e.g., Christian 2008; LGL 2006a, 2007a,b, 2008a,b, 2011a, 2012; and others). In addition to updated information, summaries of relevant information from these documents are presented in the following Sections for fish and fish habitat, seabirds, marine mammals, sea turtles and commercial fisheries, species at risk and potentially sensitive areas. In addition, the most recent seismic EA that includes the HMDC Project Area is appended in electronic form (LGL 2012).

### **4.1 Ecosystem**

Following guidance in the Scoping Document (C-NLOPB 2013), this EA focuses on components of the ecosystem such as selected species and stages of fish, seabirds and marine mammals that are important ecologically, economically, and/or socially, with potential to interact with the Project (i.e., valued ecosystem components or VECs as defined in Section 5.2).

### **4.2 Fish and Fish Habitat**

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

#### **4.2.1 Fish Habitat**

Defined broadly, fish habitat includes physical, chemical, and biological aspects of the marine environment used by invertebrate and fish species in the Study Area. The physical and chemical nature of the water column and bottom substrate is a critical factor affecting the characterization of associated marine biological communities. The biological component of fish habitat includes phytoplankton, zooplankton, and benthos (i.e., infaunal and epibenthic invertebrates such as polychaetes and echinoderms not commercially harvested in the Study Area).

#### **4.2.2 Plankton**

Plankton is composed of free-floating organisms that form the basis of the pelagic ecosystem. Members include bacteria, fungi, phytoplankton, and zooplankton (mostly invertebrates, but may also include eggs and larvae of fishes, known as ichthyoplankton). An understanding of plankton production is important because areas of enhanced production and (or) biomass are areas where fish, seabirds, and marine mammals congregate to feed (LGL 2003).

Phytoplankton distribution, productivity, and growth regulation in high-latitude ecosystems constitute a complex system with light, nutrients, and herbivore grazing being the principal factors limiting phytoplankton regulations (Harrison and Li 2008). In the NW Atlantic, there is generally a spring

plankton bloom (May/June) which is often followed by a smaller bloom in the fall (September/October). This general pattern likely applies to the Study Area. Zooplankton reproduction is tied to the phytoplankton bloom, which either coincides with or immediately follows the brief but intense phytoplankton blooms in the high latitudes (Huntley et al. 1983; Head et al. 2000; Head and Pepin 2008). Zooplankton is the foremost link between primary production and higher-level organisms in the offshore marine ecosystem. They transfer organic carbon from phytoplankton to fish, marine mammals, and birds higher in the food chain. Zooplankton is a food source for a broad spectrum of species and they contribute carbon via faecal matter and dead zooplankton to benthic food chains. Pepin et al. (2011) noted plankton distribution in the Study Area to be primarily influenced by local advective transport and mixing processes, with several species of *Calanus* copepods acting as key contributors to the regional secondary production. Plankton is discussed in more detail in the appended report (Section 4.2.2 in LGL 2012).

Planktonic organisms are so ubiquitous and abundant, and many have such rapid generation times that there will be essentially no or negligible effect on planktonic communities from the proposed seismic Project. Therefore, no further assessment of the potential effects of the Project on phytoplankton and zooplankton will be discussed here. However, planktonic stages of commercial invertebrates (e.g., shrimp, snow crab) and fishes (e.g., cod) are described in following Sections because of their VEC status.

#### **4.2.3 Benthic Invertebrates**

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 (epifauna) live attached to hard substrates and would include barnacles, tunicates, bryozoans, holothurians, and some anemones. The epibenthic organisms are active swimmers that remain in close association to the seabed and include mysids, amphipods, and decapods.

There are large gaps in the knowledge of benthic ecosystems of the offshore waters of Newfoundland and Labrador. The existing literature, although extensive in appearance, tends to be spatially restricted and often species-specific (discussed further in the appended EA).

##### **4.2.3.1 Deep-water Corals and Sponges**

Deepwater corals are receiving increased scientific attention off the east coast of Canada in recent years because of their potential importance to the ecosystem (e.g., as cover for various life stages of fish) and likely sensitivity to certain types of disturbance such as increased sedimentation or physical destruction. As a result, information on corals known to occur within and adjacent to the Study Area is presented below.



A variety of coral groups occur in Newfoundland and Labrador waters and include scleractinians (solitary stony corals), antipatharians (black wire corals), alcyonaceans (large and small gorgonians, and soft corals), and pennatulaceans (sea pens) (Wareham and Edinger 2007; Wareham 2009). Off Newfoundland and Labrador, corals are mostly distributed along the edge of the continental shelf and slope (Edinger et al. 2007; Wareham and Edinger 2007). Typically, they are found in canyons and along the edges of channels deeper than 200 m (Breeze et al. 1997). Off Newfoundland, soft corals are distributed in both shallow and deep waters, while horny and stony corals (hard corals) are normally restricted to deep water areas. Most grow on hard substrate (Gass 2003), including other corals such as large gorgonian corals (Breeze et al. 1997). Others, for example small gorgonians, cup corals, and sea pens, prefer sand or mud substrates (Edinger et al. 2007). In total, at least 30 species of corals have been documented including two antipatharians (black wire corals), 13 alcyonaceans (large gorgonians, small gorgonians, and soft corals), four scleractinians (solitary stony corals), and 11 pennatulaceans (sea pens) for offshore Newfoundland and Labrador.

Several recently published reports present knowledge on the ecology of deep cold-water corals of Newfoundland and Labrador waters, including information on biogeography, life history, biochemistry, and relation to fishes (e.g., Wilkinson and Edinger 2009; Kenchington et al. 2010a,b; Baillon et al. 2012; Baker et al. 2012). 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). A recent DFO Science Advisory Report (DFO 2010a) also discusses the occurrence and ecological function of corals in Canadian waters.

According to distribution maps provided by Wareham (2009), there are approximately four species of corals reported for the Study Area. The species identified include large gorgonians (*Paramuricea* spp.) and soft corals (*Duva florida*, *Gersemia rubiformis*, and *Nephtheid* spp.). DFO RV surveys during 2007 to 2011 also noted the presence of the large gorgonian *Paragorgia arborea*, and the scleractinian *Flabellum alabastrum* (common cup coral). The majority of coral species were observed to occur on or near the continental slope of Flemish Pass, with the exception of several soft corals (e.g., *Gersemia rubiformis* and *Duva florida*) found distributed on the shelf of Jeanne d'Arc Basin. Based on DFO RV survey data collected in the Study Area from 2007 to 2011, most of the corals were caught at mean water depths around 89 and 92 m in the spring and fall surveys, respectively.

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 observed 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. For various sample segment lengths and depth ranges in the southern Grand Banks, Baker et al. (2012) found significant positive relationships between the presence and/or abundance of roundnose grenadier (*Coryphaenoides rupestris*) with that of large skeletal corals and cup corals, of roughhead grenadier (*Macrourus berglax*) with large gorgonians/antipatharians and soft corals, and of marlin-spine grenadier (*Nezumia bairdii*) with small gorgonians. Baillon et al. (2012) determined that several types of coral, particularly sea pens (e.g., *Anthoptilum grandiflorum*) were hosts to eggs and/or larvae of two redfish species (*Sebastes fasciatus* and *S. mentella*), lantern fish (*Benthosema glaciale*) and greater eelpout

(*Lycodes esmarkii*) in the Laurentian Channel and southern Grand Banks. This suggests that habitats that support diverse corals may also support diverse assemblages of fishes. Although relationships between corals and groundfish or invertebrates are not obligate and may result from coincidence, conservation areas established for corals may effectively protect populations of groundfish, including some commercial species (Edinger et al. 2009). By increasing the spatial and hydrodynamic complexity of habitats, deep-sea corals may provide important, but probably not critical, habitat for a wide variety of fishes. Effects of deep-sea corals on fish habitat and communities may include higher prey abundance, greater water turbulence, and resting places for a wide variety of fish size classes (Auster et al. 2005, and Costello et al. 2005 in Edinger et al. 2009).

Sponges also provide fish habitat, enhance species richness and diversity, and exert clear ecological effects on other local fauna. Sponge grounds and reefs support increased biodiversity compared to structurally-complex abiotic habitats or habitats that do not contain these organisms (DFO 2010a). Kenchington et al. (2013) noted the association of several demersal fish taxa with *Geodia*-dominated sponge grounds on the Grand Banks and Flemish Cap, although the precise nature of this association is unknown. According to the DFO RV survey data collected in the Study Area from 2007 to 2011, most of the sponges were collected in approximately 80 m depth in spring and fall.

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

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

In 2008 and 2009, the NAFO Scientific Council identified areas of significant coral and sponge concentrations within the NAFO Regulatory Area. NAFO Coral/Sponge Closure Area Five was updated in 2012. These areas that have been closed to fishing with bottom gear are outside the HMDC Study Area as shown in Section 4.7 (see “Potentially Sensitive Areas” DFO 2010a).

#### **4.2.4 Fish**

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

#### **4.2.4.1 Commercial Fisheries (Primary Species)**

The total commercial fisheries catch weight within the Study Area amounted to 1,432 metric tonnes (mt) from May to December 2005 to 2010; the average weight was 239 mt (DFO Landings Data 2005-2010). Snow crab (*Chionoecetes opilio*) dominated the reported landings of commercial catches within the Study Area during May to December 2005 to 2010 (average catch weight approximately 98% of total). Northern Shrimp (*Pandalus borealis*) accounted for the remaining ~2% of the May to December 2005 to 2010 average total catch weight. The life histories of these species, along with those found within the Study Area during DFO surveys which are of special concern under COSEWIC and/or SARA, are profiled in the appended EA (Sections 4.2.4.1 and 4.2.4.2, LGL 2012); summaries are presented below for snow crab and northern shrimp. The occurrence and/or proportional abundance of snow crab and northern shrimp within the Study Area are presented below.

#### **Snow Crab**

The following summary is derived from the snow crab profile in Section 4.2.4.1 of LGL (2012). Snow crab occurs over a broad depth range in the NW Atlantic from Greenland south to the Gulf of Maine (DFO 2010b in LGL 2012). Large males are most common on mud or mud/sand, while smaller crabs are common on harder substrates. After spring hatching, snow crab undergo a multi-stage 12 to 15 week planktonic larval period before settlement. Benthic juveniles molt frequently, and at about 4 years of age they may become sexually mature. Females carry the fertilized eggs for about two years (DFO 2010b in LGL 2012). Snow crab typically feed on fish, clams, benthic worms, brittle stars, shrimps and crustaceans, including smaller snow crabs. Their predators include various groundfish and seals (DFO 2010b in LGL 2012).

Geo-referenced commercial catch data for the May to December period, 2005-2010, indicate a relatively limited distribution of catch locations for snow crab. Most snow crab catches were made beyond the 100 m isobath of the Jeanne d'Arc Basin in the north and northeastern portions of the Study Area. Scattered harvest locations were also reported for the shallower regions of the Jeanne d'Arc Basin and the Flemish Pass, in the western, southern and central-eastern portions of the Study Area. Based on DFO RV survey data collected in the Study Area from 2007 to 2011, most of the snow crab during those surveys was caught at respective mean water depths around 92 and 89 m during spring and fall surveys respectively. In terms of total catch weight, the greatest proportion of snow crab was caught in the north-eastern half of the Study Area during DFO RV surveys from 2007 to 2011.

#### **Northern Shrimp**

The following summary is derived from the northern shrimp profile in Section 4.2.4.1 of LGL (2012). Northern shrimp is distributed from Davis Strait to the Gulf of Maine. It usually occupies soft muddy substrates up to depths of 600 m in temperatures of 1°C to 6°C (DFO 2008a in LGL 2012), with larger individuals generally occurring in deeper waters (DFO 2006a in LGL 2012). A diel vertical migration is undertaken with shrimp moving off the bottom into the water column during the day, and up the water column at night to feed on small pelagic crustaceans (DFO 2006a in LGL 2012).

Northern shrimp are protandric hermaphrodites (Orr et al. 2009 *in* LGL 2012). They first mature as males, mate for one to several years, and then change to females for the remainder of their lives (DFO 2008a *in* LGL 2012). Eggs are typically extruded in the summer and remain attached to the female until the following spring, when the female spawns in shallow coastal waters (Nicolajsen 1994 *in* Ollerhead et al. 2004 *in* LGL 2012). The hatched larvae float to the surface and feed on planktonic organisms (DFO 2006a *in* LGL 2012). Northern shrimp are known to live for more than eight years in some areas and are large enough for recruitment to the fishery as early as three years of age (DFO 2008a *in* LGL 2012).

Northern shrimp grow by moulting their shells. During this period, the new shell is soft, causing them to be highly vulnerable to predators such as Greenland halibut, Atlantic cod (DFO 2006a *in* LGL 2012), Atlantic halibut, skates, wolffish and harp seals (*Pagophilus groenlandicus*) (DFO 2000a *in* LGL 2012).

Geo-referenced commercial catch data for the May to December period, 2005-2010, indicate that most northern shrimp catches within the Study Area occurred beyond the 100 m isobath in the north-eastern region of the Study Area. Scattered shrimp catches were also reported within the 100 m isobath of the Jeanne d'Arc Basin, in the north-central and north-western portions of the Study Area. Based on DFO RV survey data collected in the Study Area from 2007 to 2011, most of the northern shrimp were caught at mean water depths around 90 m during both spring and fall surveys. In terms of total catch weight, the greatest proportion of northern shrimp was caught in the western half of the Study Area during DFO RV surveys from 2007 to 2011.

#### **4.2.4.2 Other Fishes Caught in the Commercial Fishery**

Other species that have been caught during commercial fisheries being prosecuted around (though not within) the Study Area during May to December in recent years were profiled in the appended EA (Sections 4.2.4.1 and 4.2.4.2, LGL 2012). These species include:

- Stimpson's Surf Clam (*Mactromeris polynyma*);
- Cockle (likely Greenland cockle, *Serripes groenlandicus*);
- Rock Crab (*Cancer irroratus*);
- Capelin (*Mallotus villosus*);
- Skate sp.;
- Atlantic Halibut (*Hippoglossus hippoglossus*);
- Greenland Halibut (*Reinhardtius hippoglossoides*);
- Redfishes (*Sebastes* spp.);
- American Plaice (*Hippoglossoides platessoides*);
- Squid (*Illex* sp.);
- Wolffishes (*Anarhichas* spp.);
- Bluefin Tuna (*Thunnus thynnus*);
- White and Blue Hakes (*Urophycis tenuis*; *Antimora rostrata*); and
- Whelk sp.

Based on the profiles in Sections 4.2.4.1 and 4.2.4.2 in LGL (2012), the life histories of Atlantic cod (*Gadus morhua*), and witch and yellowtail flounders (*Glyptocephalus cynoglossus* and *Limanda ferruginea*) (May to December, 1990 to 2000), are summarized below. These commercial species were historically exploited in the Study Area.

### **Atlantic Cod**

The Atlantic cod is a demersal fish that inhabits cold (10 to 15°C) and very cold (less than 0 to 5°C) waters in coastal areas and in offshore waters overlying the continental shelf throughout the NW and NE Atlantic Ocean (COSEWIC 2003a in LGL 2012). Atlantic cod typically spawn over a period of less than three months in water that may vary in depth from tens to hundreds of meters (COSEWIC 2003a in LGL 2012). Cod are batch spawners, as 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. Cod eggs and larvae are pelagic for several weeks, and then juveniles settle 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 more diverse.

Dispersal in Atlantic cod appears to be limited to the egg and larval phases of life, during which surface and near-surface water currents and turbulence are the primary determinants of horizontal and vertical displacement in the water column (COSEWIC 2003a in LGL 2012). Long-term movements by cod take the form of seasonal migrations (COSEWIC 2003a in LGL 2012). 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 kilometers, or less, in distance. By contrast, cod in other populations are known to traverse hundreds of kilometers during their seasonal migrations.

A moratorium was declared on directed commercial fishing of Atlantic cod in NAFO Divisions 2J3KL in 1992. A small fishery was directed at inshore populations in Divisions 3KL in 1998, however declining catch rates led to a closure of this and the inshore food/recreational fishery in 2003 (DFO 2011a). Stewardship and recreational fisheries were re-opened and have been ongoing in the inshore since 2006 (DFO 2012a). DFO fall RV surveys indicated increases in total abundance, biomass and spawning stock biomass in the early 2000's, however these trends did not continue beyond 2009 (DFO 2012a). Total mortality rates of the offshore population declined and remained low from 2003 to 2007, however the rates have increased substantially each year as of 2009 (DFO 2012a). In combination with prolonged low recruitment levels, prospects for future stock growth are poor if the total mortality rates continue to increase (DFO 2012a).

Atlantic cod (NL population) is currently designated as *endangered* under COSEWIC, but has no status under SARA (SARA website 2013).

### **Witch Flounder**

Witch flounder range from the Hamilton Inlet Bank to North Carolina in the NW Atlantic (DFO 2011c in LGL 2012). They preferentially inhabit gullies with clay, muddy sand, or pure mud bottoms, and usually

move from shallower, soft mud bottoms in the summer to deeper gullies in the winter, with bottom temperatures ranging from -1 to +11°C (DFO 2011c *in* LGL 2012). Witch flounder are most abundant between 185 and 400 m, although some have been caught deeper than 1,500 m (DFO 2011c *in* LGL 2012). Witch flounder form dense prespawning concentrations between winter and spring, and spawning occurs in shallow water and on the slopes of the Grand Banks area, in late spring to late summer or early fall (DFO 2011c *in* LGL 2012). Eggs and larvae of witch flounder are pelagic, while juveniles can be either pelagic or deepwater fishes. Witch flounder mainly prey on polychaetes, small crustaceans and shellfish (DFO 2011c *in* LGL 2012). Although a considerable portion of witch flounder catch occurs as by-catch of other fisheries, it has been a component of the Canadian Atlantic groundfisheries since the early 1940s (DFO 2011c *in* LGL 2012).

## **Yellowtail Flounder**

Yellowtail flounder inhabit the continental shelf of the NW Atlantic from Labrador to Chesapeake Bay at depths ranging from 10 to 100 m, where substrate consists primarily of sand. Yellowtail spawning on the Grand Banks generally occurs between May and September with peaks during the latter part of June. It tends to occur at depths less than 100 m and at water temperatures exceeding 2°C (LGL 2006a *in* LGL 2012). The eggs, larvae and early juvenile stages of yellowtail are pelagic. The most common prey of yellowtail flounder includes polychaetes, amphipods, shrimp, cumaceans, isopods and small fish (LGL 2006a *in* LGL 2012).

### **4.2.5 Species Collected during DFO RV Surveys**

DFO research vessel data collected during annual multi-species trawl surveys provide distributional information for important species not discussed in the commercial fisheries as well as additional 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 with combined annual catch weights of at least approximately 100 kg (along with species of concern under COSEWIC and/or SARA, corals, and sponges) are presented in Table 4.1.

Sand lance accounted for 57.0% of the total 2007-2011 catch weight; followed by yellowtail flounder (10.7%), snake mackerel (6.8%); snow crab (4.6%); capelin (2.8%); comb-jelly (2.8%); thorny skate (2.1%); and sea urchin (1.4%). All remaining species/groups in Table 4.1 represent <1% of the RV survey total catch weight.

Catches were somewhat consistent between survey years for species type, with an average contribution to yearly total catch weight of 80.0, 19.9, and 0.1% for fish, invertebrates, and corals, respectively. An exception occurred in 2007 (fish: 95.9%, invertebrates: 4.1%), which was driven by higher catches of sand lance and lower snow crab catch.

**Table 4.1 Catch Weights and Numbers of Macroinvertebrate and Fish Species Collected during 2007 to 2011 DFO RV Surveys within the Study Area.**

Species	Catch Weight (kg)	Catch Number
Sand Lance	4,597	334,115
Yellowtail Flounder	860	2,252
Snake Mackerel	550	4,908
Snow Crab	371	1,638
Capelin	225	16,486
Comb-jelly	223	n/a
Thorny Skate	168	68
Sea Urchin ( <i>Strongylocentrotus</i> sp.)	112	9,705
Atlantic Cod	46	45
Northern Shrimp	28	5,072
Corals	6	n/a
Spotted Wolffish	5	2
Atlantic (Striped) Wolffish	4	4
Northern Wolffish	3	1
Sponge (Porifera)	3	n/a
Deepwater Redfish	1	4

Source: DFO RV Survey Data (2007-2011).

Note: n/a denotes data unavailable.

Across all species caught during the 2007 to 2011 DFO RV surveys in the Study Area, total catch weights were greatest in 2007 (2,413 kg), 2010 (1,989 kg), and 2009 (1,763 kg), and lowest in 2011 (771 kg). The total catch weight of the 2007 to 2011 DFO RV surveys in the Study Area was divided into spring (May, June, and July) and fall (November). Spring surveys accounted for 27.9% of the total catch weight, and fall surveys accounted for 72.1%. The average mean depths of catch during spring and fall surveys from 2007 to 2011 were 86 m (minimum=31 m; maximum=123 m) and 84 m (minimum=64 m; maximum=124 m), respectively.

The top five species/groups in terms of catch weight during the spring surveys were sand lance, yellowtail flounder, American plaice, capelin, and snow crab. The top five species/groups in terms of catch weight during the fall surveys were sand lance, yellowtail flounder, American plaice, comb-jelly, and snow crab.

Species/groups that were caught predominantly during the spring RV surveys included Northern wolffish and capelin. Species/groups that were caught predominantly during the fall RV surveys included Atlantic wolffish, deepwater redfish, northern shrimp, and thorny skate. With respect to capelin and comb-jelly, the survey depth differences between spring and fall surveys likely account for some of the seasonal differences; depths were similar between seasons for the remaining species (Table 4.2).

DFO RV survey catch weights in the Study Area from 2007 to 2011 were analyzed for two mean catch depth ranges and results are presented in Table 4.3.

**Table 4.2 Percentage Catch and Mean Catch Depth by Survey Season for Macroinvertebrates and Fishes Caught during DFO RV Surveys within the Study Area, 2007 to 2011 Combined.**

Species	Percentage Catch in Spring Surveys (%)	Spring Survey Mean Catch Depth (m)	Percentage Catch in Fall Survey (%)	Fall Survey Mean Catch Depth (m)
Sand Lance	48	86	52	84
Yellowtail Flounder	49	72	51	68
Snake Mackerel	51	87	49	85
Snow Crab	51	92	49	89
Capelin	95	86	5	107
Comb-jelly	68	77	32	67
Thorny Skate	21	89	79	86
Sea Urchin ( <i>Strongylocentrotus</i> sp.)	50	87	50	87
Atlantic Cod	45	85	55	73
Northern Shrimp	< 1	90	> 99	91
Corals	67	88	33	92
Spotted Wolffish	50	117	50	105
Atlantic (Striped) Wolffish	-	-	100	87
Northern Wolffish	100	97	-	-
Sponge (Porifera)	67	81	33	82
Deepwater Redfish	-	-	100	91

Source: DFO RV Survey Data (2007-2011).

**Table 4.3 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 m	6,940	Sand Lance (61%) Yellowtail Flounder (12%) Snake Mackerel (5%) Snow Crab (4%) Comb Jelly (3%) Capelin (3%)
≥100 m to <200 m	1,122	Sand Lance (35%) Snake Mackerel (16%) Snow Crab (11%) Brittle Star (Ophiuroidea) (9%) Thorny Skate (6%) Sea Urchin ( <i>Strongylocentrotus</i> sp.) (4%)

Source: DFO RV Survey Data (2007-2011).

#### 4.2.6 Reproduction in the Study Area

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



**Table 4.4      Reproduction Specifics of Macroinvertebrate and Fish Species Likely to Spawn within or near the Study Area.**

Species	Locations of Reproductive Events	Times of Reproductive Events	Duration of Planktonic Stages
Northern shrimp	On banks and in channels over the extent of its distribution	Spawning in late summer/fall  Fertilized eggs carried by female for 8 to 10 months and larvae hatch in the spring	12 to 16 weeks
Snow crab	On banks and possibly along some upper slope regions over the extent of its distribution	Mating in early spring  Fertilized eggs carried by female for 2 years and larvae hatch in late spring/early summer	12 to 15 weeks
Stimpson's surf clam	Eastern Grand Banks	Fall	4 to 8 weeks
Greenland halibut	Spawning grounds extend from Davis Strait (south of 67°N) to south of Flemish Pass between 800 m and 2,000 m depth	Spring/summer or winter months	Uncertain
Greenland cockle	Eastern Grand Banks	Uncertain	Uncertain
Yellowtail flounder	Shallower sandy areas – typically <100 m water depth – at bottom	May to September, typically peaking in June/July  Both eggs and larvae are planktonic.	Pelagic larvae are brief residents in the plankton
Witch flounder	Throughout the Grand Banks, particularly along slopes >500 m	Late spring to late summer/early fall	Uncertain
Thorny skate	Throughout distribution range	Year-round  Eggs deposited in capsule (one egg per capsule), possibly on bottom	None
Roundnose grenadier	Uncertain	Year-round  Eggs are free-floating	Uncertain
Roughhead grenadier	Likely along southern and southeastern slopes of Grand Banks	Winter/early spring	Uncertain
Capelin	Spawning generally on beaches or in deeper waters	Late June to early July	Several weeks
Atlantic halibut	Uncertain	Likely spawns between January and May.  Both eggs and larvae are planktonic	6 to 8 weeks
American plaice	Spawning generally occurs throughout the range the population inhabits	April to May	12 to 16 weeks
Redfish	Primarily along edge of shelf and banks, in slope waters, and in deep channels	Mating in late winter and release of young between April and July (peak in April)	No planktonic stage
Atlantic cod	Spawn along outer slopes of the shelf in depths from tens to hundreds of meters	March to June	10 to 12 weeks
Wolffishes	Along bottom in deeper water, typically along continental slope	Summer to early winter (species dependent)	Uncertain
Cusk	Uncertain	May to August  Eggs are buoyant	Presumed to be 4 to 16 weeks
Porbeagle shark	Very little known about the location of the pupping grounds; likely southern Grand Banks	Mating in late summer/fall and pupping between early April and early June	Uncertain
Sand lance	On sand in shallow water of the Grand Banks	November to January	Several weeks

#### **4.2.7 Concluding Summary of Marine Fish and Shellfish in Study Area**

The distribution, abundance and habitats of important fish and shellfish species are described in the preceding Sections with additional information contained in the following commercial fisheries Sections. More detail is contained in the previously approved seismic EA for the area (LGL 2012, appended).

In summary, while many of the species discussed in this Section likely occur in the Study Area to varying degrees, there are no reports of critical spawning, overwintering, nursery, or migration habitats or large concentrations in the HMDC Study Area.

### **4.3 Commercial Fisheries**

This Section describes the existing commercial fisheries in the Study Area. It also describes economic and logistical aspects of the fisheries. The biological characteristics and status of the main commercial and other marine species, including prey for commercial species were described in the preceding Section 4.2 and the appended EA (Sections 4.2.4.1 and 4.2.4.2, LGL 2012).

There are no recreational, aboriginal and/or subsistence fisheries that occur within or in the immediate area surrounding the Study Area.

Relatively little commercial fishery occurs within the Study Area itself, particularly when compared to fisheries that take place along the slopes of the Grand Banks north of the Study Area (see Figure 4.5 in Section 4.3.3.3). With respect to underutilized species that occur within the Study Area, sand lance are considered one of the most unexploited fish resources in the northwest Atlantic (DFO 2013), and were the most prevalent species caught in the Study Area during recent DFO ROV surveys (see Table 4.1). In contrast to the multinational, industrial sand lance fish operation in the North Sea and the minor bait fishery in New England, there is no Canadian fishery for sand lance (DFO 2013). The lack of sand lance fishery on the Grand Banks is likely mainly due to lack of market demand, lack of special methodology for capture, and distance from desirable markets (DFO 2013).

#### **4.3.1 Data and Information Sources**

The majority of the data used to characterize the fisheries in this subsection are quantities of harvest rather than harvest values since quantities are directly comparable from year to year, while values (for the same quantity of harvest) may vary annually with negotiated prices, changes in exchange rates and fluctuating market conditions. Some species vary greatly in landed value (e.g., snow crab vs. turbot), and thus potential effects on fisheries are best examined by catch quantity as an indicator of fishing effort and by gear types utilized.

#### **4.3.1.1 Fisheries Data Sets**

Fisheries within the Study Area are primarily managed by DFO, while NAFO manages the 3L northern shrimp fishery. The domestic commercial fisheries analysis in this subsection is based on data derived from the DFO Newfoundland and Labrador Region catch and effort data sets. Foreign catches landed outside the regions are not included in these DFO data sets. The date range of 2005 to 2010 was used for the DFO data sets for this EA, due in part to incompatibility issues with newer DFO data formats. DFO is currently in the process of altering the delivery method of commercial fishery catch data for 2011 onward, from specific georeferenced point locations (georeferenced data were mostly used in this EA) to summarized “data blocks,” which are not directly comparable to historical catch data. NAFO datasets were not analyzed as they are not geo-referenced and therefore are specific only to the NAFO Division level (e.g., 3L) rather than Unit Areas (UAs; e.g., 3Lh). As the Study Area only partially occupies UAs 3Lhrt, the NAFO datasets would reflect a gross overestimation of the northern shrimp fishery within the Study Area.

The DFO data used in the report (2005 to 2010) represent all catch landed within the Newfoundland and Labrador region. The DFO catch data within the Study Area are geo-referenced (typically >95% of the harvest, by quantity), so that past harvesting locations can be plotted with a high level of accuracy, and these locations are shown on the fisheries maps in this subsection. The positions given in the data sets are those recorded in the vessel's fishing log, and are reported in the database by degree and minute of latitude and longitude; thus the positions should be accurate within approximately 0.5 nautical miles of the reported co-ordinates. For some gear, such as mobile gear towed over an extensive area, or for extended gear, such as longlines, the reference point does not represent the full distribution of the gear or activity on the water. However, over many data entries, the reported locations create a fairly accurate indication of where such fishing activities occur. In addition, in order to provide a historical summary of catches in the general area of the proposed Study Area, DFO data for UAs 3Lhrt (the Study Area UAs) for 1990 to 2010 were used.

#### **4.3.1.2 Consultations**

The consultations were undertaken to inform stakeholders about the proposed HMDC seismic program, to gather information about fishing activities, and to determine any issues or concerns. Fisheries-related information provided is reported in the discussions of the commercial fisheries below. Further information about the 2013 offshore fisheries obtained from industry stakeholders, as well as any issues and concerns raised by industry representatives, are discussed in Section 5.1.1.

#### **4.3.1.3 Other Information Sources**

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

### **4.3.2 Regional NAFO Fisheries**

The entirety of the Study Area is within Canada's 200-nm EEZ, overlapping relatively small portions of NAFO Division 3L (see Figure 1.1). As such, the commercial fisheries species discussed above are managed by DFO, with one key fishery cooperatively managed with NAFO (northern shrimp). Most fishing in the NAFO Convention Regulatory Area (RA) is conducted using mobile bottom-tending trawls.

The Division 3L northern shrimp fishery has a 2013 TAC of 8,600 mt (down from 12,000 mt in 2012), of which Canada is allocated just over 83%. The TAC for all the NAFO-managed species (including the Canadian and foreign allocations) can be found at the NAFO website (<http://www.nafo.int/fisheries/frames/fishery.html>).

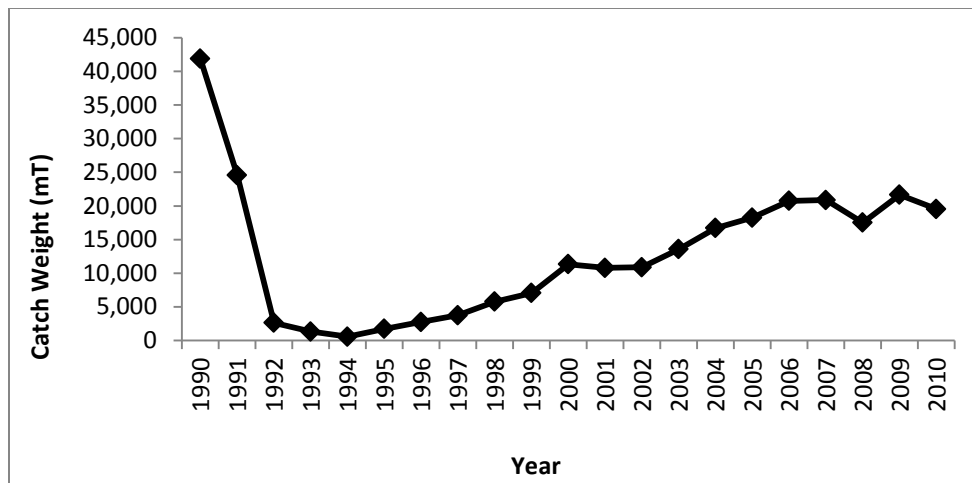
In 2013, several other NAFO managed species in Convention areas were under moratorium. Relevant to the general Study Area, there are bans on fishing cod, American plaice, and witch flounder in NAFO Division 3L. Additional information on Regional NAFO fisheries can be found in Section 4.3.2 of LGL (2012).

### **4.3.3 Study Area Domestic Fisheries**

#### ***4.3.3.1 Catch Trends 1990 to 2010***

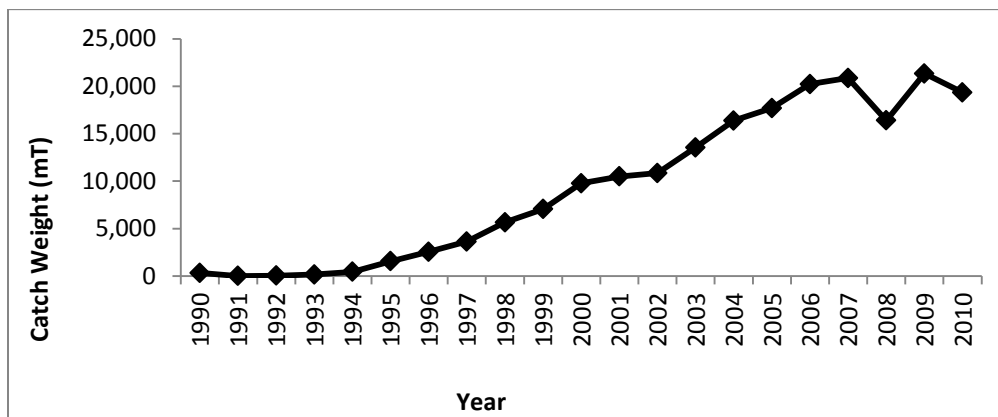
The Canadian fisheries in the eastern Grand Banks area were dominated until the early 1990s by groundfish harvesting using stern otter trawls, primarily harvesting Atlantic cod, American plaice and a few other species. In 1992, with the acknowledgement of the collapse of several groundfish stocks, a harvesting moratorium was declared and directed fisheries for cod virtually vanished in this area. Since the collapse of these fisheries, other species, mainly snow crab and northern shrimp, have come to replace groundfish as the principal harvest on and in the waters east of the eastern Grand Banks, as they have in many other areas. Based on geo-referenced DFO datasets, Figures 4.1 to 4.3 summarize catch data for the four fisheries UAs that the Study Area overlaps (Study Area UAs) and show the quantity of the total annual harvest in that Area from 1990 to 2010, the snow crab and northern shrimp harvest, and the total groundfish harvest for the same period. Although UA 3Lr was the source of practically all of the harvest in the early 1990s, UAs 3Li (62%), 3Lh (17%) and 3Lt (14%) accounted for nearly 93% of the Study Area catch from the mid 1990's to 2010.

In recent years, snow crab harvesting (fixed gear) in this area tends to be focused in areas along the shelf break and slope. Northern shrimp trawling (mobile gear) overlaps some of these areas, but these two gears have a potential to conflict with each other, and thus crab and shrimp do not typically overlap in time or location. Shrimp harvesting tends to extend into deeper water in the Study Area, along the northeastern slope of Jeanne d'Arc Basin.



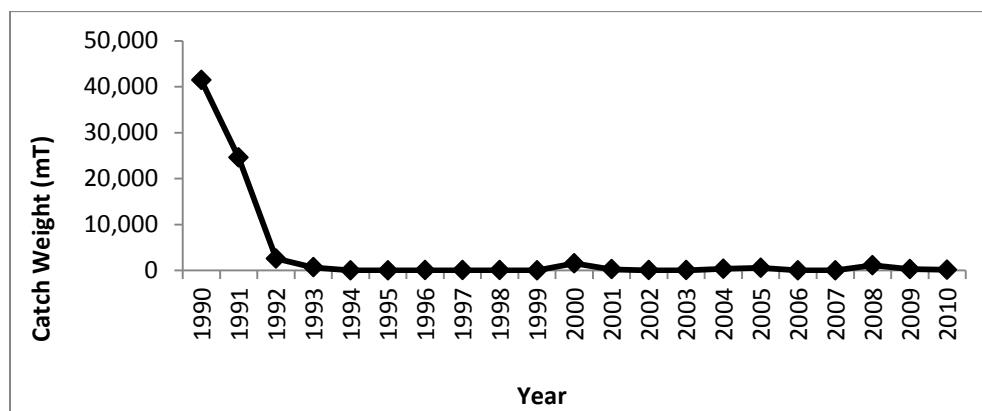
Source: DFO Commercial Fisheries Catch Data (1990-2010).

**Figure 4.1 Harvest of All Species from 1990 to 2010 within Study Area UAs.**



Source: DFO Commercial Fisheries Catch Data (1990-2010).

**Figure 4.2 Snow Crab and Northern Shrimp Harvest from 1990 to 2010 within the Study Area UAs.**



Source: DFO Commercial Fisheries Catch Data (1990-2010).

**Figure 4.3 Groundfish Harvest from 1990 to 2010 within the Study Area UAs.**

#### 4.3.3.2 Study Area Catch Analysis 2005 to 2010

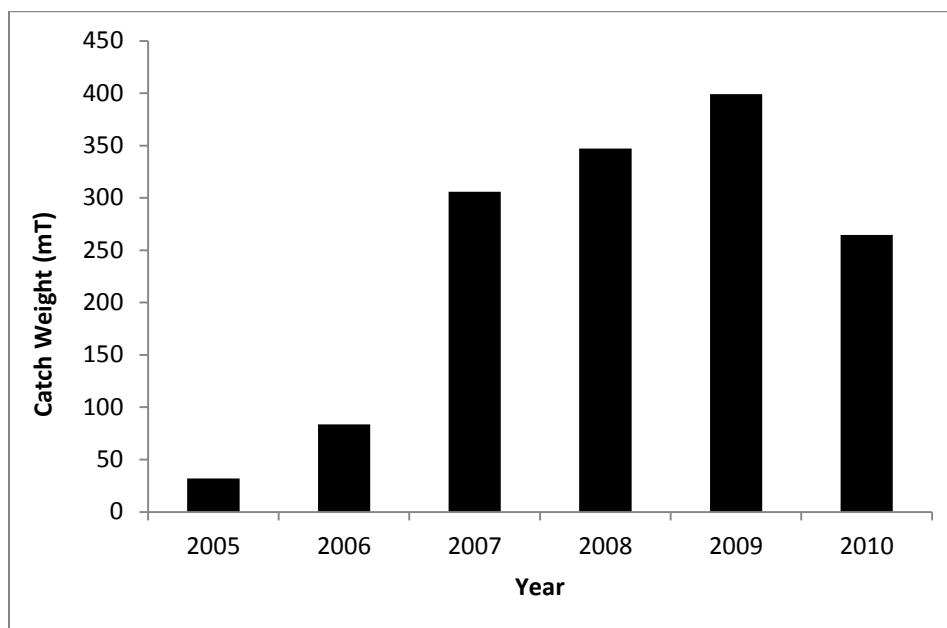
The average annual Canadian-landed harvest by species, 2005 to 2010 from within the Study Area shown below (Table 4.5) is based on the geo-referenced DFO datasets. The domestic harvest in the Study Area has been dominated by snow crab throughout this period, in terms of both quantity and value.

**Table 4.5 Average Study Area Harvest by Species, May to December 2005 to 2010.**

Species	Quantity (mt)	% of Total	Value (\$)	% of Total
Snow Crab	235	98.4	738,983	99.4
Northern Shrimp	4	1.6	4,643	0.6
Totals	239	100.0	743,625	100.0

Source: DFO Commercial Fisheries Catch Data (2005-2010).

The total quantity of the harvest increased dramatically between 2006 and 2007, mainly the result of increased snow crab catches in the Study Area, and declined in 2010 to around 265 mt per year (Figure 4.4). Catches may maintain around 250-300 mt or decrease somewhat as a result of slightly increased snow crab quotas (discussed below) but significant reductions in shrimp quotas.



Source: DFO Commercial Fisheries Catch Data (2005-2010).

