Environmental Assessment of Multiklient Invest Newfoundland Offshore Seismic Program, 2018–2023

Prepared by

Prepared for

Multiklient Invest AS

&

TGS-NOPEC Geophysical Company ASA

March 2018
LGL Report No. FA0106A

Environmental Assessment of Multiklient Invest Newfoundland Offshore Seismic Program, 2018–2023

Prepared by

LGL Limited, environmental research associates
P.O. Box 13248, Stn. A
St. John's, NL A1B 4A5
Tel: 709-754-1992
vmoulton@lgl.ca

Prepared for

Multiklient Invest AS
Lilleakerveien 4C, P.O. Box 251
Lilleaker, 0216, Oslo, Norway

&

TGS-NOPEC Geophysical Company ASA
1051 Clay Road
Houston, Texas, 77043, USA

March 2018
LGL Report No. FA0106A

Suggested Format for Citation:

LGL Limited. 2018. Environmental Assessment of Multiklient Invest Newfoundland Offshore Seismic Program, 2018–2023. LGL Rep. FA0106A. Rep. by LGL Limited, St. John's, NL for Multiklient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, Texas, USA. 233 p. + Appendix.

Table of Contents

List of Figures

List of Tables

1.0   Introduction

Multiklient Invest AS (MKI), a wholly-owned subsidiary of Petroleum Geo-Services ASA (PGS), and TGS-NOPEC Geophysical Company ASA (TGS) are proposing to conduct two-dimensional (2D), three-dimensional (3D), and/or four-dimensional (4D) seismic surveys in offshore Newfoundland (the Project). MKI will serve as the Operator. This document is the Environmental Assessment (EA) of the Project. The Project Area identified in Figure 1.1 includes Northern and Southern Grand Banks, the Flemish Cap and the shelf region off Northeast (NE) Newfoundland, as well as offshore slope and deep water regions associated with the shelf (e.g., Flemish Pass, Orphan Basin, parts of the Newfoundland basins). MKI and TGS are proposing to conduct seismic surveys, sometimes two or more operations, during one or more years within the 2018–2023 timeframe.
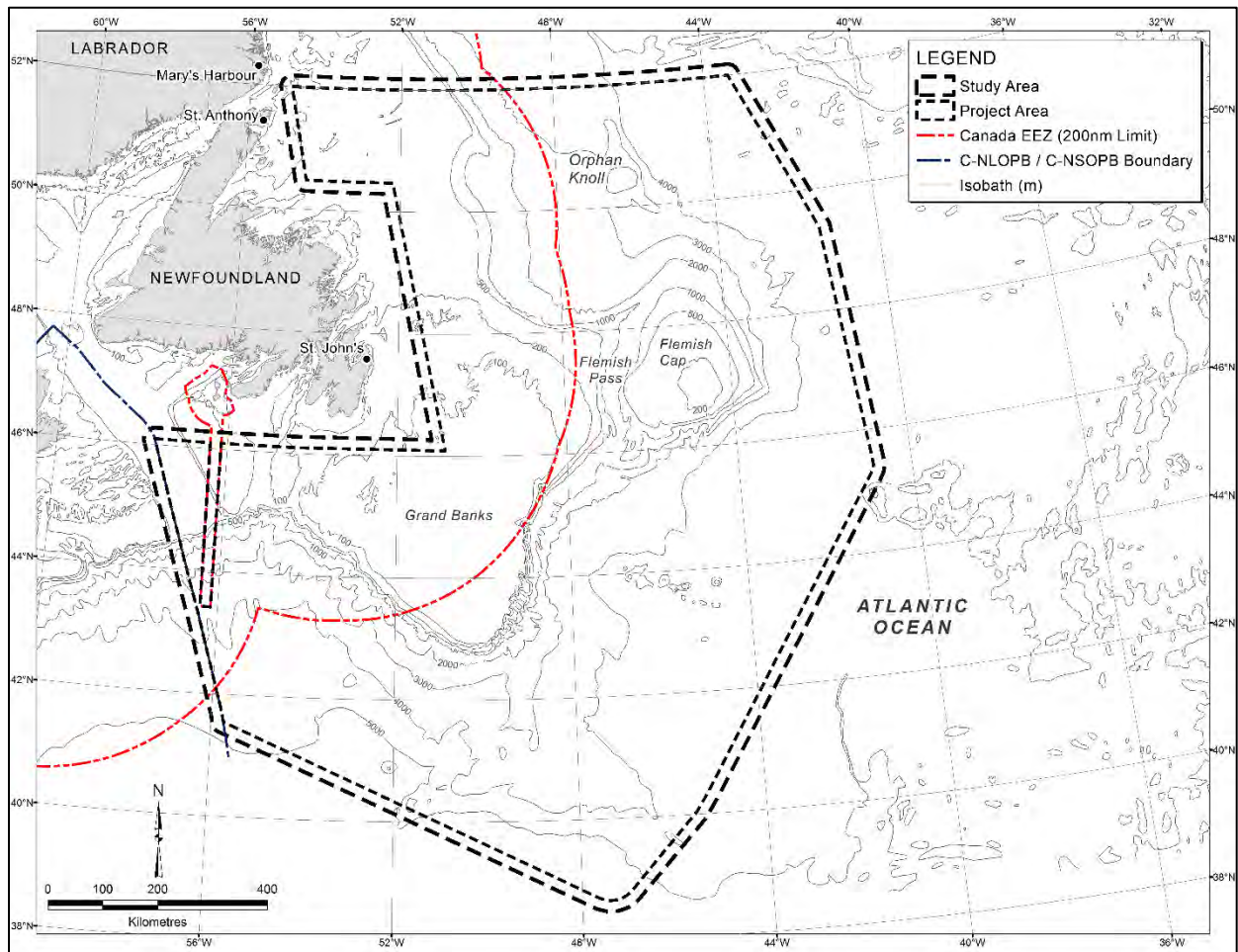
Figure 1.1   Locations of Project Area and Study Area for MKI's Proposed Newfoundland Offshore Seismic Program, 2018–2023.

The EA is intended to enable the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) to fulfill its responsibilities under § 138 (1)(b) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* and § 134(1)(b) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (Accord Acts). An EA and associated Addendum were submitted to the C-NLOPB for the Project with a 10-year temporal scope (2017–2026) and spatial scope inclusive of offshore Newfoundland and Labrador (LGL 2017a,b). The C-NLOPB recently reviewed the temporal and spatial scopes of the Accord Acts, and made the decision to reduce the temporal scope of geophysical/geological EAs to six years to better align with Period I of an exploration licence. It was also determined that the spatial scope of EAs in the Labrador Shelf offshore area will have a southern boundary of 52ºN, and EAs not offshore Labrador will have a northern boundary of 52ºN (C-NLOPB 2018). This EA reflects these decisions, and includes the offshore Newfoundland portion of the Project. This EA addresses Addendum comments (LGL 2017b; C-NLOPB 2018) associated with the original EA (LGL 2017a). This EA has been guided by the C-NLOPB's Final Scoping Document (C-NLOPB 2017a) posted on its website on 24 January 2017, as well as by advice and information received (including consolidated comments for the Addendum; C-NLOPB 2018), and issues identified through various communications and consultations with other agencies, interest groups, stakeholders and beneficiaries. An Environmental Assessment Update document will be submitted to the C-NLOPB each year that MKI plans to conduct seismic surveying.

1.1 Relevant Legislation and Regulatory Approvals

An *Authorization to Conduct a Geophysical Program* will be required from the C-NLOPB. The C-NLOPB is mandated by the Accord Acts. Pursuant to the Accord Acts, the C-NLOPB is responsible for seeking to identify the federal departments or agencies that may have expertise required in the completion of the assessment. Because seismic survey activities have the potential to affect fish and fish habitat, fisheries, marine mammals, sea turtles and marine-associated birds, Fisheries and Oceans Canada (DFO) and Environment and Climate Change Canada (ECCC) are the government agencies that have most involvement in the EA process. Legislation that is relevant to the environmental aspects of the Project includes:

- *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act*;
- *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*;
- *Oceans Act*;
- *Fisheries Act*;
- *Navigation Protection Act*;
- *Canada Shipping Act*;
- *Migratory Birds Convention Act*;
- *Species at Risk Act (SARA)*; and
- *Canadian Environmental Protection Act*.

MKI will follow guidelines issued by the C-NLOPB, the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2017b), which include DFO's *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*. The Project will also consider other relevant advice received during the consultations for this Project.

1.2 The Operator

The Operator, Multiklient Invest AS (MKI), is a wholly-owned subsidiary of Petroleum Geo-Services ASA (PGS). MKI has entered into a cooperative agreement with TGS-NOPEC Geophysical Company AS to conduct this work.

1.3 Canada-Newfoundland and Labrador Benefits

In full appreciation of the requirements of the Accord Acts, MKI is committed to providing maximum benefits associated with East Coast operations to Canadians, and in particular, to individuals and companies from Newfoundland and Labrador that are commercially competitive in accordance with MKI's requirements.

MKI will manage the seismic operations from St. John's, Newfoundland and Labrador. MKI agrees that first consideration will be given to personnel, support and other services that can be provided from within Newfoundland and Labrador, and to goods manufactured in Newfoundland and Labrador, as long as the goods and services can be delivered at a high standard of Health, Safety and Environmental competency, are of high quality, and are competitive in terms of fair market price. All contractors and subcontractors working for MKI in Newfoundland and Labrador must also apply these principles in their operations.

1.4 Contacts

1.4.1 Multiklient Invest AS

Executive Contacts

Mr. Jerry Witney
Vice-President, North America Multiklient
Petroleum Geo-Services Inc.
15375 Memorial Drive, Suite 100
Houston, Texas 77079
Phone: 1-281-509-8000
E-mail: jerry.witney@pgs.com

Mr. Neil Paddy
Contract Manager, Marine Contract, North and South America
Petroleum Geo-Services Inc.
15375 Memorial Drive, Suite 100
Houston, Texas 77079
Phone: 1-281-509-8000
E-mail: neil.paddy@pgs.com

Environmental Contacts

Mr. Magnus Christiansen
Environment Manager, Environmental Management
Petroleum Geo-Services
P.O. Box 251 Lilleaker,
0216 Oslo, Norway
Phone: +47 6752 6400
E-mail: magnus.christiansen@pgs.com

Mr. Jason Norman
Project Supervisor
Multiklient Invest AS
1 Church Hill
St. John's, NL A1C 3Z7
Tel. +1 281 509 8263
Mob. +1 709 749 6046
Note : Mr. Norman will be the point of contact for the Royal Canadian Navy Maritime Forces Atlantic Formation (MARLANT)

1.4.2   TGS-NOPEC Geophysical Company ASA

Executive Contacts

Mr. Steve Whidden
Project Development Manager, Offshore North America Arctic
TGS-NOPEC Geophysical Company ASA
2100, 250—5th Street S.W.
Calgary, Alberta T2P 0R4
Phone: 1-403-781-6245
E-mail: Steve.Whidden@tgs.com

Regulatory Contact

Mr. Troy Nelson
Senior Regulatory and Compliance Specialist
TGS-NOPEC Geophysical Company ASA
2100, 250—5th Street S.W.
Calgary, Alberta T2P 0R4
Phone: 1-403-781-1448
E-mail: Troy.Nelson@tgs.com

Regulatory Contact

Mr. Troy Nelson
Senior Regulatory and Compliance Specialist
TGS-NOPEC Geophysical Company ASA
2100, 250—5th Street S.W.
Calgary, Alberta T2P 0R4
Phone: 1-403-781-1448
E-mail: Troy.Nelson@tgs.com

2.0   Project Description

The official name of the Project is <u>Multiklient Invest Newfoundland Offshore Seismic Program, 2018–2023</u>. MKI is proposing to conduct one or more 2D, 3D and/or 4D seismic surveys within its proposed Project Area (see Figure 1.1) between 2018 and 2023. There is the possibility that MKI will concurrently conduct two or more 2D, 3D and/or 4D surveys in any given year during 2018–2023. The maximum number of simultaneous seismic surveys in a given year would be three 3D surveys and one 2D survey. The timing of the surveys is subject to MKI priorities and circumstances, weather conditions, contractor availability, and regulatory approvals. Specific details of MKI's 2018 seismic survey plans will be included in an EA Update.

2.1   Spatial and Temporal Boundaries

The Study Area includes the Project Area plus a 20 km buffer around the Project Area to account for the propagation of seismic survey sound that could potentially affect marine biota (see Figure 1.1). The proposed Project Area includes space to account for ship turning and streamer deployment. The areal extents of the Project Area and the Study Area are 1,244,143 km^2 and 1,354,951 km^2, respectively. As indicated in Figure 1.1, larger proportions of the Project Area and Study Area lie outside of Canada's Exclusive Economic Zone (EEZ) (~68%) than inside the EEZ (~32%). Water depths within the Project Area range from approximately 100 to 4,000 m (see Figure 1.1).

The Study Area and Project Area for this proposed Project are essentially amalgamates of the study areas and project areas, respectively, associated with the following MKI projects: (1) Northeast Newfoundland Slope Seismic Program, 2012–2017 (C-NLOPB File No. 45006-020-002); and (2) Southern Grand Banks Seismic Program, 2014–2018 (C-NLOPB File No. 45006-020-004). MKI has been conducting 2D and 3D seismic surveys in each of these two project areas during recent years.

The coordinates that delineate the proposed Project Area (decimal degrees, WGS84 Datum) are as follows:

- 52.000ºN, 54.913ºW (northern extreme);
- 52.000ºN, 43.348ºW;
- 49.374ºN, 41.468ºW;
- 45.417ºN, 40.887ºW (eastern extreme);
- 40.042ºN, 45.501ºW;
- 38.658ºN, 47.365ºW (southern extreme);
- 41.546ºN, 55.727ºW;
- 46.093ºN, 57.716ºW (western extreme);
- 46.099ºN, 56.404ºW;

- 43.418ºN, 56.398ºW;
- 43.416ºN, 56.157ºW;
- 46.100ºN, 56.151ºW;
- 46.091ºN, 50.869ºW;
- 50.473ºN, 52.199; and
- 50.481ºN, 54.424ºW.

The coordinates that delineate the proposed Study Area (decimal degrees, WGS84 Datum) are as follows:

- 52.114ºN, 55.138ºW (northern extreme);
- 52.151ºN, 43.189ºW;
- 49.415ºN, 41.201ºW;
- 45.395ºN, 40.636ºW (eastern extreme);
- 39.934ºN, 45.315ºW;
- 38.478ºN, 47.410ºW (southern extreme);
- 41.445ºN, 55.925ºW;
- 46.205ºN, 57.917ºW (western extreme);
- 46.274ºN, 51.184ºW;
- 50.294ºN, 52.427ºW; and
- 50.345ºN, 54.608ºW.

The temporal boundaries of the Project are 1 May–30 November during 2018–2023. In 2018, it is estimated that each 3D and 2D survey will be 100 days in duration, although this is subject to change (see below). No 4D surveys are planned for 2018.

2.2   Project Overview

The proposed Project is a ship-borne geophysical program that is planned to include up to 15,000 km^2 of 3D seismic survey and approximately 12,000–16,000 km of 2D seismic survey lines in 2018. Specific data acquisition plans for 2D, 3D and/or 4D surveys during 2019–2023 are not yet determined; however, the maximum annual amount of 2D and 3D/4D combined that will be acquired during 2019–2023 are 26,000 km and 30,000 km^2, respectively.

It is anticipated that the PGS vessels *Ramform Tethys*, *Ramform Titan* and/or *Ramform Sterling* will be used in 2018 to acquire 3D data. In 2018, the proposed 2D seismic survey will be acquired by the PGS vessel *Sanco Atlantic* (*formerly the Atlantic Explorer*). The seismic survey vessel(s) used during subsequent 2D/3D/4D surveys are currently unknown but will be approved for operation in Canadian waters and will be typical of the worldwide fleet. Details on airgun arrays and streamers are provided in § 2.2.6 and § 2.2.7, respectively.

Underwater sound will also be generated by navigational, operational and safety equipment on board the vessels, such as echo sounders and multibeam sonars (e.g., side scan sonar). A seismic survey will use an industry-standard echosounder/fathometer instrument (i.e., Kongsberg Simrad EA600 echosounder or equivalent) for navigational purposes by obtaining information on water depths and potential navigation hazards for vessel crews during routine navigation operations. Navigation echosounders direct a single acoustic signal focussed in a narrow beam directly downward to the sea floor. The reflected sound energy is detected by the echosounder, which calculates and displays water depth to the user. Typical source levels of the navigational echosounder instruments are generally 180–200 dB re 1μPa @ 1m $_{rms}$. The echosounder emits a single-beam at frequencies of 33 kHz and 200 kHz. While the seismic vessel(s) will not have a side scan sonar, support vessels associated with the program may employ some type of multibeam sonar. Depending on water depth and the level of precision required, multibeam echosounders operate at 100–700 kHz with maximum source levels of 200–215 dB re 1 μPa @ 1m $_{rms}$.

The C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2017b) will be used as the basis for the marine mammal monitoring and mitigation program for the seismic surveys. Section III of Appendix 2 of the Guidelines (C-NLOPB 2017b) states that "Operators are expected to implement a seabird and marine mammal observation program throughout all C-NLOPB authorized program activities. Such a program should involve a designated observer trained in marine mammal and seabird observations". Qualified and experienced Marine Mammal Observers (MMOs) will monitor for marine mammals and sea turtles and implement mitigation measures as appropriate throughout all of MKI's authorized program activities. Visual monitoring and passive acoustic monitoring (PAM) will be used. The aspects of the monitoring and mitigation plan include the use of the ship's bridge for MMOs from which to conduct observations (i.e., good sight lines all around the vessel), and the use of reticle binoculars and other distance estimators to accurately estimate the location of the animal with respect to the safety zone. The airgun array will be ramped up, and ramp ups will be delayed if a marine mammal or sea turtle is detected within the appropriate safety zone (minimum of 500 m as noted in DFO's *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment*). The airgun array will be shut down any time a marine mammal or sea turtle with *endangered* or *threatened* status on Schedule 1 of the *SARA* is detected within the safety zone. These measures are designed to minimize effects on marine life, particularly marine mammals and other species considered at risk under the *SARA*. In addition, the MMOs will conduct a monitoring and release program for seabirds which may strand on board Project vessels. A Fisheries Liaison Officer (FLO) will be on board the seismic vessel to ensure implementation of communication procedures intended to minimize conflict with the commercial fishery.

2.2.1 Objectives and Rationale

The primary objective of the Project is to determine the presence and likely locations of geological structures that might contain hydrocarbon deposits. Existing seismic data in the area do not provide sufficient detail or coverage to serve the needs of the energy companies in their exploration, development and production activities. Acquisition of more 2D, 3D and/or 4D seismic data is required to provide images of higher resolution and quality that will reduce the possibility of unnecessary drilling activity.

2.2.2 Project Scheduling

As already indicated in § 2.1, the seismic surveys will be conducted between 1 May and 30 November of any given year during 2018–2023.

2.2.3 Site Plans

In 2018, it is possible that there will be up to 15,000 km^2 of 3D survey lines and ~12,000–16,000 km of 2D survey lines. In 2018, it is anticipated that the 2D seismic survey lines will be primarily orientated ESE-WNW or SSW-NNE with an approximate 3–50 km separation between adjacent lines, and the line lengths may vary between 50–250 km. MKI is expecting to acquire 2D data off northeastern, southeastern, and southern Newfoundland in 2018. In 2018, MKI expects to acquire 3D seismic data off northeastern and southeastern Newfoundland and survey lines will be oriented N-S, E-W and NNE-SSW.

2.2.4 Personnel

A typical seismic vessel can accommodate ~55–60 personnel. Personnel on a seismic vessel include ship's officers and marine crew as well as technical and scientific personnel. The seismic vessel will also have MMOs and a FLO on board. All project personnel will have the required certifications as specified by the relevant Canadian legislation, the C-NLOPB, and MKI's Health, Safety, Environment, and Quality (HSEQ) agreement.

2.2.5 Seismic Vessel

As noted earlier, it is anticipated that the PGS vessels *Ramform Tethys*, *Ramform Titan* and/or *Ramform Sterling* will be used in 2018 to acquire 3D data. The proposed 2D seismic survey will be acquired by the PGS vessel *Sanco Atlantic* (*formerly the Atlantic Explorer*).

The MV *Ramform Tethys* was built in 2016 and is a Bahamian flagged vessel (Figure 2.1). It is 104.2 m long, with a beam of 70 m and a draft of 6.9 m. The *Ramform Tethys* has cruising and maximum speeds of ~28 km/h (15 knots) and ~ 30 km/h (16 knots), respectively, but will travel at a speed of ~9 km/h (5 knots) while conducting seismic surveying. The vessel is equipped with state of the art navigation, radar, communication and depth sounding equipment, bow and stern

thrusters, and a Dynamic Positioning (DP) system. It has a fuel capacity of 5,800 m^3 of HFO and uses three diesel-electric engines. Three variable pitch propellers provide 1.8 Megawatts of power, which is more than sufficient to tow the very wide spread streamers. The *Ramform Tethys* operates two work boats that permit streamer maintenance while minimizing impairment to operations.

Figure 2.1   MV *Ramform Tethys*.

The *Ramform Tethys* belongs to the PGS Titan class and has 24 streamer reels; 16 abreast with a further 8 in a second row; and 22 tow points. The back deck layout is augmented by six independent airgun array handling booms. Together these enable faster deployment and recovery with increased flexibility and safety, making it possible to fully utilize the operational

weather window. Steerable sources and streamers, combined with automated gear-handling systems increase flexibility and efficiency.

The *Ramform Titan* is a sister ship to the *Tethys*, launched in 2013 with virtually identical specifications (with the exception of a 6.4 m draft). The *Ramform Sterling* was launched in 2009; this Bahamian flagged vessel has a length of 102.2 m, beam of 40.0 m and draft of 7.3 m. The *Sterling* can tow up to 20–22 streamers (Figure 2.2).

For seismic surveys during 2019–2023, vessel specifics will be provided once the vessels have been identified.

Figure 2.2   MV *Ramform Sterling*.

2.2.6   Seismic Energy Source Parameters

The sound sources for the proposed 2D/3D/4D survey program will consist of one, two or three airgun arrays. For any sound source that consists of either two or three airgun arrays, the arrays will be discharged alternately (i.e., multiple airgun arrays will not be discharged simultaneously). In 2018, 3D seismic surveys will be conducted using two airgun arrays, each consisting of six subarrays. The total volume of an airgun array may range from 3,000–6,000 in^3. The airgun array(s) will be deployed at depths ranging from 6–15 m, and the airguns will be operated with compressed air at pressures ranging from 2,000–2,500 psi. The peak-to-peak sound source level will be ~100–200 bar-m (~260–266 dB re 1 µPa·m $_{p-p}$). Detailed specifications of the airgun

array will be provided once the 2018 project design has been completed and parameters have been selected.

2.2.7 Seismic Streamers

The maximum streamer length in a given year will be 12 km, and they will be towed at depths ranging from 9–25 m. The 2D seismic vessel will tow one streamer. In 2018, it is anticipated that the 3D seismic vessel(s) will tow 16 streamers. It is possible that a 3D survey vessel may tow more than 16 streamers, during future survey years but this will be detailed in future EA Updates; a maximum of 24 streamers will be towed during 3D surveying over the 2019–2023 period, with a maximum streamer footprint width of 2 km and distance between adjacent streamers of 200 m.

2.2.8 Logistics/Support

2.2.8.1 Vessels

MKI's primary support and supply will be provided by either the PGS vessel MV *Thor Magni* or a similar vessel. In addition, it is anticipated that at least one local escort vessel will accompany each operating seismic vessel. When necessary (i.e., when fishing vessels and gear or other hazards such as ice and floating debris are thought to be in the immediate path of the seismic vessel), escort vessels will be used to scout ahead of the seismic vessels. If a seismic survey is being conducted in an area known to be without fishing vessels and gear, the escort vessel could be sent to scout out another area where the seismic vessel would be working next.

2.2.8.2 Crew Changes

Crew changes will be conducted by either ship-to-ship transfer or ship-to-shore transfer. Although the *Ramform Tethys, Ramform Sterling, Ramform Titan,* and the *Sanco Atlantic* are equipped with a helicopter deck, it is unlikely that crew changes will be conducted by helicopter. Helicopters will likely be used for emergencies only.

2.2.8.3 Shore Base, Support and Staging

MKI will have a shore representative based in St. John's for the duration of the seismic program. No new shore-based facilities will be established as part of the Project.

2.2.9 Waste Management

Waste management will be consistent with industry best practices in offshore Newfoundland and Labrador. Any garbage generated will be collected and separated into items that are either dischargeable to the sea, non-dischargeable to the sea or reusable according to MARPOL 73/78 Annex IV: Pollution by Sewage from Ships, and Annex V: Pollution by Garbage from Ships.

Some waste will be incinerated at sea. According to MARPOL 73/78 Annex V, liquid waste discharge is not considered to be 'garbage'; see § 5.7.3 for further description of vessel discharges.

2.2.10 Air Emissions

Air emissions will be those associated with standard operations for marine vessels, including the seismic vessel, the support vessel and the escort vessel. MKI follows MARPOL 73/78 Annex VI: Regulations for the Prevention of Air Pollution from Ships.

2.2.11 Accidental Events

In the unlikely event of the accidental release of hydrocarbons during the Project, the measures outlined in MKI's oil spill response plan will be implemented. The oil spill response plan will be filed with the C-NLOPB. In addition, MKI will have an emergency response plan in place.

2.3 Mitigation and Monitoring

Project mitigation measures are detailed in the EA, some of which follow the guidelines outlined in the *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*. Mitigation procedures will include ramp-ups, implementation of ramp-up delays and airgun array shutdowns for designated marine mammal and sea turtle species, use of qualified and dedicated MMOs and FLOs, and a fisheries compensation program. PAM for cetaceans is planned; details will be provided in EA Update(s). In addition, the MMOs will conduct a monitoring and release program for seabirds that may strand on Project vessels. Seabird monitoring will include systematic counts based on protocols issued by the ECCC-Canadian Wildlife Service (CWS).

2.4 Project Site Information

The Project is located in the offshore areas east and south of Newfoundland, and south of Newfoundland. It includes Northern and Southern Grand Banks, the Flemish Cap and the shelf region off NE Newfoundland, as well as offshore slope and deep water regions associated with the shelf (e.g., Flemish Pass, Orphan Basin, parts of the Newfoundland basin) (see Figure 1.1).

2.4.1 Environmental Features

The physical and biological environments of the general area have been described in the Eastern Newfoundland SEA (C-NLOPB 2014)[1] and Southern Newfoundland SEA (C-NLOPB 2010)[2], as well as in three project-specific EAs: (1) WesternGeco Canada's Eastern Newfoundland

---

[1] Available at http://www.cnlopb.ca/sea/eastern.php
[2] Available at http://www.cnlopb.ca/sea/southern.php

Offshore Seismic Program, 2015–2024 (LGL 2015a)[3]; (2) WesternGeco Canada's Southeastern Newfoundland Offshore Seismic Program, 2015–2024 (LGL 2015b)[4]; and (3) Seitel Canada Ltd.'s East Coast Offshore Seismic Program, 2016–2025 (LGL 2016)[5]. Reviews of the physical and biological environments, based on the two SEAs, the three project-specific EAs and newly available information, are provided in § 3.0 and § 4.0 of this EA, respectively.

Figure 2.3 shows the extent to which the proposed MKI Study Area overlaps the study areas associated with the two SEAs and the Seitel EA. The proposed Study Area lies almost entirely within the Seitel EA Study Area except for a small portion west of the French EEZ of St. Pierre et Miquelon.
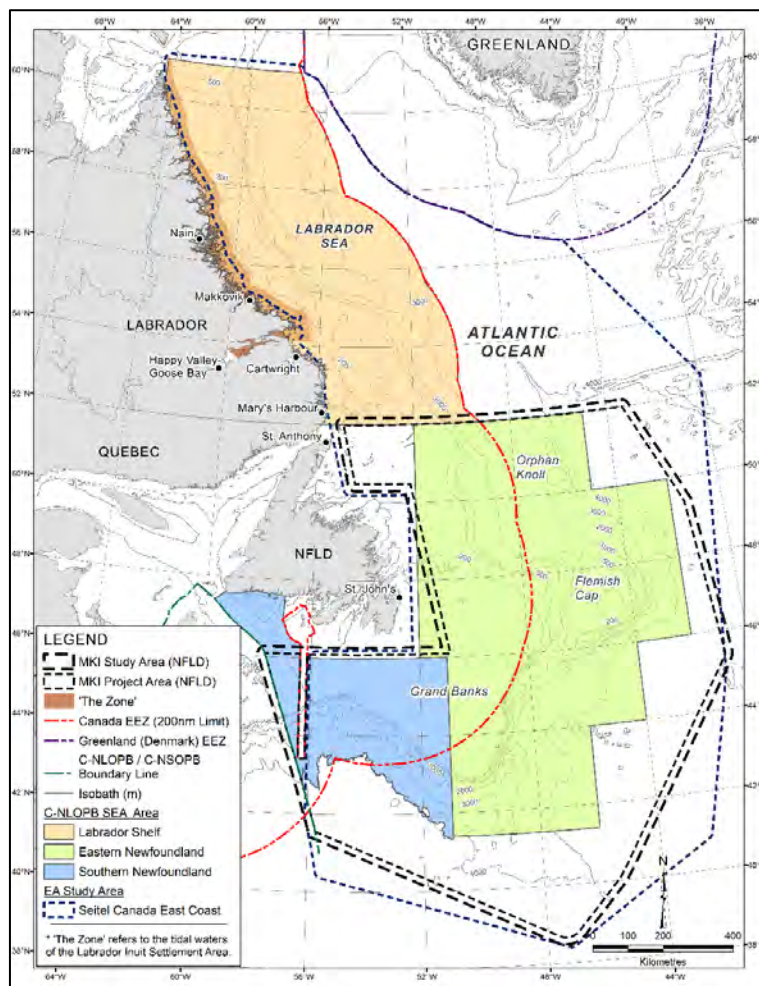
Figure 2.3   Location of MKI's Study Area Relative to Study Areas Associated with Relevant SEAs and the Seitel EA.

---

[3] Available at http://www.cnlopb.ca/assessments/westgecoeast3.php

[4] Available at http://www.cnlopb.ca/assessments/westgecose3.php

[5] Available at http://www.cnlopb.ca/pdfs/seitel/eareport.pdf?lbisphpreq=1

2.4.1.1 Physical Environment and Potential Effects on the Project

As indicated above, descriptions of the general physical environment of the Study Area are contained in the aforementioned SEAs (C-NLOPB 2010, 2014) and project-specific EAs (LGL 2015a,b, 2016). The proposed seismic surveys could be conducted in areas with water depths ranging from approximately 100–4,000 m. Extreme wind, wave and ice conditions can slow or even halt survey operations, and accidents are more likely to occur during extreme conditions than during calm conditions. The scheduling of 2D, 3D and/or 4D seismic surveys during a period (May 1 to November 30) when NW Atlantic operating conditions are typically less severe compared to the late-fall/winter/early-spring period, should decrease the risk of potential effects of the environment on the Project.

A summary of the potential effects of the physical environment on the Project, based on information in the two SEAs (C-NLOPB 2010, 2014), the relevant project-specific EAs (LGL 2015a,b, 2016), and any new available information, is provided in § 5.6.

2.4.1.2 Biological Environment

Considering the size of the Study Area for the proposed Project, the biological environment within it is varied and complex. The description of the biological environment is presented in § 4.0 on the basis of the following six Valued Environmental Components (VECs):

- Fish and fish habitat;
- Fisheries;
- Marine-associated birds;
- Marine mammals and sea turtles;
- Species at risk; and
- Sensitive areas.

The potential effects of routine Project activities and accidental events (e.g., unplanned hydrocarbon release) associated with Project activities are assessed in this EA. Cumulative effects on the VECs are also considered in this EA. Other marine users typically considered in the discussion on cumulative effects includes fishing, cargo and passenger vessels, other oil industry-related vessels, transport and military vessels, or other commercial work.

2.5 Consultations

During preparation of the EA, MKI consulted with stakeholders in St. John's. A summary of the results of those consultations are presented in § 5.1.1 and a full report on the face-to-face consultation meetings and public meetings is provided Appendix 1.

MKI sent Project information emails to the following stakeholders based in St. John's in late-January/early-February 2017. The various consultees were invited to request a face-to-face meeting if deemed necessary. The five consultees that met with MKI in person are indicated below.

- ECCC - meeting on 31 January 2017;
- Nature Newfoundland and Labrador (NNL) - meeting on 2 February 2017;
- One Ocean - meeting on 2 February 2017;
- Fish, Food and Allied Workers Union/Unifor - meeting on 31 January 2017;
- Association of Seafood Producers (ASP);
- Ocean Choice International (OCI);
- Groundfish Enterprise Allocation Council (GEAC) Ottawa;
- Canadian Association of Prawn Producers;
- Clearwater Seafoods;
- Icewater Seafoods; and
- Newfound Resources Ltd. (NRL) - meeting on 2 February 2017.

On 16 May 2017, MKI reached out to relevant fishing groups (originating from Nova Scotia) in the 4Vs area (as recommended by the Canada-Nova Scotia Offshore Petroleum Board [CNSOPB]) as part of its Southern Grand Banks seismic program. Contacted groups were sent a one-page summary document of the seismic program which provided details on survey timing, location, vessels, and equipment as well as directions on how to access EA documents. MKI also offered to send each group weekly updates on acquisition plans. The fishing organizations contacted included:

- Area 23 Snow Crab Fishermen's Association/LFA 30;
- Area 19 Snow Crab Fisherman's Association;
- Clearwater Seafoods Limited Partnership;
- Eastern Shore Fishermen's Protective Association;
- Eastern Fishermen's Federation; and
- N-ENS Snow crab Association.

In future years, MKI will contact fisheries groups originating from Nova Scotia as appropriate. This will be detailed in annual EA Updates.

2.6   Effects of the Project on the Environment

The proposed Project is within the scope of other seismic programs routinely conducted offshore Newfoundland and Labrador and elsewhere in eastern Canada. Potential environmental effects are examined with focus on the VECs listed above in § 2.4.1.2 and the cumulative effects associated with other marine users. The assessment of the effects of the Project on the

environment will also rely on information presented in the Eastern Newfoundland SEA (C-NLOPB 2014), the Southern Newfoundland SEA (C-NLOPB 2010), and the three relevant project-specific EAs (LGL 2015a,b, 2016).

2.7   Environmental Monitoring

MMOs will be on board the seismic vessel(s) to monitor for and implement mitigation measures specific to marine mammals and sea turtles, and to collect systematic data on marine mammal/sea turtle behaviour and distribution with and without airguns operating. MKI will also use PAM for cetaceans. Systematic seabird counts will also be conducted during the seismic surveys. As per the most up-to-date ECCC protocols, seabird surveys will be conducted two to three times daily, each survey period consisting of at least five, consecutive, 10-minute units, the units being separated by the time needed for the vessel to travel 300 m (2:00 minutes at 5 knots). ECCC-CWS now has a mobile version of the Eastern Canadian Seabirds at Sea (ECSAS) database, which can be used by observers to facilitate data entry with little to no need for post-processing. The decision as to whether to use the mobile version will be made by MKI in conjunction with observer provider; regardless, the ECCC-CWS ECSAS protocols will be followed and the required data fields will be collected. The seabird observations will be conducted by an experienced MMO, during which time, ideally, a second experienced MMO is observing for marine mammals and sea turtles. Therefore, marine mammal and sea turtle observations are continuous throughout the daytime period.

Weekly reports from the seismic vessel to the C-NLOPB during operations will also include information related to commercial fishing (e.g., FLO reports of gear and/or fishing vessels encountered during the seismic survey).

3.0   Physical Environment

The Final Scoping Document (C-NLOPB 2017) requires that the EA include a review of the meteorological and oceanographic characteristics of the Study Area, including extreme conditions, in order to provide a basis for assessing the effects of the environment on the Project. The physical environment of the Study Area has been described in the Eastern Newfoundland SEA (§ 4.1 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 2.0 of C-NLOPB 2010), and three relevant EAs (§ 3.0 of LGL 2015a,b, 2016). An overview of the physical environment of the Study Area, based primarily on information in the aforementioned documents, is provided below. The overview also contains new and relevant information since publication of the SEAs and the site-specific EAs.

3.1   Bathymetry and Geology

The bathymetry and geology of the Study Area is highly variable as reflected in the list of primary areas that comprise the Study Area below.

1. Orphan Knoll (rising steeply from 3,000 to 1,800 m);
2. Orphan Basin proper (1,200 to 3,500 m);
3. Sackville Spur (≤1,000 m);
4. Flemish Pass (deep water >1,000 m confined between the Grand Banks and the Flemish Cap [~130 m]);
5. Northeast Newfoundland Shelf (200 to 300 m);
6. Northeast Newfoundland Shelf Slope and Flemish Cap Shelf (>200 to 2,000 m);
7. Flemish Pass (deep water in excess of 1,000 m confined between the Grand Banks and the Flemish Cap (~130 m);
8. Jeanne d'Arc Basin (≤200 m);
9. Grand Banks of Newfoundland, including Grand Bank, Whale Bank, Green Bank, and the eastern portion of St. Pierre Bank (<200 m, and generally 50 to 100 m, with the exception of portions of St. Pierre Bank and the southeast shoal of Grand Bank, which are <50 m);
10. Halibut Channel, situated between St. Pierre Bank and Green Bank, and Haddock Channel, situated between Green Bank and Whale Bank (>300 to 2,000 m);
11. Lilly Canyon - Carson Canyon, along the 200 m isobaths of the southeast slope of Grand Bank (>200 m);
12. Laurentian Basin (500 to ~4,000 m);
13. Newfoundland Basin (2,000 to 5,000 m); and
14. Newfoundland Seamounts (peaks >2,500 m, with most >3,500 m).

The surficial geology of the Study Area ranges from fine (mud and clay) to extremely coarse (boulders and bedrock) (C-NLOPB 2008, 2010, 2014). Surficial sediments in the area are primarily hemi-pelagic, ice-rafted, and from glacial plume deposits (Toews and Piper 2002).

Five surficial sedimentary formations are recognized within the Study Area (C-NLOPB 2010, 2014).

1) Grand Banks Drift – glacial till comprised of poorly sorted sand, silt, and clay;
2) Downing Silt – clayey and sandy silt, overlying and interbedded with Grand Banks Drift;
3) Adolphus Sand – fine to coarse-grained sand, containing some silt, clay-sized fractions, and gravel;
4) Placentia Clay – thin, homogeneous sandy to silty mud formation; and
5) Grand Banks Sand and Gravel – basal transgressive sand and gravel deposit.

3.2 Climatology

All marine seismic surveys are influenced by weather conditions, from both routine operational and environmental safety perspectives. During routine activities, data quality can be affected by weather, particularly by wind and wave conditions. This subsection, based on the Southern Newfoundland, and Eastern Newfoundland SEAs (C-NLOPB 2010, 2014) and recent EAs (LGL 2015a,b, 2016), provides a general overview of climatic conditions in the Study Area, including wind, waves, temperature, precipitation, visibility, and weather systems. More detailed descriptions are provided for extreme events.

The wind and wave climatology of the Study Area was prepared using the most recent data from the Meteorological Service of Canada 50 year (MSC50) hindcast wind and wave database for the North Atlantic. The MSC50 data set was determined to be the most representative of the available data sets, as it provides a continuous 57-year period of hourly data for the Study Area. The analyses were conducted using six grid points to represent the Study Area: (1) grid point 17801 in Orphan Basin; (2) grid point 13451 on the Flemish Cap; (3) grid point 11595 on the Grand Banks; (4) grid point 05000 in the Laurentian Basin; (5) grid point 03889 on the Tail of the Banks; and (6) grid point 11154 in the Newfoundland Basin (Table 3.1, Figure 3.1).

Table 3.1   MSC50 Grid Point Locations.

Region	Grid Point	Latitude	Longitude
Orphan Basin	17801	51.0°N	49.0°W
Flemish Cap	13451	48.0°N	44.0°W
Grand Banks	11595	47.0°N	50.0°W
Laurentian Basin	05000	43.5°N	54.5°W
Tail of the Banks	03889	43.0°N	50.0°W
Newfoundland Basin	11154	44.0°N	45.0°W
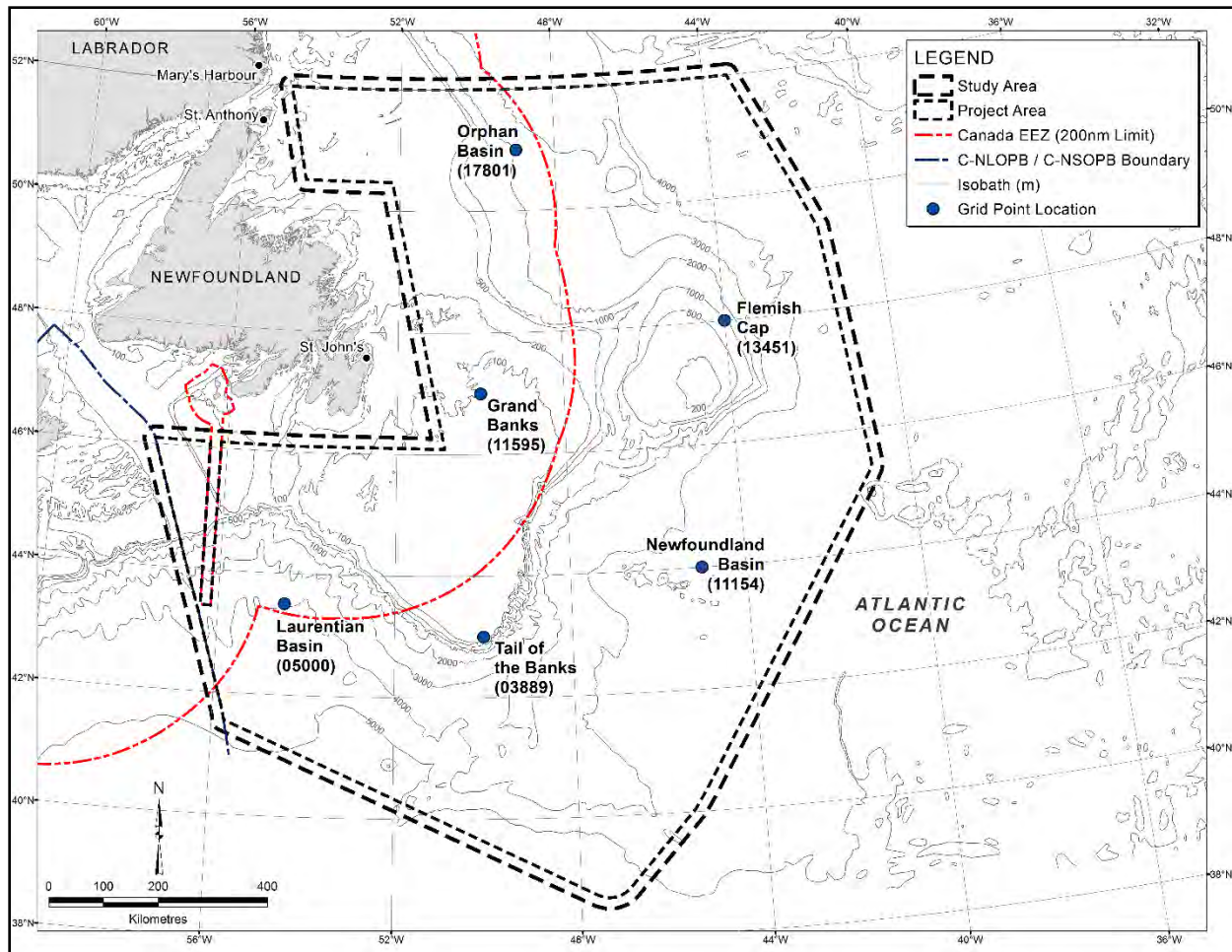
Figure 3.1   Location of MSC50 Grid Points and Regions used in the Physical Environment Analyses.

Hindcast data for grid points 17801, 13451, 11595, and 03889 are one-hour time steps from January 1954 to December 2011 (C-NLOPB 2014). Hindcast data for grid point 05000 are one-hour time steps from January 1954 to December 2010 (Oceans 2014). Hindcast data for grid point 11154 are three-hour time steps from January 1954 to December 2010 (Oceans 2014).

3.2.1   Wind

Mean wind speeds are low during the summer and peak during the winter in all regions of the Study Area (Table 3.2). From May–November, the highest mean wind speeds occur during November and the lowest during July, ranging from 9.1 to 11.1 m/s and 5.7 to 6.7 m/s, respectively. While much of the Study Area experiences primarily southwest to west winds throughout the year, there is a strong annual cycle in wind directions. Offshore Newfoundland most frequently experiences west to northwest winds during the winter months. However they begin to shift counter-clockwise during March and April, resulting in mainly southwest winds during the summer months. During autumn, the tropical-to-polar gradient strengthens and the

winds shift slightly, becoming predominately westerly by late autumn. Low pressure systems crossing south of Newfoundland are more intense during the winter months, thus wind speeds tend to peak during this season.

Table 3.2   Mean Hourly Wind Speed Statistics for Offshore Newfoundland and Labrador.

Month	Mean Wind Speed (m/s)					
	Orphan Basin (17801)	Flemish Cap (13451)	Grand Banks (11595)	Laurentian Basin (05000)	Tail of the Banks (03889)	NF Basin (11154)
Jan	12.4	12.5	11.0	11.2	10.3	11.2
Feb	12.0	12.2	10.8	11.2	10.3	11.2
Mar	11.0	11.0	9.8	10.3	9.4	10.2
Apr	9.6	9.3	8.4	9.0	8.3	9.0
May	8.1	8.1	7.1	7.5	6.9	7.6
Jun	7.1	7.4	6.6	6.8	6.2	7.0
Jul	6.6	6.7	6.2	6.3	5.7	6.2
Aug	7.0	7.1	6.6	6.7	5.9	6.5
Sep	8.6	8.6	7.7	7.9	7.1	7.6
Oct	10.0	10.1	8.9	9.1	8.2	8.9
Nov	11.1	10.8	9.7	10.1	9.1	9.7
Dec	12.0	11.9	10.6	11.2	10.1	10.9

Sources: C-NLOPB 2014; Oceans 2014.

3.2.2   Waves

Within the majority of the Study Area, the predominant direction of the combined significant wave heights is from the west during autumn and winter, primarily due to a high frequency of occurrence of wind waves during these seasons. During March and April, the wind waves remain primarily westerly while the swell begins to move southerly. During the summer, southwesterly wind waves and southwesterly swell contribute to produce combined significant wave heights in the southwest direction. During September and October, the wind waves deviate again to the west and become the predominant component of the combined significant wave heights. Extratropical storms can occur in the Study Area, predominantly during October through to March. Hurricanes are generally reduced to tropical or post-tropical storms by the time they reach the Study Area, but may still produce gale force winds and high waves. Tropical storms have the greatest possibility of occurring from late-August through October. Extratropical storms are discussed in more detail in § 3.2.5 of this EA.

Wave conditions are characterized by significant wave height and maximum wave height (described below), as well as peak spectral period and characteristic period. Significant wave height is defined as the average height of one-third of the highest waves. Its value approximates the characteristic height observed visually. From May–November, the highest significant wave

heights occur during November and the lowest during July in all regions, ranging from 3.2–3.8 m and 1.6–1.8 m, respectively (Table 3.3).

Maximum wave height is defined as the greatest vertical distance between a wave crest and adjacent trough. From May–November, the most severe sea states occur from September through November based on maximum wave heights (Table 3.4).

Table 3.3   Combined Significant Wave Height Statistics for Offshore Newfoundland and Labrador.

Month	Significant Wave Height (m)					
	Orphan Basin (17801)	Flemish Cap (13451)	Grand Banks (11595)	Laurentian Basin (05000)	Tail of the Banks (03889)	NF Basin (11154)
Jan	4.3	4.9	3.7	4.0	3.9	4.3
Feb	3.6	4.6	3.3	3.9	3.8	4.3
Mar	3.3	4.0	2.8	3.5	3.4	3.7
Apr	2.9	3.2	2.5	2.9	2.8	3.1
May	2.3	2.5	2.2	2.2	2.2	2.3
Jun	1.9	2.1	1.9	1.9	1.8	2.0
Jul	1.7	1.8	1.7	1.7	1.6	1.7
Aug	1.8	2.0	1.8	1.8	1.7	1.8
Sep	2.6	2.7	2.3	2.3	2.3	2.4
Oct	3.2	3.4	2.9	2.8	2.8	2.9
Nov	3.7	3.8	3.2	3.3	3.2	3.4
Dec	4.3	4.5	3.8	4.0	3.8	4.0

Sources: C-NLOPB 2014; Oceans 2014.

Table 3.4   Combined Maximum Wave Height Statistics for Offshore Newfoundland and Labrador.

Month	Maximum Wave Height (m)					
	Orphan Basin (17801)	Flemish Cap (13451)	Grand Banks (11595)	Laurentian Basin (05000)	Tail of the Banks (03889)	NF Basin (11154)
Jan	15.9	14.8	11.5	14.1	12.0	15.4
Feb	13.4	15.8	13.3	13.3	13.3	14.1
Mar	12.1	15.6	10.4	12.6	12.6	13.1
Apr	11.5	11.7	10.3	11.2	11.5	10.2
May	10.9	11.8	9.6	10.2	8.5	9.2
Jun	8.7	11.4	9.1	9.7	8.7	7.7
Jul	6.3	6.8	6.0	6.7	5.9	7.1
Aug	11.1	9.8	8.5	10.1	9.7	7.9
Sep	12.1	12.9	12.8	13.0	10.9	11.3
Oct	12.7	13.8	10.5	12.7	11.9	12.0
Nov	13.1	14.2	10.7	11.8	12.1	12.0
Dec	15.1	16.5	12.1	12.6	12.1	12.9

Sources: C-NLOPB 2014; Oceans 2014.

3.2.3 Wind and Wave Extreme Value Analysis

The occurrence of severe wind and waves associated with extreme storm events is of particular importance for the planning and execution of marine seismic surveys. An analysis of extreme wind and waves was performed using the six grid points already indicated to represent the Study Area (see Table 3.1, Figure 3.1). Extreme value analyses were performed to determine the highest expected values for wind speed and significant wave height for each of the MSC50 grid points (C-NLOPB 2014; Oceans 2014).

3.2.3.1 Extreme Value Estimates for Winds from the Gumbel Distribution

Extreme wind speed estimates were calculated using Oceanweather's Osmosis software for return periods of 1-year, 10-years, 50-years, and 100-years, using hourly mean wind speeds for a reference height of 10 m above sea level (C-NLOPB 2014; Oceans 2014). A storm with a return period of 100 years means that the calculated extreme wind speed will occur once every 100 years, averaged over a long period of time. The calculated annual 100-year extreme 1-hour wind speed ranged from 30.8 to 35.8 m/s (Table 3.5). From May–November, the highest 100-year extreme 1-hour wind speeds occur from September–November, while the lowest occur during June and July (C-NLOPB 2014; Oceans 2014).

Table 3.5   Extreme Wind Speed Estimates for Offshore Newfoundland and Labrador.

Return Period (years)	Wind Speed (m/s)					
	Orphan Basin (17801)	Flemish Cap (13451)	Grand Banks (11595)	Laurentian Basin (05000)	Tail of the Banks (03889)	NF Basin (11154)
1	21.9	23.8	21.5	24.9	21.8	23.9
10	30.9	31.1	29.7	28.5	29.2	27.4
50	34.3	34.4	33.3	30.8	32.6	29.8
100	35.8	35.8	34.8	31.8	34.0	30.8

Sources: C-NLOPB 2014; Oceans 2014.

3.2.3.2 Extreme Value Estimates for Waves from a Gumbel Distribution

Monthly extreme significant wave height estimates for return periods of 1-year, 10-years, 50-years, and 100-years for grid points within the Study Area are presented in Table 3.6. From May–November, the highest 100-year extreme significant wave heights occur during October and November, while the lowest extreme significant wave heights occur during July (C-NLOPB 2014; Oceans 2014).

Table 3.6   Extreme Significant Wave Height Estimates for Offshore Newfoundland and Labrador.

Return Period (years)	Significant Wave Height (m)					
	Orphan Basin (17801)	Flemish Cap (13451)	Grand Banks (11595)	Laurentian Basin (05000)	Tail of the Banks (03889)	NF Basin (11154)
1	11.5	12.8	9.9	11.0	10.4	10.6
10	13.7	15.5	11.9	12.8	12.4	12.8
50	15.5	17.7	13.6	14.1	14.0	14.2
100	16.3	18.6	14.3	14.6	14.7	14.8

Sources: C-NLOPB 2014; Oceans 2014.

3.2.4   Weather Variables

For offshore Newfoundland, data related to air temperature, sea surface temperature, and visibility were compiled using the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) (ICOADS 2016). A subset of global marine surface observations from ships, drilling rigs, and buoys in the Study Area, covering the period from January 1950 to December 2012, was used in the analyses for the Orphan Basin, Flemish Cap, Grand Banks and Tail of the Banks (C-NLOPB 2014).   A subset of observations covering the period from January 1980 to December 2013 was used in the analyses for the Laurentian Basin and the Newfoundland Basin (Oceans 2014).

3.2.4.1   Temperature

The moderating influence of the ocean serves to limit both the diurnal and the annual temperature variation in the Study Area. Diurnal temperature variations due to the day/night cycles are very 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 months. Mean monthly air temperatures and sea surface temperatures for the Study Area are presented in Tables 3.7 and 3.8, respectively, and are the mean of all recorded temperatures for a particular region during that month.

The temperature data indicate that from May–November, the air is warmest during August and coldest during May in all regions. Sea surface temperature is also warmest during August and coldest during May in all regions.

Table 3.7   Mean Monthly Air Temperatures for Offshore Newfoundland and Labrador.

Month	Air Temperature (°C)					
	Orphan Basin	Flemish Cap	Grand Banks	Laurentian Basin	Tail of the Banks	NF Basin
Jan	-1.4	3.1	0.4	1.9	5.3	6.4
Feb	-2.9	2.6	-0.1	0.8	4.7	6.0
Mar	-0.4	3.4	0.7	1.4	5.5	6.8
Apr	1.3	5.1	2.3	4.0	7.2	9.6
May	3.5	7.0	4.4	6.9	9.5	11.1
Jun	6.6	9.2	7.6	10.6	12.3	13.6
Jul	10.1	12.4	12.1	16.0	16.7	17.6
Aug	11.7	14.2	14.6	18.3	18.9	18.7
Sep	10.3	13.3	12.8	16.2	16.8	17.1
Oct	6.6	10.4	9.2	12.3	13.4	14.0
Nov	3.7	7.8	5.6	8.6	10.4	11.2
Dec	1.1	5.4	2.5	4.8	7.5	8.5

Sources: C-NLOPB 2014; Oceans 2014.

Table 3.8   Mean Monthly Sea Surface Temperatures for Offshore Newfoundland and Labrador.

Month	Sea Surface Temperature (°C)					
	Orphan Basin	Flemish Cap	Grand Banks	Laurentian Basin	Tail of the Banks	NF Basin
Jan	0.9	4.8	0.9	4.3	10.9	11.7
Feb	0.4	3.8	0.0	3.2	10.3	10.2
Mar	0.7	4.1	0.1	2.9	10.2	9.9
Apr	1.2	4.8	0.7	3.7	11.8	9.9
May	2.5	6.3	2.6	6.1	13.1	11.8
Jun	4.8	8.4	5.5	10.3	15.2	14.0
Jul	8.4	11.4	10.3	15.3	19.2	17.5
Aug	11.3	13.7	14.0	18.3	21.1	20.3
Sep	10.6	13.7	13.5	17.0	20.1	18.8
Oct	7.7	11.4	10.5	13.4	17.9	16.3
Nov	4.7	9.2	6.8	10.0	15.8	14.9
Dec	2.5	6.5	3.5	7.0	12.8	13.2

Sources: C-NLOPB 2014; Oceans 2014; C-NLOPB 2010.

3.2.4.2 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), and blowing snow. Reduced visibility can affect crew changes and work boat operations as well as increase the risk of

interactions of the seismic vessel and its towed gear with obstructions in the water. The ability of MMOs to effectively monitor the safety zone is also affected by reduced visibility.

The frequency distributions of visibility states from the ICOADS data set for each region within the Study Area are presented in Tables 3.9–3.14. The visibility states have been defined as very poor (less than 1 km for the Laurentian Basin, and Newfoundland Basin, and less than 0.5 km for all other regions), poor (1–2 km for the Laurentian Basin, and Newfoundland Basin, and 0.5–2 km for all other regions), fair (2–10 km), and good (>10 km).

During the winter months, the main obstruction is snow, although mist and fog may also reduce visibility at times. As spring approaches, the reduction in visibility attributed to snow decreases. As air temperature increases, the occurrence of advection fog also increases. Advection fog, which forms when warm moist air moves over cooler waters, may persist for days or weeks. By April, the sea surface temperature south of Newfoundland is cooler than the surrounding air, and 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 may also contribute to the reduction in visibility. During August, the temperature difference between the air and the sea begins to decrease, and by September the air temperature begins to fall below the sea surface temperature and the occurrence of fog decreases.

Throughout the May–November period, September and October have the lowest occurrences of reduced visibility within the Study Area because the air temperature has, on average, decreased below the sea surface temperature but is not cold enough for snow. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low pressure systems. There is less seasonal variation in visibility in the Newfoundland Basin and south of the Grand Banks.

Table 3.9 Frequency of Occurrence of Visibility States for Orphan Basin.

Month	Frequency of Occurrence (%)			
	Very Poor (<0.5 km)	Poor (0.5–2 km)	Fair (2–10 km)	Good (>10 km)
January	3.7	7.6	59.3	29.3
February	3.5	8.7	55.7	32.1
March	6.7	10.9	54.8	27.6
April	9.5	11.4	52.3	26.8
May	14.2	10.3	43.4	32.1
June	20.2	14.1	36.8	28.9
July	27.2	14.3	33.3	25.2
August	15.3	9.4	37.2	38.0
September	8.4	5.7	38.3	47.6
October	4.9	6.2	44.3	44.5
November	5.0	7.2	48.3	39.6
December	4.5	7.5	54.5	33.5
Annual	10.1	9.4	46.5	34.0

Source: C-NLOPB 2014.

Table 3.10   Frequency of Occurrence of Visibility States for the Flemish Cap.