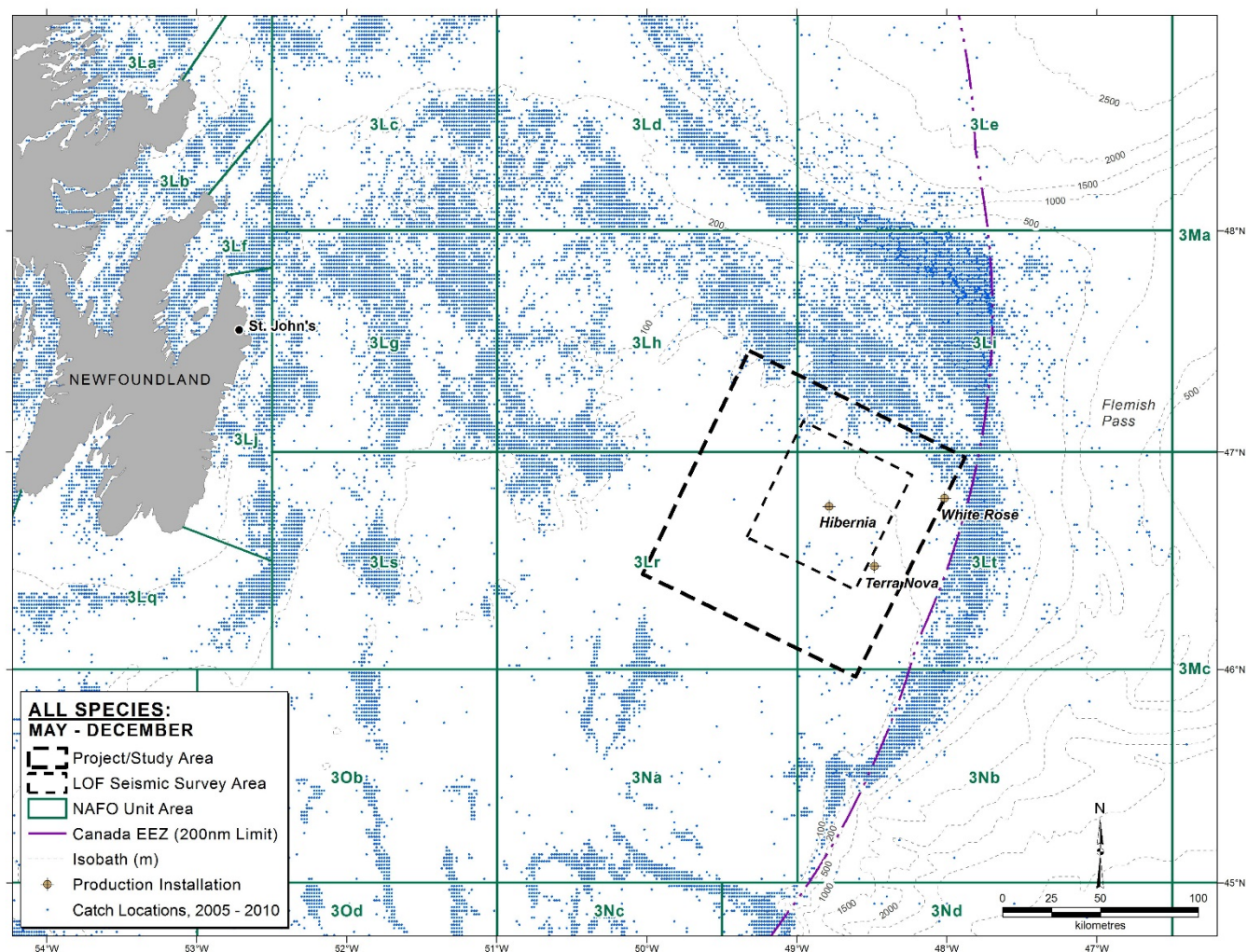
**Figure 4.4 Harvest of All Species within the Study Area, May to December 2005 to 2010.**

#### 4.3.3.3 Harvesting Locations

The following maps (Figures 4.5 and 4.6) show DFO dataset geo-referenced fish harvesting locations in relation to the Study Area for May to December, 2005 to 2010, combined. As Figure 4.5 illustrates,

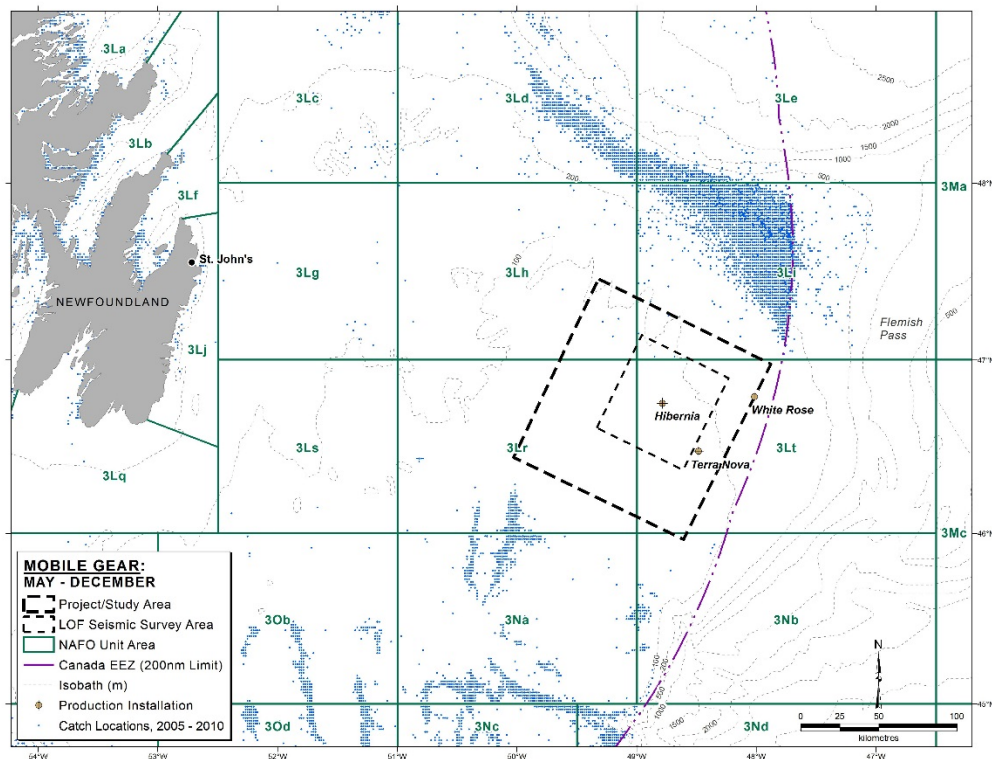
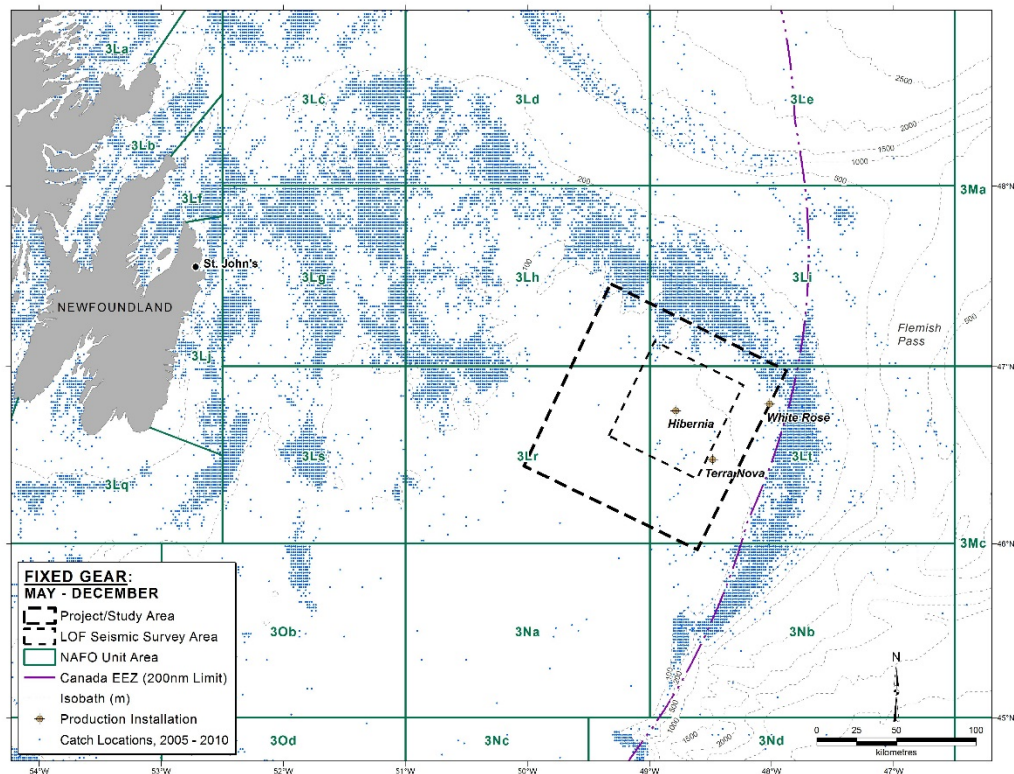
most of the domestic fish harvesting in the general area is concentrated outside of the Study Area between the 100 m and 1,000 m contours of the eastern Grand Banks, inside and to a lesser extent, outside the 200-Nm EEZ. The harvesting locations tend to be quite consistent from year to year, and this has been the case for most of the last decade. It is not possible to directly compare the more recent 2011-2013 data to 2005-2010 data, because of the recent DFO changes to data output which provide a grid format rather than showing georeferenced catches as points. Nonetheless, it is clear that catch locations near the Study Area have remained consistent over these periods (see Appendix 2 for maps showing DFO grid catch coverage for all species, May to December 2011-2012).

In terms of average yearly catch weight, snow crab consisted of the entirety of the domestic harvest in the Study Area using fixed gear, while northern shrimp made up the entirety using mobile gear between May and December, 2005 to 2010 (see Table 4.6 and Figure 4.6).



**Figure 4.5 Commercial Catches (All Species) May to December 2005-2010.**





Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.6 Fixed (top) and Mobile (bottom) Gear Harvest Locations, May to December from 2005 to 2010 Combined.**



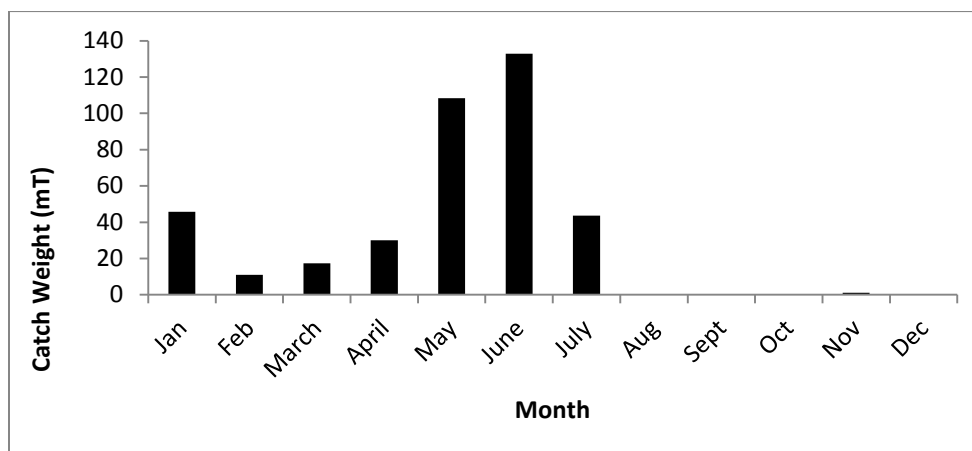
**Table 4.6 Average Study Area Harvest by Species for Fixed and Mobile Gear, May to December, 2005 to 2010 Combined.**

Species	Fixed Gear (mt)	% of Total	Mobile Gear (mt)	% of Total
Snow Crab	235	100.0	0	0
Northern Shrimp	0	0	4	100.0
Totals	235	100.0	4	100.0

Source: DFO Commercial Fisheries Catch Data (2005-2010).

#### 4.3.3.4 Harvest Timing

The times that commercial species are harvested may change, depending on seasons and regulations set by DFO, the harvesting strategies of fishing enterprises, or on the availability of the resource itself. Figure 4.7 shows the 2005 to 2010 catch by month (averaged) from the Study Area; May and June were the most productive months during this period, followed by January and July, accounting for just over 62 and 23% of the annual catch, respectively.



Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.7 Average Monthly Domestic Harvest, All Species, 2005 to 2010 Combined.**

#### 4.3.4 Principal Species Fisheries

As noted above, the domestic harvest within the Study Area is dominated by snow crab, with a minor component of northern shrimp. With decreasing shrimp quotas the relative importance of the species may change somewhat in the next few years. This subsection describes these two fisheries.

##### 4.3.4.1 Snow Crab

Snow crab was the most significant species harvested within the Study Area in terms of average quantity and value (see Table 4.4), accounting for an average of 235 mt (98.4% of total harvest) between May and December from 2005 to 2010. The season is defined each year, but typically runs from April to July

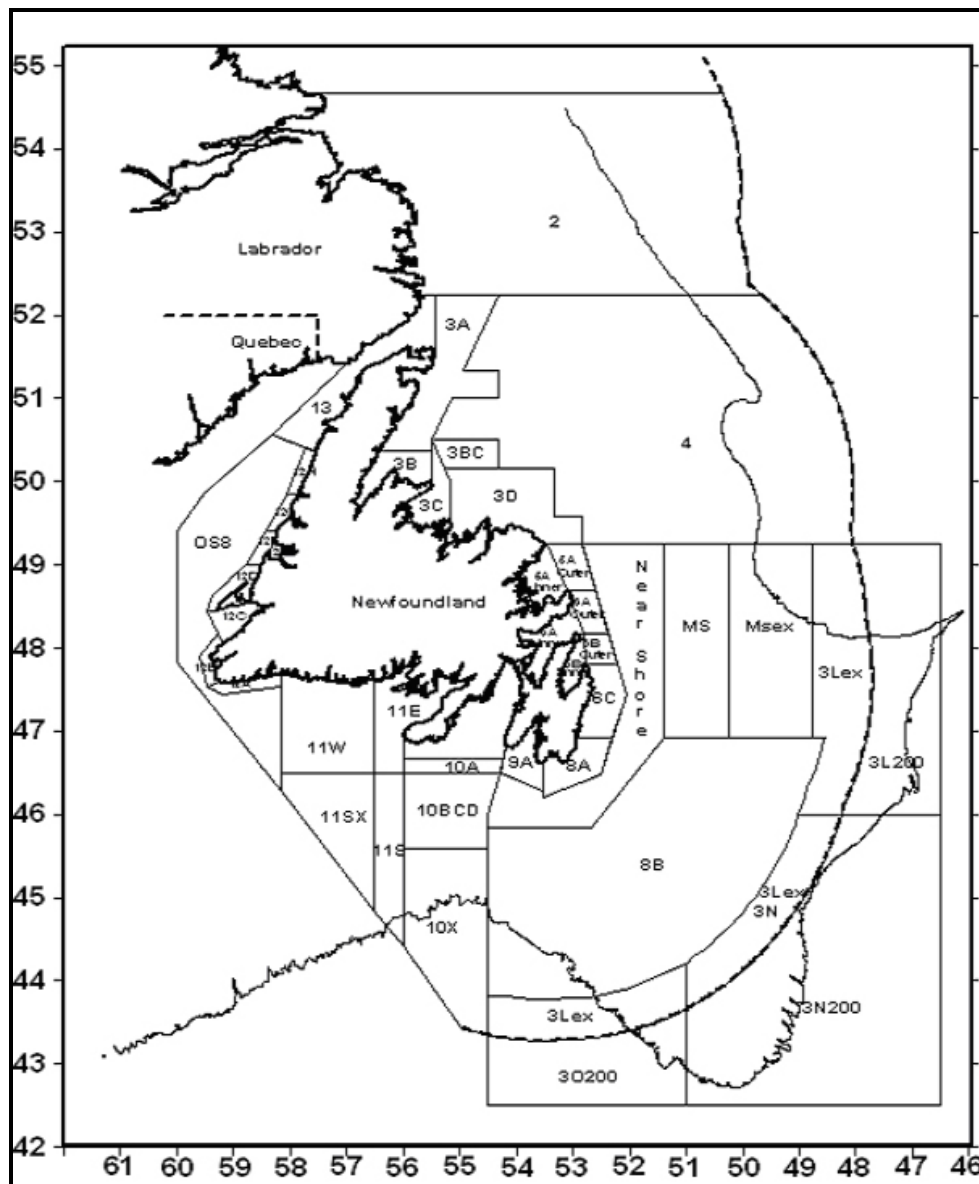
or August. The 2013 snow crab season is set to open on April 1<sup>st</sup> (One Ocean Board Meeting January 2013 Minutes).

Over the past decade, the Newfoundland and Labrador snow crab fishery has gone through a number of fluctuations, with changes in both quantity and value in many Crab Fishing Areas (CFAs). Landed prices have been lower in recent years compared to the late 1990s and early 2000s.

A recent DFO snow crab science advisory report (DFO 2012b) notes that “[Division 3LNO Offshore] landings, mostly in Div. 3L, decreased from 24,500 t in 2007 to 22,000 t in 2009 but since increased to 26,000 t. Effort increased slightly in 2011 following a 2008-2010 decrease. Both the trap and trawl survey exploitable biomass indices increased in 2009. However, the trawl survey index decreased by 34% since 2009, while the trap survey index increased by 21%. Opposing survey trends create an uncertainty about the exploitable biomass...Recruitment has recently peaked and will likely decrease in the short term.” The report further states that “...long-term recruitment prospects are unfavourable due to a warming oceanographic regime.”

The Fisheries Resource Conservation Council’s 2005 Strategic Conservation Framework for Atlantic Snow Crab (FRCC 2005) describes the general conduct of the offshore sector: “Vessels fishing up to and beyond 200 miles from the coast conduct voyages up to four and five days and greater depending on the vessel’s holding system. Typically these vessels leave the traps for shorter periods, sometimes only a few hours, prior to retrieving the catch. Given that snow crab must be live at the time of landing and processing, the duration of fishing trips is limited, although some vessels are now able to keep crab live on board in tanks permitting them to extend the length of their trips.” Quotas have been established by DFO in all management areas, the different fleets have trap and trip limits, and fish specified CFAs. Since the mid-2000s, electronic vessel monitoring systems (VMS) are required on all offshore vessels to ensure compliance (DFO 2012b). A new evergreen multi-year Integrated Fisheries Management Plan (IFMP) was implemented by DFO in 2012, which – in addition to continued sustainability management measures – introduced the mandatory use of biodegradable twine in crab traps in 2013 in an effort to reduce ghost fishing by lost traps (DFO 2012c).

Figure 4.8 shows the regulatory fishing areas for snow crab. The Study Area overlaps with portions of CFAs Msex (mid-shore extended), 3Lex (from 170 miles to 200 miles from shore) and 8B (southern Avalon, outside of 50 miles). The quotas for these CFAs (within the 200 nm-EEZ) remained the same for 2011 and 2012: Msex (3,780 t), 3Lex (2,822 t), and 8B (650 t); overall crab quotas have been stable for the Study Area region, while there have been significant declines in quota and catch rates north of the Study Area in NAFO Divisions 3K and 2J (One Ocean Board Meeting Jan. 2013 Minutes). Quotas for 2013 have not yet been listed by DFO for snow crab.

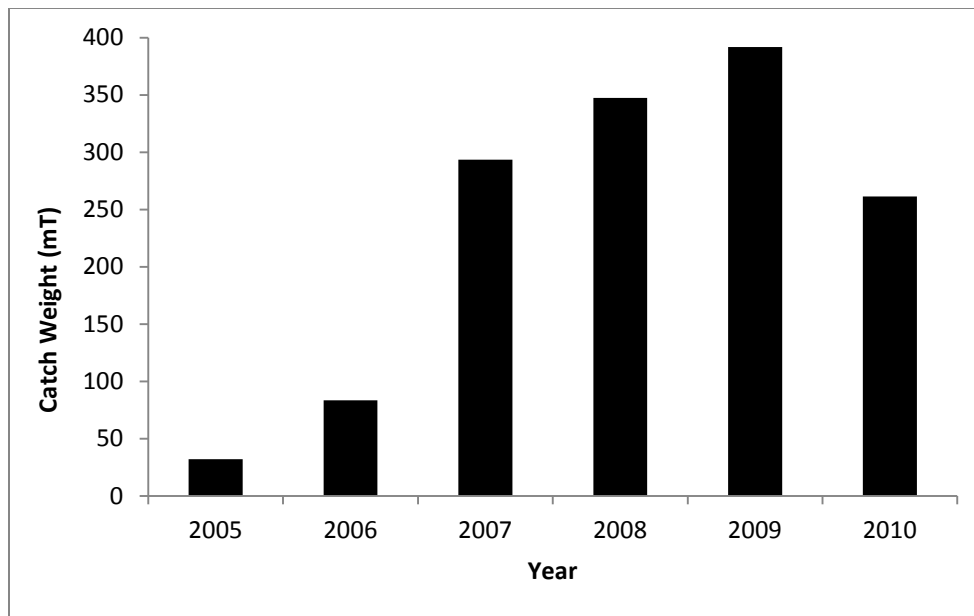


Source: DFO (2013).

**Figure 4.8 Snow Crab Fishing Areas.**

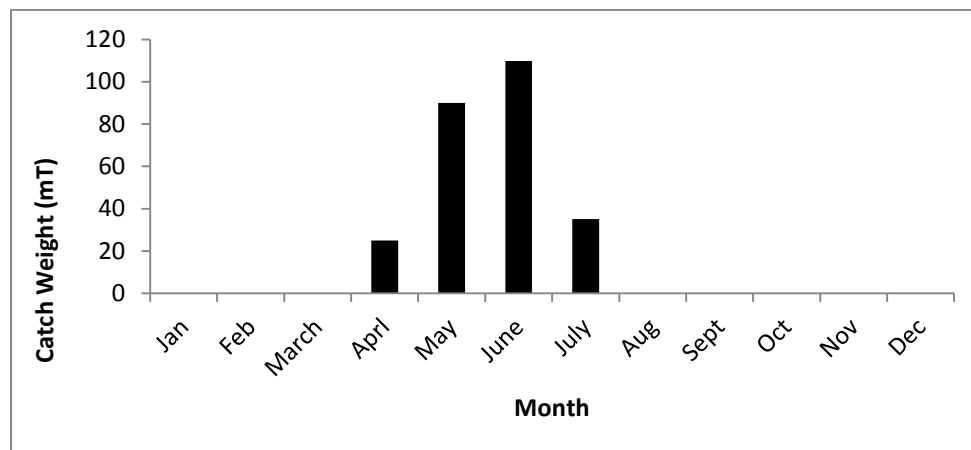
Figure 4.9 shows the aggregated annual snow crab quantities of harvest from the Study Area for May to December 2005 to 2010. Annual snow crab harvest levels increased between 2005 and 2009 from 32 to 392 mt, and decreased in 2010 down to 261 mt. As quotas and catch-rates have remained stable in recent years, catches are anticipated to remain at this level.

Figure 4.10 shows the average snow crab harvest by month, 2005-2010, and indicates that the harvest has occurred between April and July in the Study Area. In 2012, the Msex, 3Lex, and 8B seasons closed on 31 July.



Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.9 Yearly Snow Crab Harvest, May to December 2005 to 2010.**



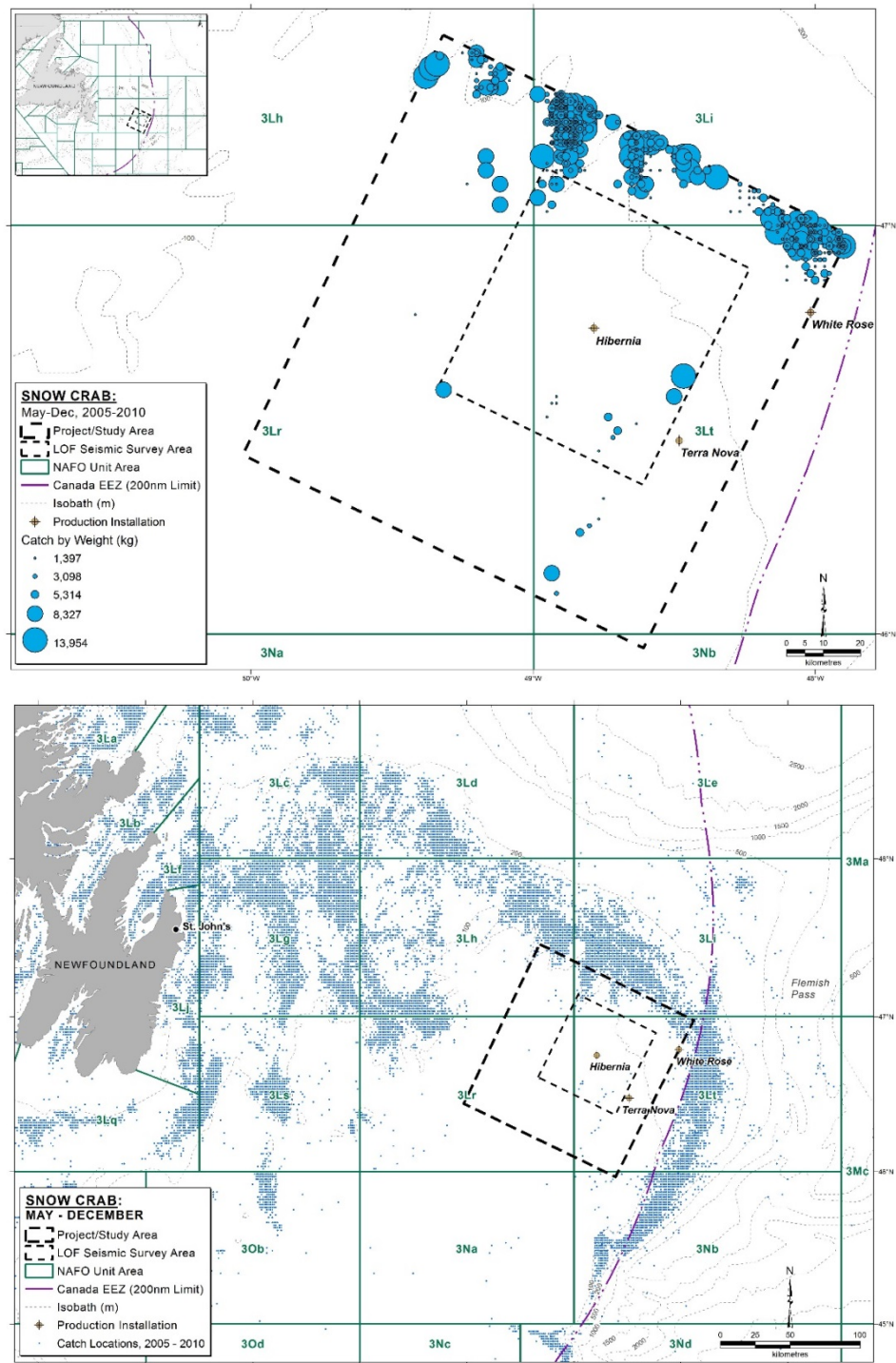
Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.10 Average Monthly Snow Crab Harvest, 2005 to 2010.**

Figure 4.11 shows the proportional and non-proportional aggregated harvesting locations for this species (May to December, 2005 to 2010) in relation to the Study Area. This fishery is focused along the slope edge of Jeanne d'Arc Basin, beyond the 100 m isobath in the north-eastern region of the Study Area. The proposed seismic survey activities do not overlap with the domestic snow crab harvesting locations indicated in Figure 4.11.

This fixed gear fishery poses more potential than mobile gear fisheries for seismic /fishing gear conflicts in those areas where the two marine activities might overlap in time and space. However, as no snow

crab harvest has been reported within the proposed Seismic Survey Area from 2005 through 2010, the likelihood of gear conflict is probably low.



Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.11 Proportional (within Study Area only; top) and Non-proportional (bottom) Snow Crab Harvesting Locations, May to December, 2005 to 2010 Combined.**

#### 4.3.4.2 Northern Shrimp

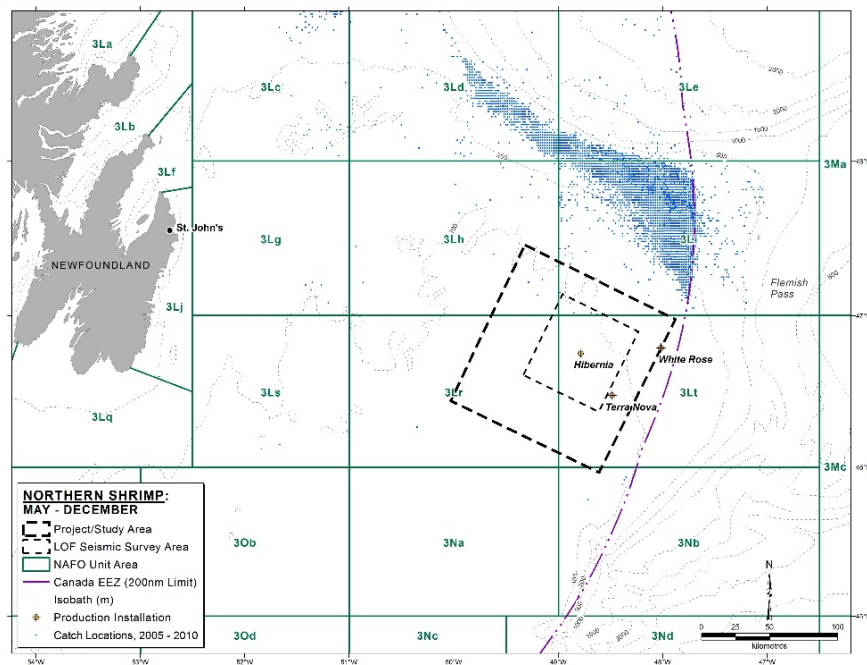
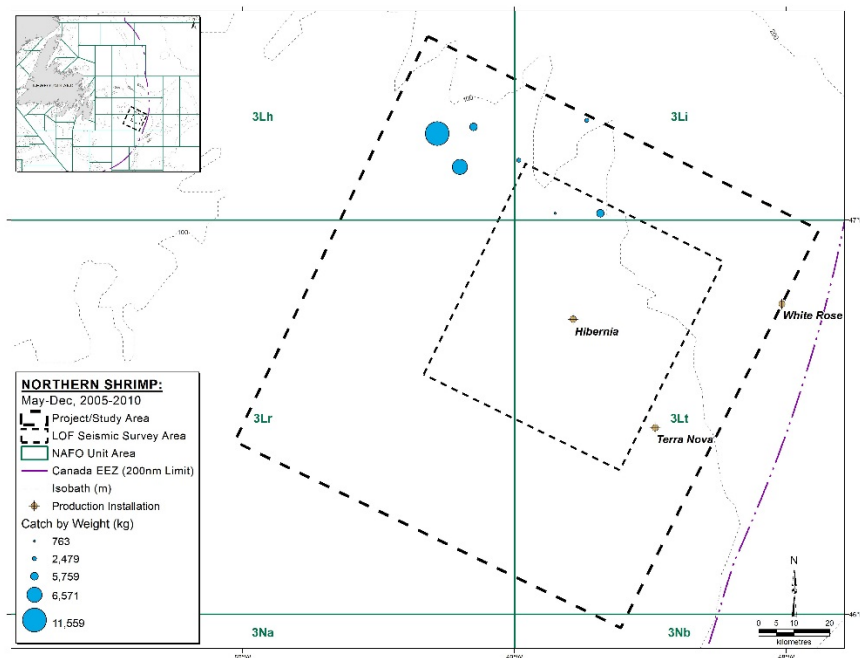
Figure 4.12 shows proportional and non-proportional domestic harvesting locations for northern shrimp for May to December, 2005 to 2010, aggregated. This fishery occurred in the north-eastern portion of the Study Area, outside of the proposed Seismic Survey Area. The majority of shrimp harvesting occurs north and northeast of the Study Area, between the 200 and 500 m isobaths. Northern shrimp trawls are mobile gear, and pose a relatively low potential for conflict with seismic gear if in the same area at the same time. As no northern shrimp catches have been reported in recent years within the proposed Seismic Survey Area, the likelihood of gear conflict is probably low.

Figure 4.13 shows the aggregated annual quantity of the northern shrimp harvest taken from the Study Area from May to December 2005 to 2010. Northern shrimp harvest has been sporadic in the Study Area during this time, with no reported harvests in 2005, 2006 and 2008 and variable levels of harvest in the remaining years. Because of increasing scientific concerns about the status of the resource, catch allowances have been cut in this area since 2009/10 so a decrease in catch is expected, potentially for the next several years. As discussed above, the overall quota for NAFO Division 3L has been reduced considerably, and may drop further in future years. The 2013 quota for SFA 7 (Figure 4.14) is 7,162 mt (DFO 2012d), down from 10,000 t in 2011. The offshore fleet's 2013 quota allocation is 1,377 t (DFO 2012d). In accordance with NAFO recommendations, Canadian harvesters are currently permitted to fish their quota in the entire 3L Division, while harvesting outside of Canadian waters requires obtaining a Schedule from Conservation and Protection and appending this to relevant licences (DFO 2012d). The northern shrimp operates on a calendar year, and is set to open on 1 April 2013 (One Ocean Board Meeting Jan. 2013 Minutes).

Figure 4.15 shows the northern shrimp harvest by month (averaged) from the Study Area, for the period 2005 to 2010. Harvest for northern shrimp occurs mainly in the winter months (January to February), with lesser amounts in the summer and fall.

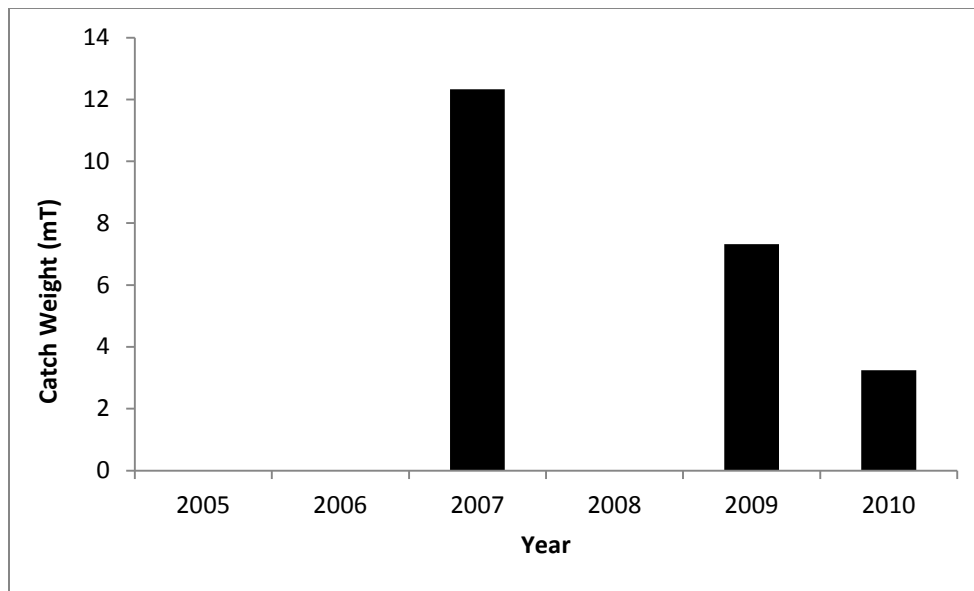
#### 4.3.5 Industry and DFO Science Surveys

Fisheries research surveys conducted by DFO, and sometimes by the fishing industry, are important to the commercial fisheries to determine stock status, as well as for scientific investigation. In any year, there may be overlap between the Study Area and DFO research surveys in NAFO Division 3L, depending on the timing in a particular year. Typically, DFO conducts a spring survey in Sections of 3LNOPs (April to July), and a fall survey of 2HJ3KLMNO (September or October to December). The fall survey may employ two vessels. The deeper waters of 3L (slope areas) are typically surveyed in October, and the shallower areas in November or December. There is also an annual spring acoustic survey for capelin in NAFO Division 3L. Schedules of the 2013 DFO multispecies science surveys are presently available as of October 22, 2012 (*RV Needler*), March 1 and 6, 2013 (*RV Vladikov* and *Teleost*, respectively) (G. Sheppard, DFO, pers. comm., 2013).



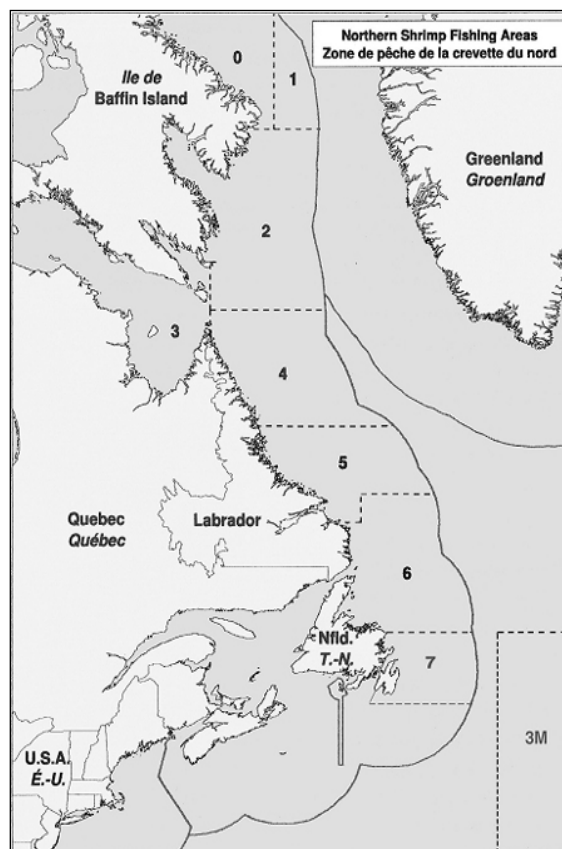
Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.12 Proportional (within Study Area only; top) and Non-proportional (bottom) Northern Shrimp Harvesting Locations, May to December, 2005 to 2010.**



Source: DFO Commercial Fisheries Catch Data (2005-2010).

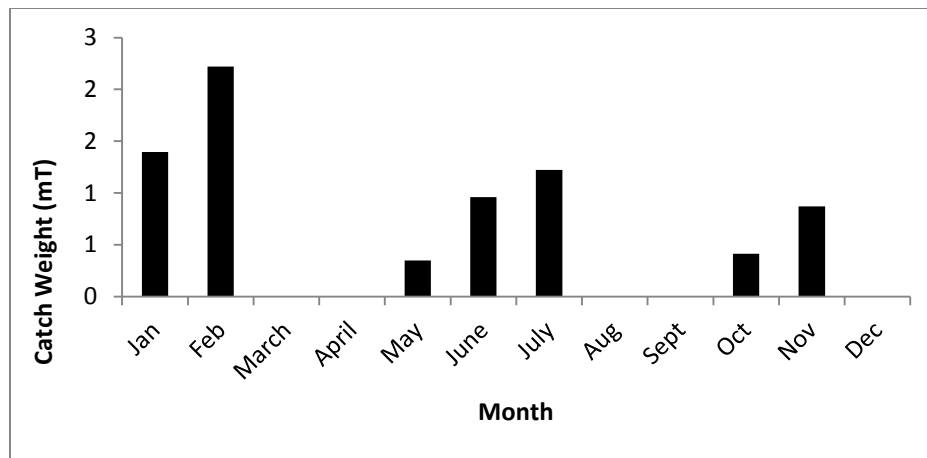
**Figure 4.13 Annual Northern Shrimp Harvest from May to December 2005 to 2010.**



Source: DFO (2013).

**Figure 4.14 Northern Shrimp Fishing Areas.**

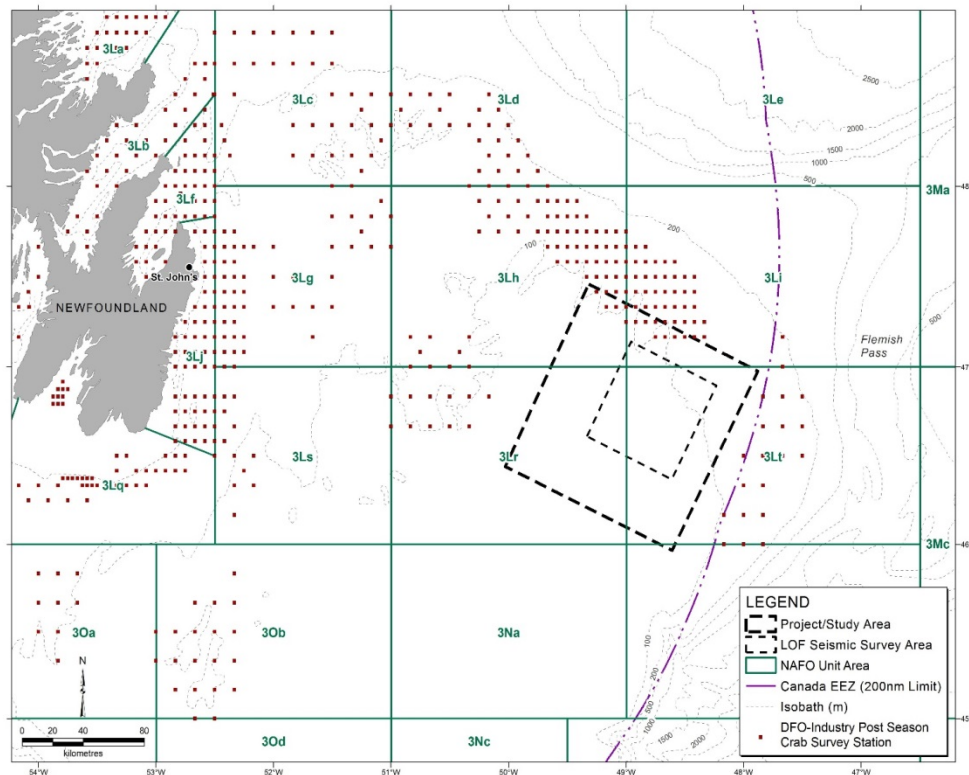




Source: DFO Commercial Fisheries Catch Data (2005-2010).

**Figure 4.15 Average Monthly Northern Shrimp Harvesting, 2005 to 2010.**

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. Only eight of the stations fall within HMDC's Study Area. Research stations are shown in Figure 4.16.



Source: DFO 2013.

**Figure 4.16 DFO-Industry Post-season Crab Survey Locations, 2013.**

#### **4.3.6 Concluding Summary of Commercial Fisheries in Study Area**

While the species discussed in this Section have been commercially harvested in the Study Area to varying degrees, there have been few reported harvests from 2005 to 2010 within the Project Area and none within the proposed Seismic Survey Area. The probability of interaction with fishers, fishing gear, and/or harvests during the proposed seismic surveys is low. The proposed seismic surveys will likewise pose little to no potential conflict with post-season crab surveys, as there are no survey locations within the Project or proposed Seismic Survey Areas. This statement will continue to be validated for future surveys.

Interactions with commercial fisheries will be addressed in the Fishery VEC Section (Section 5.6.2).

### **4.4 Seabirds**

#### **4.4.1 Seabird Surveys in the Study Area**

Seabird surveys in the Study Area and surrounding areas have been conducted by the Canadian Wildlife Service (CWS) and oil industry related seabird monitoring programs. Prior to 2000, seabird surveys were sparse on the Orphan Basin, northern Grand Banks and Flemish Cap. Original baseline information has been collected by the CWS through PIROP (Programme intégré de recherches sur les oiseaux pélagiques). These data have been published for 1969-1983 (Brown 1986) and up to the early 1990s (Lock et al. 1994). Since the late 1990s, additional seabird observations have been collected on the NE Grand Banks by the offshore oil and gas industry from drill platforms and supply vessels (Baillie et al. 2005; Burke et al. 2005; Fifield et al. 2009). From 2005 to 2008, seabird surveys were conducted from vessels conducting seismic surveys on the northern Grand Banks as part of the marine bird monitoring and mitigation programs required by C-NLOPB (Abgrall et al. 2008a, 2009). These surveys were conducted in the months of May to November. The CWS also initiated the Eastern Canadian Seabirds at Sea (ECSAS) surveys of Newfoundland and Nova Scotia waters. The Environmental Studies Research Funds (ESRF) combined with CWS to fund a 3.5 year project focused on improving the knowledge of seabirds at sea on the northern Grand Banks and other areas of oil industry activity in eastern Canada (Fifield et al. 2009). A total of 76 surveys conducted in this time span include many from the Grand Banks and Orphan Basin. Monthly surveys were conducted including the NE Grand Banks production area from 2006 to 2009.