Month	Frequency of Occurrence (%)			
	Very Poor (<0.5 km)	Poor (0.5–2 km)	Fair (2–10 km)	Good (>10 km)
January	2.5	5.2	48.9	43.4
February	2.8	5.2	49.3	42.7
March	4.4	7.0	45.6	43.1
April	7.8	8.5	41.4	42.4
May	10.8	8.6	37.9	42.7
June	17.6	11.5	35.9	35.0
July	26.0	14.0	30.5	29.6
August	15.4	8.8	34.1	41.7
September	6.8	5.6	37.7	50.0
October	4.0	4.2	39.9	51.9
November	3.9	4.3	43.1	48.6
December	2.9	4.4	45.7	47.0
Annual	9.1	7.5	40.7	42.7

Source: C-NLOPB 2014.

Table 3.11   Frequency of Occurrence of Visibility States for the Grand Banks.

Month	Frequency of Occurrence (%)			
	Very Poor (<0.5 km)	Poor (0.5–2 km)	Fair (2–10 km)	Good (>10 km)
January	6.0	5.9	45.3	42.9
February	7.7	7.3	45.6	39.3
March	9.2	8.4	43.5	38.9
April	16.6	9.3	39.2	34.9
May	21.5	10.9	34.6	33.1
June	29.3	11.6	31.8	27.3
July	40.3	11.5	25.4	22.9
August	21.5	7.9	32.7	37.9
September	10.1	5.0	33.5	51.3
October	7.3	4.6	36.8	51.4
November	8.3	5.6	38.6	47.5
December	6.5	5.5	42.6	45.4
Annual	15.8	7.9	37.2	39.1

Source: C-NLOPB 2014.

Table 3.12   Frequency of Occurrence of Visibility States for the Laurentian Basin.

Month	Frequency of Occurrence (%)			
	Very Poor (<1 km)	Poor (1–2 km)	Fair (2–10 km)	Good (>10 km)
January	6.5	3.3	19.3	70.9
February	9.5	3.9	21.1	65.4
March	11.1	3.2	15.6	70.1
April	21.2	4.1	14.7	60.0
May	28.5	3.8	11.3	56.3
June	30.6	3.6	12.1	53.7
July	33.0	3.1	13.2	50.8
August	16.6	2.4	13.6	67.3
September	7.3	1.6	11.7	79.4
October	5.4	1.5	11.3	81.7
November	7.9	2.0	14.0	76.0
December	5.6	2.2	16.1	76.0
Annual	15.6	2.9	14.3	67.2

Source: Oceans 2014.

Table 3.13   Frequency of Occurrence of Visibility States for the Tail of the Banks.

Month	Frequency of Occurrence (%)			
	Very Poor (<0.5 km)	Poor (0.5–2 km)	Fair (2–10 km)	Good (>10 km)
January	4.0	4.2	42.0	49.8
February	4.1	4.7	41.3	49.9
March	5.1	4.9	38.5	51.5
April	9.4	6.8	38.5	45.3
May	14.5	8.6	34.9	42.0
June	20.7	11.4	32.8	35.1
July	21.6	11.0	32.1	35.3
August	10.6	6.6	35.2	47.7
September	5.1	4.0	33.0	57.9
October	4.0	4.5	33.8	57.8
November	5.2	4.5	37.3	53.0
December	3.8	4.1	40.6	51.5
Annual	9.8	6.6	36.2	47.4

Source: C-NLOPB 2014.

Table 3.14   Frequency of Occurrence of Visibility States for the Newfoundland Basin.

Month	Frequency of Occurrence (%)			
	Very Poor (<1 km)	Poor (1–2 km)	Fair (2–10 km)	Good (>10 km)
January	2.9	2.0	16.9	78.2
February	4.5	1.8	17.5	76.2
March	4.3	1.8	15.5	78.4
April	8.6	1.8	14.3	75.4
May	12.8	2.6	13.0	71.7
June	16.9	2.6	13.8	66.7
July	22.1	2.7	14.1	61.1
August	11.1	1.7	12.1	75.0
September	5.1	1.4	10.6	82.9
October	3.4	1.5	10.9	84.3
November	4.3	1.6	12.7	81.5
December	3.2	1.7	15.5	79.6
Annual	8.5	1.9	13.9	75.7

Source: Oceans 2014.

3.2.5   Weather Systems

The climate of the Study Area is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in and steered by the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes and arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence, is considerably stronger in the winter months than during the summer months due to an increase in the south to north temperature gradient.

The passage of high and low pressure circulation systems yield a climate within the Study Area that can be highly variable. Conversely, intense low pressure systems also frequently slow down or stall off the coasts of Newfoundland and Labrador. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity, and size of the system, from relatively benign to heavy weather conditions. Prevailing winds are from the west in the Study Area, typical of such mid-latitudes due to the normal tropical to polar temperature gradient. The intensity of this gradient directly affects the mean strength of the westerly flow, resulting in a much stronger flow during the winter than the summer with the increase in the south-to-north temperature gradient.

Major storms travelling west-to-east across Canada generally pass through St. Lawrence and move seaward over the Grand Banks and Labrador Sea (CCG 2012). During the winter months, an upper level trough and upper ridge typically occur over central Canada and the North Atlantic, respectively, causing three primary storm tracks which affect the Study Area: (1) from the Great Lakes Basin; (2) from Cape Hatteras, North Carolina; and (3) from the Gulf of Mexico. These

storm tracks bring an average of eight low pressure systems per month to the eastern Newfoundland and southern portions of the Study Area. The storms can range in intensity from relatively weak to major winter storms.

Problematic and quickly deepening storms are a concern south of Newfoundland, near the warm Gulf Stream waters. Rapidly deepening oceanic cyclones can develop into a "weather bomb"; defined as a storm that undergoes central pressure drops greater than 24 mb in 24 h. Weather bombs typically include hurricane-force winds near the storm's center during the rapidly deepening stage and a clear area near the center during the storm's mature stage. Post-development, these systems travel either across Newfoundland or near the southeast coast, producing gale- to storm-force winds from the southwest to south.

In addition to extratropical cyclones, tropical cyclones often retain their tropical characteristics as they enter the Study Area, producing the strongest sustained surface winds observed on earth. The hurricane season in the North Atlantic Basin normally extends from June through November, although tropical storm systems occasionally occur outside this period. A tropical storm will maintain its energy until there is no longer a sufficient supply of warm, moist air available, and typically moves east to west over the warm waters in the southern tropics. If a tropical storm turns northwards and heads toward Newfoundland, it begins to lose some of its tropical characteristics while moving over the colder oceanic waters. Once these weakening storms reach Newfoundland, they are typically embedded into a mid-latitude low and are often down-classified to post-tropical, either as an extratropical cyclone or a remnant low. However, tropical cyclones occasionally encounter favourable conditions as they travel northwards, and retain their tropical characteristics long enough to reach the Orphan Basin.

Approximately half of the tropical cyclones formed in the Atlantic that travel into the mid-latitude region transform into extratropical cyclones. During this transformation, the system loses its tropical characteristics but still produces large waves, gale- to hurricane-force winds and intense rainfall. The likelihood of the transformation of a tropical storm to an extratropical storm increases during the latter half of the hurricane season, with the highest probability of transition occurring in October. In the Atlantic, this transition occurs in the early and late hurricane season at lower latitudes, and during the peak of the season in higher latitudes.

3.3 Physical Oceanography

A detailed review of the key physical oceanographic conditions and characteristics, including ocean currents, current velocities, and water mass properties (temperature, salinity, density), has been provided in the Southern Newfoundland, and Eastern Newfoundland SEAs (C-NLOPB 2010, 2014). A summary of the major currents in the Study Area is provided below, with additional information from project-specific EAs (LGL 2015a,b).

3.3.1 Major Currents in the Study Area

The large scale circulation off the coast of Newfoundland and Labrador is dominated by well-established currents that flow along the margins of the continental shelf. Three major current systems in the area are the Labrador Current, the North Atlantic Current, and the Gulf Stream. The main current pattern is shown in Figure 3.2, with cold shelf break waters shown in blue and warm Gulf Stream waters shown in red.
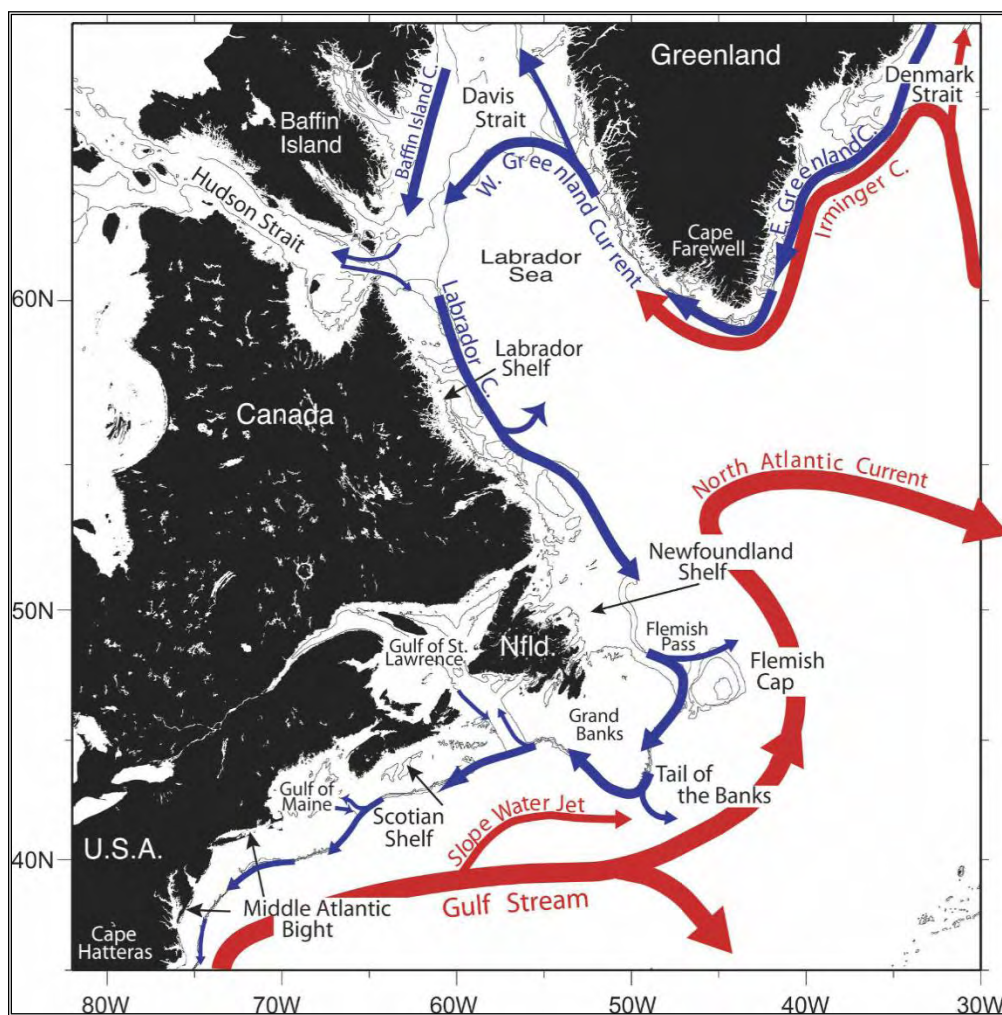
Source: Fratantoni and Pickart 2007.

Figure 3.2   Major Ocean Currents and Surface Circulation Features in the Northwest Atlantic Ocean.

The Labrador Current, originating in the Davis Strait, runs south along the Labrador Coast, with contributions from the warmer, more saline waters of the West Greenland Current, and the colder, less saline waters of the Baffin Island Current and Hudson Bay. The Labrador Current divides into two major branches on the northern Grand Banks. The inshore branch, which is approximately 100 km wide, is steered by the local underwater topography through the Avalon

Channel, and then continues to follow the bathymetry around the Avalon Peninsula and southern Newfoundland. This branch then divides into two parts, one flowing west and around the north side of St. Pierre Bank and the other flowing south in Haddock Channel between Green Bank and Whale Bank.

The stronger offshore branch of the Labrador Current flows along the shelf break over the upper portion of the continental slope. This branch divides east of 48°W, resulting in part of the branch flowing to the east around Flemish Cap and the other part flowing south around the eastern edge of the Grand Banks and through Flemish Pass. Within the Flemish Pass, the width of the Labrador Current is reduced to 50 km with speeds of about 30 cm/s. This flow transports cold, relatively low salinity Labrador Slope water into the region. To the southeast of the Flemish Cap, the North Atlantic Current transports warmer, high salinity water to the northeast along the southeast slope of the Grand Banks and the Flemish Cap.   The southward flowing stream of the offshore branch of the Labrador Current splits into two parts south of the Grand Banks. One section continues eastward as a broad flow, part of which breaks off to return southward, while the other turns offshore at the tail of the Grand Banks to flow northward along the edge of the North Atlantic Current.

The Gulf Stream and its associated eddies play an important role in the southern region of the Study Area. This extensive western boundary current plays a significant part in the poleward transfer of heat and salt and serves to warm the European subcontinent. While the Gulf Stream is usually located south of 40°N, one of the inherent features of this current system is its meandering path. These meanders may be formed both in northward and southward directions. At certain stages of their development, northward forming meanders separate from the main stream and generate rings or eddies, which begin moving independently from the Gulf Stream flow. Once eddies are formed, they drift in different directions and can be sustained for a considerable period of time. Their size may be of 100–300 km in diameter and may reach considerable depths. The trajectory of these warm water rings once they depart from the Gulf Steam jet, along with their interaction with the bathymetry of the Continental Slope and with other current flows, influence the dynamic regime in the vicinity of the shelf break of the Grand Banks and the Scotian Shelf.

The structure of the Gulf Stream changes from a single, meandering front to multiple, branching fronts when it reaches the Grand Banks. Between 65°W and 50°W, the Gulf Stream flows eastward. Shortly after passing east of 50°W, the Gulf Stream splits into two currents. One branch, the North Atlantic Current, curves north along the continental slope, eventually turning east between 50° and 52°N. The other branch, the Azores Current, flows southeastward towards the Mid-Atlantic Ridge. The Gulf Stream transport also varies in time. According to GeoSat altimetry results, the current transports a maximum amount of water in the autumn and a minimum amount in the spring, in phase with the north-south shifts of its position.

There is another major current between the eastward flowing Gulf Stream and the westward flowing Labrador Current, referred to as the Slope Water. This current is described as the northern bifurcation of the Gulf Stream that runs east-northeast along the continental slope south of Newfoundland. The Slope Water has been found to have distinct and unique properties because of mixing with coastal waters and underlying water masses. The Slope Water position varies laterally with the Gulf Stream at 55°W and its transport varies with the transport of the Labrador Current, as well as with changes in the deeper components of the slope water, at about 50°W.

An additional influence on ocean circulation in the southern region of the Study Area is the water exchange with the Gulf of St. Lawrence through the Laurentian Channel. In Laurentian Channel, the currents flow into the Gulf of St. Lawrence along the east side of the channel and out of the Gulf along the west side. The flow into the Gulf of St. Lawrence on the eastern side of Cabot Strait is mainly barotropic with a speed of 20 cm/s. The flow out of the Gulf of St. Lawrence on the western side of the Cabot Strait flows mainly along the western side of Laurentian Channel. A smaller portion flows along the inner Scotian Shelf and onto the Mid-shelf.

The interaction among these circulations is known to correlate with the behaviour of the North Atlantic Oscillation (NAO) index. The NAO index, the difference in winter sea level atmospheric pressures between the Azores and Iceland, is a measure of the strength of the winter westerly winds over the northern North Atlantic. A high NAO index corresponds to an intensification of the Icelandic Low and Azores High which creates strong northwest winds, cold air and sea temperatures, and heavy ice in the Labrador Sea and Newfoundland Shelf regions. In low index years, the north wall of the Gulf Stream is displaced to the south and the southward transport associated with the Labrador Current is intensified. As a consequence of these north-south displacements of the shelf/slope front, the area is subject to thermal anomaly oscillations.

At all locations within the Study Area, the currents vary on different time scales related to factors such as tides, wind stress, atmospheric pressure changes from the passage of storm systems, volume transport of the Labrador Current, seasonal temperature changes and salinity variations. The current variability in the Slope Region is influenced by the intermittent presence of Gulf Stream rings as well as by the relative position of the northern boundary of the Gulf Stream. On an inter-annual scale, the baroclinic transport component of the Labrador Current is negatively correlated with the NAO index. The relative strength of the two pressure systems control the strength and direction of westerly winds and the position of storm tracks in the North Atlantic, which in turn affects the volume transport of the Labrador Current. Similarly, the current variability on a synoptic scale is directly linked to the passage of low pressure systems.

3.4 Ice Conditions

Ice conditions are an important component of the physical environment and can directly affect offshore activities, including seismic surveys, along the coast of Newfoundland and Labrador. A review of ice conditions in the Study Area has been provided in the Southern Newfoundland, and Eastern Newfoundland SEAs (C-NLOPB 2010, 2014). A summary of ice conditions is provided below, with updated information on sea ice extent and iceberg sightings for offshore Newfoundland and Labrador. The classification of ice commonly found along Canada's eastern seaboard is based on internationally accepted terminology (CIS 2011).

3.4.1 Sea Ice

Sea ice generally begins to form in mid-November to mid-December on the coast of southern Labrador, spreading south to Newfoundland waters by early-January. The 30-year median concentration of sea ice reaches its maximum in the southern Labrador (south of 55ºN extending to Newfoundland) and eastern Newfoundland (extending towards the Flemish Cap) portions of the Study Area during the week of 5 March (Figure 3.3). Thirty-year median concentrations of sea ice are not present in the southern (including the southern Grand Banks) portion of the Study Area.

The maximum median sea ice extent reaches from northern Labrador to ~51ºW in the southern Labrador portion and to ~48ºN, 49ºW in the eastern Newfoundland portion of the Study Area. Based on the 30-year median of data for 1981–2010, only the northern portions of the Study Area would have some ice cover (Figures 3.4–3.6). During extreme years, sea ice could occur throughout the southern Labrador and eastern Newfoundland portions of the Study Area (Figures 3.4–3.6). Sea ice typically extends southwards to ~44ºN during extreme years in the southern portion of the Study Area (Figures 3.4–3.6); however, sea ice could occur as far south as ~43ºN (Figure 3.5). From mid-August until mid-November, the majority of the southern Labrador portions of the Study Area will be free of sea ice. From mid-July to mid-December the eastern Newfoundland portion of the Study Area will be virtually or entirely ice-free. Lastly, from early-May until early-February the southern portion of the Study Area will generally be ice-free (CIS 2011).

The northern portion of the Study Area is first affected by sea ice during the week of 26 November, and is ice-free beginning between the weeks of 20 and 27 August. The eastern Newfoundland portion of the Study Area is initially affected by sea ice beginning the week of 18 December, with ice present until the week beginning 23 July. The southern portion of the Study Area is first affected by sea ice during the week of 5 February, lasting until the week beginning 14 May (CIS 2011). The frequency of presence of sea ice is greatest over the southern Labrador, eastern Newfoundland and southern portions of the study area during the week of 12 March (Figure 3.6).
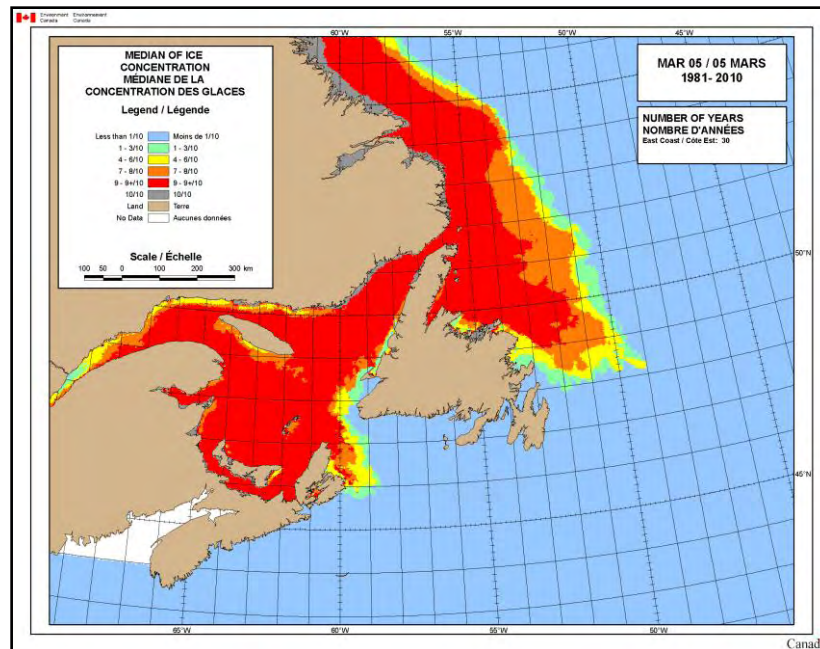
Source: Canadian Ice Service 30-Year Ice Atlas.
(http://iceweb1.cis.ec.gc.ca/30Atlas/page1.xhtml?grp=Guest&lang=en), accessed January 2018.

Figure 3.3   30-Year Median Concentration of Sea Ice in East Coast Waters, 1981–2010 (5 March).
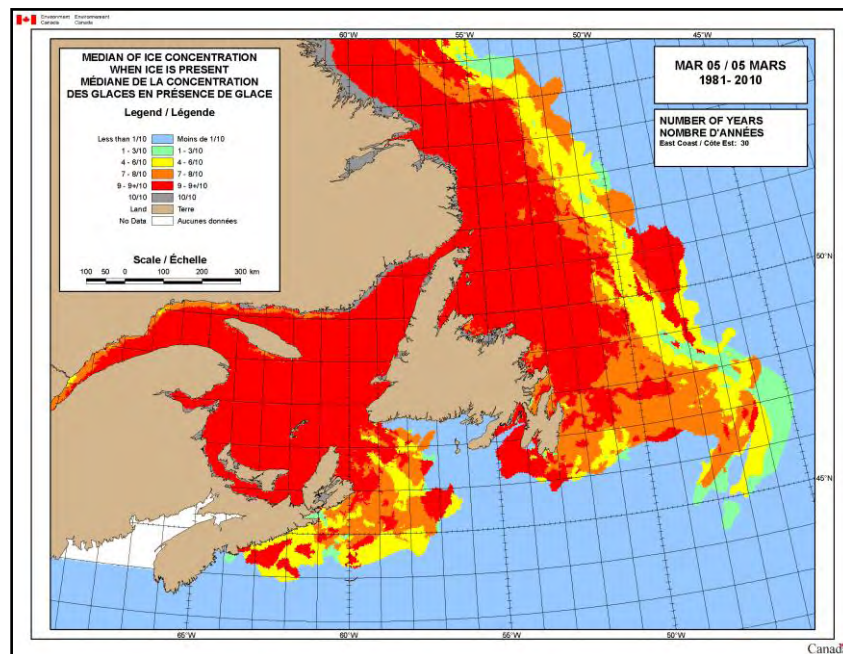
Source: Canadian Ice Service 30-Year Ice Atlas.
(http://iceweb1.cis.ec.gc.ca/30Atlas/page1.xhtml?grp=Guest&lang=en), accessed January 2018.

Figure 3.4   30-Year Median Concentration of Sea Ice when Ice is Present in East Coast Waters, 1981–2010 (5 March).
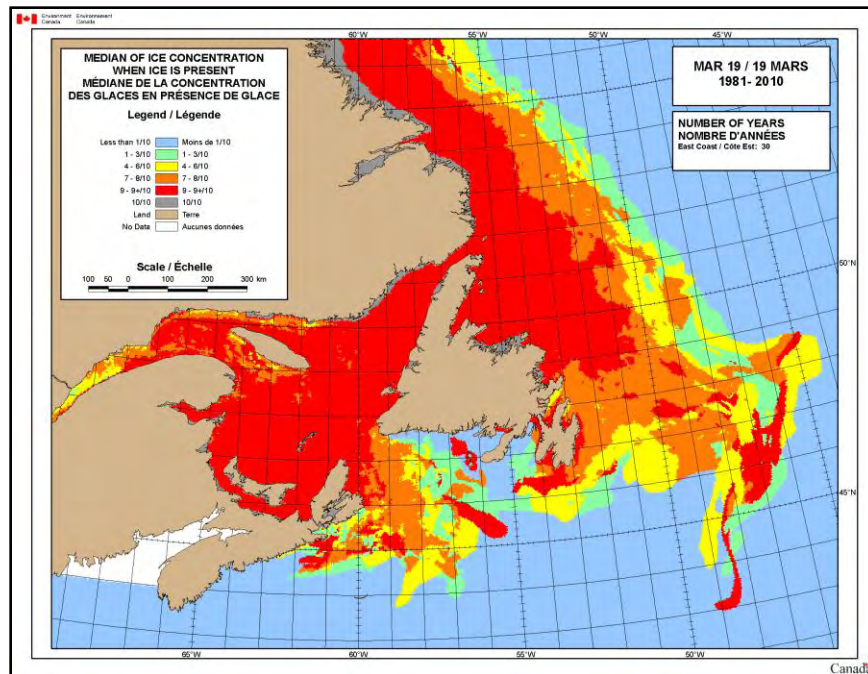
Source: Canadian Ice Service 30-Year Ice Atlas.
(http://iceweb1.cis.ec.gc.ca/30Atlas/page1.xhtml?grp=Guest&lang=en), accessed January 2018.

Figure 3.5   30-Year Median Concentration of Sea Ice when Ice is Present in East Coast Waters, 1981–2010 (19 March).
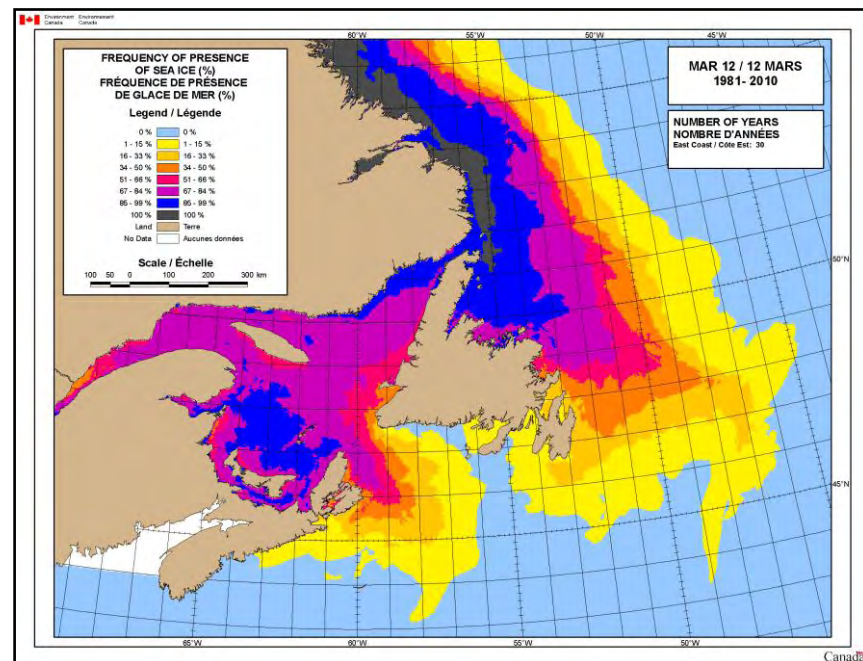
Source: Canadian Ice Service 30-Year Ice Atlas.
(http://iceweb1.cis.ec.gc.ca/30Atlas/page1.xhtml?grp=Guest&lang=en), accessed January 2018.

Figure 3.6   30-Year Frequency of Presence of Sea Ice in Canadian East Coast Waters, 1981–2010 (12 March).

New ice begins to form near the coast in the week of 19 November within the northern portion of the Study Area, with grey and grey-white ice also present as of the weeks of 4 and 18 December, respectively. Thin first year-ice begins to form near the Labrador coast by the week of 1 January and extends eastwards over the next month, with medium first-year ice also present as of the week of 5 February. Thick first-year ice is observed by the week of 12 March, with some old ice present by the week of 4 June, and these two ice types consist of the majority of sea ice present by the week of 2 July, after which much of the ice begins to recede (CIS 2011).

Grey-white ice begins to enter the southern portion of the Study Area by the week of 15 January, followed by a mixture of grey and grey-white ice by the week of 22 January. New ice also extends into the southern Study Area by the week of 5 February, with thin first-year ice appearing by the week of 12 February. Medium first-year ice is present by the week of 5 March and old ice by the week of 26 March (CIS 2011).

3.4.2   Icebergs

Icebergs often cause concern with regard to navigation and offshore activities (including seismic surveys) along the coast of Newfoundland and Labrador. The major sources, contributing ~90% of icebergs in Canadian waters, are glaciers along the west coast of Greenland. Prevailing northwest winds and the strong Labrador Current move icebergs south along the coast of Labrador. The presence of easterly and northeasterly winds strongly influences the number of icebergs that move into the coast or remain offshore. Major iceberg drift patterns flow southward from offshore Labrador to Newfoundland, branching eastward towards the Flemish Cap and extending towards the south-central portion of the Study Area. No iceberg sightings were recorded in the easternmost portion of the Study Area, and sightings decrease in the southwestern and southeastern portions of the Study Area (Figure 3.7).

An analysis was performed to determine the threat posed by icebergs in the Study Area. The International Ice Patrol (IIP) Iceberg Sightings Database was used as the primary data source in this analysis (NSIDC 1995, updated annually). As shown in Table 3.15, during the period from 2002–2015, a total of 42,050 icebergs were observed in the Study Area. Sightings may not include all icebergs passing through the Study Area, but indicate the relative abundance by month.   Of the 42,050 icebergs sighted, 47.8% were observed during the period of May–November.   Most were sighted in April, May and June (34.9, 27.5 and 14.3%, respectively), followed by March (15.2%) and July (5.2%). All remaining months contributed <3% each to the total number of iceberg sightings. Additionally, there was a great deal of inter-annual variability in the numbers of iceberg sightings.   For example, during May–November of 2009, there were 5,315 icebergs observed in the Study Area. During the same time period of 2010, there were only 25 icebergs observed.
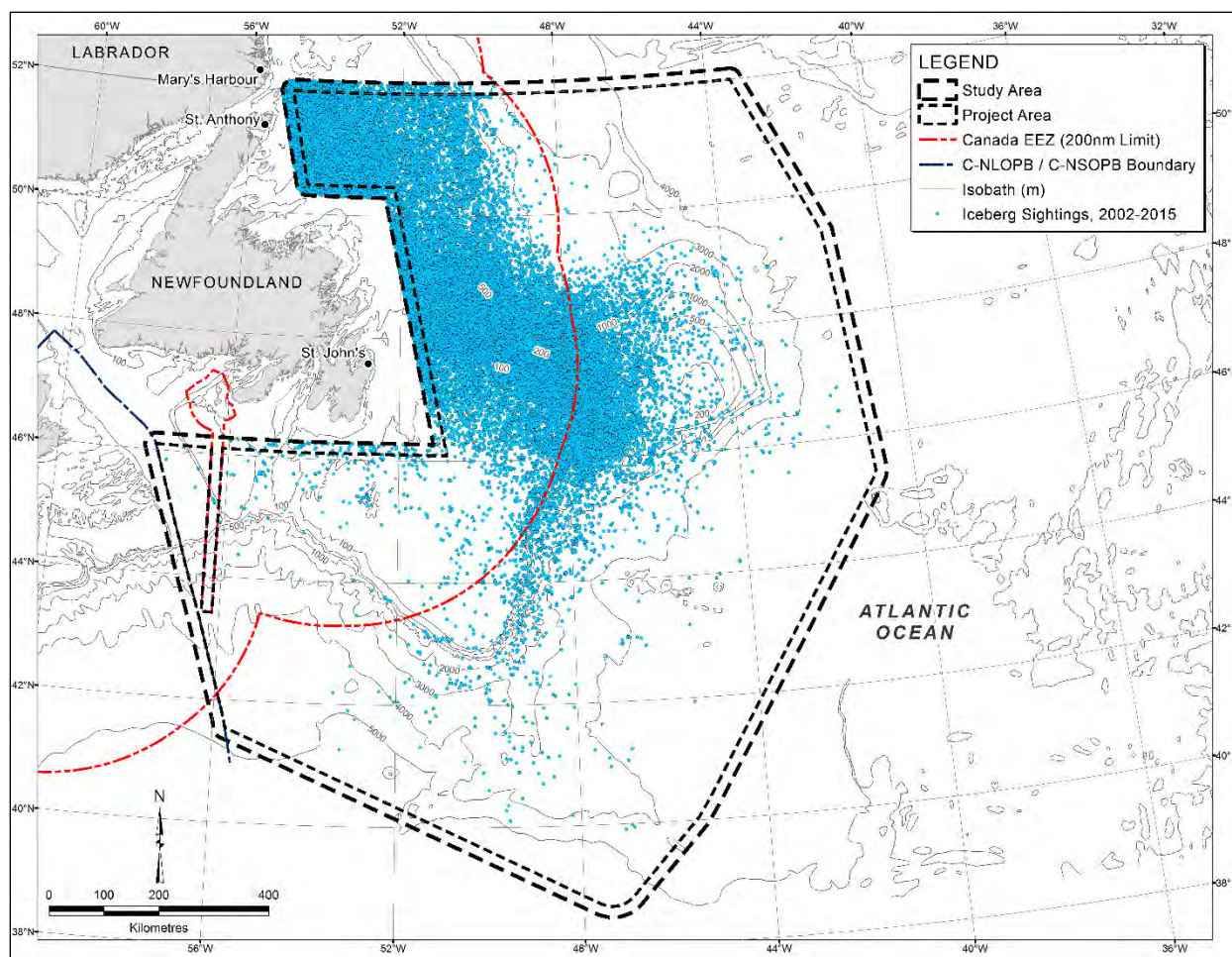
Source: NSIDC 1995, IIP Iceberg Sightings Database, accessed January 2018.

Figure 3.7   Iceberg Sightings in the Study Area, 2002–2015.

Iceberg size is typically characterized by waterline length, defined as the maximum dimension of the iceberg along the waterline, with a growler being defined as <5 m, a bergy bit as 5–14 m, small as 15–60 m, medium as 61–122 m, large as 123–213 m, and very large as >213 m. During the period from 2002–2015, 40.1% of the 42,050 icebergs with a defined sized classification recorded in the Study Area were classified as medium, large, or very large-sized.

Table 3.15   Annual and Monthly Iceberg Sightings within the Study Area, 2002–2015.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2002	-	67	785	1,269	766	614	100	-	-	-	-	-	3,601
2003	-	10	386	1,259	1,869	348	58	-	-	-	-	-	3,930
2004	-	1	74	969	1,301	175	39	6	-	-	-	-	2,565
2005	-	5	15	41	6	18	-	-	-	-	-	-	85
2006	-	-	11	1	37	24	-	-	-	-	-	-	73
2007	-	1	15	206	271	488	163	20	1	-	-	-	1,165
2008	1	76	465	2,363	328	126	53	3	-	-	-	-	3,415
2009	-	110	1,016	1,694	3,764	1,199	346	3	3	-	-	-	8,135
2010	-	-	14	32	4	10	9	1	1	-	-	-	71
2011	-	-	6	34	69	45	252	208	6	-	-	-	620
2012	-	31	249	668	1,099	115	13	1	-	-	-	-	2,176
2013	-	53	5	175	293	580	170	21	6	-	-	-	1,303
2014	21	479	2,015	3,534	804	316	364	38	1	-	-	2	7,574
2015	4	67	1,333	2,417	936	1,960	598	13	9	-	-	-	7,337
Total	26	900	6,389	14,662	11,547	6,018	2,165	314	27	0	0	2	42,050
% of Total	0.0	2.1	15.2	34.9	27.5	14.3	5.2	0.8	0.0	0.0	0.0	0.0	-

Source: NSIDC 1995, IIP Iceberg Sightings Database, accessed January 2018.

4.0   Biological Environment

The biological environment in and near the Study Area has been recently described in the Eastern Newfoundland SEA (C-NLOPB 2014), the Southern Newfoundland SEA (C-NLOPB 2010), and three project-specific EAs (LGL 2015a,b, 2016). In addition to updated information, overviews of relevant information are presented in the following subsections for fish and fish habitat, fisheries, marine-associated birds, marine mammals, sea turtles, species at risk and sensitive areas. Data gaps identified in the two SEAs (C-NLOPB 2010, 2014) have also been examined for any change in status.

4.1 Ecosystem

An ecosystem is an inter-related complex of physical, chemical, geological, and biological components that can be defined at many different scales from a relatively small area that may only contain one primary habitat type (e.g., a shelf) to a relatively large regional area ecosystem which is topographically and oceanographically complex with shelves, slopes, valleys and several major water masses and currents (e.g., the NW Atlantic). This EA focuses on components of the ecosystem such as selected species and stages of fish, marine-associated birds and marine mammals that are important ecologically, economically, and/or socially, with potential to interact with the Project. This is the VEC approach (see § 2.4.1.2) to environmental assessment and this approach is described in § 5.0. The VECs and/or their respective groups are discussed in the following subsections.

4.2 Fish and Fish Habitat VEC

This subsection provides a description of the existing fish and fish habitat in the Study Area. Fish habitat is considered first, followed by a discussion of macro-invertebrates and fishes in the Study Area.

4.2.1   Fish Habitat

In this EA, 'fish habitat' includes physical and biological aspects of the marine environment used by macro-invertebrate and fish species in the Study Area. The physical and chemical nature of the water column (i.e., water temperature, depth, salinity) and bottom substrate (i.e., surficial sediment) are critical factors affecting the characterization of associated marine biological communities. Subsection 3.1 of this EA discusses both the bathymetry and the geology of the Study Area. The biological component of fish habitat refers to phytoplankton, zooplankton, and benthos (i.e., infaunal and epibenthic invertebrates, such as polychaetes and echinoderms, not typically harvested during commercial fisheries in the Study Area).

4.2.1.1 Plankton

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

Phytoplankton distribution, productivity, and growth regulation in high-latitude ecosystems constitute a complex system in which light, nutrients, and herbivore grazing are the principal factors limiting phytoplankton regulation (Harrison and Li 2008). In the NW Atlantic, there is generally a spring plankton bloom (May/June) which is typically followed by a smaller bloom in the fall (September/October). This general pattern likely applies to the Study Area. There are areas of enhanced production in the Study Area, similar to other slope areas that have been studied. For example, Moderate Resolution Imaging Spectroradiometer (MODIS) chlorophyll 'a' concentration images from 2015 and 2016 (DFO 2016a) indicate the highest chlorophyll 'a' concentrations in the southern portion of the Study Area occurred on the shelf and along the slope areas between April and June. A second peak, albeit less than the spring peak, occurred in October and November, primarily in slope areas.

Zooplankton reproduction is tied to the phytoplankton bloom and 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 seabirds higher in the food chain. Zooplankton, a food source for a broad spectrum of species, contribute carbon via faecal matter and dead zooplankton to benthic food chains. Pepin et al. (2011) noted that plankton distribution in the Study Area is primarily influenced by local advective transport and mixing processes, with several species of *Calanus* copepods acting as key contributors to the regional secondary production.

The information on plankton within the Study Area has been reviewed extensively in the Eastern Newfoundland SEA (§ 4.2.1.3 of C-NLOPB 2014), and the Southern Newfoundland SEA (§ 3.1.3 of C-NLOPB 2010), and is summarized in this subsection. Some of the key points concerning the various components of planktonic communities for the eastern and southern Grand Banks as well as the Labrador Shelf area are highlighted below.

- In the North Atlantic, there is strong seasonal variability in primary production, typically characterized by a peak phytoplankton bloom in early-spring (April or May) that is dissipated over the summer by the formation of a summer thermocline that prevents the movement of nutrients throughout the water column (Maillet et al. 2004; Harrison et al. 2013);
- Another smaller phytoplankton bloom is created when fall winds and cooler temperatures break down the thermocline, allowing nutrients to be circulated in the water column and utilized by phytoplankton (Maillet et al. 2004);
- Nitrate and silicate are considered limiting nutrients to phytoplankton and their relative abundance can affect community structure;
- In general, larger microplankton are dominated by diatoms (e.g., *Chaetoceros* sp.), but dinoflagellates (*Ceratium* spp.) become more abundant in fall/winter (Harrison et al. 2013);
- Copepods account for a majority of the zooplankton abundance, followed by cladocerans;
- The copepod *Calanus finmarchicus* is considered a keystone species in the region due to its importance to higher trophic levels;
- Euphausids, such as krill, are important prey for marine mammals and have the highest densities in slope waters and offshore regions;
- Spawning periods for many fish species are synchronized with plankton blooms to provide larvae access to seasonally abundant food supplies, thereby increasing survivorship;
- Microbiota consisting of bacteria, mould, and yeast are ubiquitous in the marine environment. These microflora occupy a unique niche in marine ecosystems in that they both serve as a food source and degrade organic matter (Bunch 1979). Typically, microflora are most abundant in the upper layers and their numbers decrease with depth (Li and Harrison 2001);
- Ichthyoplankton assemblages (fish eggs and larvae) on the Northeast Newfoundland Shelf are dominated by capelin (*Mallotus villosus*), sand lance (*Ammodytes* sp.), lanternfishes, and Arctic cod (*Boreogadus saida*);
- The vertical distributions of many zooplankton species exhibit diurnal variability, resulting in higher concentrations in the surface waters during the day;
- The areas within the Southern NL SEA Study Area, where primary production was highest at certain times during 2008 (based on chlorophyll-a concentration), included the coastal region of the southwest coast of Newfoundland, the western edge of

St. Pierre Bank/Laurentian Channel, and both the slope and shelf of the southwest Grand Bank; and

- Nitrates, important in the growth of diatoms, are limited in the Eastern NL SEA Study Area relative to other areas of the NW Atlantic.

The Atlantic Zone Monitoring Program (AZMP) was implemented by DFO in 1998 in order to better understand, describe and forecast the state of the marine ecosystem. A critical element of the AZMP is an observation program designed to assess the variability in nutrients, phytoplankton and zooplankton (DFO 2016a). The AZMP findings in relation to oceanographic conditions in the Study Area for 2015 are summarized below.

- In the southern regions of the zone, sea-surface temperatures were above normal in January and February of 2015, and generally near normal until June across the zone. The sea-surface temperatures for Labrador and the Newfoundland shelf were below normal to normal, and normal to above normal everywhere else in the zone for the remainder of the year. Bottom temperatures were generally normal or above normal across the zone;
- Nitrate inventories in deep waters were below normal on the Newfoundland Shelf in 2015, continuing a pattern that began in 2008–2009;
- Overall abundance of copepods throughout much of the Atlantic Zone has increased compared to levels observed in 2014;
- Chlorophyll 'a' inventories were near or above normal throughout much of the Atlantic Zone except for the Newfoundland Shelf where they have continued to remain low since 2011;
- Timing indices of the spring bloom was substantially delayed on the northern Labrador and northeast Shelf compared to those in the Flemish Pass and Flemish Cap area (Pepin et al. 2015);
- The abundance of *Calanus glacialis* and *Calanus hyperboreus* has shown long-term declines in abundance on the Flemish Cap and southeast Grand Bank (Pepin et al. 2015);
- High abundance levels of non-copepod zooplankton (e.g., larval stages of benthic invertebrates and carnivores that feed on other zooplankton) were observed on the Newfoundland Shelf and Grand Banks in 2014; and
- The abundance of zooplankton *Pseudocalanus* spp. was above normal throughout the Newfoundland Shelf while abundance of *Calanus finmarchicus* has been below normal levels throughout much of the Atlantic Zone, except for the Flemish Cap.

Planktonic organisms are so ubiquitous and abundant, and typically have such rapid generation times, that there will be negligible effect on planktonic communities from the proposed seismic program. 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., northern shrimp *Pandalus borealis*, snow crab *Chionoecetes*

opilio and fishes (e.g., Atlantic cod *Gadus morhua*) are described in the following subsections because of their VEC status.

4.2.1.2   Benthic Invertebrates

Benthic invertebrates are bottom-dwelling organisms that can be classified into three categories: (1) infaunal organisms; (2) sessile organisms; and (3) epibenthic species (Barrie et al. 1980). Infaunal organisms live on or are buried in soft substrates and include bivalves, polychaetes, amphipods, sipunculids, ophiuroids, and some gastropods. Sessile organisms live attached to hard substrates and include barnacles, tunicates, bryozoans, holothurians, and some anemones. The epibenthic organisms are active swimmers that remain in close association to the seabed and include mysiids, amphipods, and decapods.

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

The benthic invertebrate communities of portions of the Study Area have been described in the Eastern Newfoundland SEA (§ 4.2.1.5 of C-NLOPB 2014), Southern Newfoundland SEA (§ 3.1.4 of C-NLOPB 2010), and three project-specific EAs (§ 4.2 of LGL 2015a,b, 2016). It is important to note that beyond the Canadian 200 nm limit, excluding the Nose and Tail of the Grand Banks, the Flemish Pass and the Flemish Cap, there is a substantial deficiency in data related to the benthos. The information presented in this subsection pertains to studies completed on the continental shelf and slope of the Study Area.

- Some of the key deep subtidal invertebrate species in the Eastern Grand Banks area include snow crab (*Chionoecetes opilio*), Iceland scallops (*Chlamys islandica*), sea scallops (*Placopecten magellanicus*), northern shrimp (*Pandalus borealis*), striped pink shrimp (*P. montagui*), Atlantic surf clams (*Spisula solidissima*), propeller clams (*Cyrtodaria silique*), pale sea urchin (*Strongylocentrotus pallidus*), hooded shrimp (Cumacea), and whelks (*Buccinum* sp.);
- Characteristic deep subtidal invertebrate species in the Southern Grand Banks area include lobster (*Homarus americanus*), snow crab, toad crab (*Hyas* sp.), rock crab (*Cancer* sp.), Iceland scallops, sea scallops, northern shrimp, Stimpson's surf clams (*Mactromeris polynyma*), propeller clams (*Cyrtodaria siliqua*), ocean quahogs (*Arctica islandica*) and sea urchins;

- The Sydney Basin SEA and the Laurentian Sub-basin SEA both described benthic invertebrate communities reported by Hutcheson et al. (1981) and Nesis (1965) in deep subtidal areas of the Grand Banks. Reported invertebrate groups included echinoderms, polychaetes, crustaceans, bivalve molluscs and benthic colonial organisms such as bryozoans, hydrozoans, sponges and corals;
- Many benthic communities in the Eastern Newfoundland SEA Study Area are quite diverse compared to higher trophic levels and can be expected to vary over time and with changing environmental conditions;
- A number of research studies have characterized benthic communities on the Grand Banks (Schneider et al. 1987; Kenchington et al. 2001; Gale 2013; Gilkinson 2013) and associated slopes (Houston and Haedrich 1984);
- Schneider et al. (1987) reported observing epifaunal communities of the northeastern part of the Grand Banks that were dominated by bivalves and echinoderms such as brittle stars, urchins, and sand dollars;
- Trawling impact studies conducted by Prena et al. (1999) and Kenchington et al. (2001) using video grabs and benthic sled and trawl bycatch sampling characterized benthic communities on the northeast slope of the Grand Banks within the Study Area over a three year period. Kenchington et al. (2001) documented 246 benthic taxa which were primarily echinoderms, polychaetes, crustaceans, and molluscs;
- In contrast to other survey types, DFO research vessel (RV) trawl survey catches are often dominated by relatively large taxa such as sponges, anemones, shrimp, crab and urchins. Other taxa included echinoids such as sand dollars, sea stars, brittle stars and basket stars (LGL 2012a, 2013); and
- Infaunal invertebrates collected at Lewis Hill (southwestern Grand Banks) were dominated by polychaetes, followed by nemertean worms, amphipods and sea cucumbers. The invertebrate community found at Lewis Hill was very similar to those found in similar surficial sediment types elsewhere on the Grand Banks (Husky 2003a,b).

Gilkinson (2013) provided summary data related to benthos caught during DFO RV survey trawling in North Atlantic Fisheries Organization (NAFO) Divisions 3LNO between 2006 and 2010. Figure 1 in Gilkinson (2013) indicates that the trawl-caught benthos biomass was dominated by sponges, sea anemones, snow crab and echinoderms. Catches of sponges and shrimp in 3L were larger than those in 3NO. Also, sponge catches tended to be higher in 2J compared to 3K while sea anemone catch biomass was greater in 3K. During the DFO NEREUS grab sampling program, from 2008–2010, a total of 455 benthic macrofaunal taxa were identified from 22,000 specimens representing 12 phyla. The average sampling depth was 92 m (range 58–157 m). Overall, 51% of samples collected were composed of pure sand. The majority (77%) of samples were collected from the mid-depth zone (>50–100 m) of which 46% contained pure sand. The percentage sand increased to 61% in the deep zone. The three phyla that dominated the grab samples included Annelida, Arthropoda, and Mollusca. These three phyla

comprised 86% of all recorded taxa. Annelida was the most species rich phylum (39% of all species) with polychaetes accounting for 99% of all annelid taxa. Amphipods accounted for 60% of arthropod taxa, while gastropods and bivalves accounted for 51% and 43% of mollusc taxa, respectively. Dominance in species richness by these three phyla is typical of NW Atlantic continental shelves that are characterized primarily by sandy seabeds (Gilkinson et al. 2005, and Kenchington et al. 2001 *in* Gilkinson 2013). Some of the main species collected in grab samples included the annelids *Glycera capitata, Prionospio steenstrupi, Terebellides stroemi, Nothria conchylega, Nothria conchylega,* and *Pectinaria granulate*, the arthropods *Hyas coarctatus, Unciola irrorata,* and *Unciola leucopis*, and the molluscs *Antalis entails, Crenella decussate, Arctica islandica, Liocyma fluctuosa*, and *Chlamys islandicus*.

During a study conducted by Houston and Haedrich (1984), grab samples were taken in the vicinity of Carson Canyon (continental edge and slope) on the southeastern Grand Banks. Faunal communities in these grab samples were dominated by polychaetes, hooded shrimp, sipunculid worms, amphipods, echinoderms, isopods and bivalves. The relative dominance of these taxa depended on substrate type, although polychaetes were among the top four taxa, in terms of abundance, in each of sand, gravel and silt (Houston and Haedrich 1984).

A recent study (Murillo et al. 2016) provided information on the epibenthic invertebrate assemblages that occur beyond the Canadian 200 nm limit on the Tail and southern Nose of the Grand Bank, and in the Flemish Cap area. Sampling was conducted with bottom trawls. Twelve spatially coherent epibenthic megafaunal assemblages were identified, nested within three major regional-scale faunal groups: (1) the continental shelf of the Tail of the Grand Bank, typified by the sea cucumber (*Cucumaria frondosa)* and the sand dollar (*Echinarachnius parma*); (2) the upper slope of the Grand Bank and the top of the Flemish Cap, typified by the sponges *Radiella hemisphaerica* and *Iophon piceum*, and the sea star *Ceramaster granularis*; and (3) the lower slope of the Grand Bank and Flemish Cap, typified by the sea urchin *Phormosoma placenta*, and the sea pens *Anthoptilum grandiflorum* and *Funiculina quadrangularis*. Statistical analysis concluded that faunal group 1 is most closely associated with shallow depth (i.e., <200 m), coarse sediments, and cold fresh water associated with the Labrador Current, while faunal group 3 is most closely associated with greater depth (i.e., 500–600 m), muddy sediments, and warmer, more saline water. An extensive comprehensive list of epifauna collected during the bottom trawl surveys is presented in Table A.1 *in* Murillo et al. (2016). This study fills a knowledge gap in these areas.

There is a substantial deficiency in data related to the benthos that occurs in the portion of the Study Area beyond the Canadian 200 nm, excluding the Nose and Tail of the Grand Banks, the Flemish Pass and the Flemish Cap.

For more information on the life history and biology of some of the key benthic species in the Study Area see Table 4.58 of the Eastern Newfoundland SEA (C-NLOPB 2014).

Deep-water Corals and Sponges

A variety of coral groups occur in Newfoundland and Labrador waters. These include scleractinians (solitary stony corals), antipatharians (black wire corals), alcyonaceans (large and small gorgonians, soft corals), and pennatulaceans (sea pens) (Wareham and Edinger 2007; Wareham 2009). Corals are largely distributed along the edge of the continental shelf and slope off Newfoundland and Labrador (Edinger et al. 2007; Wareham and Edinger 2007). Typically, they are found in canyons and along the edges of channels (Breeze et al. 1997), at depths greater than 200 m. Soft corals are distributed in both shallow and deep waters, while horny and stony corals (hard corals) are restricted to deep water only in this region. Dense congregations of coral off Labrador are referred to as coral "forests" or "fields". Most grow on hard substrate (Gass 2003), including the large gorgonian corals (Breeze et al. 1997). Others, such as small gorgonians, cup corals, and sea pens, prefer sand or mud substrate (Edinger et al. 2007). The distribution of various corals along the continental shelf and slope regions of the Study Area based on data collected by fisheries observers, are provided in Figure 3 of Wareham and Edinger (2007) and Map 1 of Wareham (2009). In total, thirty species of corals were 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). The authors noted that corals were more widely distributed on the continental edge and slope.

Several studies present information on the ecology of deep cold-water corals of Newfoundland and Labrador waters, including information on biogeography, life history, biochemistry, and their relation to fishes (e.g., Gilkinson and Edinger 2009; Kenchington et al. 2010a,b, 2016; 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). Their study area encompassed the continental shelf, edge, and slope ranging from Baffin Bay to the Grand Banks, including the Labrador Shelf (NAFO Divisions 2GHJ). Distributional maps were compiled by Wareham (2009) using DFO Newfoundland and Labrador Region multispecies surveys (2000–2007), DFO Arctic multispecies surveys (2006–2007), a northern shrimp survey (2005), and information provided by fisheries observers aboard commercial fishing vessels (2004–2007). The maps in Wareham (2009) show the distribution of several coral groups occurring along the continental edge and slope from Baffin Bay to the Grand Banks. The groups profiled include antipatharians, alcyonaceans, scleractinians, and pennatulaceans. Six previously undocumented coral species, composed of one alcyonacean, two scleractinians, and three pennatulaceans, were identified in the Newfoundland and Labrador and Arctic Regions (Wareham 2009).

According to distribution maps included in Wareham (2009), there are numerous species of corals occurring within or adjacent to the Study Area. The species identified include large gorgonians (*Keratoisis ornata*, *Paragorgia arborea*, and *Paramuricea* spp.), small gorgonians

(*Acanthogorgia armata*, *Acanella arbuscula*, *Radicipes gracilis*, and *Anthothela grandiflora*), and soft corals (*Anthomastus grandiflorus*, *Duva florida*, *Gersemia rubiformis*, and *Nephtheid* spp.). Also noted were scleractinian species (*Flabellum alabastrum, Javania cailleti, Dasmosmilia lymani,* and *Flabellum macandrewi*) and several pennatulacean species (*Protoptilum carpenteri*, *Anthoptilum grandiflorum*, *Halipteris finmarchica*, *Pennatula grandis, Pennatula phosporea, Distichoptilum gracile*, *Funiculinia quandrangularis* and unspecified sea pen species). Antipatharian species were also observed within the Study Area along the Flemish Pass and NE Newfoundland shelf. The majority of coral species observed occurred on the continental slope, with the exception of several soft corals (*Gersemia rubiformis* and *Nephtheid* spp.) found distributed on the shelf. Map 1 in Wareham (2009) indicates a continuous coral distribution within the Study Area primarily on the edges of the continental shelf and slope of the Grand Banks. In another deep-water coral distribution study within the eastern region of the Study Area, it was determined that the Flemish Cap supported the greatest species diversity of-deep-water corals (Murillo et al. 2011). They observed 34 species on the Flemish Cap, followed by 22 species in the Flemish Pass and on the Nose of the Grand Banks.

The patterns of association between deep-sea corals, fish, and invertebrate species, based on DFO scientific surveys and ROV surveys, are discussed by Edinger et al. (2009). Although there were no dramatic relationships between corals and abundance of the ten groundfish species studied, there was a weak but statistically significant positive correlation between coral species richness and fish species richness. 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-spike 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*), a lanternfish (*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 significant deep-sea habitat, enhance species richness and diversity, and cause 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 (Beazley et al. 2013). Kenchington et al. (2013) noted the association of several demersal fish taxa with Geodia-dominated sponge grounds on the Grand Banks and Flemish Cap. Beazley et al. (2013) determined that deep-water sponge grounds in the NW Atlantic were characterized by a significantly higher biodiversity and abundance of associated megafauna compared to non-sponge habitat.

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

Although some of the siliceous spicules of non-reef-forming species dissolve quickly, there is some accumulation of shed spicules forming a thick sediment-stabilizing mat, which constitutes a special bottom type supporting a rich diversity of species. Organisms commonly associated with sponges and sponge grounds include species of marine worms and bryozoans, as well as fauna of higher trophic levels. 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 a recent DFO report by Guijarro et al. (2016), sponge and coral distributions based on research vessel survey data and associated environmental data contributed to the development of a species distribution modelling approach called "random forest" to identify significant benthic areas and predict the probable occurrence of sponges, sea pens (*Pennatulacea*), large gorgonians, and small gorgonians within the entire Newfoundland and Labrador region. Random forest modelling can be used to predict the probability of species occurrence in an unsampled area. Data were collected from DFO research vessel multispecies trawl surveys, DFO/industry northern shrimp surveys, and Spanish research vessel groundfish trawl surveys. All tows followed a stratified random trawl design using Campelen trawl gear. Data concerning sponges were drawn from trawl data conducted from 1995–2015 and from 2003–2015 for all other species. Figures 5, 20, 35, and 50 *in* Guijarro et al. (2016) display the probability of species' distributions in unsampled areas overlaying known presence/absence of species from survey tows for sponges, sea pens, large gorgonians, and small gorgonians. This modelling approach is useful for filling data gaps in survey coverage and extrapolating probable significant benthic areas for unsampled areas.

Similarly, Kenchington et al. (2016) provided maps displaying the locations of significant coral and sponge concentrations on the Newfoundland and Labrador Shelf and Slope. Using DFO research vessel trawl survey data and an updated kernel density estimation analysis, they modeled the distribution of sponges, small and large gorgonian corals, and sea pens throughout the Study Area; identifying sponge and coral concentrations and significant benthic areas (SBAs). Updated locations of high concentration areas of sponge, sea pen, large gorgonian, and

small gorgonian corals can be seen in Figures 37, 42, 47, and 52 respectively of Kenchington et al. (2016). Also, SBAs were identified within the Study Area for the above sponge and coral groups on the continental shelf of the southwestern Grand Banks and the Northeast Newfoundland Shelf and Slope regions (see Figure 99 of Kenchington et al. (2016).

Since 2008, the NAFO Scientific Council has been identifying various areas of significant coral and sponge concentrations within the NAFO Regulatory Area. These areas that have been closed to fishing with bottom gear are shown in § 4.7, Sensitive Areas (NAFO 2017a).

DFO has recently published a report that discusses its coral and sponge conservation strategy for Eastern Canada (DFO 2015a). The report includes discussion of the current status of coral and sponge conservation in Eastern Canada, research on corals and sponges in Eastern Canada, and other aspects of corals and sponges in both Canadian and international contexts.

DFO RV survey data collected in the Study Area during May–November 2014, indicate that sponges and corals were caught primarily in the slope areas of the Grand Banks and off Labrador although some were also caught on the shelf (see Figures 4.32 and 4.34 *in* § 4.3.7).

4.2.2   Fish

For the purposes of this EA, 'fish' includes macro-invertebrates that are targeted in the commercial fisheries and all fishes, either targeted in the commercial fisheries or otherwise. The focus is on key commercially- and ecologically-important fishes.

4.2.2.1   Principal Macro-invertebrates and Fishes Commercially Harvested

This subsection describes the principal macroinvertebrate and fish species that are typically harvested in the Study Area during commercial fisheries. These include both targeted species (e.g., snow crab, northern shrimp and Greenland halibut *Reinhardtius hippoglossoides*) and other species caught incidentally (e.g., wolffishes [*Anarhichas* spp.]).

Snow crab, northern shrimp and Greenland halibut have dominated directed commercial fishery landings for the Study Area in recent years. Some of the 'incidental catch' species and key ecologically-important fishes are also discussed in this subsection.

Macroinvertebrates

Snow Crab

Aspects of the snow crab life history, including information on distribution, are discussed in § 4.2.2.1 of LGL (2014, 2015a,b, 2016). Subsections 4.2.1.5 of the Eastern Newfoundland SEA

(C-NLOPB 2014), and 3.2.1.1 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on snow crab.

Landings in the offshore of NAFO Div. 3K have declined by 50% since 2008 (7,200 t in 2015), the lowest level in two decades. Effort in this area has also been near its lowest level for the last three years. Snow crab landings in the offshore of NAFO Div. 3LNO have increased slightly since 2009 to a historic high of 28,750 t in 2015. Effort has increased slightly in the past three years (DFO 2016b). Long-term recruitment prospects in these NAFO Divisions are considered unfavourable based on a recent warming oceanic regime and a low abundance of young crabs in the past decade (DFO 2016b).

There is one fishery closure area that occurs within the Project Area: Funk Island Deep (see Figure 4.40); created to offer protection to snow crab (DFO 2016b). More details on this closure area is provided in § 4.7, Sensitive Areas.

In the commercial fishery conducted within the Study Area during May–November 2015, snow crab harvesting was conducted along the southeastern, eastern and northeastern shelf and upper slope of the Grand Banks, on the shelf south of the Avalon and Burin Peninsulas, on the shelf immediately east of the Avalon Peninsula, and the area off northeastern Newfoundland and southeastern Labrador (see Figure 4.12 in § 4.3.3.2). Fishing effort distribution for snow crab within the Study Area during 2013–2014 are provided in Figure 4.13 in § 4.3.3.2 of LGL (2016).

<u>Northern Shrimp</u>

Aspects of the northern shrimp life history, including information on distribution, are discussed in § 4.2.2.1 of LGL (2015a,b, 2016). Subsections 4.2.1.5 of the Eastern Newfoundland SEA (C-NLOPB 2014), and 3.1.4.1 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on northern shrimp.

The northern shrimp fishery in NAFO Div. 3LNO within the Study Area has seen a reduction in shrimp catch and declining Total Allowable Catch (TAC) levels in recent years. TACs increased from 6,000 t in 2000 to 30,000 t in 2009 and 2010 but declined to 4,300 t in 2014 due to continued declines in survey and commercial fishery indices. Small and large Canadian fishing fleets have altered their fishing patterns in response to low catch rates by fishing along the border to 3K. The number of countries fishing for shrimp in 3L decreased, from as many as 16 in 2006 to only one country in 2013. The majority (>92.7%) of total shrimp biomass in NAFO Div. 3LNO caught during either spring or fall surveys has come from 3L, while 3N accounted for only 0.2–8.1%, and 3O accounted for less than 1% (Orr and Sullivan 2014). Northern shrimp have also been significantly increasing in biomass and abundance in NAFO Div. 3M since 2014, with biomass and abundance increasing by 70% and 117% respectively in 2015 from the previous year (Casas 2015). Fishable biomass in Shrimp Fishing Area (SFA) 6 (NAFO Div. 3K)

decreased by 41% in 2015 relative to 2014. The fishable biomass in SFA 6 is estimated at 138,000 t (DFO 2016c).

In the commercial fishery conducted within the Study Area, northern shrimp harvesting during May–November 2015 was prosecuted primarily in the area off northeastern Newfoundland and southeastern Labrador (see Figure 4.9 in § 4.3.3.2). Fishing effort distributions for northern shrimp within the Study Area during 2013–2014 are provided in Figure 4.10 in § 4.3.3.2 of LGL (2016). Shrimp was also harvested along the northeastern, southeastern and southwestern slopes of the Grand Banks (see Figure 4.30 in § 4.3.7).

Note that a portion of NAFO Div. 3L where water depth <200 m is closed to commercial shrimp fishing during 2017 due to the decline of the stock (NAFO 2017a).

Cockles

Life history aspects of the cockle (family Cardiidae), including distribution information, are presented in § 4.2.2.1 of LGL (2015b).

Figures 4.27 and 4.28 in § 4.3.3.2 of LGL (2015b) show the locations of cockle harvesting in the Study Area during May–November between 2005 and 2012. Cockle harvesting is concentrated on the eastern shelf of the Grand Banks in the general vicinity of Lilly Canyon and Carson Canyon.

Stimpson's Surf Clam

Life history aspects of the Stimpson's surf clam, including distribution information, are presented in § 4.2.2.1 of LGL (2015b). Subsection 3.1.4.1 of the Southern Newfoundland SEA (C-NLOPB 2010) also provides life history information on this bivalve.

The fishery for Stimpson's surf clam takes place on Banquereau Bank and the Grand Banks using factory freezer fishing vessels equipped with hydraulic clam dredges. The fishery was established in 1986 (Roddick et al. 2011). Although there are four licenses for offshore vessels in this fishery, only two vessels are currently active. The stock, which does not have a high exploitation rate, is thought to be relatively healthy. The fishery typically takes place in areas with water depths of 45–65 m (Roddick 2013).

Fishes

Greenland Halibut (Turbot)

Life history aspects of Greenland halibut, including distribution information, are presented in § 4.2.2.1 of LGL (2015a, 2016). Subsections 4.2.1.6 of the Eastern Newfoundland SEA

(C-NLOPB 2014), and 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on Greenland halibut.

In the commercial fishery conducted within the Study Area during May–November 2015, Greenland halibut harvesting was prosecuted primarily along the northeastern slope of the Grand Banks, the slope region off southern Labrador and secondarily along the slope region of the Southern Grand Banks (see Figure 4.15 in § 4.3.3.2). Distributions of fishing effort for Greenland halibut within the Study Area during 2013 and 2014 are provided in Figure 4.16 in § 4.3.3.2 of LGL (2016). Most catch locations for Greenland halibut in the Study Area during DFO RV surveys in May–November 2014, were distributed along the slope of the Grand Banks, the shelf and slope areas off northeastern Newfoundland, and the shelf and slope area off Labrador (see Figure 4.31 in § 4.3.7).

Atlantic Halibut

Life history aspects of Atlantic halibut (*Hippoglossus hippoglossus)*, including distribution information, are presented in § 4.2.2.1 of LGL (2015a, 2016). Subsections 4.2.1.2 and 4.2.1.5 of the Eastern Newfoundland SEA (C-NLOPB 2014), and 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on Atlantic halibut.

In the commercial fishery conducted within the Study Area during May–November 2015, Atlantic halibut harvesting was conducted along the northeastern slope of the Grand Banks, the slope region of the Southern Grand Banks and on the Southeast Shoal (see Figure 4.21 in § 4.3.3.2). Distributions of fishing effort for Atlantic halibut within the Study Area during recent years are provided in Figures 4.48–4.51 in § 4.3.3.2 of LGL (2015b) and Figure 4.21 in § 4.3.3.2 of LGL (2016).

Atlantic Cod

Life history aspects of Atlantic cod (*Gadus morhua*), including distribution information, are presented in § 4.2.2.1 of LGL (2015a,b, 2016). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014), and 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on Atlantic cod.

A recent study by Rose and Rowe (2015) discusses the comeback of northern cod. Using data collected during acoustic-trawl surveys of the main pre-spawning and spawning components of the stock, they show that biomass has increased from tens of thousands of tonnes to >200 thousand tonnes during the last decade. The increase was first signalled by the observation of massive schooling behaviour in late winter in 2008 in the southern range of the stock (i.e., Bonavista Corridor) after a 15-year absence. In the spring of 2015, large increases in cod abundance and size composition were observed for the first time since 1992 in the more

northerly spawning groups of the stock complex (i.e., outer Notre Dame Channel, southern Hamilton Bank and Hawke Channel).

The latest DFO stock assessments indicate that the "Northern" cod stocks in NAFO Divs. 2J3KL have increased considerably over the past decade. Overall biomass increased between 2005 and 2012 but has remained stable in recent years. DFO continues to manage the stock using the precautionary principle, keeping removals at the lowest possible level until assessments indicate the stock has cleared the critical zone (DFO 2016d).

In the commercial fishery conducted within the Study Area during May–November 2015, Atlantic cod were harvested along the northeastern slope of the Grand Banks, the slope region of the Southern Grand Banks and on the Southeast Shoal (see Figure 4.19 in § 4.3.3.2). Distributions of fishing effort for Atlantic cod within the Study Area during 2013 and 2014 are provided in Figure 4.20 in § 4.3.3.2 of LGL (2016). DFO RV data collected in the Study Area during May–November 2014 indicated Atlantic cod catches in the shelf and slope areas of most of the Study Area (see Figure 4.28 in § 4.3.7).

American Plaice

Life history aspects of American plaice (*Hippoglossoides platessoides*), including distribution information, are presented in § 4.2.2.1 of LGL (2015a,b, 2016). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014), and 3.7.1 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on American plaice.

In the commercial fishery conducted within the Study Area during May–November 2015, American plaice were harvested primarily on the shelf of the Southern Grand Banks but also along the slope of the northeastern Grand Banks (see Figure 4.22 in § 4.3.3.2). Distributions of fishing effort for American plaice within the Study Area during 2013 and 2014 are provided in Figure 4.21 in § 4.3.3.2 of LGL (2016).   DFO RV data collected in the Study Area during May–November 2014 indicated American plaice catches primarily throughout the shelf areas of the Study Area as well as some slope areas of the Grand Banks (see Figure 4.27 in § 4.3.7).

Yellowtail Flounder

Life history aspects of yellowtail flounder (*Pleuronectes ferruginea)*, including distribution information, are presented in § 4.2.2.1 of LGL (2015a,b, 2016). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014) and 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on yellowtail flounder.

In the commercial fishery conducted within the Study Area during May–November 2015, yellowtail flounder harvesting was prosecuted primarily in the Southeast Shoal area of the Southern Grand Bank with some harvesting also occurring on St. Pierre Bank (see Figure 4.18 in

§ 4.3.3.2). Fishing effort distribution for yellowtail flounder within the Study Area during 2013 and 2014 are provided in Figure 4.19 in § 4.3.3.2 of LGL (2016). Catch locations for yellowtail flounder in the Study Area during DFO RV surveys in May–November 2014, were distributed across the shelf of the Northern and Southern Grand Banks (see Figure 4.26 in § 4.3.7).

White Hake

Life history aspects of white hake (*Urophycis tenuis*), including distribution information, are presented in § 4.2.2.1 of LGL (2015b, 2016). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014) and 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on white hake.

White hake biomass and abundance estimates for NAFO Divs. 3NOPs have been at stable low levels since 2003. The abundance of white hake in these areas are above the recovery target set under current conditions and fishing rates. Current harvesting levels are not expected to negatively affect the recovery of the stocks (DFO 2016e).

Redfishes

Life history aspects of redfishes, including distribution information, are presented in § 4.2.2.1 of LGL (2015a,b, 2016). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014) and 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on redfishes.

In the commercial fishery conducted within the Study Area during May–November 2015, redfish harvesting was conducted primarily along the slope area of the northeastern Grand Bank and the southern Grand Bank (see Figure 4.20 in § 4.3.3.2). Fishing effort distribution for redfishes within the Study Area during 2013 and 2014 are provided in Figure 4.20 in § 4.3.3.2 of LGL (2016). Catch locations for deepwater redfish in the Study Area during DFO RV surveys in May–November 2014, were distributed along the slope of the Northern and Southern Grand Banks, and on the shelf and upper slope off northeastern Newfoundland and southern Labrador (see Figure 4.25 in § 4.3.7).

4.2.2.2 Other Fishes of Note

Capelin

Life history aspects of capelin, including distribution information, are presented in § 4.2.2.2 of LGL (2015a). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014) and 3.2.2.3 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on capelin.

In the latest DFO CSAS document for capelin, landings in 2013 and 2014 were determined to be 23,755 t and 23,173 t, respectively, with a Total Allowable Catch (TAC) in Divs. 2J3KL of 22,771 t. Fish harvesters reported increased abundance and distribution for capelin in all NAFO areas, including those that did not support a commercial fishery in 2014. Capelin were noted to be longer, heavier and have higher fat levels (DFO 2015b).

Wolffishes

Three species of wolffish (i.e., northern *Anarhichas denticulatus*, spotted *A. minor*, and Atlantic *A. lupus)* are listed on Schedule 1 of *SARA*. The northern and spotted wolffishes are considered *threatened* under Schedule 1 of *SARA* and under COSEWIC. The Atlantic wolffish has *special concern* status under Schedule 1 of *SARA* and under COSEWIC.

Profiles for northern and spotted wolffishes are included in § 4.6, Species at Risk. The profile for Atlantic wolffish is provided below.

<u>Atlantic Wolffish</u>

Life history aspects of Atlantic wolffish, including distribution information, are presented in § 4.2.2.1 of LGL (2015b) and § 4.2.2.2 of LGL (2015a). Subsections 4.2.1.6 of the Eastern Newfoundland SEA (C-NLOPB 2014) and 3.7.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provide life history information on Atlantic wolffish.

DFO RV data collected in the Study Area during May–November 2014 indicated that Atlantic wolffish were caught in the shelf and slope areas of the Northern and Southern Grand Banks, as well as on the shelf area off southern Labrador (see Figure 4.33 in § 4.3.7).

Swordfish

Life history aspects of swordfish (*Xiphias gladius*), including distribution information, are presented in § 4.2.2.1 of LGL (2015b). Subsection 3.2.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010) also provides life history information on swordfish.

Anadromous Fishes

The predominant anadromous fish species that occurs within the Study Area is Atlantic salmon (*Salmo salar*). Subsection 3.2.2.8 of the Southern Newfoundland SEA (C-NLOPB 2010) discusses the Atlantic salmon populations that occur in the southern portion of the Study Area.

4.2.2.3 Macroinvertebrate and Fish Reproduction in the Study Area

Temporal and spatial details of macroinvertebrate and fish reproduction within the Study Area are provided in Table 4.1.

Table 4.1   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 8–10 months and larvae hatch in the spring	12–16 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	12–15 weeks
Greenland Cockle	Eastern Grand Banks	Uncertain	Uncertain
Stimpson's Surf Clam	Eastern Grand Banks	Fall	4–8 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
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	6–8 weeks
American Plaice	Spawning generally occurs throughout the range the population inhabits.	April–May	12–16 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 metres	March–June	10–12 weeks
Atlantic Salmon	Spawn in freshwater	October–November	Several weeks in freshwater
Wolffishes	Along bottom in deeper water, typically along continental slope	Summer to early-winter (species-dependent)	Uncertain
Swordfish	NW Atlantic population believed to spawn in the Caribbean Sea, Gulf of Mexico, and off Florida	Year-round	Uncertain
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
Cusk	Uncertain	May–August	Presumed to be 4–16 weeks
Sand Lance	On sand in shallow water of the Grand Banks	November–January	Several weeks

4.2.3 Fish and Fish Habitat Data Gaps Identified in Relevant SEAs

The following data gap associated with the Fish and Fish Habitat VEC was identified in the Eastern Newfoundland SEA (§ 6.1.6 of C-NLOPB 2014).

- Limited data regarding fish and fish habitat in deep water beyond the continental slope, particularly for species that are not commercially important at this time.

The following data gaps associated with the Fish and Fish Habitat VEC were identified in the Southern Newfoundland SEA (§ 3.1.6 and 3.2.6 of C-NLOPB 2010).

- Data regarding the spatial and temporal distributions of macroinvertebrate eggs and larvae, and ichthyoplankton are deficient. Some spawning areas have been identified but little work has been done on the passive movements of the eggs and larvae of macroinvertebrates and fishes. More knowledge of drift routes would also provide more perspective on nursery areas;
- Data regarding benthos are quite dated and are primarily related to specific coastal areas and/or restricted time periods;
- Data regarding benthic community composition are limited, most resulting from species-specific studies;
- Data regarding the life histories of many macroinvertebrates and fishes are deficient;
- Data regarding the population size and structure of several macroinvertebrate and fish species are deficient; and
- Data regarding many pelagic fishes are deficient.

All of the data gaps indicated above still exist. The collection of temporal and spatial data with regards to species life history (e.g., spawning locations, abundance, distribution, areas of high productivity) for data-deficient and lesser known non-commercial species would be valuable when considering environmental effects assessments and fisheries resource management. Similarly, addressing these data gaps would aid in assessing cumulative effects from multiple industrial activities, especially in terms of mitigating possible marine ecosystem impacts. Gaps in our knowledge of marine ecosystems are significant and these deficiencies make it difficult to determine the extent to which humans have influenced and affected marine ecosystems, particularly with the current expansion and intensification of anthropogenic activities. The interaction between climate change and ecosystem/species specific impacts is a developing research area that will most likely help fill existing data gaps and provide new data on climate change. As stated in § 6.2 of the Eastern Newfoundland SEA (C-NLOPB 2014): "The C-NLOPB, in consultation with advisory agencies within governments and with relevant stakeholders, will promote the planning, prioritizing and undertaking of research (e.g., through research organizations such as the Environmental Studies Research Funds). In addition, Operators may be required to collect data as part of their program operations, either

opportunistically during program operations or prior to the start of program activities. The requirement and nature of the latter will be determined during project-specific assessment."

4.3   Fisheries VEC

The Fisheries VEC of the Study Area has been previously described in the Eastern Newfoundland SEA (§ 4.3.4 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 3.3 of C-NLOPB 2010), and three project-specific EAs (§ 4.3 of LGL 2015a,b, 2016). An overview of the fisheries of the Study Area, based on information within these documents and new information, is provided below. Relevant data gaps identified in the three SEAs are also discussed in terms of current status.

This subsection describes the commercial fishery in the Study Area during 2010–2015. The Study Area overlaps portions of NAFO Divisions 3KLMNOPs, 4VnVs and 6H (Figure 4.1).
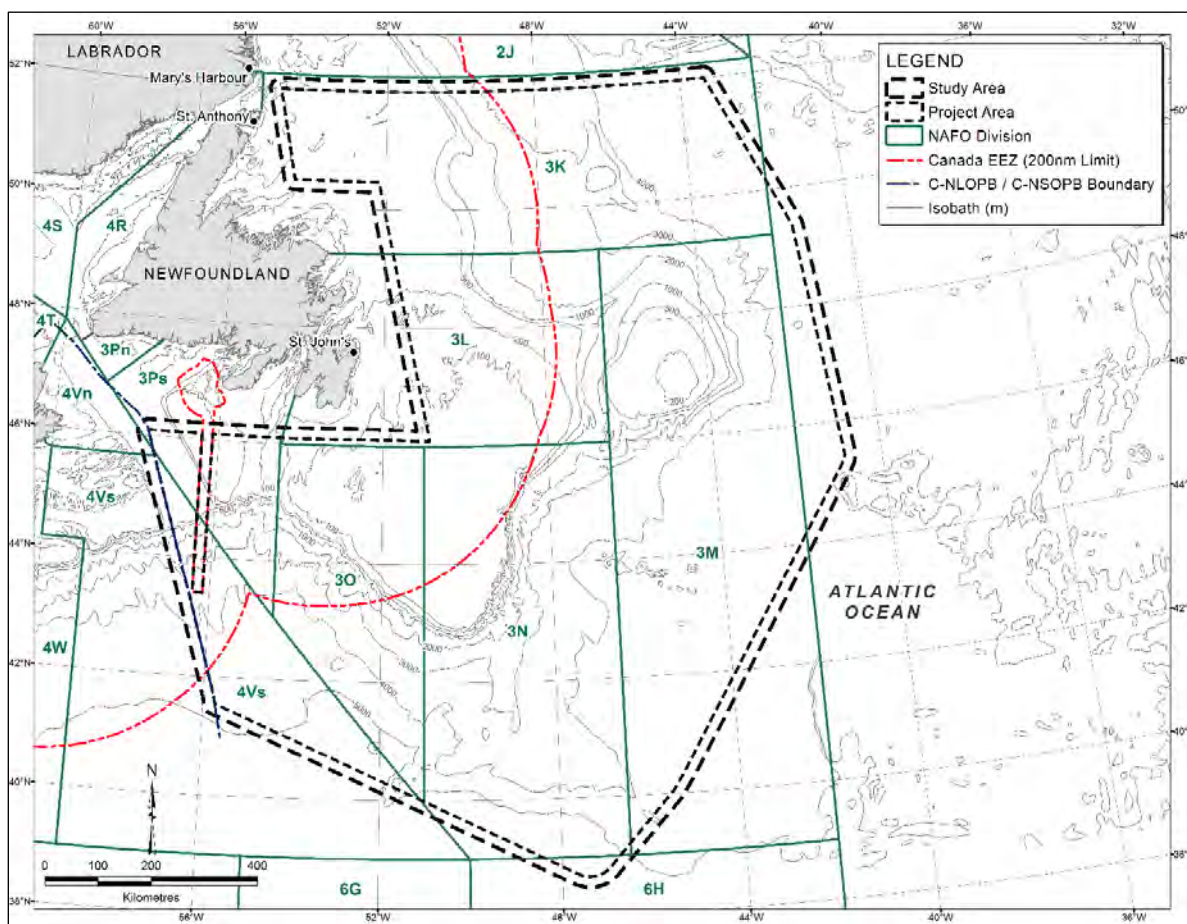
Figure 4.1   Study Area and Project Area in Relation to Regional Fisheries Management Areas (NAFO Divisions).

This subsection also briefly describes historical, recreational and traditional fisheries, aquaculture activity and fisheries research surveys in the Study Area. New information regarding the biology and status of the principal macro-invertebrates and fishes discussed in this section was included in § 4.2, Fish and Fish Habitat.

4.3.1   Information Sources

NAFO catch weight data are used to describe domestic and foreign fisheries conducted beyond the 200 nm EEZ. Much of the Study Area is located outside of the 200 nm limit (see Figure 4.1). The NAFO data were obtained from the STATLANT21A dataset for 2010–2015 (Table 4.2). The STATLANT reporting system of questionnaires data are described in § 4.3.1 of LGL (2015a). The data analyses in this EA quantify harvesting in NAFO Divisions 3KLMNOPs, 4VnVs and 6H (see Figure 4.1).

Table 4.2   Summary of Information Sources for Commercial Fisheries Data.

Data Source	Domestic/Foreign Fisheries	Temporal Period	Geographic Area	Spatial Resolution
DFO	Domestic	May–November, 2010–2015	Within Study Area; mostly within Canadian EEZ but generally within 2,000 m depth	Geo-referenced (2010); Gridded 6'x6' cells (2011+)
NAFO	Domestic/Foreign	2010–2015 (1989–2015 for historical overview, § 4.3.3.1	Within/beyond Study Area; beyond Canadian EEZ	NAFO Divisions

The primary fisheries data analyses use all DFO Atlantic Regions georeferenced landings data for the 2010 time period, as well as grid cell landings for 2011–2015 (see Table 4.2). The DFO datasets, analyses and georeferencing/grid methodology of pre- and post-2010 DFO data are described in § 4.3.1 of LGL (2015a). References to figures in the Eastern Newfoundland SEA (C-NLOPB 2014), the Southern Newfoundland SEA (C-NLOPB 2010), and three project-specific EAs (LGL 2015a,b, 2016) are provided for commercial harvest locations prior to 2015. Other sources used for this assessment include DFO species management plans, DFO stock status reports and other internal documents.

4.3.2   Regional NAFO Fisheries

The stocks and species managed by NAFO are described in § 4.3.2 of LGL (2015a). During the 2010–2015 period, commercial harvesting within the Study Area beyond the 200 nm EEZ, in terms of catch weight, was dominated by snow crab (21% of total catch weight; primarily in NAFO Division 3L), northern shrimp (18%; primarily in 3K), Atlantic redfish (9%; primarily in 3MO), Atlantic cod (8%; primarily in 3MPs), capelin (8%; primarily in 3KL), surf clam (8%; primarily in 4Vs), and Greenland halibut (5%; primarily in 3L). Proportional catch weights in

the Study Area during the six year period, in descending order of magnitude, were 26% in NAFO Division 3L, 25% in 3K, 13% in 4Vs, 10% in 3Ps, 9% in 3M, 8% in 3N, and ≤5% each in 3O, 4Vn and 6H.

Canadian vessels accounted for 40% of the commercial catch weight reported for this area during 2010–2015. While Canadian vessels accounted for the majority of catches in NAFO Divisions 3KLPs and 4VnVs, foreign vessels dominated catches in Divisions 3M and 6H. Catches in Division 3M were dominated by Atlantic cod, Atlantic redfish, great blue shark and Greenland halibut, and in 6H by great blue shark and swordfish. Canadian and foreign vessels captured ~44% and 56%, respectively, of the total catches in Division 3N, and ~33% and 67%, respectively, in Division 3O. The primary species captured included yellowtail flounder, skates and snow crab in 3N, and Atlantic redfish, snow crab and yellowtail flounder in 3O.

4.3.3 Domestic Fisheries

The following subsection provides an overview of the commercial fisheries within and/or adjacent to the Study Area. Traditional historical fishing activity during the last 20 years, including abundance data for historically principal species, are presented. Statistical summaries of the commercial catch data specific to the Study and Project Areas, based on the georeferenced (lat/long) data for 2010 and annual gridded cell (6' x 6') data for 2011–2015, are also provided in this subsection.

4.3.3.1 Historical Fisheries

A historical overview of fisheries was given in § 4.3.4.2 of the Eastern Newfoundland SEA (C-NLOPB 2014), and § 4.3.3.1 of LGL (2015a,b, 2016). In the late 1980s, fishes such as Atlantic cod, capelin, Atlantic redfish and American plaice were the primary species harvested in NAFO Divisions 3KLMNOPs, 4VnVs and 6H. These fisheries were considerably reduced in the early 1990s during the moratorium, after which crustaceans such as northern shrimp and snow crab became the predominant target species (Figure 4.2). Much lower quotas have been allocated in recent years, based on scientific advice and other relevant considerations (see § 4.3.3.1 of LGL [2015a] for a description of Integrated Fisheries Management Plans for priority groundfish species).

Northern shrimp stocks have recently declined (see § 4.3.3.1 of LGL 2015a), resulting in a shrimp fishing moratorium in Shrimp Fishing Area (SFA) 7 since 2015 (NAFO 2015b,d *in* LGL 2016; NAFO 2017a). As indicated in § 4.2.2.1, the overall exploitable biomass and recruitment of snow crab in the region have declined in recent years to historically low levels. Although some Divisions may experience a modest increase in recruitment within approximately five to seven years due to a small pulse of young crabs which emerged during 2013–2014, the warming oceanographic climate and relatively low abundance during the past decade indicate overall poor long-term recruitment (DFO 2016c). Given these recent declines in predominant

shellfish species, a regime shift is currently underway from a shellfish to groundfish-dominated fishery. Cod and redfish stocks on the Flemish Cap in Division 3M appear healthy, with relatively high recruitment levels since 2005. The Total Allowable Catch (TAC) remained unchanged for cod and redfish in 3M during 2016 and 2017, and redfish TAC in 3LN was increased for 2017 (NAFO 2017b,c). In a continued effort to improve stocks, fishing moratoria remain in place for 2017 for several fish species, including Atlantic cod in 3LNO, American plaice in 3LMNO, witch flounder in 3L, and capelin in 3NO (NAFO 2017b,c).

NAFO's bottom fishing footprint was described in § 4.3.3.1 of LGL (2015a). The footprint lies entirely within the Project Area (Figure 4.3).
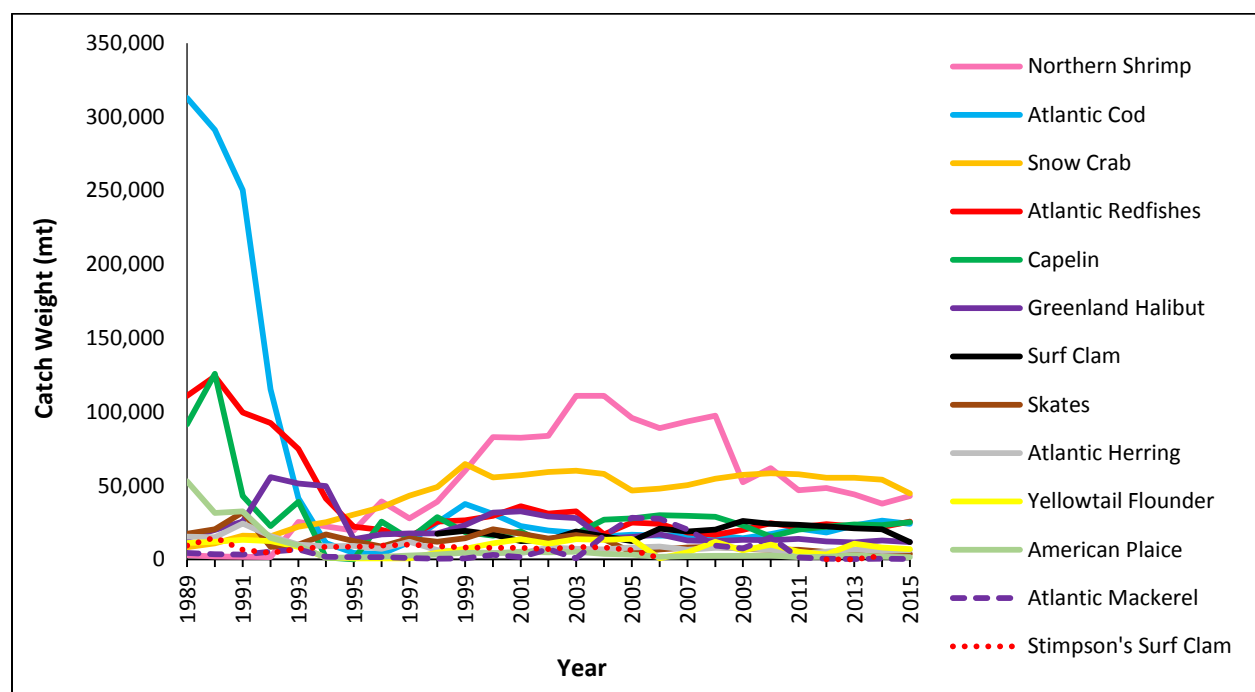
Source: NAFO STATLANT21A Data Extraction Tool.

Figure 4.2   Historical Catch Weights for Predominant Species in the Commercial Fisheries in NAFO Divisions 0B, 1EF, 2GHJ, 3KLMNOPs, 4VnVs and 6H, All Countries, 1989–2015.
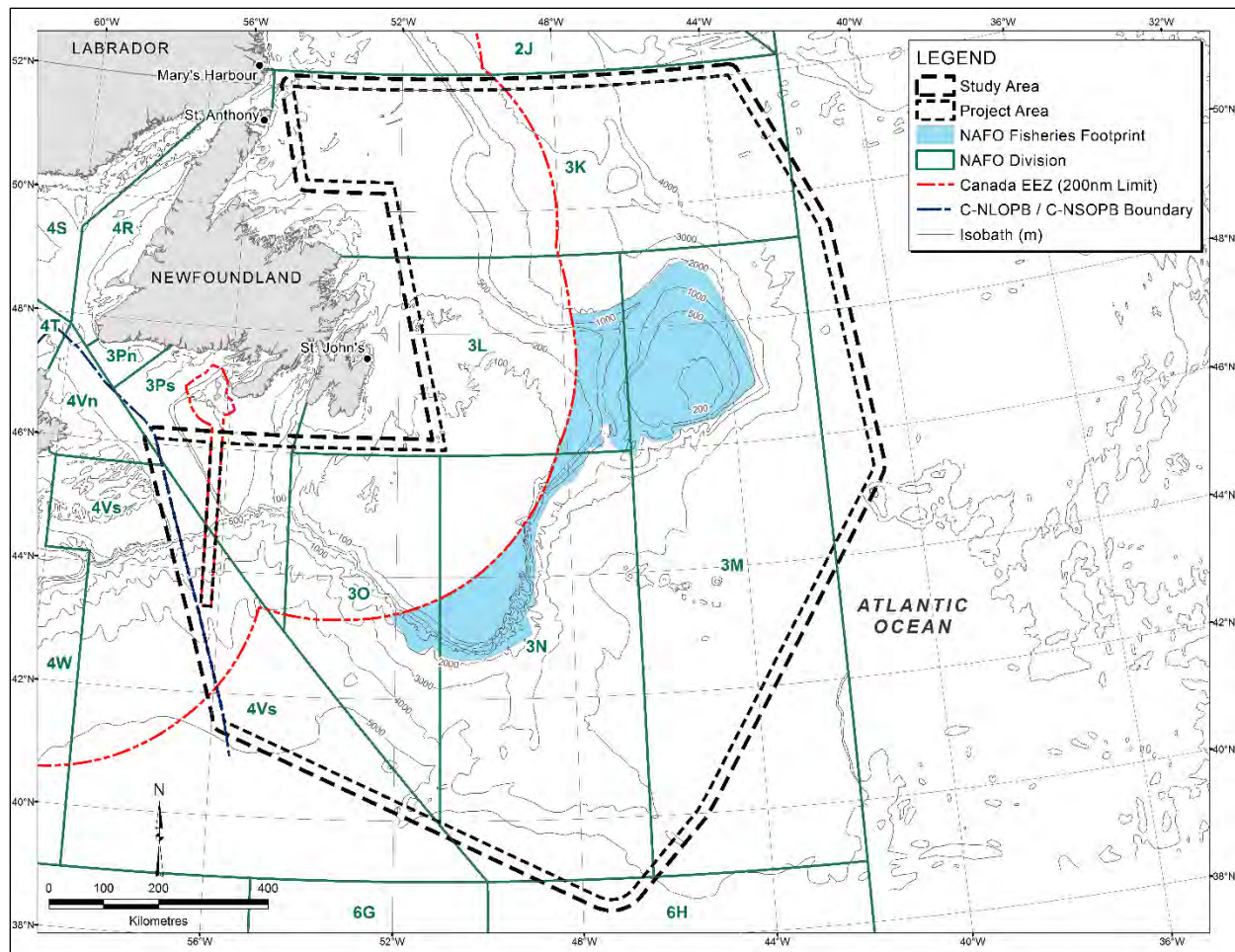
Source: NAFO 2017d.

Figure 4.3   Location of the NAFO Bottom Fisheries Footprint, 1987–2007.

4.3.3.2   Study Area Catch Analysis, 2010–2015

Information on domestic harvests in the Study and Project areas during May–November 2010 are shown in Table 4.3 and in the Study Area during May–November 2011–2015 in Tables 4.4–4.8. The principal fisheries in 2010, in descending order of catch weight magnitude, targeted northern shrimp, snow crab and Greenland halibut, accounting for ~83% of the total annual catch weight (95,865 mt; see Figure 4.4).   Other notable species harvested in the 2010–2015 commercial fisheries in the Study Area include yellowtail flounder, Atlantic cod, redfish, Atlantic halibut and American plaice.   During May–November, 2011–2015, the sum of quartile catch ranges in the Study Area decreased by about 16% between 2011 and 2012, was consistent into 2013, followed by a ~31% decrease in 2014, and then remained relatively steady in 2015 (see Figure 4.4).

Table 4.3   Study Area and Project Area Annual Catch Weight and Value by Species, May–November 2010 (also includes summary of catches in the Saint Pierre et Miquelon waters within the Study Area).

Species	Study Area				Project Area				Saint-Pierre-et-Miquelon			
	Quantity		Value		Quantity		Value		Quantity		Value	
	mt	% of Total	$	% of Total	mt	% of Total	$	% of Total	mt	% of Total	$	% of Total
Northern Shrimp	48,775	51	60,634,196	37	46,034	52	57,536,982	39	0	0	0	0
Snow Crab	27,970	29	83,329,432	51	24,859	28	74,038,105	50	0	0	0	0
Yellowtail Flounder	4,880	5	1,267,407	1	4,880	6	1,267,407	1	0	0	0	0
Whelk	3,898	4	3,434,568	2	3,820	4	3,366,315	2	6	11	4,859	14
Greenland Halibut	3,149	3	7,199,722	4	3,142	4	7,185,016	5	0	0	0	0
Redfish sp.	2,935	3	1,513,183	1	1,382	2	678,872	0.5	28	56	11,625	34
Atlantic Cod	1,340	1	1,354,219	1	1,312	1	1,321,916	1	16	32	15,677	46
American Plaice	828	1	309,698	0.2	826	1	308,036	0.2	0.1	0.2	99	0.3
White Hake	423	0.4	152,259	0.1	419	0.5	147,449	0.1	0.01	0.03	17	<0.1
Atlantic Halibut	313	0.3	2,226,815	1	289	0.3	2,053,629	1	0.4	0.7	1,908	6
Pollock	255	0.3	176,771	0.1	253	0.3	174,494	0.1	0	0	0	0
Monkfish	219	0.2	237,616	0.1	219	0.2	236,935	0.2	0.01	<0.1	9	<0.1
Hagfish	162	0.2	125,138	0.1	162	0.2	125,138	0.1	0	0	0	0
Cockle	146	0.2	173,359	0.1	146	0.2	173,359	0.1	0	0	0	0
Witch Flounder	128	0.1	42,917	<0.1	128	0.1	42,884	<0.1	0	0	0	0
Skate sp.	122	0.1	33,120	<0.1	110	0.1	30,807	<0.1	0.1	0.1	17	<0.1
Stimpson's Surf Clam	56	0.1	86,277	0.1	54	0.1	83,075	0.1	0	0	0	0
Atlantic Haddock	53	0.1	46,179	<0.1	52	0.1	43,626	<0.1	0	0	0	0
Atlantic Herring	40	<0.1	8,149	<0.1	40	<0.1	8,149	<0.1	0	0	0	0
Bluefin Tuna	37	<0.1	392,079	0.2	37	<0.1	392,079	0.3	0	0	0	0
Mackerel	32	<0.1	14,226	<0.1	32	<0.1	14,226	<0.1	0	0	0	0
Roughhead Grenadier	31	<0.1	20,723	<0.1	31	<0.1	20,723	<0.1	0	0	0	0
Capelin	28	<0.1	3,346	<0.1	28	<0.1	3,346	<0.1	0	0	0	0
Swordfish	25	<0.1	133,338	0.1	21	<0.1	114,733	0.1	0	0	0	0
Sea Scallop	8	<0.1	12,682	<0.1	8	<0.1	12,682	<0.1	0	0	0	0
Cusk	7	<0.1	4,720	<0.1	7	<0.1	4,151	<0.1	0.01	<0.1	6	<0.1
Porbeagle Shark	2	<0.1	2,219	<0.1	2	<0.1	1,660	<0.1	0	0	0	0
Roundnose Grenadier	1	<0.1	848	<0.1	1	<0.1	848	<0.1	0	0	0	0
Atlantic (striped) Wolffish	1	<0.1	322	<0.1	0.4	<0.1	207	<0.1	0	0	0	0
Mako Shark	0.3	<0.1	844	<0.1	0.3	<0.1	777	<0.1	0	0	0	0
Bigeye Tuna	0.1	<0.1	1,250	<0.1	0.1	<0.1	1,250	<0.1	0	0	0	0
Flounder sp.	0.04	<0.1	51	<0.1	0.04	<0.1	51	<0.1	0	0	0	0
Yellowfin Tuna	0.04	<0.1	307	<0.1	0.04	<0.1	307	<0.1	0	0	0	0
Shark sp.	0.03	<0.1	10	<0.1	0.02	<0.1	6	<0.1	0.01	<0.1	4	<0.1
Albacore Tuna	0.01	<0.1	18	<0.1	0.01	<0.1	18	<0.1	0	0	0	0
Totals	**95,865**	**100**	**162,938,008**	**100**	**88,295**	**100**	**149,389,258**	**100**	**50**	**100**	**34,220**	**100**

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

Table 4.4   Commercial Catch Weights and Values in the Study Area, May–November 2011 (values indicate the frequency of catch weight and value quartile codes [i.e., 1–4] attributed to each species).

Species	Catch Weight Quartile Code Counts [a]				Catch Value Quartile Code Counts [b]				Total Counts [c]
	1	2	3	4	1	2	3	4	
Snow Crab	557	1,047	1,402	256	389	889	1,309	675	3,262
Northern Shrimp	575	768	983	926	785	876	1,025	566	3,252
Greenland Halibut	126	227	185	62	96	242	196	66	600
Redfish sp.	76	148	172	78	147	142	133	52	474
Atlantic Halibut	134	165	115	54	144	231	83	10	468
Atlantic Cod	97	111	125	86	144	161	92	22	419
American Plaice	45	92	114	60	123	109	62	17	311
Witch Flounder	39	87	115	57	90	89	75	44	298
Whelk	14	35	74	70	34	46	85	28	193
Atlantic Haddock	32	52	55	47	67	68	45	6	186
Skate sp.	22	83	64	9	42	89	37	10	178
Yellowtail Flounder	23	59	63	32	80	67	24	6	177
White Hake	43	56	46	18	48	74	40	1	163
Monkfish	21	63	48	17	42	72	31	4	149
Roughhead Grenadier	17	46	56	17	14	44	55	23	136
Pollock	9	25	21	33	27	27	30	4	88
Bluefin Tuna	42	10	3	7	23	28	7	4	62
Swordfish	39	16	1	0	23	29	4	0	56
Cusk	28	17	4	3	7	37	8	0	52
Mako Shark	15	9	1	0	9	13	3	0	25
Hagfish	1	2	9	2	3	9	2	0	14
Cockle	1	5	1	3	3	4	0	3	10
Sea Cucumber	0	0	1	7	0	1	5	2	8
Roundnose Grenadier	5	3	0	0	0	8	0	0	8
Bigeye Tuna	5	2	0	0	4	3	0	0	7
Porbeagle Shark	4	2	0	0	2	3	1	0	6
Stimpson's Surf Clam	0	2	0	3	0	2	0	3	5
Winter Flounder	2	0	1	1	2	1	1	0	4
Albacore Tuna	2	0	1	0	1	1	1	0	3
Yellowfin Tuna	3	0	0	0	2	1	0	0	3
Sea Scallop	2	0	0	1	2	0	1	0	3
Atlantic (striped) Wolffish	3	0	0	0	2	1	0	0	3
Capelin	0	1	1	0	1	0	1	0	2
Mahi Mahi (dolphinfish)	2	0	0	0	2	0	0	0	2
Atlantic Rock Crab	2	0	0	0	2	0	0	0	2
Shark sp.	1	0	0	1	1	0	1	0	2
Mackerel	0	1	1	0	0	2	0	0	2
Groundfish sp.	1	0	0	0	1	0	0	0	1
White Marlin	1	0	0	0	1	0	0	0	1
Total	**1,989**	**3,134**	**3,662**	**1,850**	**2,363**	**3,369**	**3,357**	**1,546**	**10,635**

Source: DFO commercial landings database, All Atlantic Regions (2011).

[a] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch weights in a given year, all species combined). 2011 quartile ranges: 1 = 0 – 2,377 kg, 2 = 2,378 – 11,045 kg, 3 = 11,046 – 45,183 kg, 4 = ≥ 45,184 kg.

[b] Quartile ranges provided by DFO (Quartile ranges calculated annually by DFO based on total catch values in a given year, all species combined). 2011 quartile ranges: 1 = $0 – $7,281, 2 = $7,282 – $32,789, 3 = $32,790 – $126,294, 4 = ≥ $126,295.

[c] Total counts of the number of catch records per species; the total quartile range counts for catch weight and catch value are equal.

Table 4.5   Commercial Catch Weights and Values in the Study Area, May–November 2012 (values indicate the frequency of catch weight and value quartile codes [i.e., 1–4] attributed to each species).

Species	Catch Weight Quartile Code Counts [a]				Catch Value Quartile Code Counts [b]				Total Counts [c]
	1	2	3	4	1	2	3	4	
Snow Crab	536	1,049	1,049	241	418	866	1,103	488	2,875
Northern Shrimp	402	669	736	847	616	700	755	583	2,654
Greenland Halibut	125	204	159	26	132	202	162	18	514
Atlantic Halibut	173	159	110	42	180	196	96	12	484
Redfish sp.	83	130	142	44	135	118	130	16	399
Atlantic Cod	94	98	112	64	146	123	86	13	368
White Hake	50	85	65	22	71	92	53	6	222
American Plaice	44	51	64	20	93	50	30	6	179
Whelk	17	38	59	57	35	44	72	20	171
Monkfish	29	77	49	13	57	72	38	1	168
Skate sp.	26	73	51	5	41	65	47	2	155
Atlantic Haddock	27	35	51	28	47	53	37	4	141
Yellowtail Flounder	39	34	38	15	75	36	13	2	126
Witch Flounder	23	28	59	16	38	29	50	9	126
Pollock	9	40	44	20	39	37	33	4	113
Cusk	35	19	17	18	21	38	24	6	89
Roughhead Grenadier	17	25	32	9	18	33	29	3	83
Swordfish	23	37	5	2	10	39	18	0	67
Bluefin Tuna	44	7	11	3	34	16	15	0	65
Mako Shark	11	24	3	2	5	20	15	0	40
Porbeagle Shark	22	4	0	0	8	15	3	0	26
Hagfish	1	5	9	0	4	6	5	0	15
Roundnose Grenadier	11	3	0	0	6	6	2	0	14
Albacore Tuna	8	4	0	1	4	7	2	0	13
Bigeye Tuna	7	5	0	1	5	5	3	0	13
Winter Flounder	3	2	2	5	5	2	4	1	12
Mahi Mahi (dolphinfish)	4	5	0	0	3	3	3	0	9
Sea Cucumber	0	0	1	6	0	1	4	2	7
White Marlin	0	6	0	0	0	3	3	0	6
Capelin	0	0	5	1	5	0	1	0	6
Iceland Scallop	3	2	0	0	3	2	0	0	5
Yellowfin Tuna	3	0	0	0	2	1	0	0	3
Atlantic (striped) Wolffish	0	1	1	1	0	1	2	0	3
Flounder sp.	0	1	2	0	0	1	2	0	3
Sea Scallop	2	0	1	0	2	1	0	0	3
Shark sp.	0	1	0	1	0	1	1	0	2
Stimpson's Surf Clam	0	1	0	0	1	0	0	0	1
Atlantic Rock Crab	1	0	0	0	1	0	0	0	1
Total	**1,872**	**2,922**	**2,877**	**1,510**	**2,260**	**2,884**	**2,841**	**1,196**	**9,181**

Source: DFO commercial landings database, All Atlantic Regions (2012).

[a] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch weights in a given year, all species combined). 2012 quartile ranges: 1 = 0 – 2,618 kg, 2 = 2,619 – 12,233 kg, 3 = 12,234 – 47,739 kg, 4 = ≥ 47,740 kg.

[b] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch values in a given year, all species combined). 2012 quartile ranges: 1 = $0 – $8,240, 2 = $8,241 – $35,022, 3 = $35,023 – $130,732, 4 = ≥ $130,733.

[c] Total counts of the number of catch records per species; the total quartile range counts for catch weight and catch value are equal.

Table 4.6 **Commercial Catch Weights and Values in the Study Area, May–November 2013 (values indicate the frequency of catch weight and value quartile codes [i.e., 1–4] attributed to each species).**

Species	Catch Weight Quartile Code Counts [a]				Catch Value Quartile Code Counts [b]				Total Counts [c]
	1	2	3	4	1	2	3	4	
Snow Crab	401	956	1,033	270	344	755	987	574	2,660
Northern Shrimp	423	564	643	697	702	550	646	429	2,327
Atlantic Halibut	210	171	145	43	192	209	146	22	569
Greenland Halibut	126	203	166	30	139	197	159	30	525
Atlantic Cod	102	165	177	56	146	182	151	21	500
American Plaice	56	155	121	48	142	120	97	21	380
Redfish sp.	89	109	115	24	114	103	101	19	337
Witch Flounder	64	103	119	36	105	94	101	22	322
Yellowtail Flounder	48	127	99	42	119	104	78	15	316
Whelk	26	56	100	31	51	81	73	8	213
White Hake	69	61	26	1	83	64	9	1	157
Atlantic Haddock	34	60	44	16	65	56	29	4	154
Roughhead Grenadier	33	30	29	5	36	31	23	7	97
Skate sp.	25	34	28	6	44	25	20	4	93
Cusk	45	12	3	0	29	30	1	0	60
Pollock	18	27	14	1	38	21	1	0	60
Monkfish	14	23	17	5	30	22	7	0	59
Bluefin Tuna	2	1	12	0	1	5	9	0	15
Hagfish	0	7	7	0	3	10	1	0	14
Swordfish	7	4	0	0	3	6	2	0	11
Sea Cucumber	0	0	3	7	0	3	3	4	10
Stimpson's Surf Clam	0	2	7	1	0	6	3	1	10
Mako Shark	5	3	0	0	1	6	1	0	8
Sculpin sp.	6	1	0	0	6	1	0	0	7
Mahi Mahi (dolphinfish)	3	3	0	0	0	4	2	0	6
Roundnose Grenadier	2	3	0	0	2	0	2	1	5
Flounder sp.	1	0	2	2	1	2	2	0	5
Cockle	0	2	3	0	0	4	1	0	5
Dogfish sp.	2	3	0	0	2	0	2	1	5
Capelin	0	1	2	1	3	1	0	0	4
Porbeagle Shark	3	0	0	0	2	1	0	0	3
Propeller Clam	0	0	2	1	0	2	0	1	3
Sea Scallop	3	0	0	0	3	0	0	0	3
Atlantic Herring	1	0	0	0	1	0	0	0	1
Albacore Tuna	0	1	0	0	0	0	1	0	1
Toad Crab	0	0	1	0	0	1	0	0	1
Atlantic (striped) Wolffish	0	1	0	0	0	1	0	0	1
Total	**1,818**	**2,888**	**2,918**	**1,323**	**2,407**	**2,697**	**2,658**	**1,185**	**8,947**

Source: DFO commercial landings database, All Atlantic Regions (2013).

[a] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch weights in a given year, all species combined). 2013 quartile ranges: 1 = 0 – 2,565 kg, 2 = 2,566 – 11,872 kg, 3 = 11,873 – 48,585 kg, 4 = ≥ 48,586 kg.

[b] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch values in a given year, all species combined). 2013 quartile ranges: 1 = $0 – $8,934, 2 = $8,395 – $35,699, 3 = $35,700 – $125,728, 4 = ≥ $125,729.

[c] Total counts of the number of catch records per species; the total quartile range counts for catch weight and catch value are equal.

Table 4.7   Commercial Catch Weights and Values in the Study Area, May–November 2014 (values indicate the frequency of catch weight and value quartile codes [i.e., 1–4] attributed to each species).

Species	Catch Weight Quartile Code Counts [a]				Catch Value Quartile Code Counts [b]				Total Counts [c]
	1	2	3	4	1	2	3	4	
Snow Crab	389	737	799	237	283	663	790	426	2,162
Northern Shrimp	246	283	271	272	332	272	267	201	1,072
Atlantic Halibut	188	149	115	48	169	192	106	33	500
Atlantic Cod	101	147	129	58	142	175	103	15	435
Greenland Halibut	73	119	121	39	80	128	105	39	352
American Plaice	46	75	80	31	89	85	53	5	232
Yellowtail Flounder	41	71	68	32	81	75	52	4	212
White Hake	82	61	44	9	95	82	18	1	196
Redfish sp.	56	62	46	28	77	63	33	19	192
Atlantic Haddock	26	44	50	20	48	54	34	4	140
Whelk	32	34	55	12	50	49	31	3	133
Skate sp.	45	27	22	8	57	30	11	4	102
Swordfish	38	25	8	0	21	29	19	2	71
Witch Flounder	15	18	19	17	21	19	15	14	69
Pollock	8	27	29	4	35	28	5	0	68
Atlantic (striped) Wolffish	2	17	24	12	10	25	18	2	55
Mako Shark	20	20	7	0	12	19	14	2	47
Cusk	30	14	3	0	22	22	3	0	47
Monkfish	9	15	10	8	20	13	9	0	42
Bluefin Tuna	13	7	7	6	10	12	8	3	33
Roughhead Grenadier	2	13	10	8	2	16	11	4	33
Argentine	4	14	8	4	6	19	4	1	30
Porbeagle Shark	19	2	0	0	8	13	0	0	21
Sea Scallop	2	3	9	4	3	5	6	4	18
Mahi Mahi (dolphinfish)	7	6	2	0	4	5	5	1	15
Sea Cucumber	0	0	3	8	0	3	8	0	11
White Marlin	5	4	1	0	3	2	4	1	10
Albacore Tuna	3	3	2	0	1	2	4	1	8
Bigeye Tuna	2	3	1	0	1	2	3	0	6
Groundfish sp.	0	4	0	0	0	1	3	0	4
Iceland Scallop	3	0	0	0	3	0	0	0	3
Stimpson's Surf Clam	0	1	1	0	0	1	1	0	2
Propeller Clam	0	1	1	0	0	1	1	0	2
Capelin	0	0	2	0	2	0	0	0	2
Blue Marlin	2	0	0	0	1	1	0	0	2
Cockle	0	1	1	0	0	1	1	0	2
Mackerel	0	0	1	0	0	1	0	0	1
Striped Shrimp	0	1	0	0	1	0	0	0	1
Quahaug Clam	0	0	1	0	0	0	1	0	1
Total	**1,509**	**2,008**	**1,950**	**865**	**1,689**	**2,108**	**1,746**	**789**	**6,332**

Source: DFO commercial landings database, All Atlantic Regions (2014).

[a] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch weights in a given year, all species combined). 2014 quartile ranges: 1 = 0 – 2,421 kg, 2 = 2,422 – 10,786 kg, 3 = 10,787 – 42,872 kg, 4 = ≥ 42,873 kg.

[b] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch values in a given year, all species combined). 2014 quartile ranges: 1 = $0 – $8,851, 2 = $8,852 – $38,076, 3 = $38,077 – $140,695, 4 = ≥ $140,696.

[c] Total counts of the number of catch records per species; the total quartile range counts for catch weight and catch value are equal.

Table 4.8   Commercial   Catch   Weights   and   Values   in   the   Study   Area, May–November 2015 (values indicate the frequency of catch weight and value quartile codes [i.e., 1–4] attributed to each species).

Species	Catch Weight Quartile Code Counts [a]				Catch Value Quartile Code Counts [b]				Total Counts [c]
	1	2	3	4	1	2	3	4	
Snow Crab	486	683	722	267	396	624	664	474	2,158
Northern Shrimp	200	291	261	342	215	271	230	378	1,094
Atlantic Halibut	165	173	120	59	178	180	126	33	517
Greenland Halibut	81	154	145	37	95	150	137	35	417
Atlantic Cod	79	129	127	56	108	159	102	22	391
Redfish sp.	68	89	87	39	112	79	61	31	283
American Plaice	38	85	97	46	99	94	53	20	266
Yellowtail Flounder	40	82	76	34	99	81	43	9	232
White Hake	88	77	51	4	117	81	21	1	220
Witch Flounder	22	54	67	26	47	55	43	24	169
Whelk	20	35	45	22	39	36	34	13	122
Atlantic Haddock	30	35	37	14	48	40	23	5	116
Cusk	50	37	16	2	50	46	9	0	105
Monkfish	25	36	24	9	56	24	11	3	94
Pollock	10	20	27	3	27	26	7	0	60
Swordfish	21	15	10	1	16	10	14	7	47
Mako Shark	10	11	10	1	7	8	11	6	32
Skate sp.	7	13	8	1	14	11	3	1	29
Bluefin Tuna	4	5	12	6	5	6	9	7	27
Porbeagle Shark	6	9	1	2	2	11	4	1	18
Atlantic (striped) Wolffish	3	12	1	1	2	12	2	1	17
Sea Cucumber	1	1	4	9	2	3	5	5	15
Albacore Tuna	8	3	3	1	7	2	4	2	15
Bigeye Tuna	2	3	6	1	1	1	5	5	12
Arctic Skate	2	5	0	0	2	5	0	0	7
Roughhead Grenadier	0	1	4	1	0	1	4	1	6
Capelin	0	3	1	0	4	0	0	0	4
Silver Hake	1	1	2	0	2	1	0	1	4
Sea Scallop	2	0	0	1	2	0	1	0	3
Yellowfin Tuna	0	2	1	0	0	1	1	1	3
Shark sp.	0	1	2	0	0	1	2	0	3
Stimpson's Surf Clam	0	1	1	0	0	2	0	0	2
Mahi Mahi (dolphinfish)	1	0	1	0	1	0	0	1	2
Iceland Scallop	0	1	0	0	0	1	0	0	1
Propeller Clam	0	0	1	0	0	1	0	0	1
Hagfish	0	0	1	0	0	1	0	0	1
Total	**1,470**	**2,067**	**1,971**	**985**	**1,753**	**2,024**	**1,629**	**1,087**	**6,493**

Source: DFO commercial landings database, All Atlantic Regions (2015).

[a] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch weights in a given year, all species combined). 2015 quartile ranges: 1 = 0 – 2,253 kg, 2 = 2,254 – 9,535 kg, 3 = 9,536 – 40,703 kg, 4 = ≥ 40,704 kg.