The results from all of the above surveys have been used to describe the abundance, diversity and spatial distribution of seabirds in the Study Area. The predicted monthly occurrences for each species expected to occur regularly in the Study Area are provided in Table 4.7.

**Table 4.7 Predicted Monthly Abundances of Seabird Species Occurring in the Study Area.**

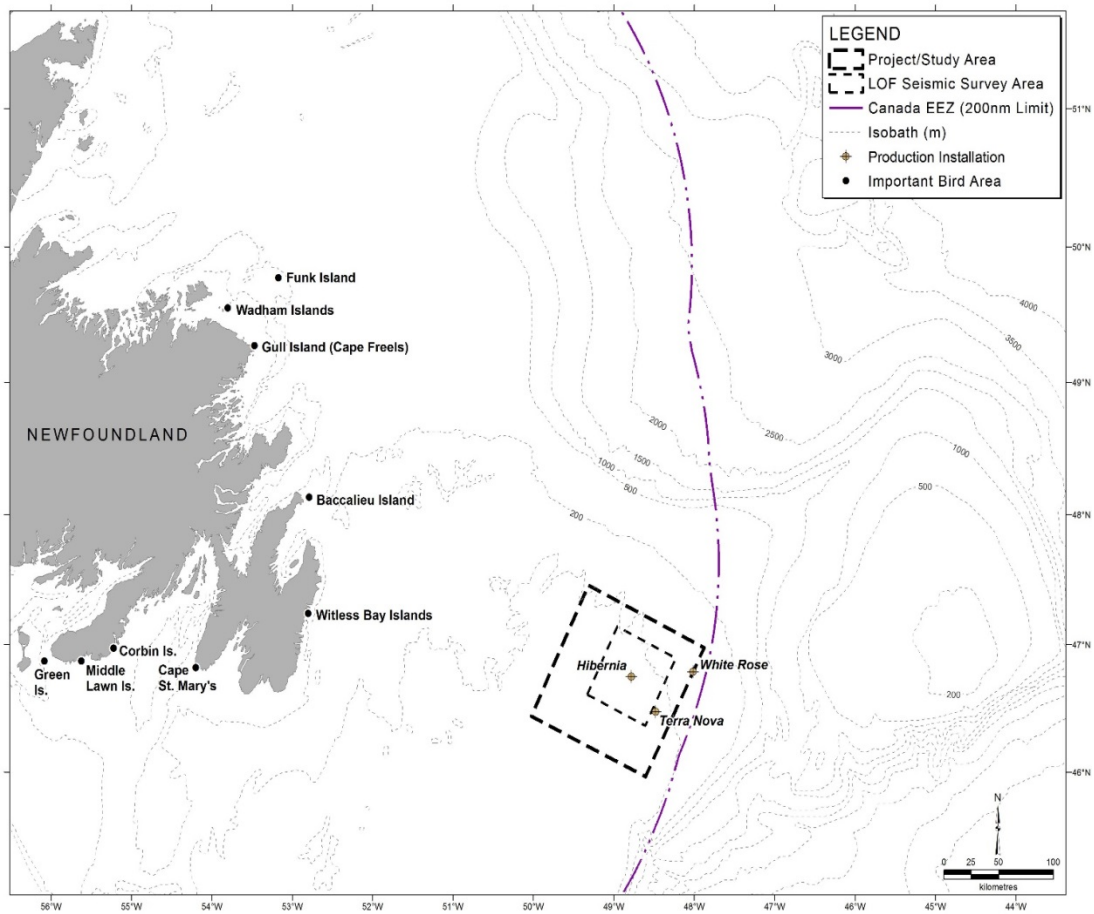
Common Name	Scientific Name	Monthly Abundance											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Procellariidae													
Northern Fulmar	<i>Fulmarus glacialis</i>	C	C	C	C	C	C	C	C	C	C	C	C
Great Shearwater	<i>Puffinus gravis</i>					U	C	C	C	C	C	S	
Sooty Shearwater	<i>Puffinus griseus</i>					S	S-U	S-U	S-U	S-U	S-U	S	
Manx Shearwater	<i>Puffinus puffinus</i>					S	S	S	S	S	S		
Hydrobatidae													
Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>				U-C	C	C	C	C	C	C	S	
Wilson's Storm-Petrel	<i>Oceanites oceanicus</i>						S	S	S	S			
Sulidae													
Northern Gannet	<i>Morus bassanus</i>				S	S	S	S	S	S	S		
Phalaropodinae (Scolopacidae)													
Red Phalarope	<i>Phalaropus fulicarius</i>					S	S	S	S	S	S		
Red-necked Phalarope	<i>Phalaropus lobatus</i>					S	S	S	S	S			
Herring Gull	<i>Larus argentatus</i>	U	U	U	U	U	S	S	S	S	S	S	S
Iceland Gull	<i>Larus glaucoides</i>	S	S	S	S						S	S	S
Lesser Black-backed Gull	<i>Larus fuscus</i>					VS	VS	VS	VS	VS	VS	VS	VS
Glaucous Gull	<i>Larus hyperboreus</i>	S	S	S	S						S	S	S
Great Black-backed Gull	<i>Larus marinus</i>	U	U	U	U	U	S	S	U	U	U	U	U
Ivory Gull	<i>Pagophila eburnea</i>	VS?	VS?	VS?	VS?								
Black-legged Kittiwake	<i>Rissa tridactyla</i>	C	C	C	C	C	S	S	S	U	C	C	C
Arctic Tern	<i>Sterna paradisaea</i>					S	S	S	S	S			
Stercorariidae													
Great Skua	<i>Stercorarius skua</i>					S	S	S	S	S	S		
South Polar Skua	<i>Stercorarius maccormicki</i>					S	S	S	S	S	S		
Pomarine Jaeger	<i>Stercorarius pomarinus</i>				S	S	S	S	S	S	S		
Parasitic Jaeger	<i>Stercorarius parasiticus</i>					S	S	S	S	S	S		
Long-tailed Jaeger	<i>Stercorarius longicaudus</i>					S	S	S	S	S			
Alcidae													
Dovekie	<i>Alle alle</i>	C	C	C	C	U	VS	VS	VS	S	C	C	C
Common Murre	<i>Uria aalge</i>	S-U	S-U	S-U	S-U	S	S	S	S	S	S-U	S-U	S-U
Thick-billed Murre	<i>Uria lomvia</i>	U-C	U-C	U-C	U-C	S-U	S-U	S-U	S-U	U-C	U-C	U-C	U-C
Razorbill	<i>Alca torda</i>				S	S	S	S	S	S	S	S	
Atlantic Puffin	<i>Fratercula arctica</i>				S	S	S	S	S	S-U	S-U	S-U	
Sources: Brown (1986); Lock et al. (1994); Baillie et al. (2005); Moulton et al. (2005, 2006); Lang et al. (2006); Lang (2007); Lang and Moulton (2008); Abgrall et al. (2008a, 2008b, 2009.)													
Notes: C = Common, present daily in moderate to high numbers; U = Uncommon, present daily in small numbers; S = Scarce, present, regular in very small numbers; VS = Very Scarce, very few individuals or absent. Blank spaces indicate not expected to occur in that month. Predicted monthly occurrences derived from 2004, 2005, 2006, 2007 and 2008 monitoring studies in the Orphan Basin and Jeanne d’Arc Basin and extrapolation of marine bird distribution at sea in eastern Canada in Brown (1986); Lock et al. (1994) and Fifield et al. (2009)													

#### 4.4.2 Breeding Seabirds in Eastern Newfoundland

Hundreds of thousands of pairs of seabirds nesting on the Avalon Peninsula reflect the richness of the offshore regions off southeastern Newfoundland. The seabird breeding colonies on Baccalieu Island, the Witless Bay Islands and Cape St. Mary's are among the largest in Atlantic Canada. More than 4.6 million pairs nest at these three locations alone (Table 4.8; Figure 4.17). This includes the largest Atlantic Canada colonies of Leach's Storm-Petrel (3,336,000 pairs on Baccalieu Island), Black-legged Kittiwake (23,606 pairs on Witless Bay Islands), Thick-billed Murre (1,000 pairs at Cape St. Mary's) and Atlantic Puffin (216,000 pairs on Witless Bay Islands). These birds and along with non-breeding seabirds feed on the Grand Banks during the nesting season from May to September. In addition, Funk Island, 150 km northwest of the Grand Banks supports the largest colony of Common Murre (412,524 pairs) in Atlantic Canada (Chardine et al. 2003). Many of these birds could reach the Study Area in the non-breeding season.

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

Species	Wadham Islands	Funk Island	Cape Freels and Cabot Island	Baccalieu Island	Witless Bay Islands	Cape St. Mary's	Middle Lawn Island	Corbin Island	Green Island
Northern Fulmar	-	46 <sup>A</sup>	-	12 <sup>A</sup>	22 <sup>A,F</sup>	Present <sup>A</sup>	-	-	-
Manx Shearwater	-	-	-	-	-	-	13 <sup>K</sup>	-	-
Leach's Storm-Petrel	1,038 <sup>D</sup>	-	250 <sup>J</sup>	3,336,000 <sup>J</sup>	667,086 <sup>H,I,J</sup>	-	13,879 <sup>H</sup>	100,000 <sup>J</sup>	103,833 <sup>M</sup>
Northern Gannet		9,837 <sup>b</sup>		1,712 <sup>B</sup>	-	14,789 <sup>L</sup>	-	-	-
Herring Gull	-	500 <sup>J</sup>	-	Present <sup>A</sup>	4,638 <sup>e,j</sup>	Present <sup>J</sup>	20 <sup>J</sup>	5,000 <sup>J</sup>	Present <sup>mM</sup>
Great Black-backed Gull	Present <sup>D</sup>	100 <sup>J</sup>	-	Present <sup>A</sup>	166 <sup>E,J</sup>	Present <sup>J</sup>	6 <sup>J</sup>	25 <sup>J</sup>	-
Black-legged Kittiwake	-	810 <sup>J</sup>	-	12,975 <sup>J</sup>	23,606 <sup>F,J</sup>	10,000 <sup>J</sup>	-	50 <sup>J</sup>	-
Arctic and Common Terns	376 <sup>J</sup>	-	250 <sup>J</sup>	-	-	-	-	-	-
Common Murre	-	412,524 <sup>C</sup>	2,600 <sup>J</sup>	4,000 <sup>J</sup>	83,001 <sup>F,J</sup>	15,484 <sup>J</sup>	-	-	-
Thick-billed Murre		250 <sup>J</sup>	-	181 <sup>J</sup>	600 <sup>J</sup>	1,000 <sup>J</sup>	-	-	-
Razorbill	273 <sup>D</sup>	200 <sup>J</sup>	25 <sup>J</sup>	100 <sup>J</sup>	676 <sup>F,J</sup>	100 <sup>J</sup>	-	-	-
Black Guillemot	25 <sup>J</sup>	1 <sup>J</sup>	-	100 <sup>J</sup>	20+ <sup>J</sup>	Present <sup>J</sup>	-	-	-
Atlantic Puffin	6,190 <sup>D</sup>	2,000 <sup>J</sup>	20 <sup>J</sup>	30,000 <sup>J</sup>	272,729 <sup>F,G,J</sup>	-	-	-	-
TOTALS	7,902	426,268	3,145	3,385,080	1,052,546	32,256	13,918	105,075	103,833
Sources: <sup>A</sup> Stenhouse and Montevecchi (1999); <sup>B</sup> Chardine (2000); <sup>C</sup> Chardine et al. (2003); <sup>D</sup> Robertson and Elliot (2002); <sup>E</sup> Robertson et al. (2001); <sup>F</sup> Robertson et al. (2004); <sup>G</sup> Rodway et al. (2003); <sup>H</sup> Robertson et al. (2002); <sup>I</sup> Stenhouse et al. (2000); <sup>J</sup> Cairns et al. (1989); <sup>K</sup> Robertson (2002); <sup>L</sup> CWS (unpubl. Data); <sup>M</sup> Russell (2008).									



**Figure 4.17 Locations of Seabird Nesting Colonies at Important Bird Areas (IBAs) Most Proximate to the Study Area.**

There are nine significant seabird nesting sites on the SE coast of Newfoundland from Cape Freels to the Burin Peninsula. Each meets the criteria for an Important Bird Area (IBA) (Figure 4.17). IBA is a site that provides essential habitat for one or more species of breeding or non-breeding birds. These sites may contain threatened species, endemic species, species representative of a biome, or highly exceptional concentrations of birds ([www.ibacanada.com](http://www.ibacanada.com)).

In addition to local breeding birds, there are many non-breeding seabirds on the Grand Banks during the summer months. A significant portion of the world's population of Great Shearwater is thought to migrate to the Grand Banks and eastern Newfoundland to moult and feed during the summer months after completion of nesting in the southern hemisphere (Lock et al. 1994). Depending on the species, seabirds require two to four years to become sexually mature. Many non-breeding sub-adult seabirds, notably Northern Fulmars and Black-legged Kittiwakes are present on the Grand Banks and Flemish Cap year round. During the non-breeding season large numbers of Arctic breeding Thick-billed Murre, Dovekie, Northern Fulmar and Black-legged Kittiwake migrate to eastern Newfoundland, including the Grand Banks and Flemish Cap to spend the winter.

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

#### **4.4.3 Seasonal Occurrence and Abundance of Seabirds**

The world range and seasonal occurrence and abundance of seabirds occurring regularly in the Study Area are described below. Table 4.7 summarizes the predicted abundance status for each species monthly. The table uses four categories to define a relative abundance of seabirds species observed:

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

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

Descriptions of seasonal distribution and abundance of seabirds is provided in summary form in the following Sections. These are based on Husky's seismic study area which encompasses the smaller HMDC seismic Study Area (for additional detail see appended LGL 2012, especially Section 4.4.3).

##### **4.4.3.1 *Procellariidae (fulmars and shearwaters)***

Northern Fulmar is common in the Study Area year round. The Northern Fulmar breeds in the N Atlantic, N Pacific, and Arctic oceans. In the Atlantic, it winters south to North Carolina and southern Europe (Brown 1986; Lock et al. 1994). Through band recoveries, it is known that most individuals in Newfoundland waters are from Arctic breeding colonies. Adults and sub-adult birds are present in the winter with sub-adults remaining through the summer. About 80 pairs breed in eastern Newfoundland (Stenhouse and Montevecchi 1999; Robertson et al. 2004). Fulmars were found to be most numerous during spring and autumn 1999 to 2002 on the NE Grand Banks, based on observations from drill rigs (Baillie et al. 2005). Results from the Jeanne d'Arc Basin 2005, 2006 and 2008 show an average of 5.06 birds/km<sup>2</sup> for July and August 2006, an average of 1.24 birds/km<sup>2</sup> late May to September 2008, and 14.72 birds/km<sup>2</sup> in October and early November in 2005.

The CWS ECSAS survey data from 2006-2009 in the Study Area show Northern Fulmar was present during all seasons (spring, summer and winter) surveyed (Fifield et al. 2009). Northern Fulmar is expected to be common year round in the Study Area.

Great Shearwater migrate north from breeding islands in the S Atlantic and arrive in the northern hemisphere during summer. A large percentage of the world population of Great Shearwaters is thought to moult their flight feathers during the summer month while in Newfoundland waters (Brown 1986; Lock et al. 1994). Seismic monitoring on the Jeanne d'Arc Basin showed Great Shearwater were common in summer with a mean weekly density of 5.06 birds/km<sup>2</sup> from 9 July to 16 August 2006 (Appendix 4 in LGL 2012 appended).

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

#### **4.4.3.2 *Hydrobatidae (storm-petrels)***

Leach's Storm-Petrel is common in offshore waters of Newfoundland from April to early November. Very large numbers nest in eastern Newfoundland with more than 3,300,000 pairs breeding on Baccalieu Island (see Table 4.8). Adults range far from nesting sites on multiday foraging trips during the breeding season. Non-breeding sub-adults stay at sea during the breeding season. Leach's Storm-Petrel is widespread in Newfoundland waters. Densities of Leach's Storm-Petrels during seismic surveys on the Jeanne d'Arc Basin averaged of 0.60 birds/km<sup>2</sup> during the survey period 9 July to 16 August 2006 (Appendix 4 in LGL 2012 appended).

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

#### **4.4.3.3 *Sulidae (gannets)***

More than 26,000 pairs of Northern Gannets nest on three colonies in eastern Newfoundland (see Table 4.8). Gannets are common near shore and scarce beyond 100 km from shore. The Study Area is beyond the range of most Northern Gannets. It is expected to be a scarce visitor from April to October within the Study Area.

#### **4.4.3.4 *Phalaropodinae (phalaropes)***

The Red Phalarope and Red-necked Phalarope both breed in the Arctic to sub-Arctic regions of N America and Eurasia. They winter at sea mostly in the southern hemisphere. They migrate and feed offshore, including Newfoundland waters during their spring and autumn migrations. Phalaropes seek out areas of upwelling and convergence where rich sources of zooplankton are found. Small numbers of migrant Red Phalaropes and Red-necked Phalaropes have been observed in the Orphan Basin and northern Grand Banks during monitoring surveys on geophysical survey vessels, 2005-2008 (Abgrall et al. 2008a, 2009) in the Study Area during spring and fall migration. Phalaropes are expected to be very scarce in the Study Area during May to October.

#### 4.4.3.5 *Laridae (gulls and terns)*

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

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

Great Black-backed Gull is usually the most numerous of the large gulls found in the offshore regions of Newfoundland. On drilling platforms on the NE Grand Banks during 1999 to 2002, Great Black-backed Gull was common from September to February and nearly absent from March to August (Baillie et al. 2005). A similar pattern was observed by environmental observers on offshore installations on the Terra Nova oil field from 1999 to 2009 (Suncor, unpubl. data). The ECSAS survey data from 2006-2009 in the Study Area show 'large gulls' were present during all seasons (spring, summer, fall and winter) surveyed (Fifield et al. 2009). Herring Gulls were present in consistent numbers throughout the year but in lower numbers than Great Black-backed Gulls. Results from seismic monitoring programs in Jeanne d'Arc Basin between May and October showed that large gulls were most numerous from mid-August to October (Appendix 4 in LGL 2012).

##### **Black-legged Kittiwake**

Black-legged Kittiwake is an abundant species in the N Atlantic Ocean. It is a pelagic gull that goes to land only during the nesting season. Non-breeding sub-adults remain at sea for the first year of life. Black-legged Kittiwake is expected to be present within the Study Area year round, and most numerous during the non-breeding season (August to May). Black-legged Kittiwake is present in all months of the year on the Grand Banks. Observations from the drilling platforms on the NE Grand Banks during 1999 to 2002 showed Black-legged Kittiwakes were present in October to May, but were most prevalent during November to December (Baillie et al. 2005). It was among the most numerous species observed by environmental observers on offshore installations on the Terra Nova oil field during the winter months (Suncor, unpubl. data). In the Jeanne d'Arc Basin, highest densities were observed in October and November vs. summer months (Appendix 4 in LGL 2012 appended).

##### **Ivory Gull**

Concerns over reduced numbers of Ivory Gulls at known breeding colonies in the Canadian Arctic have resulted in COSEWIC listing it as *endangered*. This species is discussed further in Section 4.6.



#### **4.4.3.6 *Stercorariidae (skuas and jaegers)***

##### **Great Skua and South Polar Skua**

These two skua species occur regularly but in very low densities in offshore waters of Newfoundland during the May to October period. The Great Skua breeds in the northern hemisphere, in Iceland and northwestern Europe. The South Polar Skua breeds in the southern hemisphere from November to March and migrates to the northern hemisphere where it is present May to October. Identifying skuas to species is very difficult at sea. They usually occur where other marine birds are numerous, particularly along shelf edges.

Skuas occurred in such low densities that they were infrequently recorded during systematic surveys on during monitoring surveys on the Jeanne d’Arc Basin in 2005-2008 (Abgrall et al. 2008a, 2009). Skuas are expected to be scarce in the Study Area from May to October, or early November.

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

All three species of jaeger nest in the subarctic and Arctic in N America and Eurasia. They winter at sea in the Pacific and Atlantic oceans. Pomarine and Parasitic Jaegers winter mainly south of 35°N, while Long-tailed Jaegers winter mainly south of the equator. The three species of jaeger are relatively easy to identify in adult plumage but difficult in sub-adult plumages. Adults migrate through Newfoundland waters in spring and late summer and fall, while sub-adults migrate only part way to the breeding grounds and are present in Newfoundland waters all summer. Like skuas, they are kleptoparasites, preying chiefly on Black-legged Kittiwakes and Arctic Terns. The Long-tailed Jaegers also often hunt for fish and invertebrates on their own. Because of the low densities of jaegers they are infrequently recorded on systematic surveys. All three jaeger species were observed in low densities during monitoring programs on the Jeanne d’Arc Basin in 2005, 2006 and 2008 (Appendix 4 in LGL 2012 appended) (Abgrall et al. 2008a, 2009). Jaegers are expected to be scarce in the Study Area from May to October or early November.

##### **Arctic Tern**

Arctic Tern is the only species of tern expected in offshore waters of Newfoundland. It breeds in sub-Arctic to Arctic regions of N America and Eurasia. It winters at sea in the southern hemisphere. It migrates in small numbers through the Study Area from May to September. During Husky’s seismic program (9 July to 16 August 2006) a total of 10 Arctic Terns and 15 unidentified terns (probably Arctic) were observed during systematic and incidental observations (Abgrall et al. 2008a).

#### **4.4.3.7 *Alcidae (Dovekie, murre, Black Guillemot, Razorbill and Atlantic Puffin)***

There are six species of alcids breeding in the N Atlantic. All of these except for Dovekie nest in large numbers in eastern Newfoundland (see Table 4.8). Dovekies nest mainly in Greenland. Dovekie,

Common Murre, Thick-billed Murre and Atlantic Puffin occur in the Study Area during part of the year. Black Guillemot and Razorbills are more coastal and are expected to be rare within the Study Area.

### **Dovekie**

Dovekie breeds in the N Atlantic, primarily in Greenland and east Nova Zemlya, Jan Mayen and Franz Josef Land in northern Russia. This species winters at sea south to 35°N. The Dovekie is a very abundant bird, with a world population estimated at 30 million (Brown 1986). A large percentage of the Greenland-breeding Dovekies winter in the western Atlantic, mainly off Newfoundland (Brown 1986). The predicted status in the Study Area is common from October to April, uncommon during the end of spring migration in May and at the beginning of fall migration in September, and very scarce during the summer months (June to August; LGL 2012; Fifield et al. 2009).

### **Murres**

The two species of murre, Common and Thick-billed, are often difficult to identify with certainty at sea so are often grouped as “murres” during offshore seabird surveys. Common Murre is an abundant breeding species in eastern Newfoundland with just over a half million pairs nesting (see Table 4.8). These birds spend the winter from eastern Newfoundland south to Massachusetts. Thick-billed Murre is an uncommon breeder in eastern Newfoundland. However, Newfoundland waters are an important wintering area for many of the two million pairs breeding in Arctic Canada and Greenland.

Global location sensors deployed on ten Common Murre during the breeding season at Funk Island showed the birds were present on the Grand Banks year round particularly at the shelf edge (Hedd et al. 2011). All ten birds were present on the Jeanne d’Arc Basin area in November and December. The predicted status of Common Murre in the Study Area is scarce to uncommon October to April and scarce from May to August. The predicted status of Thick-billed Murre in the Study Area is uncommon to common October to April and scarce from May to August.

### **Other Alcids**

Atlantic Puffins winter off southern Newfoundland and Nova Scotia and they occur in low densities as far offshore as the Study Area. Non-breeding sub-adults occur throughout the summer whereas adults and juveniles can occur in late summer and fall. As expected, very low densities of puffins were recorded during surveys conducted from mid-May to late September in the Jeanne d’Arc basin (Appendix 4 in LGL 2012 appended). Densities of Atlantic Puffins increased in October and November in Jeanne d’Arc Basin (Appendix 4 in LGL 2012). Within the Study Area, Atlantic Puffin is expected to be scarce during the breeding season (April to August) and scarce to uncommon during the post-breeding season September to November. Razorbills tend to occur closer to shore than the murres. Very few were recorded during monitoring programs on the Jeanne d’Arc Basin in 2005-2008 between mid-May and early-November (Appendix 4 in LGL 2012). Razorbill is expected to be very scarce in the Study Area during April to November and absent during December to March. Black Guillemot is common near shore in Newfoundland and Labrador but would not be expected as far offshore as the Study Area.

#### **4.4.4 Prey and Foraging Habits**

Marine birds in the Study Area consume a variety of prey ranging from small fish to zooplankton. Different foraging methods include plunge diving from a height of 30 m into the water, feeding on the surface, and sitting on the water then diving. Table 4.9 summarizes the feeding habits of birds expected to occur in the Study Area.

##### **4.4.4.1 *Procellariidae (fulmar and shearwaters)***

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

##### **4.4.4.2 *Sulidae (Northern Gannet)***

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

##### **4.4.4.3 *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. The head probably rarely goes beneath surface.

##### **4.4.4.4 *Hydrobatidae (storm-petrels)***

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

##### **4.4.4.5 *Laridae (skuas, jaegers, gulls, terns)***

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

**Table 4.9 Foraging Strategy and Prey of Seabirds in the Study Area.**

Species	Prey	Foraging Strategy	Time with Head Under Water	Depth (m)
<b><i>Procellariidae</i></b>				
Northern Fulmar	Fish, cephalopods, crustaceans, zooplankton, offal	Surface feeding	Brief	1-2
Great Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	Usually < 2, recorded maximum of 18.
Sooty Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	Usually <10, maximum recorded 60.
Manx Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
<b><i>Hydrobatidae</i></b>				
Wilson's Storm-Petrel	Crustaceans, zooplankton	Surface feeding	Brief	<0.5
Leach's Storm-Petrel	Crustaceans, zooplankton	Surface feeding	Brief	<0.5
<b><i>Sulidae</i></b>				
Northern Gannet	Fish, cephalopods	Deep plunge diving	Brief	10
<b><i>Phalaropodinae</i></b>				
Red Phalarope	Zooplankton, crustaceans	Surface feeding	Brief	0
Red-necked Phalarope	Zooplankton, crustaceans	Surface feeding	Brief	0
<b><i>Laridae</i></b>				
Great Skua	Fish, cephalopods, offal	Kleptoparasitism	Brief	< 0.5
South Polar 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
Herring Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	< 0.5
Iceland Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	< 0.5
Glaucous Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	< 0.5
Great Black-backed Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	< 0.5
Ivory Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	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
<b><i>Alcidae</i></b>				
Dovekie	Crustaceans, zooplankton, fish	Pursuit diving	Prolonged	Max 30, average is < 30
Common Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100 , average 20-50
Thick-billed Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100 , average 20-60
Razorbill	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 120, average 25
Atlantic Puffin	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 60, average < 60

Sources: Cramp and Simmons (1983); Nettleship and Birkhead (1985); Lock et al. (1994); Gaston and Jones (1998), Ronconi et al. (2010a, b).

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

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

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

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

#### **4.4.4.6 *Alcidae (Dovekie, murre, 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 feed on zooplankton including larval fish. They can dive down to 30 m and remain under water up to 41 seconds, but average dives are somewhat shallower and shorter in duration (Gaston and Jones 1998). Common Murre and Thick-billed Murre have been recorded diving to 100 m but 20-60 m is thought to be average. Dives have been timed up to 202 seconds but 60 seconds is closer to average (Gaston and Jones 1998). Razorbill has been recorded diving to 120 m but 25 m is thought to be more typical with time under water about 35 seconds (Gaston and Jones 1998). Black Guillemot usually feeds in water <30 m in depth but in deep water has been recording diving to 50 m with a maximum 147 seconds under water. Average depth and duration of dives is expected to be less (Gaston and Jones 1998). Atlantic Puffin will dive to 60 m but 10 to 45 m is thought to be typical. Maximum length of time recorded under water is 115 seconds but a more typical dive would be about 30 seconds.

#### **4.4.5 Concluding Summary of Seabirds in Study Area**

The northeast Grand Banks is an important feeding, migratory and over-wintering area for seabirds. At least 26 species of seabirds occur in the HMDC Study Area.

The groups of seabirds potentially most sensitive to seismic survey activities are probably the storm petrels and the alcids. The former because they have a tendency to strand on lighted vessels at night particularly in times of low visibility, and the latter because they spend more time underwater than the other species. These interactions are addressed in the effects Section (Section 5.6.3). Storm petrels are likely the most common bird species in the Study Area during the proposed time frame of the Project. Murres occur in very high numbers in the Study Area but are relatively scarce during the timeframe of

the proposed surveys. Other alcids may occur there but not in large numbers since many of them are found closer inshore.

## 4.5 Marine Mammals and Sea Turtles

### 4.5.1 Marine Mammals

Much of the information on marine mammal occurrence and abundance in the Study Area is based upon the results of marine mammal monitoring for seismic surveys in Jeanne d’Arc basin and adjacent areas (e.g., Moulton et al. 2005, 2006; Abgrall et al. 2008a,b; 2009). There are also sighting data (incidental and systematic) compiled by DFO. Recent exploration and drilling EAs and their amendments for Jeanne d’Arc Basin (LGL 2008a, 2011a, 2012), and the northern Grand Banks (LGL 2011b) have provide up to date information on marine mammals. The following “biological background” overview of marine mammal species likely to occur in the Study Area summarizes relevant information with particular focus on spatial and temporal distribution and life history parameters.

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

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

1. The sighting data have not yet been completely error-checked;
2. The quality of some of the sighting data is unknown;
3. Most data have been gathered from platforms of opportunity that were vessel-based. The inherent problems with negative or positive reactions by cetaceans to the approach of such vessels have not yet been factored into the data;
4. Sighting effort has not been quantified (i.e., the numbers cannot be used to estimate true species density or abundance for an area);
5. Both older and some more recent survey data have yet to be entered into this database. These other data will represent only a very small portion of the total data;
6. Numbers sighted have not been verified (especially in light of the significant differences in detectability among species);
7. For completeness, these data represent an amalgamation of sightings from a variety of years and seasons. Effort (and number of sightings) is not necessarily consistent among months, years, and areas. There are large gaps between years. Thus seasonal, depth, and distribution information should be interpreted with caution; and
8. Many sightings could not be identified to species, but are listed to the smallest taxonomic group possible.

#### **4.5.1.1 Overview of Marine Mammals**

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

A summary of the prey of marine mammals that occur in the Study Area is summarized in Table 4.14 in LGL (2008a). For most species of marine mammals there are no reliable population estimates for Atlantic Canada; most estimates are based on data collected in northeastern U.S. waters. Thus, Waring et al. (2011) was reviewed to acquire updated population estimates for cetaceans considered a part of the Western N Atlantic stock.

The summary of sightings below combines the data sources described above as well as historical and new sightings from commercial whaling, fisheries observers, MMOs aboard seismic vessels, and the general public. Within the Study Area, sighting dates ranged from 1961 to 2009 and included baleen whales, large toothed whales, and dolphins and porpoises (Figure 4.18). These data are summarized in Table 4.11.

#### **4.5.1.2 Baleen Whales (Mysticetes)**

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

#### **Fin Whale**

The Atlantic population of fin whale is currently designated as *special concern* under Schedule 1 of SARA and by COSEWIC (Table 4.10). Fin whales are distributed throughout the world's oceans, but are most common in temperate and Polar Regions (Jefferson et al. 2008). Fin whales were heavily targeted by commercial whalers in Newfoundland and Labrador, and the current estimate for the western N Atlantic stock is 3,985 individuals (CV=0.24; Waring et al. 2011). Fin whales continue to regularly occur in Newfoundland and Labrador waters, particularly during summer months. Based on the DFO cetacean sightings database, fin whales have been sighted in the Study Area (Figure 4.18) from June to September (Table 4.11). Fin whales were also sighted during a recent Statoil/Husky seismic monitoring program in Jeanne d'Arc Basin (Abgrall et al. 2009).

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

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

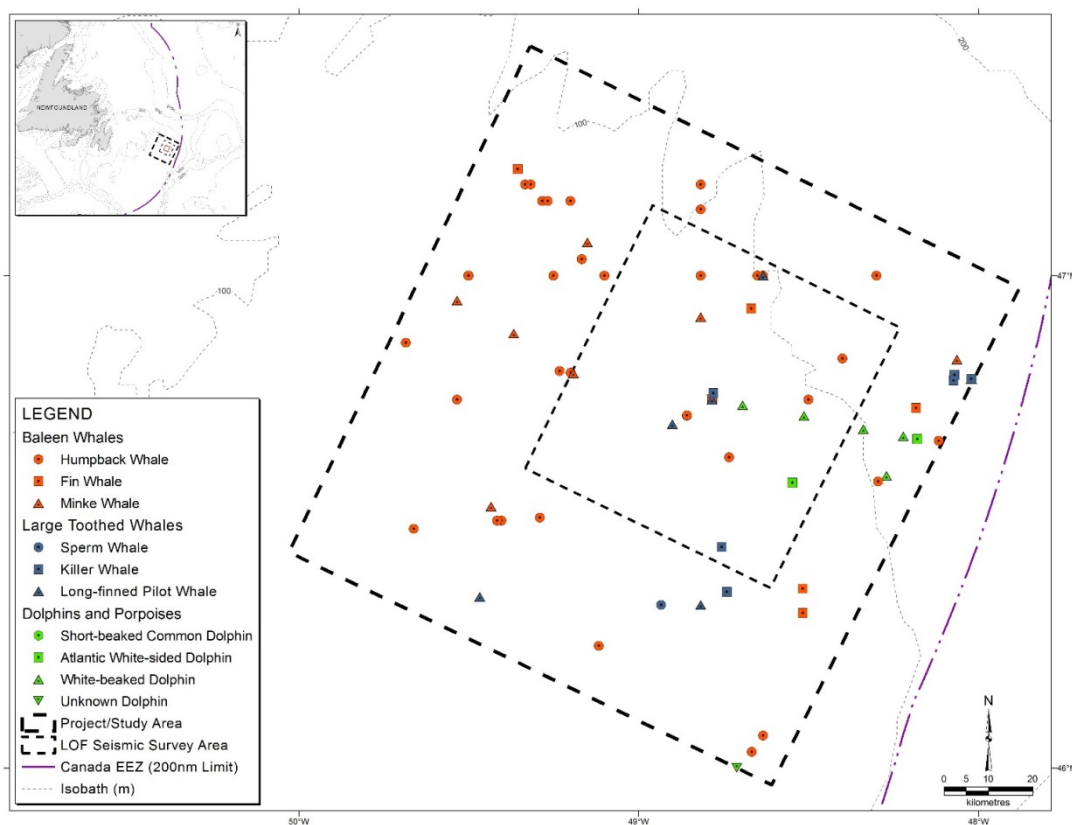
Notes: E=Endangered, T=Threatened, SC=Special Concern, NAR=Not at Risk, NC=Not Considered, DD=Data Deficient, NS=No Status, LPC=Low Priority Candidate, MPC=Medium Priority Candidate. ? indicates uncertainty.

<sup>a</sup> [www.sararegistry.gc.ca/default\\_e.cfm](http://www.sararegistry.gc.ca/default_e.cfm), accessed November 2012.

<sup>b</sup> [www.cosewic.gc.ca/eng/sct5/index\\_e.cfm](http://www.cosewic.gc.ca/eng/sct5/index_e.cfm), accessed November 2012.

<sup>c</sup> Davis Strait population.





Source: DFO sightings database.

**Figure 4.18 Marine Mammal Sightings within the HMDC Project/Study Areas.**

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

Species	Number of Sightings	Minimum Number of	Months Observed
<b><i>Mysticetes</i></b>			
Humpback Whale	85	279	March-Dec
Fin Whale	6	14	June-July; Sept
Minke Whale	13	20	May-Oct; Dec
<b><i>Large Odontocetes</i></b>			
Sperm Whale	1	1	Aug
Killer Whale	6	26	May-June; Aug; Oct-
Long-finned Pilot Whale	6	24	March; July; Sept
<b><i>Delphinids</i></b>			
Short-beaked Common Dolphin	1	90	March
Atlantic White-sided Dolphin	3	19	July-Aug
White-beaked Dolphin	5	34	Aug
<b><i>Unidentified Cetaceans</i></b>			
Unidentified Dolphin	2	21	Aug
Unidentified Cetacean	17	24	June-Oct

Source: DFO sightings database.

## Humpback Whale

The humpback whale is cosmopolitan in distribution and is most common over the continental shelf and in coastal areas (Jefferson et al. 2008). There are an estimated 11,570 individuals in the N Atlantic (Stevick et al. 2003). Based on aerial surveys conducted off the south and northeast coast of Newfoundland, an estimated 1,427 humpback whales occur there (Table 6 in Lawson and Gosselin 2009). In eastern Canada, humpback whales are considered *special concern* on Schedule 3 of the SARA and are considered *not at risk* by COSEWIC. Humpback whales migrate annually from high-latitude summer foraging areas to Caribbean breeding grounds in the winter. Primary feeding areas in the N Atlantic have been described using genetic and individual identification data as the Gulf of Maine eastern Canada, west Greenland, and the NE Atlantic (Stevick et al. 2006). Humpback whales are common over the banks and nearshore areas of Newfoundland and Labrador from June through September, sometimes forming large aggregations to feed primarily on spawning capelin, sand lance, and krill. Humpbacks are the most commonly recorded mysticetes on the Grand Banks, with sightings occurring year-round (see Tables 4.10 and 4.11), but predominantly during summer. In the Study Area they have been reported from March to December (see Table 4.11).

## Sei Whale

Sei whale distribution is poorly known, but it occurs in all oceans and appears to prefer mid latitude temperate waters (Jefferson et al. 2008). In the Canadian Atlantic, sei whales have no status under SARA and are considered *data deficient* by COSEWIC. Two stocks of sei whales are currently considered to occur in eastern Canada, on the Scotian Shelf and in the Labrador Sea, although there is limited evidence supporting the definition of the Labrador Sea stock (COSEWIC 2003a). The best estimate of abundance for the Nova Scotia stock of sei whales is 386 (CV=0.85; Waring et al. 2011). Satellite telemetry data showed that sei whales migrated from the southeast N Atlantic to the Labrador Sea, suggesting a productive feeding ground for sei whales in that area (Olsen et al. 2009; Prieto et al. 2010). Sei whales were regularly sighted in the Orphan Basin during the Chevron seismic monitoring programs in 2004 and 2005 (6 and 15 sightings, respectively; Moulton et al. 2005, 2006), and one sei whale sighting was recorded in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009). Based on the DFO cetacean sightings database, no sei whale sightings have been reported in the Study Area (see Figure 4.18; Table 4.11). Sei whales appear to prefer offshore, pelagic, deep areas that are often associated with the shelf edge, and feed primarily on copepods (COSEWIC 2003a).

## Minke Whale

The smallest of the baleen whales, minke whales have a cosmopolitan distribution and use polar, temperate, and tropical regions (Jefferson et al. 2008). Minke whales have no status under SARA and are considered *not at risk* in the Atlantic by COSEWIC. There are four populations recognized in the N Atlantic based on feeding areas, including the Canadian east coast, west Greenland, central N Atlantic, and NE Atlantic stocks (Donovan 1991). However, DNA data suggest that there may be as few as two different stocks in the N Atlantic (Anderwald et al. 2011). There are an estimated

8,987 individuals (CV=0.32) in the Canadian east coast stock, which ranges from the continental shelf of the northeastern United States to the eastern half of Davis Strait (Waring et al. 2011). Minke whales are common over the banks and coastal regions of Newfoundland and Labrador from early spring to fall, arriving as early as April and remaining as late as October and November. Within the Study Area, minke whales were the second most commonly recorded mysticetes in the DFO sightings database, with sightings predominantly recorded during May-October and December (see Figure 4.18; Table 4.11). Thirty-one sightings of minke whales were recorded in Jeanne d’Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009). Minke whales tend to forage in continental shelf waters on small schooling fish like capelin and sand lance, making relatively short duration dives (Stewart and Leatherwood 1985).

#### **4.5.1.3 Toothed Whales (Odontocetes)**

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

#### **Sperm Whale**

The sperm whale is most common in tropical and temperate waters, but is widely distributed and occurs from the edge of the polar pack ice to the equator (Jefferson et al. 2008). Sperm whales have no status under SARA and are designated *not at risk* by COSEWIC. They are currently considered a *low priority candidate species* by COSEWIC. Whitehead (2002) estimated a total of 13,190 sperm whales for the Iceland-Faroes area, the area north of it, and the east coast of N America combined, but Waring et al. (2011) reported an estimate of 4,804 animals (CV=0.38) for the N Atlantic. Since males tend to range further north (Whitehead 2003), any sperm whales encountered in the Study Area are more likely to be single males. However, mixed groups with females and juveniles have occasionally been observed in higher latitudes, and males can still form large same-sex aggregations (Whitehead and Weilgart 2000; Whitehead 2003). Sperm whales appear to prefer deep waters off the continental shelf, particularly areas with high secondary productivity, steep slopes, and canyons that may concentrate their primary prey of large-bodied squid (Jaquet and Whitehead 1996; Waring et al. 2001). Sperm whales are deep divers, routinely diving to hundreds of meters, sometimes to depths over 1,000 m and remaining submerged up to an hour (Whitehead and Weilgart 2000). Sperm whales were regularly sighted in the deep waters of Orphan Basin during the summers of 2004-2007 (Moulton et al. 2005, 2006; Abgrall et al. 2008b) but were not observed in the shallower waters of Jeanne d’Arc Basin in 2005-2008 (Lang et al. 2006; Lang and Moulton 2008; Abgrall et al. 2008a, 2009). There was one sighting of a sperm whale reported in the DFO cetacean sightings database that occurred in the Study Area in August (see Figure 4.18; Table 4.11).

#### **Northern Bottlenose Whale**

The distribution of northern bottlenose whales is restricted to the N Atlantic, primarily in deep, offshore areas with two regions of concentration: The Gully and adjacent submarine canyons on the eastern Scotian Shelf,

and Davis Strait off northern Labrador (Reeves et al. 1993). Throughout their range, northern bottlenose whales were harvested extensively during industrial whaling, which likely greatly reduced total numbers (COSEWIC 2002a; DFO 2011a). The total abundance of northern bottlenose whales in the N Atlantic is unknown, but ~163 individuals comprise the Scotian Shelf population (Whitehead and Wimmer 2005). There is no abundance estimate for Davis Strait, and few sightings were made during recent surveys (DFO 2011a). Although the Scotian Shelf population is designated *endangered* under Schedule 1 of SARA and by COSEWIC, the Davis Strait population has no status under SARA and is considered *special concern* by COSEWIC. The proposed recovery target for northern bottlenose whales is to increase population size and maintain the current distribution (DFO 2011a). Although the stock origin of northern bottlenose whales off Newfoundland and Labrador is unknown (DFO 2011a), it is expected that any whales in the Study Area would belong to the Davis Strait population. This population is considered to occur in that area year-round, with mating and births occurring between April and June, with a peak in April (COSEWIC 2002a; DFO 2011a). Occurring primarily in deep waters over canyons and the shelf edge, northern bottlenose whales routinely dive to depths over 800 m and remain submerged for over an hour (Hooker and Baird 1999). Foraging apparently occurs at depth, primarily on deep-water squid and fish (COSEWIC 2002a; DFO 2011a). Northern bottlenose whales may occur at low densities, but year-round, throughout the deep, offshore waters of the Orphan Basin and the Flemish Pass area. Based on the DFO cetacean sightings database, there have been no sightings of northern bottlenose whales in the Study Area (see Figure 4.18; Table 4.11). This species is not expected to occur in the shelf waters of the Study Area.

### **Sowerby's Beaked Whale**

The Sowerby's beaked whale is a small beaked whale found only in the N Atlantic, primarily in deep, offshore temperate to subarctic waters (COSEWIC 2006a). Designated as *special concern* (Schedule 1) under SARA and by COSEWIC, it is unclear if Sowerby's beaked whales are uncommon or poorly surveyed due to their deep-diving behaviour, small size, and offshore habitat. It is the most northerly distributed of the *Mesoplodon* spp., with all but one record occurring in the NW Atlantic between New England and Labrador (MacLeod 2000; MacLeod et al. 2006). There are an unknown number of Sowerby's beaked whales in the N Atlantic, but they are occasionally encountered offshore of eastern Newfoundland and Labrador. They are most often observed in deep water, along the shelf edge and slope. Based on analysis of stomach contents, their main prey type appears to be mid to deep water fish, with squid making up a small portion of the diet (MacLeod et al. 2003; Pereira et al. 2011). Despite the paucity of confirmed sightings, Sowerby's beaked whales may occur in low densities offshore of the Study Area. There were no records in the DFO cetacean sightings database for the Study Area (see Figure 4.18; Table 4.11).

### **Killer Whale**

Killer whales have a cosmopolitan distribution and occur in all oceans from polar pack ice to the equator, but they appear to be most common in coastal areas of higher latitudes (Jefferson et al. 2008). Killer whales offshore of eastern Newfoundland are likely members of the eastern Arctic or Atlantic populations, which were recently categorized as *special concern* by COSEWIC but have no status under SARA. An unknown number of killer whales occur in the NW Atlantic, but at least 63 individuals have been

identified in Newfoundland and Labrador (Lawson et al. 2007). Killer whale movements are generally related to the distribution and abundance of their primary prey, which can include fish, other marine mammals, seabirds, and cephalopods (Ford et al. 2000). In Newfoundland and Labrador, killer whales have been observed approaching, attacking, and/or consuming other cetaceans, seals, seabirds and several species of fish; however, it is not known if there is any prey specialization among killer whale groups or individuals (Lawson et al. 2007). Stable isotope analysis of samples from seven killer whales suggests that killer whales off Newfoundland and Labrador mainly feed on fish, although one individual was found to have fed mostly on baleen whales (Matthews and Ferguson 2011). Observed group sizes range from one to 60 individuals, averaging 5.1 whales (Lawson et al. 2007). Although they occur at relatively low densities, killer whales are considered year-round residents of NL (Lien et al. 1988; Lawson et al. 2007). Sightings seem to be increasing in recent years, but it is unclear if this is due to increasing abundance or observer effort. There were six killer whale sightings in the Study Area (see Figure 4.18); sightings in the DFO cetacean sightings database occurred sporadically from May through November (see Table 4.11). Four sightings of killer whales were recorded in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009).

### **Long-finned Pilot Whale**

The long-finned pilot whale is widespread in the N Atlantic and considered an abundant year-round resident of Newfoundland and Labrador (Nelson and Lien 1996). Long-finned pilot whales have no status under *SARA* and are considered *not at risk* by COSEWIC (see Table 4.10). An estimated 12,619 individuals (CV=0.37) occur in the NW Atlantic (Waring et al. 2011). Long-finned pilot whales were tied with sperm whales for the most commonly recorded toothed whale in the DFO cetacean database, occurring in the Study Area in March, July and September (see Figure 4.18; Table 4.11). Pilot whales studied near Nova Scotia had an average group size of 20 individuals, but groups ranged in size from 2 to 135 animals (Ottensmeyer and Whitehead 2003). Group sizes recorded in the Study Area ranged from 24 or more (see Table 4.11). 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).

### **Atlantic White-sided Dolphin**

Atlantic white-sided dolphins occur in temperate and sub-Arctic regions of the N Atlantic (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (see Table 4.10). There may be at least three distinct stocks in the N Atlantic, including the Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea areas, which combined are estimated to total ~63,368 animals (CV=0.27) in the NW Atlantic (Waring et al. 2011). However, their abundance off Newfoundland and Labrador is unknown. Atlantic white-sided dolphins occur regularly from spring to fall in offshore areas of Newfoundland, but less is known of their winter distribution. Sightings in the N Atlantic seem to coincide with the 100 m depth contour and areas of high relief. There were three sightings in the DFO cetacean sightings database in July-August in the Study Area (see Figure 4.18; Table 4.11).

## Short-beaked Common Dolphin

The short-beaked common dolphin is an oceanic species that is widely distributed in temperate to tropical waters of the Atlantic (and Pacific) Ocean (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (see Table 4.10). An estimated 120,743 individuals (CV=0.23) occur in the NW Atlantic (Waring et al. 2011). One sightings of this species was recorded in the Study Area in March in the DFO database (see Figure 4.18; Table 4.11).

## White-beaked Dolphin

White-beaked dolphins have a more northerly distribution than most dolphin species, occurring in cold temperate and sub-Arctic waters of the N Atlantic (Jefferson et al. 2008). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (see Table 4.10). Waring et al. (2011) estimated a total of 2,003 individuals (CV=0.94) in the NW Atlantic, but it is unknown how many occur off northeastern Newfoundland. Sightings of white-beaked dolphins are considered uncommon in the Study Area. There were five sightings recorded in the Study Area in August based on the DFO cetacean database (see Figure 4.18; Table 4.11). 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).

## Common Bottlenose Dolphin

This species is very widely distributed and is found most commonly in coastal and continental shelf waters of tropical and temperate regions (Jefferson et al. 2008). Bottlenose dolphins have no status under *SARA* and are considered *not at risk* by COSEWIC (see Table 4.10). An estimated 81,588 individuals (CV=0.17) occur in the NW Atlantic (Waring et al. 2011). It is considered rare in the Study Area; there were no sightings of bottlenose dolphins in the DFO cetacean database for the area (see Figure 4.18; Table 4.11). However, one sighting of 15 individuals was made to the north of the Study Area in Orphan Basin in September 2005 during the Chevron seismic monitoring program (Moulton et al. 2006).

## Striped Dolphin

The striped dolphin preferred habitat seems to be deep water along the edge and seaward of the continental shelf, particularly in areas with warm currents (Baird et al. 1993). This species has no status under *SARA* and is considered *not at risk* by COSEWIC (see Table 4.10). Offshore waters of Newfoundland are thought to be at the northern limit of its range. An estimated 94,462 individuals (CV=0.40) occur in the NW Atlantic (Waring et al. 2011). Although this species could occur in the Study Area, there were no sightings of striped dolphins recorded in the Study Area based on the DFO cetacean database (see Figure 4.18; Table 4.11).

## Harbour Porpoise

Harbour porpoises occur in continental shelf regions of the northern hemisphere, including from Baffin Island to New England in the NW Atlantic (Jefferson et al. 2008). There are at least three populations recognized in the NW Atlantic: eastern Newfoundland and Labrador, the Gulf of St. Lawrence, and the Gulf of Maine/Bay of Fundy (Palka et al. 1996). There are currently no range-wide population estimates for eastern Canada, largely due to a lack of any estimates for the Newfoundland and Labrador sub-population (COSEWIC 2006b). In the Atlantic, harbour porpoises are considered *threatened* (Schedule 2) on SARA and of *special concern* by COSEWIC. Limited information is available regarding distribution and movements of harbour porpoises in NL. Data on harbour porpoises incidentally caught in groundfish gillnets suggest that they occur around the entire island of Newfoundland and in southern Labrador (Lawson et al. 2004). Bycatch data also indicate that harbour porpoises occur as far north as Nain, and in deep water (>2,000 m) in the Newfoundland Basin and Labrador Sea (Stenson and Reddin 1990 in COSEWIC 2006b; Stenson et al. 2011). In general, harbour porpoises are primarily observed over continental shelves and in areas with coastal fronts or upwelling that concentrate small schooling fish, although sightings also occasionally occur in deeper waters (Read 1999). Harbour porpoises typically occur singly or in small groups of up to three individuals, occasionally occurring in larger groups (COSEWIC 2006b). There were no harbour porpoise sightings in the Study Area in the DFO cetacean sightings database (see Figure 4.18; Table 4.11).

### 4.5.1.4 True Seals (*Phocids*)

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

## Harp Seal

Harp seals are widespread in the N Atlantic and Arctic Ocean, ranging from northern Hudson Bay and Baffin Island to the western N Atlantic and the Gulf of St. Lawrence; vagrants have been reported as far south as Virginia (Scheffer 1958; Rice 1998). The total NW Atlantic population is estimated at 6.85 million seals in 2009 (Hammill and Stenson 2010). Harp seals are common during late winter/early spring off NE 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). Large concentrations are found on the sea ice off north-eastern Newfoundland where they moult during April and May (DFO 2010c). During the summer, the majority of harp seals migrate to Arctic and Greenland waters, but some harp seals remain in southern waters (DFO 2010c). Offshore areas of southern Labrador and eastern Newfoundland appear to be major wintering areas (Stenson and Sjøre 1997; Lacoste 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 NE Newfoundland/southern Labrador in late winter-early spring (Hammill and Stenson 2006). Four primary pupping and mating areas occur in the N Atlantic and include northeast Newfoundland/southern Labrador, the Gulf of St. Lawrence, Davis Strait, and NE Greenland (Jefferson et al. 2008). Hooded seals fitted with transmitters in the Gulf of St. Lawrence in March started their migration to Greenland in May by traveling through Cabot Strait or the Strait of Belle Isle (Bajzak et al. 2009). Hooded seals aggregate in eastern Greenland to moult during early summer before dispersing to Davis Strait or the Greenland Sea for late summer and fall (see Hammill and Stenson 2006). Less is known about winter distribution, although there have been winter sightings on the Grand Banks and in the Study Area; recent telemetry data suggests that hooded seals move along the continental shelf edge after leaving Greenland moulting grounds to Davis Strait and Baffin Bay followed by southerly migrations into the Labrador Sea during winter (Andersen et al. 2009).

## **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 348,900 grey seals occur in the NW Atlantic (Thomas et al. 2011). The majority breeds during the winter on Sable Island, south of Nova Scotia, but pups are also born in the Gulf of St. Lawrence, and along the coast of Nova Scotia (DFO 2010d). An unknown number range into eastern Newfoundland. Grey seals are considered rare in the Study Area.

### **4.5.2 Concluding Summary of Marine Mammals in Study Area**

Three species each of baleen whales, large toothed whales, dolphins, and seals have been reported in the Study Area. However, another 17 species of marine mammals could occur there at least sporadically and in low numbers, including several SARA Schedule 1 species. Potential interactions between the Project and marine mammals are discussed in Section 5.6.4.

### **4.5.3 Sea Turtles**

Sea turtles regularly occur on the Grand Banks and adjacent waters; three species could potentially occur within the Study Area although none have been recorded in the Study Area. Table 4.12 provides a summary of habitat, occurrence and status in the Project Area for leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and Kemp's Ridley sea turtles (*Lepidochelys kempii*). Of these species, the leatherback sea turtle is designated as *endangered* under COSEWIC and SARA (see Section 4.6 on Species at Risk for profile) and the loggerhead sea turtle is designated as *endangered* under COSEWIC but has no status under the SARA. Kemp's Ridley sea turtle has no status under SARA and has not been considered by COSEWIC.



**Table 4.12 Sea Turtles Potentially Occurring in the Study Area.**

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

<sup>a</sup> Species designation under the *Species at Risk Act*; E = Endangered, NS = No Status.

<sup>b</sup> Species designation by COSEWIC; E = Endangered, NC = Not Considered.

#### 4.5.3.1 Loggerhead Sea Turtle

Although the loggerhead sea turtle is the most common sea turtle in N American waters (Spotila 2004), it was recently designated as *endangered* by COSEWIC (2010). Its distribution is largely constrained by water temperature and it does not generally occur where the water temperature is below 15°C (O'Boyle 2001; Brazner and McMillan 2008), which limits its northern range. Loggerheads can migrate considerable distances between near-equatorial nesting areas and temperate foraging areas, some moving with the Gulf Stream into eastern Canada waters during the summer and fall (Hawkes et al. 2007). While foraging at sea, loggerheads likely consume gelatinous zooplankton and squid (Spotila 2004); there is no diet information available for Canadian waters (DFO 2010e). Information to date indicates a seasonal population of juvenile loggerheads in Atlantic Canada (COSEWIC 2010). Loggerheads may be seen in the open seas during migration and foraging (e.g., Mansfield et al. 2009). Although they have not been reported in the Study Area, juvenile loggerhead turtles tagged in U.S. waters were recorded just south of the Study Area (Mansfield et al. 2009). Most loggerhead records offshore Newfoundland have occurred in deeper waters south of the Grand Banks, and sightings have extended as far east as the Flemish Cap (Figures 6 and 7 in COSEWIC 2010).

#### 4.5.3.2 Kemp's Ridley Sea Turtle

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

#### 4.5.4 Concluding Summary of Sea Turtles in Study Area

Of the three species of sea turtle that could occur in the Study Area, leatherback sea turtles are the most likely species to occur there, albeit in small numbers. The leatherback is listed on SARA Schedule 1 as *endangered* and is described in the following Section on Species at Risk. Potential interactions between the Project and sea turtles are discussed in Section 5.6.4.

## 4.6 Species at Risk

A number of species are listed under the *Species at Risk Act* (SARA) on Schedules 1 to 3. However, only those designated as *endangered* or *threatened* on Schedule 1 (the official list of wildlife Species at Risk in Canada) have immediate legal implications. Two cetacean species/populations, one sea turtle species, one seabird species, and three fish species/populations are legally protected under SARA and have potential to occur in the Study Area (Table 4.13). Atlantic wolffish, the Atlantic population of fin whales and Sowerby's beaked whale are designated as *special concern* on Schedule 1 (Table 4.13). Schedules 2 and 3 of SARA identify species that were designated "at risk" by COSEWIC prior to October 1999 and must be reassessed using revised criteria before they can be considered for addition to Schedule 1. Species that potentially occur in the Study Area and are considered as *endangered*, *threatened* or species of *special concern* by COSEWIC but which have not received specific legal protection (i.e., proscribed penalties and legal requirement for recovery strategies and plans) under SARA are also listed in Table 4.13. These species are included since they may be designated under SARA in the future.

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 of the seven species currently designated as either *endangered* or *threatened* under Schedule 1 and potentially occurring in the Study Area: (1) the leatherback sea turtle (ALTRT 2006); (2) the spotted wolffish (Kulka et al. 2008), (3) the northern wolffish (Kulka et al. 2008), (4) the blue whale (Beauchamp et al. 2009), and (5) the North Atlantic right whale (Brown et al. (2009). A management plan has also been prepared for the Atlantic wolffish (Kulka et al. 2008), currently designated as *special concern* on Schedule 1.

HMDC will monitor SARA issues through the Canadian Association of Petroleum Producers (CAPP), the law gazettes, the Internet and communication with DFO and EC, and will adaptively manage any issues that may arise in the future. The company will comply with relevant regulations pertaining to SARA Recovery Strategies and Action Plans.

HMDC acknowledges the rarity of the Species at Risk and will continue to exercise due caution to minimize effects on them during all of its operations. HMDC also acknowledges the possibility of other marine species being designated as *endangered* or *threatened* on Schedule 1 during the course of the Project. Due caution will also be extended to any other species added to Schedule 1 during the life of this Project.

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

### 4.6.1 Profiles of SARA-listed Species

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

#### **4.6.1.1 Fish**

For the Study Area, only three fish species are listed as either *endangered* or *threatened* under Schedule 1 of the SARA. Profiles of these three species are provided in this Section. Some of the other fish species/populations that are included in Table 4.13 (i.e., Atlantic cod, roughhead grenadier, American plaice and redfishes) are profiled in Section 4.2.4 of the appended EA (LGL 2012).

#### **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 February 2015).

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 seven 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 February 2015).

White sharks are top level predators 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 February 2015).

White sharks were not caught in DFO RV surveys conducted in the Study Area during 2007 to 2011.

**Table 4.13 SARA- and COSEWIC-listed Marine Species that May Occur in the Study Area.**

SPECIES		SARA <sup>a</sup>			COSEWIC <sup>b</sup>		
Common Name	Scientific Name	Endangered	Threatened	Special Concern	Endangered	Threatened	Special Concern
<b>Marine Mammals</b>							
Blue whale (Atlantic population)	<i>Balaenoptera musculus</i>	Schedule 1			X		
North Atlantic right whale	<i>Eubalaena glacialis</i>	Schedule 1			X		
Fin whale (Atlantic population)	<i>Balaenoptera physalus</i>			Schedule 1			X
Sowerby's beaked whale	<i>Mesoplodon bidens</i>			Schedule 1			X
Harbour porpoise	<i>Phocoena phocoena</i>		Schedule 2				X
Humpback whale	<i>Megaptera novaeangliae</i>			Schedule 3			
<b>Sea Turtles</b>							
Leatherback sea turtle	<i>Dermochelys coriacea</i>	Schedule 1			X		
Loggerhead sea turtle	<i>Caretta caretta</i>				X		
<b>Fishes</b>							
White shark (Atlantic population)	<i>Carcharodon carcharias</i>	Schedule 1			X		
Northern wolffish	<i>Anarhichas denticulatus</i>		Schedule 1			X	
Spotted wolffish	<i>Anarhichas minor</i>		Schedule 1			X	
Atlantic wolffish	<i>Anarhichas lupus</i>			Schedule 1			X
Atlantic cod	<i>Gadus morhua</i>			Schedule 3			
Atlantic cod (NL <sup>c</sup> population)	<i>Gadus morhua</i>				X		
Cusk	<i>Brosme brosme</i>				X		
Porbeagle shark	<i>Lamna nasus</i>				X		
Roundnose grenadier	<i>Coryphaenoides rupestris</i>				X		
Shortfin mako shark	<i>Isurus oxyrinchus</i>					X	
Atlantic salmon (South Newfoundland population)	<i>Salmo salar</i>					X	
American plaice (NL population)	<i>Hippoglossoides platessoides</i>					X	
Acadian redfish (Atlantic population)	<i>Sebastes fasciatus</i>					X	
Deepwater redfish (Northern population)	<i>Sebastes mentella</i>					X	
Blue shark (Atlantic population)	<i>Prionace glauca</i>						X
Basking shark (Atlantic population)	<i>Cetorhinus maximus</i>						X
Roughhead grenadier	<i>Macrourus berglax</i>						X
Spiny dogfish (Atlantic population)	<i>Squalus acanthias</i>						X
Thorny skate	<i>Amblyraja radiata</i>						X
<b>Seabirds</b>							
Ivory Gull	<i>Pagophila eburnea</i>	Schedule 1			X		

Sources: <sup>a</sup>SARA website ([http://www.sararegistry.gc.ca/default\\_e.cfm](http://www.sararegistry.gc.ca/default_e.cfm)) (as of 1 March 2013); <sup>b</sup> COSEWIC website (<http://www.cosewic.gc.ca/index.htm>) (as of 1 March 2013); <sup>c</sup> Newfoundland and Labrador. COSEWIC candidate species not included in this table .

## **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. 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 in 2007-2011, one northern wolffish was caught, during a spring survey (2007). This single northern wolffish catch was located in the southeastern portion of the Study Area.

## **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 wolffish 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 in 2007-2011, two spotted wolffish were caught, during both spring (2007) and fall (2008) survey times. Both spotted wolffish catches were in the northeastern portion of the Study Area.

#### **4.6.1.2 Seabirds**

The Ivory Gull is the only seabird listed as either *endangered* or *threatened* under Schedule 1 of the SARA that could potentially occur in the Study Area.

#### **Ivory Gull**

The Ivory Gull has a circumpolar breeding distribution and is associated with pack ice throughout the year. In Canada, the Ivory Gull breeds exclusively in Nunavut. Breeding colonies occur on southeastern Ellesmere Island, eastern Devon Island and northern Baffin Island. In Canadian waters, Ivory Gulls occur among the pack ice of the Davis Strait, the Labrador Sea, Strait of Belle Isle, and northern Gulf of St. Lawrence. The Ivory Gull is listed as *endangered* on Schedule 1 of SARA, designated as *endangered* by COSEWIC, and considered *near threatened* on the Red List of Threatened Species (Table 4.14; IUCN 2009).

In comparison to most gulls, Ivory Gulls have reduced reproductive output, in that they usually only lay one to two eggs (Haney and MacDonald 1995). They depart from colonies immediately following breeding (~mid-August) for offshore foraging areas associated with the ice edge of permanent, multi-year pack ice. At sea, the Ivory Gull is a surface-feeder where its main prey includes small fish and macrozooplankton. It is also an opportunistic scavenger of carrion found on ice and marine mammals killed by large predators (Haney and MacDonald 1995). Currently, the Canadian breeding population is estimated at 500 to 600 individuals (COSEWIC 2006c). Surveys conducted during 2002 to 2005 indicate a total decline of 80% and an annual decline of 8.4% over the last 18 years. If this decline continues at a steady rate, the breeding population will decrease by a further 62% over the next decade, to approximately 190 individuals. A survey conducted in March 2004 within the pack ice off the coast of Newfoundland and Labrador observed a substantial decrease in Ivory Gull observations as compared to 1978 results (COSEWIC 2006c). The numbers of Ivory Gulls observed per 10-minute watch period were 0.69 and 0.02 individuals for 1978 and 2004, respectively (COSEWIC 2006c). Considering that changes to the breeding environment have been minimal, causes for the observed decline are likely related to factors occurring during migration or on the wintering grounds (Stenhouse 2004). During heavy ice winters, the Ivory Gull may occasionally reach the southern Orphan Basin and northern Grand Banks near the Study Area, late in the winter or early spring when sea ice reaches the maximum southern extremity. The thirty-year median of ice concentration shows ice extending into the northern edge of the Grand Banks east to 48°W during late February to late March. The total of 21 Ivory Gulls reported from drill platforms on the NE Grand Banks during 1999 to 2002, seems improbable, especially considering that most sightings were reported during ice-free periods. Ivory Gull is reported regularly along the coast of Labrador and

the tip of the Great Northern Peninsula of Newfoundland in winter. There are occasional sightings of Ivory Gulls south along the east coast of Newfoundland. It is expected to be very rare in the Study Area.

#### **4.6.1.3 Marine Mammals**

Only two marine mammal species are listed as either *endangered* or *threatened* under Schedule 1 of the SARA. Profiles of these two species are provided in this Section. Some of the other marine mammal species/populations that are included in Table 4.13 are profiled in Section 4.5.

#### **Blue Whale**

The blue whale has a cosmopolitan distribution, but tends to be more frequently observed in deep water than in coastal environments (Jefferson et al. 2008). Blue whales became severely depleted during industrial whaling and still occur at relatively low densities in the N Atlantic. The Atlantic population of blue whales is considered *endangered* on SARA Schedule 1, and by COSEWIC. A recently finalized recovery strategy for blue whales in the NW Atlantic is available with a long-term recovery goal to reach a total of 1,000 mature individuals through the achievement of three 5-year objectives (Beauchamp et al. 2009). No critical habitat was identified. Blue whales likely number in the low hundreds in the NW Atlantic and have been sighted only sporadically off the NE coast of Newfoundland (COSEWIC 2002b). There were no sightings of blue whales in the Study Area recorded in the DFO cetacean sightings database (see Figure 4.18; Table 4.11). During a CSEM monitoring program in 2007, there were two sightings of blues whales in Orphan Basin north of the Study Area, both occurred in August and in water depths of 2,366 m and 2,551 m (Abgrall et al. 2008b). Blue whales feed primarily on krill and their distribution is often associated with areas of upwelling or shelf edges where their prey may concentrate. Blue whales are considered rare in the Study Area.

#### **North Atlantic Right Whale**

Research results suggest the existence of six major habitats or congregation areas for NW Atlantic right whales: the coastal waters of the southeastern United States; the Great South Channel; Georges Bank/Gulf of Maine; Cape Cod and Massachusetts Bays; the Bay of Fundy; and the Scotian Shelf (COSEWIC 2003b; Waring et al. 2009). The North Atlantic right whale is currently listed as *endangered* on Schedule 1 of SARA and by COSEWIC (see Table 4.13; COSEWIC 2003b). Waring et al. (2009) suggest that the current best estimate of the minimum population size is 325 individuals. This species is considered extremely rare in the Study Area. However, there have been some relatively recent sightings of small numbers of right whales off Iceland and Norway, and it is possible (although highly unlikely) that this species may occur in the Study Area. There are no sightings of this species listed in the DFO database (see Figure 4.18; Table 4.11).

#### **4.6.1.4 Sea Turtles**

The leatherback turtle is the only sea turtle listed as either *endangered* or *threatened* under Schedule 1 of the SARA that could potentially occur in the Study Area. The other sea turtle species included in Table 4.13, the loggerhead, is profiled in Section 4.5.

## Leatherback Turtle

The largest and most widely ranging of sea turtles, the leatherback sea turtle ranges from sub-polar and cool temperate foraging grounds to tropical and sub-tropical nesting areas in all of the world's oceans (Spotila 2004). There are an estimated 26,000 to 43,000 individuals globally (Dutton et al. 1999), but there is no current estimate of the number of leatherbacks using eastern Canada waters. Leatherback sea turtle is designated as *endangered* (Schedule 1) on SARA and by COSEWIC. In the recovery strategy for leatherback sea turtle in the Canadian Atlantic Ocean, the recovery goal is to “achieve the long-term viability of the leatherback turtle populations frequenting Atlantic Canadian waters” via six supporting objectives (ALTRT 2006). No critical habitat was designated in ALTRT (2006). Adult leatherbacks are considered regular summer visitors to eastern Newfoundland, with the northernmost records occurring off Labrador at nearly 54°N; observations around Newfoundland and Labrador occur from June to November, but are most common in August and September (Goff and Lien 1988). Exhibiting wide-ranging oceanic movements, leatherbacks occur in pelagic regions of the N Atlantic to forage on gelatinous zooplankton (Hays et al. 2006). Most leatherbacks that occur in Atlantic Canadian waters are large sub-adults and adults, with a female-biased sex ratio among mature turtles (James et al. 2007). These turtles represent nesting populations in a minimum of 10 countries in South and Central America, and the Caribbean (James et al. 2007). DFO Newfoundland Region maintains a database of leatherback turtle sightings and entanglements in Newfoundland and Labrador (J. Lawson, DFO Research Scientist, pers. comm.); one leatherback turtle observation was recorded just southwest of the Study Area in August 2007 (LGL 2012). There was also a sighting of a leatherback turtle made in Jeanne d’Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009).

### 4.6.2 Concluding Summary of Species at Risk in Study Area

There are no known concentrations or critical habitat of SARA species in the HMDC Study Area. Seven SARA Schedule 1 species that may occur in the Study Area include:

- White shark—listed as *endangered*. We are aware of no reported sightings in the Study Area;
- Northern wolffish—listed as *threatened*. Mostly found in deeper water (500-1,000 m) than the Study Area (<200m);
- Spotted wolffish—listed as *threatened*. Mostly found in deeper water (200-750 m) than the Study Area;
- Blue whale—listed as *endangered*. Generally prefers deeper water than the Study Area and no sightings there in the DFO database;
- North Atlantic Right Whale—listed as *endangered*. Mostly found well to the south of the Study Area and no sightings in the DFO data base there;
- Leatherback turtle—listed as *endangered*; and
- Ivory Gull—listed as *endangered*. We are aware of no credible sightings in the Study Area and they would be very rare there in the absence of ice.

Interactions with SARA species are discussed in Section 5.6.5.



## 4.7 Potentially Sensitive Areas

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

### 4.7.1 Special Areas

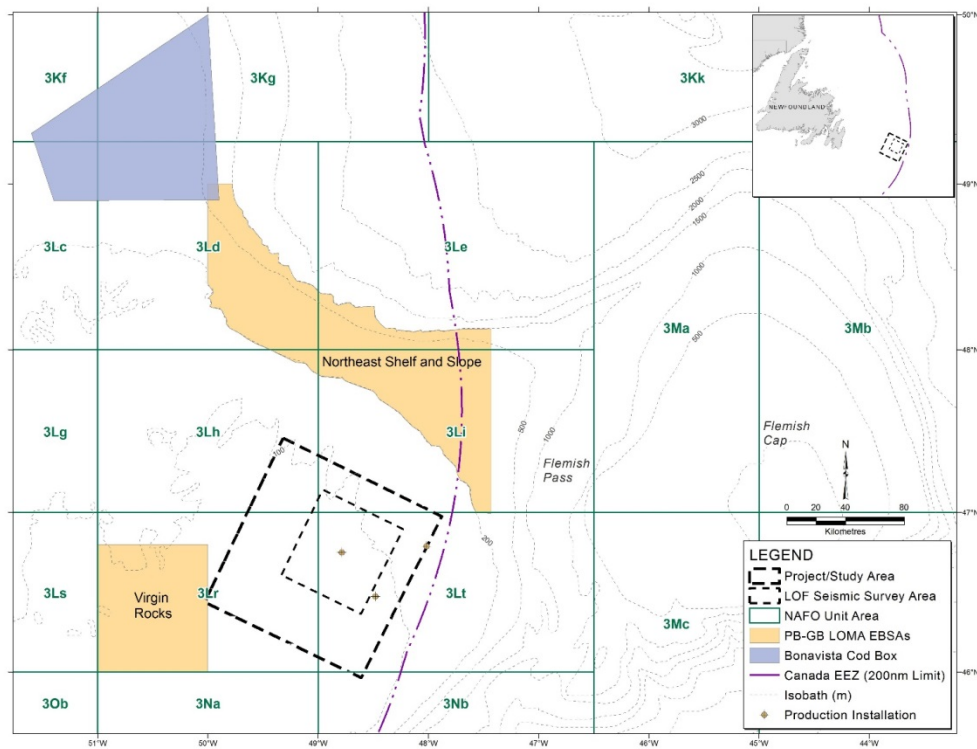
There are no designated special areas in the Project or Study areas. The Project Area is over 50 km from parts (the two Ecologically and Biologically Significant Areas (EBSAs) of Virgin Rocks and NE Newfoundland Shelf and Slope) of the Placentia Bay Grand Banks (PBGB) Large Ocean Management Area (LOMA), one of the marine regions established to form the planning basis for implementation of integrated-management plans by DFO (Figure 4.19). The LOMAs and EBSAs are described in detail in Section 4.7.1 of LGL (2012) (appended).

In April 2003, DFO announced that special conservation measures were required for the Bonavista Corridor, including the Bonavista Cod Box, located >188 km northwest of the Study Area (Figure 4.19).

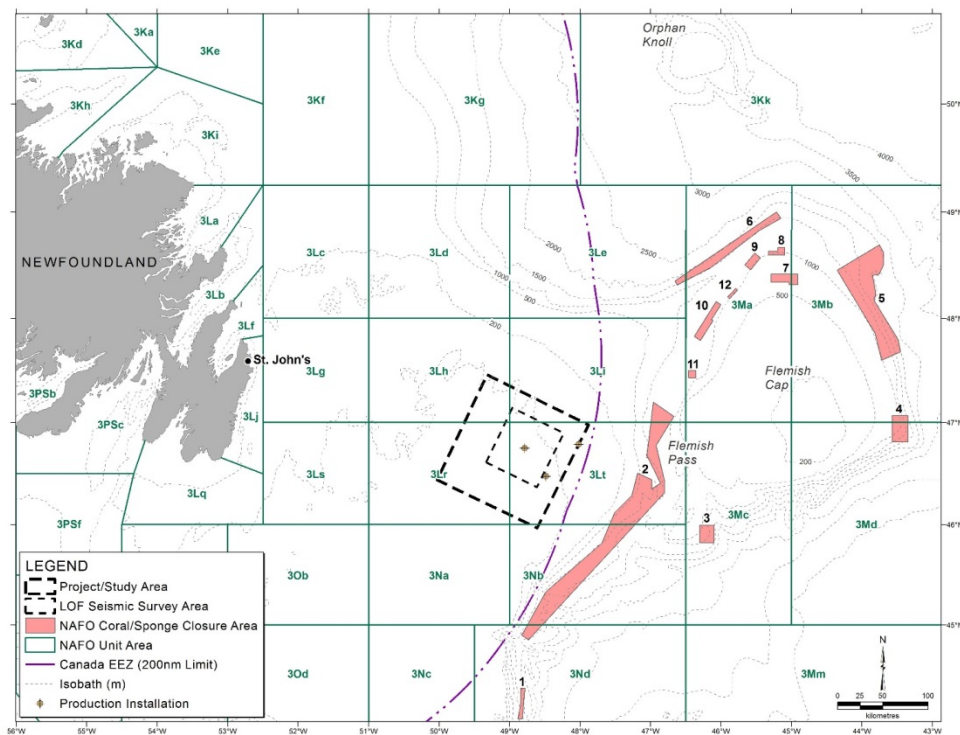
In 2008 and 2009, the North Atlantic Fisheries Organization (NAFO) Scientific Council identified areas of significant coral and sponge concentrations within the NAFO Regulatory Area. NAFO Coral/Sponge Closure Area Five was updated in 2012. These areas that are closed to fishing with bottom gear are shown in Figure 4.20 (see also Potentially Sensitive Areas in DFO 2010). Figure 4.20 shows the locations of these 12 areas, none of which occur either entirely or partially within the proposed HMDC Study Area. Given the nature of seismic survey equipment, there should be no interaction with corals and sponges.

### 4.7.2 Concluding Summary of Special Areas in Study Area

As there are no known special or sensitive areas in the HMDC Study Area or immediately adjacent to it, special areas are not discussed further in this EA.



**Figure 4.19** Locations of the PBGB LOMA EBSAs and Bonavista Cod Box Relative to the HMDC Project and Study Areas.



**Figure 4.20** Locations of NAFO Coral/Sponge Closure Areas in Region of HMDC's Study and Project Areas.

## 5.0 Effects Assessment

Two general types of effects are considered in this document:

1. Effects of the environment on the Project; and
2. Effects of the Project on the environment, particularly the biological environment represented by “Valued Ecosystem Components” (VECs) as described below in Section 5.2.

Methods of effects assessment used here are comparable to those used in recent east coast offshore drilling (e.g., LGL 2005, 2008b) and seismic EAs (e.g., LGL 2008a; LGL 2012). These documents conform to the *Canadian Environmental Assessment Act (CEAA)* and associated Responsible Authority’s Guide and the CEA Agency Operational Policy Statement (OPS-EPO/5-2000) (CEA Agency 2000). Cumulative effects are incorporated within the procedures in accordance with *CEAA* (CEA Agency 1994) as adapted from Barnes and Davey (1999) and used in the White Rose EA (Husky 2000).

### 5.1 Scoping

The C-NLOPB provided a Scoping Document (dated March 4, 2013) for the Project which outlined the factors to be considered in the assessment. In addition, various stakeholders were contacted for input (see below). Scoping for the effects assessment also involved reviewing recent regional EAs including (but not limited to) the Orphan Basin SEA (LGL 2003), the Jeanne d’Arc Basin seismic and geohazard program EA for StatoilHydro (LGL 2008a), exploration and drilling EAs and their amendments for Orphan Basin (LGL 2005, 2006b, 2009), Chevron’s Labrador and northern Grand Banks seismic EAs (LGL 2010, 2011b respectively), and Husky’s Jeanne d’Arc Basin/Flemish Pass seismic EA (LGL 2012). A review of current knowledge of the effects of seismic sound on marine organisms is also included.

Consultations were undertaken with representatives of the fishing industry (e.g., FFAW, One Ocean, and others). The purpose of consultations was to describe HMDC’s proposed seismic program, to identify any issues and concerns, and to gather any additional information relevant to the EA. A summary of the results of these consultations is provided in the following Section

#### 5.1.1 Consultations

A short description of the program and a location map were sent to the FFAW and One Ocean prior to the consultation meeting. HMDC and its consultant met with representatives of the FFAW and One Ocean on 28 March 2013 to review and discuss the proposed program. In addition, the following individuals and organizations were contacted:

- Michael O’Conner, Fish Harvesting Consultant, Icwater Seafoods;
- Tom Osbourne, Arnold’s Cove Fish Plant, Icwater Seafoods;
- Rick Ellis, Fleet Manager, Ocean Choice International;

- Derek Butler, Executive Director, Association of Seafood Producers;
- Bruce Chapman, Executive Director, Groundfish Enterprise Allocation Council (GEAC); and
- Catherine Boyd, Manager Corporate Affairs, Clearwater Seafoods Ltd.

#### **5.1.1.1 Issues and Concerns**

No significant issues/concerns were raised during the consultation meeting with the FFAW and One Ocean. The topics that were discussed included the following:

- Details of crew changes in relation to FLOs;
- Temporal and spatial details related to streamer deployment;
- Necessity of having a paper marine chart at consultation meetings;
- Temporal and spatial details of post-season snow crab survey;
- Single Point of Contact (SPOC);
- A 'seismic protocol' document recently completed by One Ocean; and
- The westward distributional expansion of snow crab in NAFO Unit Areas 3Li and 3Lt to around the 57 fathom depth.

Some of the topics for discussion (e.g., snow crab survey, SPOC) will continue to be addressed during lead up to the program. Other respondents (ASP and GEAC) to date have not identified any issues associated with the proposed project. HMDC will continue to communicate with the FFAW, One Ocean and others throughout the assessment process.

## **5.2 Valued Ecosystem Components**

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

- Rare or threatened species or habitats (as defined by the SARA and COSEWIC);
- Species or habitats that are either unique to an area or valued for their aesthetic properties;
- Marine species that are harvested by people (e.g., commercial fishery target species); and
- Marine species with some potential to be affected by the Project.

The VECs were identified based on the scoping exercise as described in Section 5.1 above. The VECs and their associated rationale include:

- **Fish and Fish Habitat** with emphasis on the Study Area's four most important (past and present) commercial species: (1) shrimp, (2) snow crab, (3) Greenland halibut (turbot), and (4) Atlantic cod (a representative species with a swim bladder and hence, may be susceptible to seismic survey sound). It is recognized that there are many other fish species, commercial or prey species, that could be considered but it is LGL's professional opinion that this suite

of species captures the relevant issues concerning the potential effects of seismic surveys on important invertebrate and fish populations of the Study Area.

- **Commercial fisheries** are directly linked to the fish and fish habitat VEC above but all fisheries (trawling, gillnetting, longlines, pots, etc.) are considered where relevant. The commercial fishery is a universally acknowledged important element in the society, culture, economic and aesthetic environments of Newfoundland and Labrador. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.
- **Seabirds** with emphasis on those species most sensitive to seismic activities (e.g., deep divers such as murrelets) or vessel stranding (e.g., petrels), and SARA species (e.g., Ivory Gull). Newfoundland and Labrador waters support some of the largest seabird colonies in the world and the Study Area hosts large populations during all seasons. They are important socially, culturally, economically, aesthetically, ecologically and scientifically. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.
- **Marine Mammals** with emphasis on those species potentially most sensitive to low frequency sound (e.g., baleen whales) and SARA species (e.g., blue whale). Whales and seals are key elements in the social and biological environments of Newfoundland and Labrador. The economic and aesthetic importance of whales is evidenced by the large number of tour boats that feature whale watching as part of a growing tourist industry. This VEC is also of prime concern from both a public and scientific perspective, at local, national and international scales.
- **Sea Turtles**, uncommon in the Study Area, are mostly *threatened* and *endangered* on a global scale. The leatherback sea turtle that forages in eastern Canadian waters is considered *endangered* under SARA. While they are of little or no economic, social or cultural importance to Newfoundland and Labrador, their *endangered* status warrants their inclusion as a VEC. Also, this VEC is of prime concern from both a public and scientific perspective, at national and international scales.
- **Species at Risk** are those listed as *endangered* or *threatened* on Schedule 1 of SARA. All species at risk in Newfoundland and Labrador offshore waters are captured in the VECs listed above. However, due to their special status, they are also discussed separately.

### 5.3 Boundaries

For the purposes of this EA, the following temporal and spatial boundaries were defined.

### 5.3.1 Temporal

Seismic surveys may occur from 1 May to 31 December in any given year through the Life of Field (LOF).

### 5.3.2 Spatial

The **Project Area** is defined as the area within which all routine project activities occur, including streamer and array deployment and vessel turns (see Figure 1.1). A **LOF Seismic Survey Area** a smaller area within the Project Area is defined as that area within which the sound source arrays may be active.

The **Study Area** is defined as the area within which any potential effects of the Project on the VECs, based on the scientific literature, could occur. The Study Area is the same as the “Affected Area” as originally defined by CEAA.

The **Regional Area** is loosely defined as the northern Grand Banks and Orphan Basin (e.g., to include the major Grand Banks developments such as Hibernia, Terra Nova, White Rose, and Hebron). This area is referred to when considering cumulative effects.

## 5.4 Effects Assessment Procedures

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

1. Preparation of interaction matrices (i.e., interactions of Project activities and the environment);
2. Identification and evaluation of potential effects, including description of mitigation measures and residual effects; and
3. Preparation of residual effects summary tables, including evaluation of cumulative effects.

### 5.4.1 Identification and Evaluation of Effects

Interaction matrices identifying all possible Project activities that could interact with any of the VECs were prepared. The interaction matrices are used to identify potential interactions only and they do not make any assumptions about the potential effects of the interactions.

Interactions were then evaluated for their potential to cause effects. In instances where the potential for an effect of an interaction was deemed impossible or extremely remote, these interactions were not considered further. This approach allows the assessment to focus on key issues and the more substantive environmental effects.

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

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

If data were insufficient to allow precise effects evaluations, predictions were made based on professional judgement. In such cases, the uncertainty is documented in the EA. Effects were evaluated for the proposed geophysical survey program, and included the consideration of mitigation measures that are either mandatory or have become standard operating procedure in the industry.