[b] Quartile ranges provided by DFO (quartile ranges calculated annually by DFO based on total catch values in a given year, all species combined). 2015 quartile ranges: 1 = $0 – $9,539, 2 = $9,540 – $37,526, 3 = $37,527 – $134,094, 4 = ≥ $134,095.

[c] Total counts of the number of catch records per species; the total quartile range counts for catch weight and catch value are equal.
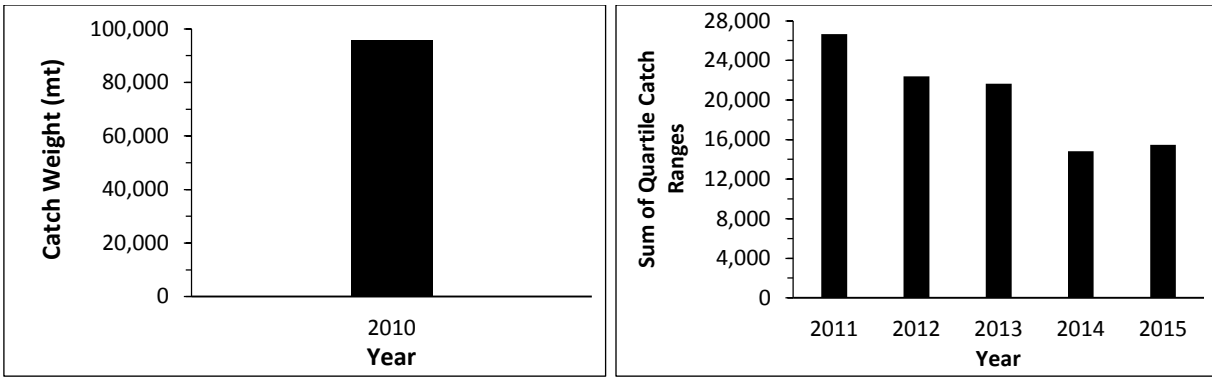
Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.4   Total Catch Weight, May–November 2010 (left), and Annual Total Catch Weight Quartile Codes, May–November 2011–2015 (right) (all species within the Study Area).

During May–November 2010, <0.1% of the Study Area catch weight was harvested within St. Pierre et Miquelon waters. The principal fisheries in St. Pierre et Miquelon waters during this time period, in descending order of catch weight magnitude, targeted redfish, Atlantic cod, whelk and Atlantic halibut, accounting for >99% of the total annual catch weight (50 mt; see Table 4.3). Other notable species harvested in St. Pierre et Miquelon waters during 2010 included American plaice.

Commercial Harvest Locations in the Study Area

Georeferenced harvest locations for all species, May–November 2005–2010 for offshore Labrador and eastern/southern Newfoundland are shown in Figure 4.5 of LGL (2015a,b). Grid cell harvest locations (6' x 6' cells) during May–November 2011–2013 for eastern/southern offshore Newfoundland are shown in Figures 4.6–4.8 of LGL (2015a,b). Year-round harvest locations are indicated in Figures 4.123–4.124 of the Eastern Newfoundland SEA (C-NLOPB 2014) and Figure 3.18 of the Southern Newfoundland SEA (C-NLOPB 2010). Figure 4.5 shows grid cell harvest locations for all species within the Study Area, May–November 2015. Minimal fish harvesting occurred in the eastern portion of the Study Area. Most harvesting occurred on the shelf and slope of the Grand Banks out to the 1,000 m isobath. These locations are quite consistent from year to year.
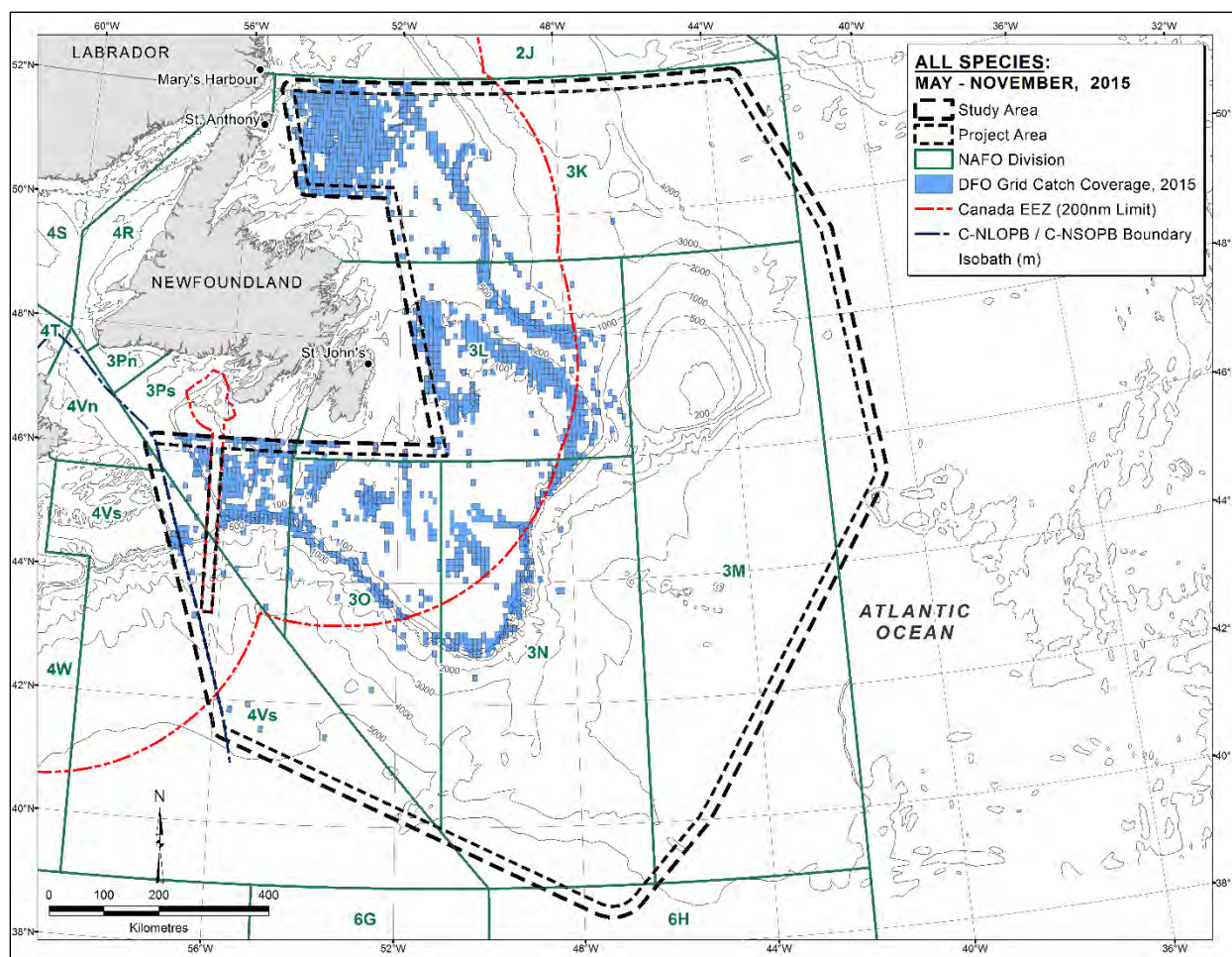
Source: DFO commercial landings database, 2015.

Figure 4.5   Distribution   of   Commercial   Harvest   Locations,   All   Species, May–November 2015.

Fishing Gear Used in the Study Area

A variety of fishing gear types were used in the Study Area during May–November 2010–2015. Snow crab were fished using pots, and several other species, including Greenland halibut, redfish, American plaice, Atlantic cod and Atlantic halibut were caught incidentally in the pots (Tables 4.9 and 4.10). Longlines were used to harvest Atlantic halibut and, to a lesser extent, Atlantic cod, with several additional species as incidental bycatch such as Greenland halibut, redfish, American plaice and yellowtail flounder. Many of the fish species in Table 4.10 were caught using gillnets and trawls, either as targeted or incidental catch. Several species were caught using trap or seine nets, including capelin, hagfish, Atlantic herring and mackerel. Atlantic cod were also harvested using hand-line (baited) and rod and reel, although there is no direct commercial fishery for this species using rod and reel. Bivalve species were harvested using dredges. Shrimp trawls (mobile gear) accounted for about 51% of the total catch weight of all species in the Study Area during 2010. Pots (fixed gear) accounted for ~29% of the total

catch weight during this period. Overall, mobile and fixed gears accounted for 61% and 39%, respectively (Table 4.9).

Table 4.9   Total Study Area Catch Weight by Gear Type, May–November 2010.

Species	Fixed Gear		Mobile Gear	
	mt	% of Total	mt	% of Total
Northern Shrimp	-	-	48,775	83
Snow Crab	27,970	75	-	-
Yellowtail Flounder	0.2	<0.1	4,880	8
Whelk	3,898	11	-	-
Greenland Halibut	2,262	6	887	2
Redfish sp.	198	1	2,736	5
Atlantic Cod	1,133	3	207	0.4
American Plaice	23	0.1	804	1
White Hake	420	1	2	<0.1
Atlantic Halibut	293	1	20	<0.1
Pollock	248	1	7	<0.1
Monkfish	219	1	0.4	<0.1
Hagfish	162	0.4	-	-
Cockle	-	-	146	0.2
Witch Flounder	3	<0.1	125	0.2
Skate sp.	120	0.3	2	<0.1
Stimpson's Surf Clam	-	-	56	0.1
Atlantic Haddock	31	0.1	22	<0.1
Atlantic Herring	5	<0.1	35	0.1
Bluefin Tuna	1	<0.1	36	0.1
Mackerel	-	-	32	0.1
Roughhead Grenadier	31	0.1	-	-
Capelin	-	-	28	<0.1
Swordfish	25	0.1	-	-
Sea Scallop	-	-	8	<0.1
Cusk	7	<0.1	0.1	<0.1
Porbeagle Shark	2	<0.1	-	-
Roundnose Grenadier	1	<0.1	-	-
Atlantic (striped) Wolffish	1	<0.1	0.01	<0.1
Mako Shark	0.3	<0.1	-	-
Bigeye Tuna	0.1	<0.1	-	-
Flounder sp.	-	-	0.04	<0.1
Yellowfin Tuna	0.04	<0.1	-	-
Shark sp.	0.03	<0.1	-	-
Albacore Tuna	0.01	<0.1	-	-
Subtotal	**37,056**	**100**	**58,808**	**100**
Grand Total (mt)	**95,865**			

Source: DFO commercial landings database, 2010.

Table 4.10 Summary of Gear Type Used and Timing of the Commercial Fishery in the Study Area, May–November 2010–2015.

Species	Month Caught						Gear Type	
	2010	2011	2012	2013	2014	2015	Fixed	Mobile
Northern Shrimp	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	-	Trawl
Snow Crab	May–Aug; Nov	May–Aug	May–Aug	May–Aug	May–Aug	May–Aug	Pot	-
Greenland Halibut	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	Gillnet; Longline; Pot	Trawl
American Plaice	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Jun; Aug–Nov	Gillnet; Longline; Pot	Trawl
Redfish sp.	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	Gillnet; Longline; Pot	Trawl
Yellowtail Flounder	May–Jun; Aug–Nov	May–Jul; Sep–Nov	May–Jun; Oct–Nov	May–Jul; Sep–Nov	May–Aug; Oct–Nov	May–Jun; Aug–Nov	Gillnet; Longline	Trawl
Atlantic Cod	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	Gillnet; Longline; Pot	Trawl; Hand Line (baited); Rod and Reel
Skate sp.	May–Nov	May–Nov	May–Nov	May–Aug; Oct–Nov	May–Sep; Nov	May–Nov	Gillnet; Longline	Trawl
Atlantic Halibut	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	Gillnet; Longline; Pot	Trawl
Whelk	May–Aug	May–Aug	May–Aug	May–Oct	May–Oct	May–Oct	Pot	-
Roughhead Grenadier	Jun–Oct	Jun–Aug; Nov	May–Oct	May–Nov	Jun–Aug	Jun–Jul; Sep	Gillnet; Longline	Trawl
Witch Flounder	May–Nov	May–Sep; Nov	May–Nov	May–Nov	May–Nov	May–Jun; Aug–Nov	Gillnet	Trawl
White Hake	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	May–Nov	Gillnet; Longline	Trawl
Atlantic Haddock	May–Nov	May–Nov	Jun–Nov	May–Nov	May–Nov	May–Nov	Gillnet; Longline; Pot	Trawl
Pollock	May–Nov	Jun–Nov	May–Nov	May–Aug; Oct–Nov	May–Nov	Jun–Nov	Gillnet; Longline	Trawl
Monkfish	May–Nov	Jun–Nov	May–Nov	May–Aug; Oct–Nov	May–Nov	May–Nov	Gillnet; Longline	Trawl
Capelin	May–Nov	Jul	Jul	Jul	Jul	Jul	Trap Net	Trawl; Seine
Cusk	May–Nov	May–Nov	May–Nov	May–Nov	May–Aug; Nov	May–Nov	Gillnet; Longline	Trawl
Bluefin Tuna	Sep–Nov	Jul–Nov	Jul–Nov	Jul; Sep	Aug–Nov	Aug–Nov	Longline	Troller Lines; Rod and Reel; Electric Harpoon
Atlantic (striped) Wolffish	Jun–Aug	Jun–Jul	Jun–Jul	Jul	May–Jul	Jun–Aug	Gillnet; Longline	Trawl
Hagfish	Sep–Nov	Sep–Oct	Sep–Nov	Jun; Aug–Oct	-	May	Hagfish Barrel; Trap Net	-
Shark sp.	Jul–Oct	Oct	Nov	-	-	Aug–Sep	Gillnet	Trawl

Species	Month Caught						Gear Type	
	2010	2011	2012	2013	2014	2015	Fixed	Mobile
Swordfish	Aug–Nov	Jul–Nov	Jul–Nov	Jul–Aug; Oct	Aug–Oct	Aug–Oct	Longline	Trawl
Stimpson's Surf Clam	May; Jul; Oct	Oct	Jun	Jun–Nov	May; Aug	May; Oct	-	Dredge
Mako Shark	Jun–Oct	Jul–Oct	Jul–Nov	Jul–Aug	Jun; Aug–Oct	Aug–Oct	Gillnet; Longline	-
Cockle	Jul	Oct	-	Jun; Aug–Nov	May; Aug	-	-	Dredge
Porbeagle Shark	May–Jun; Aug; Oct–Nov	Jun–Aug; Nov	May–Jun; Nov	Jun	May–Jul; Sep–Oct	May–Jul; Sep	Gillnet; Longline	-
Atlantic Herring	Jun–Jul; Sep; Nov	-	-	May	-	-	Gillnet	Trawl; Seine
Roundnose Grenadier	Jun–Jul	Jul–Aug	Jun	Nov	-	-	Longline	-
Sea Scallop	Jun; Oct–Nov	May; Sep	Jul–Aug; Nov	May; Jul	Jul–Sep	Jul–Aug	-	Dredge
Flounder sp.	Nov	-	Sep	Aug; Nov	-	-	Gillnet	Trawl
Mackerel	Sep–Oct	Sep–Oct	-	-	Oct	-	-	Seine
Bigeye Tuna	Sep–Oct	Jul–Sep	Jul–Sep; Nov	-	Sep–Oct	Aug–Oct	Longline	-
Yellowfin Tuna	Oct	Jul–Aug; Oct	Aug–Sep	-	-	Sep	Longline	-
Albacore Tuna	Aug	Jul–Sep	Jul–Sep; Nov	Jul	Aug–Oct	Aug–Oct	Longline	-
Sea Cucumber	-	Aug–Nov	Jul–Oct	Aug–Oct	Sep–Nov	Jun–Oct	-	Dredge; Drag Rake
Winter Flounder	-	Sep	Jul; Sep	-	-	-	Gillnet	Trawl
Mahi Mahi (dolphinfish)	-	Jul–Aug	Jul–Aug; Oct	Jul–Aug	Aug–Sep	Aug; Oct	Longline	-
Atlantic Rock Crab	-	Sep–Oct	Aug	-	-	-	Pot	-
Groundfish sp.	-	Jul	-	-	Nov	-	Longline	-
White Marlin	-	Jul	Aug	-	Aug–Sep	-	Longline	-
Iceland Scallop	-	-	Aug	-	Jul–Aug; Oct	Sep	-	Dredge
Dogfish sp.	-	-	-	Nov	-	-	Longline	
Toad Crab	-	-	-	Aug	-	-	Pot	
Sculpin sp.	-	-	-	Oct	-	-	-	Trawl
Propeller Clam	-	-	-	Jun–Jul	May; Aug	May	-	Dredge
Blue Marlin	-	-	-	-	Sep	-	Longline	
Argentine	-	-	-	-	Aug	-	-	Trawl
Quahaug Clam	-	-	-	-	May	-	-	Dredge
Striped Shrimp	-	-	-	-	May	-	-	Trawl
Arctic Skate	-	-	-	-	-	Jul	Longline	
Silver Hake	-	-	-	-	-	Oct	-	Trawl

Source: DFO commercial landings database, 2010–2015.

Fishing gears and harvest locations by gear type typically used in the Study Area are provided in Table 4.119 and Figure 4.137 of the Eastern Newfoundland SEA (C-NLOPB 2014) and Table 3.5 and Figures 2.19–3.20 in the Southern Newfoundland SEA (C-NLOPB 2010). As described in § 4.3.3.2 of LGL (2016), the fixed gears have greater potential to interact with Project activities than the mobile gears.

Mobile and fixed gear harvest locations offshore eastern Newfoundland during May–November 2008–2012 are shown in Figures 4.9–4.12 of LGL (2015a) and Figures 4.138–4.139 of C-NLOPB (2014). Figures 4.9–4.12 of LGL (2015b) show similar information for the southeastern/southern Newfoundland offshore during May–November 2005–2013. Fixed and mobile gear harvest locations in the Study Area during May–November 2013–2014 are shown in Figures 4.6–4.7 of LGL (2016). Figure 4.6 shows fixed and mobile gear catch locations in the Study Area during May–November 2015.
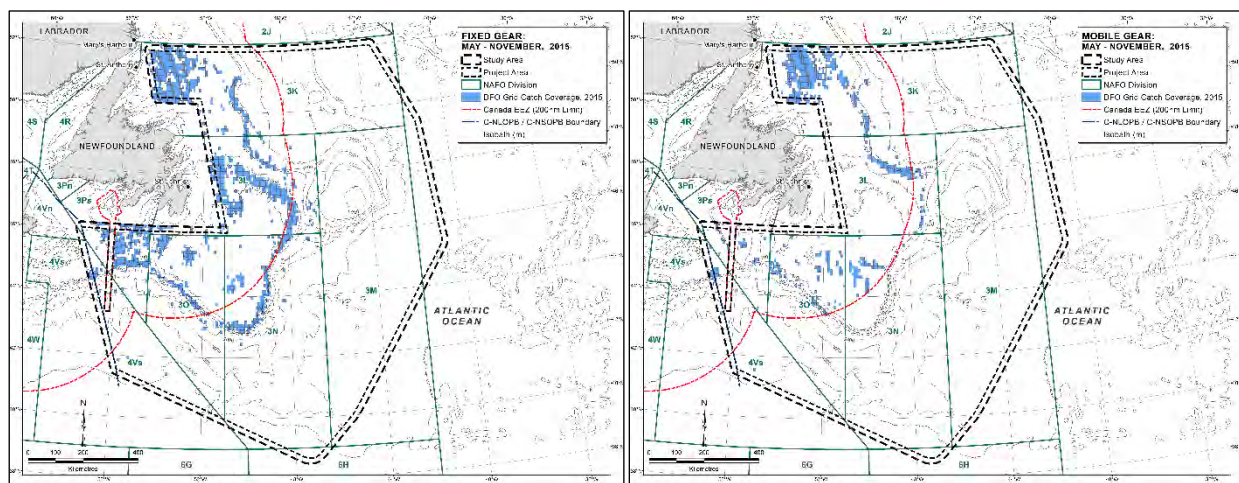
Source: DFO commercial landings database, 2015.

Figure 4.6   Distribution of Fixed (left) and Mobile (right) Gear Commercial Harvest Locations, All Species, May–November 2015.

Harvest Timing in the Study Area

Total monthly catch weights of all species within the Study Area during May–November 2010 and total sum of monthly catch weight quartile codes for May–November 2011–2015 are indicated in Figure 4.7. Monthly catch weights were highest during the May–August period and lowest during the fall. Note that the timing of harvesting can vary from year to year depending on resource availability, fisheries management plans and enterprise harvesting strategies.
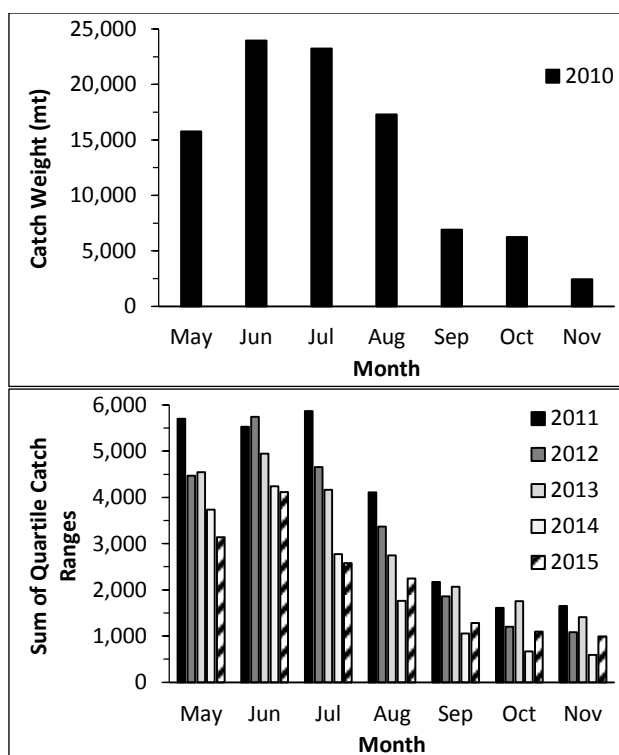
Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given month.

Figure 4.7   Total Monthly Catch Weight during May–November 2010 (left) and Total Monthly Sum of Catch Weight Quartile Codes, May–November 2011–2015 (right) (all species within the Study Area).

Principal Species in the Study Area

Northern Shrimp

Based on both quantity and value, northern shrimp was the most important commercial species in the Study Area during May–November 2010, and the second most important during May–November 2011–2015. The total annual catch weight (2010) and total annual catch weight quartile codes (2011–2015) for northern shrimp in the Study Area during May–November are shown in Figure 4.8. Shrimp harvest locations in the Study Area during 2005–2014 are provided in recent EAs (LGL 2015a,b, 2016). Harvest locations during May–November 2015 are shown in Figure 4.9. The majority of northern shrimp were harvested in the northwestern portion of the Study and Project Areas, between the 200 and 500-m isobaths. An indication of total monthly northern shrimp harvests in the Study Area during the May–November 2010–2015 period is shown in Figure 4.10. Most of the northern shrimp was harvested between June and August.

Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.8   Total Annual Catch Weight, May–November 2010 (left) and Total Annual Catch Weight Quartile Codes, May–November 2011–2015 (right) for Northern Shrimp in the Study Area.
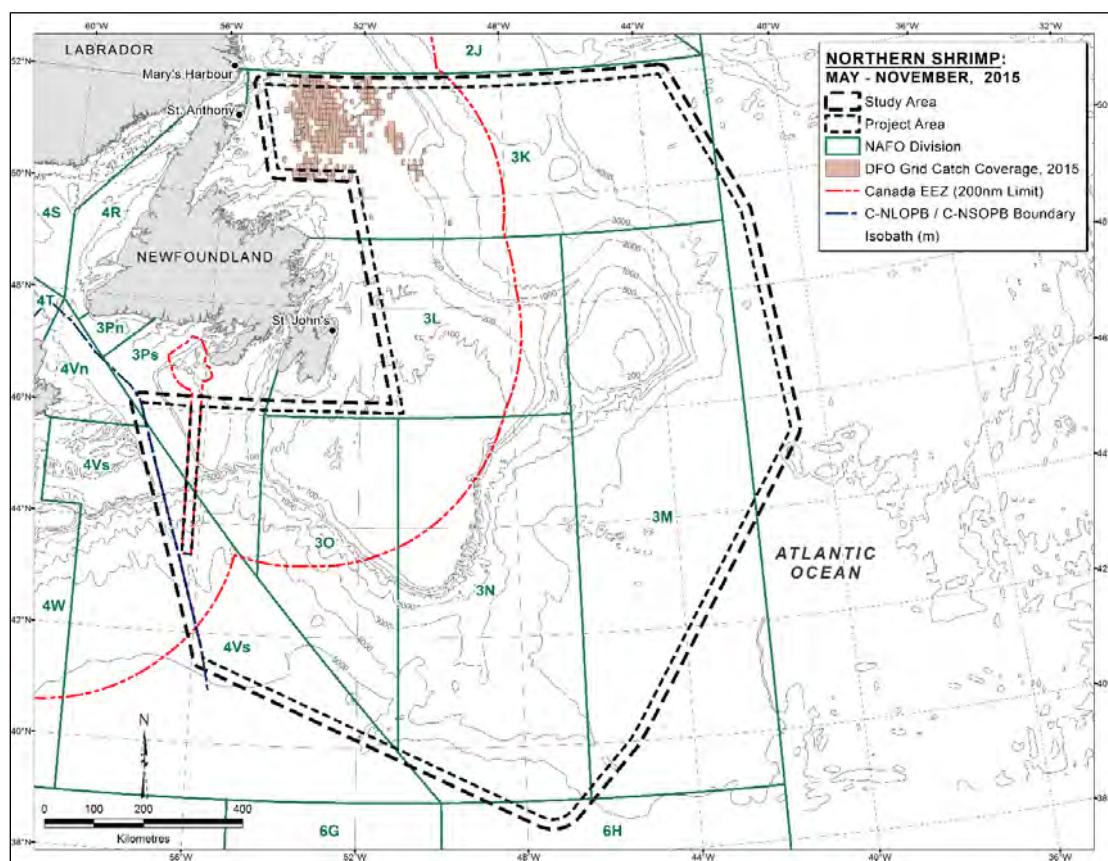
Source: DFO commercial landings database, 2015.

Figure 4.9   Distribution of Commercial Harvest Locations for Northern Shrimp, May–November 2015.

Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given month.

Figure 4.10   Total Monthly Catch Weights, May–November 2010 (left) and Total Monthly Catch Weight Quartile Codes, May–November 2011–2015 (right) for Northern Shrimp in the Study Area.

Snow Crab

In terms of catch weight, snow crab was the second most important commercial species in the Study Area during 2010, and the most important during 2011–2015. Total annual catch weight (2010) and the total sum of catch weight quartile codes (2011–2015) for snow crab in the Study Area between May and November are indicated in Figure 4.11. Snow crab harvest locations in the Study Area during 2005–2014 are provided in recent EAs (LGL 2015a,b, 2016). Figure 4.12 indicates snow crab harvesting locations in the Study Area during May–November 2015. The majority of snow crab were caught in the western portion of the Study and Project Areas, in water depths <200 m. The total monthly snow crab harvests in the Study Area during May–November 2010–2015 are shown in Figure 4.13. Snow crab were captured between May and August in the Study Area, with the majority of catch taken during May and June.

Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.11   Total Annual Catch Weight, May–November 2010 (left) and Total Annual Catch Weight Quartile Codes, May–November 2011–2015 (right) for Snow Crab in the Study Area.
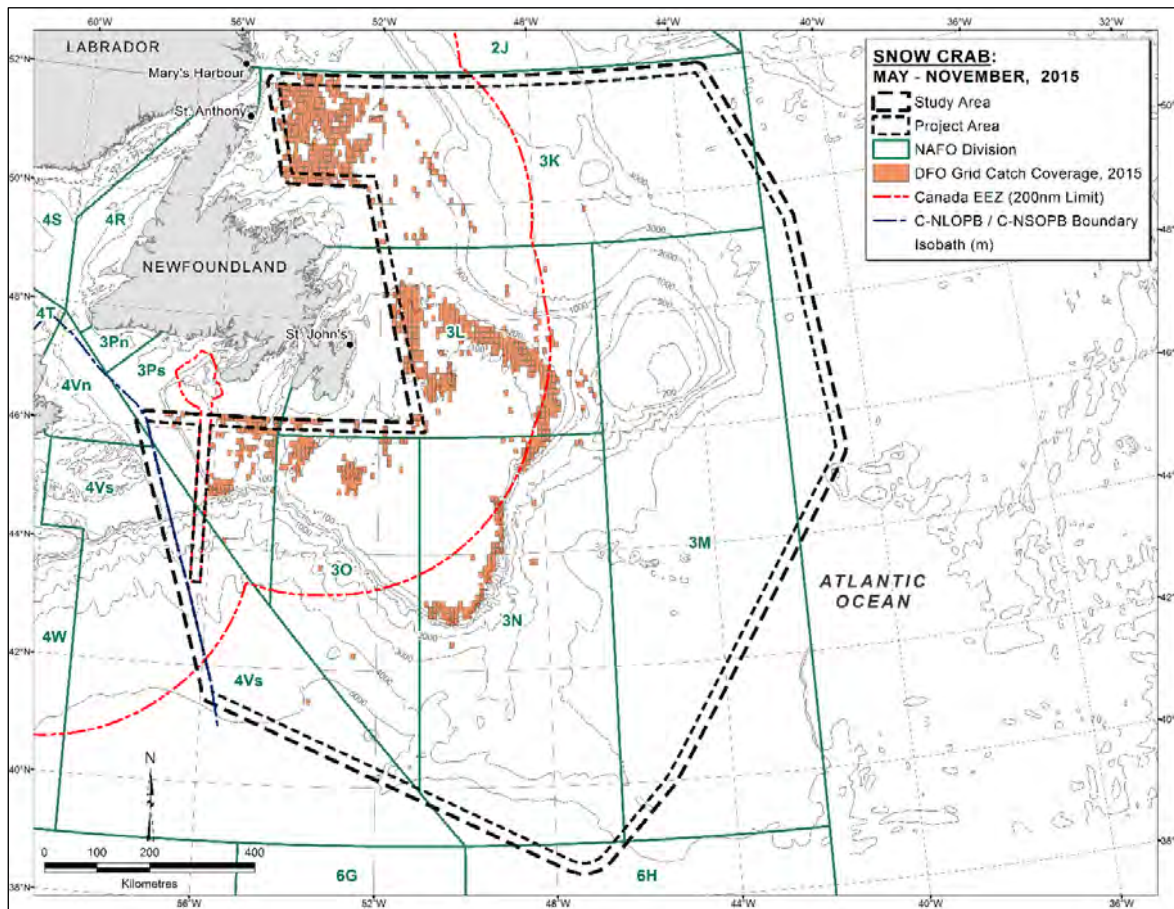
Source: DFO commercial landings database, 2015.

Figure 4.12   Distribution of Commercial Harvest Locations for Snow Crab, May–November 2015.

Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given month.

Figure 4.13   Total Monthly Catch Weights, May–November 2010 (left) and Total Monthly Catch Weight Quartile Codes, May–November 2011–2015 (right) for Snow Crab in the Study Area.

Greenland Halibut

Greenland halibut comprised the largest portion of groundfish catches and was the third most important commercial species in the Study Area during 2010–2012 (fourth most important during 2013/2015 and fifth in 2014). Total catch weight (2010) and the total sum of catch weight quartile codes (2011–2015) for Greenland halibut in the Study Area during May–November are shown in Figure 4.14. Greenland halibut harvest locations in the Study Area during 2005–2014 are provided in recent EAs (LGL 2015a,b, 2016). Figure 4.15 shows Greenland halibut catch locations in the Study Area during May–November 2015. Greenland halibut were predominantly captured in the southwestern and northwestern portions of the Study and Project Areas, almost exclusively between the 500 and 1,000-m isobaths. The total monthly Greenland halibut harvests in the Study Area during May–November, 2010–2015 are indicated in Figure 4.16. This species was primarily taken during the June–August period in the Study Area.
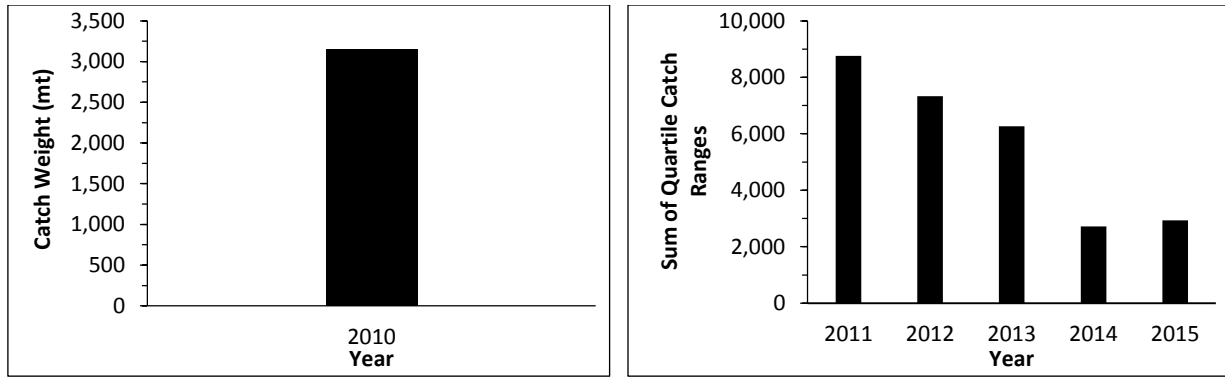
Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.14   Total Annual Catch Weight, May–November 2010 (left) and Total Annual Catch Weight Quartile Codes, May–November 2011–2015 (right) for Greenland Halibut in the Study Area.
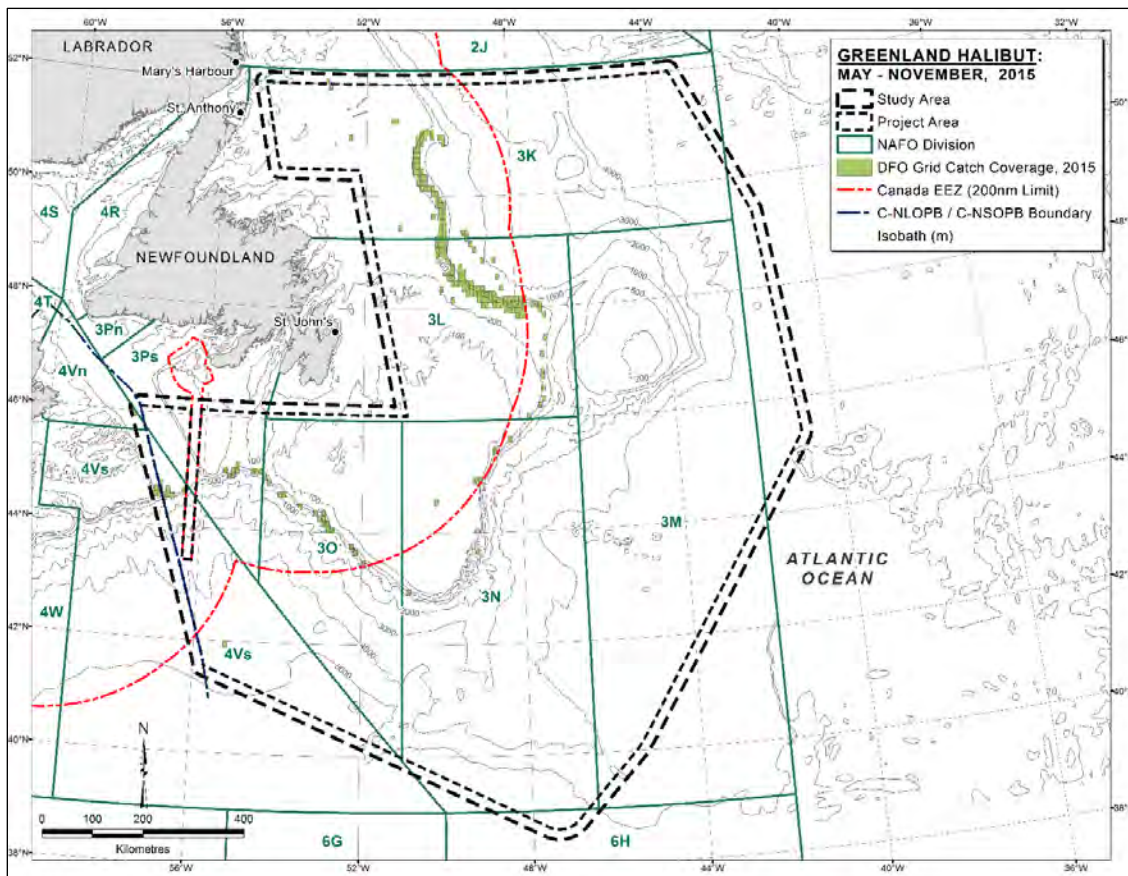
Source: DFO commercial landings database, 2015.

Figure 4.15   Distribution of Commercial Harvest Locations for Greenland Halibut, May–November 2015.
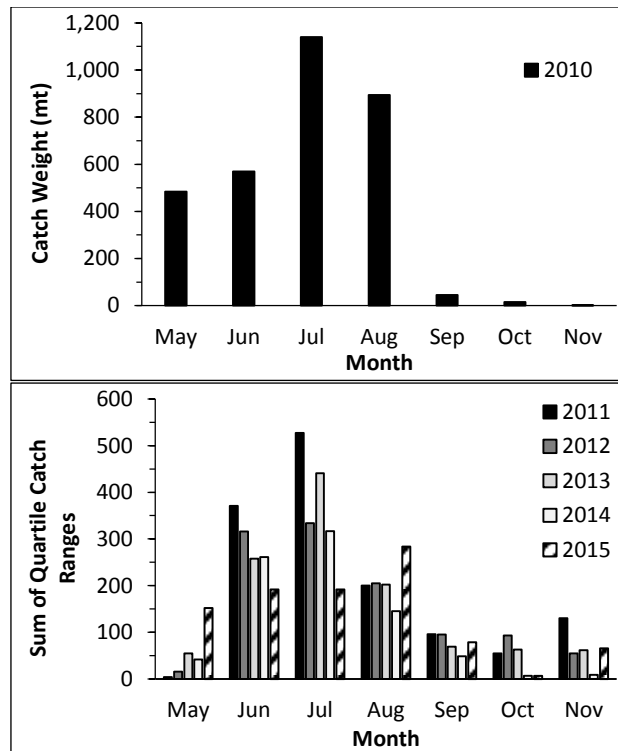
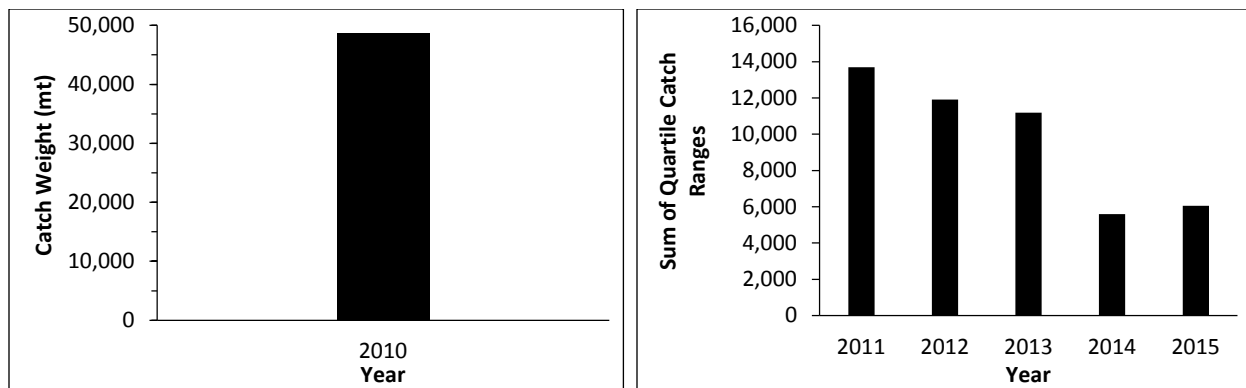Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given month.

Figure 4.16 Total Monthly Catch Weights, May–November 2010 (left) and Total Monthly Catch Weight Quartile Codes, May–November 2011–2015 (right) for Greenland Halibut in the Study Area.

Other Notable Species: Yellowtail Flounder, Atlantic Cod, Redfish, Atlantic Halibut and American Plaice

In addition to the three species already discussed, yellowtail flounder, Atlantic cod, redfish, Atlantic halibut and American plaice have also been identified as important commercial species in the Study Area (see § 4.3.3.2 and Tables 4.3–4.8). Total catch weight (2010) and the total sum of catch weight quartile codes (2011–2015) for these species between May and November are shown in Figure 4.17. Harvest locations for yellowtail flounder, Atlantic cod, redfish, and Atlantic halibut in the Study Area during May–November 2013 and 2014, are shown in Figures 4.19–4.21 of LGL (2016). Figures 4.18–4.22 indicate harvest locations in the Study Area during May–November 2015. Most of these species were harvested in the western and southwestern portions of the Study Area, in areas with water depths <1,000 m. The total monthly harvests for these species in the Study Area during the May–November 2010–2015 period are shown in Figure 4.23. Most harvesting of yellowtail flounder, Atlantic cod and American plaice occurred during late-spring and fall. Redfish and Atlantic halibut were caught primarily during late-spring and summer.
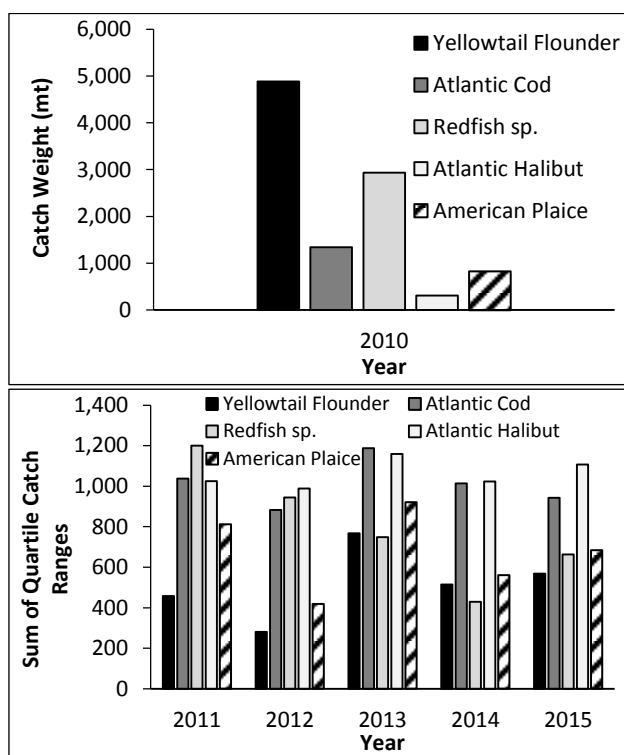
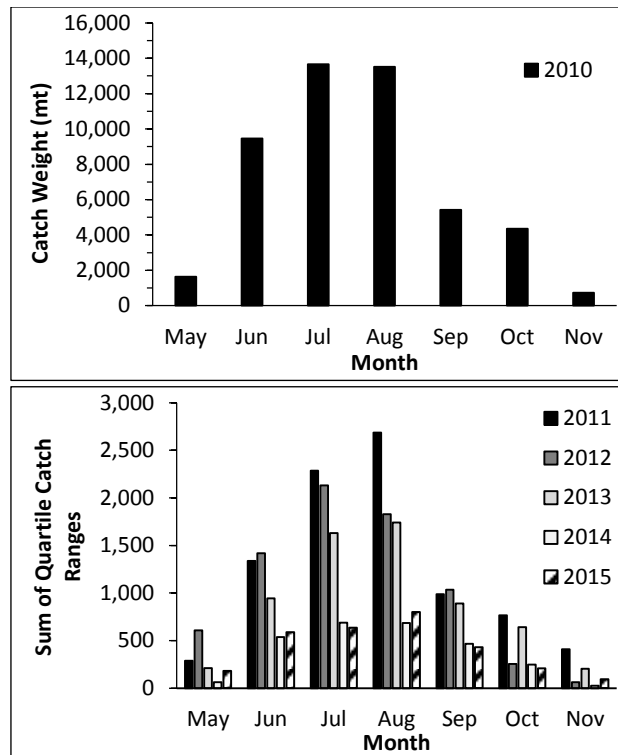Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.17   Total Annual Catch Weight, May–November 2010 (left) and Total Annual Catch Weight Quartile Codes, May–November 2011–2015 (right) for Yellowtail Flounder, Atlantic Cod, Redfish, Atlantic Halibut and American Plaice in the Study Area.
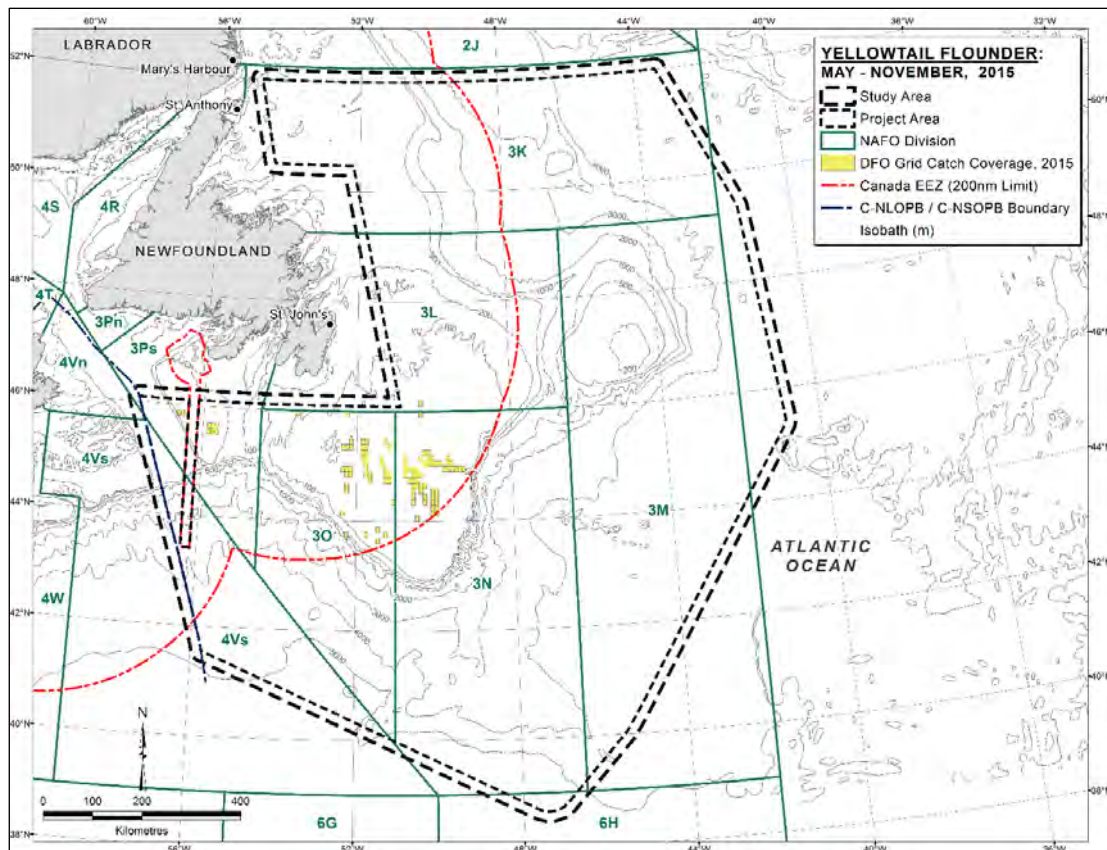
Source: DFO commercial landings database, 2015.

Figure 4.18   Distribution of Commercial Harvest Locations for Yellowtail Flounder, May–November 2015.
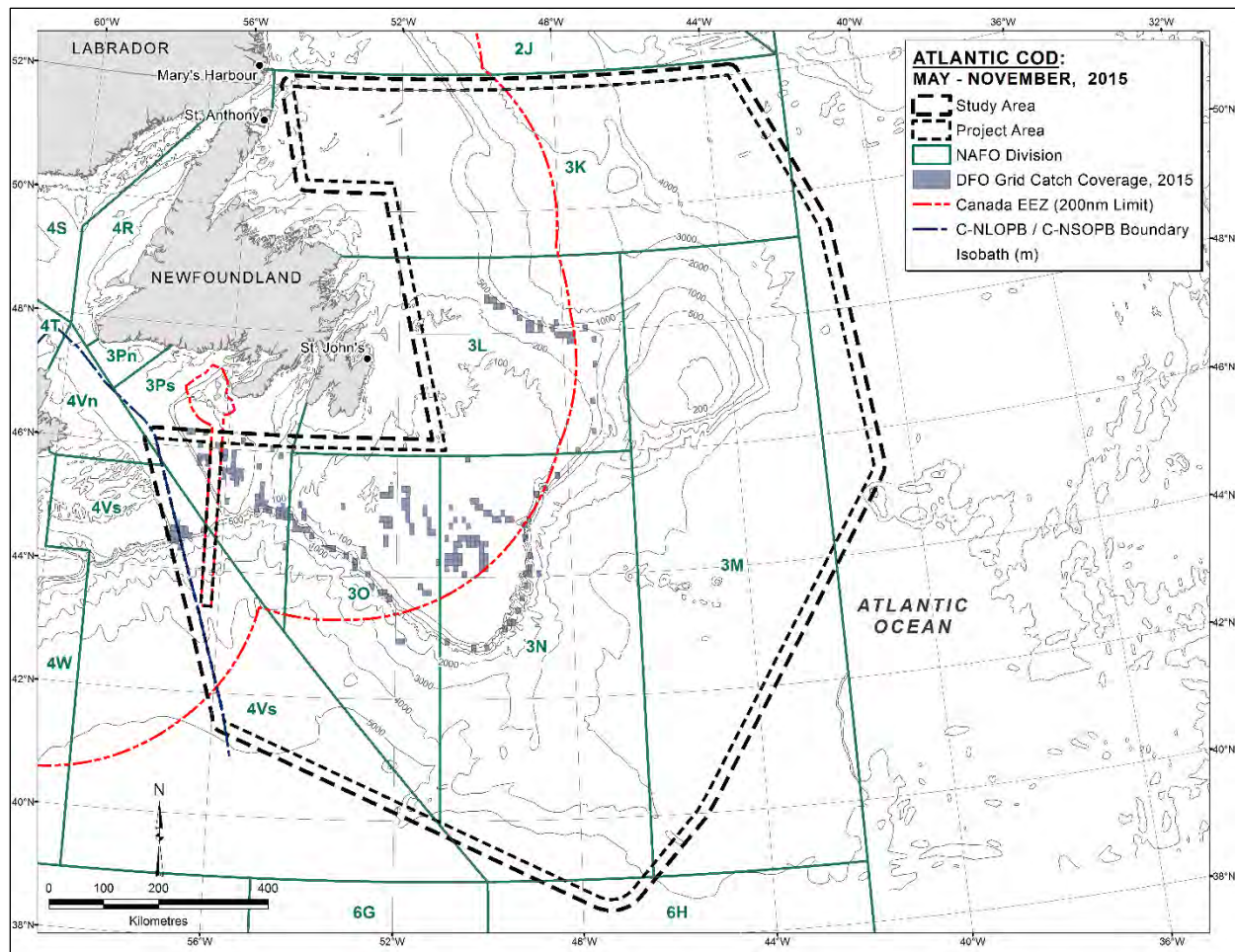
Source: DFO commercial landings database, 2015.

Figure 4.19   Distribution of Commercial Harvest Locations for Atlantic Cod, May–November 2015.
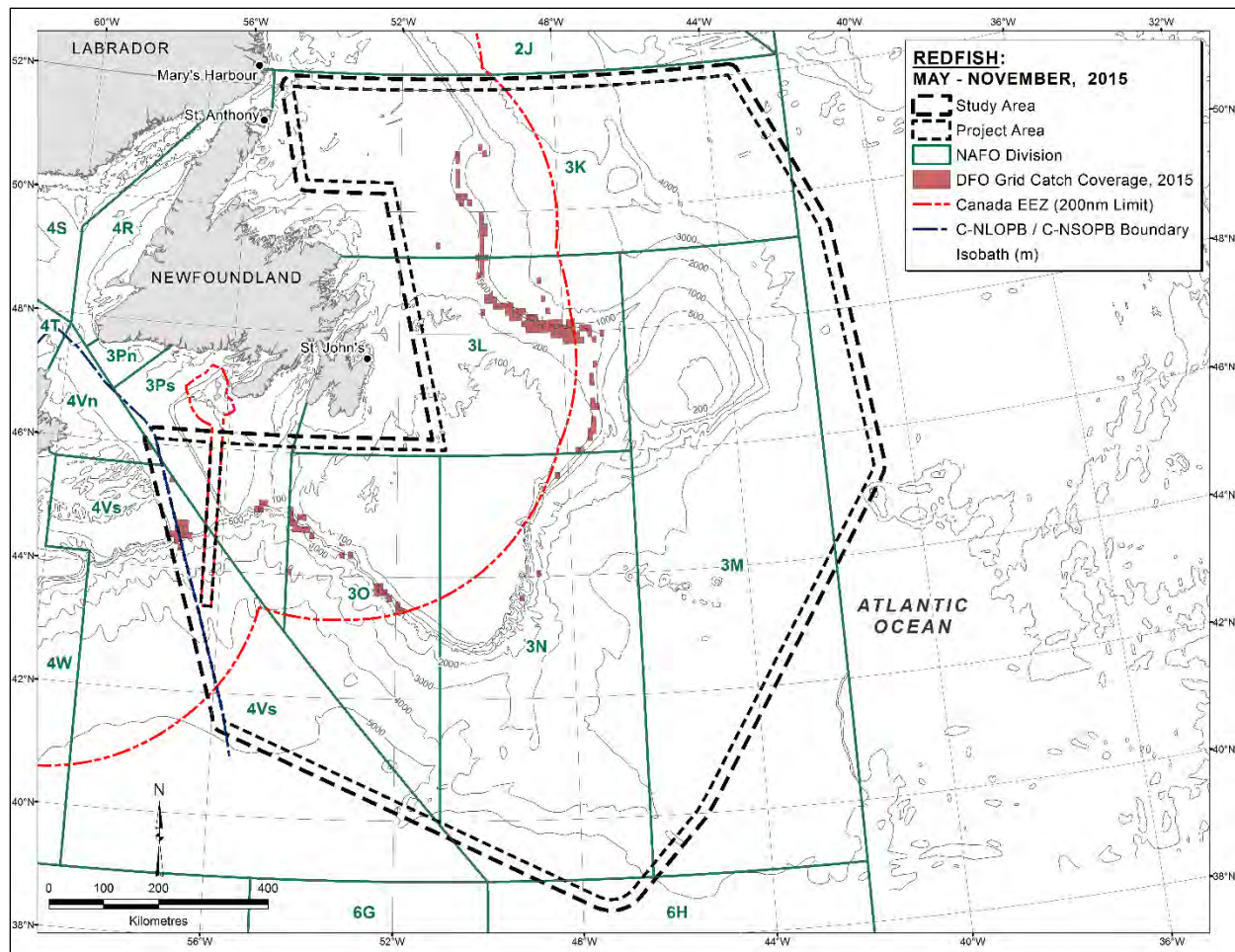
Source: DFO commercial landings database, 2015.

Figure 4.20   Distribution   of   Commercial   Harvest   Locations   for   Redfish, May–November 2015.
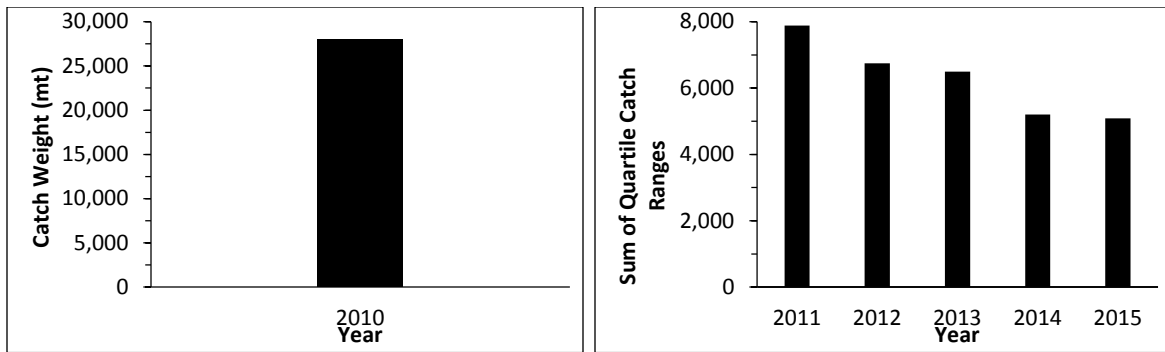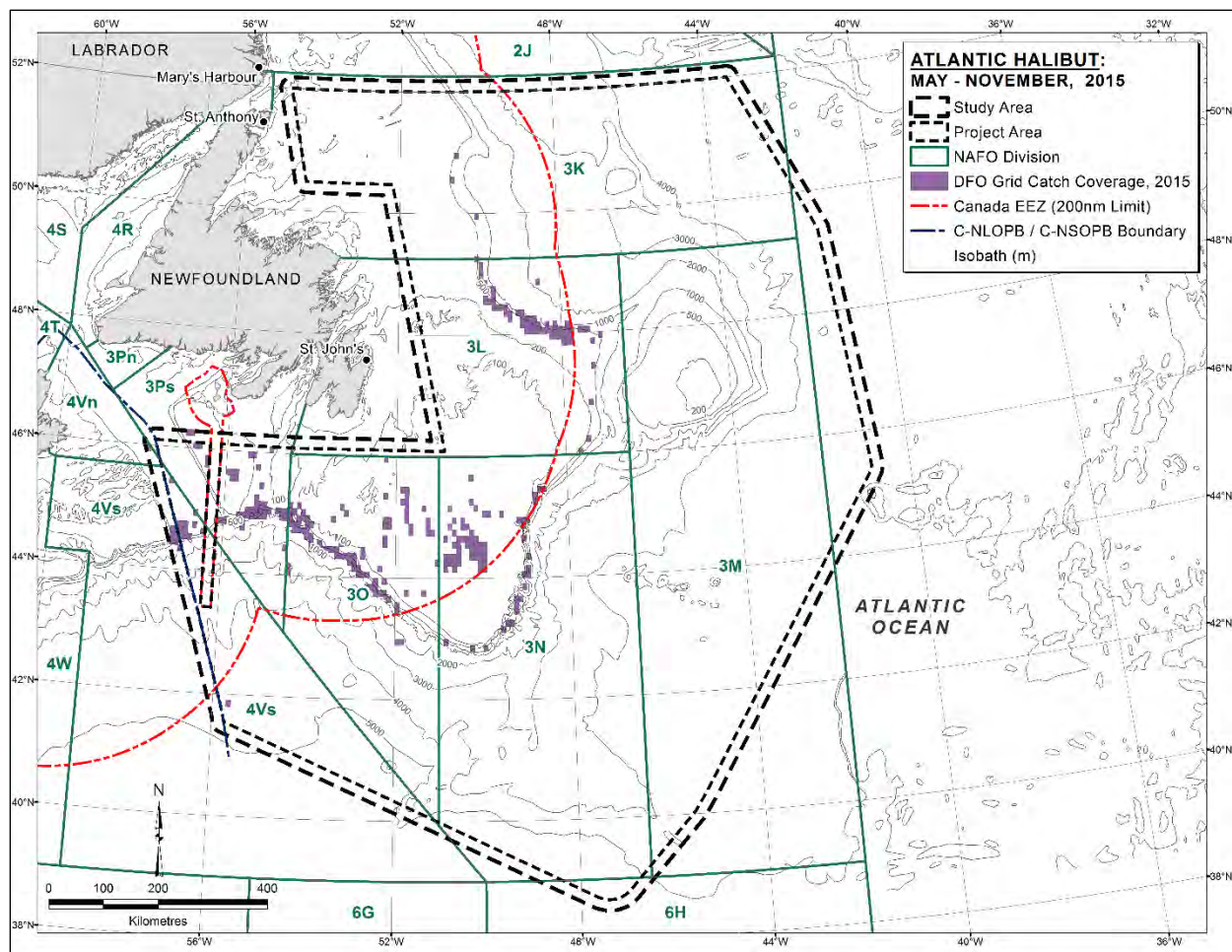
Source: DFO commercial landings database, 2015.

Figure 4.21   Distribution of Commercial Harvest Locations for Atlantic Halibut, May–November 2015.
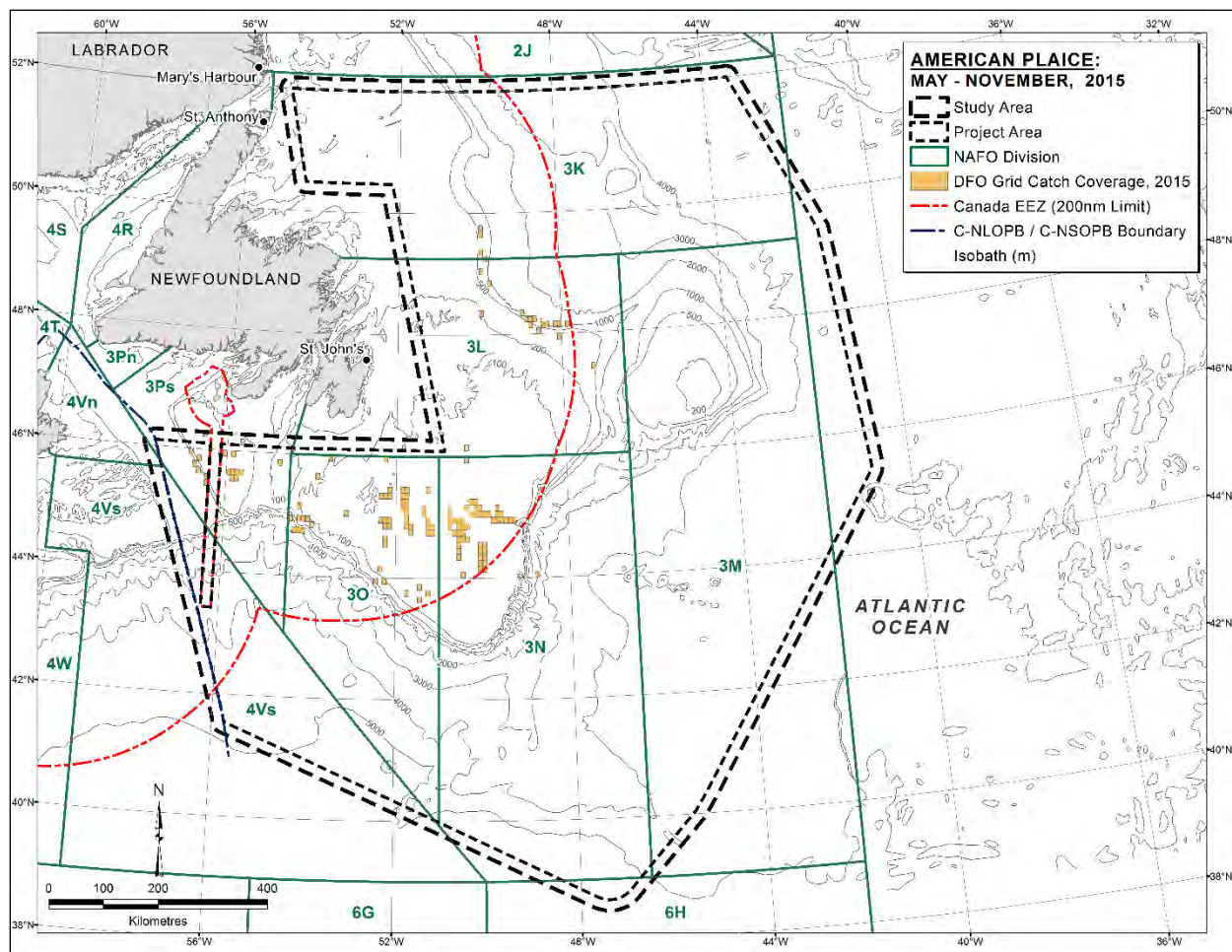
Source: DFO commercial landings database, 2015.

Figure 4.22   Distribution of Commercial Harvest Locations for American Plaice, May–November 2015.
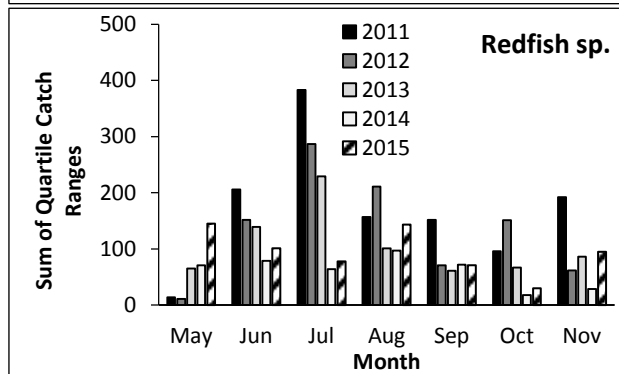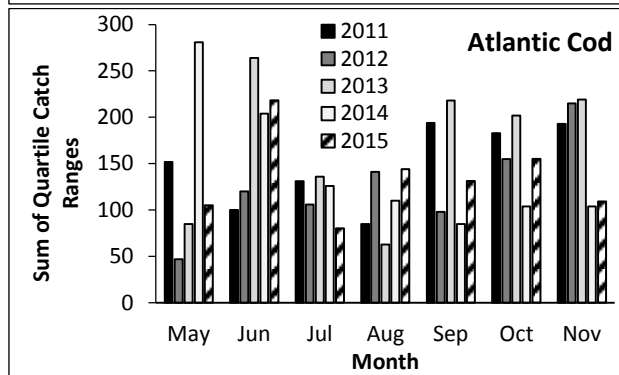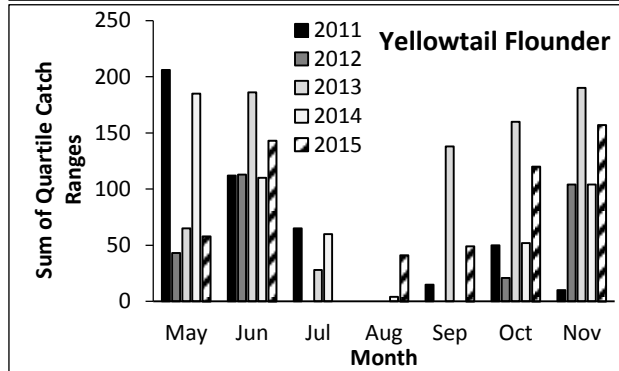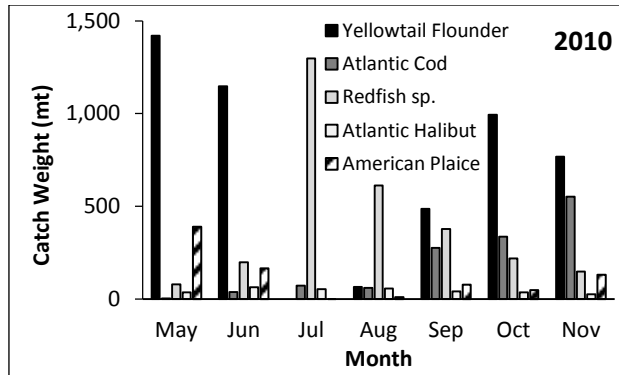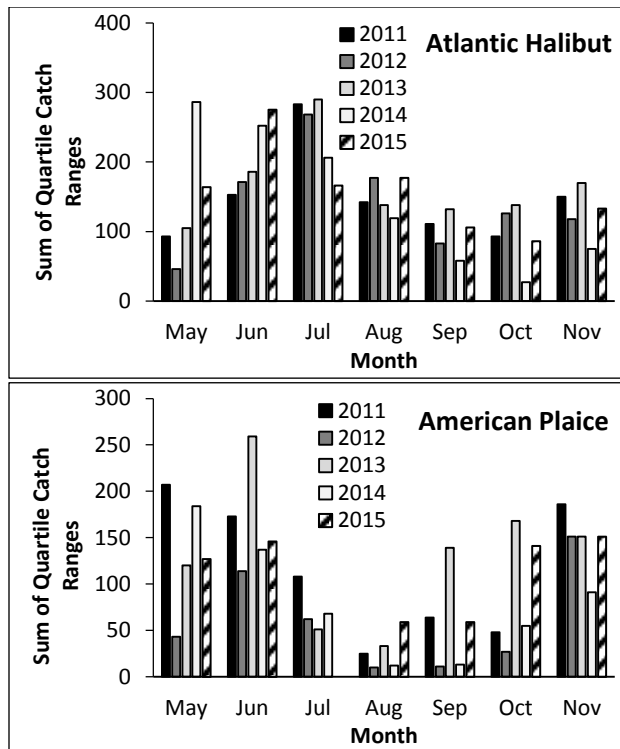
Source: DFO commercial landings database, 2010–2015.

Note: Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given month.

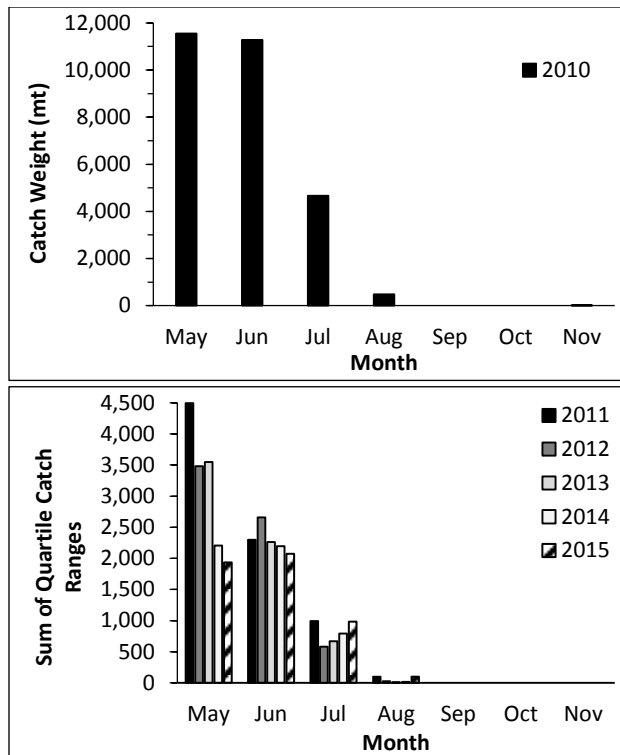**Figure 4.23** **Total Monthly Catch Weights, May–November 2010 (top left) and Total Monthly Catch Weight Quartile Codes, May–November 2011–2015 for Yellowtail Flounder, Atlantic Cod, Redfish, Atlantic Halibut and American Plaice in the Study Area.**

4.3.4 Traditional and Aboriginal Fisheries

Traditional and Aboriginal fisheries within the Study Area, including Communal Commercial Fisheries Licences (CCFL) and a communal fixed gear groundfish licence, are described in § 4.3.4 of LGL (2016) (Note: pers. comm.'s within the aforementioned section are attributed to D. Ball and D. Tobin of "DFO, Resource Management and Aboriginal Affairs"; this should instead be listed as "DFO, Resource Management and Aboriginal Fisheries"). Traditional fishing activities are also reviewed in § 3.3.4 of the Southern Newfoundland SEA (C-NLOPB 2010). According to the Eastern Newfoundland SEA (C-NLOPB 2014), there are no known Aboriginal fisheries that occur within the easternmost portion of the Study Area.

4.3.5 Recreational Fisheries

Recreational fisheries in Newfoundland are described in § 4.3.4.4 of the Eastern Newfoundland SEA (C-NLOPB 2014), and § 3.3.1.2, Fishing Enterprises and Licenses, § 3.3.3 of the Southern Newfoundland SEA (C-NLOPB 2010), and § 4.3.5 of LGL (2015a).

The 2017 Newfoundland and Labrador recreational groundfish fishery has concluded. This fishery was open for a total of 46 days, an increase of 14 days from previous years (prior to 2016), beginning with the first weekend in July and ending in the beginning of October (DFO 2017a). This extension is considered a transitional measure that was implemented ahead of the upcoming licence and tag regime for all recreational fishery participants, which was anticipated prior to the 2017 season (DFO 2016f); however, as of the 2017 season, there was still no requirement for licences or tags (DFO 2017a). The recreational groundfish fishery occurs in all NAFO Divisions around the province, including 2GHJ, 3KLPsPn and 4R, with the exception of the Eastport and Gilbert Bay Marine Protected Areas (MPA) (DFO 2017a). Of these NAFO Divisions, 3KLPs overlap with the Study Area.

It is possible that recreational fisheries will be conducted within the shallower portions of the Study Area.

4.3.6 Aquaculture

Aquaculture operations (or the absence thereof) in Newfoundland are described in § 4.3.4.3 of the Eastern Newfoundland SEA (C-NLOPB 2014), and § 3.3.2 of the Southern Newfoundland SEA (C-NLOPB 2010). Currently, all aquaculture sites in the province are located in coastal waters. There are no approved aquaculture sites within the Study Area (DFFA 2016).

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

DFO RV survey data collected during annual multi-species trawl surveys provide additional distributional information for some of the commercial species described in § 4.3.3, as well as for species not discussed in that subsection.

The total catch weight during the 2009–2014 spring (May, June, August) and fall (September–November) DFO RV surveys in the Study Area was 939 mt. Data collected during these surveys were analyzed, and catch weights, catch numbers and mean catch depths of species/groups contributing ≥0.1% of the total catch weight as well as species at risk (§ 4.6) are presented in Table 4.11.

Table 4.11   Catch Weights and Numbers, and Mean Catch Depths of Macroinvertebrates and Fishes Collected during DFO RV Surveys within the Study Area, May–November 2009–2014.

Species	Catch Weight (mt)	Catch Number	Mean Catch Depth (m)	
			Spring	**Fall**
Deepwater Redfish	450	3,152,317	363	291
Yellowtail Flounder	88	300,841	75	76
American Plaice	63	399,054	173	156
Atlantic Cod	61	84,669	171	143
Thorny Skate	41	23,903	240	199

Species	Catch Weight (mt)	Catch Number	Mean Catch Depth (m)	
			Spring	Fall
Northern Shrimp	34	7,736,965	287	254
Capelin	28	1,966,960	150	147
Greenland Halibut	18	73,493	324	404
Sand Lance (offshore)	17	1,370,905	91	88
Silver Hake	12	86,094	265	233
Sea Cucumber (*Cucumaria frondosa*)	10	36,279	115	115
Witch Flounder	8	24,988	289	275
Roughhead Grenadier	7	16,386	519	538
Snow Crab	7	44,745	178	185
Shrimp (Natantia)	5	106[a]	466	267
White Hake	4	4,917	275	246
Atlantic (striped) Wolffish	4	4,615	209	175
Longfin Hake	4	45,905	423	415
Sea Anemone (Actinaria)	4	43,770	313	276
Sponges	4	89[a]	267	256
Basket Star (*Gorgonocephalus arcticus*)	4	162	147	176
Atlantic Haddock	4	3,768	132	125
Striped Shrimp	3	904,688	105	118
Jellyfishes (Schyphozoa)	3	396	389	428
Comb Jelly (Ctenophora)	3	654	72	74
Sea Cucumber (Holothuroidea)	2	11,517	127	156
Marlin Spike	2	38,193	444	502
Atlantic Halibut	2	173	238	346
Green Sea Urchin	2	120,268	108	99
Blue Hake	2	17,322	629	737
Shrimp (*Argis dentata*)	2	309,410	122	118
Basket Star (Gorgonocephalidae)	2	244	177	174
Sand Dollar (*Echinarachnius parma*)	2	75,981	135	146
Northern Wolffish	2	548	596	435
Black Dogfish Shark	2	2,777	591	806
Greenland Shark	2	2	593	798
Longnose Eel	2	28,968	512	616
Monkfish	1	368	246	318
Spotted Wolffish	1	650	363	280
Sea Urchin (Echinoidea)	1	46,747	198	188
Longhorn Sculpin	1	4,640	73	73
Shorthorn Sculpin	1	1,893	113	84
Roundnose Grenadier	1	7,946	639	758
Spinytail Skate	1	119	621	615
Arctic Eelpout	1	4,905	152	129
Brittle Star (Ophiuroidea)	1	23,245	178	272
Sea Urchin (*Strongylocentrotus* sp.)	1	35,370	120	128
Toad Crab	1	96,077	125	111
Sea Raven	1	586	74	64
Sand Sifting Sea Star (*Astropecten americanus*)	1	11,290	424	533
Corals	1[a]	11,197[a]	303	424
Brittle Star (*Ophiura* sp.)	1	8,492	90	92
Atlantic Argentine	1	3,532	313	313
Eelpout (*Lycodes* sp.)	1	8,429	325	255
Moustache Sculpin	1	60,382	101	115
Pollock	1	193	168	234

Species	Catch Weight (mt)	Catch Number	Mean Catch Depth (m)	
			Spring	Fall
Atlantic Herring	1	3,449	168	144
Sand Dollar (Clypeasteroida)	1	26,230	160	139
Mailed Sculpin	1	52,837	129	119
Vahl's Eelpout	0	5,050	334	346
Smooth Skate	0	548	240	219
Spiny Dogfish	0	14	120	152
Winter Skate	0	12	318	695
Cusk	0	4	615	377
Wolffishes	0	2	635	-
Total	**928**	**17,346,279**	**206**	**228**

Source: DFO RV Survey Data, 2009–2014.

[a] Denotes data incomplete.

Deepwater redfish accounted for 48% of the total May–November 2009–2014 catch weight, followed by yellowtail flounder (9%), American plaice (7%), Atlantic Cod (6%), thorny skate and northern shrimp (4% each), capelin (3%), Greenland halibut and sand lance (2% each), and silver hake, sea cucumber (*Cucumaria frondosa*), witch flounder, roughhead grenadier, snow crab and shrimp (Natantia) (1% each). All other species/groups accounted for <1% of the total May–November 2009–2014 catch weight in the Study Area. Principal species captured during the May–November 2009–2014 DFO RV surveys were generally representative of predominant species targeted using similar mobile gear (bottom trawls) in the commercial fishery in recent years (§ 4.3.3).

DFO RV survey catch locations for corals (2000–2012) and for sand lance, capelin, redfish, yellowtail flounder, American plaice, sculpins, lanternfish, Atlantic cod, Greenland halibut, blue hake and roughhead grenadier (2005–2009) are shown in Figure 4.72 and Figures 4.74–4.84, respectively, of the Eastern Newfoundland SEA (C-NLOPB 2014). Catch locations for all deepwater redfish, thorny skate, yellowtail flounder, American plaice, Atlantic cod, sand lance, winter flounder, white hake, sea cucumber, black dogfish shark, longfin hake, Greenland halibut and haddock (2006–2007 combined) are presented in Figures 3.2–3.8 of the Southern Newfoundland SEA (C-NLOPB 2010). DFO RV survey catch locations for all species in the Study Area during May–November 2013 are shown in Figure 4.23 of LGL (2016). The distribution of georeferenced catch locations reported during the May–November 2014 DFO RV surveys within the Study Area is shown in Figure 4.24. Species were captured in the western portions of the Study Area during the May–November 2009–2014 DFO RV surveys, in water depths <2,000 m (predominantly <1,000 m). Across all species caught during the May–November 2009–2014 DFO RV surveys in the Study Area, total catch weight ranged from 100–196 mt per year.

Spring and fall surveys accounted for 51% and 49% of the total catch weight, respectively. The average mean depths of catch during spring and fall surveys during 2009–2014 were 206 m (min: 38 m; max: 1,054 m) and 228 m (min: 39 m; max 1,469 m), respectively.

In descending order, the top five species/groups in terms of catch weight during the 2009–2014 spring surveys were deepwater redfish, yellowtail flounder, Atlantic cod, American plaice and capelin; and during the fall surveys were deepwater redfish, yellowtail flounder, American plaice, Atlantic cod and northern shrimp. Species/groups captured predominantly during the spring surveys included wolffishes, sand sifting sea star, winter skate, Atlantic herring, pollock, sand dollar (*E. parma*), mailed sculpin, capelin and Atlantic argentine; and during the fall surveys included shrimp (Natantia), roundnose grenadier and eelpout (*Lycodes* sp.). Species/groups captured in essentially equal portions during both spring and fall surveys included thorny skate, Vahl's eelpout, Atlantic halibut, smooth skate, Arctic eelpout, American plaice, striped shrimp, spiny dogfish and deepwater redfish. The survey depth differences between spring and fall surveys likely account for some of the seasonal differences observed.

Figures 4.33–4.41 of LGL (2015a) and Figures 4.54–4.61 of LGL (2015b) indicate 2008–2012 DFO RV survey catch locations for offshore eastern and southeastern Newfoundland, respectively; specifically, maps were presented for deepwater redfish, sponges, corals and wolffishes in LGL (2015a,b), northern shrimp and Greenland halibut in LGL (2015a), American plaice and Atlantic cod in LGL (2015a,b), and thorny skate in LGL (2015b). Figures 4.24–4.26 of LGL (2016) indicate 2013 DFO RV survey catch locations within the Study Area for deepwater redfish, yellowtail flounder, American plaice, Atlantic cod, thorny skate, northern shrimp, Greenland halibut, sponges, wolffishes and corals. Figures 4.25–4.34 below show catch locations during 2014 DFO RV surveys for these species, in order of descending total catch weight (see Table 4.11).
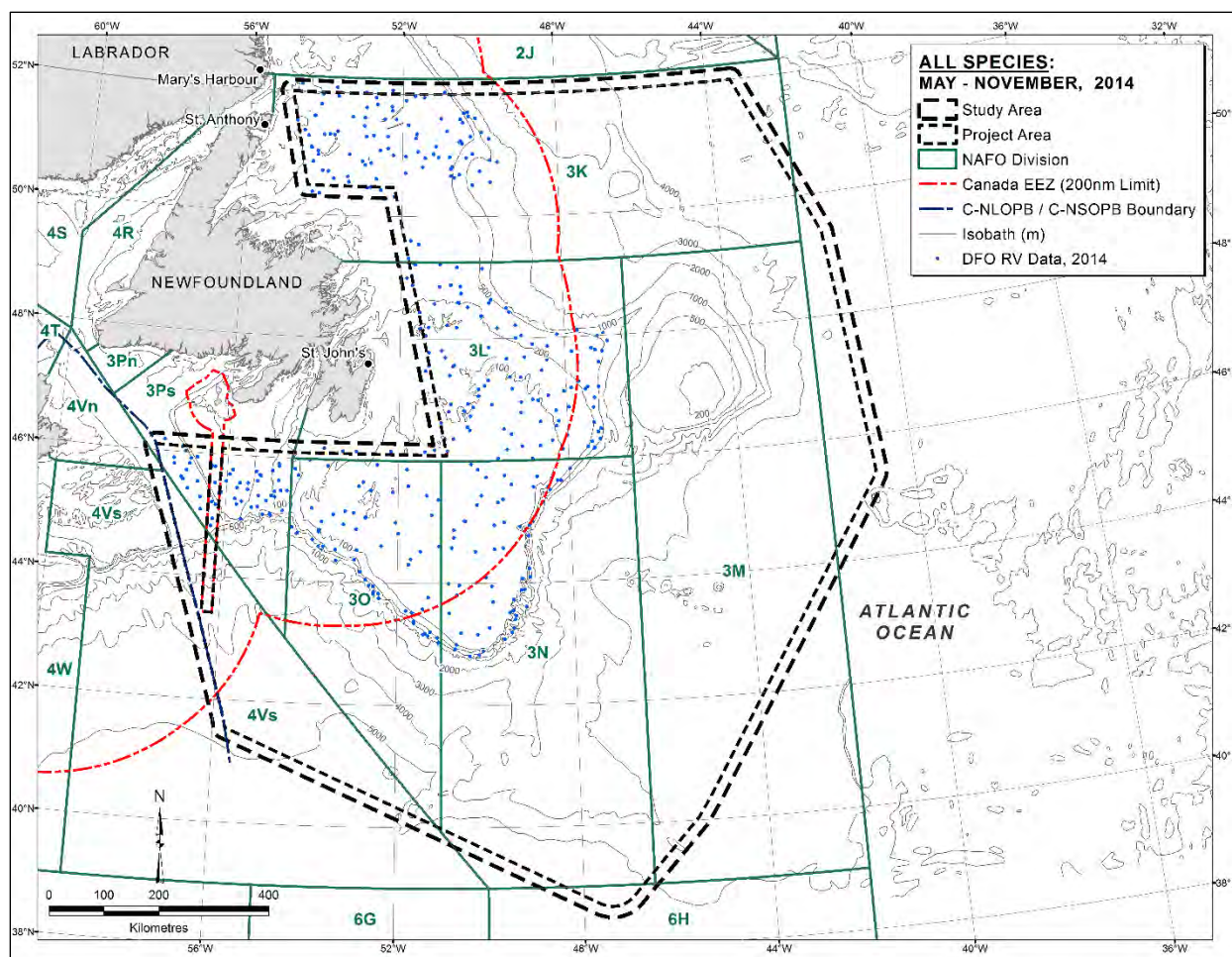
Source: DFO RV Survey database, 2014.

Figure 4.24   Distribution of DFO RV Survey Catch Locations in the Study Area, All Species, May–November 2014.
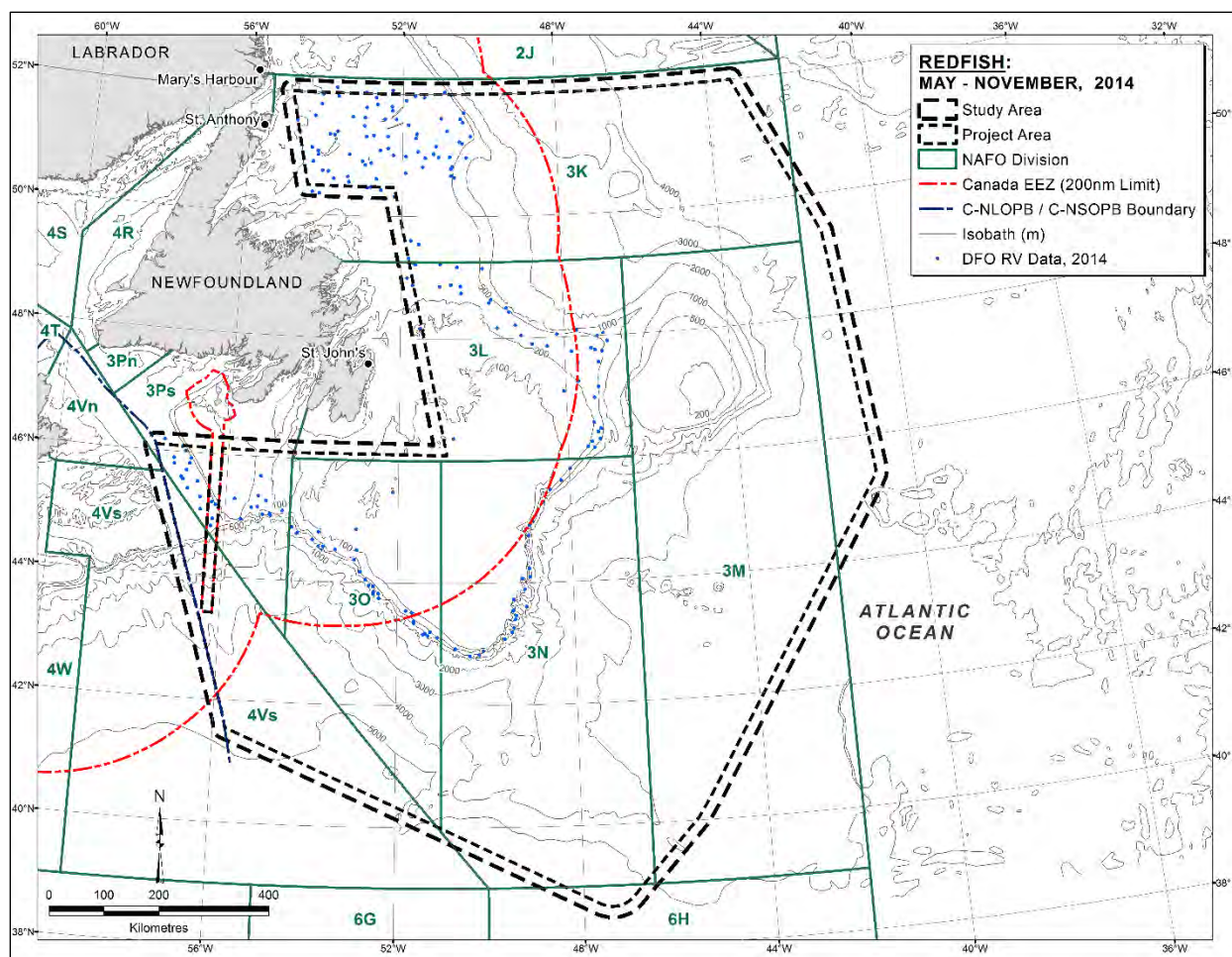
Source: DFO RV Survey database, 2014.

Figure 4.25   Distribution of DFO RV Survey Catch Locations of Deepwater Redfish in the Study Area, May–November 2014.
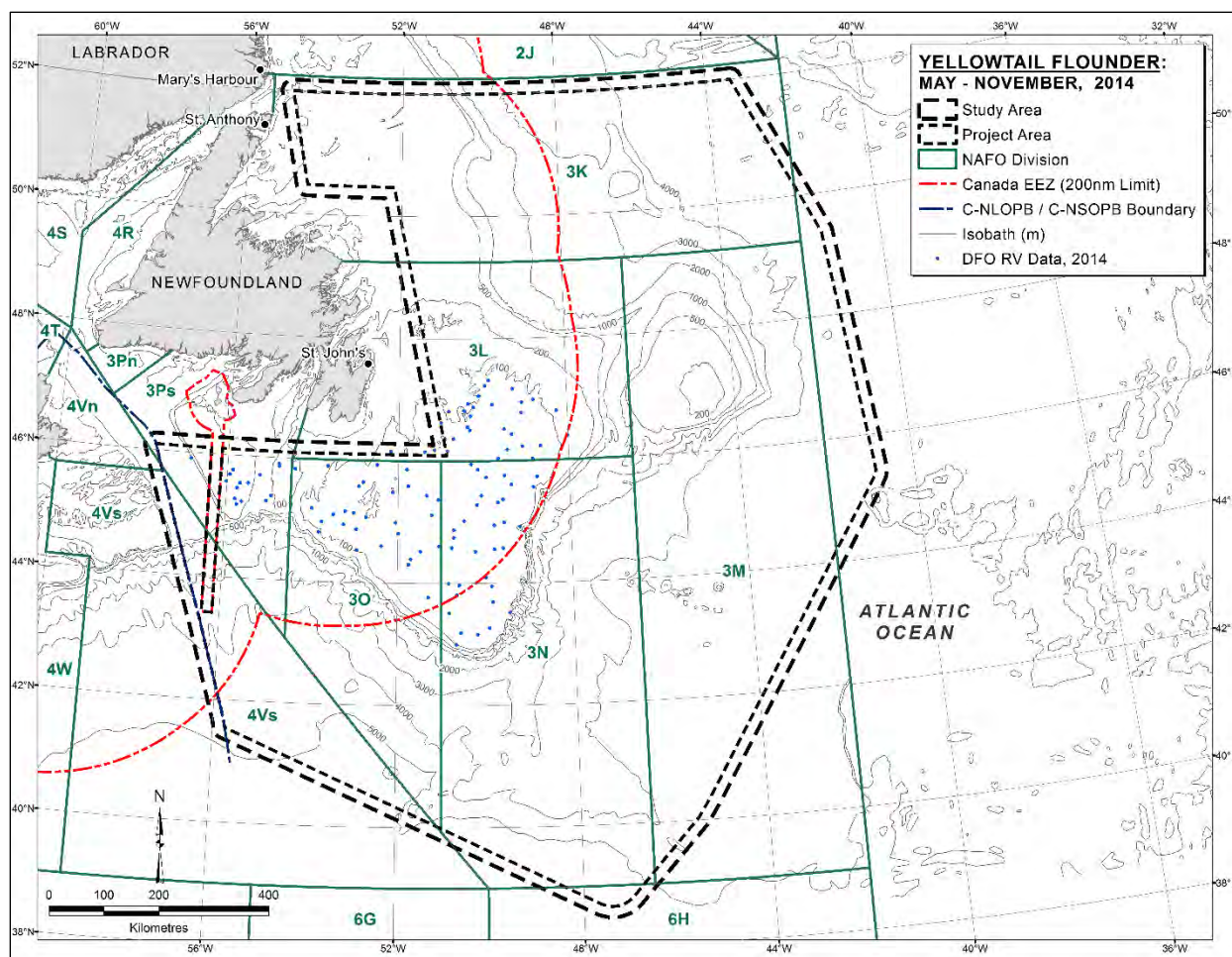
Source: DFO RV Survey database, 2014.

Figure 4.26   Distribution of DFO RV Survey Catch Locations of Yellowtail Flounder in the Study Area, May–November 2014.
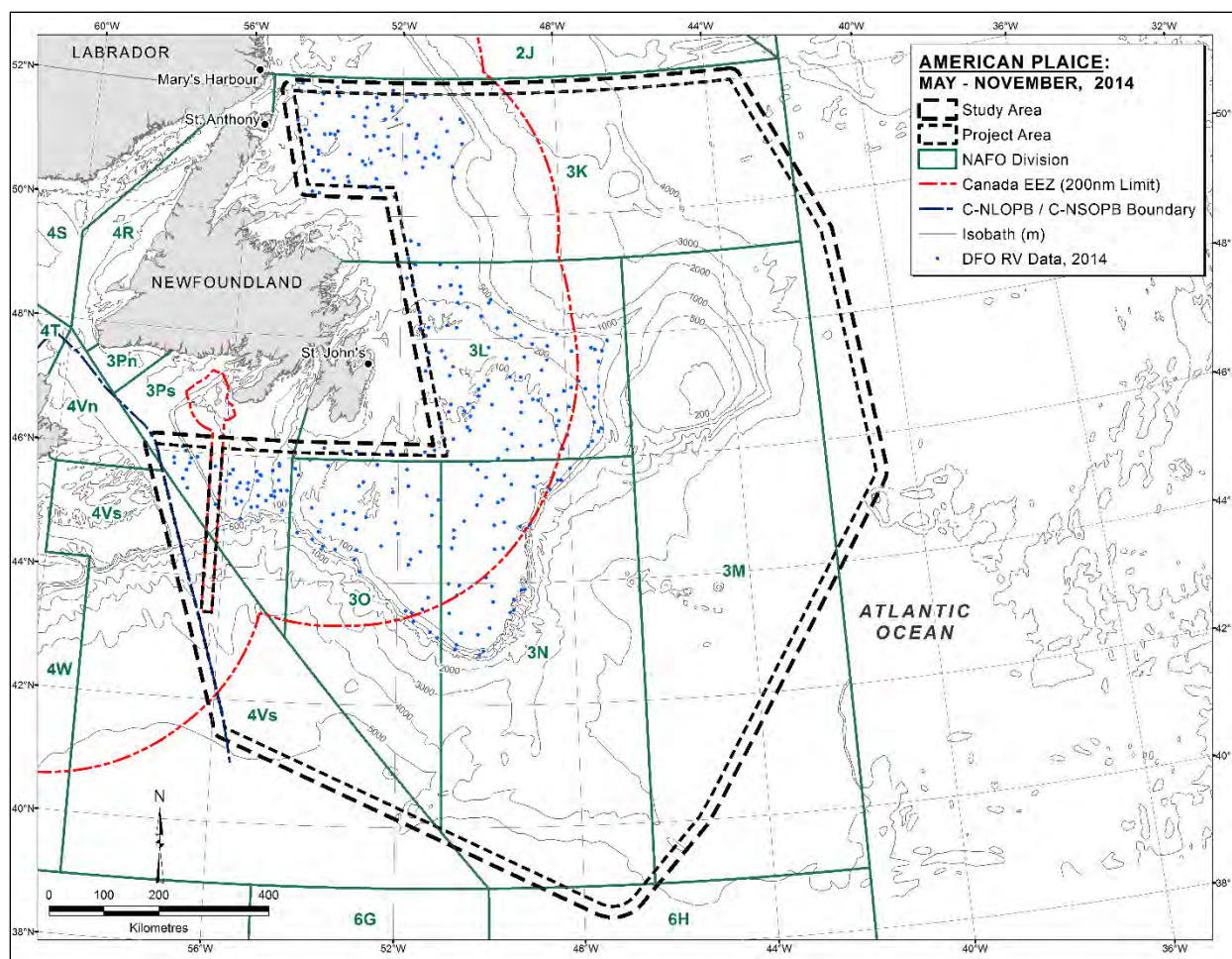
Source: DFO RV Survey database, 2014.

Figure 4.27   Distribution of DFO RV Survey Catch Locations of American Plaice in the Study Area, May–November 2014.
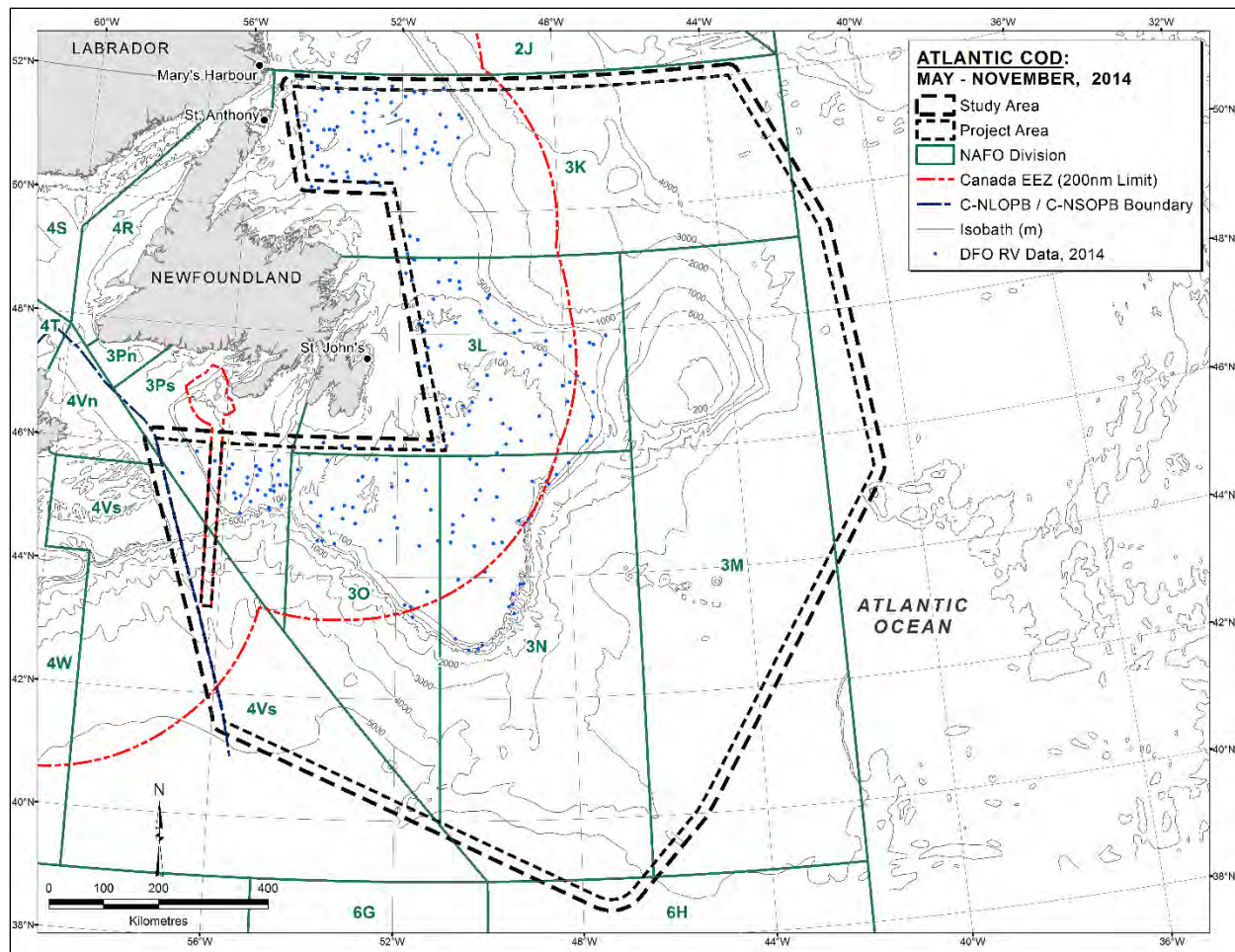
Source: DFO RV Survey database, 2014.

Figure 4.28   Distribution of DFO RV Survey Catch Locations of Atlantic Cod in the Study Area, May–November 2014.
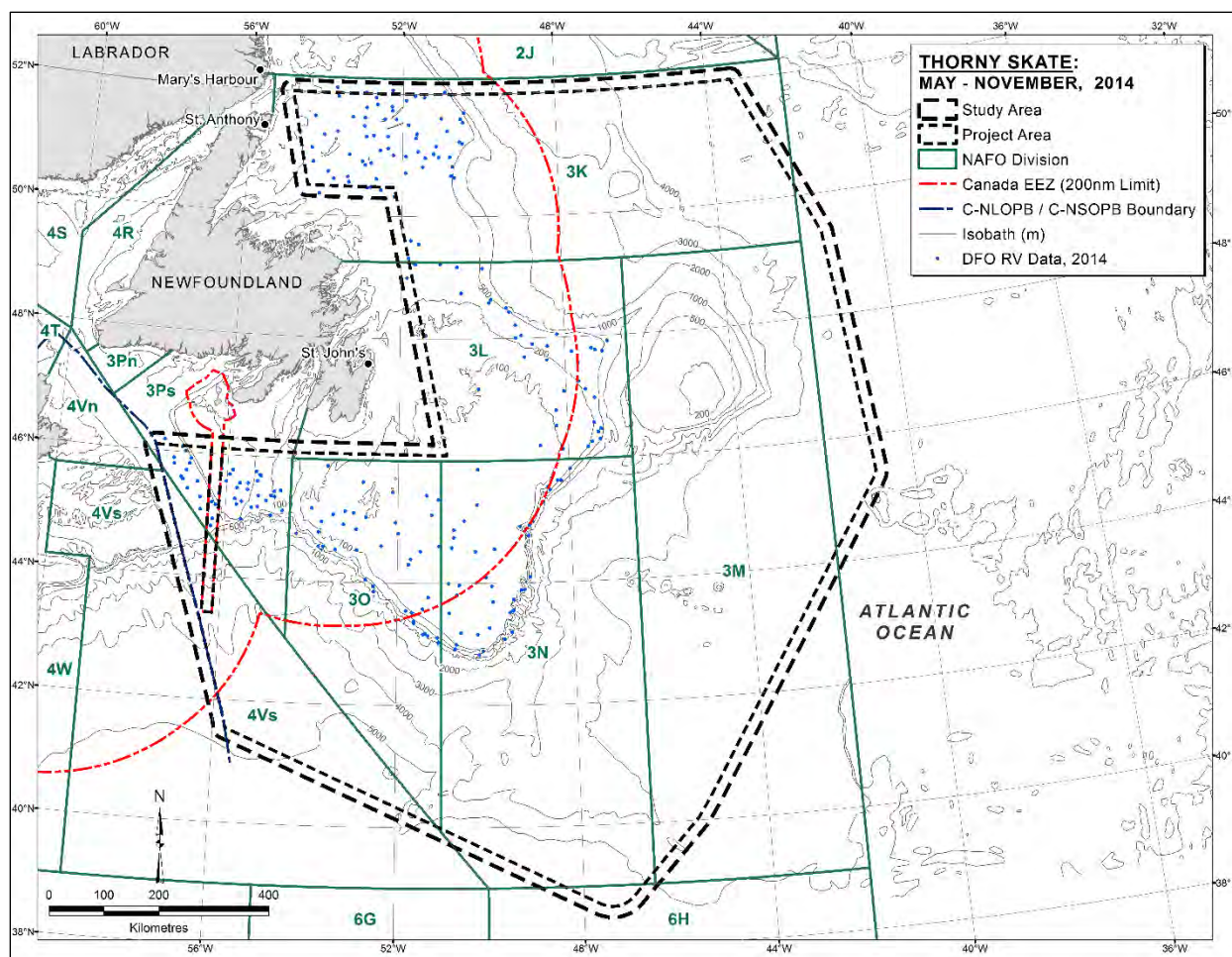
Source: DFO RV Survey database, 2014.

Figure 4.29   Distribution of DFO RV Survey Catch Locations of Thorny Skate in the Study Area, May–November 2014.
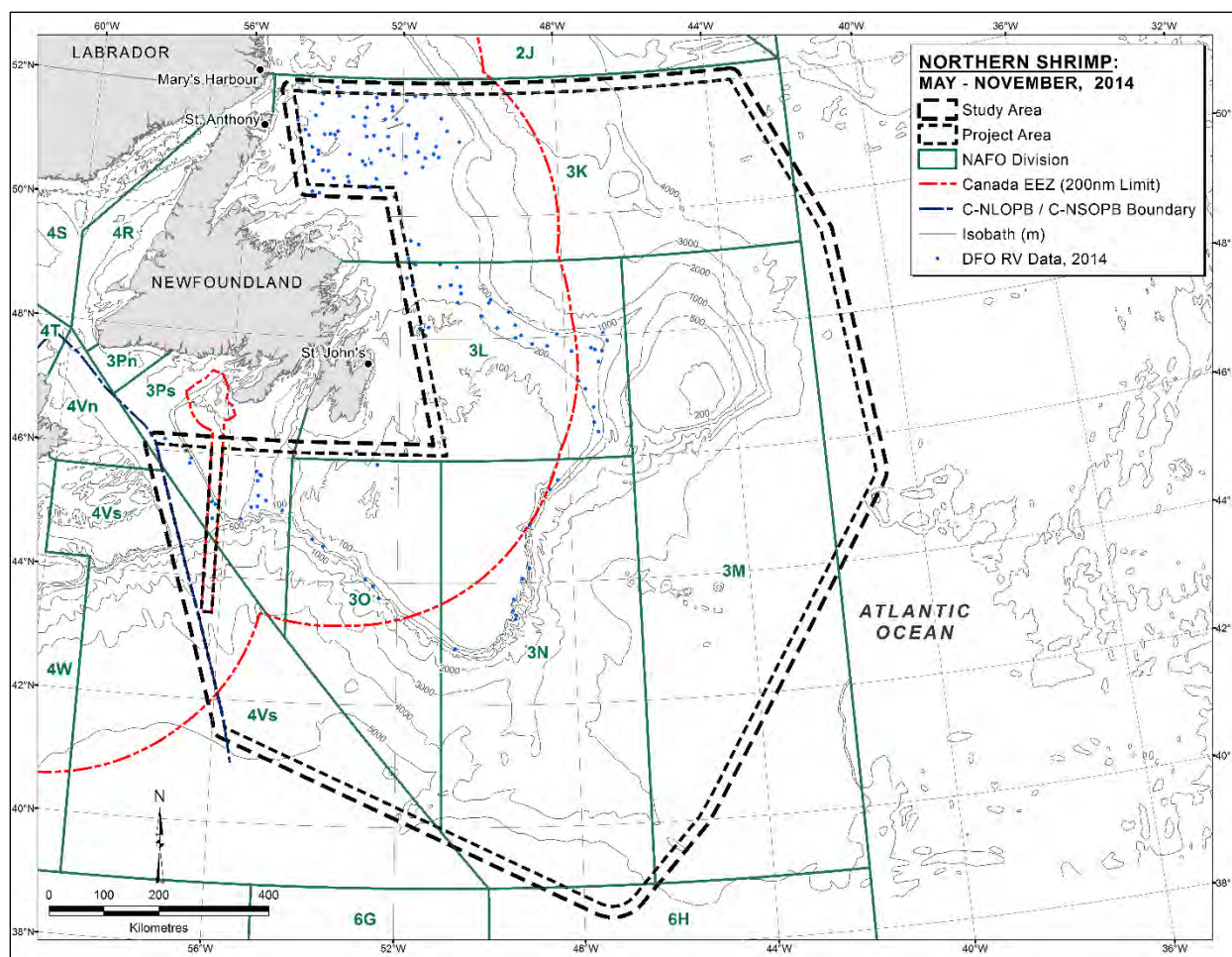
Source: DFO RV Survey database, 2014.

Figure 4.30   Distribution of DFO RV Survey Catch Locations of Northern Shrimp in the Study Area, May–November 2014.
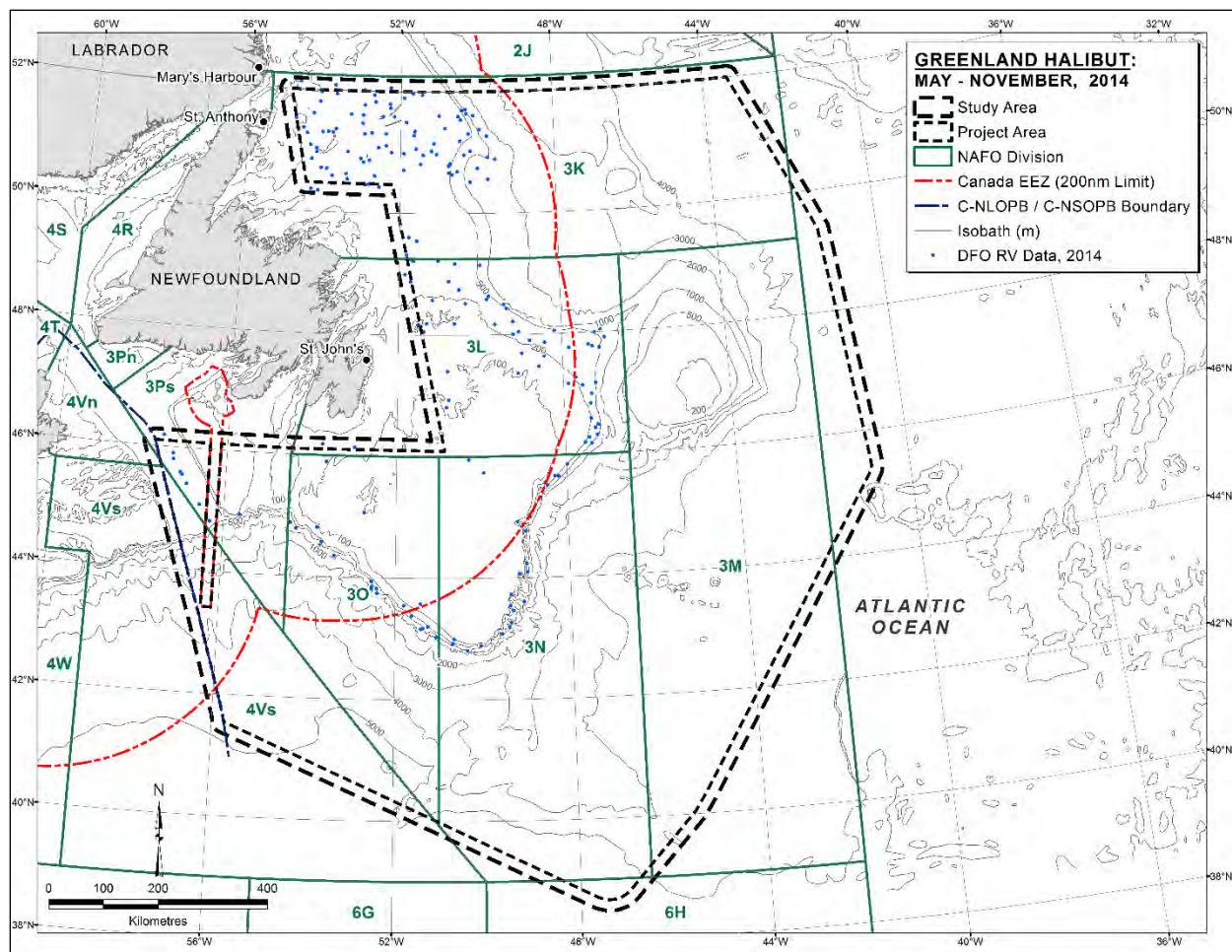
Source: DFO RV Survey database, 2014.

Figure 4.31   Distribution of DFO RV Survey Catch Locations of Greenland Halibut in the Study Area, May–November 2014.
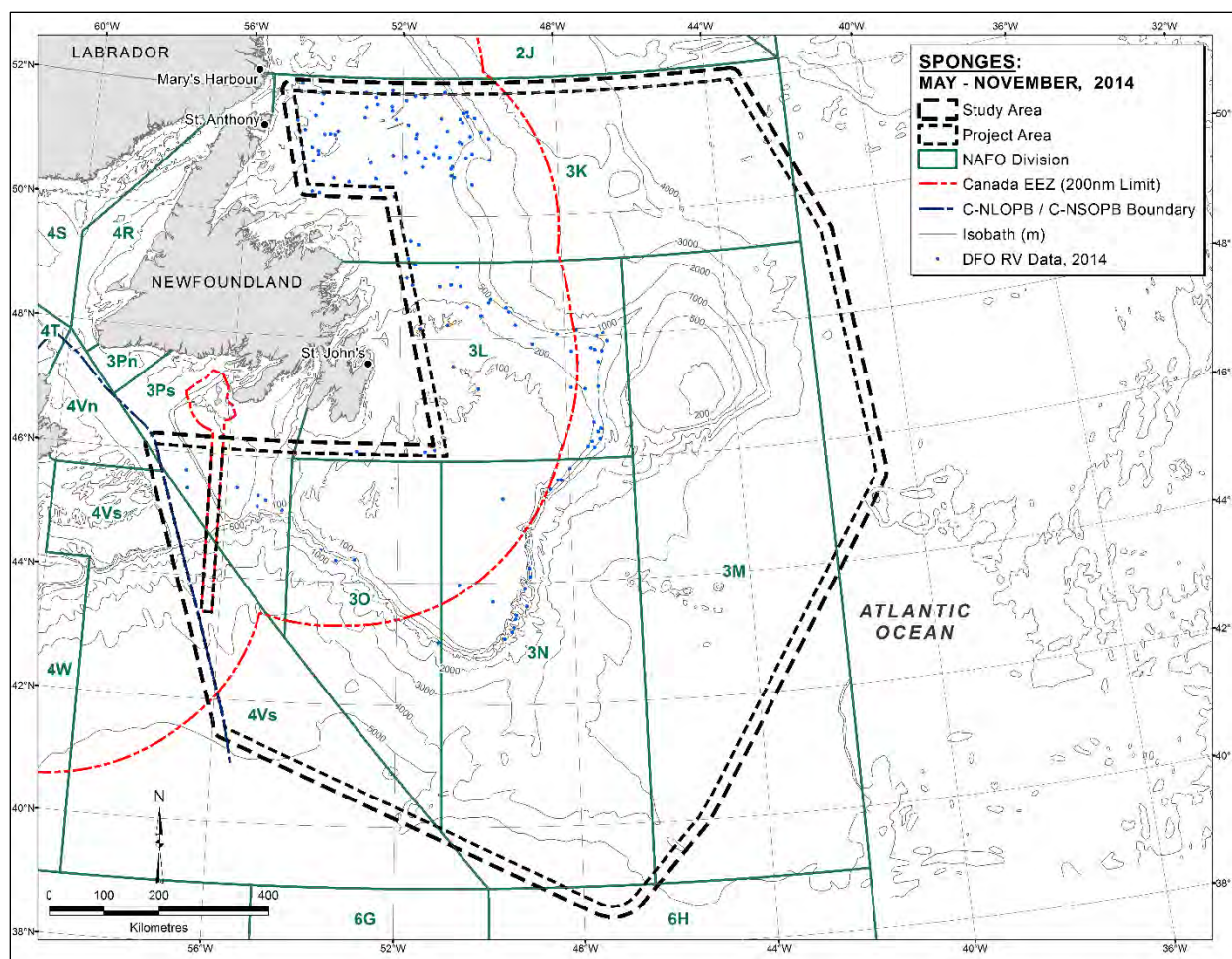
Source: DFO RV Survey database, 2014.