#### **5.4.2 Classifying Anticipated Environmental Effects**

Classification of environmental effects means determining whether they are negative, positive or neutral. The following are key factors that are considered for determining negative environmental effects, as per the CEA Agency guidelines (CEA Agency 1994):

- Negative effects on the health of biota;
- Loss of rare or *endangered* species;
- Reductions in biological diversity;
- Loss or avoidance of productive habitat;
- Fragmentation of habitat or interruption of movement corridors and migration routes;
- Transformation of natural landscapes;
- discharge of persistent and/or toxic chemicals;
- Toxicity effects on human health;
- either loss of or detrimental change in the current use of lands and resources for traditional purposes;
- Foreclosure of future resource use or production; and
- Negative effects on human health or well-being.

#### **5.4.3 Mitigation**

Mitigation measures appropriate for effects predicted in the matrix were identified and the effects of various Project activities were then evaluated assuming the application of appropriate mitigation measures. These effects after application of the mitigation measures are known as 'residual effects'. Residual effects predictions were made taking into consideration both standard and Project-specific mitigations.

#### 5.4.4 Evaluation Criteria for Assessing Environmental Effects

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

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

##### 5.4.4.1 Magnitude

Magnitude describes the nature and extent of the residual effect for each activity.

Ratings for this criterion are defined as:

- 0 *Negligible* - Measureable effect on individuals but less than the 'low' rating.
- 1 *Low* - Affecting >0 to 10 percent of individuals in the affected area (i.e. Study Area) (e.g., geographic extent). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.
- 2 *Medium* - Affecting >10 to 25 percent of individuals in the affected area (i.e. Study Area). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.
- 3 *High* - Affecting >25 percent of individuals in the affected area (i.e. Study Area). Effects may include acute mortality, sublethal effects or exclusion due to disturbance.

Definitions of magnitude used in this EA have been used previously in numerous offshore oil-related environmental assessments under CEAA. Some example assessments include the Petro-Canada seismic EA (LGL 2007a), the White Rose Oilfield Comprehensive Study (Husky 2000), the StatoilHydro Jeanne d'Arc Basin area seismic and geohazard program EA (LGL 2008a), the ConocoPhillips Laurentian Sub-Basin exploration drilling EA (Buchanan et al. 2006), the Chevron Labrador and northern Grand Banks seismic EAs (LGL 2010, 2011b), the Hebron Project Comprehensive Study (ExxonMobil 2011), and Husky seismic EA (LGL 2012).

##### 5.4.4.2 Geographic Extent

Geographic extent refers to the specific area (km<sup>2</sup>) of the residual effect caused by the Project activity. Geographic extent will likely vary depending on the activity and the relevant VEC.



Ratings for this criterion are defined as:

- 1 =  $<1 \text{ km}^2$
- 2 =  $1\text{-}10 \text{ km}^2$
- 3 =  $>10\text{-}100 \text{ km}^2$
- 4 =  $>100\text{-}1,000 \text{ km}^2$
- 5 =  $>1,000\text{-}10,000 \text{ km}^2$
- 6 =  $>10,000 \text{ km}^2$

#### **5.4.4.3 Duration and Frequency**

Duration describes how long a residual effect will occur.

Ratings for this criterion are defined as:

- 1 =  $<1 \text{ month}$
- 2 =  $1\text{--}12 \text{ month}$
- 3 =  $13\text{--}36 \text{ month}$
- 4 =  $37\text{--}72 \text{ month}$
- 5 =  $>72 \text{ month}$

Short duration can be considered 12 months or less, medium duration 13 to 36 months, and long duration  $>36$  months.

#### **5.4.4.4 Frequency**

Frequency describes how often a residual effect will occur.

Ratings for this criterion are defined as:

- 1 =  $<11 \text{ events/yr}$
- 2 =  $11\text{-}50 \text{ events/yr}$
- 3 =  $51\text{-}100 \text{ events/yr}$
- 4 =  $101\text{-}200 \text{ events/yr}$
- 5 =  $>200 \text{ events/yr}$
- 6 = continuous

#### **5.4.4.5 Reversibility**

Reversibility refers to the capability of a VEC population to return to either its pre-Project or an improved condition, after the Project has ended.

Ratings for this criterion are defined as:

R = reversible

I = Irreversible

#### **5.4.4.6 *Ecological, Socio-cultural and Economic Context***

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

Ratings for this criterion are defined as:

1 = Environment not negatively affected by human activity (i.e., relatively pristine area)

2 = Evidence of existing negative effects on the environment

#### **5.4.5 Cumulative Effects**

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

- Within-Project cumulative impacts. For the most part, and unless otherwise indicated, within-Project cumulative effects are fully integrated within this assessment;
- Existing and *in progress* offshore oil developments in Newfoundland and Labrador: Hibernia (GBS platform), Terra Nova FPSO, White Rose FPSO and associated extension, and the Hebron GBS;
- Other offshore oil exploration activity (particularly seismic surveys and exploratory drilling as outlined on the C-NLOPB website). In 2013, other possible oil exploration activity in the Regional Area included 2D/3D seismic surveying by Hebron and the possibility that Chevron would drill an exploratory well in the Orphan Basin (just north of the Grand Banks) in 2013. There is also some potential for several 2D/3D/4D, geohazard and VSP surveys in any given year;
- Fisheries (domestic and foreign commercial, recreational, aboriginal/subsistence);
- Marine transportation (tankers, cargo ships, supply vessels, naval vessels, fishing vessel transits, etc.); and
- Hunting activities (marine birds and seals).

#### 5.4.6 Integrated Residual Environmental Effects

Upon completion of the evaluation, the residual environmental effects are assigned a rating of significance for:

- Each project activity;
- Cumulative effects of activities within the Project; and
- Cumulative effects of combined projects in the Regional Area.

As such, this represents an integrated residual environmental effects evaluation.

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

- Determination of the significance of residual environmental effects;
- Establishment of the level of confidence for prediction; and
- Evaluation of the scientific certainty and probability of occurrence of the residual impact prediction.

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

##### 5.4.6.1 Significance Rating

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

*Having either a high magnitude regardless of duration and geographic extent ratings, or a medium magnitude for more than one year over a geographic extent greater than 100 km<sup>2</sup>*

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

##### 5.4.6.2 Level of Confidence

The significance of the residual environmental effects is based on a review of relevant literature, consultation with experts, and professional judgment. In some instances, making predictions of potential residual environmental effects are difficult due to the limitations of available data (i.e., technical boundaries). Ratings are therefore provided to qualitatively indicate the level of confidence for each prediction. The level of confidence is considered low (1), medium (2) or high (3).

#### **5.4.6.3 Probability of Occurrence**

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

#### **5.4.6.4 Scientific Certainty**

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

### **5.5 Effects of the Environment on the Project**

The physical environment is summarized in Section 3.0 and the reader is referred to this Section and Section 5.5 in LGL (2012) (appended) to assist in determining the effects of the environment on the Project. Furthermore, safety issues are assessed in detail during the permitting and program application processes established by the C-NLOPB as the regulatory authority in this matter. Nonetheless, effects on the Project are important to consider, at least on a high level, because they may sometimes cause effects on the environment. For example, accidental spills may be more likely to occur during rough weather.

Given the Project time window of May to December 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 spring and early summer may cause some survey delays if tracks have to be altered to avoid them. Icebergs may cause some detours in May when iceberg occurrence of any size is on the order of 28% (of total for the year) as opposed to June (9%), July (2%), and August through December (essentially 0%) based on data contained in Table 3.5.3 in LGL (2012). All necessary measures will be taken to ensure the safety of the vessel and personnel. If extreme weather conditions become a threat warranting a deviation from the survey plan, the vessel could be forced to sail outside the Project Area but no source array activation will be required. In such a case, a notification to mariners will be issued. The FLO and picket vessel will continue to function to identify fishing gear locations and communicate with fishers as needed.

Most environmental constraints on seismic surveys on the Grand Banks are those imposed by wind and wave. If the Beaufort wind scale is six or greater, there is generally too much noise for seismic data to be of use. A Beaufort wind scale of six is equivalent to wind speeds of 22-27 knots (11.3-13.9 m/s), and is associated with wave heights ranging from 2.4-4.0 m. In the Study Area, these conditions are typically reached at a consistent level in the late autumn and winter months. Certainly, if the sea state exceeds 5 (3.0 m waves) or winds exceed 40 kt (20.6 m/s), then continuation/termination of seismic surveying will be evaluated. The absolute operating limits for most seismic vessels are 3.5 m combined sea significant wave height and 45 kt (23.2 m/s) winds. Based on multi-year data at a nearby grid point, these wave limits may be approached about 8% of the time in May, 4% in June, 2% in July, 4% in August, 12% in September, 26% in October, 38% in November, and 55% of the time in December

(see Figure 3.2.1 in LGL 2012). Similarly, 23.2 m/s winds might occur 1% or less of the time during the Project time frame based on historical data (see Figure 3.10 in LGL 2012).

As a prediction of the effects of the environment on the Project, some operators have used an estimate of 25% weather-related down time for the project planning purposes. If 25% is used as a guideline, then conditions in November and December might be considered a significant effect on Project logistics and economics by some proponents although this is likely to be variable depending upon the operator.

The Project scheduling avoids most of the continuous extreme weather conditions and HMDC's contractors will be thoroughly familiar with East Coast operating conditions. 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.

Environmental effects on other Project vessels (e.g., picket and service vessels) are likely less than on the seismic vessel which is constrained by safety of towed gear and data quality issues.

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

DND is likely to be operating in the vicinity of the study area in a non-interference manner during the project timeframe.

A search of the unexploded ordnates (UXO) records was conducted by DND to determine the possible presence of UXO within the Project Area. Records indicate that there are no wrecks present within this area. Given DND's understanding of the survey activities to be conducted, the associated UXO risk is assessed as negligible. Nonetheless, due to the inherent dangers associated with UXO and the fact that the Atlantic Ocean was exposed to many naval engagements during WWII, should any suspected UXO be encountered during the course of the Hibernia's operations it will not be disturbed/manipulated. Hibernia will mark the location and immediately inform the Coast Guard. Additional information is available in the 2012 Annual Edition - Notices to Mariners. Section F, No.37. In the event of activities which may have contact with the seabed (such as OBC installation and removal), DND strongly advises that operational aids, such as remote operated vehicles, be used to conduct seabed surveys in order to prevent unintentional contact with harmful UXO items that may have gone unreported or undetected. General information regarding UXO is available at DND's website at [www.uxocanada.forces.gc.ca](http://www.uxocanada.forces.gc.ca).

## **5.6 Effects of the Project on the Environment**

The main pathway that links the Project and environment is the transmission of sound from the seismic survey sources to the various VECs (or "receivers"). The basics of sound and its propagation in the marine environment are described in Richardson et al. (1995). Of principal concern during seismic programs is the potential effects of sound from air sources on VECs as air sources used during marine seismic operations introduce strong sound impulses into the water (see Appendix C in LGL 2007a) for a detailed review of the characteristics of air source pulses). The seismic pulses produced by the air

sources are intentionally directed downward toward the seafloor, insofar as possible; however, energy will propagate outward from the source through the water. The following Sections review the hearing/detection abilities of VECs and the available information on potential effects of sound (as well as other Project activities) from the proposed seismic program on VECs.

### **5.6.1 Fish and Fish Habitat VEC**

There will be interaction between Project activities and the ‘fish habitat’ component of the Fish and Fish Habitat VEC (i.e., water and sediment quality, phytoplankton, zooplankton, and benthos) (Table 5.1). However, such interactions are so small relative to the overall environments or populations that they are considered *negligible* residual effects and hence *not significant*. The Project 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 offshore fish habitat. Therefore, except for interactions identified in Table 5.1, 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.

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

#### **5.6.1.1 Sound**

The marine acoustic environment is filled with natural and anthropogenic sounds some of which may influence survival and reproduction of fish (Slabbekoorn et al. 2010). The potential effects of exposure to air source sound on invertebrates and fishes can be categorized as either physical (includes both pathological and physiological) or behavioural. Pathological effects include lethal and sub-lethal damage, physiological effects include temporary primary and secondary stress responses, and behavioural effects refer to deviations from normal behavioural activity. Physical and behavioural effects are likely related in some instances and should therefore not be considered as completely independent of one another.

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 air source sounds and higher frequency sounds that could be emitted from survey gear such as sonar.

#### **Sound Detection**

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

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

Valued Ecosystem Component: Fish and Fish Habitat							
Project Activities	Non-Biological Environment	Feeding		Reproduction		Adult Stage	
	Water and Sediment Quality	Plankton	Benthos	Eggs and Larvae	Juveniles <sup>a</sup>	Pelagic Fish	Groundfish
<b>Sound Emissions and Receivers</b>							
Air Sources		X	X	X	X	X	X
Seismic Vessel						X	
Supply Vessel						X	
Picket Vessel						X	
Secondary Source Vessel						X	
Helicopter <sup>b</sup>							
Echo Sounder						X	
Side Scan Sonar						X	
Boomer			X	X	X	X	X
<b>Vessel Lights</b>							
<b>Vessel Presence</b>							
Seismic Vessel							
Supply Vessel							
Picket Vessel							
Undershoot Vessel							
<b>Sanitary/Domestic Waste</b>	X	X		X		X	
<b>Atmospheric Emissions</b>	X	X		X		X	
<b>Garbage<sup>c</sup></b>							
<b>Helicopter Presence<sup>b</sup></b>							
<b>Shore Facilities<sup>d</sup></b>							
<b>Accidental Releases</b>	X	X		X		X	
<b>Other Projects and Activities</b>							
Oil & Gas: Grand Banks and Orphan Basin	X	X	X	X	X	X	X
Fisheries (incl. research)	X	X	X	X	X	X	X
Marine Transportation	X	X		X		X	
<sup>a</sup> Juveniles are young fish that have left the plankton and are often found closely associated with substrates. <sup>b</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks. <sup>c</sup> Not applicable as garbage will be brought ashore. <sup>d</sup> There will not be any new onshore facilities. Existing infrastructure will be used.							

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 Air Source Sound

Most air source 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-air source 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 meter 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  $\mu\text{Pa}_{0-p}$ ) and sound exposure levels (SELs) (<130–187 dB re 1  $\mu\text{Pa}^2 \cdot \text{s}$ ). Neither acute nor chronic (12 weeks post-exposure) mortality was observed for the adult crabs. However, a significant difference in development rate was noted between the exposed and unexposed fertilized eggs/embryos. The egg mass exposed to seismic energy had a higher proportion of less-developed eggs than did the unexposed mass. It should be noted that both egg masses came from a single female and any measure of natural variability was unattainable (Christian et al. 2003, 2004).

In 2003, a collaborative study was conducted in the southern Gulf of St. Lawrence, Canada, to investigate the effects of exposure to sound from a commercial seismic survey on egg-bearing female snow crabs (DFO 2004a). This study had design problems that impacted interpretation of some of the results (DFO 2004b). Caged animals were placed on the ocean bottom at a location within the survey area and at a location outside of the survey area. The maximum received SPL was ~195 dB re 1  $\mu\text{Pa}_{0-p}$ . 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 air source sound on various health endpoints of the American lobster. Adult lobsters were exposed either 20 to 200 times to 202 dB re 1  $\mu\text{Pa}_{\text{p-p}}$  or 50 times to 227 dB re 1  $\mu\text{Pa}_{\text{p-p}}$ , 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<sup>3</sup> air source with maximum SPLs of >200 dB re 1  $\mu\text{Pa}_{0-\text{p}}$ . Statocysts were removed and preserved, but at the time of publication, results of the statocyst analyses were not available. No squid or cuttlefish mortalities were reported as a result of these exposures.

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

Stress indicators in the haemolymph of adult male snow crabs were monitored immediately after exposure of the animals to seismic survey sound (Christian et al. 2003, 2004) and at various intervals after exposure. No significant acute or chronic differences were found between exposed and unexposed animals in which various stress indicators (e.g., proteins, enzymes, and cell type count) were measured. Payne et al. (2007), in their study of the effects of exposure of adult American lobsters to air source 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 air sources.

Fertilized capelin (*Mallotus villosus*) eggs and monkfish (*Lophius americanus*) larvae were exposed to seismic air source sound and subsequently examined and monitored for possible effects of the exposure (Payne et al. 2009). The laboratory exposure studies involved a single air source. Approximate received SPLs measured in the capelin egg and monkfish larvae exposures were 199 to 205 dB re 1  $\mu\text{Pa}_{p-p}$  and 205 dB re 1  $\mu\text{Pa}_{p-p}$ , respectively. The capelin eggs were exposed to either 10 or 20 air source 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 one to four 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 air sources. With the seismic air source 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 air source sound source. The range of received SPLs was about 215 to 233 dB re 1  $\mu\text{Pa}_{0-p}$ .

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  $\mu\text{Pa}$  (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 air source 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 air source-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 air source every 10 seconds over a period of 1 hour and 41 minutes. The source SPL at 1 m was about 223 dB re 1  $\mu\text{Pa}$  at 1  $\text{m}_{p-p}$ , and the received SPLs ranged from 165 to 209 dB re 1  $\mu\text{Pa}_{p-p}$ . The sound energy was highest over the 20 to 70 Hz frequency range. The pink snapper were exposed to more than 600 air source 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) air source 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 air source. The mean received peak SPL was 205 to 209 dB re 1  $\mu$ Pa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1  $\mu$ Pa<sup>2</sup> · 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<sup>3</sup> seismic air source 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 air source with source level ~230 dB re 1  $\mu$ Pa 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 air source 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<sub>0-p</sub> and <130 dB re 1  $\mu$ Pa<sup>2</sup> · 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 air source 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<sub>0-p</sub> and 150 dB re 1  $\mu$ Pa<sup>2</sup> · 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 air source 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 air source 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<sup>3</sup> air source. The cephalopods were exposed to both stationary and mobile sound sources. The two-run total exposure times during the three trials ranged from 69 to 119 min. at a firing rate of once every 10 to 15 seconds. The maximum SPL was >200 dB re 1  $\mu\text{Pa}_{0-p}$ . 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 air source. In addition to the above-described startle responses, some squid also moved towards the water surface as the air source approached. McCauley et al. (2000a, b) reported that the startle and avoidance responses occurred at a received SPL of 174 dB re 1  $\mu\text{Pa}_{\text{rms}}$ . They also exposed squid to a ramped approach-depart air source 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  $\mu\text{Pa}_{\text{rms}}$  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  $\mu\text{Pa}_{\text{rms}}$ , 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 air source sound is expected to result in less masking effect than would occur with continuous sound.

### ***Invertebrate Fisheries***

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

Andriguetto-Filho et al. (2005) attempted to evaluate the impact of seismic survey sound on artisanal shrimp fisheries off Brazil. Bottom trawl yields were measured before and after multiple-day shooting of an air source 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 air source 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.

### ***Fishes***

Pearson et al. (1992) investigated the effects of seismic air source sound on the behaviour of captive rockfishes *Sebastes* sp. exposed to the sound of a single stationary air source at a variety of distances. The air source used in the study had a source SPL at 1 m of 223 dB re 1  $\mu$ Pa at 1 m<sub>0-p</sub>, and measured received SPLs ranged from 137 to 206 dB re 1  $\mu$ Pa<sub>0-p</sub>. The authors reported that rockfishes reacted to the air source 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<sub>0-p</sub>, and alarm responses occurred at a minimum received SPL of 177 dB re 1  $\mu$ Pa<sub>0-p</sub>.

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 air source 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  $\mu\text{Pa}_{0-p}$  and 161 dB re 1  $\mu\text{Pa}_{0-p}$ , respectively.

Fish exposed to the sound from a single air source in the study by McCauley et al. (2000a,b) exhibited startle responses to short range start up and high level air source signals (i.e., with received SPLs of 182 to 195 dB re 1  $\mu\text{Pa}_{\text{rms}}$ ). Smaller fish were more likely to display a startle response. Responses were observed above received SPLs of 156 to 161 dB re 1  $\mu\text{Pa}_{\text{rms}}$ . 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 air source sound on the distribution and catchability of rockfishes. The source SPL of the single air source used in the study was 223 dB re 1  $\mu\text{Pa}$  at 1  $\text{m}_{0-p}$ , and the received SPLs at the bases of the rockfish aggregations ranged from 186 to 191 dB re 1  $\mu\text{Pa}_{0-p}$ . Characteristics of the fish aggregations were assessed using echosounders. During long-term stationary seismic air source 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 air source array with a source SPL of about 256 dB re 1  $\mu\text{Pa}$  at 1  $\text{m}_{0-p}$  (unspecified measure type) (Santulli et al. 1999). The air sources 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 air source discharge. Resultant video indicated slight startle responses by some of the sea bass when the seismic air source array discharged as far as 2.5 km from the cage. The proportion of sea bass that exhibited startle response increased as the air source 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 air source 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 air source sound. This Brazilian study used an array of eight air sources 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 air source 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 air source with a source SPL of 220 dB re 1  $\mu$ Pa at 1 m<sub>0-p</sub>. Received SPLs were estimated to be 178 dB re 1  $\mu$ Pa<sub>0-p</sub>. The whiting were monitored with an echosounder. Prior to any air source discharge, the fish were located at a depth range of 25 to 55 m. In apparent response to the air source sound, the fish descended, forming a compact layer at depths greater than 55 m. After an hour of exposure to the air source sound, the fish appeared to have habituated as indicated by their return to the pre-exposure depth range, despite the continuing air source discharge. Air source 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 air source 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 air source array had an estimated source SPL of 256 dB re 1  $\mu$ Pa 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 air source array and fish cage ranged from 55 m when the array was overhead to 7.5 km. No mortality attributable to exposure to the air source 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 air source 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 air source discharge ceased. The sandeel tended to remain higher in the water column during the air source 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 air source array with a source SPL of about 250 dB re 1  $\mu$ Pa 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  $\mu$ Pa (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 air source 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 air source 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 air sources and had a source SPL of 256 dB re 1  $\mu$ Pa at 1 m<sub>0-p</sub>. 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 air source. The received SPLs ranged from about 195 to 218 dB re 1  $\mu$ Pa<sub>0-p</sub>. Pollock did not move away from the reef in response to the seismic air source 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 air source array with a source SPL of 222.6 dB re 1  $\mu$ Pa at 1 m<sub>p-p</sub>. 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 air source sound. The mean received peak SPL was 205 to 209 dB re 1  $\mu$ Pa per discharge, and the approximate mean received SEL was 176 to 180 dB re 1  $\mu$ Pa<sup>2</sup> · s per discharge. They used hydroacoustic survey techniques to determine whether fish behaviour upon exposure to air source 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 air source

sound. The tracked fish did not exhibit herding behaviour in front of the mobile air source 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 air source array. Received SPLs were 142 to 186 dB re 1  $\mu\text{Pa}_{\text{p-p}}$ . The fish were exposed to 124 pulses over a three day period. In addition to monitoring fish behaviour with underwater video cameras, the authors also analyzed cod and haddock catch data from a longline fishing vessel operating in the immediate area. Only eight of the 124 shots appeared to evoke behavioural reactions by the salmonids, but overall impacts were minimal. No fish mortality was observed during or immediately after exposure. The author reported no significant effects on cod and haddock catch rates, and the behavioural effects were hard to differentiate from normal behaviour.

### ***Finfish Fisheries***

Early comprehensive experimentation on the effects of seismic air source sound on catchability of fishes was conducted in the Barents Sea by Engås et al. (1993, 1996). They investigated the effects of seismic air source 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  $\mu\text{Pa}$  at 1  $\text{m}_{0-p}$  based on calculations using sound measurements collected by a hydrophone suspended at a depth of 80 m. No measurements of the received SPLs were made. Davis et al. (1998) estimated the received SPL at the sea bottom immediately below the array and at 18 km from the array to be 205 dB re 1  $\mu\text{Pa}_{0-p}$  and 178 dB re 1  $\mu\text{Pa}_{0-p}$ , respectively. Engås et al. (1993, 1996) concluded that there were indications of distributional change during and immediately following the seismic air source 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 air source discharge, those for cod increased.

Dalen and Knutsen (1986), Løkkeborg (1991), and Løkkeborg and Soldal (1993) also examined the effects of seismic air source sound on demersal fish catches. Løkkeborg (1991) examined the effects on cod catches. The source SPL of the air source array used in his study was 239 dB re 1  $\mu\text{Pa}$  at 1 m (unspecified measure type), but received SPLs were not measured. Approximately 43 hours of seismic air source discharge occurred during an 11 day period, with a five-second interval between pulses. Catch rate decreases ranging from 55 to 80% within the seismic survey area were observed. This apparent effect persisted for at least 24 hours within about 10 km of the survey area. The effect of exposure to seismic sound on commercial demersal fishes was again studied in 2009 using gillnet and longline fishery methods off the coast of Norway (Løkkeborg et al. 2010). Study results indicated that fishes did react to air source 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  $\mu\text{Pa}_{0-p}$ . They also concluded that

reaction thresholds of fishes lacking a swim bladder (e.g., flatfish) would likely be about 20 dB higher. Given the considerable variability in sound transmission loss between different geographic locations, the SPLs that were assumed in these studies were likely quite inaccurate. Turnpenny and Nedwell (1994) also reported on the effects of seismic air source discharge on inshore bass fisheries in shallow U.K. waters (5 to 30 m deep). The air source array used had a source level of 250 dB re 1  $\mu$ Pa at 1  $m_{0-p}$ . Received levels in the fishing areas were estimated to range between 163 and 191 dB re 1  $\mu$ Pa $_{0-p}$ . Using fish tagging and catch record methodologies, they concluded that there was not any distinguishable migration from the ensonified area, nor was there any reduction in bass catches on days when seismic air sources 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<sup>3</sup> air source with a source level of 223 dB re 1  $\mu$ Pa at 1  $m_{0-p}$  to examine the potential effects of air source sound on the catchability of rockfishes. The moving air source 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 $_{0-p}$ . The catch-per-unit-effort (CPUE) for rockfish declined on average by 52.4% when the air sources 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 air source 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 air source 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 air source discharge. However, in an area where exposure to air source 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 air source arrays with a source SPL of 262 dB re 1  $\mu$ Pa at 1  $m_{0-p}$  (Pickett et al. 1994). The seismic survey was conducted over a period of four to five months. The study was intended to investigate the effects of seismic air source 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).

### **Effects of Exposure to Marine Vessel Sound**

Numerous papers about the behavioural responses of fishes to marine vessel sound have been published in the primary literature. They consider the responses of small pelagic fishes (e.g., Misund et al. 1996; Vabo et al. 2002; Skaret et al. 2005; Ona et al. 2007; Sand et al. 2008), large pelagic fishes (Sarà et al. 2007), and groundfishes (Engås et al. 1998; Handegard et al. 2003; De Robertis et al. 2008). Generally, most of the papers indicate that fishes typically exhibit some level of reaction to the sound of

approaching marine vessels, the degree of reaction being dependent on a variety of factors including the activity of the fish at the time of exposure (e.g., reproduction, feeding, and migration), characteristics of the vessel sound, and water depth.

## **Sound Exposure Effects Assessment**

The reader should first refer to the interaction table (see Table 5.1) to determine if there are any interactions with Project activities, secondly to the assessment table (Table 5.2) which contains ratings for magnitude, extent, and duration, and thirdly to the significance predictions table (Table 5.3).

It is impossible to assess in detail the potential effects of every type of sound on every species in the Study Area. The best approach, and common practice in EA, is to focus by selecting (1) the strongest sound source, in this case the air source 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 were selected to serve as surrogates for the discussion of the potential effects of sound on fish species found within the Study Area.

The most notable criteria in the assessment include (1) distance between air source 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 as surrogate species. Potential interactions between the proposed Project activities and the Fish and Fish Habitat VEC are shown in Table 5.1.

As already indicated in this Section, although research on the effects of exposure to air source 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 air source 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 air source sound.

**Table 5.2 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
Sound Emissions and Receivers								
Air Sources	Physical effects (N); Disturbance (N)	Ramp-up of array; Spatial & temporal avoidance	1	1-3	6	1-2	R	2
Seismic Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Picket Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
Secondary Source Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1-2	R	2
Echo Sounder	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Boomer	Disturbance (N)	Spatial & temporal avoidance	0-1	1	6	1	R	2
Vessel Lights	Neutral effect	-	-	-	-	-	-	-
Sanitary/Domestic Waste	Pathological effects (N); Contamination (N)	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Accidental Releases	Pathological effects (N); Contamination (N)	Solid streamers <sup>a</sup> ; prevention protocols; Spill Response Plan	0-1	1-2	1	1	R	2
Key:								
<div>Magnitude:0 = Negligible, essentially no effect1 = Low2 = Medium3 = High</div> <div>Frequency:1 = &lt;11 events/yr2 = 11-50 events/yr3 = 51-100 events/yr4 = 101-200 events/yr5 = &gt;200 events/yr6 = continuous</div> <div>Reversibility:R = ReversibleI = Irreversible (refers to population)</div> <div>Duration:1 = &lt;1 month2 = 1-12 months3 = 13-36 months4 = 37-72 months5 = &gt;72 months</div> <div>Geographic Extent:1 = &lt;1 km<sup>2</sup>2 = 1-10 km<sup>2</sup>3 = 11-100 km<sup>2</sup>4 = 101-1,000 km<sup>2</sup>5 = 1,001-10,000 km<sup>2</sup>6 = &gt;10,000 km<sup>2</sup></div> <div>Ecological/Socio-cultural and Economic Context:1 = Relatively pristine area or area not negatively affected by human activity2 = Evidence of existing negative effects</div>								
<sup>a</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.								

**Table 5.3 Significance of Potential Residual Environmental Effects of Project Activities on the Fish and Fish Habitat VEC.**

Valued Ecosystem Component: Fish and Fish Habitat				
Project Activity	Significance Rating	Level of Confidence	Likelihood <sup>a</sup>	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Sound Emissions and Receivers</b>				
Air Sources	NS	2-3	-	-
Seismic Vessel	NS	2-3	-	-
Supply Vessel	NS	2-3	-	-
Picket Vessel	NS	2-3	-	-
Secondary Source Vessel	NS	2-3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
<b>Vessel Lights</b>	NS	3	-	-
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Atmospheric Emissions</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2-3	-	-
<p>Key:</p> <p>Residual environmental Effect Rating:  S = Significant Negative Environmental Effect  NS = Not-significant Negative Environmental Effect  P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:  1 = Low Level of Confidence  2 = Medium Level of Confidence  3 = High Level of Confidence</p> <p>Probability of Occurrence: based on professional judgment:  1 = Low Probability of Occurrence  2 = Medium Probability of Occurrence  3 = High Probability of Occurrence</p> <p>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</p> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p>				

Snow crab, sensitive to the particle displacement component of sound only, will be at least 90 m or more from the air sources and will not likely be affected by any particle displacement resulting from air source 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.

As indicated in Table 5.2, sound produced as a result of the proposed Project (air source 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<sup>2</sup>*. Based on these criteria ratings, the *reversible* residual effects of *continuous* Project-related sound (assumes continuous for the duration of each individual seismic program) on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.3).

#### **5.6.1.2 Other Project Activities**

##### **Vessel Lights**

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

##### **Sanitary/Domestic Waste**

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

##### **Atmospheric Emissions**

As indicated in Table 5.1, 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, the residual effects of exposure to them on the Fish and Fish Habitat VEC are predicted to be *negligible* (see Table 5.2). Therefore, residual effects of atmospheric emissions associated with the proposed Project on the Fish and Fish Habitat VEC are predicted to be *not significant* (see Table 5.3).

##### **Accidental Releases**

Planktonic invertebrate and fish eggs and larvae are less resistant to effects of contaminants than are adults because they are not physiologically equipped to detoxify them or to actively avoid them. In addition, many eggs and larvae develop at or near the surface where hydrocarbon exposure may be the greatest (Rice 1985). Generally, fish eggs appear to be highly sensitive at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Larval sensitivity varies



with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to high concentrations of hydrocarbons generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. The natural mortality rate in fish eggs and larvae is extremely high and very large numbers would have to be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985).

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

As indicated in Table 5.1, there are potential interactions 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 offshore on the Fish and Fish Habitat VEC are predicted to be *not significant* especially in case of a seismic vessel where most plausible petroleum spills would be small (e.g., streamer fluid or diesel spills).

With proper mitigations in place, the residual effects of an accidental release associated with the HMDC'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<sup>2</sup>* (see Table 5.2). Based on these criteria ratings and consideration that the probability of accidental hydrocarbon releases during the proposed seismic program are low, the *reversible* residual effects of accidental releases associated with the proposed program on the Fish and Fish Habitat VEC are predicted to be *not significant* (see Table 5.3).

### **5.6.2 Fishery VEC**

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

The seismic survey vessel and Project-related support vessel traffic will be present within NAFO Division 3L. Behavioural changes in commercial species in relation to catchability, and conflict with harvesting activities and fishing gear were raised as potential issues during the consultations and issues scoping for this assessment (see Section 5.1.1). Seismic streamers and vessels can conflict with and damage fishing gear, particularly fixed gear (e.g., snow crab pots or gillnets). 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.

**Table 5.4 Potential Interactions of Project Activities and the Fishery VEC.**

Valued Ecosystem Component: Fishery			
Project Activities	Mobile Invertebrates and Fishes (fixed [e.g., gillnet] and mobile gear [e.g., trawls])	Sedentary Benthic Invertebrates (fixed gear [e.g., crab pots])	Research Surveys (mobile gear-trawls; fixed gear-crab pots)
<b>Sound Emissions and Receivers</b>			
Air Sources	X	X	X
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Secondary Source Vessel	X	X	X
Helicopter <sup>a</sup>			
Echo Sounder	X		
Side Scan Sonar	X		X
Boomer	X	X	X
<b>Vessel Lights</b>			
<b>Vessel Presence</b>			
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Picket Vessel	X	X	X
Secondary Source Vessel	X	X	X
<b>Sanitary/Domestic Waste</b>	X	X	X
<b>Atmospheric Emissions</b>			
<b>Garbage<sup>b</sup></b>			
<b>Helicopter Presence<sup>a</sup></b>			
<b>Shore Facilities<sup>c</sup></b>			
<b>Accidental Releases</b>	X	X	X
<b>Other Projects and Activities</b>			
Oil & Gas: Grand Banks and Orphan Basin	X	X	X
Fisheries (incl. research)	X	X	X
Marine Transportation	X	X	X
<sup>a</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks. <sup>b</sup> Not applicable as garbage will be brought ashore. <sup>c</sup> There will not be any new onshore facilities. Existing infrastructure will be used.			

The chief means of mitigating potential impacts on fishery activities is to avoid active fishing areas, particularly fixed gear zones. For the commercial fisheries, gear damage compensation provides a means of final mitigation of impacts, in case a conflict does occur with fishing gear (i.e., accidental contact of gear with the survey air source array, streamers or seismic vessel).

The document *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012) provides guidance aimed at minimizing any impacts of petroleum industry surveys on commercial fish harvesters and other marine users. The mitigations described below are also relevant to DFO and joint DFO/Industry research surveys. Development of the guidelines was based on best practices applied during previous surveys in Atlantic Canada, as well as guidelines from other national jurisdictions. The relevant guidelines state the following (in Appendix 2 of C-NLOPB (2012) - Environmental Planning, Mitigation and Reporting – II. Interaction with Other Ocean Users):

### ***2D and 3D Seismic Programs***

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

- a) Surveys should be scheduled, to the extent possible, to reduce potential for impact or interference with Department of Fisheries and Ocean (DFO) science surveys. Spatial and temporal logistics should be determined with DFO to reduce overlap of seismic operations with research survey areas, and to allow an adequate temporal buffer between seismic survey operations and DFO research activities.*
- b) Seismic activities should be scheduled to avoid heavily fished areas, to the extent possible. The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained. The use of a 'Fisheries Liaison Officer' (FLO) onboard the seismic vessel is considered best practice in this respect.*
- c) Where more than one survey operation is active in a region, the operator(s) should arrange for a 'Single Point of Contact' for marine users that may be used to facilitate communication.*

The following Sections assess the potential effects of Project activities on the Fishery VEC.

#### ***5.6.2.1 Sound***

As indicated in the description of commercial fisheries in Section 4.3, there has been substantial harvesting within NAFO Units 3Lh, 3Li, 3Lr, 3Lt in the Study Area between 2005 and 2010. Snow crab and northern shrimp accounted for most of the commercial harvest within the Study Area during that period.

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, and the type of fishing gear used in any given 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).

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

## **Mitigation**

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

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

## **Avoidance**

The potential effects of seismic sound on fishery catch success can be mitigated by avoiding heavily fished areas when these fisheries are active (specifically the shrimp and snow crab areas) to the greatest extent possible. As described in this report, most of the domestic fishing in the past has been concentrated in well-defined areas within the Study Area. During any seismic survey, the location of current fishing activities will be monitored by the ship and the FLO (see below) and fishing boats will be contacted by radio as required. Survey personnel (through the Single Point of Contact (SPOC), described below) will also continue to be updated about fishing activity near the active survey area. The mapping of fishing activities contained in this EA report will also be an important source of fisheries information for the survey operators.

## **Communications**

During the fisheries consultations for this and other surveys, fisheries representatives noted that good communications is one of the best ways to minimize interference between the seismic operations and fishing activities. Communication will be maintained (both directly at sea and through the survey SPOC) to facilitate information exchange, which includes such groups as DFO managers, independent fishers, representatives of fisheries organizations such as the FFAW, and managers of other key corporate fisheries in the area.

Relevant information about the seismic survey operations will also be transmitted using established communications mechanisms, such as the Notices to Shipping (Continuous Marine Broadcast and NavTex), the CBC (Newfoundland) Radio's Fisheries Broadcast, by the FFAW in the FFAW Union Forum (as suggested during previous consultations), and by direct communication between the seismic survey vessels and fishing vessels via marine radio at sea. This includes seismic survey vessel transit before and after the survey itself.

## **Fisheries Liaison Officer (FLO)**

As a specific means of facilitating at-sea communications, and informing the survey vessel operators about local fisheries, when necessary HMDC will have an on-board fisheries industry liaison officer serving as a "fisheries representative". The FLO will remain on the relevant survey vessel for the entire program. This will provide a dedicated marine radio contact for all fishing vessels in the vicinity of seismic operations to discuss interactions and resolve any problems that may arise at sea. This person will inform the vessel's bridge personnel about any local fishing activities.

Appendix 3 contains a description of the FLO responsibilities and qualifications, as agreed in previous discussions with the FFAW.

## **Assessment of the Effects of Seismic Survey Sound**

Since commercial catches are quota based, the overlap between fishing activity and seismic activity is unknown at the moment, but will be determined prior to the commencement of the seismic surveys. The best way to prevent overlap between the DFO and joint DFO/Industry research surveys is to exchange detailed locational information and establish a tailored temporal and spatial separation plan, as was implemented with DFO Newfoundland and Labrador in past seasons. With application of the mitigations discussed above, effects of seismic survey sound on the Fishery VEC are predicted to be a *negligible to low* magnitude during *<1 to 1-12 months* over an area of *<1 to 11-100 km<sup>2</sup>* (Table 5.5). Based on these criteria ratings, the *reversible* residual effects of seismic survey sound on the Fishery VEC are predicted to be *not significant* (Table 5.6).

**Table 5.5 Assessment of Effects of Project Activities on the Fishery VEC.**

Valued Ecosystem Component: Fishery								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air Sources	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0-1	3	6	1-2	R	2
Seismic Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1-2	R	2
Supply Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	1	1-2	R	2
Picket Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1-2	R	2
Secondary Source Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1-2	R	2
Echo Sounder	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2
Side Scan Sonar	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2
Boomer	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communications	0	1	6	1	R	2
Vessel Presence								
Seismic Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	6	1-2	R	2
Supply Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	1	1	R	2
Picket Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	6	1-2	R	2
Secondary Source Vessel	Conflict with gear (N)	FLO; communications; Compensation Plan	0-1	1-3	6	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Sanitary/Domestic Wastes	Taint (N); Perceived taint (N)	Primary treatment	0-1	1	1	2	R	2
Accidental Releases	Taint (N); Perceived taint (N)	Solid streamers <sup>c</sup> ; prevention protocols; Spill Response Plan; communications; Compensation Plan	0-1	1-2	1	1	R	2
<div>Key:</div> <div><div>Magnitude: 0 = Negligible, essentially no effect 1 = Low 2 = Medium 3 = High</div><div>Frequency: 1 = &lt; 11 events/yr 2 = 11-50 events/yr 3 = 51-100 events/yr 4 = 101-200 events/yr 5 = &gt; 200 events/yr 6 = continuous</div><div>Reversibility: R = Reversible I = Irreversible (refers to population)</div><div>Duration: 1 = &lt; 1 month 2 = 1-12 months 3 = 13-36 months 4 = 37-72 months 5 = &gt; 72 months</div></div> <div>Geographic Extent: 1 = &lt; 1-km<sup>2</sup> 2 = 1-10-km<sup>2</sup> 3 = 11-100-km<sup>2</sup> 4 = 101-1,000-km<sup>2</sup> 5 = 1,001-10,000-km<sup>2</sup> 6 = &gt; 10,000-km<sup>2</sup></div> <div>Ecological/Socio-cultural and Economic Context: 1 = Relatively pristine area or area not affected by human activity 2 = Evidence of existing effects</div> <div><sup>a</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks. <sup>b</sup> This is considered negligible since, if a conflict occurs, compensation will eliminate any economic impact. <sup>c</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.</div>								

**Table 5.6 Significance of Potential Residual Environmental Effects on the Fishery VEC.**

Valued Ecosystem Component: Fishery				
Project Activity	Significance Rating	Level of Confidence	Likelihood <sup>a</sup>	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Sound Emissions and Receivers</b>				
Air source Array	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
<b>Vessel Presence</b>				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2-3	-	-
<p>Key:</p> <p>Residual environmental Effect Rating:  S = Significant Negative Environmental Effect  NS = Not-significant Negative Environmental Effect  P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:  1 = Low Level of Confidence  2 = Medium Level of Confidence  3 = High Level of Confidence</p> <p>Probability of Occurrence: based on professional judgment:  1 = Low Probability of Occurrence  2 = Medium Probability of Occurrence  3 = High Probability of Occurrence</p> <p>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</p> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p>				

#### 5.6.2.2 Vessel Presence Including Streamers

Commercial fish harvesting activities occur throughout the May to December 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 2D/3D seismic surveying, operations will be conducted continuously for 20-90 days. Because of the length of the streamers being towed behind it, the maneuverability 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. During transit to the seismic survey area, streamers may be deployed. Therefore, a separate route analysis will be prepared and discussions with fishing interests will be conducted before the transit.

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 losses attributable to the seismic survey.