Figure 4.32   Distribution of DFO RV Survey Catch Locations of Sponges in the Study Area, May–November 2014.
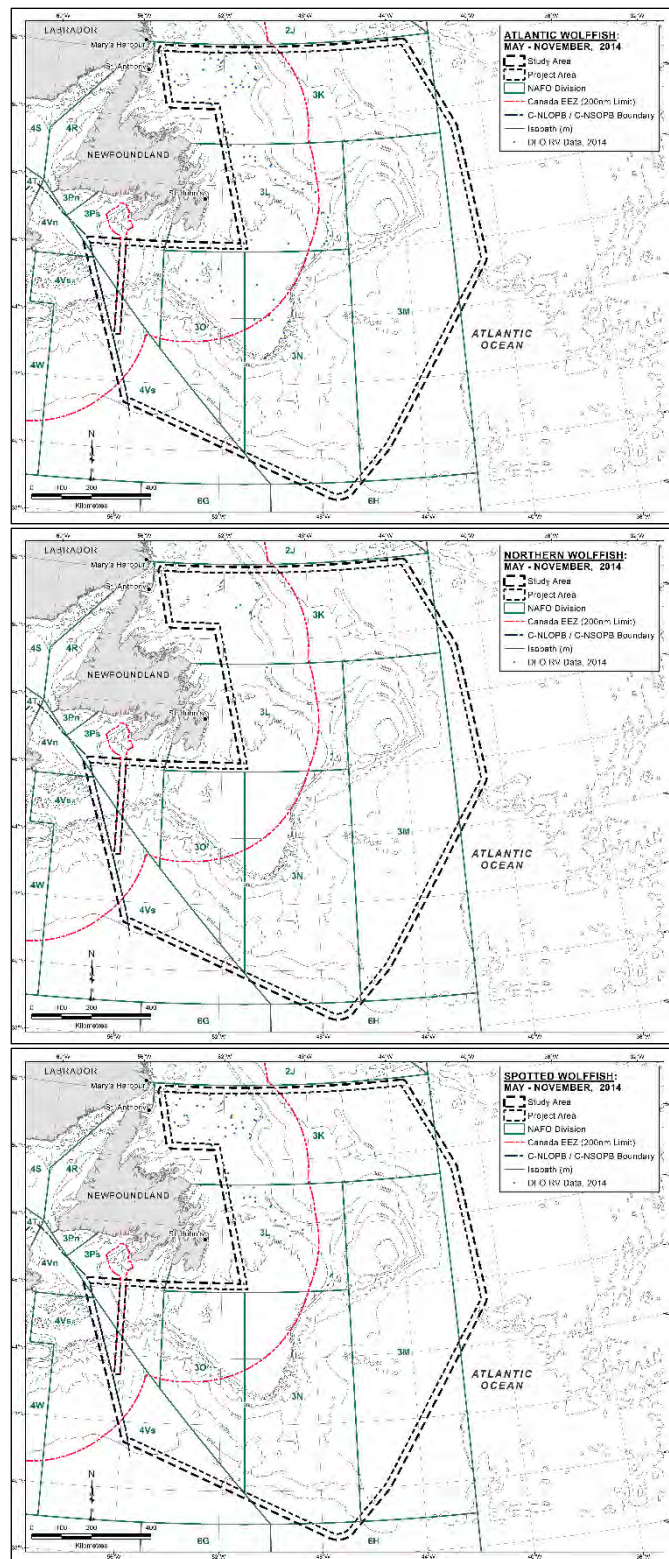
Source: DFO RV Survey database, 2014.

Figure 4.33   Distribution of DFO RV Survey Catch Locations of Atlantic (striped), Northern and Spotted Wolffish in the Study Area, May–November 2014.
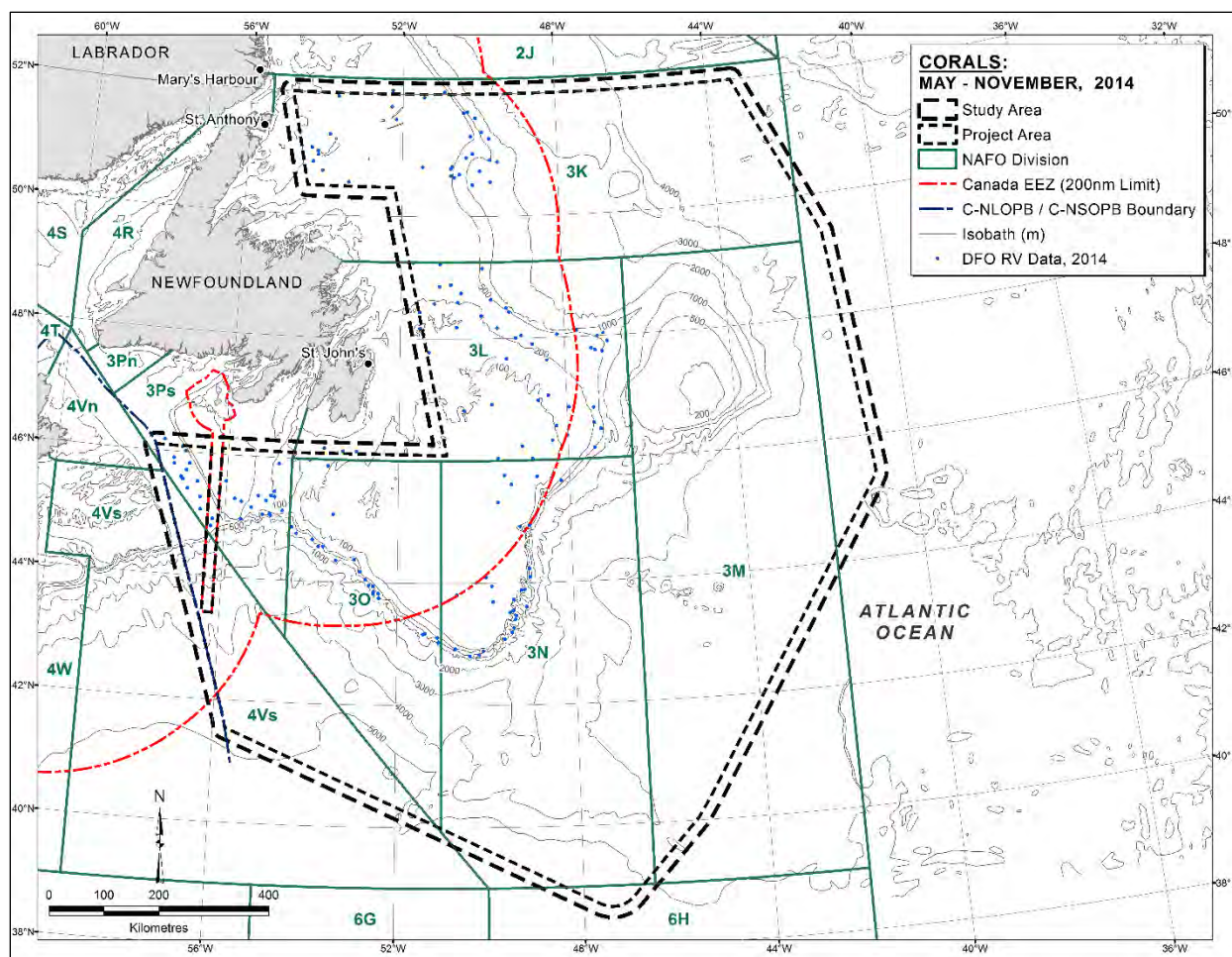
Source: DFO RV Survey database, 2014.

Figure 4.34   Distribution of DFO RV Survey Catch Locations of Corals in the Study Area, May–November 2014.

Catches at various mean depth ranges are also examined in this subsection. Table 4.12 presents total catch weights and predominant species/groups caught within each mean depth range in the Study Area during the 2009–2014 period. Northern shrimp and Greenland halibut (predominant commercial species; mainly targeted using mobile gear) were caught primarily at depths ranging from 200–300 m and 300–500 m, respectively.

Table 4.12   Total Catch Weights and Predominant Species Caught at Various Mean Catch Depth Ranges, DFO RV Surveys, May–November 2009–2014.

Mean Catch Depth Range (m)	Total Catch Weight (mt)	Predominant Species (% of Total Catch Weight)
<100	111	Yellowtail Flounder (79%) Sand Lance (15%)
≥100 – <200	198	American Plaice (32%) Atlantic Cod (31%) Capelin (14%)
≥200 – <300	104	Thorny Skate (40%) Northern Shrimp (33%) Silver Hake (11%)
≥300 – <400	493	Deepwater Redfish (91%) Greenland Halibut (4%)
≥ 400 – <500	11	Longfin Hake (39%) Jellyfishes (Schyphozoa; 26%) Marlin Spike (19%)
≥500 – <600	12	Roughhead Grenadier (62%) Northern Wolffish (14%) Longnose Eel (13%)
≥600 – <700	5	Blue Hake (40%) Greenland Shark (31%) Spinytail Skate (20%)
≥700 – <800	3	Black Dogfish Shark (53%) Roundnose Grenadier (36%)
≥800 – <900	0.3	Smoothheads (57%) Scopelosaurus (6%) Goitre Blacksmelt (6%) Baird's Smoothhead (6%)
≥900 – <1,000	0.3	Jensen's Skate (84%) Agassiz's Smoothhead (7%)
≥1,000	0.3	Longnose Chimaera (31%) Deepsea Cat Shark (23%) Black Herring (17%)

Source: DFO Research Vessel Survey Database, 2009–2014.

4.3.8   Industry and DFO Science Surveys

Fisheries research surveys conducted by DFO and the fishing industry are important to the commercial fisheries in determining stock status. In a given year, there will be spatial overlap between the Study Area and research surveys in NAFO Divisions 3KLNOPs.

The tentative schedule of DFO RV surveys in the Study Area in 2018 is indicated in Table 4.13. Spring surveys within the Study Area are scheduled to commence 31 March and continue until 5 June. Fall RV surveys are set to occur in the Study Area from 12 September until 19 December.

Table 4.13   Tentative 2018 Schedule of DFO RV Surveys in the Study Area Vicinity.

NAFO Division	Start Date	End Date	Vessel
3P	31 March	12 April	*Needler*
3P	12 April	24 April	*Needler*
3P + 3O	25 April	8 May	*Needler*
3O + 3N	8 May	22 May	*Needler*
3L + 3N	23 May	5 June	*Needler*
3O	12 September	25 September	*Needler*
3O + 3N	25 September	9 October	*Needler*
3N + 3L	10 October	23 October	*Needler*
3L	23 October	6 November	*Needler*
3K + 3L	7 November	20 November	*Needler*
3K	20 November	4 December	*Teleost*
3K	5 December	19 December	*Teleost*

Note: Start/end dates subject to change as trip plans are finalized (D. Power, DFO, NAFO Senior Science Advisor/Coordinator, Science Branch, pers. comm., 31 January 2018).

Members of the FFAW have been involved in a DFO-industry collaborative post-season snow crab trap survey annually since 2003. This survey is intended to "allow the fishing industry to more accurately assess and ultimately better manage the valuable snow crab resource" (FFAW|Unifor 2017). Data from these surveys are incorporated into the scientific assessment of snow crab and as a result, harvesters and managers have improved partnership and higher confidence in the accuracy of recent stock status assessments (FFAW|Unifor 2017).

The post-season snow crab survey typically occurs between early-September and November. The annual snow crab TAC for this survey was 350 mt during the 2015 and 2016 seasons (DFO 2016f), and 470 mt during 2017. The station locations remained consistent from year to year up to and including the 2016 survey year. The total number of stations increased to 1,316 in 2017, occurring in NAFO Divisions 2J3KLOPs. Of these, 431 stations occur in the Project Area and within 30 km of the Project Area (i.e., spatial buffer for the stations) (369 in Project Area; 62 within 30 km of Project Area). The survey station locations in relation to the Study and Project Areas are shown in Figure 4.35. All of the stations will not necessarily be sampled during a given year; rather, the new plan by DFO is to randomize the survey locations within each NAFO Division (N. Paddy, PGS, Contract Manager, pers. comm., 11 February 2017).
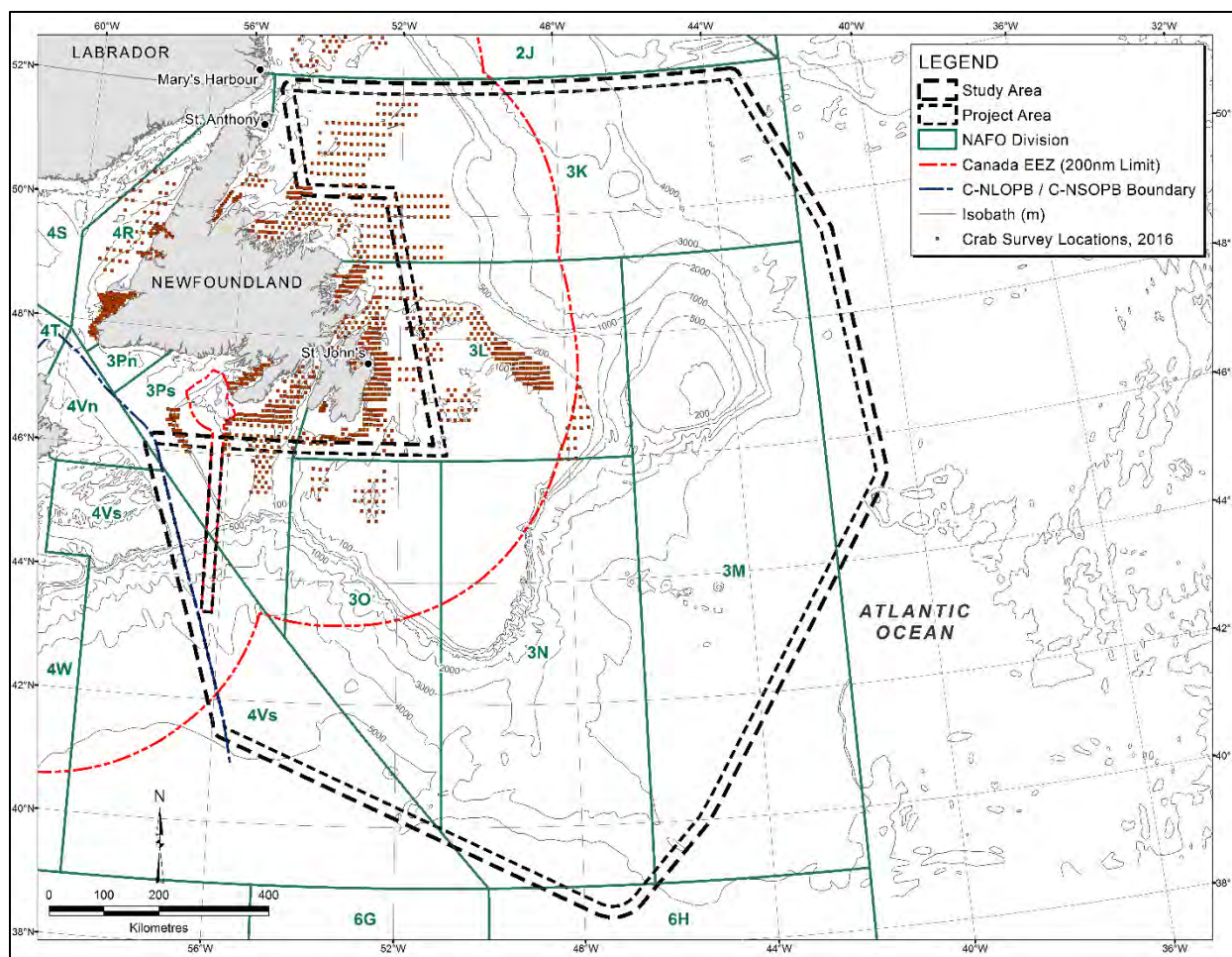
Figure 4.35 Locations of DFO-Industry Collaborative Post-Season Snow Crab Trap Survey Stations in relation to the Study Area and Project Area.

4.3.9 Data Gaps associated with the Fisheries VEC

The following data gaps associated with the Fisheries VEC were identified in the Eastern Newfoundland SEA (§ 6.1.6 of C-NLOPB 2014).

- DFO datasets are known not to be entirely comprehensive, particularly with regard to important inshore fisheries.

The following data gaps associated with the Fisheries VEC were identified in the Southern Newfoundland SEA (§3.3.6 of C-NLOPB 2010).

- DFO data related to certain inshore fisheries (e.g., lobster) are lacking; and
- Data related to foreign fisheries outside the 200 nm limit have poor spatial resolution. These data are currently only available on a NAFO Division basis.

In addition to the data gaps identified in the two SEAs, as of 2011, DFO commercial fishery landings data are no longer provided as empirical data, but rather as quartile ranges of landed catch weight and value for 6' x 6' grid cells. There is also uncertainty regarding the spatial and/or temporal extent of potential reduction in catch rates of shrimp and groundfish species associated with nearby seismic activity, a concern reported by stakeholders during consultations for the original EA (e.g., see questions from Mary's Harbour, Appendix A *in* LGL 2017a).

All of the above data gaps still exist, although efforts are being put forth for upcoming seasons to improve the gathering of data regarding recreational fisheries in Newfoundland and Labrador by implementing a licence and tag regime for all recreational fishery participants (see § 4.3.5), and post-season snow crab survey data will be altered through randomization of survey stations to be sampled as of 2017 (see § 4.3.8).

Although filling these data gaps could result in changes to the data presented in § 4.3, it is unlikely that increased data accuracy would alter the overall results, such as predominant species caught within the Study Area. As such, these data gaps are unlikely to limit the assessment of potential interactions between the Project and the Fisheries VEC. MKI will revise the Fisheries VEC and associated assessments as needed as new fisheries data become available, and will reflect these changes in future EA Updates.

4.4 Marine-associated Bird VEC

The Marine-associated Bird VEC of the Study Area has been described in the Eastern Newfoundland SEA (§ 4.2.2 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 3.4 of C-NLOPB 2010), and three project-specific EAs (§ 4.4 of LGL 2015a,b, 2016). An overview of the marine-associated birds of the Study Area, based on the aforementioned documents, is provided below. Newly available information since publication of the SEAs and EAs is also summarized. Data gaps regarding marine-associated birds identified in the two SEAs are reviewed in terms of current status.

Pelagic seabird abundance data in the shelf areas off Newfoundland are available from the ECCC-CWS programme intégré de recherches sur les oiseaux pélagiques (PIROP) shipboard surveys conducted during 1967–1994 (Lock et al. 1994). The more recent (2006–2009) ECCC-CWS Eastern Canadian Seabirds at Sea (ECSAS) survey program sampled areas off eastern and southern Newfoundland (Fifield et al. 2009).

Since the late 1990s, seabird observations have been collected on the northeast Grand Banks by the offshore oil and gas industry from drill platforms and supply vessels (Baillie et al. 2005; Burke et al. 2005; Fifield et al. 2009). Reports on seabird surveys conducted from vessels associated with geophysical surveys in the Study Area during 2004–2008 are available (Moulton et al. 2005, 2006a; Lang et al. 2006; Lang 2007; Lang and Moulton 2008; Abgrall et al. 2008a,b, 2009). The most current census data related to important seabird nesting colonies in

Newfoundland have been acquired from the ECCC-CWS and are incorporated into this EA (Sabina Wilhelm, ECCC-CWS, unpublished data, December 2017).

The Study Area encompasses a wide range of marine habitats extending from the Northeast Newfoundland Shelf to the deep water south of the Grand Banks of Newfoundland. Seabirds tend to concentrate over oceanographic features such as continental shelf edges and convergences of warm and cold currents, both of which occur in the Study Area. The Labrador Current running southward along the edge of continental shelf edge from the northern tip of Labrador to the northern Grand Banks creates areas of upwelling and water mixing that brings mineral nutrients to the surface, thereby resulting in high phytoplankton productivity which forms the basis for increased productivity at higher trophic levels (e.g., seabirds). South of Flemish Cap and the Grand Banks, the Gulf Stream meets the Labrador Current, causing more mixing of different water types and potentially rich zones for marine productivity. A summary of the marine bird life in the Study Area can be found in § 4.4 of LGL (2016).

The winter distribution of the Ivory Gull (*Pagophila eburnea*), a species with *endangered* status under Schedule 1 of *SARA*, COSEWIC, and the Newfoundland and Labrador *Endangered Species Act*, extends as far south as approximately 50°N (Spencer et al. 2016). Ivory Gull occurs in the Study Area mainly outside the time frame of the proposed seismic survey period (i.e., May–November) (Spencer et al. 2016). This species is typically associated with pack ice, which will be avoided during seismic exploration. Harlequin Duck (*Histrionicus histrionicus*) and Barrow's Goldeneye (*Bucephala islandica*) eastern population moult and stage at some sites along the Labrador coast and around islands off the Labrador coast. Both species have *special concern* status under Schedule 1 of *SARA* and COSEWIC. Typically they occur outside the Study Area close to shorelines of the coast or coastal islands, but may also occur incidentally in the Study Area during migration. Other species of conservation interest that may rarely occur in the Study Area during migration are Piping Plover (*Charadrius melodus*), Red Knot *rufa* subspecies (*Calidris canutus rufa*), Common Nighthawk (*Chordeiles minor*), Olive-sided Flycatcher (*Contopus cooperi*), and Red Crossbill *percna* subspecies (*Loxia curvirostra percna*). Details on Barrow's Goldeneye and Harlequin Duck are in § 4.4.2.1 of LGL (2016) while Ivory Gull is discussed in § 4.6 of LGL (2016). Shorebirds and other species found on the coast but not in the Study Area are not discussed in detail in this EA.

4.4.1   Seasonal Occurrence and Abundance

The global range, seasonal occurrence and seasonal abundance of seabirds occurring regularly in the Study Area are described below. Table 4.14 summarizes the predicted monthly abundance status for each species in the Study Area. The following four categories that qualitatively define the relative abundance of seabirds are used.

1)   Common: likely present daily in moderate to high numbers;
2)   Uncommon: likely present daily in small numbers;

3) Scarce: likely present regularly in very small numbers; and
4) Rare: usually absent, individuals occasionally present.

Table 4.14   Monthly Occurrences and Abundances of Pelagic Seabirds in Offshore Newfoundland and South of Grand Banks (38°N to 52°N).

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

Sources: Brown (1986); Lock et al. (1994); Baillie et al. (2005); Moulton et al. (2005, 2006a,b); Lang et al. (2006); Lang (2007); Lang and Moulton (2008); Abgrall et al. (2008a,b, 2009).

Notes: * Breeds in Newfoundland and Labrador.

[1] Abundance definitions valid for at least part of Study Area but not necessarily the whole Study Area. C=common - likely present daily in moderate to high numbers; U=uncommon - likely present daily in small numbers; S=scarce - likely present regularly in very small numbers; R=rare - usually absent, individuals occasionally present. 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, Jeanne d'Arc Basin, Laurentian Sub-basin and extrapolation of marine bird distribution at sea in eastern Canada in Brown (1986); Lock et al. (1994) and Fifield et al. (2009).

Seasonal occurrence and abundance information was derived from Brown (1986), Lock et al. (1994), Baillie et al. (2005), Moulton et al. (2005, 2006a,b), Lang et al. (2006), Lang (2007), Abgrall et al. (2008a,b), and Fifield et al. (2009).

There are 30 species of marine-associated birds occurring regularly on the east and south coast of Newfoundland (see Table 4.14). Large numbers of seabirds occur in parts of the Study Area at all times of the year.

4.4.2   Breeding Seabirds in Newfoundland and Labrador

There are seabird breeding colonies of worldwide significance in eastern Newfoundland (Table 4.15). Over 4 million pairs of seabirds nest on the southeast coast of Newfoundland alone. These include 2.8 million pairs of Leach's Storm-Petrels and 796,000 pairs of Common Murres (Table 4.15). Funk Island, Baccalieu Island, and the Witless Bay are the largest seabird breeding colonies in Atlantic Canada. More than 3.4 million pairs of seabirds nest at these three locations alone (Table 4.15). These include the largest Atlantic Canadian colonies of Leach's Storm-petrel (2.02 million pairs on Baccalieu Island), Common Murre (470,000 pairs on Funk Island), Black-legged Kittiwake (13,950 pairs on Witless Bay Islands), and Atlantic Puffin (324,650 pairs on Witless Bay Islands). These birds use the Study Area during their breeding season. After the nesting season, seabirds disperse over a wider area of the Newfoundland and Labrador offshore area, including most of the Study Area. Large numbers of seabirds that did not nest in Newfoundland and Labrador also spend part of their non-breeding season within the Study Area. Several million Great Shearwater and Sooty Shearwater migrate from breeding islands in the South Atlantic and occur in the waters offshore Newfoundland and Labrador in summer. Many of the 3.8 million Thick-billed Murres breeding in the eastern Canadian Arctic as well as up to 10 million Dovekies from Greenland either winter in the Labrador Sea and Grand Banks or migrate through these areas on the way to the continental shelf waters of Nova Scotia and areas farther south. Large numbers of sub-adults of Northern Fulmar and Black-legged Kittiwake from breeding colonies in the eastern Arctic and Europe spend the early parts of their lives in the Labrador Sea.

Important Bird Areas (IBAs) form a network of sites that are important to the natural diversity of Canadian bird species and are critical for the long-term viability of naturally occurring bird populations. The Canadian IBA program (www.ibacanada.ca) was launched in 1996 by BirdLife International partners Bird Studies Canada and the Canadian Nature Federation (now Nature Canada). The goal of the IBA program is to ensure the conservation of sites through the development and implementation of conservation plans in partnership with local stakeholders for priority IBAs. There are 25 IBAs along the north, east, and southeast coasts of Newfoundland. Figures 4.110 in C-NLOPB (2014) and 3.69 in C-NLOPB (2010) show the IBA locations in and proximate to the Study Area.

The following subsections address the distribution and abundance of the various regularly occurring species of marine-associated birds in the Study Area.

Table 4.15   Number of Pairs of Seabirds Nesting at Colonies in Northern and Eastern Newfoundland (52°N to 46°N).

Species	Northern Groais Island	Wadham Islands	Funk Island	Cape Freels/Cabot Island	Baccalieu Island	Witless Bay Islands	Mistaken Point	Cape St. Mary's	Middle Lawn Island	Corbin Island	Green Island	Grand Colombier Island	Miquelon Cape
Northern Fulmar	-	-	6[a]	-	-	60[a]	-	Present[a]	-	-	-		
Manx Shearwater	-	200[a]	-	250[a]	-	-	-	-	7[c]	-	-		
Leach's Storm-Petrel	-	-	10,159[a]	-	2,022,000[a,b]	314,020[a]	-	-	8,773[a]	100,000[b]	48,000[a]	363,787[e]	
Northern Gannet	-	-	150[a]	-	3,092[a]	-	-	13,515[a]	-	-	-		
Herring Gull	-	-	-	-	46[a]	2,266[a]	-	39[b]	20[b]	50[b]	Present[b]	60[f]	265[d]
Great Black-backed Gull	-	-	75[a]	-	2[a]	15[a]	-	Present[b]	6[b]	25[b]	-	10[f]	
Black-legged Kittiwake	1,050[g]	-	95[a]	-	5,096[a]	11,787[a]	4,170[f]	10,000[b]	-	50[b]	-	196[f]	2,415[d]
Arctic and Common Terns	-	22[g]	-	250[a]	-	-	-	-	-	-	Present[b]		
Common Murre	-	-	472,259[g]	9,897[a]	1,440[a]	252,667[a]	84[b]	15,484[a]	-	-	-	7,176[h]	
Thick-billed Murre	-	-	250[a]	-	73[a]	240[a]	-	1,000[f]	-	-	-		
Razorbill	-	273[k]	200[a]	25[a]	406[a]	846[a]	22[f]	100[b]	-	-	-	1,443[h]	
Black Guillemot	-	50[a]	1[b]	-	113[a]	20[a]	Present[b]	Present[b]	-	-	-	95[i]	Present[d]
Atlantic Puffin	-	6,190[k]	2,000[a]	20[a]	75,000[f]	304,042[a,j]	79[f]	-	-	-	-	9,543[i]	
TOTALS	**1,050**	**6,735**	**485,195**	**10,442**	**2,107,268**	**885,963**	**4,355**	**40,138**	**8,806**	**100,125**	**48,000**	**382,310**	**2,680**

Sources: [a] EC-CWS unpublished data, [b] Wilhelm et al., submitted; [c] Fraser et al. (2013); [d] Cairns et al. (1989); [e] Lormée et al. (2012); [f] Parks and Natural Areas Division, unpublished data; [g] Thomas et al. (2014a); [h] Lormée et al. (2015); [i] Lormée (2008); [j] Wilhelm et al. (2015); [k] Robertson and Elliot 2002.

4.4.2.1 Anatidae (Ducks and Geese)

Common Eider nest on the Newfoundland coast and occur during migration and winter in open water along the same coastlines (Lock et al. 1994). Significant numbers of Surf, Black and White-winged Scoters occur on the coast by during spring and fall migration. Barrow's Goldeneye and Harlequin Duck both have *special concern* status under Schedule 1 of *SARA*. Detailed profiles of Barrow's Goldeneye and Harlequin Duck are provided in § 4.4.2.1 of LGL (2016).

Subsection 4.4.2.1 of LGL (2016) provides more information on waterfowl occurrence and abundance in the Study Area.

4.4.2.2 Procellariidae (Fulmarine Petrels and Shearwaters)

Five species of this family occur regularly in the Study Area: (1) Northern Fulmar; (2) Great Shearwater; (3) Cory's Shearwater; (4) Sooty Shearwater; and (5) Manx Shearwater.

Northern Fulmar

Northern Fulmar is expected to be common throughout the Study Area during fall through spring, and uncommon during summer (see Table 4.14). The number of breeding pairs and their breeding locations are indicated in Table 4.15.

Subsections 4.4.4.1 of LGL (2015a) and 4.4.3.2 of LGL (2015b) provide more information on Northern Fulmar occurrence and abundance in the Study Area.

Great Shearwater

Great Shearwater is expected to be common throughout the Study Area during June–October but either uncommon or scarce during May and November (see Table 4.14).

Subsections 4.4.4.1 of LGL (2015a) and 4.4.3.3 of LGL (2015b) provide more information on Great Shearwater occurrence and abundance in the Study Area.

Other Shearwaters

Cory's Shearwater is expected to be scarce in the Study Area during June–September (see Table 4.14).

Sooty Shearwater is expected to be uncommon in the Study Area during June–October and scarce during May and November (see Table 4.14).

Manx Shearwater is expected to be rare in the Study Area during May–October (see Table 4.14). Manx Shearwater breeds at a colony at Middle Lawn Island (see Table 4.15).

Subsections 4.4.4.1 of LGL (2015a) and 4.4.3.3 of LGL (2015b) provide more information on occurrences and abundances of Cory's Shearwater, Sooty Shearwater and Manx Shearwater in the Study Area.

4.4.2.3   Hydrobatidae (Storm-Petrels)

Leach's Storm-Petrel

Leach's Storm-Petrel is expected to be uncommon to common in the Study Area during April, common during May–October, and scarce during November (see Table 4.14). The number of breeding pairs and their breeding locations are indicated in Table 4.15.

More than two million pairs of Leach's Storm-Petrel nested on the Avalon Peninsula in the recent past. Accumulating evidence suggests the population of Newfoundland Leach's Storm-Petrels is experiencing a significant decline. Preliminary results from a 2013 survey of nesting Leach's Storm-Petrel on Baccalieu Island, the largest breeding colony of Leach's Storm-Petrels in the world, give an estimate of just over 2 million pairs, a decline of 40% from the previous survey in 1984 (ECCC-CWS unpublished data). The results of surveys of nesting Leach's Storm-Petrels on Gull Island in the Witless Bay Ecological Reserve indicated a decline from 352,000 breeding pairs in 2001 to 180,000 pairs in 2012, a decrease of 51% (ECCC-CWS unpublished data). A 2015 population estimate update for Green Island, Fortune Bay (next to St. Pierre et Miquelon) was 48,000 pairs (ECCC-CWS unpublished data), down from a previous estimate of 103,833 pairs (Russell 2008). The cause of the Leach's Storm-Petrel population decline has not yet been determined.

Recent studies using geolocators attached to the birds examined the movements of Leach's Storm-Petrel. A bird outfitted with a geolocator in the Gull Island, Newfoundland colony migrated to Cape Verde Islands off the west coast of Africa in early-December, averaging 420 km/day over 12 days of migration (Pollet et al. 2014a). It remained in this area for at least five weeks at which time the transmitter stopped working. A Nova Scotia bird followed a similar track southward but departed in mid-October. It staged for several weeks near the Cape Verde Islands before continuing to the eastern tip of Brazil where it spent the rest of the winter. It migrated north in early-April.

Leach's Storm-Petrels with geolocators have been shown to travel up to 1,015±238 km during foraging trips from nesting colonies to deep waters off of the continental shelf in Nova Scotia (Pollet et al. 2014b). Newfoundland breeders can be expected to travel a similar distance from the Great Island breeding colony (W.A. Montevecchi, Memorial University of Newfoundland, pers. comm., 2016).

Subsections 4.4.4.2 of LGL (2015a) and 4.4.3.4 of LGL (2015b) provide more information on Leach's Storm-Petrel occurrence and abundance in the Study Area.

Wilson's Storm-Petrel

Wilson's Storm-Petrel is expected to be either rare or scarce during June–October in the Study Area (see Table 4.14).

Subsections 4.4.4.2 of LGL (2015a) and 4.4.3.4 of LGL (2015b) provide more information on Wilson's Storm-Petrel occurrence and abundance in the Study Area.

4.4.2.4   Sulidae (Gannets)

Northern Gannet

Northern Gannet is expected to be uncommon in the Study Area during March–October (see Table 4.14). The number of breeding pairs and their breeding locations are indicated in Table 4.15.

Subsections 4.4.4.3 of LGL (2015a) and 4.4.3.5 of LGL (2015b) provide more information on Northern Gannet occurrence and abundance in the Study Area.

4.4.2.5   Phalaropodinae (Phalaropes)

Red and Red-necked Phalarope

Red Phalarope is expected to be rare to scarce in the Study Area during May–October (see Table 4.14). Red-necked Phalarope is expected to be rare in the Study Area during May–October (see Table 4.14).

Subsection 4.4.4.4 of LGL (2015a) provide more information on Red and Red-necked Phalarope occurrences and abundances in the Study Area.

4.4.2.6   Laridae (Gulls and Terns)

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

In the Study Area, Great Black-backed Gull and Herring Gull are expected to be either uncommon or scarce year-round, while Glaucous Gulls are expected to be common during December–April, uncommon during May and November and rare during June (see Table 4.14).

Iceland Gull is expected to be scarce in the Study Area in May and October and common during November–April (see Table 4.14). Lesser Black-backed Gull is expected to be rare in the Study Area during April–December (see Table 4.14).

The numbers of breeding pairs of Herring, Glaucous, and Great Black-backed Gulls and their breeding locations are indicated in Table 4.15.

Subsections 4.4.4.5 of LGL (2015a) and 4.4.3.6 of LGL (2015b) provide more information on the occurrences and abundances of these gull species in the Study Area.

Black-legged Kittiwake

Black-legged Kittiwake is expected to be common during year-round in the Study Area (see Table 4.14). The number of breeding pairs of Black-legged Kittiwake and their breeding locations are indicated in Table 4.15.

Subsections 4.4.4.5 of LGL (2015a) and 4.4.3.6 of LGL (2015b) provide more information on the occurrence and abundance of Black-legged Kittiwake in the Study Area.

Ivory Gull

The Ivory Gull likely occurs in small numbers in the portion of the Study Area north of 50°N during periods when sea ice is present (i.e., late-winter and early-spring). It probably occurs irregularly south of 50°N in the ice pack during heavier ice years. As indicated in Table 4.14, Ivory Gull is expected to be either rare or scarce during January–April in the Study Area, and to not occur during May–November.

The Ivory Gull has *endangered* status under both Schedule 1 of *SARA* and COSEWIC (COSEWIC website 2018). More information on the Ivory Gull is presented in § 4.6 of LGL (2016).

Arctic and Common Tern

Arctic Tern and Common Tern are expected to be scarce and rare, respectively, in the Study Area during May–September (see Table 4.14). Common Tern is less likely to occur in the offshore areas than Arctic Tern. The numbers of breeding pairs of Arctic Tern and Common Tern and their breeding locations are indicated in Table 4.15.

Subsections 4.4.4.5 of LGL (2015a) and 4.4.3.6 of LGL (2015b) provide more information on tern occurrence and abundance in the Study Area.

4.4.2.7 Stercorariidae (Skuas and Jaegers)

Great and South Polar Skua

In the Study Area, Great Skua is expected to be rare during May–November (see Table 4.14). South Polar Skua is expected to be rare during May–October in the Study Area (see Table 4.14).

Subsection 4.4.4.6 of LGL (2015a) provides more information on skua occurrence and abundance in the Study Area.

Pomarine, Parasitic and Long-tailed Jaeger

These species are expected to be scarce or rare in the Study Area during May–November (see Table 4.14); Parasitic Jaeger does not occur in the Study Area during November, and Long-tailed Jaeger does not occur beyond September.

Subsection 4.4.4.6 of LGL (2015a) provides more information on jaeger occurrence and abundance in the Study Area.

4.4.2.8 Alcidae (Dovekie, Murres, Atlantic Puffin, Razorbill, Black Guillemot)

There are six species of alcids that breed in the North Atlantic. All of these, except for Dovekie, nest in large numbers in eastern Newfoundland (see Table 4.15). Dovekie nests primarily in Greenland. Dovekie, Common Murre, Thick-billed Murre, and Atlantic Puffin occur in the Study Area during a large portion of the year. Black Guillemot and Razorbills are more coastal and are expected to be scarce or uncommon within most of the Study Area.

Dovekie

In the Study Area, Dovekie is expected to be uncommon in May, rare during June–August, scarce in September, and common in October and November (see Table 4.14).

Subsections 4.4.4.7 of LGL (2015a) and 4.4.3.7 of LGL (2015b) provide more information on Dovekie occurrence and abundance in the Study Area.

Murres

Since Common Murre and Thick-billed Murre are often difficult to differentiate with certainty at sea, they are often aggregated as "murres" during offshore seabird surveys.

Common Murre is expected to be common in the Study Area year-round (see Table 4.14). Thick-billed Murre is expected to be common in the Study Area during October–May, scarce during June–August, and uncommon during September (see Table 4.14).

Studies using geolocators attached to 19 Thick-billed Murres and 20 Common Murres from five nesting colonies in the Northwest Atlantic revealed that murres exhibit a combination of site fidelity and flexibility during both migration and the winter (McFarlane et al. 2014). During the non-breeding season, Thick-billed Murres occurred in the offshore from Davis Strait south to the Flemish Cap and Southeast Grand Banks. Common Murres occurred off eastern Newfoundland to the Flemish Cap and the Southeast Grand Banks during migration and winter (McFarlane et al. 2014).

The numbers of breeding pairs for each species and their breeding locations are indicated in Table 4.15.

Subsections 4.4.4.7 of LGL (2015a) and 4.4.3.7 of LGL (2015b) provide more information on murre occurrence and abundance in the Study Area.

Atlantic Puffin

Atlantic Puffin is expected to be common in the Study Area year-round (see Table 4.14). The number of breeding pairs and their breeding locations are indicated in Table 4.15.

Subsection 4.4.4.7 of LGL (2015a) provides more information on Atlantic Puffin occurrence and abundance in the Study Area.

Razorbill and Black Guillemot

Razorbill and Black Guillemot are expected to be uncommon and rare, respectively, in the Study Area during May–November (see Table 4.14).

Black Guillemot is expected to be common nearshore in Newfoundland and Labrador. Unlike the other members of the Alcidae, it feeds near shore and is rarely found more than a few kilometres from shore or pack ice. The number of breeding pairs for each species and their breeding locations are indicated in Table 4.15.

Subsection 4.4.4.7 of LGL (2015a) provides more information on Razorbill and Black Guillemot occurrences and abundances in the Study Area.

4.4.3 Prey and Foraging Habits

Seabirds in the Study Area employ a variety of foraging strategies and feed on a variety of prey species. The estimated head submergence time and diving depth of various seabirds are provided in Table 4.16 in § 4.4.3 of LGL (2016).

More details regarding prey and foraging habits of seabirds likely to occur in the Study Area are provided in § 4.4.5 of LGL (2015a), and § 4.4.4 of LGL (2015b).

4.4.4 Marine-associated Bird Data Gaps Identified in Relevant SEAs

The following data gap associated with the Marine-associated Bird VEC was identified in the Eastern Newfoundland SEA (§ 6.1.6 of C-NLOPB 2014).

- Detailed information on the occurrence, abundance and distribution of marine-associated birds is not available for all locations and times in the Study Area.

The following data gaps associated with the Marine-associated Bird VEC were identified in the Southern Newfoundland SEA (§ 3.4.9 of C-NLOPB 2010).

- Knowledge of the offshore distribution and abundance of seabirds is incomplete;
- Seabird data for areas that have been surveyed typically do not cover all seasons;
- Pelagic seabird distribution data are lacking during winter on much of the continental shelf and the deep waters beyond the shelf; and
- Much of the existing data on seabirds are dated.

All of the data gaps indicated above still exist and thus limit the certainty of impact predictions made in § 5.7.6. Opportunistic efforts are being made during geophysical surveys to collect more distribution and abundance data for seabirds.

The ECCC-CWS ECSAS survey program sampled areas off eastern and southern Newfoundland (Fifield et al. 2009).

4.5 Marine Mammals and Sea Turtles VEC

The Marine Mammal and Sea Turtle VEC of the Study Area has been recently described in the Eastern Newfoundland SEA (§ 4.2.3 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 3.5 and 3.6 of C-NLOPB 2010), and three project-specific EAs (§ 4.5 of LGL 2015a,b, 2016). An overview of marine mammals and sea turtles that occur in the Study Area, based primarily on the aforementioned documents, is provided below. New information not included in the SEAs and EAs is also summarized. DFO research and scientific documents and COSEWIC species assessment and status reports also served as primary sources of information on the occurrence,

distribution, and abundance of marine mammals and sea turtles in the Study Area. Historical and more recent sightings of cetaceans and sea turtles within Newfoundland and Labrador waters have been compiled and made available by DFO in St. John's (§ 4.5.1.1). Marine mammal and sea turtle data gaps identified in the two SEAs are also discussed in terms of current status.

4.5.1   Marine Mammals

Twenty-three marine mammal species are known to occur near or within the Study Area, including 19 species of cetaceans (whales, dolphins, and porpoises), and four species of phocids (true seals). Most marine mammals use the area seasonally. The region likely represents important foraging habitat for many marine mammals.

Information on the occurrence, habitat, and conservation status for each of the marine mammal species that could occur near or within the Study Area is presented in Table 4.16. Five cetacean species that have been reported within or near the Study Area (bowhead whale, *Balaena mysticetus*; beluga whale, *Delphinapterus leucas*, pygmy sperm whale, *Kogia breviceps*; false killer whale, *Pseudorca crassidens*; Cuvier's beaked whale, *Ziphius cavirostris*), three pinniped species (ringed seal, *Phoca hispida*; bearded seal, *Erignathus barbatus*; Atlantic walrus, *Odobenus rosmarus rosmarus*), and the polar bear (*Ursus maritimus*) are considered unlikely to occur in the Study Area during the seismic program and are not discussed further.

4.5.1.1   DFO Sightings Database

A large database of cetacean and sea turtle sightings in Newfoundland and Labrador waters has been compiled from various sources by DFO in St. John's (J. Lawson, DFO Research Scientist, pers. comm., January 2017), and has been made available for the purposes of describing species sightings within the Study Area. These data have been opportunistically gathered and have no indication of survey effort. Therefore, while these data can be used to indicate what species may occur in the Study Area, they cannot be used to predict species abundance, distribution, or fine-scale habitat use in the area.

The caveats that should be considered when using data from the DFO sightings database were described in § 4.5.1.1 of LGL (2015a,b).

Cetacean sightings in the Study Area within the temporal boundary of the Project (May–November) compiled from the DFO sightings database (1947–2015) are summarized in Table 4.17. Sightings include baleen whales, large toothed whales, dolphins and porpoises.

4.5.1.2   Baleen Whales (Mysticetes)

Six species of baleen whales are known to occur in the Study Area, three of which occur commonly (Table 4.16). Given that the Atlantic population of blue whale and the North Atlantic right whale each have *endangered* status under Schedule 1 of *SARA*, they are described in § 4.6,

Species at Risk. Although some individual baleen whales may be present in offshore waters of Newfoundland and Labrador year-round, most baleen whale species presumably migrate to lower latitudes during the winter months (C-NLOPB 2014).

Table 4.16   Marine Mammals with Reasonable Likelihood of Occurrence in the Study Area.

Species	Study Area		Habitat	*SARA* Status[a]	COSEWIC Status[b]
	Occurrence	Season			
Baleen Whales (Mysticetes)					
North Atlantic Right Whale (*Eubalaena glacialis*)	Rare	Summer	Coastal, shelf & pelagic	Schedule 1: Endangered	E
Humpback Whale (*Megaptera novaeangliae*) (Western North Atlantic population)	Common	Year-round, but mostly May–Sept	Coastal & banks	Schedule 3: Special Concern	NAR
Minke Whale (*Balaenoptera acutorostrata*)	Common	Year-round, but mostly May–Oct	Coastal, shelf, & banks	NS	NAR
Sei Whale (*B. borealis*)	Uncommon	May–Nov	Pelagic	NS	DD
Fin Whale (*B. physalus*) (Atlantic population)	Common	Year-round, but mostly summer	Shelf breaks, banks & pelagic	Schedule 1: Special Concern	SC
Blue Whale (*B. musculus*)	Uncommon	Year-round	Coastal & pelagic	Schedule 1: Endangered	E
Toothed Whales (Odontocetes)					
Sperm Whale (*Physeter macrocephalus*)	Common	Year-round, but mostly summer	Slope, canyons & pelagic	NS	NAR; MPC
Northern Bottlenose Whale (*Hyperoodon ampullatus*) (Scotian Shelf and Davis Strait-Baffin Bay-Labrador Sea populations)	Uncommon	Year-round	Slope, canyons & pelagic	Schedule 1: Endangered [c] / NS [d]	E [c] / SC [d]
Sowerby's Beaked Whale (*Mesoplodon bidens*)	Rare	Year-round	Slope, canyons & pelagic	Schedule 1: Special Concern	SC
Striped Dolphin (*Stenella coeruleoalba*)	Rare	Summer	Shelf & pelagic	NS	NAR
Atlantic Spotted Dolphin (*Stenella frontalis*)	Rare	Summer	Shelf, slope & pelagic	NS	NAR
Short-beaked Common Dolphin (*Delphinus delphis*)	Common	Summer	Shelf & pelagic	NS	NAR
White-beaked Dolphin (*Lagenorhynchus albirostris*)	Common	Year-round, but mostly June–Sept	Shelf & pelagic	NS	NAR
Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)	Common	Year-round, but mostly summer–fall	Coastal & shelf	NS	NAR
Common Bottlenose Dolphin (*Tursiops truncatus*)	Rare	Summer	Coastal & pelagic	NS	NAR
Risso's Dolphin (*Grampus griseus*)	Rare	Year-round	Continental slope	NS	NAR

Species	Study Area		Habitat	*SARA* Status[a]	COSEWIC Status[b]
	Occurrence	Season			
Killer Whale (*Orcinus orca*) (Northwest Atlantic/Eastern Arctic population)	Uncommon	Year-round	Coastal & pelagic	NS	SC
Long-finned Pilot Whale (*Globicephala melas*)	Common	Year-round, but mostly spring–fall	Shelf break, pelagic & slope	NS	NAR
Harbour Porpoise (*Phocoena phocoena*) (Northwest Atlantic population)	Uncommon	Year-round, but mostly spring–fall	Coastal, shelf & pelagic	Schedule 2: Threatened	SC
True Seals (Phocids)					
Harp Seal (*Pagophilus groenlandicus*)	Common	Year-round, but mostly winter–spring	Pack ice & pelagic	NS	NC; LPC
Hooded Seal (*Cystophora cristata*)	Common	Year-round, but mostly winter–spring	Pack ice & pelagic	NS	NAR; MPC
Grey Seal (*Halichoerus grypus*)	Uncommon	Year-round, but mostly summer	Coastal & shelf	NS	NAR
Harbour Seal (*Phoca vitulina*)	Uncommon	Year-round	Coastal	NS	NAR

[a] Species designation under the Species at Risk Act (*SARA* website 2018); NS = No Status.

[b] Species designation by COSEWIC (Committee on the Status of Endangered Wildlife in Canada; COSEWIC website 2017); E = Endangered, SC = Special Concern, DD = Data Deficient, NAR = Not at Risk, NC = Not Considered, LPC = Low-priority Candidate, MPC = Mid-priority Candidate.

[c] Scotian Shelf population.

[d] Davis Strait-Baffin Bay-Labrador Sea population.

Humpback Whale

Humpbacks are the most commonly recorded mysticete in the Study Area in the DFO sightings database (1,496 sightings; 4,476 individuals). While humpback sightings occur year-round, they are predominant during June–September (Table 4.17; Figure 4.36). Similarly, based on habitat-density modeling for the southwestern region of the Study Area, the U.S. National Oceanic and Atmospheric Administration (NOAA 2018) predicted the highest densities (up to 0.68 whales/100 km^2) from May–November. Modeling by Mannocci et al. (2017) for the summer months showed the highest densities in the southern portion of the Study Area. Humpback whales are expected to be common throughout the Study Area.

Table 4.17   Cetacean Sightings in the Study Area during the Temporal Boundary of the Project (compiled from the DFO sightings database, 1947–2015).

Species	Number of Sightings	Number of Individuals	Months Sighted
Mysticetes			
North Atlantic Right Whale	1	2	Jun
Humpback Whale	1,496	4,476	May–Nov
Minke Whale	396	654	May–Nov
Sei Whale	105	194	May–Nov
Fin Whale	2,164	2,587	May–Nov
Sei/Fin Whale	40	53	May–Sep
Blue Whale	84	109	May–Nov
Bowhead Whale	1	1	May
Unidentified Baleen Whale	305	394	May–Nov
Odontocetes			
Sperm Whale	291	653	May–Nov
Pygmy Sperm Whale	1	2	Jun
Northern Bottlenose Whale	103	329	May–Nov
Sowerby's Beaked Whale	1	4	Sep
Cuvier's Beaked Whale	1	1	Jul
Beluga	2	2	Jul
Striped Dolphin	10	487	Aug–Sep
Atlantic Spotted Dolphin	1	1	Jun
Common Dolphin	271	5,133	Jun–Nov
White-beaked Dolphin	184	1,464	May–Nov
Atlantic White-sided Dolphin	413	6,363	May–Nov
Bottlenose Dolphin	17	150	May–Jun, Aug–Sep
Risso's Dolphin	10	46	Jun–Aug, Nov
False Killer Whale	1	2	Jun
Killer Whale	135	959	May–Nov
Long-finned Pilot Whale	813	12,442	May–Nov
Harbour Porpoise	141	810	May–Nov
Unidentified Dolphin	776	13,872	May–Nov
Unidentified Beaked Whale	2	2	Jun, Sep
Unidentified Toothed Whale	20	53	Jun–Sep
Other			
Unidentified Cetacean	856	2,167	May–Nov

Note: see § 4.3.1.1 for description of DFO sightings database and caveats associated with these data.
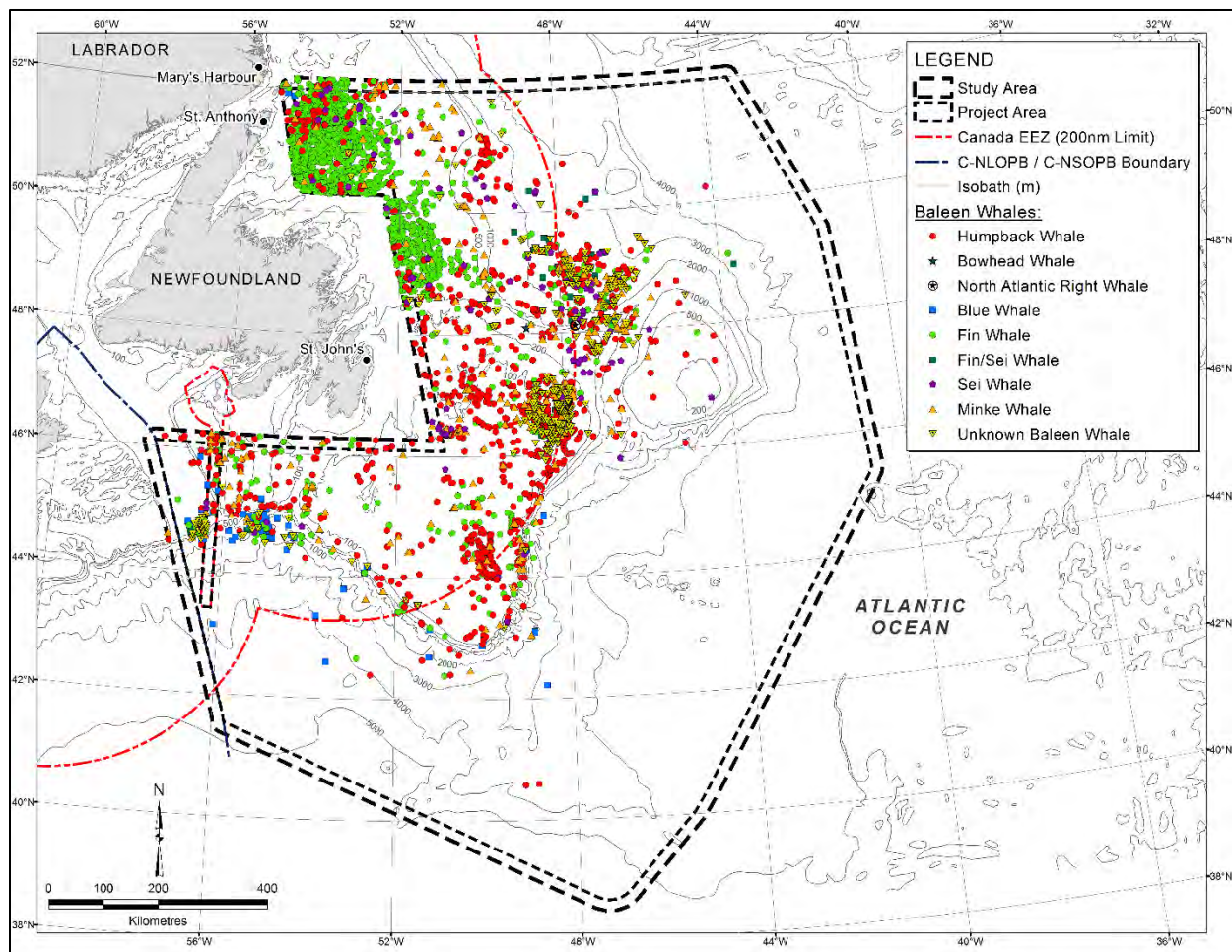
Data source: DFO cetacean sightings database, see text for description of data and caveats associated with these data.

Figure 4.36   Baleen Whale Sightings in the Study Area during May–November (compiled from the DFO sightings database, 1947–2015).

Two humpbacks outfitted with satellite transmitters near the Dominican Republic travelled within the Study Area.   One whale was recorded on the eastern edge of Cabot Strait in May 2011, and a second whale was recorded on the Grand Banks in June 2012 (Kennedy et al. 2014). Humpbacks were also sighted within the Study Area off eastern Newfoundland and in the southern Laurentian Channel during July 2012 (Ryan et al. 2013). In addition, sightings were made off the northeast coast of Newfoundland, just to the west of the Study Area, during 2000–2011 (Davoren 2013). Humpback whales have also been sighted off the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014).

Minke Whale

The minke whale is the third most commonly recorded mysticete in the Study Area in the DFO sightings database (396 sightings; 654 individuals), with most sightings recorded during June–September (see Table 4.17; Figure 4.36). Similarly, based on habitat-density modeling for

the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (up to 3.2 whales/100 km^2) from June–November. Modeling by Mannocci et al. (2017) showed the highest year-round densities in the southern portion of the Study Area. Minke whales are considered common throughout the Study Area.

Minke whales were commonly recorded in Jeanne d'Arc Basin during seismic monitoring programs in 2008, 2013, and 2015 (Abgrall et al. 2009; Holst and Lang 2014; Keats 2015). Minke whales were also sighted within the Study Area off southern Newfoundland, eastern Newfoundland, and south of the Grand Banks during July 2012 (Ryan et al. 2013). In addition, sightings were made during surveys off the northeastern coast of Newfoundland, just to the west of the Study Area, during 2000 and 2007–2011 (Davoren 2013). Minke whales have also been sighted along the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014). Whitehead (2013) reported one sighting in Haldimand Canyon at the edge of the Scotian Shelf near the Study Area between 1988 and 2012.

Sei Whale

Based on the DFO sightings database, there have been at least 105 sightings (194 individuals) of sei whales in the Study Area; sightings occurred mainly during June–September (see Table 4.17; Figure 4.36). Based on habitat-density modeling for the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (~1 whale/100 km^2) from July–September. Habitat-density modeling for the summer by Mannocci et al. (2017) showed that sei whales are likely to occur throughout the Study Area. Nonetheless, sei whales are considered uncommon in the Study Area.

Sei whales were occasionally sighted in the Orphan Basin during the seismic monitoring programs in 2004 and 2005 (6 and 15 sightings, respectively; Moulton et al. 2005, 2006a). One sei whale sighting was recorded in Jeanne d'Arc Basin during seismic monitoring programs in 2008 and 2013 (Abgrall et al. 2009; Holst and Lang 2014). In addition, one sei whale was observed off southern Newfoundland during a summer 2007 aerial survey (Lawson and Gosselin 2009). A sei whale that was tagged in the Azores during 2005 (Olsen et al. 2009) and seven individuals that were tagged in the Azores during 2008–2009 travelled to the Labrador Sea, where they spent extended periods of time on the northern shelf, presumably to feed (Prieto et al. 2010, 2014). Sei whales were sighted off the northeastern coast of Newfoundland, just to the west of the Study Area, during surveys in 2000–2002 (Davoren 2013). Sei whales have also been seen off the northeastern edge of the Scotian Shelf near or within the Study Area (Gomez-Salazar and Moors-Murphy 2014). Whitehead (2013) reported two sightings in Haldimand Canyon at the edge of the Scotian Shelf near the Study Area between 1988 and 2012.

Fin Whale

The Atlantic population of fin whale currently has a *special concern* status under Schedule 1 of *SARA* (*SARA* website 2018) and COSEWIC (COSEWIC 2005), and a management plan was released in 2017 (DFO 2017b). Delarue et al. (2014) suggested that there are four distinct stocks in the NW Atlantic based on geographic differences in fin whale calls.

Fin whales are the second most commonly recorded mysticete in the Study Area in the DFO sightings database (2,587 individuals), with most sightings occurring during June–October (see Table 4.17; Figure 4.36). Similarly, according to Edwards et al. (2015), highest densities of fin whales occur in offshore waters off Newfoundland during June–August. Based on habitat-density modeling in the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (up to 3.2 whales/100 km^2) from May–December. Modeling by Mannocci et al. (2017) showed the highest year-round densities in the southern portion of the Study Area. Fin whales are expected to be common throughout the Study Area during late-spring to fall.