## **Mitigation**

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

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

## **Avoidance**

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

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

In addition to avoidance based on route analysis and selection, the onshore SPOC and the at-sea FLO will advise the vessel en route to ensure fishing gear is avoided. In the case the avoidance mitigate measure fails, a gear damage program will be in place to compensate fishers whose gear is damaged or lost.

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



Hibernia will contact DFO to obtain information on the timing and locations of any DFO and joint DFO/Industry research surveys in order to avoid any potential conflicts.

### **Communications**

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

Relevant information about the survey operations will also be publicized using established communications mechanisms, such as the Notices to Shipping (Continuous Marine Broadcast and NavTex), the CBC (Newfoundland) Radio's Fisheries Broadcast, by the FFAW in the FFAW Union Forum (as suggested during previous consultations), and by direct communication between the survey vessel and fishing vessels via marine radio at sea. This will also include information about transit routes.

### **Fisheries Liaison Officer**

As described above, the on-board fisheries industry FLO will provide a dedicated marine radio contact for all fishing vessels near project operations to help identify gear locations, assess potential interactions and provide guidance to those on the bridge, including during transit to and from St. John's.

### **Single Point of Contact**

The SPOC has become a standard and effective mitigation for all seismic surveys operating in this sector. The HMDC Environment Advisor/Lead or designate will serve as the survey's Single Point of Contact with the fishing industry, as described in the C-NLOPB Guidelines. The SPOC will endeavour to update vessel personnel (e.g. the FLO) about known fishing activities in the area, and will relay relevant information from DFO and fishing companies.

### **Fishing Gear Compensation**

HMDC has developed a fishing gear damage compensation policy consistent with C-NLOPB guidelines that will be filed with the Board in support of the *Authorization to Conduct a Geophysical Program* application. In case of accidental damage to fishing gear or vessels, HMDC will implement gear damage compensation contingency plans to provide appropriate and timely compensation to any affected fishery participants. The Notices to Shipping, filed by the vessels for surveys and for transits to and from the survey sites, will also inform fishers that they may contact the SPOC if they believe that they have sustained survey-related gear damage. HMDC will follow its C-NLOPB approved Incident Reporting and Investigation Procedure for reporting and documenting incidents associated with fishing gear.

## Assessment of the Effects of Vessel and Seismic Equipment Presence

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

### 5.6.2.3 Sanitary/Domestic Wastes

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

### 5.6.2.4 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. Streamer floatation fluid can be expected to dissipate relatively rapidly. Any effect on access to fishing grounds would be of relatively short duration. In the unlikely event of a substantial hydrocarbon release, the need of compensation for commercial fishers will be determined through the C-NLOPB's guidelines.

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

## 5.6.3 Seabirds

There are three main potential types of effect sources on seabirds due to the proposed seismic program: (1) underwater sound from air source arrays; (2) leakage of petroleum product from oil-filled streamer (s) (in the unlikely event of their use); and (3) attraction to ship lights at night and potential stranding. Potential interactions of the Project activities and the Seabird VEC are indicated in Table 5.7, and a review of available information related to potential effects on seabirds is provided in this Section.

**Table 5.7 Potential Interactions of the Project Activities and the Seabird VEC.**

Project Activities	Valued Ecosystem Component: Seabird
<b>Sound Emissions and Receivers</b>	
Air Sources	X
Seismic Vessel	X
Supply Vessel	X
Picket Vessel	X
Secondary Source Vessel	X
Helicopter <sup>a</sup>	X
Echo Sounder	X
Side Scan Sonar	X
Boomer	X
<b>Vessel Lights</b>	X
<b>Vessel Presence</b>	
Seismic Vessel	X
Supply Vessel	X
Picket Vessel	X
Secondary Source Vessel	X
<b>Sanitary/Domestic Waste</b>	X
<b>Atmospheric Emissions</b>	X
<b>Garbage<sup>b</sup></b>	-
<b>Helicopter Presence<sup>a</sup></b>	X
<b>Shore Facilities<sup>c</sup></b>	-
<b>Accidental Releases</b>	X
<b>Other Projects And Activities</b>	
Oil & Gas: Grand Banks and Orphan Basin	X
Fisheries (incl. research)	X
Marine Transportation	X
<sup>a</sup> A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks. <sup>b</sup> Not applicable as garbage will be brought ashore. <sup>c</sup> There will not be any new onshore facilities. Existing infrastructure will be used.	

### 5.6.3.1 Sound

Most of the seabird species expected to occur in the Study Area feed at either the ocean's surface or in the upper meter of the water column. This includes members of *Procellariidae* (Northern Fulmar), *Hydrobatidae* (Wilson's Storm-Petrel and Leach's Storm-Petrel), *Phalaropodinae* (Red Phalarope and Red-necked Phalarope), *Stercorariidae* (Great Skua, South Polar Skua, Pomarine Jaeger, Parasitic Jaeger and Long-tailed Jaeger), and *Laridae* (Herring Gull, Iceland Gull, Glaucous Gull, Great Black-backed Gull, Ivory Gull, Black-legged Kittiwake and Arctic Tern).

Northern Gannet plunge dive to a depth of 10 m. It is below surface for a few seconds during each dive so could possibly have minimal exposure to underwater sound. Great Shearwater, Sooty Shearwater and Manx Shearwater feed mainly at the surface but may also briefly chase prey below surface down to a depth of 2-10 m (Brown et al. 1978, 1981; Ronconi 2010a, b).

One seabird group, *Alcidae* (e.g., Dovekie, Common Murre, Thick-billed Murre, Razorbill and Atlantic Puffin) that occurs regularly in the Study Area, spends a relatively longer time below the ocean's surface to secure food than do other seabirds. 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 and depth of dive for the five species of *Alcidae* is 25 to 40 seconds (s) and 20-60 m, respectively. Murres are capable of diving to a 120 m depth for up to 202 s (Gaston and Jones 1998). The effects of underwater sounds on *Alcidae* are unknown. In fact, the effects of underwater sound on birds in general have not been well studied. One study of the effects of underwater seismic survey sound on moulting Long-tailed Ducks in the Beaufort Sea showed little effect on their behaviour (Lacroix et al. 2003). However, the study did not consider potential physical effects on the ducks. The authors suggested caution in interpreting the data because of their limited utility to detect subtle disturbance effects, and recommended studies on other species to better understand the effects of seismic air source sound on seabirds. Sound is probably not important to *Alcidae* for securing food. However, all five species mentioned above are quite vocal out of water at breeding sites, suggesting that auditory capability is important during that part of the life cycle.

The sound from air sources is typically focused downward during seismic surveying. In air, air source sound is reduced to a “muffled shot” that should have little or no effect on seabirds that either have their heads above water or are in flight. It is possible that birds on the ocean's surface and proximate to discharging air sources would be startled by the sound. However, the presence of the ship and the associated seismic equipment in the water should have already warned the bird of unnatural visual and auditory stimuli. The standard mitigation of ramping up air sources to minimize effects on marine mammals should also deter seabirds in the area from submerging near the air sources.

Sound produced as a result of the proposed Project is predicted to cause effects on seabirds of *negligible* to *low* magnitude for a duration of *<1 month to 1 to 12 months* over a geographic extent of *<1 to 1-10 km<sup>2</sup>* (Table 5.8). Therefore, the *reversible* residual effects of Project sound on the Seabird VEC are predicted to be *not significant* (Table 5.9).

#### **5.6.3.2 Vessel Lights**

Birds that spend most of their lives at sea are often influenced by artificial light (Montevecchi et al. 1999; Montevecchi 2006). Even before the era of electrical lights, humans used fires on shore to attract seabirds for food (Montevecchi 2006). Birds are more strongly attracted to lights at sea during fog and drizzly conditions. Moisture droplets in the air refract light, thereby increasing illumination and creating a glow around vessels at sea. In Newfoundland waters, the Leach's Storm-Petrel is the species most often stranded on the decks of offshore vessels after being attracted to lights at night (Moulton et al. 2005, 2006; Abgrall et al. 2008a, 2008b 2009). Occasionally, other Newfoundland seabirds (e.g., Great Shearwater, Northern Fulmar, Thick-billed Murre and Dovekie) have stranded on vessels in Newfoundland waters at night, presumably due to the attraction to ship lights. In Alaska, a species related to the Dovekie, the Crested Auklet (*Aethia cristatella*), mass-stranded on a crab fishing boat (Dick and Donaldson 1978). An estimated 1.5 tons of the Crested Auklet either collided with or landed on the brightly lit fishing boat at night. There are not any known mass stranding events involving large numbers of Dovekies or any alcid species on vessels in Newfoundland and Labrador waters.

**Table 5.8 Assessment of Potential Effects of Project Activities on the Seabird VEC.**

Valued Ecosystem Component: Seabirds								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air Sources	Disturbance (N)	Ramp-up	0	2	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0	1	6	1	R	2
Picket Vessel	Disturbance (N)	-	0	1	6	1-2	R	2
Secondary Source Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Helicopter	Disturbance (N)	Avoidance	0-1	2	1	1	R	2
Echosounder	Disturbance (N)	-	0-1	2	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1	6	1	R	2
Boomer	Disturbance (N)	-	0-1	1	6	1	R	2
Vessel Lights	Attraction (N)	Reduce lighting (if possible); stranded bird release	1-2	2	2-3	1-2	R	2
Vessel Presence								
Seismic Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	6	1-2	R	2
Supply Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	1	1	R	2
Picket Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	6	1-2	R	2
Secondary Source Vessel	Disturbance (N)	Reduce lighting (if possible); stranded bird release	0	2	6	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2

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
Sanitary/Domestic Waste	Increased Food (N/P)	Primary treatment	0	1	1	1-2	R	2
Atmospheric Emissions	Air Contaminants (N)	Equipment maintenance	0	2	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0-1	2	1	1	R	2
Accidental Releases	Mortality (N)	Solid streamer <sup>a</sup> ; prevention protocols; Spill Response Plan	1-2	1-2	1	1	R	2
Key:								
Magnitude:			Frequency:			Reversibility:		Duration:
0 = Negligible,			1 = <11 events/yr			R = Reversible		1 = <1 month
1 = Low			2 = 11-50 events/yr			I = Irreversible		2 = 1-12 months
2 = Medium			3 = 51-100 events/yr			(refers to population)		3 = 13-36 months
3 = High			4 = 101-200 events/yr					4 = 37-72 months
			5 = >200 events/yr					5 = >72 months
			6 = continuous					
Geographic Extent:			Ecological/Socio-cultural and Economic Context:					
1 = < 1 km <sup>2</sup>			1 = Relatively pristine area or area not affected by human activity					
2 = 1-10 km <sup>2</sup>			2 = Evidence of existing effects					
3 = 11-100 km <sup>2</sup>								
4 = 101-1,000 km <sup>2</sup>								
5 = 1,001-10,000 km <sup>2</sup>								
6 = >10,000 km <sup>2</sup>								
<sup>a</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.								

To date, bird strandings in the Newfoundland offshore have almost all involved Leach's Storm-Petrels. This is not surprising given the large numbers of this species in these waters coupled with their relative inability to become airborne after landing on a ship or platform. Numbers of strandings on seismic vessels have ranged from zero during the early part of the season to tens of birds; mostly late in the season after fledging has occurred. On a Grand Banks seismic vessel, the stranding of tens of birds in one night can be considered a "large scale stranding". The largest single stranding event observed by LGL biologists on seismic vessels was 46 birds, all of which were released live (LGL Limited, unpublished data). This stranding occurred in the Orphan Basin in October 2005.

**Table 5.9      Significance of the Potential Residual Effects of the Project Activities on the Seabird VEC.**

<b>Valued Ecosystem Component: Seabirds</b>				
<b>Project Activity</b>	<b>Significance Rating</b>	<b>Level of Confidence</b>	<b>Likelihood <sup>a</sup></b>	
	<b>Significance of Predicted Residual Environmental Effects</b>		<b>Probability of Occurrence</b>	<b>Scientific Certainty</b>
<b>Sound</b>				
Air Sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
<b>Vessel Lights</b>	NS	3	-	-
<b>Vessel Presence</b>				
Seismic Vessel and Streamer	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Atmospheric Emissions</b>	NS	3	-	-
<b>Helicopter Presence</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2	-	-
<p>Key:</p> <div> <p>Residual environmental Effect Rating:</p> <p>S = Significant Negative Environmental Effect</p> <p>NS = Not-significant Negative Environmental Effect</p> <p>P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> </div> <div> <p>Probability of Occurrence: based on professional judgment:</p> <p>1 = Low Probability of Occurrence</p> <p>2 = Medium Probability of Occurrence</p> <p>3 = High Probability of Occurrence</p> <p>Scientific Certainty: based on scientific information and statistical analysis or professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> </div> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p>				

Monitoring of pelagic seabird stranding on board seismic vessels due to light attraction has been conducted by LGL biologists during 16 seismic programs between 2004 and 2011 off both Newfoundland and Labrador. While seismic programs off Newfoundland and Labrador have been initiated as early as 7 May and terminated as late as 8 November, most have been conducted during the June to September period. Bird stranding during these seismic programs has been monitored for a total of 888 nights. The number of nights per week with strandings and the number of individuals stranded

per night have been highest from late-August to mid-October. This period coincides with the fledging of Leach's Storm-Petrels from Newfoundland colonies. Young of this species fledge from Great Island (Witless Bay), Newfoundland, as early as 10 September but the majority fledges from mid-September to late-October (Huntington et al. 1996). The mean fledging date is 25 September. Juveniles constituted a large majority of stranded Leach's Storm-Petrels near a colony off Scotland (Miles et al. 2010). However, in wintering areas, adult Leach's Storm-Petrels may also strand due to attraction to light (Rodríguez and Rodríguez 2009). Visibility during nights when storm-petrels stranded on seismic vessels off Newfoundland and Labrador was typically reduced due to fog, rain or overcast conditions. This has also been documented for other seabird species (Telfer et al. 1987; Black 2005). It has also been noted that seabird strandings seem to peak around the time of the new moon (i.e., when moonlight levels are lowest) (Telfer et al. 1987; Rodríguez and Rodríguez 2009; Miles et al. 2010).

Birds may be attracted to light because of a preference for bioluminescent prey (Imber 1975) or the red component of lights disrupts their magnetic orientation (Poot et al. 2008). Many seabirds have great difficulty becoming airborne from flat surfaces. Once on a hard surface, stranded seabirds tend to crawl into corners or under objects to hide and may die from exposure, dehydration or starvation over hours or days. A stranded seabird's plumage is prone to oiling from residual oil that may be present on a ship's deck. The open ended structure of the stern of a typical seismic ship allows entry of seabirds to several decks. These decks are lighted to various degrees, sometimes quite brightly. This is unavoidable as seismic surveying is conducted around the clock and adequate lighting is required for safe work practices.

Mitigation measures to rescue stranded storm-petrels on board the seismic vessel will be the responsibility of the MMO and procedures will follow conditions of the CWS *Bird Handling Permit*. In general, the MMO will conduct daily searches of the ship and the ship's crew will also be notified to contact the MMO if a bird is found. Project personnel will also be made aware of bird attraction to the lights on offshore structures. Deck lighting will be minimized (if it is safe and practical to do so) to reduce the likelihood of stranding. A report documenting each stranded bird will be completed and delivered to the CWS by the end of the calendar year. Any oiled birds will be handled according to the CWS bird handling permit.

Mitigation and monitoring for stranded birds will result in residual effects of attraction to lights of *low* to *medium* magnitude for a duration of *<1 month* to *1 to 12 months* over a geographic extent of *<1 to 1-10 km<sup>2</sup>* (see Table 5.8). Therefore, the reversible residual effects of vessel lights on the Seabird VEC are predicted to be *not significant* (see Table 5.9).

#### **5.6.3.3 Vessel Presence**

The potential effects of the physical presence of vessels are likely minimal. Seabirds may be attracted to the seismic, picket or supply vessel while prospecting for fish wastes associated with fishing vessels. Since there is little or no food made available by these vessels, seabirds are temporarily interested in the vessels and soon go elsewhere in search of food. Seabirds sitting on the water in the path of these



vessels can move out of the way. Therefore, the residual effects of vessel presence on the Seabird VEC are predicted to be *negligible* and hence *not significant* (see Tables 5.8 and 5.9).

#### **5.6.3.4 Sanitary/Domestic Wastes**

Sanitary waste generated by the vessels will be macerated before subsurface discharge. While it is possible that seabirds, primarily gulls, may be attracted to the sewage particles, the small amount discharged below surface over a limited period of time will not likely 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. Therefore, the residual effects of sanitary/domestic wastes on the Seabird VEC are predicted to be *negligible* and hence *not significant* (see Tables 5.8 and 5.9).

#### **5.6.3.5 Atmospheric Emissions**

Although atmospheric emissions could, in theory, affect the health of some resident seabirds, these effects will be *negligible* considering that emissions of potentially harmful materials will be low and will rapidly disperse to undetectable levels due to their volatility, temperature of emission and the exposed and often windy nature of the offshore. Therefore, the residual effects of atmospheric emissions on the Seabird VEC are predicted to be *not significant* (see Tables 5.8 and 5.9).

#### **5.6.3.6 Helicopter Presence**

Personnel may be transported to and from the seismic vessel via helicopters if a survey last longer than five to six weeks. Potential effects of helicopters on the marine environment are mainly related to the sound they generate (see a review of the effects of sound on seabirds above) and not their physical presence. Therefore, the residual effects of helicopter presence on the Seabird VEC are predicted to be *negligible* and hence *not significant* (see Tables 5.8 and 5.9).

#### **5.6.3.7 Accidental Releases**

Seismic contractors may use either solid flotation or a paraffinic hydrocarbon called Isopar to provide buoyancy for streamers. It is ExxonMobil and Hibernia's policy to require the seismic contractor to use solid streamers. If unforeseen circumstances necessitate the use of liquid-filled (Isopar) streamers then the Hibernia Oil Spill Response Plan will be amended accordingly. Isopar M is a light hydrocarbon subject to rapid dispersal in the marine environment. While recovery with absorbents would be considered in a plan amendment, the most likely and practical response option is to have a work boat and/or picket vessel mechanically disperse the fluid to reduce the risk to wildlife. Solid streamers were used in 2013 and most likely for any future seismic programs. Isopar is discussed below in the unlikely event that it becomes necessary to use it in the future.

The specific effects of Isopar M on seabirds are not known. However, petroleum products typically have detrimental effects on the insulating attributes of seabird feathers. Isopar M is a kerosene-like

product that leaves a relatively thin layered slick on the surface of water and evaporates readily. Typical fluid-filled streamers are constructed of self-contained 100 m long units. Therefore, a single leak in a streamer could result in a maximum loss 208 L of Isopar M.

All seabirds expected to occur in the Study Area, except Arctic Tern, spend considerable time resting on the water. Birds that spend most of their time on water, such as the murres, Dovekie and Atlantic Puffin, are the species most likely to suffer negative effects from an accidental release of Isopar M. Northern Fulmar, the shearwaters and storm-petrels are attracted to sheens but would not likely confuse them with a natural oceanic “sheen” comprised of zooplankton or offal. However, flocks of seabirds resting on the water would not necessarily leave the water if they drifted into an area with Isopar M.

An exposure to a surface release of a kerosene-like substance under calm conditions may harm or kill individual birds. O’ Hara and Morandin (2010) demonstrated that it requires only a small amount of oil (e.g., 10 ml) to affect the feather structure of Common Murre and Dovekie with potential to lethally reduce thermoregulation. Such modifications to feather structure cause a loss of insulation, which in turn can result in mortality. However, because potential accidental releases would likely be small and evaporation/dispersion rapid, the effects on seabirds are predicted to have *low to medium* magnitude for a duration of *<1 month* over a geographic extent of *<1 km<sup>2</sup> to 1-10 km<sup>2</sup>* (see Table 5.8). Therefore, the residual effects of an accidental release (e.g., Isopar M) on the seabird VEC are predicted to be *not significant* (see Table 5.9).

#### **5.6.4 Marine Mammals and Sea Turtles**

The potential effects of marine seismic activities on marine mammals and sea turtles have been reviewed for several recent 3-D seismic projects in the Jeanne d’Arc Basin (e.g., LGL 2007a, 2008a, 2011a, b, 2012 (appended)), Labrador (LGL 2010), Orphan Basin (LGL 2003) and several others (e.g., Gordon et al. 2004; Stone and Tasker 2006; Southall et al. 2007; Abgrall et al. 2008c).

##### **5.6.4.1 Sound**

Air source arrays used during marine seismic operations introduce strong sound impulses to the underwater environment. These sound impulses could have several types of effects on marine mammals and sea turtles and represent one of the main issues associated with HMDC’s proposed seismic project. The effects of exposure to human-generated underwater sound on marine mammals and sea turtles are quite variable depending on the species involved, the activity of the animal during exposure to the sound, and the distance of the animal from the sound source.

Underwater sound as it relates to marine mammals and sea turtles can be categorized as follows (adapted from Richardson et al. 1995):

- The sound is too weak to be heard at the location of the animal (i.e., lower than the prevailing ambient sound level, the hearing threshold of the animal at relevant frequencies, or both);

- Sound is audible but not strong enough to elicit overt behavioural response, (i.e., the animal may tolerate it, either with or without some deleterious effects such as masking and stress);
- The sound elicits behavioural reactions of variable conspicuousness and relevance to the well-being of the animal, ranging from subtle effects on respiration or other behaviours detectable by statistical analysis only to active avoidance reactions. Upon repeated exposure to sound, animals may either exhibit diminishing responsiveness (habituation) or the disturbance effects may persist. The latter is most likely with sounds that are highly characteristically variable, unpredictable in terms of occurrence, and associated with situations perceived as threats by the animal;
- The sound has the potential to reduce the animal's capability to hear natural sounds of similar frequency (i.e., masking), including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or ice noise. Intermittent air source and sonar pulses would have the potential to cause masking for only a small proportion of the time, given their short durations relative to the inter-pulse intervals; and
- The sound is very strong and has the potential to cause temporary or permanent reduction in hearing sensitivity, and other physical or physiological effects. The received sound levels must far exceed the animal's hearing threshold to cause either temporary threshold shift or permanent hearing impairment.

As part of the assessment of the potential effects of HMDC's proposed seismic program on marine mammals and sea turtles, this Section reviews: (1) the hearing abilities of marine mammals and sea turtles; (2) potential masking caused by air source sound; (3) potential disturbance caused by air source sound; (4) potential hearing impairment caused by air source sound; and (5) potential physical and non-auditory physiological effects caused by air source sound.

## **Hearing Abilities of Marine Mammals and Sea Turtles**

Marine mammals and sea turtles use underwater sound to communicate and gain information about their environment. Experiments and monitoring studies suggest that they hear and may react to man-made sounds, including those caused by 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 that have been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but relatively high sensitivity at frequencies of several kHz. Most of the odontocetes have been classified as having functional hearing over a frequency range of about 150 Hz to 160 kHz (Southall et al. 2007). There are very few data related to the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales. However, Cook et al. (2006) reported that a stranded Gervais' beaked whale exhibited evoked potentials at frequencies of 5 to 80 kHz, sensitivity being highest at 80 kHz. In another study, Finneran et al. (2009) observed that an adult Gervais' beaked whale had a similar upper cutoff of 80 to 90 kHz. Pacini et al. (2011) reported a sub-adult Blainville's beaked whale's best hearing range as 40 to 50 kHz.

Porpoises have higher functional hearing over a frequency range of 200 Hz to 180 kHz (Southall et al. 2007).

Only a small proportion of air source sound energy occurs at mid- and high-frequencies, with levels progressively decreasing with increasing frequency. In other words, most of the energy in air source sound pulses occurs at the lower frequencies (i.e. <500 Hz). Air source sound levels are high enough and contain sufficient levels of mid- and high-frequency energy so that received levels often remain above the hearing thresholds of large odontocetes at distances of several tens of kilometers from the sound source (Richardson and Würsig 1997). There is no evidence that small odontocetes react to air source pulses at similar long distances. However, beluga whales do seem quite responsive at intermediate distances (10 to 20 km) when sound levels are well above the ambient sound level.

### **Baleen Whales**

The hearing abilities of baleen whales have not been studied directly. Behavioural and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales 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 2000; Parks et al. 2007a). Although humpback and minke whales exhibit auditory sensitivity to frequencies >22 kHz (Berta et al. 2009), baleen whales, as a group, have a functional hearing range of about 7 Hz to 22-25 kHz. Baleen whales are said to constitute the “low-frequency” (LF) hearing group (Southall et al. 2007).

The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small toothed whales that have been studied directly. Thus, baleen whales are likely to hear air source pulses at greater distances than small toothed whales and, at closer distances, air source sound may seem more prominent to baleen whales than to toothed whales.

### **Pinnipeds**

Underwater audiograms exist for three species of phocid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211ff; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002, 2009). The functional hearing range for pinnipeds in water is considered to be 75 Hz to 75 kHz (Southall et al. 2007). Compared to odontocetes, pinnipeds tend to have highest auditory sensitivity at lower frequencies.

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

## **Sea Turtles**

Hearing in sea turtles occurs through a combination of bone and water conduction rather than air conduction (Lenhardt 1982; Lenhardt and Harkins 1983). Although there are limited available data on sea turtle hearing capability, it appears that they are low-frequency specialists with a hearing range of 50 to 1,600 Hz for the species that have been tested (i.e., green, loggerhead, and Kemp's ridley sea turtles). The highest auditory sensitivities of sea turtles appear to be within the frequency range of ~200 to 700 Hz (Ridgway et al. 1969; Bartol et al. 1999; Bartol and Ketten 2006; Ketten and Bartol 2006; Yudhana et al. 2010; Dow Piniak et al. 2012; Lavender et al. 2012). Available information suggests that there is substantial overlap of the frequencies audible to sea turtles and the dominant frequencies of air source pulses. It is likely sea turtles can hear boomer sounds but not those emitted by side scan sonars and echosounders.

## **Masking**

Masking is defined as the obscuring of sounds of interest by interfering sounds generally at similar frequencies (Richardson et al. 1995). Through masking, introduced underwater sound will reduce the effective communication distance of a marine mammal species if the frequency of the introduced sound is similar to the frequency of the sound used as a signal by the marine mammal, and if the introduced sound is occurring for a significant fraction of the time (Richardson et al. 1995; Clark et al. 2009). Therefore, if there is little frequency overlap of the introduced sound and the sound of interest, and, if the occurrence of the introduced sound is infrequent, communication is unlikely to be disrupted. Using an analytical paradigm, Clark et al. (2009) found that of the large baleen whales, the North Atlantic right whale may be most prone to communication masking by commercial vessel traffic noise. They found that two commercial ships in the U.S. Stellwagen Bank National Marine Sanctuary could cause an 84% reduction in the whale's communication space for at least 13.2 h a day. Gedamke (2011) suggested that blue and fin whale communication space may be reduced by 36 to 51% during seismic survey operations. Nieuwkirk et al. (2011) suggested the potential of masking effects of seismic survey operations sounds on large whales in Fram Strait and the Greenland Sea. The biological repercussions of a temporary loss of communication space are unknown (Clark et al. 2009).

The duty cycle of air sources is low. The air source sounds are pulsed, with relatively quiet periods between pulses. In most situations, strong air source sound will only be received for a brief period (<1 s or much less), and these sound pulses will be separated by at least several seconds of relative silence, longer in the case of deep-penetration surveys or refraction surveys. A single air source array might cause appreciable masking when propagation conditions are such that sound from each air source pulse reverberates strongly and persists for either much or the entire interval until the next air source discharge (e.g., Simard et al. 2005; Clark and Gagnon 2006). Situations with prolonged strong reverberation are typically infrequent. However, it is common for pulse reverberation to cause some lesser degree of elevation of the background sound level between air source pulses (e.g., Guerra et al. 2009), thereby causing reduction in 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 to support this thought. Some whales continue calling in the presence of seismic pulses and these calls often can be heard between the seismic pulses (e.g., Richardson et al. 1986; Greene et al. 1999a, b; Smultea et al. 2004; Holst et al. 2005a, b, 2006, 2011; Cerchio et al. 2011). However, there is one recent summary report indicating that calling fin whales distributed in one part of the North Atlantic became 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 report whether the whales ceased calling because of masking, or whether this was a behavioural response not directly involving masking. Castellote et al. (2009, 2010a, b) reported that singing fin whales moved away from an operating air source array rather than cease vocalizations. Bowhead whales in the Beaufort Sea may decrease their call rates in response to seismic survey operations, although movement out of the area might also have contributed to the lower call detection rate (Blackwell et al. 2011). In contrast, Di Iorio and Clark (2010) found that blue whales in the St. Lawrence Estuary increased their call rates during seismic operations using a lower-energy seismic source (i.e., a sparker).

Among the odontocetes, there has been one report that sperm whales ceased calling when exposed to sound 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 sound (Madsen et al. 2002; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006, 2011; Jochens et al. 2008). Madsen et al. (2006) noted that air source sounds would not be expected to mask sperm whale calls given the intermittent nature of air source pulses. Dolphins and porpoises are also commonly heard calling while air sources are operating (Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a, b, 2011; Potter et al. 2007). Masking effects of seismic pulses are expected to be *negligible* in the case of the smaller odontocetes, given the intermittent nature of seismic pulses and that sounds important to them are predominantly at much higher frequencies than are the dominant components of air source sound.

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

A few cetaceans are known to increase the source levels of their calls, to shift their peak frequencies or otherwise modify their vocal behaviour in response to increased levels of introduced sound (reviewed in Richardson et al. 1995:233ff, 364ff; Lesage et al. 1999; Terhune 1999; Nieukirk et al. 2005; Scheifele et al. 2005; Parks et al. 2007b, 2009, 2011; Hanser et al. 2009; Holt et al. 2009; Castellote et al. 2010a, b; Di Iorio and Clark 2010). It is not known how often these types of responses occur upon exposure to air source sounds. However, blue whales in the St. Lawrence Estuary significantly increased their call rates during sparker operations (Di Iorio and Clark 2010). The sparker, used to obtain seismic reflection data, emitted frequencies of 30 to 450 Hz with a source level of 193 dB re 1  $\mu\text{Pa}_{\text{pk-pk}}$ . If cetaceans exposed to air source 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 masking effect.

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. Some studies suggest that visual, wave, and magnetic cues are the main navigational cues used by sea turtles, at least by hatchlings and juveniles (Lohmann et al. 1997, 2001; Lohmann and Lohmann 1998). Therefore, masking is probably not relevant to sea turtles. Even if acoustic signals were important to sea turtles, their hearing is best at frequencies slightly higher (200 to 700 Hz) than the dominant frequencies of air source sound (<200 Hz). If sea turtles do rely on acoustic cues from the environment, the relatively long interval between seismic and sonar pulses should allow them to receive these cues during survey operations. Thus, masking is unlikely to be a significant issue for either marine mammals or sea turtles exposed to the pulsed sounds emitted during seismic survey operations.

## **Disturbance**

Disturbance includes a variety of effects, including subtle to conspicuous changes in behaviour, movement, and displacement. Behavioural reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007). If a marine mammal reacts to an underwater sound by changing its behaviour or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (e.g., Lusseau and Bejder 2007; Weilgart 2007). Also, various authors have noted that even marine mammals that show no obvious avoidance or behavioural changes may still be adversely affected by noise (Brodie 1981; Richardson et al. 1995: 317ff; Romano et al. 2004; Weilgart 2007; Wright et al. 2009, 2011). For example, some research suggests that animals in poor condition or in an already stressed state may not react as strongly to human disturbance as would more robust animals (e.g., Beale and Monaghan 2004).

A committee of specialists on noise impact issues has proposed new science-based impact criteria (Southall et al. 2007). Available detailed data on reactions of marine mammals to air source 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. Fewer 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 air sources but avoidance radii are quite variable depending on species, location, whale activity, oceanographic conditions affecting sound propagation, etc. (reviewed in Richardson et al. 1995; Gordon et al. 2004). It is often reported that whales show no overt reactions to pulses from large arrays of air sources at distances beyond a few kilometers, even

though the sound levels remain well above ambient sound levels at greater distances from the air sources. However, baleen whales exposed to strong sound pulses from air sources often react by deviating from their normal migration route and/or interrupting their feeding and moving away from the sound source. 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 air source arrays (e.g., Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010), strong avoidance reactions by several species of mysticetes have been observed as far as 20 to 30 km from the source vessel when large arrays of air sources were used (e.g., Miller et al. 1999; Richardson et al. 1999). Experiments have shown that bowhead, humpback and grey whales exhibited localized avoidance to a single air source of 20 to 100 in<sup>3</sup> (Malme et al. 1984, 1985, 1986, 1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b).

Studies of grey, bowhead, and humpback whales have shown that seismic sound pulses with received levels of 160 to 170 dB re 1  $\mu\text{Pa}_{\text{rms}}$  seem to cause obvious avoidance behaviour in a substantial portion of the exposed animals (Richardson et al. 1995). In many areas, seismic sound pulses from large air source arrays 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, particularly bowheads and humpbacks, sometimes show strong avoidance at received levels lower than 160 to 170 dB re 1  $\mu\text{Pa}_{\text{rms}}$ . The largest observed avoidance radius involved migrating bowhead whales avoiding an operating seismic vessel by 20 to 30 km (Miller et al. 1999; Richardson et al. 1999; 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 still remained 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, exhibit 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 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 air source 2,678 in<sup>3</sup> array, and to a single 20 in<sup>3</sup> air source with a (horizontal) source level of 227 dB re 1  $\mu\text{Pa} \cdot \text{m}_{\text{p-p}}$ . 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 indicated as 14 km. Avoidance reactions (course and speed changes) began at four to five km for traveling pods; with the closest point of approach (CPA) being three to four km at an estimated received level of 157 to 164 dB re 1  $\mu\text{Pa}_{\text{rms}}$  (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 air source was 140 dB re 1  $\mu\text{Pa}_{\text{rms}}$  for humpback pods containing females, and at the mean CPA distance the received level was 143 dB re 1  $\mu\text{Pa}_{\text{rms}}$ . One startle response was reported at 112 dB re 1  $\mu\text{Pa}_{\text{rms}}$ . The initial avoidance response generally occurred at distances of five to eight km from the air source array and two km from the single air source. 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  $\mu\text{Pa}_{\text{rms}}$ . The McCauley et al. (1998, 2000a, b) studies show evidence of greater avoidance of seismic air source 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).

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<sup>3</sup>) air source (Malme et al. 1985). Some humpbacks seemed “startled” at received levels of 150 to 169 dB re 1  $\mu\text{Pa}$ . Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1  $\mu\text{Pa}$  on an approximate rms basis. However, Moulton and Holst (2010) reported that humpback whales monitored during seismic surveys in the NW Atlantic had significantly lower sighting and were most often seen swimming away from the vessel during seismic periods compared with periods when air sources were silent.

Among wintering humpback whales off Angola (n=52 useable groups), there were no significant differences in encounter rates (sightings/hr) between times when a 24 air source array (3,147 in<sup>3</sup> or 5,085 in<sup>3</sup>) was operating and times with no operating air sources (Weir 2008a). There was also no significant difference in the mean CPA distance of the humpback sightings between times when air sources were discharging versus times when they were not (3,050 m vs. 2,700 m, respectively). Cerchio et al. (2011) suggested that the breeding display of humpback whales off Angola may be disrupted by seismic sounds, as singing activity declined with increasing received levels.

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

## **Rorquals**

Blue, sei, fin, and minke whales (all of which are members of the genus *Balaenoptera*) often have been seen in areas ensonified by air source pulses (Stone 2003; MacLean and Haley 2004; Stone and Tasker 2006; Moulton and Holst 2010), and calls from blue and fin whales have been localized in areas with air source operations (e.g., McDonald et al. 1995; Dunn and Hernandez 2009; Castellote et al. 2010a, b). 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 visibility, sighting rates for mysticetes (mainly fin and sei whales) were similar when large arrays of air sources were discharging and when they were not (Stone 2003; Stone and Tasker 2006). However, these whales tended to exhibit localized avoidance, remaining significantly further (on average) from the air source array during seismic operations compared with non-seismic periods (Stone and Tasker 2006). The average CPA distances for baleen whales sighted when large air source arrays were operating and not operating silent were 1.6 km and 1.0 km, respectively. Baleen whales, as a group, were more often oriented away from the vessel while a large air source array was shooting compared with periods of no shooting (Stone and Tasker 2006). Similarly, Castellote et al. (2009, 2010a,b) reported that singing fin whales in the Mediterranean moved away from an operating air source array and avoided the area of operations even for days after air source activity had ceased. In addition, Stone (2003) noted that fin/sei whales were less likely to remain submerged during periods of seismic shooting.

Blue whales were seen significantly farther from the vessel during single air source operations, ramp-up, and all other air source operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, the mean CPA distance for fin whales was significantly greater during ramp up than during periods without air source operations. There was also a trend for fin whales to be sighted farther from the vessel during other air source 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 air sources were not operating (Moulton and Holst 2010). MacLean and Haley (2004) occasionally observed minke whales approaching active air source arrays where received sound levels were estimated to be near 170 to 180 dB re 1  $\mu$ Pa.

## **Conclusions**

Baleen whales generally tend to avoid operating air sources but avoidance radii are quite variable in length. Whales are often reported to show no overt reactions to air source pulses at distances beyond a few kilometers, even though the air source pulses remain well above ambient noise levels out to much longer distances. However, studies since the late 1990s on migrating humpback and bowhead whales show whale reactions, including avoidance, that sometimes extend to greater distances than earlier documented. Avoidance distances often exceed the maximum distances at which boat-based observers can see whales, so observations from the source vessel can be biased.

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  $\mu\text{Pa}_{\text{rms}}$  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 air source array. However, in other situations, various mysticetes tolerate exposure to full-scale air source 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  $\mu\text{Pa}_{\text{rms}}$ ). Also, even in cases where there is no conspicuous avoidance or change in activity upon exposure to sound pulses from distant seismic operations, there are sometimes subtle changes in behaviour (e.g., surfacing–respiration–dive cycles) that are only evident through detailed statistical analysis (e.g., Richardson et al. 1986; Gailey et al. 2007).

Mitigation measures for seismic surveys, especially nighttime seismic surveys, typically assume that many marine mammals (at least baleen whales) tend to avoid approaching air sources, 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 air source 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 Temporary Threshold Shift (TTS). As noted above, single-air source experiments with three species of baleen whales show that those species typically do tend to move away when a single air source starts firing nearby, simulating the onset of a ramp-up. The three species that showed avoidance when exposed to the onset of pulses from a single air source 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 air source and during ramp-up compared with periods without air source operations. Since startup of a single air source is equivalent to the start of a ramp-up (i.e., soft start), this strongly suggests that many baleen whales will likely begin to move away during the initial stages of a ramp-up.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. Castellote et al. (2009) reported that fin whales avoided their potential winter ground for an extended period of time (at least 10 days) after seismic operations in the Mediterranean Sea had ceased. However, grey whales have continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship

traffic) in that area for decades (Appendix A in Malme et al. 1984; Richardson et al. 1995). There has also been a substantial increase in that grey whale population over recent decades (Allen and Angliss 2010). The W Pacific grey whale population did not seem affected by a seismic survey in its feeding ground during a prior year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). In addition, bowhead numbers have increased notably (Allen and Angliss 2010). Bowheads also have been observed over periods of days or weeks in areas ensonified repeatedly by seismic pulses (Richardson et al. 1987; Harris et al. 2007). However, it is generally not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. In any event, in the absence of some unusual circumstances, the history of coexistence between seismic surveys and baleen whales suggests that brief exposures to sound pulses from any single seismic survey are unlikely to result in prolonged effects.

### **Toothed Whales**

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales. However, there are recent systematic data on sperm whales (e.g., Gordon et al. 2006; Madsen et al. 2006; Winsor and Mate 2006; Jochens et al. 2008; Miller et al. 2009). There is also an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Hauser et al. 2008; Holst and Smultea 2008; Weir 2008a; Barkaszi et al. 2009; Richardson et al. 2009; Moulton and Holst 2010).

### ***Delphinids (Dolphins and similar) and Monodontids (Beluga)***

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating air source arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a, b, c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008a; Richardson et al. 2009; Barkaszi et al. 2009; Moulton and Holst 2010). In most cases, the lengths of 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 air sources include Duncan (1985), Arnold (1996), Stone (2003), and Holst et al. (2006). When a 3,959 in<sup>3</sup>, 18 air source array was firing off California, toothed whales behaved in a manner similar to that observed when the air sources 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 air sources is discharging (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away or maintain a somewhat greater distance from the vessel when a large array of air sources is operating compared to when it is not operating (e.g., Stone and Tasker 2006; Weir 2008a; Barry et al. 2012; Moulton and Holst 2010).

Weir (2008b) noted that a group of short-finned pilot whales initially showed an avoidance response to ramp-up of a large air source 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 NW Atlantic (Moulton and Holst 2010).

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 air sources (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c). Based on data from 21 offshore surveys from 2001-2008, Barry et al. (2012) found that bottlenose and short-beaked common dolphins were seen exhibiting “close to boat” behaviours more often during non-seismic periods than seismic periods, and that higher proportions of both species were seen “travelling” during seismic operations compared with non-seismic periods.

The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the southeastern Beaufort Sea in summer found that sighting rates of belugas were significantly lower at distances 10 to 20 km compared with 20 to 30 km from an operating air source array (Miller et al. 2005). The low number of beluga sightings by marine mammal observers on the vessel seemed to confirm there was a strong avoidance response to the 2,250 in<sup>3</sup> air source 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 air source pulses (e.g., Harris et al. 2007).

Observers stationed on seismic vessels operating off the U.K. from 1997 to 2000 have provided data on the occurrence and behaviour of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004; Stone and Tasker 2006). Dolphins of various species often showed more evidence of avoidance of operating air source 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<sup>1</sup> air source 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 greater from large air source 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 air source 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 air sources 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

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<sup>1</sup> Large volume means at least 1,300 in<sup>3</sup>, with most (79%) at least 3,000 in<sup>3</sup>.

vessels, the median CPA distance was  $\geq 0.5$  km larger during air source operations (Stone and Tasker 2006). Killer whales appeared to be more tolerant of seismic shooting in deeper waters.

Data collected during seismic operations in the Gulf of Mexico and off Central America show similar patterns. A summary of vessel-based monitoring data from the Gulf of Mexico during 2003 to 2008 showed that delphinids were generally seen farther from the vessel during seismic than during non-seismic periods (based on Barkaszi et al. 2009, excluding sperm whales). Similarly, during two National Science Foundation (NSF)-funded Lamont-Doherty Earth Observatory of Columbia University (L-DEO) seismic surveys that used a large 20 air source array ( $\sim 7,000$  in<sup>3</sup>), sighting rates of delphinids were lower and initial sighting distances from the vessel were greater 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 compared to 172 m when the air sources 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 air sources 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 compared to 178 m when the air sources 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 air source array ( $\sim 6,600$  in<sup>3</sup>), 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 less during seismic periods (Hauser et al. 2008; Holst and Smultea 2008).