Fin whales were commonly observed in the Orphan Basin during 2004 and 2005 seismic monitoring programs (Moulton et al. 2005, 2006a) and during seismic monitoring programs in Jeanne d'Arc Basin in 2008 and 2013 (Abgrall et al. 2009; Holst and Lang 2014). Fin whales were also seen within the Study Area south of the Grand Banks during July 2012 (Ryan et al. 2013). In addition, sightings were made during surveys off the northeastern coast of Newfoundland, just to the west of the Study Area, during 2000 and 2009–2011 (Davoren 2013). Fin whales have also been sighted off the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014). Whitehead (2013) reported three sightings in Haldimand Canyon and four in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, during 1988–2012.

4.5.1.3 Toothed Whales (Odontocetes)

Thirteen species of toothed whales are likely to occur in the Study Area (see Tables 4.16–4.17), ranging from the largest, the sperm whale, to one of the smallest, the harbour porpoise. Several of these species only occur in the Study Area seasonally, but in general, there is little information about the distribution and abundance of these species. Two genetically distinct populations of northern bottlenose whales have been identified in Canada (Dalebout et al. 2006). The Scotian Shelf population of northern bottlenose whale has *endangered* status under Schedule 1 of *SARA*, and its profile is included in § 4.6, Species at Risk. The Davis Strait-Baffin Bay-Labrador Sea population of northern bottlenose whales could also occur in the Study Area.

Sperm Whale

There are 291 sightings (653 individuals) of sperm whales in the Study Area in the DFO sightings database for May–November, but sightings occur year-round (see Table 4.17; Figure 4.37). Based on habitat-density modeling for the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (~3.2 whales/100 km^2) from June–October. Mannocci et al. (2017) presented modeled year-round densities of sperm whales, with higher densities occurring in deep, offshore waters of the Study Area. Sperm whales are expected to be common in deep waters of the Study Area.

Sperm whales were regularly sighted in the deep waters of the Orphan Basin during the summers of 2004–2007 (Moulton et al. 2005, 2006a; Abgrall et al. 2008c), but were not observed in the shallower waters of Jeanne d'Arc Basin in 2005–2008, 2013, or 2015 (Lang et al. 2006; Lang and Moulton 2008; Abgrall et al. 2008a, 2009; Holst and Lang 2014; Keats 2015). There were two sightings in the Flemish Pass Basin during a monitoring program in 2014 (Thomas et al. 2014b). Sperm whales were observed in small numbers (11 sightings of single individuals) off eastern and southern Newfoundland during aerial surveys conducted in the summer of 2007 (Lawson and Gosselin 2009). Sperm whales have also been sighted in Shortland Canyon at the edge of the Scotian Shelf near the Study Area (Gomez-Salazar and Moors-Murphy 2014).

Northern Bottlenose Whale

The Davis Strait-Baffin Bay-Labrador Sea population of northern bottlenose whale has no status under *SARA* (*SARA* website 2018) and *special concern* status under COSEWIC (COSEWIC 2011); there is no reliable population estimate. Profiles of the northern bottlenose whale are provided in § 4.6.1.3 of LGL (2015a,b).

Northern bottlenose whales are expected to be uncommon in the Study Area (see Table 4.16 in § 4.5). There are 103 sightings (329 individuals) of northern bottlenose whales in the Study Area in the DFO sightings database. These sightings occurred primarily in the deeper waters and near the shelf break (Harris et al. 2013) during May–August (see Table 4.17 and Figure 4.37 in § 4.5).

Preliminary photo-ID work has found that at least 78 different animals occurred in the Grand Banks, Flemish Pass, and Flemish Cap area during 2016–2017 (L.J. Feyrer, Ph.D. Candidate, Dalhousie University, pers. comm., 5 February 2018). Although genetic and other tissue analyses are underway at Dalhousie University based on samples collected from some of those individuals, results are not yet available to elucidate whether animals in that area were from the Scotian Shelf or Davis Strait-Baffin Bay-Labrador Sea populations (L.J. Feyrer, Ph.D. Candidate, Dalhousie University, pers. comm., 5 February 2018).

Sowerby's Beaked Whale

Sowerby's beaked whale has a *special concern* status under Schedule 1 of *SARA* (*SARA* website 2018) and COSEWIC (COSEWIC 2006), and a management plan was released in 2017 (DFO 2017c). It is considered rare in the Study Area.

There is one sighting of four Sowerby's beaked whales in the Study Area in the DFO sightings database for May–November (see Table 4.17; Figure 4.37). The sighting of four individuals was made during a seismic survey in Orphan Basin in September 2005 (Moulton et al. 2006a). There are also several stranding records for Newfoundland and Labrador (DFO 2017c).
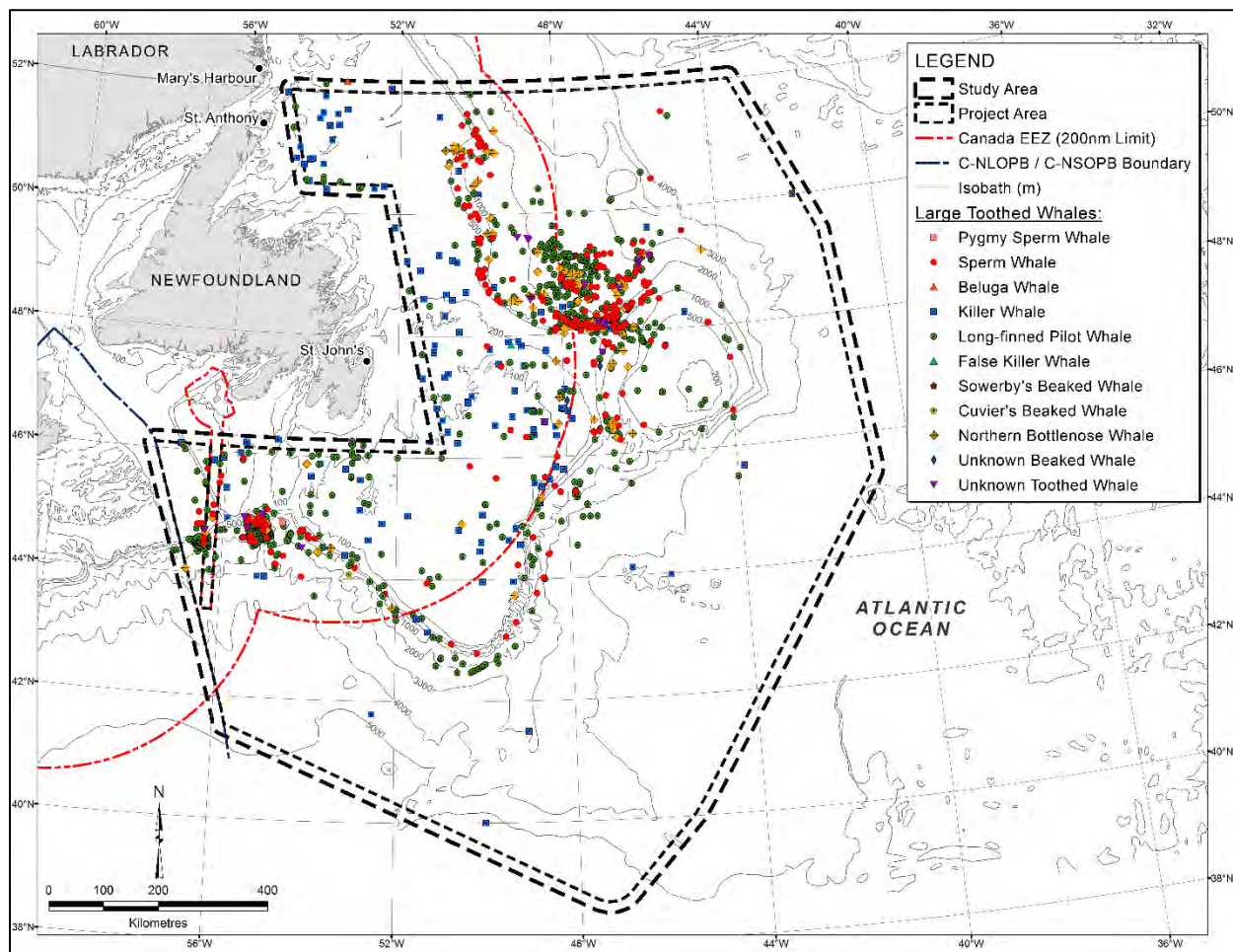
Data source: DFO cetacean sightings database, see text for description and caveats associated with these data.

Figure 4.37   Toothed Whale Sightings in the Study Area during May–November (compiled from the DFO sightings database, 1947–2015).

Whitehead (2013) reported a significant increase in Sowerby's beaked whale sightings in the Gully, on the edge of the Scotian Shelf, from 1988–2011; 30 sightings were made in Haldimand Canyon and 12 in Shortland Canyon, near the Study Area.

Striped Dolphin

Based on the DFO sightings database, there are 10 sightings (487 individuals) of striped dolphins in the Study Area. All sightings occurred in August and September (see Table 4.17; Figure 4.38). Mannocci et al. (2017) also reported on the occurrence of striped dolphins in deep, offshore waters of the Study Area, with highest densities generally occurring in the southern portion. Based on habitat-density modeling NOAA (2018) predicted a density of up to 68 striped dolphins/100 km^2 in the southwestern region of the Study Area.
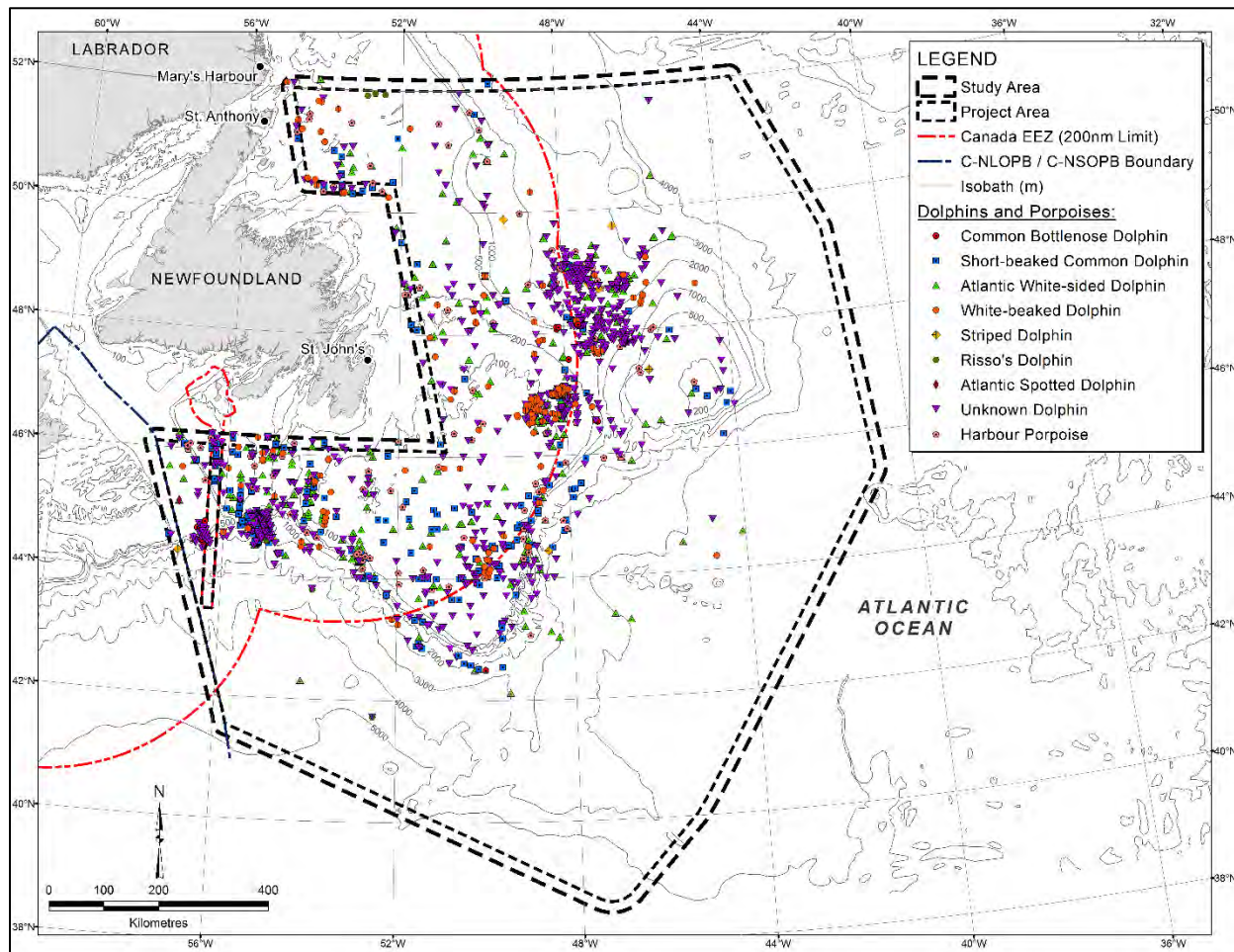
Data source: DFO cetacean sightings database, see text for description and caveats associated with these data.

Figure 4.38   Dolphin and Porpoise Sightings in the Study Area during May–November (compiled from the DFO sightings database, 1947–2015).

Whitehead (2013) reported six sightings in Haldimand Canyon and six in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, during 1988–2012. Nonetheless, striped dolphins are considered rare in the rest of the Study Area.

Atlantic Spotted Dolphin

Based on the DFO sightings database, a single sighting of an Atlantic spotted dolphin was made in the Laurentian Channel within the Study Area during June 2007. Neither Whitehead (2013) nor Gomez-Salazar and Moors-Murphy (2014) reported any sightings along the edge of the Scotian Shelf near the Study Area. However, Mannocci et al. (2017) reported relatively high densities (up to 40 individuals/100 km^2) in the southern portion of the Study Area. Atlantic spotted dolphins are considered rare in the rest of the Study Area.

Short-beaked Common Dolphin

Based on the DFO sightings database, there are 271 sightings (5,133 individuals) of short-beaked common dolphins in the Study Area; sightings were reported in shelf, upper slope and deep-water regions (see Table 4.17; Figure 4.38). Most sightings occurred during July–September (see Table 4.17). Similarly, based on habitat-density modeling for the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (~100 common dolphins/100 km^2) from June–November. Mannocci et al. (2017) presented modeled year-round densities of short-beaked common dolphins for Study Area, with higher densities in deep, offshore waters. The short-beaked common dolphin is considered common in the Study Area.

Common dolphins have been sighted along the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014). Whitehead (2013) reported nine sightings in Haldimand Canyon and 10 in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, during 1988–2012.

White-beaked Dolphin

Based on the DFO sightings database, there are 184 sightings (1,464 individuals) of white-beaked dolphins in the Study Area. Most sightings occurred during June–August (see Table 4.17; Figure 4.38). The white-beaked dolphin is considered common in the Study Area. White-beaked dolphins were sighted during surveys off the northeast coast of Newfoundland, just to the west of the Study Area, during 2000–2011 (Davoren 2013).

Atlantic White-sided Dolphin

Based on the DFO sightings database, there are 413 sightings (6,363 individuals) of white-sided dolphins in the Study Area. Sightings occurred primarily during July–August (see Table 4.17; Figure 4.38). Based on habitat-density modeling for the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (up to ~10 dolphins/100 km^2) from May–December. Based on modeling by Mannocci et al. (2017), higher year-round densities

likely occur in the southern portion of the Study Area. The Atlantic white-sided dolphin is considered common in the Study Area.

Atlantic white-sided dolphins were sighted during surveys off the northeast coast of Newfoundland, just to the west of the Study Area, during 2000–2011 (Davoren 2013). Atlantic white-sided dolphins have also been sighted along and off the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014). In addition, Whitehead (2013) reported four sightings in Haldimand Canyon, at the edge of the Scotian Shelf near the Study Area, during 1988–2012.

Common Bottlenose Dolphin

Two morphologically and genetically distinct stocks of common bottlenose dolphins occur in the NW Atlantic, referred to as the coastal and offshore forms (Hoelzel et al. 1998). There are 17 bottlenose dolphin sightings (150 individuals) in the Study Area in the DFO cetacean sighting database. They occurred during May–June and August–October (see Table 4.17; Figure 4.38). Mannocci et al. (2017) reported low densities (<6 dolphins/100 km^2) in deep, offshore waters of the southern Study Area. Based on habitat-density modeling for the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (up to ~15 dolphins/100 km^2) from May–December. The common bottlenose dolphin is considered rare in the rest of the Study Area. South of Newfoundland, they have been sighted in the Laurentian Channel within the Study Area (Gomez-Salazar and Moors-Murphy 2014). In addition, Whitehead (2013) reported one sighting in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, between 1988 and 2012.

Risso's Dolphin

There are 10 sightings (46 individuals) of Risso's dolphins in the Study Area in the DFO sightings database; sightings occurred during July–August and October–November (see Table 4.17; Figure 4.38). Jefferson et al. (2014) also reported on the occurrence of Risso's dolphins off Newfoundland and Labrador and Nova Scotia. Based on habitat-density modeling for the southwestern region of the Study Area, NOAA (2018) predicted the highest densities (up to ~6.8 dolphins/100 km^2) during June–December. Mannocci et al. (2017) predicted the highest densities in the deeper, offshore waters of the Study Area. Risso's dolphins are considered rare in the Study Area. Nonetheless, Risso's dolphins have been sighted off the northeastern edge of the Scotian Shelf near the Study Area (Gomez-Salazar and Moors-Murphy 2014). Whitehead (2013) also reported one sighting in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, between 1988 and 2012.

Killer Whale

Based on the DFO sightings database, there are 135 sightings (959 individuals) of killer whales in the Study Area (see Table 4.17; Figure 4.37). Most sightings off Newfoundland and Labrador occurred during May–September (see Table 4.17; Lawson and Stevens 2013). High scarring rates on humpback whales indicate that killer whales may preferentially feed on marine mammals off Newfoundland (McCordic et al. 2014). Killer whales are considered uncommon in the Study Area.

Sightings of killer whales were recorded in Jeanne d'Arc Basin during seismic monitoring programs in 2008, 2013 and 2015 (Abgrall et al. 2009; Holst and Lang 2014; Keats 2015). One sighting was also recorded in the Flemish Pass during a seismic monitoring program in 2014 (Thomas et al. 2014b). In addition, killer whales were sighted off northeastern Newfoundland, just to the west of the Study Area, during 2000–2002 (Davoren 2013). At least one sighting has been made off the northeastern edge of the Scotian Shelf near the Study Area (Gomez-Salazar and Moors-Murphy 2014).

Long-finned Pilot Whale

Long-finned pilot whales are the most commonly recorded odontocete (12,442 individuals) in the Study Area in the DFO sightings database (see Table 4.17; Figure 4.37); sightings have been reported year-round but predominantly during July and August. Long-finned pilot whales are considered common in the Study Area. Mannocci et al. (2017) modeled year-round densities of pilot whales off Nova Scotia and Newfoundland and Labrador, showing the highest densities in deeper, offshore areas. Long-finned pilot whales have been sighted off the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014). In addition, Whitehead (2013) reported 15 sightings in Haldimand Canyon and 26 in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, during 1988–2012.

Harbour Porpoise

Based on the DFO sightings database, there are 141 sightings (810 individuals) of harbour porpoises in the Study Area. While sightings are reported year-round, the majority occurred from May–August (see Table 4.17; Figure 4.38). Harbour porpoises are generally considered uncommon in the offshore regions of the Study Area, although Mannocci et al. (2017) reported relatively high densities in offshore and nearshore waters of Nova Scotia and Newfoundland and Labrador. In addition, harbour porpoises were detected acoustically in the Study Area off the east coast of Newfoundland during July 2012 (Ryan et al. 2013). Sightings were also made off northeastern Newfoundland, just to the west of the Study Area, during 2000–2002 (Davoren 2013).

4.5.1.4 True Seals (Phocids)

Four seal species occur in the Study Area (see Table 4.16). Given their preference for nearshore areas, grey and harbour seals are likely to be uncommon in the Study Area. The 2014 grey seal population was estimated at 505,000 individuals (Hammill et al. 2014). The 2012 estimate for harbour seals in New England was 75,834 individuals (Waring et al. 2015). The NW Atlantic harp seal population appears to have levelled off since 2008 at ~7.4 million (Hammill et al. 2015). Declines in sea ice associated with climate change may cause harp seals to use whelping areas farther to the north (Stenson and Hammill 2014).

Hooded seals are also likely to be uncommon in the Study Area during the summer and fall when seismic operations will likely occur. However, during spring and late-fall/winter, hooded seals outfitted with satellite relay data loggers showed movements throughout the Study Area during 2004–2008 (Andersen et al. 2012, 2013, 2014). Andersen et al. (2012) suggested that hooded seals prefer areas with topographic and oceanographic conditions off the coast of Newfoundland that produce good feeding conditions. During autumn/winter, males showed greater search effort in areas with complex seabed relief, including areas in the Flemish Cap; whereas females spent more effort along the Labrador Shelf. Juveniles occurred off the east coast of Newfoundland between the Grand Banks and the Flemish Cap during spring.

4.5.2 Sea Turtles

While four species of sea turtles have been reported in Newfoundland waters, only three are likely to occur in the Study Area. Information on the occurrence, habitat, and conservation status for the leatherback, loggerhead, and green sea turtles in the Study Area is presented in Table 4.18. The fourth species, Kemp's ridley sea turtle (*Lepidochelys kempii*), is unlikely to occur in the Study Area. The leatherback and loggerhead sea turtles have an *endangered* status under Schedule 1 of *SARA* and are included in § 4.6, Species at Risk. Figure 4.39 shows locations of sea turtle sightings in the Study Area, based on the DFO sightings database.

Table 4.18   Sea Turtles with Reasonable Likelihood of Occurrence in the Study Area.

Species	Study Area		Habitat	*SARA* Status[a]	COSEWIC Status[b]
	Occurrence	Season			
Leatherback Sea Turtle (*Dermochelys coriacea*) (Atlantic population)	Rare	April to December	Shelf & pelagic	Schedule 1: Endangered	E
Loggerhead Sea Turtle (*Caretta caretta*)	Rare	Summer and fall	Pelagic	Schedule 1: Endangered	E
Green Sea Turtle (*Chelonia mydas*)	Rare	Summer	Pelagic	NS	NC; LPC

a   Species designation under the *Species at Risk Act* (*SARA* website 2018); NS = No Status.
b   Species designation by COSEWIC (Committee on the Status of Endangered Wildlife in Canada; COSEWIC website 2017); E = Endangered, NC = Not Considered, LPC = Low priority Candidate.

4.5.2.1 Green Sea Turtle

Green sea turtles are expected to be very rare in the Study Area. Nonetheless, there are two records of green turtles in the Study Area in July in the DFO sightings database. Both sightings were in the eastern part of the Study Area, near the Flemish Cap, in water depth >4,000 m (Figure 4.39).
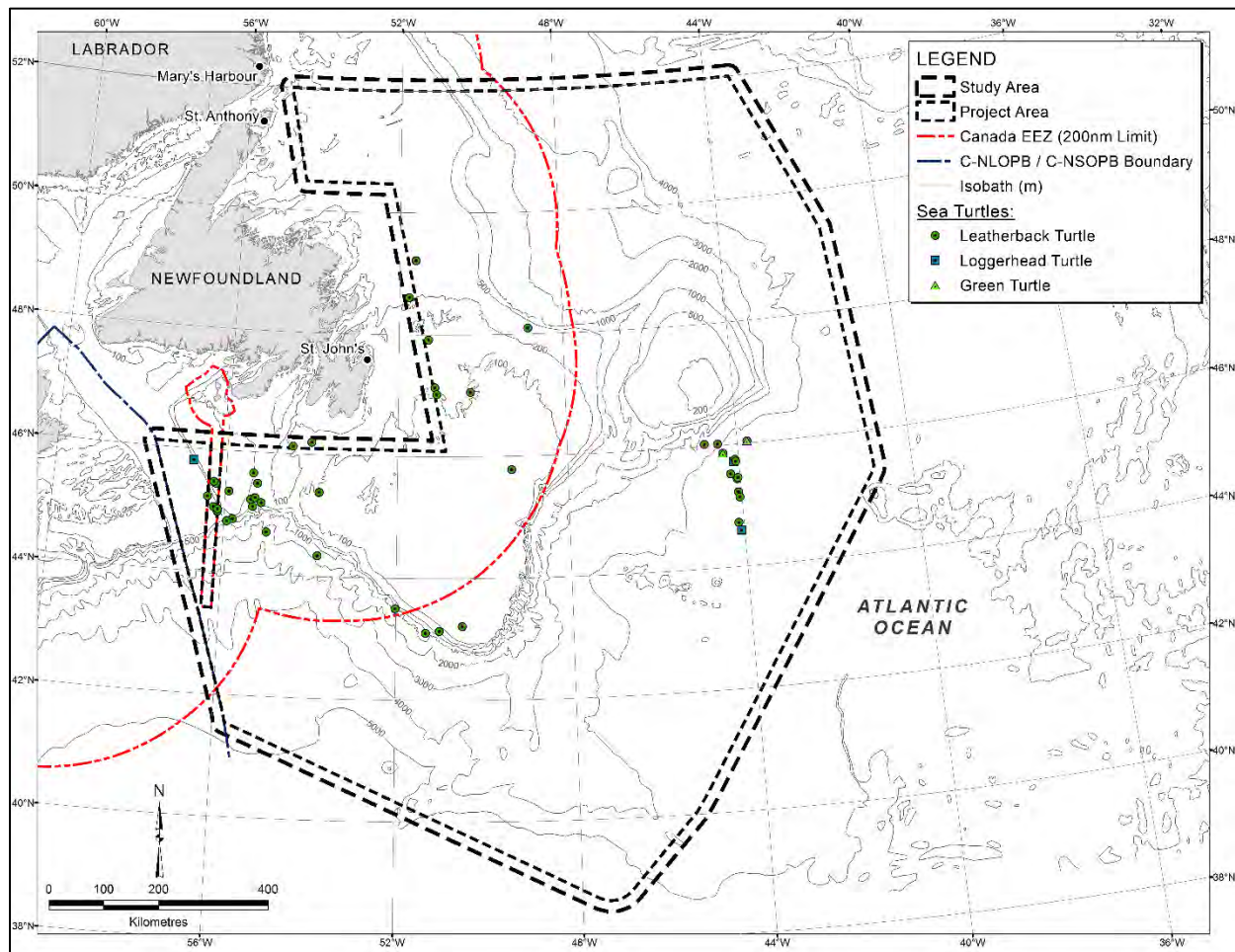
Data source: DFO cetacean sightings database, see text for description of data and caveats associated with these data.

Figure 4.39   Sea Turtle Sightings in the Study Area during May–November (compiled from the DFO sightings database, 1947–2015).

4.5.3   Marine Mammal and Sea Turtle Data Gaps Identified in Relevant SEAs

The following data gap associated with the Marine Mammal and Sea Turtle VEC was identified in the Eastern Newfoundland SEA (§ 6.1.6 of C-NLOPB 2014).

- Occurrence, abundance, and distribution of marine mammals and sea turtles is not available for all locations and times in the Study Area.

The following data gaps associated with the Marine Mammal and Sea Turtle VEC were identified in the Southern Newfoundland SEA (§ 3.5.7 and 3.6.4 of C-NLOPB 2010).

- Distribution and abundance of marine mammals and sea turtles;
- Potential migration routes and foraging areas of marine mammals and sea turtles are poorly understood;
- Basic life history characteristics of marine mammals and sea turtles which leads to uncertainty in the global and regional abundance estimates and population trends for many marine mammal and sea turtle species;
- Identification of marine mammal and sea turtle critical habitat; and
- Most available data on marine mammal and sea turtle species occurrence are opportunistic or incidental in nature (i.e., few directed surveys).

All of the data gaps indicated above still exist and thus limit the certainty of impact predictions made in § 5.7.7. However, opportunistic efforts are being made during seismic surveys to collect more distribution and abundance data for marine mammals and sea turtles. More specifically, during periods of daylight, MMOs are required to be on watch during the 30-minute pre-ramp up watch and during all periods while airguns are active. During seismic monitoring programs, MMOs will also conduct systematic watches during periods when the airguns are inactive. All marine mammal and sea turtle data are summarized in a data report and included in an Excel spreadsheet; this information is then submitted to the C-NLOPB. It is the proponent's understanding that the C-NLOPB then forwards the data and report to DFO each year. If funding were available, it would be possible to analyze the data in more detail to determine relative abundance for each species.

4.6 Species at Risk VEC

The Species at Risk VEC has been recently described in the Eastern Newfoundland SEA (§ 4.2.1.7, 4.2.2.5 and 4.2.3.5 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 3.7 of C-NLOPB 2010), and three project-specific EAs (§ 4.6 of LGL 2015a,b, 2016). An overview of the species at risk of the Study Area, based on information from the aforementioned SEAs and EAs, along with new information, is provided below. Relevant data gaps identified in the three SEAs are also discussed in terms of current status.

4.6.1 Species at Risk within the Study Area

The *Species at Risk Act* (*SARA*) was assented to in December 2002 with certain provisions coming into force in June 2003 (e.g., independent assessments of species/populations by COSEWIC) and June 2004 (e.g., prohibitions against harming or harassing species/populations with either endangered and threatened status or damaging or destroying their critical habitat). Species/populations are listed under *SARA* on Schedules 1 to 3, with only those with either an *endangered* or *threatened* status under Schedule 1 having immediate legal implications.

Schedule 1 is the official list of wildlife species/populations at risk in Canada. Once a species/population is designated, the measures to protect and recover that species/population are implemented. Three fish species/populations, two seabird species, three cetacean species/populations, and two sea turtle species that have potential to occur in the Study Area are legally protected under *SARA* (Table 4.19). In addition, Sowerby's beaked whale, the Atlantic population of fin whale, and the Atlantic wolffish have a *special concern* status under Schedule 1 of *SARA*. Schedules 2 and 3 of *SARA* identify species that have "at risk" status under COSEWIC prior to October 1999 and must be reassessed using revised criteria before they can be considered for addition to Schedule 1 of *SARA*. Species/populations that potentially occur in the Study Area and are considered at risk but have not received specific legal protection (i.e., prescribed penalties and legal requirement for recovery strategies and plans) under *SARA* are also listed in Table 4.19, as are species/populations with *endangered*, *threatened*, or *special concern* status under COSEWIC.

Under *SARA*, a 'recovery strategy' and corresponding 'action plan' must be prepared for *endangered*, *threatened* and *extirpated* species/populations. A 'management plan' must be prepared for species/populations with *special concern* status. Final recovery strategies have been prepared for eight species/populations currently with *endangered* or *threatened* status under Schedule 1 and the potential to occur in the Study Area: (1) the northern wolffish (Kulka et al. 2007); (2) the spotted wolffish (Kulka et al. 2007); (3) the Ivory Gull (ECCC 2017a); (4) the Red Knot (ECCC 2017a); (5) the blue whale (Beauchamp et al. 2009); (6) the North Atlantic right whale (DFO 2014); (7) the Scotian Shelf population of the northern bottlenose whale (DFO 2010b; amended in DFO 2016g); and (8) the leatherback sea turtle (ALTRT 2006). An action plan has been released for the Scotian Shelf population of northern bottlenose whale (DFO 2017d), and an action plan has been proposed for the North Atlantic right whale (DFO 2016h), and Atlantic salmon (Inner Bay of Fundy population; DFO 2016i). A management plan has been prepared for the Atlantic wolffish (Kulka et al. 2007), red knot (ECCC 2017a), fin whale (DFO 2017b), and Sowerby's beaked whale (DFO 2017c).

During 2016–2017, DFO planned to develop and post a recovery strategy for white shark (Atlantic population), and action plans for blue whale (Atlantic population), leatherback sea turtle (Atlantic population), and northern and spotted wolffish (DFO 2016j).

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

MKI acknowledges the possibility of other marine species/populations receiving *endangered* or *threatened* status under Schedule 1 of *SARA* during the course of the Project.

Table 4.19   *SARA*- and COSEWIC-listed Marine Species with Reasonable Likelihood of Occurrence in the Study Area.

SPECIES		SARA[a]			COSEWIC[b]		
Common Name	**Scientific Name**	**Endangered**	**Threatened**	**Special Concern**	**Endangered**	**Threatened**	**Special Concern**
Marine Fish							
White Shark (Atlantic population)	*Carcharodon carcharias*	Schedule 1			X		
Northern Wolffish	*Anarhichas denticulatus*		Schedule 1			X	
Spotted Wolffish	*Anarhichas minor*		Schedule 1			X	
Atlantic Wolffish	*Anarhichas lupus*			Schedule 1			X
Atlantic Cod	*Gadus morhua*			Schedule 3			
Atlantic Cod (Newfoundland and Labrador population)	*Gadus morhua*				X		
Atlantic Bluefin Tuna	*Thunnus thynnus*				X		
Porbeagle Shark	*Lamna nasus*				X		
Roundnose Grenadier	*Coryphaenoides rupestris*				X		
Cusk	*Brosme brosme*				X		
Smooth Skate (Funk Island Deep population)	*Malacoraja senta*				X		
Winter Skate (Eastern Scotian Shelf-Newfoundland population)	*Leucoraja ocellata*				X		
American Eel	*Anguilla rostrata*					X	
American Plaice (Newfoundland and Labrador population)	*Hippoglossoides platessoides*					X	
Atlantic Salmon (South Newfoundland population)	*Salmo salar*					X	
Acadian Redfish (Atlantic population)	*Sebastes fasciatus*					X	
Deepwater Redfish (Northern population)	*Sebastes mentella*					X	
White Hake (Atlantic and Northern Gulf of St. Lawrence population)	*Urophycis tenuis*					X	
Lumpfish	*Cyclopterus lumpus*					X	
Atlantic Salmon (various populations)	*Salmo salar*				X		X
Shortfin Mako Shark (Atlantic population)	*Isurus oxyrinchus*						X
Basking Shark (Atlantic population)	*Cetorhinus maximus*						X
Spiny Dogfish (Atlantic population)	*Squalus acanthias*						X
Roughhead Grenadier	*Macrourus berglax*						X
Thorny Skate	*Amblyraja radiata*						X
Smooth Skate (Laurentian-Scotian population)	*Malacoraja senta*						X
Marine-associated Birds							
Ivory Gull	*Pagophila eburnea*	Schedule 1			X		

SPECIES		SARA[a]			COSEWIC[b]		
Common Name	**Scientific Name**	**Endangered**	**Threatened**	**Special Concern**	**Endangered**	**Threatened**	**Special Concern**
Red Knot *rufa* spp.	*Calidris canutus rufa*	Schedule 1			X		
Harlequin Duck (Eastern population)	*Histrionicus histrionicus*			Schedule 1			X
Barrow's Goldeneye (Eastern population)	*Bucephala islandica*			Schedule 1			X
Marine Mammals							
Blue Whale (Atlantic population)	*Balaenoptera musculus*	Schedule 1			X		
North Atlantic Right Whale	*Eubalaena glacialis*	Schedule 1			X		
Northern Bottlenose Whale (Scotian Shelf population)	*Hyperoodon ampullatus*	Schedule 1			X		
Fin Whale (Atlantic population)	*Balaenoptera physalus*			Schedule 1			X
Sowerby's Beaked Whale	*Mesoplodon bidens*			Schedule 1			X
Harbour Porpoise (Northwest Atlantic population)	*Phocoena phocoena*		Schedule 2				X
Humpback Whale (Western North Atlantic population)	*Megaptera novaeangliae*			Schedule 3			
Killer Whale (Northwest Atlantic/Eastern Arctic populations)	*Orcinus orca*						X
Northern Bottlenose Whale (Davis Strait-Baffin Bay-Labrador Sea population)	*Hyperoodon ampullatus*						X
Sea Turtles							
Leatherback Sea Turtle (Atlantic population)	*Dermochelys coriacea*	Schedule 1			X		
Loggerhead Sea Turtle	*Caretta caretta*	Schedule 1			X		

Sources: [a]*SARA* website (http://www.sararegistry.gc.ca/default.asp?lang=En&n=24F7211B-1), accessed February 2018; [b]COSEWIC website (https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html), accessed February 2018.

4.6.2 Profiles of Marine Species/Populations with *Endangered* or *Threatened* Status under Schedule 1 of *SARA*

The status of all species/populations profiled below are current as of February 2018.

4.6.2.1 Fishes

Three fish species/populations have an *endangered* or *threatened* status under Schedule 1 of the *SARA*: (1) white shark (Atlantic population); (2) northern wolffish; and (3) spotted wolffish. These three species are profiled in this section. Some of the other fish species/populations that are included in Table 4.19 above (e.g., Atlantic wolffish, Atlantic cod) are profiled in § 4.2 of this EA.

White Shark

The Atlantic population of white shark currently has *endangered* status under both Schedule 1 of *SARA* and COSEWIC. This population was profiled in § 4.6.1 of LGL (2015a,b).

An adult female, 'Katharine,' originally tagged in August 2013 off Cape Cod, was present within the southern portion of the Study Area during November 2015 through February 2016 (OCEARCH website). A second adult female, 'Lydia', originally tagged in March 2013 off Jacksonville, FL, was present within the southern and eastern portions of the Study Area during December 2014 to February 2015 (OCEARCH website).

Northern and Spotted Wolffishes

Northern and spotted wolffishes currently have a *threatened* status under both Schedule 1 of *SARA* and COSEWIC. Profiles of these species are provided in § 4.6.1 of LGL (2015a,b).

During DFO RV surveys conducted in the Study Area during May–November 2014, northern wolffish and spotted wolffish were caught primarily along the northeastern and southeastern slope areas of the Grand Banks (see Figure 4.33 in § 4.3.7).

4.6.2.2 Marine-associated Birds

Two marine-associated birds have an *endangered* status under Schedule 1 of *SARA*: (1) Ivory Gull; and (2) Red Knot. These two species are profiled in this section. The remaining two bird species in Table 4.19, Harlequin Duck (eastern population) and Barrow's Goldeneye (eastern population) are profiled in § 4.4.2.1 of LGL (2016).

Ivory Gull

The Ivory Gull currently has an *endangered* status under Schedule 1 of *SARA* and COSEWIC, and is profiled in § 4.6.1 of LGL (2015a,b).

Red Knot

The Red Knot currently has an *endangered* status under both Schedule 1 of *SARA* and COSEWIC. This species at risk is profiled in § 4.2.2.5 of C-NLOPB (2014), and § 3.7.2.6 of C-NLOPB (2010).

4.6.2.3   Marine Mammals and Sea Turtles

Three marine mammal and two sea turtle species/populations that have some likelihood of occurrence in the Study Area have either *endangered* or *threatened* status under Schedule 1 of *SARA*: (1) blue whale (Atlantic population); (2) North Atlantic right whale; (3) northern bottlenose whale (Scotian Shelf population); (4) leatherback sea turtle; and (5) loggerhead sea turtle. Profiles of these species are provided in this section. Some of the other marine mammal and sea turtle species/populations that are included in Table 4.19 above (e.g., Atlantic population of fin whale, Sowerby's beaked whale) are profiled in § 4.5 of this EA.

Blue Whale

The Atlantic population of blue whale currently has an *endangered* status under Schedule 1 of *SARA* and COSEWIC. This population is profiled in § 4.6.1.3 of LGL (2015a,b).

There are 84 sightings (109 individuals) of blue whales in the Study Area in the DFO sightings database. Blue whales were observed during spring, summer and fall within the Study Area in the DFO sightings database, with peak numbers in July and August (see Table 4.17 in § 4.5). Sightings were made primarily in upper slope regions, particularly in the area of the St. Pierre Bank and Laurentian Channel (see Figure 4.36 in § 4.5). Blue whales are considered uncommon in the Study Area (see Table 4.16 in § 4.5).

One blue whale that was tagged in the St. Lawrence Estuary in November 2014 travelled through the southwestern portion of the Study Area during March. Another individual tagged in the Gulf of St. Lawrence in September 2013 also travelled through the southwestern portion of the Study Area during October (Lesage et al. 2016). An additional blue whale that was tagged in the estuary in September 2013 was recorded along the southern Grand Banks during December where it was likely foraging (Lesage et al. 2016). Results from this study suggest that underwater seamounts and the deep ocean structures along the shelf edge may be important habitat for blue whales.

Sightings were made in and near the Study Area in the southern Laurentian Channel and south of the Grand Banks during July 2012 (Ryan et al. 2013). In addition, two sightings of blue whales were made in the Orphan Basin in August–September 2007 (Abgrall et al. 2008c), and 49 sightings (53 individuals) were made during a 3D seismic program that occurred from June–September 2005 in the Laurentian Sub-basin (Moulton et al. 2006b). Blue whales have also been sighted along the northeastern edge of the Scotian Shelf within and near the Study Area (Gomez-Salazar and Moors-Murphy 2014). Whitehead (2013) reported five sightings in Haldimand Canyon and nine in Shortland Canyon, at the edge of the Scotian Shelf near the Study Area, during 1988–2012.

North Atlantic Right Whale

The North Atlantic right whale currently has an *endangered* status under Schedule 1 of *SARA* and COSEWIC. There are at least 524 and perhaps as many as 716 catalogued individuals in the western North Atlantic (Pettis and Hamilton 2016). Profiles of this species are provided in § 4.6.1.3 of LGL (2015a,b).

The North Atlantic right whale is expected to be rare in the Study Area (see Table 4.16 in § 4.5). There is one sighting of two individual right whales in the Study Area in the DFO sightings database, in June near the Flemish Cap (see Figure 4.36 in § 4.5). Right whale sightings have also been made in the Laurentian Channel, within the southwestern edge of the Study Area (Gomez-Salazar and Moors-Murphy 2014). One individual was seen off the southeastern Avalon Peninsula during July 2016, but it was outside of the Study Area (LGL, unpublished data).

Northern Bottlenose Whale

The Scotian Shelf population has *endangered* status under Schedule 1 of *SARA* (*SARA* website 2018) and COSEWIC (COSEWIC 2002, 2011) and is estimated to comprise 143 individuals (O'Brien and Whitehead 2013). Profiles of the northern bottlenose whale are provided in § 4.6.1.3 of LGL (2015a,b).

Northern bottlenose whales are expected to be uncommon in the Study Area (see Table 4.16 in § 4.5). There are 103 sightings (329 individuals) of northern bottlenose whales in the Study Area in the DFO sightings database. These sightings occurred primarily in the deeper waters and near the shelf break (Harris et al. 2013) during May–August (see Table 4.17 and Figure 4.37 in § 4.5). Northern bottlenose whales have been sighted in Haldimand and Shortland canyons, and off the northeastern edge of the Scotian Shelf within and near the Study Area (Harris et al. 2013; Gomez-Salazar and Moors-Murphy 2014). Acoustic evidence indicates that the Scotian Shelf population remains within the Gully and adjacent submarine canyons year-round (H. Moors-Murphy, DFO Biologist, pers. comm., 18 December 2015).

Preliminary photo-ID work has found that at least 78 different animals occurred in the Grand Banks, Flemish Pass, and Flemish Cap area during 2016–2017 (L.J. Feyrer, Ph.D. Candidate, Dalhousie University, pers. comm., 5 February 2018). Although genetic and other tissue analyses are underway at Dalhousie University based on samples collected from some of those individuals, results are not yet available to elucidate whether animals in that area were from the Scotian Shelf or Davis Strait-Baffin Bay-Labrador Sea populations (L.J. Feyrer, Ph.D. Candidate, Dalhousie University, pers. comm., 5 February 2018).

Leatherback Sea Turtle

The leatherback sea turtle currently has an *endangered* status under Schedule 1 of *SARA*. Additionally, the Atlantic population of leatherbacks currently has an *endangered* status under COSEWIC. Profiles of this species/population of leatherback sea turtle are provided in § 4.6.1.4 of LGL (2015a,b).

Leatherback sea turtles are considered rare in the Study Area (see Table 4.18 in § 4.5). Nonetheless, there are 46 sightings (up to 59 individuals) of leatherback turtles within the Study Area in the DFO sightings database (see Figure 4.39 in § 4.5). The majority of sightings were made in the southwestern Study Area and during the months of July and August, but records were reported from May–November. There was also a sighting of a leatherback turtle in Jeanne d'Arc Basin during the Statoil/Husky seismic monitoring program in 2008 (Abgrall et al. 2009). Leatherback turtles outfitted with satellite telemetry tags and vessel-based sightings have been reported near and within the Study Area mainly off northern Nova Scotia and southern Newfoundland (DFO 2012; Howard 2012; Stewart et al. 2013; Dodge et al. 2014; Archibald and James 2016).

Recent efforts in Atlantic Canadian waters have yielded new insight into the foraging and movements of leatherback sea turtles using both satellite telemetry and camera tags, providing footage of leatherbacks searching for, capturing and handling their prey (from the turtle's perspective). This footage revealed that this species finds its prey by entirely visual means and feeds only during daylight hours, predominantly within the top 30 m of the water column (DFO 2016k).

Loggerhead Sea Turtle

There are three records of loggerhead turtles in the Study Area in the DFO sightings database. Two sightings were made in the eastern part of the Study Area, near the Flemish Cap, in water depth >4,000 m during May–July, and another sighting was made during August in the Laurentian Channel (see Figure 4.39). Loggerhead turtles are likely to be rare in the Study Area. Nonetheless, neonate loggerheads from Florida beaches equipped with satellite tags travelled through the southern region of the Study Area after release (Mansfield et al. 2014). Additionally,

a juvenile loggerhead equipped with a satellite tag in the Canary Islands was tracked in the southern portion of the Study Area (Varo-Cruz et al. 2016).

4.6.3 Data Gaps associated with the Species at Risk VEC

No data gaps associated with the Species at Risk VEC were specified in the Eastern Newfoundland SEA (§ 5.4.8 of C-NLOPB 2014). However, the following general data gaps identified in § 6.1.6 of the SEA (C-NLOPB 2014) are applicable to the Species at Risk VEC:

- Fish and fish habitat in deep water beyond the continental slope, particularly for currently non-commercially important species;
- Presence, abundance and spatial and temporal distribution of marine mammals, sea turtles, fishes, invertebrates (including deep-sea corals and sponges) and seabirds throughout eastern offshore Newfoundland and Labrador; and
- Biologically-essential behaviour for marine mammals along with associated locations and time.

The following data gaps associated with the Species at Risk VEC were identified in the Southern Newfoundland SEA (§ 3.7.6 of C-NLOPB 2010):

- Migration routes, breeding grounds, feeding areas, and seasonal distribution;
- Biological and ecological information, including critical habitat, behaviour of critical life stages, inter-species relationships and the effects of ongoing human activities; and
- Marine mammal hearing capabilities, and understanding of sound exposure characteristics and intensity that result in hearing or behavioural changes.

All of the above data gaps still exist. Any new information that has been made available since the two SEAs were completed and for areas that were beyond the scope of the SEAs is noted throughout § 4.2, 4.4 and 4.5.

These data gaps limit the assessment of potential interactions between the Project and the Species at Risk VEC until updated species distributional information is available and there is an improved understanding of essential behaviour(s) and reaction to sound exposure. MKI will revise assessments as needed if new data become available, and will incorporate any necessary revisions into future EA Updates.

4.7 Sensitive Areas VEC

The Sensitive Areas VEC of the Study Area has been recently described in the Eastern Newfoundland SEA (§ 4.2.4 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 3.8 of C-NLOPB 2010), and three project-specific EAs (§ 4.7 of LGL 2015a,b, 2016). An overview of the sensitive areas of the Study Area, based on information from the aforementioned SEAs and

EAs along with new information, is provided below; sensitive areas listed but not otherwise described below were previously described in the aforementioned SEAs and EAs. Relevant data gaps identified in the two SEAs are also discussed in terms of current status.

4.7.1 Sensitive Areas associated with the Study Area

Sensitive areas which occur either entirely or partially within the Study Area are as follows (Figure 4.40):
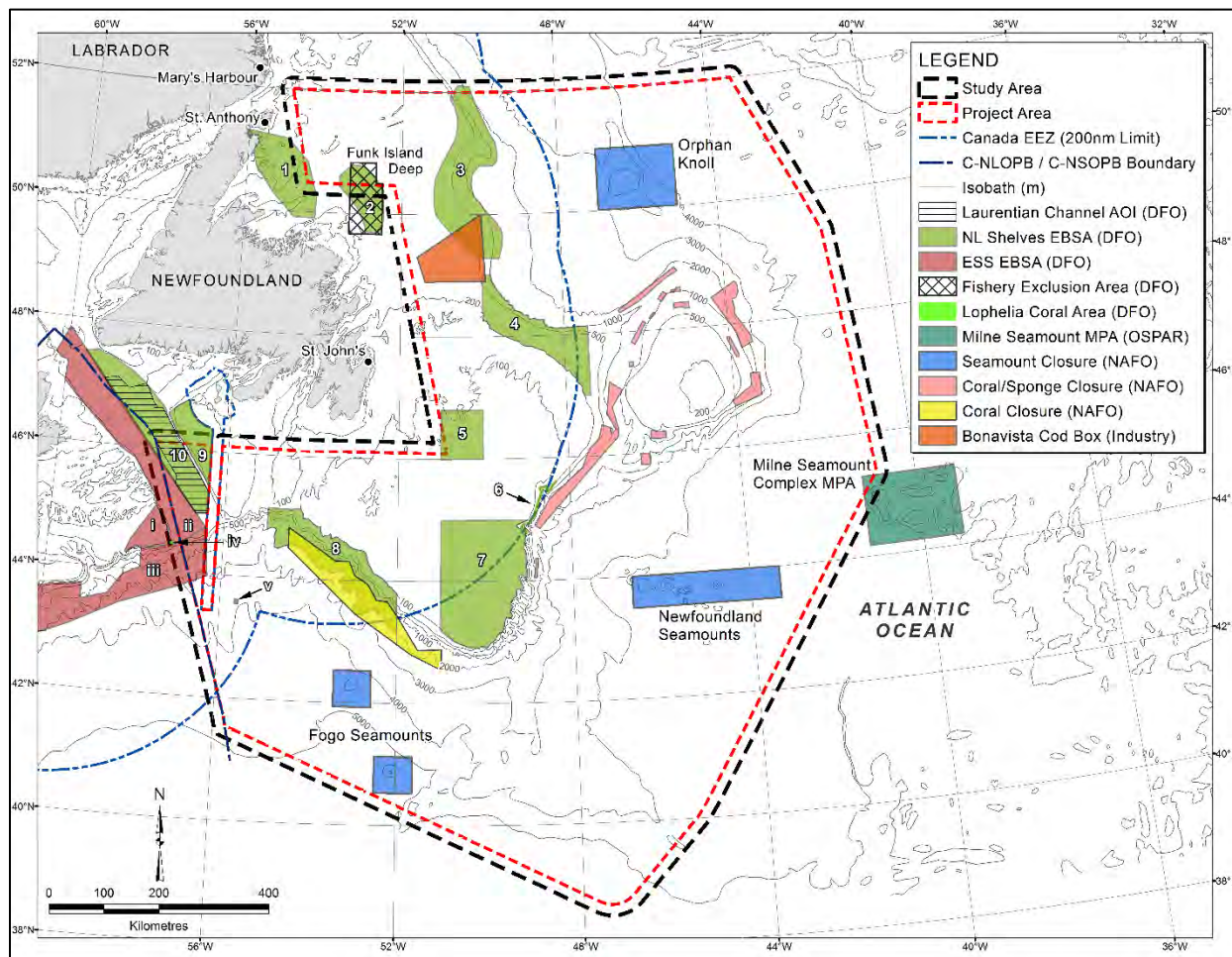
Figure 4.40   Location of Sensitive Areas that Overlap the MKI Study Area.

- Fourteen NAFO coral/sponge fishery closure areas, and the 3O Coral Protection Zone;
- Four seamount fishery closure areas: (1) Orphan Knoll Seamount; (2) Newfoundland Seamount; (3) Fogo Seamount 1; and (4) Fogo Seamount 2;
- Ten NL Shelves Bioregion Ecologically and Biologically Significant Areas (EBSAs): (1) Grey Islands; (2) Notre Dame Channel; (3) Orphan Spur; (4) Northeast Shelf and Slope; (5) Virgin Rocks; (6) Lilly Canyon-Carson Canyon; (7) Southeast Shoal and

Tail of the Banks; (8) Southwest Shelf Edge and Slope; (9) St. Pierre Bank; and (10) Laurentian Channel and Slope;

- Five Scotian Shelf Bioregion EBSAs: (i) Eastern Shoal; (ii) Laurentian Channel Cold Seep Communities; (iii) Laurentian Channel Slope; (iv) Scotian Slope; and (v) Stone Fence and Laurentian Environs;
- DFO Laurentian Channel Area of Interest (AOI);
- Bonavista Cod Box;
- One Fishery Exclusion Area: (1) Funk Island Deep; and
- One Marine Protected Area (MPA): (1) Milne Seamount Complex – designated internationally as a component of the OSPAR Network of MPAs (IUCN and UNEP-WCMC 2016).

The Milne Seamount Complex MPA (Milne), which encompasses an area of 20,914 km^2, is a component of the Oil Spill Prevention, Administration and Response (OSPAR) Network of MPAs (MPAtlas n.d.; OSPAR 2015). Designated in 2010 with the goal to "protect and conserve the biodiversity and ecosystems of the seabed and superjacent waters of the site," Milne consists of near-pristine oceanic seamount ecosystems (OSPAR 2010; MPAtlas n.d.), including coral gardens, deep-sea sponge aggregations, *Lophelia pertusa* reefs and seamounts (OSPAR 2016). This MPA serves as habitat for numerous species of marine fishes, mammals, sea turtles and seabirds, including orange roughy (*Hoplostethus atlanticus*), gulper shark (*Centrophorus granulosus*), leafscale gulper shark (*Centrophorus squamosus*), Portuguese dogfish (*Centroscymnus coelolepis*), sperm whale, leatherback sea turtle and Cory's Shearwater (OSPAR 2016). No area within Milne has been closed to bottom fisheries or exploratory/extraction activities of non-living resources (OSPAR 2015, 2016).

The Laurentian Channel AOI is currently being proposed as an MPA (DFO 2017e). See Table 3.22 *in* the Southern Newfoundland SEA (C-NLOPB 2010) for a description of this AOI, listed as 'Laurentian Channel and Slope EBSA'.

The *Lophelia* Coral Conservation Area, established by DFO in June 2004, consists of a 15 km^2 area surrounding the only known living *Lophelia pertusa* colonies on Canada's Atlantic coast (DFO 2015c). This area, located at the Stone Fence southeast of Cape Breton, NS, is closed to all bottom fisheries with the goal of protecting the reef complex from further damage and allowing for recovery (DFO 2015c).

In response to the Addendum (LGL 2017b) of the original EA (LGL 2017a), DFO indicated that candidate National Marine Conservation Area (NMCA) sites off Newfoundland and Labrador may have been recently revised (C-NLOPB 2018). The only potential NMCA site currently off Newfoundland includes the South Coast Fjords area (~75 km beyond the Study Area), and revised candidate NMCA sites are located off Labrador (F. Mercier, Parks Canada, A/Manager, Marine Establishment, Protected Areas Establishment Branch, pers. comm., 21 February 2018). Parks Canada intends to update studies for the Newfoundland Shelf and Grand Banks before

proposing candidate NMCA sites for these regions (F. Mercier, Parks Canada, A/Manager, Marine Establishment, Protected Areas Establishment Branch, pers. comm., 21 February 2018). DFO also advised that a Science Advisory Document will be released in the near future with an updated map/list of EBSAs for the southern and eastern portions of Newfoundland, including possible modifications to EBSA boundaries. The document was not yet released as of the writing of this EA; new information and EBSA boundaries will be included as they become available in EA Updates for the Project.

4.7.2 Data Gaps associated with the Sensitive Areas VEC

No data gaps associated with the Sensitive Areas VEC were specifically identified in the Eastern Newfoundland SEA (§ 5.4.8 of C-NLOPB 2014). However, the same data gaps identified from the SEA for the Species at Risk VEC (see § 4.6) are applicable to the Sensitive Areas VEC.

The following data gaps associated with the Sensitive Areas VEC were identified in the Southern Newfoundland SEA (§ 3.8.8 of C-NLOPB 2010):

- Detailed delineation of special areas, their relative importance and their eventual legal status; and
- Future uncertainty regarding special areas, some of which overlap biologically, geographically and jurisdictionally.

All of the data gaps indicated above still exist, although there have been recent data updates for deep-sea coral and sponge distribution (see § 4.2.1.2; Kenchington et al. 2016), and an Ecological Risk Assessment (ERA) to evaluate the risk posed by bottom contact fisheries on deep-sea coral and sponge communities in eastern Canadian waters has been carried out on several areas mentioned in Kenchington et al. (2016). These areas are being proposed as fisheries closures and extensive consultations on each area are currently underway. The Government of Canada has also recently committed to "establishing a more systematic approach to MPA planning and establishment," "enhance collaboration for management and monitoring of MPAs," "increase awareness, understanding and participation of Canadians in the MPA network," and "link Canada's network of MPAs to continental and global networks" (DFO 2016l). Any new information that has been made available since the two SEAs were completed and for areas that were beyond the scope of the SEAs is noted throughout § 4.2.

The above data gaps constrain the assessment of potential interactions between the Sensitive Areas VEC and the Project, owing particularly to the limited ecological and distributional knowledge of various species which utilize these areas. MKI will continue to monitor for updated information, including the modification of existing and the establishment of new Sensitive Areas in the vicinity of the Study Area, and include newly available data in future EA Updates.

5.0   Effects Assessment

The various aspects of the effects assessment methodology have been recently described in the WesternGeco Eastern Newfoundland EA (§ 5.0 of LGL 2015a), WesternGeco Southeastern Newfoundland EA (§ 5.0 of LGL 2015b) and Seitel East Coast Offshore EA (§ 5.0 of LGL 2016).

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.

5.1   Scoping

The C-NLOPB provided a Final Scoping Document (C-NLOPB 2017a; dated 24 January 2017) for the Project which outlined the factors to be considered in the assessment. In addition, various stakeholders were contacted for input (see § 5.1.1 below). Another aspect of scoping for the effects assessment involved reviewing relevant SEAs (C-NLOPB 2010, 2014) and EAs (LGL 2015a,b, 2016).