During seismic surveys in the NW Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly greater (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 air source array (3,147 in<sup>3</sup> or 5,085 in<sup>3</sup>) (Weir 2008a). Sample sizes were low, but CPA distances of dolphin groups were significantly larger when air sources were operating (mean 1,080 m) compared to when they were not (mean 209 m). No Atlantic spotted dolphins were seen within 500 m of the air sources when they were operating, whereas all sightings when air sources were silent occurred within 500 m, including the only recorded “positive approach” behaviours.

Reactions of toothed whales to a single air source or other small air source sources are not well documented, but tend to be less substantial than reactions to large air source 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<sup>2</sup> air source 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<sup>3</sup>) 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 less during seismic operations during one cruise (Holst et al. 2005b) and greater during the other cruise (Haley and Koski 2004). Interpretation of the data was confounded by the fact that survey effort and/or number of sightings during non-seismic periods during both surveys was small. Results from two small-array surveys in southeast Alaska were even more variable (MacLean and Koski 2005; Smultea and Holst 2003).

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<sup>3</sup>). Compared to air source 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 air source 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 with received levels of about 185 dB re 1  $\mu$ Pa (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.

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<sup>2</sup> For low volume arrays, maximum volume was 820 in<sup>3</sup>, with most (87%)  $\leq$  180 in<sup>3</sup>.

### ***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 air source sound ( $<145$  dB re  $1 \mu\text{Pa}_{\text{rms}}$  at a distance  $>70$  km; Bain and Williams 2006). Similarly, during seismic surveys with large air source arrays off the U.K. in 1997 to 2000, there were significant differences in directions of travel by harbour porpoises between periods when the air sources were shooting and those without air source discharging (Stone 2003; Stone and Tasker 2006). A captive harbour porpoise exposed to single sound pulses from a small air source showed aversive behaviour upon receipt of a pulse with a received level above  $174$  dB re  $1 \mu\text{Pa}_{\text{pk-pk}}$  or  $\text{SEL} >145$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  (Lucke et al. 2009). In contrast, Dall's porpoises seem relatively tolerant of air source operations (MacLean and Koski 2005; Bain and Williams 2006), although they too have been observed to avoid large arrays of operating air sources (Calambokidis and Osmek 1998; Bain and Williams 2006). The apparent tendency for greater responsiveness by harbour porpoise is consistent with their relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

### ***Beaked Whales***

There are almost no specific data on the behavioural reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986), although it is uncertain how much longer such dives may be as compared to dives by undisturbed beaked whales which also are often quite long (Baird et al. 2006; Tyack et al. 2006a, b). In any event, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel, regardless of whether or not the air sources are operating. However, this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels not emitting air source pulses (Reeves et al. 1993; Hooker et al. 2001). Several studies have indicated that some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Gosselin and Lawson 2004; Laurinolli and Cochrane 2005; Simard et al. 2005; Potter et al. 2007). Moulton and Holst (2010) reported 15 sightings of beaked whales during seismic studies in the NW Atlantic. Seven of those sightings were made at times when at least one air source was operating. There was little evidence to indicate that beaked whale behaviour was affected by air source operations since sighting rates and distances were similar during seismic and non-seismic periods (Moulton and Holst 2010).

### ***Sperm Whales***

All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting air source sounds (e.g., Richardson et al. 1995; Würsig et al. 1998; McAlpine 2002; Baird 2005). However, most studies of sperm whales exposed to air source sounds indicate that this species



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

Recent and more extensive data from vessel-based monitoring programs in U.K. waters, the NW Atlantic, and off Angola suggest that sperm whales in those areas show little evidence of avoidance or behavioural disruption in the presence of operating seismic vessels (Stone 2003; Stone and Tasker 2006; Weir 2008a; Moulton and Holst 2010). Among sperm whales off Angola ( $n = 96$  useable groups), there were no significant differences in encounter rates (sightings/h) between times when a 24 air source array (3,147 in<sup>3</sup> or 5,085 in<sup>3</sup>) was operating and times without operating air sources. The encounter rate tended to increase over the 10 month duration of the seismic survey (Weir 2008a). There was also no significant difference in the CPA distances of the sperm whale sightings between times when air sources were operating and times when they were not (means 3,039 m vs. 2,594 m, respectively). Similarly, in the NW Atlantic, sighting rates and distances of sperm whales did not differ between seismic and non-seismic periods (Moulton and Holst 2010). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive animals which may be beyond visual range. However, these results do seem to indicate considerable tolerance of seismic surveys by at least some sperm whales. Also, a study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1  $\mu\text{Pa}_{\text{p-p}}$  (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 whether the air sources were operating or not (Barkaszi et al. 2009). For example, the mean sighting distance was 1,839 m when the air source array was in full operation ( $n=612$ ) and 1,960 m when all air sources 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 air source arrays (Jochens et al. 2008; Miller et al. 2009).

Whales were exposed to maximum received sound levels of 111 to 147 dB re 1  $\mu\text{Pa}_{\text{rms}}$  (131 to 162 dB re 1  $\mu\text{Pa}_{\text{pk-pk}}$ ) at ranges of ~1.4 to 12.8 km from the sound source (Miller et al. 2009). Although the tagged whales showed no discernible horizontal avoidance, some whales showed changes in diving and foraging behaviour during full-array exposure, possibly indicative of subtle negative effects on foraging (Jochens et al. 2008; Miller et al. 2009; Tyack 2009). Two indicators of foraging that they studied included 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 seven 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 air source-whale distance (Miller et al. 2009: Fig. 5; Tyack 2009).

### ***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 air source pulses, contrary to earlier indications.

There are almost no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. Northern bottlenose whales seem to continue to call when exposed to pulses from distant seismic vessels.

Overall, odontocete reactions to large arrays of air sources are variable and, at least for delphinids and some porpoises, seem to be confined to a smaller reaction 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 air source sound to the animals' location (DeRuiter et al. 2006; Goold and Coates 2006; Tyack et al. 2006a,b; Potter et al. 2007).

For delphinids, and possibly the Dall's porpoise, the available data suggest that a  $\geq 170$  dB re 1  $\mu\text{Pa}_{\text{rms}}$  disturbance criterion (rather than  $\geq 160$  dB) would be appropriate. With a medium to large air source 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  $\mu\text{Pa}_{\text{rms}}$  distances. The 160 dB (rms) criterion currently applied by

NMFS was based primarily on data from grey and bowhead whales. Avoidance distances for delphinids and Dall's porpoises tend to be less 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  $\sim 170$  dB re  $1 \mu\text{Pa}_{\text{rms}}$  (on the order of 2 or 3 km for a large air source 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 of) and associated behaviour. Additional monitoring of that type has been done in the Beaufort and Chukchi seas in 2006 to 2010. Pinnipeds exposed to air source sounds have also been observed during seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of pinnipeds exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from air sources and linear explosive charges reportedly did not react strongly (J. Parsons *in* Greene et al. 1985). An air source 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 either tolerant of or able 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 air source pulses (Thompson et al. 1998). Harbour seals were exposed to seismic pulses from a  $90 \text{ in}^3$  array ( $3 \times 30 \text{ in}^3$  air sources), 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 air source array showed no detectable behavioural response, even when the array was within 500 m. Grey seals exposed to a single  $10 \text{ in}^3$  air source 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 greater when air sources were operating; both species tended to orient away whether or not the air sources were firing (Calambokidis and Osmek 1998). Bain and Williams (2006) also observed that their small sample of harbour seals and sea lions tended to orient and/or move away upon exposure to sounds from a large air source 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 air sources with total volumes 560 to 1,500 in<sup>3</sup>. Subsequent monitoring work in the Canadian Beaufort Sea in 2001 to 2002, with a somewhat larger air source system (24 air sources, 2,250 in<sup>3</sup>), 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 were, on average, farther away from the seismic vessel when the air sources were operating than when they were not (Moulton and Lawson 2002). Also, seal sighting rates at the water surface were lower during air source array operations than during no- air source 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 meters, with many seals remaining within 100 to 200 m of the trackline as the operating air source array passed by.

The operation of the air source array had minor and variable effects on the behaviour of seals visible at the surface within a few hundred meters of the air source (Moulton and Lawson 2002). The behavioural data indicated that some seals were more likely to swim away from the source vessel during periods of air source operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to air source 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 air source 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 air source operations. However, seals tended to be seen closer to the vessel during non-seismic than during seismic periods. In contrast, during 2002, sighting rates of seals were higher during non-seismic periods than during 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 air source 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  $\geq 160$  and 159-120 dB rms, and sighting rates

were greater from source than monitoring vessels at locations with received sound levels were <120 dB rms (Haley et al. 2010). In the Beaufort Sea, sighting rates for seals exposed to received sound levels  $\geq 160$  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  $\geq 160$  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  $\geq 160$  dB rms. These observations are indicative of a tendency for phocid seals to exhibit localized avoidance of the seismic source vessel when air sources 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  $\geq 160$  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 air sources by moving away from the source vessel.

## ***Conclusions***

Visual monitoring from seismic vessels has shown only slight (if any) avoidance of air sources 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 meters of an operating air source array. However, based on the studies with large sample size, observations from a separate monitoring vessel, or radio telemetry, it is apparent that some phocid seals do show localized avoidance of operating air sources. 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.

## **Sea Turtles**

There have been few studies of the effects of air source noise (or indeed any type of noise) on sea turtles, and little is known about the sound levels that will elicit various types of behavioural reactions. There have been four directed studies that focused on short-term behavioural responses of sea turtles in enclosures to single air sources. 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 air source pulses received by the turtles. Although monitoring studies are now providing some information on responses (or lack of) of free-ranging sea turtles to seismic surveys are now being reported, HMDC is not aware of any directed studies on responses of free-ranging sea turtles to seismic sounds or on the long-term effects of exposure of sea turtles to seismic or other sounds.

The most recent of the studies of caged sea turtles exposed to air source 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<sup>3</sup> air source operating at 1,500 psi and 5 m air source depth. The single air source fired every 10 s. There were two trials separated by two days; the first trial involved ~2 h of air source exposure and the second ~1 h. The

results from the two trials showed that, above a received level of 166 dB re 1  $\mu$ Pa (rms), the turtles noticeably increased their swim speed relative to periods when no air sources were operating. The behaviour of the sea turtles became more erratic when received levels exceeded 175 dB re 1  $\mu$ Pa 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 air sources 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<sup>3</sup> air source plus two 0.8 in<sup>3</sup> "poppers" operating at 2,000 psi<sup>3</sup> and air source depth of 2 m for prolonged periods of 20 to 36 hours in duration. The turtles maintained a standoff range of about 30 m when exposed to air source 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 air source pulses. O'Hara and Wilcox (1990) did not measure the received air source 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  $\mu$ Pa 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. (2000a, b) apparently did not allow for the shallow 2 m air source depth in the Florida study. The effective source level of air source 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 air source, as well as the effects on their hearing as summarized earlier. The turtles were held in a netted enclosure ~18 m by 61 m by 3.6 m deep, with an air source of unspecified size at each end. Only one air source was operated at any one time; the firing rate was one shot every 5 to 6 s. Ten turtles were tested individually, and seven of these were retested several days later. The air source 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 air source 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 air source pulses may have resulted in TTS (discussed earlier). Reduced hearing sensitivity may also have contributed to the waning response upon continued exposure. Based on physiological measurements, there was some evidence of increased stress in the sea turtles, but this stress could also have resulted from handling of the turtles.

Inconsistencies in reporting procedures and experimental design prevent direct comparison of this study with either McCauley et al. (2000a, b) or O'Hara and Wilcox (1990). Moein et al. (1994) stated, without further details, that "three different decibel levels (175, 177, 179) were utilised" during each test. These sound levels probably are received levels in dB re 1  $\mu$ Pa, and probably relate to the initial exposure distance (mean 24 m), but these details were not specified. Also, it was not specified whether

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<sup>3</sup> There was no significant reaction by five turtles during an initial series of tests with the airguns operating at the unusually low pressure of 1,000 psi. The source and received levels of airgun sounds would have been substantially lower when the air pressure was only 1,000 psi than when it was at the more typical operating pressure of 2,000 psi.

these values were measured or estimated, or whether they are expressed in peak-peak, peak, rms, SEL, or some other units. Given the shallow water in the enclosure (3.6 m), any estimates based on simple assumptions about propagation would be suspect.

Despite the problems in comparing these studies, there is a consistent trend showing that, at some received level, sea turtles show avoidance of an operating air source. Lenhardt (2002) reported behavioural responses to Bolt 600 air sources at received levels of 151 to 161 dB SPL re 1  $\mu$ m, 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 air source was 166 dB re 1  $\mu$ Pa rms, and avoidance responses at 175 dB re 1  $\mu$ Pa rms. Based on these data, McCauley et al. (2000a,b) estimated that, for a typical air source array (2,678 in<sup>3</sup>, 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 air sources (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 air source impulse, or to bottom vibrations.

Two studies involving stimuli other than air sources may also be relevant:

1. Two loggerhead turtles resting on the bottom of shallow tanks responded repeatedly to low-frequency (20 to 80 Hz) tones by becoming active and swimming to the surface. They remained at the surface or only slightly submerged for the remainder of the 1 min trial (Lenhardt 1994). Although no detailed data on sound levels at the bottom vs. surface were reported, the surfacing response probably reduced the levels of underwater sound to which the turtles were exposed.
2. In a separate study, a loggerhead and a Kemp’s Ridley sea turtle responded similarly when 1 s vibratory stimuli at 250 or 500 Hz were applied to the head for 1 s (Lenhardt et al. 1983). There appeared to be rapid habituation to these vibratory stimuli.

The tones and vibratory stimuli used in these studies were quite different from air source 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 air source 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 air sources; 3,050 to 8,760 in<sup>3</sup>) and small-source (up to six air sources or three GI guns; 75 to 1,350 in<sup>3</sup>) surveys conducted by

L-DEO during 2003 to 2005, the mean closest point of approach (CPA) for turtles was less during non-seismic than seismic periods: 139 m vs. 228 m and 120 m vs. 285 m, respectively (Holst et al. 2006). During one of these surveys an observer sighted an olive Ridley sea turtle (*Lepidochelys olivacea*) which appeared at the surface within the 190 dB re 1  $\mu$ Pa isopleth while the 10 air source 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 air source array when it was operating (mean 159 m,  $n=77$ ) than when the air sources 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 air source 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 air source arrays with total volumes 5,085 and 3,147  $\text{in}^3$  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 2,028 h of marine mammal mitigation and monitoring of seismic exploration using 4 to 8 GI air sources; no evidence of adverse impacts on sea turtles from seismic operations was apparent (Parente et al. 2006b). A recent paper by DeRuiter and Doukara (2012) reports observations of loggerhead turtles during a seismic survey in the Mediterranean Sea in 2009. Over 50% of the turtles being visually tracked dove at or before their closest point of approach to the air source arrays. DeRuiter and Doukara (2012) suggested that this diving behavior might be an avoidance response to the air source sound.

The paucity of data precludes specific predictions as to how free-ranging sea turtles respond to seismic sounds. The possible responses could include one or more of the following: (1) avoidance of the entire seismic survey area to the extent that the turtles move to less preferred habitat; (2) avoidance of only the immediate area around the active seismic vessel, i.e., local avoidance of the source vessel but remain in the general area; and/or (3) no appreciable avoidance, although short-term behavioural reactions are likely.

The potential alteration of a migration route might have negative impacts. However, it is not known whether the alteration would ever be on a sufficient geographic scale, or be sufficiently prolonged, to prevent turtles from reaching an important destination.

Avoidance of a preferred foraging area because of seismic survey noise may prevent sea turtles from obtaining preferred prey species and hence could impact their nutritional status. However, it is highly unlikely that sea turtles would completely avoid a large area along a migration route. Available evidence suggests that the zone of avoidance around seismic sources is not likely to exceed a few kilometers



(McCauley et al. 2000b). Avoidance reactions on that scale could prevent sea turtles from using an important coastal area or bay if there was a prolonged seismic operation in the area. Sea turtles might be excluded from the area for the duration of the seismic operation, or they might remain but exhibit abnormal behavioural patterns (e.g., lingering at the surface where received sound levels are lower). Whether those that were displaced would return quickly after the seismic operation ended is generally unknown. Again, this is not a likely possibility in the circumstances of the present project, since operations will be in offshore areas that are not known or expected to be preferred foraging habitat.

The results of experiments and monitoring studies on responses of marine mammals and fish to seismic surveys show that behavioural responses are possible, depending on species, time of year, activity of the animal, and other unknown factors. The same species may show different kinds of responses at different times of year or even on different days (Richardson et al. 1995). It is reasonable to expect similar variability in the case of sea turtles exposed to air source 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 air source sound effects on sea turtles. However, it is reasonable to expect lesser effects in young turtles concentrated near the surface (where levels of air source sounds are attenuated) as compared with older turtles that spend more time at depth where air source sounds are generally stronger.

## ***Conclusions***

Most studies on sea turtles have been conducted on species not common on the Grand Banks, in shallow water, enclosed areas and thus are not directly applicable to the Study Area. The limited available data indicate that sea turtles will hear air source 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. Sound from seismic operations in or near areas where turtles concentrate is likely to have the greatest effect. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Study Area is not a breeding area for sea turtles and it is not known or thought to be an important feeding or migration area; thus, high concentrations of sea turtles are unlikely.

## **Hearing Impairment**

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. Temporary threshold shift (TTS) has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed in Southall et al. 2007). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., permanent threshold shift (PTS), in free-ranging marine mammals exposed to sequences of air source pulses during realistic field conditions. Current National Marine Fisheries Service (NMFS) policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds  $\geq 180$  and  $190$  dB re  $1 \mu\text{Pa}_{\text{rms}}$ , respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shut-down) radii planned for numerous seismic surveys conducted under U.S. jurisdiction. Those criteria have also been used in establishing the safety (=power-down)

zones for seismic surveys in some parts of Canada. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause TTS in marine mammals. The 180 dB criterion for cetaceans is probably conservative for at least some species including bottlenose dolphin and beluga, i.e., lower than necessary to avoid temporary auditory impairment let alone permanent auditory injury.

Recommendations for new science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters have been published (Southall et al. 2007). Those recommendations have not, as of 2011, been formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys. However, some aspects of the recommendations have been taken into account in certain EAs and small-take authorizations, and NMFS is moving toward adoption of new procedures taking at least some of Southall et al. 2007 recommendations into account (Scholik-Schlomer 2012). Preliminary information about possible changes in the regulatory and mitigation requirements, and about the possible structure of new criteria, was given by Wieting (2004) and NMFS (2005).

Several aspects of the planned monitoring and mitigation measures for the proposed project are designed to detect marine mammals occurring near the air source array (i.e., MMOs), 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 air source 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 finless porpoise. The majority of these data concern non-impulse sound, but there are some limited published data concerning TTS onset upon exposure to a single pulse of sound from a watergun (Finneran et al. 2002). A detailed review of all TTS data from marine mammals can be found in Southall et al. (2007). 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  $\mu\text{Pa}^2 \cdot \text{s}$ ). 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). 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  $\mu\text{Pa}$  for periods of 1.88 to 30 min. Higher SELs were required to induce a given TTS if exposure duration was short than if it was longer. Exposure of the aforementioned bottlenose dolphin to a sequence of brief sonar signals showed that, with those brief (but non-impulse) sounds, the received energy (SEL) necessary to elicit TTS was higher than was the case with exposure to the more prolonged octave-band noise (Mooney et al. 2009b). Those authors concluded that, when using (non-impulse) acoustic signals of duration ~0.5 s, SEL must be at least 210 to 214 dB re 1  $\mu\text{Pa}^2 \cdot \text{s}$  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  $\mu\text{Pa}$  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  $\sim 186$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  or 186 dB SEL (Finneran et al. 2002).<sup>4</sup> The rms level of an air source pulse (in dB re  $1 \mu\text{Pa}$  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 kilometers of the air sources. Thus, a single air source pulse might need to have a received level of  $\sim 196$  to 201 dB re  $1 \mu\text{Pa}_{\text{rms}}$  in order to produce brief, mild TTS. Exposure to several strong seismic pulses that each has a flat-weighted received level near 190 dB<sub>rms</sub> (175 to 180 dB SEL) could result in cumulative exposure of  $\sim 186$  dB SEL (flat-weighted) or  $\sim 183$  dB SEL (Mmf-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 air source with a cumulative SEL of  $\sim 195$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$ .

The conclusion that 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 air source sound that elicited onset of TTS was lower. The animal was exposed to single pulses from a small ( $20 \text{ in}^3$ ) air source, 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 air source pulse with received level  $\sim 200$  dB re  $1 \mu\text{Pa}_{\text{pk-pk}}$  or an SEL of 164.3 dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$ . 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 air source pulses received by an odontocete is a function of their cumulative energy.

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<sup>4</sup> If the low-frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005) and Southall et al. (2007) using their  $M_{\text{mf}}$ -weighting curve, the effective exposure level for onset of mild TTS was 183 dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  (Southall et al. 2007).

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 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 air source sound with variable received levels. To determine how close an air source 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 air source shots would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Erbe and King 2009; Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy even though that energy is received in multiple pulses separated by gaps. The lack of data on the exposure levels necessary to cause TTS in toothed whales when the signal is a series of pulsed sounds, separated by silent periods, remains a data gap, as is the lack of published data on TTS in odontocetes other than the beluga, bottlenose dolphin, and harbour porpoise.

### ***Baleen Whales***

There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale. The frequencies to which mysticetes are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in mysticetes (Southall et al. 2007). However, based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, Gedamke et al. (2011) suggested that some baleen whales whose closest point of approach to a seismic vessel is 1 km or more could experience TTS.

In practice during seismic surveys, few if any cases of TTS are expected given the strong likelihood that baleen whales would avoid the approaching air sources (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 air source operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As discussed earlier, results from numerous studies indicate that many baleen whales; particularly bowhead, grey, humpback, and blue whales are likely to move away from the source vessel during the initial stages of a ramp-up.

## ***Pinnipeds***

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels of ~178 and 183 dB re 1  $\mu\text{Pa}_{\text{rms}}$  and total energy fluxes of 161 and 163 dB re 1  $\mu\text{Pa}^2 \cdot \text{s}$  (Finneran et al. 2003). However, initial evidence from more prolonged (non-pulse and pulse) exposures suggested that some pinnipeds (harbour seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; Kastelein et al. 2011). Kastak et al. (2005) reported that the amount of threshold shift increased with increasing SEL in a California sea lion and harbour seal. 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  $\mu\text{Pa}^2 \cdot \text{s}$ , 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  $\mu\text{Pa}^2 \cdot \text{s}$  (Southall et al. 2007). That would be approximately equivalent to a single pulse with received level ~181 to 186 dB re 1  $\mu\text{Pa}_{\text{rms}}$ , 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 air source 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 air source of unspecified size on loggerhead sea turtles. Apparent TTS was observed after exposure to a few hundred air source pulses at distances no more than 65 m. The hearing capabilities had returned to “normal” when the turtles were re-tested two weeks later. Similarly, Lenhardt (2002) exposed loggerhead turtles in a large net enclosure to air source pulses. They noted TTS of >15 dB in one loggerhead turtle, with recovery occurring in two weeks. Turtles in the open sea might have moved away from an air source operating at a fixed location, and in the more typical case of a towed air source or air source array, very few shots would occur at or around one location. Thus, exposure to underwater sound during net-enclosure experiments was not typical of that expected during an operational seismic survey.

Studies with terrestrial reptiles have also demonstrated that exposure to impulse noise can cause hearing loss. For example, desert tortoises (*Gopherus agassizii*) exhibited TTS after exposure to repeated high-intensity sonic booms (Bowles et al. 1999). Recovery from these temporary hearing losses was usually rapid (<1 h), which suggested that tortoises can tolerate these exposures without permanent injury (Bowles et al. 1999). However, there are no data to indicate whether or not there are any plausible situations in which exposure to repeated air source 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 (i.e., 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  $\leq 100$  m around a typical array of operating air sources might be exposed to a few seismic pulses with levels of  $\geq 205$  dB, and possibly more pulses if the mammal moved with the seismic vessel.

Most cetaceans show some degree of avoidance of seismic vessels operating an air source array (see above). It is unlikely that these cetaceans would be exposed to air source 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 air sources. 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 air sources, they would be exposed to strong sound pulses, possibly repeatedly.

If some cetaceans did incur mild or moderate TTS through exposure to air source 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 air sources, 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 air source array could incur TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels  $>180$  dB re  $1 \mu\text{Pa}_{\text{rms}}$ . 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  $1 \mu\text{Pa}_{\text{rms}}$  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 air source pulses in which the strongest pulse has a received level substantially exceeding 190 dB re  $1 \mu\text{Pa}_{\text{rms}}$ . On the other hand, for the harbour seal, harbour porpoise, and perhaps some other species, TTS may occur upon exposure to one or more air source pulses whose received level equals the NMFS “do not exceed” value of 190 dB re  $1 \mu\text{Pa}_{\text{rms}}$ . That criterion corresponds to a single pulse with a SEL of 175 to 180 dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  in typical conditions, whereas TTS is suspected to be possible in harbour seals and harbour porpoises with a cumulative SEL of  $\sim 171$  and  $\sim 164$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$ , 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 meters of an air source 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 air source arrays, which is standard operational protocol for many seismic operators, should allow cetaceans near the air sources at the time of startup to move away from the seismic source and to avoid being exposed to the full acoustic output of the air source array (see above). Thus, most baleen whales likely will not be exposed to high levels of air source 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 air sources to be close enough to an air source array to experience TTS. In the event that a few individual cetaceans did incur TTS through exposure to strong air source sounds, this is a temporary and reversible phenomenon unless the exposure exceeds the TTS-onset threshold by a sufficient amount for PTS to be incurred (see below). If TTS but not PTS were incurred, it would most likely be mild, in which case recovery is expected to be quick (probably within minutes).

There have been few studies that have directly investigated hearing or noise-induced hearing loss in sea turtles. The apparent occurrence of TTS in loggerhead turtles exposed too many pulses from a single air source  $\leq 65$  m away (Moein et al. 1994) suggests that sounds from an air source 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 air sources. However, there are few data on temporary hearing loss and no data on permanent hearing loss in sea turtles exposed to air source 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 air source sound can cause PTS in any marine mammal or sea turtle, even with large arrays of air sources. However, given the likelihood that some animals close to an air source array might incur at least mild TTS (see above), there has been further speculation about the possibility that some individuals occurring very close to air sources might incur PTS (e.g., Richardson et al. 1995, p. 372ff; 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 air source 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 air source pulses is fast, but not as fast as that of an explosion.

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

- Exposure to single very intense sound;
- Fast rise time from baseline to peak pressure;
- Repetitive exposure to intense sounds that individually cause TTS but not PTS; and
- Recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

More recently, Southall et al. (2007) estimated that received levels would need to exceed the TTS threshold by at least 15 dB, on an SEL basis, for there to be risk of PTS. Thus, for cetaceans exposed to a sequence of sound pulses, they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of  $\sim 198$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  (15 dB higher than the  $M_{\text{mf}}$ -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  $M_{\text{pw}}$ -weighted SEL of  $\sim 186$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  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  $1 \mu\text{Pa}$ , respectively. Thus, PTS might be expected upon exposure of cetaceans to either  $\text{SEL} \geq 198$  dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  or peak pressure  $\geq 230$  dB re  $1 \mu\text{Pa}$ . Corresponding proposed dual criteria for pinnipeds (at least harbour seals) are  $\geq 186$  dB SEL and  $\geq 218$  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 subsequent 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). PTS effects may also be influenced strongly by the health of the receiver’s ear.

As described above for TTS, to estimate the amount of sound energy required for 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  $1 \mu\text{Pa}_{\text{rms}}$  (175 to 180 dB re  $1 \mu\text{Pa}^2 \cdot \text{s}$  SEL) could result in cumulative exposure of  $\sim 186$  dB SEL (flat-weighted) or  $\sim 183$  dB SEL ( $M_{\text{mf}}$ -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<sub>rms</sub> (190 to 195 dB SEL) could result in cumulative exposure of  $\sim 198$  dB SEL ( $M_{\text{mf}}$ -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 air source 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 air source 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 air source 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 air source pulses. The TTS (and thus PTS) thresholds of some pinnipeds (e.g., harbour seal) as well as the harbour porpoise may be lower (Kastak et al. 2005; Southall et al. 2007; Lucke et al. 2009; Kastelein et al. 2011). If so, TTS and potentially PTS may extend to a somewhat greater distance for those animals. Again, Lloyd's mirror and surface release effects will ameliorate the effects for animals at or near the surface.

In theory, a reduction in hearing sensitivity, either temporary or permanent, may be harmful for sea turtles. However, very little is known about the role of sound perception in the sea turtle's normal activities. Hence, it is not possible to estimate how much of a problem it would be for a turtle to have either temporary or permanent hearing impairment. It is noted above that sea turtles are unlikely to use passive reception of acoustic signals to detect the hunting sonar of killer whales, because the echolocation signals of killer whales are likely inaudible to sea turtles. Hearing is also unlikely to play a major role in their navigation. However, hearing impairment, either temporary or permanent, might inhibit a turtle's ability to avoid injury from vessels, because they may not hear them in time to move out of their way. In any event, sea turtles are unlikely to be at great risk of hearing impairment.

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

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

The avoidance reactions of many marine mammals and sea turtles, along with commonly-applied monitoring and mitigation measures (visual and passive acoustic monitoring, ramp-ups, and power downs

or shut downs when mammals are detected within or approaching the “safety radii”), would reduce the already-low probability of exposure of marine mammals and sea turtles to sounds strong enough to induce PTS.

## **Physical and Non-Auditory Physiological Effects**

### **Strandings and Mortality**

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys (reviewed in LGL 2012 appended). 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 air source 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 air source, 8,490 in<sup>3</sup> air source 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 HMDC’s proposed Project 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.

Potential direct physical effects to sea turtles during seismic operations include entanglement with seismic gear (e.g., cables, buoys, streamers, etc.) and ship strikes (Pendoley 1997; Hazel et al. 2007; Ketos Ecology 2007; Weir 2007). Entanglement of sea turtles with marine debris, fishing gear, dredging operations, and equipment operations are a documented occurrence and of elevated concern for sea turtles. Turtles can become wrapped around cables, lines, nets, or other objects suspended in the water column and become injured or fatally wounded, drowned, or suffocated (e.g., Lutcavage et al. 1997; NMFS 2007). Seismic personnel have reported that sea turtles (number unspecified) became fatally entrapped between gaps in tail-buoys associated with industrial seismic vessel gear deployed off West Africa in 2003 (Weir 2007). With dedicated monitoring by trained biological observers, no incidents of entanglements of sea turtles with this gear have been documented in over 40,000 nmi (74,000 km) of previous NSF-funded seismic surveys (e.g., Holst and Smultea 2008). Towing of the hydrophone

streamer or other equipment is not expected to significantly interfere with sea turtle movements, including migration, unless they were to become entrapped as indicated above.

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

### **Non-auditory Physiological Effects**

Based on evidence from terrestrial mammals and humans, sound is a potential source of stress (Wright and Kuczaj 2007; Wright et al. 2011). However, almost no information is available on sound-induced stress in marine mammals, or on its potential (alone or in combination with other stressors) to affect the long-term well-being or reproductive success of marine mammals (Fair and Becker 2000; Hildebrand 2005; Wright et al. 2007).

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

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

### **Summary of Effects of Exposure to Sound**

Based on the above review, marine mammals and sea turtles will likely exhibit certain behavioural reactions, including displacement from an area around seismic acoustic sources. The size of this displacement area will likely vary amongst species, during different times of the year, and even amongst individuals within a given species. There is also a risk that marine mammals (and perhaps sea turtles) that are very close to a seismic array may incur temporary hearing impairment. The assessment of impacts presented here is based upon the best available information. Note that we have discussed potential impacts separately for toothed whales, baleen whales, seals, and sea turtles given their different hearing abilities and sensitivities to sound. Potential interactions between Project activities and marine mammals and sea turtles are shown in Table 5.10.

**Table 5.10 Potential Interactions of Project Activities and the Marine Mammal and Sea Turtle VEC.**

Valued Ecosystem Components: Marine Mammal and Sea Turtle				
Project Activities	Toothed Whales	Baleen Whales	Seals	Sea Turtles
<b>Sound Emissions and Receivers</b>				
Air sources	X	X	X	X
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Secondary Source Vessel	X	X	X	X
Helicopter <sup>a</sup>	X	X	X	X
Echo Sounder	X	X	X	X
Side Scan Sonar	X	X	X	X
Boomer	X	X	X	X
<b>Vessel Lights</b>				
<b>Vessel Presence</b>				
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Picket Vessel	X	X	X	X
Secondary Source Vessel	X	X	X	X
<b>Sanitary/Domestic Waste</b>	X	X	X	X
<b>Atmospheric Emissions</b>	X	X	X	X
<b>Garbage<sup>b</sup></b>	-	-	-	-
<b>Helicopter Presence<sup>a</sup></b>	X	X	X	X
<b>Shore Facilities<sup>c</sup></b>				
<b>Accidental Releases</b>	X	X	X	X
<b>Other Projects and Activities</b>				
Oil & Gas: Grand Banks and Orphan Basin	X	X	X	X
Fisheries (incl. research)	X	X	X	X
Marine Transportation	X	X	X	X

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

### **Sound Criteria for Assessing Effects**

Impact zones for marine mammals are commonly defined by the areas within which specific received sound level thresholds are exceeded. The U.S NMFS (1995, 2000) has concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 µPa (*rms*). The corresponding limit for seals has been set at 190 dB re 1 µPa (*rms*). These sound levels are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS, one cannot be certain that there will be no injurious effects, auditory or otherwise, to marine mammals. For over a decade, it has been common for marine seismic surveys conducted in some areas of U.S. jurisdiction and in some areas of Canada (Canadian Beaufort Sea and on the Scotian Shelf), to include a “shutdown” requirement for cetaceans based on the distance from the air source array at which the received level of underwater sounds is expected to diminish below 180 dB re 1 µPa (*rms*). As discussed above in

“*Hearing Impairment Effects*”, data that are now available imply that TTS is unlikely to occur in various odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several air source pulses in which the strongest pulse has a received level substantially exceeding 190 dB re 1  $\mu$ Pa (*rms*).

An additional criterion that is often used in predicting “disturbance” impacts is 160 dB re 1  $\mu$ Pa; at this received level, some marine mammals exhibit behavioural effects in response to pulsed sound. 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 (2013) recommends that seismic operators follow the “*Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*” (hereafter referred to as the *Statement*) issued by the DFO and incorporated into the C-NLOPB guidelines that are a condition of project authorizations. The *Statement* does not include noise criteria as part of the recommended mitigation measures; rather it defines (see Point 6.a) a safety zone as “a circle with a radius of at least 500 meters as measured from the centre of the air source array (s)”.

In the absence of site-specific acoustic modelling, the acoustic monitoring results in Austin and Carr (2005) have been used to provide guidance on the ranges one might expect sound levels to be 190, 180 and 160 dB re 1  $\mu$ Pa (*rms*) (from a 28 air source 3,090 in<sup>3</sup> array). The 180 and 190 dB zones were estimated at 700 m and 300 m, respectively. The 160 dB zone occurred at distances of 5,123 m to 6,393 m. The distance of 6.5 km was used as a guide when estimating disturbance effects on marine mammals. It is recognized that the distances from air source arrays where received sound levels exceed these noise criteria are dependent upon the configuration of a specific air source array and site-specific variations in the environment that influence underwater sound propagation.

### **Assessment of Effects of Sound on Marine Mammals**

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

#### ***Toothed Whales***

Despite the relatively poor hearing sensitivity of toothed whales (at least the smaller species that have been studied) at the low frequencies that contribute most of the energy in seismic pulses, sounds are sufficiently strong that they remain above the hearing threshold of odontocetes at tens of kilometers from the source.

Species of most concern are those that are designated under SARA and that may occur in the Study Area. Sowerby’s beaked whales, northern bottlenose whales, killer whales, and harbour porpoises, all with special status by COSEWIC, are not expected to occur in large numbers in the Project Area.

The received sound level of 180 dB re 1  $\mu$ Pa (*rms*) criterion is accepted as a level that below which there is no physical effect on toothed whales. It is assumed that disturbance effects for toothed whales may occur at received sound levels at or above 160 dB re 1  $\mu$ Pa (*rms*). However, it is noted that there is no good scientific basis for using this 160 dB criterion for odontocetes and that a 170 dB re 1  $\mu$ Pa (*rms*) is a more realistic indicator of the disturbance area.

### **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 air source array that are high enough to cause non-auditory physical effects or hearing impairment. It is highly unlikely that toothed whales will experience mortality or strand as a result of Project activities. The mitigation measure of ramping-up the air source array (over a 30 min period) will allow any whales close to the air sources to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the air source array will not be started if a toothed whale is sighted within the 500 m safety zone. There is little potential for toothed whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite “temporary”. The seismic project is predicted to have *negligible to low* hearing impairment and physical effects on toothed whales for a duration of *<1 month to 1-12 months* (20 to 60 days in 2012) over an area *<1 to 1-10 km<sup>2</sup>* (Table 5.11). Therefore, any residual effects of hearing impairment and/or physical effects on toothed whales would be *not significant* (Table 5.12).

### **Disturbance Effects**

Based on the above review, there could be behavioural effects on some species of toothed whales within the Study Area. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. Based on available literature, a 160 dB re 1  $\mu$ Pa (*rms*) sound level is used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. This is likely a conservative criterion since some toothed whale species:

- have been observed in other areas relatively close to an active seismic source where received sound levels are greater than 160 dB; and
- 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. Disturbance effects from Project noise on toothed whales would likely be *low* for a *<1 month to 1-12 months* over an area of *11-100 to 101-1,000 km<sup>2</sup>* (Table 5.11). Therefore, potential residual effects related to disturbance, are judged to be *not significant* for toothed whales (Table 5.12).



**Table 5.11 Assessment of Effects of Project Activities on Marine Mammals.**

Valued Ecosystem Components: Marine Mammal and Sea Turtle								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air sources	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start; shutdown <sup>a</sup>	1	3-4	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Secondary Source Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Helicopter <sup>b</sup>	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)	-	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1	6	1	R	2
Boomer	Disturbance (N)	-	0-1	1	6	1	R	2
Vessel Lights		-						
Vessel Presence								
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1	6	1	R	2
Secondary Source Vessel	Disturbance (N)	-	0-1	1	6	1	R	2
Sanitary/Domestic Waste	Increased Food (N/P); pathology	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Accidental Releases	Injury/Mortality (N)	Solid streamer <sup>c</sup> ; prevention protocols; Spill Response Plan	1	1-2	1	1	R	2
Key:								
Magnitude:			Frequency:			Reversibility:		Duration:
0 = Negligible, essentially no effect			1 = <11 events/yr			R = Reversible		1 = <1 month
1 = Low			2 = 11-50 events/yr			I = Irreversible (refers to population)		2 = 1-12 months
2 = Medium			3 = 51-100 events/yr					3 = 13-36 months
3 = High			4 = 101-200 events/yr					4 = 37-72 months
			5 = >200 events/yr					5 = >72 months
			6 = continuous					
Geographic Extent:			Ecological/Socio-cultural and Economic Context:					
1 = <1 km <sup>2</sup>			1 = Relatively pristine area or area not negatively affected by human activity					
2 = 1-10 km <sup>2</sup>			2 = Evidence of existing negative effects					
3 = 11-100 km <sup>2</sup>								
4 = 101-1,000 km <sup>2</sup>								
5 = 1,001-10,000 km <sup>2</sup>								
6 = >10,000 km <sup>2</sup>								
<sup>a</sup> The air source arrays will be shutdown if an <i>endangered</i> (or <i>threatened</i> ) marine mammal or sea turtle is sighted within 500 m of the array.								
<sup>b</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.								
<sup>c</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.								

**Table 5.12 Significance of Potential Residual Environmental Effects of the Project Activities on Marine Mammals.**

Valued Ecosystem Component: Marine Mammal and Sea Turtle				
Project Activity	Significance Rating	Level of Confidence	Likelihood <sup>a</sup>	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Sound</b>				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
<b>Vessel Lights</b>				
<b>Vessel Presence</b>				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Atmospheric Emissions</b>	NS	3	-	-
<b>Helicopter Presence</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2-3	-	-
<p>Key:</p> <p>Residual environmental Effect Rating:  S = Significant Negative Environmental Effect  NS = Not-significant Negative Environmental Effect  P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:  1 = Low Level of Confidence  2 = Medium Level of Confidence  3 = High Level of Confidence</p> <p>Probability of Occurrence: based on professional judgment:  1 = Low Probability of Occurrence  2 = Medium Probability of Occurrence  3 = High Probability of Occurrence</p> <p>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</p> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p>				

### **Prey Species**

It is unlikely that prey species for toothed whales will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature (see Section 5.6.1) and over a small portion of a whale's foraging range within the

Project Area. Potential effects of reduced prey availability on toothed whales are predicted to be negligible.

### ***Baleen Whales***

Baleen whales are thought to be sensitive to low frequency sounds such as those that contribute most of the energy in seismic pulses. Species of most concern are those that are designated under SARA and that may occur in and near the Project Area (e.g., blue whales). As with toothed whales, the 180 dB re 1  $\mu$ Pa (*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  $\mu$ Pa (*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 air source array high enough to cause non-auditory physical effects or hearing damage. The mitigation measure of ramping-up the air source array will allow any whales close to the air sources to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the air source array will not be started if a baleen whale is sighted within the 500 m safety zone. Therefore, there is little potential for baleen whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite “temporary”. The proposed seismic project is predicted to have *negligible to low* hearing impairment and physical effects on baleen whales for a duration of *<1 month to 1-12 months* over an area *<1 to 1-10 km<sup>2</sup>* (see Table 5.11). Therefore, hearing impairment and/or physical effects on baleen whales would be *not significant* (see Table 5.12).

### **Disturbance Effects**

Based on the above review, there could be behavioural effects on some species of baleen whales in the Study Area. Reported effects range from changes in swimming behaviour to avoidance of the seismic vessel. The area where displacement would most likely occur would have a predicted geographic extent of *11-100 km<sup>2</sup> to 10-1,000 km<sup>2</sup>*. This is likely a conservative estimate given that:

- Some baleen whale species have been observed in areas relatively close to an active seismic source; and
- It is unlikely that displacement from an area constitutes a significant impact for baleen whales in the Study Area.

It is uncertain how many baleen whales may occur in the Study Area during the period when seismic activity is most likely to occur (May to December). The Project Area is not known to be a unique feeding or breeding area for baleen whales. Disturbance effects on species of baleen whales would likely be *low* for a duration of *<1 month to 1-12 months* over an area of *11-100 km<sup>2</sup> to 101-1,000 km<sup>2</sup>*

(see Table 5.11). Therefore, residual effects related to disturbance, are judged to be *not significant* for baleen whales (see Table 5.12).

### **Prey Species**

It is unlikely that prey species for baleen whales, particularly euphausiids, will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature (see Section 5.6.1) and over a small portion of a whale's foraging range within the seismic area. Potential effects of reduced prey availability on baleen whales are predicted to be *negligible*.

### **Seals**

Seals are not expected to be abundant within the Study Area, particularly in the time period when seismic operations will likely occur. Harp and hooded seals are expected to have a more northerly distribution during the survey period (May to December), although they could be moving through the Study Area. Grey seals are likely uncommon and would be most common in coastal areas. None of the species of seal that occur within the Study Area are considered at risk by COSEWIC or are designated on a SARA schedule.

### **Hearing Impairment and Physical Effects**

Given that seals typically avoid the immediate area around a seismic array, seals will likely not be exposed to levels of sound from the air source array (and other noise sources) high enough to cause non-auditory physical effects or hearing impairment. The mitigation measure of ramping-up the air source array will allow any seals close to the air sources to move away before the sounds become sufficiently strong to have potential for hearing impairment. Also, a ramp-up will not be initiated if a seal is sighted within the 500 m safety zone. Therefore, there is limited potential for seals being close enough to an array to experience hearing impairment. If some seals did experience TTS, the effects would likely be quite "temporary". The seismic project is predicted to have *negligible to low* hearing impairment and/or physical effects on seals for a duration of *<1 month to 1-12 months* over an area *<1 km<sup>2</sup>* (see Table 5.11). Therefore, and residual effects of hearing impairment and physical effects on seals would be *not significant* (see Table 5.12).

### **Disturbance Effects**

Based on the above review, there could be behavioural effects on seals in the Study Area. Known effects include changes in diving behaviour and localized avoidance of the seismic vessel. It is uncertain how many seals may occur in the Study Area during the period when seismic activities are most likely to occur (May to December). There are no available criteria for assessing the sound level most likely to elicit avoidance reactions in seals. It is noteworthy that seals have been sighted inside the radius thought to cause TTS (190 dB) in other areas. A 160 dB re 1 µPa (rms) sound level has been conservatively used to assess disturbance effects, more specifically potential displacement from the area

around the seismic source. Therefore, the area where displacement may occur would have a scale of potential effect at *11-100 to 101-1,000 km<sup>2</sup>*. This estimated area around the seismic vessels would be ensonified periodically for a duration of *<1 month to 1-12 months* (see Table 5.11). The seismic project is predicted to have *low* disturbance effects on seals. Therefore, residual effects related to disturbance, are judged to be *not significant* for seals (see Table 5.12).

### **Assessment of Effects of Sound on Sea Turtles**

The effects assessment for sea turtles is summarized in Table 5.13.

#### ***Hearing Impairment and Physical Effects***

Based on available data, it is likely that sea turtles might exhibit temporary hearing loss if the turtles are close to the air sources (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 air source array over a 30 min period should permit sea turtles close to the air sources 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 air source array will be shutdown if a leatherback or loggerhead sea turtle is sighted within the safety zone.

It is very unlikely that many sea turtles will occur in the Study Area. Therefore, there is likely limited potential for sea turtles to be close enough to an array to experience hearing impairment. If some turtles did experience TTS, the effects would likely be “temporary” and hence *reversible*. The seismic project is predicted to have *negligible to low* physical effects on sea turtles for a duration of *<1 month to 1-12 months* over an area *<1 to 1-10 km<sup>2</sup>* (Table 5.13). Therefore, residual auditory and physical effects on sea turtles would be *not significant* (Table 5.14).

#### ***Disturbance Effects***

It is possible that sea turtles will occur in the Study Area, although the cooler water temperatures likely preclude some species from occurring there. If sea turtles did occur near the seismic 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  $\mu$ Pa *rms*. Based on available evidence, the area where displacement would most likely occur would have a scale of impact at 11 to 100 km<sup>2</sup>. The seismic project is predicted to have *low* disturbance effects on sea turtles for a duration of *<1 month to 1-12 months* over an area *11-100 km<sup>2</sup>* (Table 5.13). Therefore, reversible residual effects related to disturbance, are judged to be *not significant* for sea turtles (Table 5.14).

**Table 5.13 Assessment of Effects of Project Activities on Sea Turtles.**

Valued Ecosystem Component: Marine Mammal Sea Turtle								
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound Emissions and Receivers								
Air sources	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start; shutdown <sup>a</sup>	1	3	6	1-2	R	2
Seismic Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Secondary Source Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2
Helicopter <sup>b</sup>	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)	-	0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)	-	0-1	1	6	1	R	2
Boomer	Disturbance (N)	-	0-1	1	6	1	R	2
Vessel Lights		-						
Vessel Presence								
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)	-	0-1	1	1	1	R	2
Picket Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Secondary Source Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2
Sanitary/Domestic Waste	Increased Food (N/P); pathology	Primary treatment	0-1	1	1	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2
Accidental Releases	Injury/Mortality (N)	Solid streamers <sup>c</sup> ; prevention protocols; Spill Response Plan	1	1-2	1	1	R	2
Key:								
Magnitude:			Frequency:		Reversibility:		Duration:	
0 = Negligible, essentially no effect			1 = <11 events/yr		R = Reversible		1 = <1 month	
1 = Low			2 = 11-50 events/yr		I = Irreversible		2 =1-12 months	
2 = Medium			3 = 51-100 events/yr		(refers to population)		3 = 13-36 months	
3 = High			4 = 101-200 events/yr				4 = 37-72 months	
			5 = >200 events/yr				5 = >72 months	
			6 = continuous					
Geographic Extent:			Ecological/Socio-cultural and Economic Context:					
1 = <1 km <sup>2</sup>			1 = Relatively pristine area or area not negatively affected by human activity					
2 = 1-10 km <sup>2</sup>			2 = Evidence of existing negative effects					
3 = 11-100 km <sup>2</sup>								
4 = 101-1,000 km <sup>2</sup>								
5 = 1,001-10,000 km <sup>2</sup>								
6 = >10,000 km <sup>2</sup>								

Valued Ecosystem Component: Marine Mammal Sea Turtle							
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility
<sup>a</sup> The air source arrays will be shutdown if an <i>endangered</i> (or <i>threatened</i> ) marine mammal or sea turtle is sighted within 500 m of the array.							
<sup>b</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.							
<sup>c</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.							

**Table 5.14 Significance of Potential Residual Environmental Effects of Project Activities on Sea Turtles.**

Valued Ecosystem Component: Marine Mammal and Sea Turtle				
Project Activity	Significance Rating	Level of Confidence	Likelihood <sup>a</sup>	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Sound Emissions and Receivers</b>				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
<b>Vessel Lights</b>				
<b>Vessel Presence</b>				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Atmospheric Emissions</b>	NS	3	-	-
<b>Helicopter Presence</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2	-	-
<p>Key:</p> <p>Residual environmental Effect Rating:</p> <p>S = Significant Negative Environmental Effect</p> <p>NS = Not-significant Negative Environmental Effect</p> <p>P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p> <p>Probability of Occurrence: based on professional judgment:</p> <p>1 = Low Probability of Occurrence</p> <p>2 = Medium Probability of Occurrence</p> <p>3 = High Probability of Occurrence</p> <p>Scientific Certainty: based on scientific information and statistical analysis or professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p>				

## ***Prey Species***

Leatherback sea turtles are expected to feed primarily on jellyfish. It is unknown how jellyfish react to seismic noise sources, if these invertebrates react at all. Leatherbacks are also known to feed on sea urchins, tunicates, squid, crustaceans, fish, blue-green algae, and floating seaweed. It is possible that some prey species may exhibit localized avoidance of the seismic array but this is unlikely to impact sea turtles, which are also likely to avoid the seismic vessel and are known to search for aggregations of prey. Potential effects of reduced prey availability are predicted to be *negligible* and hence *not significant*.

### ***5.6.4.2 Effects of Helicopter Overflights***

A crew change may occur via helicopter if the seismic program is longer than five to six weeks, depending on the contractor. The 2013 seismic survey was relatively short in duration, so a helicopter crew change was not necessary. Some contractors may choose to conduct crew changes in port. Helicopters will maintain a regulated flight altitude above sea level unless it is necessary to fly lower for safety reasons.

## **Marine Mammals**

Available information indicates that single or occasional aircraft overflights will cause no more than brief behavioural responses in baleen whales, toothed whales and seals (summarized in Richardson et al. 1995). Disturbance effects are assessed as *negligible to low* for a duration of *<1 month* over an area *1-10 km<sup>2</sup> to 11-100 km<sup>2</sup>* (see Table 5.11). Therefore, reversible residual effects related to disturbance, are judged to be *not significant* for marine mammals (see Table 5.12).

## **Sea Turtles**

To the best of our knowledge, there are no systematic data on sea turtle reactions to helicopter overflights. Given the hearing sensitivities of sea turtles, they can likely hear helicopters, at least when the helicopters are at lower altitudes and the turtles are in relatively shallow waters. It is unknown how sea turtles would respond, but single or occasional overflights by helicopters would likely only elicit a brief behavioural response. Disturbance effects are assessed as *negligible* Table 5.13. Therefore, residual effects related to disturbance, are judged to be *not significant* for sea turtles (Table 5.14).

### ***5.6.4.3 Effects of Presence of Vessels***

During the proposed seismic program, there will be one seismic ship at all times and a picket vessel on site during most of the program (30-120 days in most cases). It is anticipated that a supply ship will also be on site occasionally. In 2015, a second source vessel will be present but will not activate air sources concurrently with the primary source vessel. There is some risk for collision between marine mammals and vessels, but given the slow surveying speed (4.5 to 5 knots; 8.3 to 9.3 km/h) of the seismic vessel (and its picket vessel); this risk is minimal (Laist et al. 2001; Vanderlaan and Taggart 2007). Marine



mammal responses to ships are presumably responses to noise, but visual or other cues are also likely involved. Marine mammal response (or lack thereof) to ships and boats (pre-1995 studies) are summarized in Richardson et al. (1995), p. 252 to 274. More recent studies are described in LGL (2007a). Marine mammal responses to the presence of vessels are variable. Seals often show considerable tolerance to vessels. Toothed whales sometimes show no avoidance reactions and occasionally approach them; however, some species are displaced by vessels. Baleen whales often interrupt their normal behaviour and swim rapidly away from vessels that have strong or rapidly changing noise, especially when a vessel heads directly towards a whale. Stationary vessels or slow-moving, “non-aggressive” vessels typically elicit very little response from baleen whales.

To the best of our knowledge, there are few systematic studies on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound. Hazel et al. (2007) evaluated behavioural responses of green turtles to a research vessel approaching at slow, moderate, or fast speeds (4, 11, and 19 km/h, respectively). Proportionately fewer turtles fled from the approaching vessel as speed increased, and turtles that fled from moderate to fast approaches did so at significantly shorter distances from the vessel than those that fled from slow approaches. The authors conclude that sea turtles cannot be relied on to avoid vessels with speeds greater than 4 km/h. However, studies were conducted in a 6 m aluminum boat powered by an outboard engine, which would presumably be more challenging for a sea turtle to detect than a seismic or supply vessel.

Effects of the presence of vessels on marine mammals or sea turtles, including the risk of collisions, are predicted to be *negligible to low* for a duration of *<1 month to 1-12 months* over an area of *1-10 km<sup>2</sup>*. Therefore, *reversible* residual effects related to the presence of vessels, are judged to be *not significant* for marine mammals and sea turtles (see Tables 5.11 to 5.14).

#### **5.6.4.4 Effects of Accidental Releases**

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with HMDC’s policy, and handling and reporting procedures. In the unlikely event that fluid-filled streamers are used in future surveys after 2013 (i.e., 2014 to EF), it is possible that small amounts of Isopar could be leaked from the streamers; a fuel spill may occur from the seismic ship and/or its support vessels. Any spills would likely be small and quickly dispersed by wind, wave, and ship’s propeller action. The effects of hydrocarbon spills on marine mammals and sea turtles were reviewed in Husky (2000) in Sections 5.9.1.3 and 5.9.2.3, respectively and are not repeated here. Based on multiple studies, whales and seals do not exhibit large behavioural or physiological responses to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil (St. Aubin 1990; Williams et al. 1994). Sea turtles are thought to be more susceptible to the effects of exposure to hydrocarbons than marine mammals (Husky 2000). Effects of an accidental release on marine mammals or sea turtles would be *low* for a duration of *<1 month* over an area *<1 km<sup>2</sup> to 1-10 km<sup>2</sup>* and are *reversible* residual effects are judged to be *not significant* (see Tables 5.11 to 5.14).

#### 5.6.4.5 Effects of Other Project Activities

There is potential for marine mammals and sea turtles to interact with domestic and sanitary wastes, and air emissions from the seismic ship and its support vessels. Any effects from these interactions are predicted to be *negligible* and, therefore *not significant* (see Tables 5.11 to 5.14).

It is unlikely that marine mammals or sea turtles would interact with OBC cables laid on the seabed and thus *no effect* is predicted.

#### 5.6.5 Species at Risk

A biological overview of all species considered *endangered* or *threatened* under Schedule 1 of the SARA that may occur in the Study Area was provided in Section 4.6. No critical habitat has been defined for the Study Area. As discussed in previous Sections and presented in Table 4.13, SARA species of relevance to the Study Area include:

- Northern, spotted, and Atlantic wolffish, and white shark;
- Ivory Gull;
- Blue and North Atlantic right whale; and
- Leatherback sea turtle.

Species not currently designated (see Table 4.13) on Schedule 1 of SARA but listed on Schedule 2 or 3 or being considered for addition to Schedule 1 (as per their current COSEWIC listing of *endangered*, *threatened* or *special concern*), are not included in the SAR VEC but have been assessed in the appropriate VEC Section (i.e., Section 5.6.1 (Fish), Section 5.6.3 (Seabirds) and Section 5.6.4 (Marine Mammals and Sea Turtles) of this EA. If species not currently designated on Schedule 1 of SARA do become listed on this legal list during the remainder of the temporal scope of the Project (2012 to EF), the Proponent will re-assess these species considering the prohibitions of SARA and any new recovery strategies, action plans, and (or) management plans that may be in place, as well as the identification of critical habitat. Possible mitigation measures as they relate to Species at Risk will be reviewed with DFO and EC. Potential interactions between the Project and SAR are shown in Table 5.15.

Hibernia will continue to refer to the Species at Risk Public Registry ([www.sararegistry.gc.ca](http://www.sararegistry.gc.ca)) to get the most up to date information in regard to changes to the SARA which could include additions to species on Schedule 1 of SARA, changes in species status, new recovery strategies, action plans and/or management plans and identification of critical habitat.

The mitigation measure of ramping up the air source array (over a 30 min period) is expected to minimize the potential for impacts on white sharks and wolffishes. As per the detailed effects assessment contained in Section 5.6.1, physical effects of the Project on the various life stages of the white shark and two wolffish species will range from *negligible* to *low* for a duration of *<1 month* to *1-12 months* over an area of *<1 km<sup>2</sup>* (Table 5.16). Reversible residual behavioural effects may extend out to a larger area but are still predicted to be *not significant* (Table 5.17).

**Table 5.15 Potential Interactions of Project Activities and the Species at Risk VEC.**

Valued Ecosystem Components: Species at Risk					
Project Activities	White Shark	Wolffishes	Ivory Gull	Blue and Right Whales	Leatherback Sea Turtle
<b>Sound Emissions and Receivers</b>					
Air sources	X	X	X	X	X
Seismic Vessel	X	X	X	X	X
Supply Vessel	X	X	X	X	X
Picket Vessel	X	X	X	X	X
Secondary Source Vessel	X	X	X	X	X
Helicopter <sup>a</sup>			X	X	X
Echosounder	X	X	X	X	X
Side Scan Sonar	X	X	X	X	X
Boomer	X	X	X	X	X
<b>Vessel Lights</b>	X	X	X		
<b>Vessel Presence</b>					
Seismic Vessel			X	X	X
Supply Vessel			X	X	X
Picket Vessel			X	X	X
Secondary Source Vessel			X	X	X
<b>Sanitary/ Domestic Waste</b>	X	X	X	X	X
<b>Atmospheric Emissions</b>	X	X	X	X	X
<b>Garbage<sup>b</sup></b>					
<b>Helicopter Presence<sup>a</sup></b>			X	X	X
<b>Shore Facilities<sup>c</sup></b>					
<b>Accidental Releases</b>	X	X	X	X	X
<b>Other Projects and Activities</b>					
Oil & Gas: Grand Banks and Orphan	X	X	X	X	X
Fisheries (incl. research)	X	X	X	X	X
Marine Transportation	X	X	X	X	X
<sup>a</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks. <sup>b</sup> Not applicable as garbage will be brought ashore. <sup>c</sup> There will not be any new onshore facilities. Existing infrastructure will be used.					

**Table 5.16 Assessment of Effects of Project Activities on the Species at Risk VEC.**

Valued Ecosystem Component: Species At Risk																	
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects														
			Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context									
Sound Emissions and Receivers																	
Air sources	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start <sup>a</sup> ; shutdown <sup>b</sup>	0-1	3-4	6	1-2	R	2									
Seismic Vessel	Disturbance (N)	-	0-1	1-2	6	1-2	R	2									
Supply Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2									
Picket Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2									
Secondary Source Vessel	Disturbance (N)	-	0-1	1-2	6	1	R	2									
Helicopter <sup>b</sup>	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2									
Echosounder	Disturbance (N)	-	0-1	1-2	6	1	R	2									
Side Scan Sonar	Disturbance (N)	-	0-1	1-2	6	1	R	2									
Boomer	Disturbance (N)	Gradual power increase; delay start; shutdown	0-1	1-2	6	1	R	2									
Vessel Lights	Attraction (N); Mortality (N)	Reduce lighting (if safe); conditions in CWS permit	0-2	1-2	2-3	1-2	R	2									
Vessel Presence																	
Seismic Vessel	Disturbance (N)	-	0-1	1	6	1-2	R	2									
Supply Vessel	Disturbance (N)	-	0-1	1	1	1	R	2									
Picket Vessel	Disturbance (N)	-	0-1	1	6	1	R	2									
Secondary Source Vessel	Disturbance (N)	-	0-1	1	6	1	R	2									
Sanitary/Domestic Waste	Increased food (N/P)	Primary treatment	0-1	1	1	1-2	R	2									
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2									
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1-2	1	1	R	2									
Accidental Releases	Injury/Mortality (N)	Solid Streamer <sup>c</sup> ; prevention protocols; Spill Response Plan	1-2	1-3	1	1-2	R	2									
<div>Key:</div> <div><div>Magnitude:</div><div>0 = Negligible, essentially no effect</div><div>1 = Low</div><div>2 = Medium</div><div>3 = High</div><div>Geographic Extent:</div><div>1 = &lt;1 km<sup>2</sup></div><div>2 = 1-10 km<sup>2</sup></div><div>3 = 11-100 km<sup>2</sup></div><div>4 = 101-1,000 km<sup>2</sup></div><div>5 = 1,001-10,000 km<sup>2</sup></div><div>6 = &gt;10,000 km<sup>2</sup></div></div> <div><div>Frequency:</div><div>1 = &lt;11 events/yr</div><div>2 = 11-50 events/yr</div><div>3 = 51-100 events/yr</div><div>4 = 101-200 events/yr</div><div>5 = &gt;200 events/yr</div><div>6 = continuous</div><div>Ecological/Socio-cultural and Economic Context:</div><div>1 = Relatively pristine area or area not negatively affected by human activity</div><div>2 = Evidence of existing negative effects</div></div> <div><div>Reversibility:</div><div>R = Reversible</div><div>I = Irreversible</div><div>(refers to population)</div></div> <div><div>Duration:</div><div>1 = &lt;1 month</div><div>2 = 1-12 months</div><div>3 = 13-36 months</div><div>4 = 37-72 months</div><div>5 = &gt;72 months</div></div> <tr><td colspan="9"><div><sup>a</sup> The air source arrays will be shutdown if an <i>endangered</i> (or <i>threatened</i>) marine mammal or sea turtle is sighted within 500 m of the array.</div><div><sup>b</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.</div><div><sup>c</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.</div></td></tr>									<div><sup>a</sup> The air source arrays will be shutdown if an <i>endangered</i> (or <i>threatened</i>) marine mammal or sea turtle is sighted within 500 m of the array.</div> <div><sup>b</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.</div> <div><sup>c</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.</div>								
<div><sup>a</sup> The air source arrays will be shutdown if an <i>endangered</i> (or <i>threatened</i>) marine mammal or sea turtle is sighted within 500 m of the array.</div> <div><sup>b</sup> A crew change may occur via helicopter if the seismic program is longer than 5 to 6 weeks.</div> <div><sup>c</sup> Solid or Isopar filled streamers may be used during future surveys, depending on the seismic contractor.</div>																	

**Table 5.17 Significance of Potential Residual Environmental Effects of Project Activities on the Species at Risk VEC.**

Valued Ecosystem Component: Species At Risk				
Project Activity	Significance Rating	Level of Confidence	Likelihood <sup>a</sup>	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Sound Emissions and Receivers</b>				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Boomer	NS	3	-	-
<b>Vessel Lights</b>	NS	3	-	-
<b>Vessel Presence</b>				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Atmospheric Emissions</b>	NS	3	-	-
<b>Helicopter Presence</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2-3	-	-
<p>Key:</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Residual environmental Effect Rating:</p> <p>S = Significant Negative Environmental Effect</p> <p>NS = Not-significant Negative Environmental Effect</p> <p>P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> </div> <div style="width: 45%;"> <p>Probability of Occurrence: based on professional judgment:</p> <p>1 = Low Probability of Occurrence</p> <p>2 = Medium Probability of Occurrence</p> <p>3 = High Probability of Occurrence</p> <p>Scientific Certainty: based on scientific information and statistical analysis or professional judgment:</p> <p>1 = Low Level of Confidence</p> <p>2 = Medium Level of Confidence</p> <p>3 = High Level of Confidence</p> </div> </div> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p>				

Ivory Gull foraging behaviour would not expose it to underwater sound, and this species is unlikely to occur in the Study Area during the time when seismic surveys will be conducted. Furthermore, Ivory Gulls are not known to strand on vessels. The mitigation measures of monitoring the seismic vessel and releasing stranded birds (in the unlikely event that an Ivory Gull did strand on the vessel) and ramping up the air source array will minimize any potential for impacts on this species. [Any injured Ivory Gull would be immediately reported to CWS.] As per the detailed effects assessment in Section 5.6.3, the predicted effects of the Project on Ivory Gulls will be *negligible*. Therefore, the predicted residual effects of the Project on Ivory Gulls are predicted to be *not significant*.

Based on available information, blue whales, right whales and leatherback sea turtles are not expected to occur regularly in the Study Area. It is extremely unlikely that a North Atlantic right whale will occur in the Study Area. There is a finalized recovery strategy for blue whales in Atlantic Canada (Beauchamp et al. 2009) as well as a final recovery strategy for North Atlantic right whales (Brown et al. 2009). A recovery strategy for leatherback sea turtles is also available (ALTRT 2006). However, critical habitat in the Study Area has not been proposed or designated for any SAR whales or leatherback sea turtles. Mitigation and monitoring designed to minimize potential effects of air source array noise on SARA-listed marine mammals and sea turtles will include:

- Ramp-up of the air source array over a 30 min period;
- Monitoring by MMO (s) during daylight hours that the air source array is active;
- Shutdown of the air source array when an *endangered* or *threatened* marine mammal or sea turtle is sighted within the 500 m safety zone; and
- Delay of ramp-up if any marine mammal or sea turtle is sighted within the 500 m safety zone.

With these mitigation measures in place and as per the detailed effects assessment in Section 5.6.4, the predicted effects of the Project on blue whales, right whales and leatherback sea turtles will range from *negligible* to *low* for a duration of *<1 month* to *1-12 months* over an area of *<1* to *101-1,000 km<sup>2</sup>* (Table 5.16). Based on these criteria, the predicted residual effects of the Project on blue whales, right whales and leatherback sea turtles are predicted to be *not significant* (Table 5.17).

In summary and based upon the preceding discussion, the potential effects of HMDC's proposed seismic program are not expected to contravene the prohibitions of SARA (Sections 32(1), 33, 58(1)).

## 5.7 Cumulative Effects

This EA has assessed cumulative effects within the Project and thus, the residual effects described in preceding Sections include any potential cumulative effects from the HMDC seismic program activities in the Project Area.

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

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

Fishing has been discussed and assessed in detail in Section 5.6.2. Fishing activities, by their nature, cause mortality and disturbance to fish populations and may cause incidental mortalities or disturbance to seabirds, marine mammals, and sea turtles. It is predicted that the seismic surveys will not cause any mortality to these VECs (with the potential exception of small numbers of petrels) and thus, there will be either *no* or *negligible* cumulative mortality effect. There is some potential for cumulative disturbance effect (e.g., fishing vessel noise) but there will be directed attempts by both industries to mitigate such effects by avoiding each other's active areas and times. The seismic surveying will also spatially and temporally avoid DFO research vessels during multi-species trawl surveys. Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to be *not significant*.

In the summer, the main North Atlantic shipping lanes between Europe and North America lie to the north of the Grand Banks into the Strait of Belle Isle. In the winter, that traffic shifts to the main shipping lanes along the southern Grand Banks into the Gulf of St. Lawrence. Thus, potential for cumulative effects with other shipping is predicted to be *low*.

The vast majority of hunting of seabirds (mostly murre) in Newfoundland and Labrador waters occurs near shore from small boats. Also, it is predicted that no murre will suffer mortality from the Project's routine activities. Thus, there is little or no potential for cumulative effects on this VEC. Similarly, most, if not all, seal hunting would occur inshore of the Project Area and the Project will cause no mortality to seals even in the event of an accidental spill of petroleum hydrocarbons.

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

- Hebron;
- Husky White Rose Extension Project (WREP);
- Multi Klient Invest ASA (MKI) 2D seismic program on Northeast Newfoundland Shelf (i.e., Labrador Basin, Orphan Basin, Flemish Pass, Jeanne d'Arc Basin), 2012-2017;
- Statoil 3D/2D geophysical program including geohazard and electromagnetic surveys in Jeanne d'Arc and Central Ridge/Flemish Pass Basins, 2011-2019;
- WesternGeco 3D/2D seismic program in the Jeanne d'Arc Basin, 2012-2015;
- Investcan Energy Corporation 2D/3D seismic program including geohazard and VSP surveys on Labrador Shelf, 2010-2017;

- Chevron Canada Resources 3D/2D seismic program including geohazard survey in offshore Labrador, 2010-2017;
- Chevron Canada Resources exploratory drilling program Orphan Basin;
- Chevron Canada Resources 3D and/or 2D seismic program including geohazard survey in the North Grand Banks Region, 2011-2017;
- Statoil exploration, appraisal, and delineation drilling program in Jeanne d’Arc Basin area, 2008-2016;
- Suncor exploration drilling in Jeanne d’Arc Basin, 2009-2017;
- Husky White Rose new drill centre construction and operations program, 2008-2015; and
- Husky exploration and delineation drilling program in Jeanne d’Arc Basin, 2008-2017.

In addition, the following Grand Banks projects are presently undergoing EA (C-NLOPB website 29 Feb 2013):

- GXT Technology Canada Ltd. 2D Seismic, Gravity, and Magnetic Survey for the Labrador Shelf Area (2013-2015);
- ARKeX Ltd. North Flemish Pass Gravity Gradient Survey (2013-2017);
- Husky Jeanne d’Arc Basin/ Flemish Pass Regional Seismic Program 2012-2020;
- Husky Sydney Basin Seismic Program 2010-2018;
- Husky 2-D and 3-D Seismic and Geohazard Surveys on Labrador Shelf 2009-2017; and
- Suncor exploration drilling program within Jeanne d’Arc Basin 2009-2017.

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

In addition, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. Additional production developments (Hebron and WREP) are anticipated to commence installation in the near future. These existing developments fall inside the boundaries of the HMDC’s Study Area but do not create the same levels of underwater noise as seismic programs. Any cumulative effects (i.e., disturbance), if they occur, are predicted to be additive (not multiplicative or synergistic) and *not significant*.

There is potential for cumulative effects with other seismic programs that may active in the future including other 2D, 3D, 4D and geohazard survey programs). Hebron and HMDC used the same survey vessel in 2013 so cumulative effects were minimal. In future years, different seismic programs could potentially be operating in relatively close proximity. During these periods, VECs may be exposed to noise from more than one of the seismic survey programs. It will be in the interests of the different parties for good coordination between programs in order to provide sufficient buffers and to minimize acoustic interference. HMDC will participate in a coordinated effort to provide sufficient spatial buffers between seismic vessels operating concurrently in the northern Grand Banks area.



Assuming maintenance of sufficient separation of seismic vessels operating concurrently in the Project Area, cumulative effects of seismic sound on fish and fish habitat, fisheries, seabirds, marine mammals, sea turtles and species at risk are predicted to be *not significant*. However, there are uncertainties regarding this prediction. The potential for temporal and spatial overlap of future activity of seismic programs (2014-LOF) in the area will be assessed in the EA update process.

As discussed in this EA, negative effects on key sensitive VECs such as marine mammals appear unlikely beyond a localized area from the sound source. In addition, all programs will use mitigation measures such as ramp-ups, delayed startups, and shutdowns of the air source arrays. Thus, it seems likely that while some animals may receive sound from one or more geophysical programs, the current scientific prediction is that *no significant residual effects* will result.

## **5.8 Mitigations and Follow-up**

Project mitigations have been detailed in the various individual Sections of the preceding EA and are summarized in the text provided below and in Table 5.18. HMDC and contractors will adhere to mitigations detailed in Appendix C of the *Geophysical, Geological, Environmental and Program Guidelines* (C-NLOPB 2012) including those in the *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*.

While this EA covers 2013 to LOF, details on any post-2013 surveys will be provided in EA validation documents to be submitted to the C-NLOPB. [Note: An update/validation of this EA is submitted in a separate 2015 document.]

### **5.8.1 Marine Mammals and Sea Turtles**

Several environmental factors are known to affect the ability of a MMO to visually detect a marine mammal. Offshore Newfoundland, these factors include darkness, fog, sea state, swell, glare, and precipitation. In June and July, when fog was most prevalent, visibility was <500 m (minimum safety zone for marine mammals) during ~40% of the MMO effort when air sources were active in the NW Atlantic (Moulton et al. 2009). Considering that daylight hours account for ~65% of the day during June and July in the NW Atlantic and assuming that air sources were active throughout the day and night, the 500-m safety zone could be fully monitored (visually) only ~39% of the time, on average (minimum 25%) in months during which seismic exploration commonly occurs (Moulton et al. 2009).

The *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment* (the *Statement*) states that when the full safety zone (minimum of 500 m from the air source array) is not visible, cetacean detection technology such as Passive Acoustic Monitoring should be used in areas identified as critical habitat (for a vocalizing cetacean listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*) or in areas where a vocalizing cetacean occurs that has been identified through the environmental assessment process as a species for which there could be significant adverse effects. Critical habitat for marine mammals has not been identified in the Study

Area and significant adverse effects on marine mammals are not predicted in the environmental assessment.

**Table 5.18 Summary of Mitigation Measures.**

Potential Effects	Primary Mitigations
Interference with fishing vessels	<ul style="list-style-type: none"> <li>• Conduct upfront planning to avoid high concentrations of fishing vessels</li> <li>• Request input from fishing captains through FFAW PIL regarding streamer deployment and testing plan</li> <li>• Utilize Single Point of Contact (SPOC)</li> <li>• Release advisories and communications</li> <li>• Employ FLO and picket vessel</li> <li>• Plan transit route to and between Survey Areas (if required)</li> </ul>
Fishing gear damage	<ul style="list-style-type: none"> <li>• Conduct upfront planning to avoid high concentrations of fishing gear</li> <li>• Utilize SPOC</li> <li>• Release advisories and communications</li> <li>• Employ FLO and picket vessel</li> <li>• Compensation Plan</li> <li>• Plan transit route to and between Survey Areas (if required)</li> </ul>
Interference with shipping	<ul style="list-style-type: none"> <li>• Utilize SPOC</li> <li>• Release advisories and communications</li> <li>• Employ FLO and picket vessel</li> </ul>
Interference with DFO/FFAW research vessels	<ul style="list-style-type: none"> <li>• Maintain communications and scheduling</li> </ul>
Temporary or permanent hearing damage/disturbance to marine animals	<ul style="list-style-type: none"> <li>• Delay start-up if marine mammals or sea turtles are within 500 m.</li> <li>• Ramp-up of air sources over 30 min-period</li> <li>• Shutdown air source arrays for endangered or threatened marine mammals and sea turtles within 500 m</li> <li>• Use qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations</li> </ul>
Temporary or permanent hearing damage/disturbance to Species at Risk or key habitats	<ul style="list-style-type: none"> <li>• Delay start-up if any marine mammals or sea turtles are within 500 m</li> <li>• Ramp-up air sources</li> <li>• Shutdown air source arrays for endangered or threatened marine mammals and sea turtles</li> <li>• Use qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations.</li> </ul>
Injury (mortality) to stranded seabirds	<ul style="list-style-type: none"> <li>• Monitor vessel daily</li> <li>• Comply with conditions in CWS permit</li> <li>• Minimize lighting if safe</li> <li>• See also Section 5.6.3.2 in regard to Leach's Storm-Petrel.</li> </ul>
Exposure to hydrocarbons	<ul style="list-style-type: none"> <li>• Adhere to International Convention for the Prevention of Pollution from Ships (MARPOL)</li> <li>• Prevention protocols</li> <li>• Utilize Spill Response Plan</li> <li>• Use solid streamer when feasible</li> </ul>

Given the large portion of time that the full safety zone may not be visible, the use of a single air source during line changes has been used in some previous seismic programs in Atlantic Canada to “warn” marine mammals so that they will not approach the air source array. The *Statement* gives the seismic operator the option of shutting down all air sources or operating a single air source during line changes (or periods of equipment maintenance). It is unclear if operating a single air source between seismic survey lines in periods of poor visibility, i.e., when the 500 m safety zone is not visible, will deter marine mammals from approaching closely to the air source array. There is evidence that, in some species of marine mammals, some individuals do show avoidance reactions to the onset of sound from a single air source. Experiments with a single air source showed that bowhead, humpback, and gray whales all showed localized avoidance of a single air source of 20–100 in<sup>3</sup> (see Moulton et al. 2009 for a review). It seems likely that species known to show strong avoidance responses to various sources of anthropogenic sound, such as most beaked whales and harbour porpoises would also show avoidance during periods when a single air source was active, but insofar as we know this has not been documented empirically. The other option of shutting down all air sources during line changes reduces the amount of seismic sound introduced into the water column, hence avoids any impacts of this sound on marine mammals. A ramp up procedure, starting with the smallest air source in the array, would be required before the air source arrays are activated at full power. The ramp up procedure is theorized to deter marine mammals from the immediate area around the air source array before animals are exposed to maximum sound levels.

Mitigation measures designed to reduce the likelihood of impacts on marine mammals and sea turtles will include ramp-ups, no initiation of air source array if a marine mammal or sea turtle is sighted 30 min prior to ramp-up within 500 m safety zone of the energy source, shutdown of the energy source if an *endangered* (or *threatened*) whale or sea turtle is observed within the 500 m safety zone. Prior to the onset of the seismic survey, the air source array will be gradually ramped up. One air source will be activated first and then the volume of the array will be increased gradually over a recommended 30 min period. An observer aboard the seismic ship will watch for marine mammals and sea turtles 30 min prior to ramp-up. If a marine mammal or sea turtle is sighted within 500 m of the array, then ramp-up will not commence until the animal has moved beyond the 500 m zone or 20 min have elapsed since the last sighting. The observers will watch for marine mammals and sea turtles when the air source array is active (during daylight periods) and note the location and behaviour of these animals. The seismic array will be shut down if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within the safety zone. The planned monitoring and mitigation measures, including ramp-ups, visual monitoring, and shut-down of the air sources when *endangered* or *threatened* marine mammals or turtles are seen within the “safety radii”, will minimize the already-low probability of exposure of marine animals to sounds strong enough to induce hearing impairment. Any dead or distressed marine mammals or sea turtles will be recorded and reported to the C-NLOPB.

## 5.8.2 Seabirds

HMDC will follow all requirements specified in the CWS seabird handling permit and CWS bird handling protocols. These typically include:

### Live Birds:

1. Uninjured, non-oiled birds will be captured and released as per "Williams and Chardine" protocol.
2. Storm-petrels showing signs of possible oiling will be captured and released as per "Williams and Chardine" protocol. Any birds contaminated with oil should be kept in a separate box and not mixed with clean birds. Contact the Canadian Wildlife Service at 709-772-5585 for instructions on how to deal with contaminated birds.
3. Sabina Wilhelm, Canadian Wildlife Service will be notified and contacted for instructions immediately upon discovery of injured birds (709)-772-5568, sabina.wilhelm@ec.gc.ca.

### Dead Birds:

1. Non-oiled birds found dead or that die before release should be identified, recorded and disposed of at sea. If more than 10 birds are found dead in the same event, they need to be collected and sent ashore to Canadian Wildlife Service personnel at Environment Canada as per CWS protocols designed for handling non-oiled, dead birds.

### Oiled Birds:

1. If oil contamination is noted on any live or deceased birds, immediately notify Canadian Coast Guard 1-800-563-9089 and proceed as instructed.

### Report:

A written report detailing numbers of all birds (oiled or not) that were captured and released as well as those deceased during each year's survey is required by end of January following each year's seismic program.

Any seabird survey data collection will be consistent with protocols provided by CWS in Gjerdrum et al. (2012). Data will be collected by a qualified MMO or MMO/SBO.

## 5.8.3 Fisheries

Fishers who may be operating in the area will be notified of the timing and location of planned activities by means of a CCG "Notice to Mariners" and a "Notice to Fishers" on the CBC Radio Fisheries Broadcast. In addition, if necessary, individual fixed gear fishers will be contacted to arrange mutual avoidance. Any contacts with fishing gear, with any identifiable markings, will be reported to the

C-NLOPB immediately. Fishing gear may only be retrieved from the water by the gear owner (i.e. fishing license owner). This includes buoys, radar reflectors, rope, nets, pots, etc. associated with fishing gear and/or activity. If gear contact is made during seismic operations it should not be retrieved or retained by the seismic vessel. There are conditions that may warrant gear being retrieved or retained if it becomes entangled with seismic gear; however, further clarification on rules and regulations regarding fishing gear should be directed to the Conservation and Protection Division of Fisheries and Oceans Canada (NL Region). HMDC will advise the C-NLOPB prior to compensating and settling all valid lost gear/income claims promptly and satisfactorily.

Specific mitigations to minimize potential conflicts and any negative effects with other vessels; these include:

- Timely and clear communications (VHF, HF, Satellite, etc.);
- Utilization of fisheries liaison officers (FLOs) for advice and coordination in regard to avoiding fishing vessels and fishing gear;
- MMO(s) and FLO onboard;
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast;
- Compensation program in the event any project vessels damage fishing gear; and
- Single Point of Contact (SPOC).

HMDC will also coordinate with DFO, St. John's, and the FFAW to avoid any potential conflicts with survey vessels that may be operating in the area. HMDC commits to ongoing communications with other operators with active seismic programs within the general vicinity of its seismic program to minimize the potential for cumulative effects on the VECs.

While this EA covers the Project from 2013 to LOF, details on any post-2013 surveys will be provided in EA validation documents to be submitted to the C-NLOPB. For seismic projects conducted beyond 2013, this EA will be amended accordingly if it is determined the Project differs substantially from the activity assessed herein. [Note that the original 2013 EA is amended herein to be subsequently updated and validated for 2015 and beyond.]

## **5.9 Residual Effects of the Project**

A summary of the Project's residual effects on the environment, in other words those effects that remain after mitigations have been instituted, are shown in Table 5.19. HMDC's seismic program is predicted to have *no significant effects* on the VECs.

**Table 5.19 Significance of Potential Residual Environmental Effects of HMDC's Proposed Seismic Program on VECs in the Study Area.**

Valued Ecosystem Component: Fish and Fish Habitat, Fishery, Seabirds, Marine Mammals and Sea Turtles, Species at Risk				
Project Activity	Significance Rating	Level of Confidence	Likelihood <sup>a</sup>	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
<b>Sound Emissions and Receivers</b>				
Air sources	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Picket vessel	NS	3		
Supply Vessel	NS	3	-	-
Secondary Source Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Boomer	NS	2-3	-	-
<b>Vessel Lights</b>	NS	3	-	-
<b>Vessel Presence</b>				
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Picket Vessel	NS	3	-	-
Secondary Source Vessel	NS	3		
<b>Sanitary/Domestic Wastes</b>	NS	3	-	-
<b>Atmospheric Emissions</b>	NS	3	-	-
<b>Helicopter Presence</b>	NS	3	-	-
<b>Accidental Releases</b>	NS	2-3	-	-
<p>Key:</p> <p>Residual environmental Effect Rating:  S = Significant Negative Environmental Effect  NS = Not-significant Negative Environmental Effect  P = Positive Environmental Effect</p> <p>Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent &gt;100 km<sup>2</sup> (4 or greater rating).</p> <p>Level of Confidence: based on professional judgment:  1 = Low Level of Confidence  2 = Medium Level of Confidence  3 = High Level of Confidence</p> <p><sup>a</sup> Considered only in the case where 'significant negative effect' is predicted.</p> <p>Probability of Occurrence: based on professional judgment:  1 = Low Probability of Occurrence  2 = Medium Probability of Occurrence  3 = High Probability of Occurrence</p> <p>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</p>				

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## **Appendices**

### **Appendix 1: A Recent Grand Banks Seismic EA (LGL 2012, electronic version)**

See attached disc (if using hard copy of this HMDC EA) or download from  
<http://www.cnlopb.nl.ca/pdfs/huskyenergy/eareport.pdf> (if using electronic copy of this HMDC EA)

### **Appendix 2: Distribution of Commercial Catches in and Near the Study Area, 2011 to 2012 Based on DFO Grid Data.**

### **Appendix 3: SPOC (and FLO) Protocols, Procedures and Reporting Forms**

See attached One Ocean Guidelines