5.1.1   Consultations

5.1.1.1   MKI's Consultation Approach

MKI's approach to consultation on marine seismic projects is to, whenever possible, consult (primarily through in-person meetings) with relevant agencies, stakeholders and rights-holders (e.g., beneficiaries) during the pre-survey and survey stages. MKI will initiate meetings and respond to requests for meetings with the interested groups throughout this period. After the survey is complete MKI will conduct follow-up communications. The same approach would be followed before, during and after any survey work conducted in 2018–2023. In summary, each year MKI will consult with stakeholders before the survey is permitted, during survey activities, and after survey completion as outlined below.

- Before the survey is permitted: provide Project information, gather information about area fisheries, determine issues or concerns, discuss communications and mitigation measures, and discuss potential solutions;
- During survey activities: provide forward looking acquisition plans for discussion in a weekly meeting, communicate current and projected vessel positions every 12 hours via email, and maintain communication with active stakeholders to ensure concerns are addressed rapidly; and
- After the survey is completed: provide an update on the Project, discuss any issues that arose, and present results of the MMO and FLO reports.

The in-person meetings included the direct participation of MKI's Marine Shore Manager.

5.1.1.2 Program Consultations

Consultations were held with groups in St. John's in January and February 2017.

St. John's

Stakeholder groups in St. John's that were initially contacted by email are listed below.

- Environment and Climate Change Canada (ECCC);
- Nature Newfoundland and Labrador (NNL);
- One Ocean;
- Fish, Food and Allied Workers Union (FFAW)/Unifor;
- Association of Seafood Producers (ASP);
- Ocean Choice International (OCI);
- Groundfish Enterprise Allocation Council (GEAC) Ottawa;
- Canadian Association of Prawn Producers;
- Clearwater Seafoods;
- Icewater Fisheries; and
- Newfound Resources Ltd. (NRL).

The face-to-face consultations held in St. John's were organized and coordinated by MKI. Those that requested face-to-face meetings are indicated below. Topics raised at each meeting after the MKI presentation are bulleted below.

ECCC (31 January 2017)

- Source array ramp up protocol was explained;
- MARPOL reporting was clarified;
- After-dark lighting on Project vessels was described; and
- Provided details on a typical acquisition season and how weather affects operations.

FFAW/Unifor (31 January 2017)

- Discussion about the post-season snow crab survey, particularly regarding the addition of sampling stations.

Newfound Resources Ltd. (2 February 2017)

- Shrimp harvesting season is complete by the time of onset of seismic activity.

One Ocean (2 February 2017)

- No details from the meeting.

Nature Newfoundland and Labrador (2 February 2017)

- Question about minimizing the level of light being emitted during seismic operation – MKI indicated that lighting on the outside of the seismic vessel is limited to navigation lights and lights in the back deck work areas;
- Question about the effectiveness of source ramp-up to motivate marine mammals to move away from the sound source – MKI indicated that data collected thus far indicates that marine mammals are observed farther from the sound source when it is active than when it is inactive; and
- Request that MKI make metadata collected during seismic operations available for metocean research – MKI indicated that it would look into what archived metadata are available for release.

MKI provided more details about its 2017 activities to all consultees once they were finalized.

More details regarding the St. John's consultations in late-January/early-February 2017 are included in the full consultation report in Appendix 1.

5.1.1.3 Consultation Follow-Up

As described above, MKI will conduct follow-up discussions with all interested groups during and after the survey. This would include reporting on the progress of the survey, monitoring the effectiveness of the mitigations, determining if any survey-related issues had arisen, and presenting monitoring results.

5.2 Valued Environmental Components

The VEC approach was used to focus the assessment on those biological resources of most potential concern and value to society. Descriptions of these VECs are provided in § 5.2 of LGL (2015a,b, 2016).

5.3 Boundaries

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

5.3.1 Temporal

The temporal boundaries of the Project are May 1 to November 30, 2018–2023.

5.3.2 Spatial

5.3.2.1 Project Area

The 'Project Area' is defined as the area within the C-NLOPB jurisdiction where seismic data could be acquired and all vessel movements with deployed equipment will occur (see Figure 1.1). The coordinates of the Project Area (WGS84, unprojected geographic coordinates) are provided in § 2.1.

5.3.2.2 Affected Area

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

5.3.2.3 Study Area

The 'Study Area' is an area larger than the Project Area that encompasses routine potential effects reported in the literature. The coordinates of the Study Area (WGS84, unprojected geographic coordinates) are provided in § 2.1.

5.3.2.4 Regional Area

The 'Regional Area' is an area larger than the Study Area and is typically used when assessing 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.

The following is a summary of the effects assessment procedures used in the EA:

1. The preparation of interaction matrices to identify potential interactions between the various Project activities and the VECs;
2. The assessment of the residual effects (post-mitigation) of the various Project activities on the VECs, based on identified interactions;

a. Identification of the potential effect as positive or negative;
b. Identification of mitigations to be applied to each potential effect; and
c. Provision of 'ratings' to the various criteria used in the assessment to describe the residual effect.
   i. The criteria and their associated ratings used in the assessment include the following:
      - Magnitude (proportion of individuals in the affected area) (4 ratings: negligible, low, medium and high);
      - Geographic Extent (6 ratings: <1 km^2, 1–10 km^2, 11–100 km^2, 101–1,000 km^2, 1,001–10,000 km^2, and >10,000 km^2);
      - Frequency (6 ratings: <11 events/year, 11–50 events/year, 51–100 events/year, 101–200 events/year, >200 events/year, and continuous);
      - Duration (5 ratings: <1 month, 1–12 months, 13–36 months, 37–72 months, and >72 months);
      - Reversibility (2 ratings: reversible and irreversible); and
      - Ecological/Socio-cultural and Economic Context (2 ratings: relatively pristine area and evidence of existing negative effects).
3. The determination of significance of residual effects;
   a. A significant effect is defined as: high magnitude, or medium magnitude for a duration of >1 year over a geographic area >100 km^2;
   b. A level of confidence (low, medium or high) is provided for each determination of significance; and
   c. If a residual effect is deemed 'significant', then ratings of 'probability of occurrence' and 'scientific certainty' are provided.

Note that professional judgement is applied during the assessment in addition to the consideration of scientific information. More details on the effects assessment procedures are provided in § 5.4 of LGL (2015a,b).

5.5 Mitigation Measures

The effects assessments that follow (see § 5.7) consider the potential effects of the proposed Newfoundland offshore seismic program in light of the specific mitigation measures that will be applied during this Project. The purpose of these measures is to eliminate or reduce the potential effects on VECs. MKI recognizes that the careful and thorough implementation of, and adherence to, these measures will be critical for ensuring that the Project does not result in unacceptable environmental consequences.

This section details the various measures that will be established and applied for this Project. Collectively, they are based on several sources, including:

- Discussions and advice received during consultations for this Project (§ 5.1.1 and Appendix 1), and for other relevant EAs;
- The C-NLOPB Final Scoping Document (C-NLOPB 2017a), and the Environmental Planning, Mitigation and Reporting guidance in Appendix 2 of the Board's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2017b);
- DFO's *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment;*
- National and international acts, regulations or conventions, such as the *SARA*, *Fisheries Act* and Regulations (including the Marine Mammal Regulations [MMR]), *International Convention for the Prevention of Pollution from Ships* (MARPOL), and International Maritime Organization (IMO) standards;
- Other standards and guidance, such as the One Ocean *Protocol for Seismic Survey Programs in Newfoundland and Labrador* (One Ocean 2013);
- Industry best practices; and
- Expert judgement/experience from past surveys.

Proposed mitigations are organized under the following principal categories:

- Survey layout and location;
- Communications and liaison;
- Fisheries avoidance;
- Fishing gear damage program;
- Marine mammal, sea turtle, and seabird monitoring and mitigation; and
- Pollution prevention and emergency response.

Several of the mitigation measures listed under these categories are designed to mitigate potential effects on more than one VEC (e.g., seismic array ramp-up/soft start can, in theory, deter marine mammals, sea turtles, and fish). Table 5.1 summarizes the measures by VEC and type of effect. These measures will be adhered to during each survey year, with necessary adjustments based on monitoring and follow-up. As per § 5.1.4.1 of the Guidelines (C-NLOPB 2017b), a tracking table identifying the status of each of the commitments and mitigation measures made by the proponent during the EA process shall be submitted to the C-NLOPB at least 30 days prior to the commencement of the Project.

Table 5.1   Summary of Mitigations Measures by Potential Effect.

VEC, Potential Effects	Primary Mitigations
Fisheries VEC: Interference with fishing vessels/mobile and fixed gear fisheries	• Pre-survey communications, liaison and planning to avoid fishing activity • Continuing communications throughout the program • FLOs • SPOC • Advisories and communications • VMS data • Avoidance of actively fished areas • Start-up meetings on ships that discuss fishing activity and communication protocol with fishers
Fisheries VEC: Fishing gear damage	• Pre-survey communications, liaison and planning to avoid fishing gear • Use of escort vessel • SPOC • Advisories and communications • FLOs • Compensation program • Reporting and documentation • Start-up meetings on ships that discuss fishing activity, communication protocol with fishers, and protocol in the event of fishing gear damage
Interference with shipping [a]	• Advisories and at-sea communications • FLOs (fishing vessels) • Use of escort vessel • SPOC (fishing vessels) • VMS data
Fisheries VEC: Interference with DFO/FFAW research program	• Communications and scheduling • 7-day/30-km temporal/spatial avoidance protocol [b]
Fish and Fish Habitat, Marine Mammal and Sea Turtle, and Marine-associated Bird VECs: Temporary or permanent hearing damage/disturbance to marine animals (marine mammals, sea turtles, seabirds, fish, invertebrates)	• "Pre-watch" (30 minute) of 500 m safety zone using visual and PAM • Delay start-up if any marine mammals or sea turtles are detected within 500 m with visual and PAM • Ramp-up of airguns • Use of experienced, qualified MMO(s) to monitor for marine mammals and sea turtles during all daylight periods when airguns are in use • Minimum separation distance of 30 km for simultaneous seismic surveys in the Project Area based on separation distances required in other jurisdictions (i.e., Gulf of Mexico [G. Morrow, PGS, Senior Contract Manager, pers. comm., June 2017] and Greenland [LGL 2012b]).
Species at Risk and Sensitive Areas VEC: Temporary or permanent hearing damage/ disturbance to Species at Risk or other key habitats	• "Pre-watch" (30 minute) of 500 m safety zone using visual and PAM • Delay start-up if any marine mammals or sea turtles are detected within 500 m with visual and PAM • Ramp-up of airguns • Shutdown of airgun arrays for *endangered* or *threatened* marine mammals and sea turtles within 500 m • Use of experienced, qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations. • Use of PAM for cetaceans (details to be provided in EA Updates) • Minimum separation distance of 30 km for simultaneous seismic surveys in the Project Area based on separation distances required in other jurisdictions (see above).
Marine-associated Bird VEC: Injury (mortality) to stranded seabirds	• Daily search of seismic and support vessels • Implementation of handling and release protocols • Minimize lighting if safe
Marine-associated Bird VEC: Seabird oiling	• Adherence to MARPOL • Adherence to conditions of ECCC-CWS migratory bird permit • Spill contingency and response plans • Use of solid streamer

[a] MKI will engage CTF 84, through Director General Naval Strategic Readiness (DGNSR), to ensure de-confliction with possible Allied submarine activities.

[b] DFO does not indicate an official spatial and/or temporal buffer mitigation method for seismic operations in the vicinity of survey stations. MKI will work cooperatively with FFAW|Unifor and DFO in an effort to avoid survey stations prior to their sampling to the best extent possible.

There will be full opportunity for adaptive mitigation during MKI's proposed six-year program. If there are any new techniques developed during the six-year period that may help to further mitigate environmental effects, they will be investigated and incorporated into the program if deemed useful. The MMR are currently undergoing amendment, and Schedule 11 of the proposed amended MMR provides approach distances for marine mammals based on species, vehicle, area, and timing (LGL 2017b); if the proposed amendments to the MMR are accepted during the spatial scope of the Project (2018–2023), MKI will adhere to any implications relevant to Project operations. Annual updates of the EA that will be prepared during the six-year scope of the Project will include any relevant new information related to mitigation not provided in the EA.

The mitigation categories are described in detail in § 5.5 of LGL (2015a,b, 2016) and summarized below.

1. Planning Survey Layout and Location
    a. Early planning of the layout of survey transect lines helps to reduce the probability of effects of VECs. A certain level of spatial and temporal flexibility associated with this planning serves as a mitigation measure for numerous VECs.
2. Communications and Liaison
    a. A number of strategies associated with communications and liaison are available to serve as mitigation measures. They are as follows:
        i. Information exchange
        ii. Weekly status updates
        iii. Fisheries Liaison Officers (FLOs)
        iv. Single Point of Contact (SPOC)
        v. FFFAW/One Ocean petroleum liaison contacts
        vi. Vessel Monitoring System (VMS) data
        vii. Notices to shipping
        viii. Survey start-up sessions
        ix. Consultation
        x. Communications follow-up
3. Fisheries Avoidance
    a. There are a number of examples associated with this category. They are as follows:
        i. Temporal avoidance of active fishing areas, to the best of the proponent's ability (related to communications with FFAW and fishers)
        ii. No seismic gear deployment until arrival within the Project Area
        iii. Spatial and temporal avoidance of active fisheries science surveys
        iv. Use of a picket vessel
4. Fishing Gear Damage Program
    a. Each proponent will prepare its own Fisheries Compensation Plan in case the seismic survey activities result in gear/vessel damage and/or loss. This process

involves contact with the SPOC. A protocol developed by One Ocean describes responses to a gear conflict to be followed by those on a Project vessel.

5. Marine Mammal/Wildlife Protection

    a. Some of the following measures related to marine mammals and sea turtles are based on the *Statement of Canadian Practice* (see C-NLOPB 2017b):

        i. The establishment of a **safety zone** with at least a 500 m radius measured from the airgun source array

        ii. Implementation of a **pre-start up watch** of the safety zone by a qualified and experienced MMO for at least 30 minutes prior to array start-up. If a marine mammal or sea turtle is detected within the safety zone during the 30 minute pre-start up watch, ramp up cannot commence until at least 30 minutes have passed since the last detection within the safety zone. It is anticipated that PAM for cetaceans will occur during the pre-start up watch.

        iii. If array activation is permitted, based on the pre-start up watch, a gradual **ramp up/soft start** of the airgun source array may take place over a minimum period of 20 minutes

        iv. The airgun source array(s) will be **shut down** immediately if a marine mammal or sea turtle with either *endangered* or *threatened* status on Schedule 1 of the *SARA* is detected within the safety zone. For the Study Area, this currently includes North Atlantic right whales, blue whales, northern bottlenose whales, leatherback sea turtles, and loggerhead sea turtles. Note that MKI also commits to implementing shut downs for all sea turtle species and all beaked whales, including Sowerby's beaked whale.

        v. When seismic surveying ceases during l**ine changes, maintenance or other operational reasons**, the airgun source array(s) will either be **shut down completely** or **reduced to a single source element**

        vi. Any **seabirds that become stranded on vessels** during the seismic surveying will be **released** using the mitigation methods consistent with *Procedures for handling and documenting stranded birds encountered on infrastructure offshore Atlantic Canada* (ECCC-CWS 2017)

        vii. **Marine mammal, sea turtle and seabird observations** will be made by qualified and experienced environmental observers during operations, including those related to marine mammal behavioural responses to the vessels and airgun source array(s)

        viii. The results of the marine mammal and seabird monitoring program will be included in the **EA mitigation and monitoring report**; this report will be submitted to the C-NLOPB within six months after completion of the fieldwork, as per C-NLOPB (2017b)

6. Pollution Prevention / Emergency Response

    a. Waste Management

      i. Wastes produced during activities, including hazardous and non-hazardous material, will be managed in accordance with MARPOL and the vessel-specific management plan. All solid wastes will be sorted by type, compacted where practical, and stored on board until disposal at an appropriate certified reception facility.

b. Discharge Prevention and Management

      i. Vessel discharges will not exceed those of standard vessel operations, and will adhere to all applicable regulations. The primary discharges include grey water (e.g., wastewater from washing, bathing, laundry and food preparation), black water (e.g., human wastes), bilge water, deck drainage and discharge from machinery spaces.

c. Air Emission Control

      i. The vessels will have an International Air Pollution Prevention Certificate issued under the provisions of the Protocol of 1997 as amended by resolution MEPC 176 (58) in 2008, to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978. Air emissions will be those associated with standard operations of marine vessels in general.

d. Response to Accidental Events

      i. MKI will implement the measures outlined in the Shipboard Oil Pollution Emergency Plans (SOPEPs) which will be filed with the C-NLOPB. In addition, MKI has an emergency response plan in place which bridges the emergency plans of all project entities and vessels to the local facilities and the Halifax Search and Rescue Region. The vessels also carry Spill Kits.

e. Use of Streamers with a Solid Core

      i. MKI will use a solid core streamer, thereby removing any risk of flotation fluid leakage.

5.6 Effects of the Environment on the Project

The physical environment is summarized in § 3.0 of this EA and the reader is referred to this section 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. 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 1 to November 30 for seismic operations and the requirement of a seismic survey to avoid periods and locations of sea ice, sea ice should have little or no effect on the Project (see § 3.4.1). Icebergs in the spring and early-summer may cause some survey delays if tracks have to be altered to avoid them (see Table 3.15 and

Figure 3.7 in § 3.4.2). Within the Project time frame, icebergs may require the vessels to detour in May and June when almost 48% of the yearly total of icebergs are expected to occur, based on monthly iceberg distribution data (see Table 3.15 in § 3.4.2).

Most environmental constraints on seismic surveys on the Grand Banks are those imposed by wind and wave conditions. If the Beaufort wind scale is seven or greater, there is generally too much noise for seismic data to be of use. A Beaufort wind scale of seven is equivalent to wind speeds of 33 knots (13.9–17.1 m/s), and is associated with wave heights ranging from 4.0–5.5 m. In the Study Area, these conditions are not uncommon in the late-autumn and winter months. If the sea state exceeds 3.0 m or wind speed exceeds 40 kt (20.6 m/s), then continuation/termination of seismic surveying will be evaluated. Based on multi-year data at eight grid points in the Study Area (see Figure 3.1 in § 3.2), these wave limits are typically approached during the October–April period.

Poor visibility (e.g., due to inclement weather or fog) can constrain helicopter operations and streamer repair. It also may hinder sightings of marine mammals and sea turtles within the 500-m safety zone, other vessels and fishing gear. These constraints are alleviated somewhat by state of the art forecasting, and the use of radar and FLOs to detect fishing vessels and gear. The Project scheduling avoids most of the continuous extreme weather 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., escort and supply 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 accounts of sharks attacking and damaging streamers.

The Department of National Defense (DND) records indicate that there are at least 70 shipwrecks, including two Unexploded Explosive Ordnance (UXO) sites of concern and at least 29 sites in which UXO may be present, and five legacy sites present in the Study Area (LGL 2017b). Due to the inherent dangers of associated UXO and the fact that the northwest Atlantic Ocean was exposed to many naval engagements during WWII, any suspected UXO encountered during the course of the operations will be geo-referenced, immediately reported to the Coast Guard, and left undisturbed.

Effects of the environment on the Project are predicted to be *not significant* for the reasons discussed above.

5.7 Effects of the Project Activities on the Environment

This effects assessment is organized so that issues generic to any type of ship activity in the Study Area (e.g., seismic operations vessels, fisheries vessels, DFO research vessels, military ships, marine transporters) are discussed first. The detailed effects assessment that follows focuses on the effects of noise (primarily on marine mammals, fish and fisheries) from the airgun array(s) and the towed seismic streamers (primarily on fishing gear), which is the major distinction between the effects of seismic surveys versus those of other marine vessels. The applicable mitigation measures (§ 5.5) are also noted for the relevant activity. The detailed assessment includes the generic effects in the ratings and predictions tables but does not discuss these generic issues in any detail.

5.7.1 Generic Activities - Air Quality

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

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

5.7.2 Generic Activities - Marine Use

Project-related traffic will include one seismic survey vessel and one escort vessel. A supply vessel will not necessarily be required in all instances. The seismic and support vessels will operate within the Project Area (see Figure 1.1), except when transiting to or from the survey area. The seismic and/or support vessels may operate occasionally to and from the Project Area for re-provisioning, re-fuelling, and crew changes. The escort vessel will be onsite with the seismic vessel at all times during which the seismic vessel is acquiring data. If the escort vessel is to be unavoidably absent from the operational area and/or is unable to perform its duties for any reason, the seismic operator will perform a risk assessment of their ongoing operations and plan and implement risk mitigation measures to minimize the potential for negative interaction with commercial fishers. The risk assessment and type of mitigations expected were previously communicated to MKI by the C-NLOPB (LGL 2017b).

Other ships operating in the area could include freighters, tankers, fishing vessels, research vessels, naval vessels, and private yachts. Mitigation measures (detailed in § 5.5) intended to minimize potential conflicts and any adverse effects with other vessels include the following.

- At sea communications (VHF, HF, Satellite, radar etc.);
- Utilization of FLOs for advice and coordination in regard to avoiding fishing vessels and fishing gear;
- Support vessel to alert other vessels of towed gear in water;
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast (e.g., Notice to Mariners, Notice to Airmen);
- Compensation program in the event any project vessels damage fishing gear; and
- Single Point of Contact (SPOC).

MKI will also coordinate with DFO, St. John's, to avoid any potential conflicts with research vessels that may be operating in the area, and will engage with CTF 84, through DGNSR, to ensure de-confliction with possible Allied submarine activities. Given the expected number of vessels in the Project Area and mitigation measures described above, there should be *negligible* adverse effects on other marine users of the Project Area.

5.7.3   Generic Activities - Waste Handling

Project waste will be generated by about 55–85 personnel. Waste will include the following.

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

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

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

5.7.4   Fish and Fish Habitat VEC

Despite the certainty of 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 5.2), the residual effects are predicted to be *negligible* and *not significant*. The seismic program will not result in any direct physical disturbance of the bottom substrate. Also, there is a very low probability of any accidental event (i.e., hydrocarbon release) large enough to cause a significant effect on fish habitat. Therefore, other than its inclusion in

Table 5.2, no further reference to the 'fish habitat' component of the Fish and Fish Habitat VEC is made in this assessment subsection. Note that ichthyoplankton, invertebrate eggs and larvae, and macrobenthos are considered part of the 'fish' component of the Fish and Fish Habitat VEC.

Table 5.2   Potential Interactions of the Project Activities and the Fish and Fish Habitat VEC.

	Non-Biological Environment	Feeding		Reproduction		Adult Stage	
Valued Environmental Component: Fish and Fish Habitat							
Project Activities	**Water and Sediment Quality**	**Plankton**	**Benthos**	**Eggs and Larvae**	**Juveniles [a]**	**Pelagic Fish**	**Groundfish**
Sound							
Airgun Array (2D, 3D and 4D)		X	X	X	X	X	X
Seismic Vessel		X	X	X	X	X	X
Supply Vessel		X	X	X	X	X	X
Escort Vessel		X	X	X	X	X	X
Helicopter							
Echo Sounder						X	
Side Scan Sonar						X	
Vessel Lights		X				X	
Vessel/Equipment Presence							
Seismic Vessel and Equipment							
Supply Vessel							
Escort Vessel							
Sanitary/Domestic Waste	X	X		X		X	
Atmospheric Emissions	X	X		X		X	
Garbage [b]							
Helicopter Presence							
Shore Facilities [c]							
Accidental Releases	X	X	X	X	X	X	X
Other Projects and Activities in Regional Area							
Oil and Gas Activities	X	X	X	X	X	X	X
Fisheries	X	X	X	X	X	X	X
Marine Transportation	X	X	X	X	X	X	X

[a] Juveniles are young fish that are no longer planktonic and are often closely associated with the sea bottom.
[b] Not applicable as garbage will be brought ashore.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

5.7.4.1 Sound

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

Information related to interactions between underwater sound and invertebrates and fishes is available in § 5.7.4 and Appendices 2 and 3 of the WesternGeco Eastern Newfoundland EA (LGL 2015a), and the WesternGeco Southeastern Newfoundland EA (LGL 2015b); § 5.1 of the Eastern Newfoundland SEA (C-NLOPB 2014), and § 5.1.2 of the Southern Newfoundland SEA (C-NLOPB 2010). Topics in these subsections and appendices include sound detection and production by marine invertebrates and fishes, and the potential effects of exposure to underwater sound, particularly seismic airgun sound, on marine invertebrates and fishes.

The assessment in this subsection is structured such that the reader should first refer to the interactions table (e.g., Table 5.2) to determine the interactions of the Fish and Fish Habitat VEC with project activities, secondly to the assessment table (e.g., Table 5.3) which contains criteria ratings, including those for magnitude, geographic extent, and duration, and thirdly to the significance predictions table (e.g., Table 5.4).

Sound Exposure Effects Assessment

It is not practical to assess in detail the potential effects of every type of sound on every species in the Study Area. The best approach in environmental assessment is to provide focus by selecting (1) the sound source with the highest sound level, in this case the seismic airgun sound, and (2) example species that are both representative of the different types of sensitivities to underwater sound and have been scientifically studied with respect to interaction with underwater sound (e.g., snow crab and Atlantic cod).

The primary factors considered in the assessment include (1) distance between airgun array and animal under normal conditions (post-larval snow crabs remain on bottom, post-larval cod occur in the water column, and larvae of both snow crab and cod are planktonic in upper water column), (2) motility of the animal (post-larval snow crabs are much less motile than post-larval cod, and larvae of both are essentially passive drifters), (3) absence or presence of a swim bladder (i.e., auditory sensitivity) (snow crabs without swim bladder and cod with swim bladder), and (4) reproductive strategy (snow crabs carry fertilized eggs at the bottom until larval hatch, and cod eggs are planktonic).

Potential effects on other marine invertebrate and fish species are inferred from the assessment using snow crab and Atlantic cod as representative species of the Fish and Fish Habitat VEC. Potential interactions between the proposed Project activities and the Fish and Fish Habitat VEC are shown in Table 5.2.

Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, several data gaps remain (Hawkins et al. 2015).

Physical and Physiological Effects

Available experimental data suggest that there may be physical effects on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range (Booman et al. 1996; Christian et al. 2003; Sierra-Flores et al. 2015). Considering the typical source levels associated with commercial seismic airgun arrays, an invertebrate or fish close to the source could be exposed to very high sound levels. While egg and larval stages are unable to actively move away from the sound source, juvenile and adult cod can. 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 an effect. However, there remains a lack of knowledge regarding exposure of benthic organisms to substrate vibration and energy waves associated with the water-substrate interface and substrate. 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 events (e.g., unique spawning aggregations, particularly in terms of location) and ramp-up of the airgun array should theoretically mitigate the population-level effects of exposure to airgun sound.

Particle motion is the component of underwater acoustic stimuli generated partly by hydrodynamic flow near the acoustic stimulus source and partly by the oscillations associated with the sound pressure waves as they propagate from the acoustic source as a cyclic compression and rarefaction of water molecules (Higgs et al. 2006). Snow crab, thought to be sensitive to the particle motion component of sound only (Popper et al. 2001) will be a considerable distance from the airguns and will not likely be affected by any particle motion in the water column resulting from airgun discharge. However, as stated above, there is a lack of knowledge regarding exposure of benthic organisms to substrate vibration and energy waves associated with the water-substrate interface and substrate.

Limited data regarding physiological effects on fish and invertebrates suggest that these effects 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. The duration of such a temporary effect varies depending on numerous factors, including the species being exposed, the behaviour being exhibited by fishes when exposed to low frequency sound, the characteristics of the sound (e.g., source level, continuous vs. impulsive sound, captive vs. non-captive fishes, etc.). For example, captive fishes exposed to sound from a single airgun by McCauley et al. (2000) exhibited acute startle and alarm responses that ceased 15–30 minutes after cessation of exposure. Pearson et al. (1992) exposed non-captive fishes to sound from a single airgun and these fishes also exhibited startle and alarm responses which subsided 20–60 minutes after exposure. On the other end of the 'temporary' spectrum, various studies (Løkkeborg and Soldal

1993; Løkkeborg et al. 2012; Engås et al. 1993, 1996) have investigated behavioural effects on wild fish from a fisheries perspective. The temporary effect observed in these studies appeared to persist for a number of days before 'normal' distribution was re-established

A more comprehensive discussion regarding the physical and physiological effects of exposure to seismic sound on fishes is contained in the appendices of recently completed seismic EAs (e.g., LGL 2015a,b).

Behavioural Effects

Studies suggest that effects on fish behaviour due to exposure to airgun sound are temporary in nature, and that response thresholds for various demersal and pelagic species are quite variable. Numerous studies have reported startle/alarm responses by fish (Pearson et al. 1992; Fewtrell and McCauley 2012). Pearson et al. (1992) also reported observations of localized distributional shifts, tightening of schools, and random movement and orientation. Løkkeborg et al. (2012) reported differences between species in terms of catchability after being exposed to seismic sound. They observed higher catches in gill nets but lower catches on baited hooks, possibly resulting from increased random movement by the fish causing a higher incidence of fish being caught up in gill nets but a lower incidence of fish targeting baited hooks. There is some thought that the degree of behavioural response by fishes to exposure to anthropogenic sounds such as seismic airgun sound depends on what natural behaviour the fish is exhibiting at the time of exposure. For example, fish exhibiting reproductive and/or feeding behaviour may have a higher response threshold to anthropogenic sound than fish exhibiting migratory behaviour. More study is required to test this hypothesis.

A more comprehensive discussion regarding the behavioural effects of exposure to seismic sound on fishes is contained in the appendices of recently completed seismic EAs (e.g., LGL 2015a,b).

New Literature

Recently published review papers related to the potential effects of exposure to anthropogenic sound on invertebrates and fishes include Aguilar de Soto (2016), Carroll et al. (2016) and Edmonds et al. (2016). Another recently-published paper by Hawkins and Popper (2016) provides a recommended approach to assessing the impact of underwater noise on marine fishes and invertebrates. Hawkins and Popper (2016) point out the existing hurdles that limit one's ability to assess these impacts with more certainty.

A recently released report on a study conducted in Tasmanian waters during 2013–2015 (Day et al. 2016) describes the results of exposure of captive adult southern rock lobsters (*Jasus edwardsii*), including berried females, and adult commercial scallops (*Pecten fumatus*) to seismic sound in a field setting. Sound measurement instrumentation was deployed throughout the

experimentation to record both sound pressure and ground borne vibration. The number of airgun pulses per exposure replicate for the lobster and scallop experiments ranged from 110–126, and 51–167, respectively. The lobsters were exposed to two types of passes: (1) a control pass of a non-operating airgun; and (2) a pass of an operating airgun. The scallops were exposed to four types of passes: (1) a control pass of a non-operating airgun; (2) one pass of an operating airgun; (3) two passes of an operating airgun; and (4) four passes of an operating airgun. Maximum received SEL_{cum} for the lobster experiments ranged from 192–199 dB re 1 μPa^2 ·s, while maximum received SEL_{cum} for the scallop experiments ranged from 189–198 dB re 1 μPa^2 s. Various parameters for the lobsters were measured at four sampling times between Day 0 (exposure day) and Day 120 (120 days post-exposure). Some lobsters were assessed at 365 days post-exposure. Various parameters for the scallops were measured at three sampling times between Day 0 and Day 120.

The key findings of Day et al. (2016) during the lobster experiments include:

1. No mortality observed;
2. Two reflexes, tail extension and righting, showed responses following exposure to airgun sound. Tail extension was reduced in lobsters exposed during the lone summer exposure for 14 days, and righting was compromised in three of the four exposure experiments and persisted to 120 days post-exposure in all experiments and to 365 days post-exposure in the one experiment conducted for that duration;
3. Damage to the statocyst sensory hairs was observed in lobsters exposed in three of the four experiments;
4. Haemolymph biochemistry showed little effect from exposure;
5. Counts of the number of circulating haemocytes showed a significant reduction in all four experiments; and
6. Embryos exposed to airgun sound and subsequently hatched showed neither qualitative nor quantitative effects.

The key findings of Day et al. (2016) during the scallop experiments include:

1. Acute mass mortality was not observed but repeated exposure significantly increased mortality. The risk of mortality increased with time, based on the fact that the majority of mortality was recorded at the Day 120 sample points;
2. Substantial disruptions in haemolymph biochemistry were observed. A range of electrolytes, minerals and metabolites showed disrupted levels through to Day 120 post-exposure;
3. Haemolymph pH was affected in two of the three experiments. A slight but persistent alkalosis was observed at Day 14 post-exposure;
4. Scallops demonstrated a reduction of classic behaviours during exposure. In addition, it seemed that airgun exposure elicited a novel velar flinch behaviour; and
5. Scallop reflexes were affected, with exposures resulting in faster recessing times and some indication that righting time was reduced.

Day et al. (2016) concluded that until the full scope of these observed changes and their ecological effects are thoroughly investigated, caution must be taken against extrapolating the results of this study.

Assessment of Effects of Exposure to Sound

Table 5.3 provides the details of the assessment of the residual effects of exposure to Project-related sound on the Fish and Fish Habitat VEC. MKI seismic vessels from simultaneous 3D and 2D surveys will maintain a minimum separation distance (>30 km) when operating airgun arrays in the Project Area. This should decrease the probability of synergistic effects on fishes and invertebrates. Relative to the effects predictions made for a single 2D or 3D seismic survey, the potential residual effects on the Fish and Fish Habitat VEC related to sound from three simultaneous 3D seismic surveys and one 2D seismic survey (worst-case scenario) is predicted to occur over a larger area (i.e., maximum geographic extent of *1001–10,000* km^2 vs. *101–1000* km^2). With mitigation measures in place (see Table 5.1), residual effects on the Fish and Fish Habitat VEC associated with sound from the Project during simultaneous 3D and 2D seismic surveys are predicted to range from *low to medium* in magnitude for a duration of *<1 month* to *1–12 months* over an area of *<1 km^2 to 1001–10,000 km^2*. Based on these criteria ratings, the *reversible* residual effects of underwater sound on the Fish and Fish Habitat VEC are predicted to be *not significant.* The level of confidence associated with this prediction is *low to medium* (Table 5.4) given the scientific data gaps.

5.7.4.2   Effects Assessment of other Routine Project Activities

Vessel Lights

As indicated in Tables 5.2–5.4, vessel lights may attract plankton and pelagic fishes towards the upper water column. However, seismic vessels are typically travelling at a high enough rate so that the attraction effect is not spatially static. Therefore, the overall effect of vessel lights on the Fish and Fish Habitat VEC is somewhat neutral. Therefore, the effects of vessel lights associated with MKI's proposed 2D/3D/4D seismic program on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.4). The level of confidence associated with this prediction is *medium* to *high* (Table 5.4).

Sanitary/Domestic Waste

Table 5.3 provides the details of the assessment of the effects of exposure to Project-related sanitary and domestic waste on the Fish and Fish Habitat VEC, including appropriate mitigation measures. As indicated in § 5.7.3, appropriate treatment of wastes produced by the Project will result in residual effects that are *negligible* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1 km^2* (Table 5.3). Based on these criteria ratings, the *reversible* residual effects of sanitary/domestic wastes produced during MKI's proposed

2D/3D/4D seismic program on the Fish and Fish Habitat VEC are predicted to be *not significant* (Table 5.4). The level of confidence associated with this prediction is *high* (Table 5.4).

Table 5.3   Assessment of Effects of Project Activities on the Fish and Fish Habitat VEC.

Valued Environmental Component: Fish and Fish Habitat								
			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound								
Airgun Array (2D, 3D and 4D)	Physical effects (N); Disturbance (N)	Ramp-up of array; Spatial & temporal avoidance	0-2	1-5	6	1-2	R	2
Seismic Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1-2	6	1-2	R	2
Supply Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1-2	1	1	R	2
Escort Vessel	Disturbance (N)	Spatial & temporal avoidance	0-1	1-2	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
Vessel Lights	Attraction (Neutral)	-	-	-	-	-	-	-
Sanitary/Domestic Waste	Pathological effects (N); Contamination (N)	Treatment	0	1	4	1-2	R	2
Atmospheric Emissions	Pathological effects (N); Contamination (N)	Equipment maintenance	0	1	6	1-2	R	2
Accidental Releases	Pathological effects (N); Contamination (N)	Prevention protocols; Response plan	0-1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

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

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

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

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

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

Table 5.4 Significance of Potential Residual Environmental Effects of Project Activities on the Fish and Fish Habitat VEC.

| Project Activity | Significance of Predicted Residual Environmental Effects | | Likelihood[a] | |
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Sound				
Airgun Array (2D, 3D and 4D)	NS	1-2	-	-
Seismic Vessel	NS	2-3	-	-
Supply Vessel	NS	2-3	-	-
Escort Vessel	NS	2-3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Vessel Lights	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Valued Environmental Component: Fish and Fish Habitat

Key:
Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.

Residual environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Level of Confidence: based on professional judgment:
1 = Low
2 = Medium
3 = High

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

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

Atmospheric Emissions

Table 5.3 provides the details of the assessment of the effects of exposure to Project-related atmospheric emissions on the Fish and Fish Habitat VEC, including appropriate mitigation measures. As indicated in § 5.7.1, atmospheric emission levels produced by the Project will be similar to those produced by other marine vessels not directly related to the Project. Residual effects of Project-related atmospheric emissions will be *negligible* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1 km^2*. Based on these criteria ratings, the *reversible* residual effects of atmospheric emissions produced during MKI's proposed 2D/3D/4D seismic program on the Fish and Fish Habitat VEC are predicted to be *not significant* (see Table 5.4). The level of confidence associated with this prediction is *high* (see Table 5.4).

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 5.2, there are potential interactions of accidental releases and components of the Fish and Fish Habitat VEC that occur near surface. The effects of hydrocarbon spills on marine invertebrates and fish have been discussed and assessed in numerous recent environmental assessments of proposed offshore drilling programs and assessments have concluded that the residual effects of accidental hydrocarbon releases on the Fish and Fish Habitat VEC are predicted to be *not significant*. With proper mitigation measures in place (see Table 5.3), the residual effects of an accidental release associated with MKI'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 km²* (see Table 5.3). 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 MKI's proposed 2D/3D/4D seismic program on the Fish and Fish Habitat VEC are predicted to be *not significant* (see Table 5.4). The level of confidence associated with this prediction is *medium* to *high* (see Table 5.4).

5.7.5   Fisheries VEC

The potential interactions of the Project activities and the Fisheries VEC are indicated in Table 5.5. DFO and joint DFO/Industry Research Surveys are included in the assessment of the Fisheries VEC.

Table 5.5   Potential Interactions of Project Activities and the Fisheries VEC.

Project Activities	Valued Environmental Component: Fisheries		
	Mobile Invertebrates and Fishes (fixed [e.g., gillnet] and mobile gear [e.g., trawls])	**Sedentary Benthic Invertebrates (fixed gear [e.g., crab pots])**	**Research Surveys (mobile gear-trawls; fixed gear-crab pots)**
Sound			
Airgun Array (2D, 3D and 4D)	X	X	X
Seismic Vessel	X	X	X
Supply Vessel	X	X	X
Escort Vessel	X	X	X
Helicopter			
Echo Sounder	X		
Side Scan Sonar	X		X
Vessel Lights			
Vessel/Equipment Presence			
Seismic Vessel/Gear	X	X	X
Supply Vessel	X	X	X
Escort Vessel	X	X	X
Sanitary/Domestic Waste	X	X	X
Atmospheric Emissions			
Garbage[a]			
Helicopter Presence			
Shore Facilities[b]			
Accidental Releases	X	X	X
Other Projects and Activities in Regional Area			
Oil and Gas Activities	X	X	X
Marine Transportation	X	X	X
[a] Not applicable as garbage will be brought ashore. [b] There will not be any new onshore facilities. Existing infrastructure will be used.			

Behavioural changes relating to catchability of commercial species, and conflict with harvesting activities, fishing gear and lost fishing time have been raised as potential issues either during consultations and issues scoping for this assessment (§ 5.1.1) or during consultations for recent EAs for offshore eastern and southern offshore Newfoundland (e.g., § 5.1.1 of LGL 2016). Conflicts between seismic vessels and associated gear and fishing activities/gear have occurred in the past in Atlantic Canada when seismic vessels were operating in areas with high levels of fishing activity. This is particularly relevant in relation to fixed gear, such as crab pots and gillnets within the Study Area. Other potential sources of interference from seismic activities may include temporal and spatial conflicts with DFO and DFO/Industry research surveys if both are being conducted concurrently in the same general area, and an accidental release of petroleum hydrocarbons, which may result in tainting (or perceived tainting) and affect product quality and marketing.

The primary means of mitigating potential impacts on the Fishery VEC is to avoid active fishing areas, particularly fixed gear zones. For the commercial fisheries, compensation for damaged gear provides a means of final mitigation of impacts, in the event a conflict occurs (e.g., accidental contact of fishing gear with the survey airgun array, seismic vessel or streamers). Information regarding mitigation measures, including those associated with the Fisheries VEC, is provided in § 5.5.

The document *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2017b) provides guidance aimed at minimizing any impacts of petroleum industry geophysical surveys on commercial fish harvesters and other marine users. The mitigations provided below are also relevant to DFO and joint DFO/Industry research surveys. Development of the guidelines was based on best practices applied during previous geophysical surveys in Atlantic Canada, as well as guidelines from other national jurisdictions.

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

5.7.5.1 Sound

The potential for impacts on fish harvesting are dependent on the location and timing of the surveying activities in relation to fishing areas, and the type of fishing gear used in any given season. If the survey work is situated away from active fishing areas or occurs 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 § 5.7.4.1. While adult fish could be injured by airgun sound if they are within a few metres of a sound source, this is unlikely since fish may 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 § 5.7.4.1. While some of the behavioural effects studies report decreases in catch rates near seismic survey areas, there is some disagreement on the duration and geographical extent of the effect.

Mitigations are discussed in § 5.5. The primary measures intended to minimize the effects of Project activities on the Fisheries VEC include:

- Good communication between the Operator and fishers/researchers;
- Spatial and temporal avoidance of areas where concentrated fishing is occurring; and
- Deployment of at least one FLO on each seismic vessel.

It is imperative that detailed temporal and spatial information regarding seismic and fishing/research surveying operations be exchanged between the various parties. This will allow the establishment of temporal and spatial separation plan, as has been successfully done with DFO Newfoundland and Labrador in past seasons.

Relative to the effects predictions for a single 2D or 3D seismic survey, the potential residual effects on fisheries related to sound from three simultaneous 3D seismic surveys and one 2D seismic survey is predicted to occur over a larger area (i.e., maximum geographic extent of *1001–10,000* km^2 vs.*101–1000* km^2). With mitigation measures in place (see § 5.5 and above), residual effects on the Fisheries VEC associated with sound from the Project during simultaneous 3D seismic surveys and one 2D seismic survey are predicted to range from *low to medium* in magnitude for a duration of *<1 month* to *1–12 months* over an area of *<1 km^2 to 1001–10,000 km^2* (Table 5.6). Based on these criteria ratings, the *reversible* residual effects of underwater sound on the Fisheries VEC are predicted to be *not significant*, and the level of confidence associated with this prediction is *low* to *medium* (Table 5.7) given the scientific data gaps.

5.7.5.2 Vessel/Equipment Presence

Commercial fish harvesting activities occur throughout the May–November temporal scope period for the proposed Project. Fishing with fixed gear (e.g., pot fishery for snow crab) poses the highest potential for conflict. During 2D/3D/4D seismic surveying, operations will be conducted continuously unless weather or technical issues cause interruptions. The length of the seismic streamers (maximum of 12,000 m) used during MKI's seismic operations during 2018–2023 will restrict the maneuverability of the seismic vessel, such that 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. Gear deployment will be conducted within the Project Area only. If conflict events occur resulting in gear damage or loss, compensation will be paid.

Mitigations relevant to Fisheries VEC are discussed in § 5.5. Mitigations measures intended to minimize the effects of vessel and equipment presence on the Fisheries VEC include:

- Good communication between the Operator and fishers/researchers;
- Spatial and temporal avoidance of areas where concentrated fishing is occurring;
- Deployment of at least one FLO on each seismic vessel;
- Single Point of Contact (SPOC); and
- Compensation for gear damage and/or loss.

With application of the mitigations discussed in § 5.5 and above, the residual effects of vessel and equipment presence on the Fisheries VEC are predicted to have a *negligible* to *low* magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *11–100 km^2*

(Table 5.6). Based on these criteria ratings, the *reversible* residual effects of vessel/gear presence associated with MKI's proposed 2D/3D/4D seismic program on the Fisheries VEC are predicted to be *not significant* (Table 5.7). The level of confidence associated with this prediction is *high* (Table 5.7).

Table 5.6   Assessment of Effects of Project Activities on the Fisheries VEC.

Valued Environmental Component: Fisheries								
Project Activity	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Sound								
Airgun Array (2D, 3D and 4D)	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0-1	1-5	6	1-2	R	2
Seismic Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1-2	R	2
Supply Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	1	1	R	2
Escort Vessel	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1-2	R	2
Echo Sounder	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1	R	2
Side Scan Sonar	Disturbance (N); Effect on catch rate (N)	Spatial & temporal avoidance; communication	0	1	6	1	R	2
Vessel/Equipment Presence								
Seismic Vessel/Gear (2D, 3D and 4D)	Conflict with gear (N)[a]	FLO; communication	0-1	1-3	6	1-2	R	2
Supply Vessel	Conflict with gear (N)[a]	FLO; communication	0-1	1-3	1	1	R	2
Escort Vessel	Conflict with gear (N)[a]	FLO; communication	0-1	1-3	6	1-2	R	2
Sanitary/Domestic Wastes	Taint (N); Perceived taint (N)	Treatment	0-1	1	4	1-2	R	2
Accidental Releases	Taint (N); Perceived taint (N)	Preventative protocols; response plan; communications	0-1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

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

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

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

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

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

[a] This is considered negligible since, if a conflict occurs, compensation will eliminate any economic impact.

Table 5.7   Significance of Potential Residual Environmental Effects on the Fisheries VEC.

Project Activity	Significance Rating	Level of Confidence	Likelihood[a]	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
Valued Environmental Component: Fisheries				
Sound				
Airgun Array (2D, 3D and 4D)	NS	1-2	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Echo Sounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Vessel/Equipment Presence				
Seismic Vessel (2D, 3D and 4D)	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Key:
Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.

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

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

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

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

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

5.7.5.3 Sanitary/Domestic Wastes

As indicated in § 5.7.3, appropriate treatment of wastes produced by the Project will result in residual effects that are *negligible* to *low* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1 km^2* (see Table 5.6). Based on these criteria ratings, the *reversible* residual effects of sanitary/domestic wastes produced during MKI's proposed 2D/3D/4D seismic program on the Fisheries VEC are predicted to be *not significant* (see Table 5.7). The level of confidence associated with this prediction is *high* (see Table 5.7).

5.7.5.4 Accidental Releases

In the event of an accidental release of hydrocarbons (e.g., fuel spill), there is the 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, 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. 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 (C-NLOPB 2017b). Compensation protocols based on C-NLOPB Guidelines (C-NLOPB 2017b) are described in § 3.2.5.5 of the Eastern Newfoundland SEA (C-NLOPB 2014).

With application of the mitigations discussed above, the residual effects of accidental hydrocarbon releases on the Fisheries VEC are predicted have a *negligible* to *low* magnitude for a duration of *<1 month* over a geographic area of *<1* to *1–10 km^2* (see Table 5.6). Based on these criteria ratings, the *reversible* residual effect of accidental releases associated with MKI's proposed 2D/3D/4D seismic program on the Fisheries VEC is predicted to be *not significant* (see Table 5.7). The level of confidence associated with this prediction is *medium* to *high* (see Table 5.7).

5.7.6 Marine-associated Bird VEC

All potential interactions of the Project activities and the Marine-associated Bird VEC are indicated in Table 5.8. The routine Project activity that has the highest probability of affecting marine-associated birds is 'vessel lights'.

5.7.6.1 Sound

The effect of exposure to anthropogenic underwater sound on birds has not been well studied. Subsections 5.7.6.1 of LGL (2015a), and LGL (2015b) describe the interaction between birds and sound.

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related sound on the Marine-associated Bird VEC. With mitigation measures in place (see Table 5.1), residual effects of three simultaneous seismic surveys and one 2D seismic survey on seabirds are predicted to range from *negligible to low* in magnitude for a duration of *<1 month* to *1–12 months* over an area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual effects of simultaneous seismic surveys on the Marine-associated Bird VEC are predicted to be *not significant.* The level of confidence associated with this prediction is *medium to high* (see Table 5.10).

Table 5.8   Potential Interactions between Project Activities and the Marine-associated Bird VEC.

Project Activities	Valued Environmental Component: Marine-associated Birds
Sound	
Airgun Array (2D, 3D and 4D)	X
Seismic Vessel	X
Supply Vessel	X
Escort Vessel	X
Helicopter	X
Echo Sounder	X
Side Scan Sonar	X
Vessel Lights	X
Vessel/Equipment Presence	
Seismic Vessel and Equipment	X
Supply Vessel	X
Escort Vessel	X
Sanitary/Domestic Waste	X
Atmospheric Emissions	X
Garbage[a]	
Helicopter Presence	X
Shore Facilities[b]	
Accidental Releases	X
Other Projects and Activities in Regional Area	
Oil and Gas Activities	X
Fisheries	X
Marine Transportation	X
[a] Not applicable as garbage will be brought ashore. [b] There will not be any new onshore facilities. Existing infrastructure will be used.	

5.7.6.2   Vessel Lighting

Artificial lighting on ships at sea, offshore oil and gas drilling and production structures, coastal communities, and oceanic island communities is known to interact with marine-associated birds (see Table 5.8) and has often been implicated in the stranding of nocturnally-active seabirds and nocturnally-migrating land- and water-birds (Montevecchi et al. 1999; Gauthreaux and Belser 2006; Montevecchi 2006; Ronconi et al. 2015). Subsection 5.7.6.2 of LGL (2015a,b) describes the interaction between birds and artificial light.

Table 5.9 **Assessment of Potential Effects of Project Activities on the Marine-associated Bird VEC.**

			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
**Sound**								
Airgun Array (2D, 3D and 4D)	Disturbance (N)	Ramp up of array	0-1	1-2	6	1-2	R	2
Seismic Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Supply Vessel	Disturbance (N)		0	1	1	1	R	2
Escort Vessel	Disturbance (N)		0	1	6	1-2	R	2
Helicopter	Disturbance (N)		0-1	2	1	1	R	2
Echosounder	Disturbance (N)		0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1	R	2
Vessel Lights	Attraction (N)	Reduce lighting (if possible); Monitoring; Seabird handling and release	1	1-3	2-3	1-2	R	2
**Vessel/Equipment Presence**								
Seismic Vessel/Gear (2D, 3D and 4D)	Disturbance (N)		0	1-3	6	1-2	R	2
Supply Vessel	Disturbance (N)		0	1	1	1	R	2
Escort Vessel	Disturbance (N)		0	1	6	1-2	R	2
Sanitary/Domestic Waste	Increased Food (N/P)	Treatment	0	1	4	1-2	R	2
Atmospheric Emissions	Air Contaminants (N)	Equipment maintenance	0	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1-2	R	2
Accidental Releases	Mortality (N)	Solid streamer; spill response	1-2	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

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

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

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

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

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

Table 5.10   Significance of the Potential Residual Effects of the Project Activities on the Marine-associated Bird VEC.

Project Activity	Significance of Predicted Residual Environmental Effects		Likelihood[a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Sound				
Airgun Array (2D, 3D and 4D)	NS	2-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Vessel Lights	NS	2-3	-	-
Vessel/Equipment Presence				
Seismic Vessel and Gear (2D, 3D and 4D)	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	2	-	-
Key: Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km². Residual environmental Effect Rating: S = Significant Negative Environmental Effect NS = Not-significant Negative Environmental Effect P = Positive Environmental Effect Level of Confidence: based on professional judgment 1 = Low 2 = Medium 3 = High		Probability of Occurrence: based on professional judgment: 1 = Low Probability of Occurrence 2 = Medium Probability of Occurrence 3 = High Probability of Occurrence Scientific Certainty: based on scientific information and statistical analysis or professional judgment: 1 = Low 2 = Medium 3 = High ᵃ Considered only in the case where 'significant negative effect' is predicted.		

Bird attraction to artificial lighting at sea may be mitigated in a variety of ways. Recovering grounded seabirds and returning them to sea after their plumage has sufficiently dried greatly reduces mortality (Telfer et al. 1987; Le Corre et al. 2002; Abgrall et al. 2008b; Rodríguez and Rodríguez 2009; ECCC 2017b). Reducing, shielding or eliminating skyward radiation from artificial lighting also appears to reduce the number of stranded birds (Reed et al. 1985; Rodríguez and Rodríguez 2009; Miles et al. 2010). A preliminary study of the effect of replacing white and red lights with green lights on an offshore natural gas production platform

suggested that there was a reduction in the number of nocturnally-migrating birds attracted to the artificial lighting (Poot et al. 2008).

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related vessel lighting on the Marine-associated Bird VEC, including appropriate mitigations. As indicated in Table 5.9, artificial light produced by the Project is predicted to have residual effects on the Marine-associated Bird VEC that are *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *11–100 km²*. Based on these criteria ratings, the *reversible* residual effects of artificial light associated with MKI's proposed 2D/3D/4D seismic program on the Marine-associated Bird VEC are predicted to be *not significant* (see Table 5.10). The level of confidence associated with this prediction is *medium* to *high* (see Table 5.10).

5.7.6.3   Effects Assessment of other Routine Project Activities

Vessel/Equipment Presence

The potential effects of the physical presence of vessels and seismic gear are likely to be minimal. Seabirds may be attracted to the seismic, escort 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 move elsewhere in search of food. Seabirds sitting on the water in the path of these vessels can easily evade the vessels and any equipment associated with the vessels.

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related vessel/equipment presence on the Marine-associated Bird VEC, including appropriate mitigations. As indicated in Table 5.9, the presence of vessels and equipment associated with the Project is predicted to have residual effects on the Marine-associated Bird VEC that are *negligible* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *11–100 km²*. Based on these criteria ratings, the *reversible* residual effects of the presence of vessels and equipment associated with MKI's proposed 2D/3D/4D seismic program on the Marine-associated Bird VEC are predicted to be *not significant* (see Table 5.10). The level of confidence associated with this prediction is *high* (see Table 5.10).

Sanitary/Domestic Waste

Sanitary waste generated by the vessels will be macerated before subsurface discharge (see § 5.7.3). 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.

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related sanitary and domestic waste on the Marine-associated Bird VEC, including appropriate mitigations. As indicated in Table 5.9, sanitary/domestic waste associated with the Project is predicted to have residual effects on the Marine-associated Bird VEC that are *negligible* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1 km²*. Based on these criteria ratings, the *reversible* residual effects of sanitary/domestic waste associated with MKI's proposed 2D/3D/4D seismic program on the Marine-associated Bird VEC are predicted to be *not significant* (see Table 5.10). The level of confidence associated with this prediction is *high* (see Table 5.10).

Atmospheric Emissions

Although atmospheric emissions could, in theory, affect the health of some resident seabirds, these effects will be *negligible* considering that emissions consisting of potentially harmful materials will be low and will rapidly disperse to undetectable levels. As indicated in § 5.7.1, atmospheric emission levels produced by the Project will be similar to those produced by other marine vessels not related to the Project.

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related atmospheric emissions on the Marine-associated Bird VEC, including appropriate mitigations. As indicated in Table 5.9, atmospheric emissions associated with the Project are predicted to have residual effects on the Marine-associated Bird VEC that are *negligible* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual effects of atmospheric emissions associated with MKI's proposed 2D/3D/4D seismic program on the Marine-associated Bird VEC are predicted to be *not significant* (see Table 5.10). The level of confidence associated with this prediction is *high* (see Table 5.10).

Helicopter Presence

The 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.

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related helicopter presence on the Marine-associated Bird VEC, including appropriate mitigations. As indicated in Table 5.9, helicopter presence associated with the Project is predicted to have residual effects on the Marine-associated Bird VEC that are *negligible* to *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual effects of the presence of helicopters associated with MKI's proposed 2D/3D/4D seismic program on the Marine-associated Bird VEC are predicted to be *not*

significant (see Table 5.10). The level of confidence associated with this prediction is *high* (see Table 5.10).

Accidental Releases

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 hydrocarbons. Northern Fulmar, the shearwaters and storm-petrels are attracted to sheens. The visual appearance of a hydrocarbon sheen would resemble a sheen of biological origin and may initially attract such species (Nevitt 1999). However, these species also search for food by olfaction, relying on the smell of chemicals found in their foods, such as dimethyl sulfide (e.g., Leach's Storm-Petrel; Nevitt and Haberman 2003). Upon investigation of a visually identified hydrocarbon sheen, such birds would find that its odour does not resemble that of any food item (Hutchison and Wenzel 1980). As a result, these birds would be unlikely to come in contact with a sheen during foraging. However, flocks of seabirds resting on the water would not necessarily leave the water if they drifted into an area with hydrocarbons.

An exposure to a surface release of hydrocarbons under calm conditions may harm or kill individual birds. Morandin and O'Hara (2016) 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, the potential of accidental releases of hydrocarbons during the proposed seismic program is low and the evaporation/dispersion rate of any released hydrocarbons would be high.

Table 5.9 provides the details of the assessment of the effects of exposure to Project-related accidental releases of hydrocarbons on the Marine-associated Bird VEC, including appropriate mitigations. As indicated in Table 5.9, accidental releases of hydrocarbons associated with the Project is predicted to have residual effects on the Marine-associated Bird VEC that are *low* to *moderate* in magnitude for a duration of *<1 month* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual effects of the accidental release of hydrocarbons associated with MKI's proposed 2D/3D/4D seismic program on the Marine-associated Bird VEC are predicted to be *not significant* (see Table 5.10). The level of confidence associated with this prediction is *high* (see Table 5.10).

5.7.7   Marine Mammal and Sea Turtle VEC

The potential effects of seismic activities on marine mammals and sea turtles have previously been reviewed in the Eastern Newfoundland and Southern Newfoundland SEAs (C-NLOPB 2010, 2014), previous EAs for seismic programs offshore Newfoundland and Labrador (e.g., LGL 2015a,b), and literature reviews (e.g., Richardson et al. 1995;

Gordon et al. 2004; Stone and Tasker 2006; Nowacek et al. 2007; Southall et al. 2007; Abgrall et al. 2008b; Gomez et al. 2016). Only new or updated information from these documents have been included in the impact assessment of the Project activities on marine mammals and sea turtles.

The assessment of impacts is based on the best available information. However, there are data gaps that limit the certainty of these impact predictions. 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 5.11.

5.7.7.1 Sound

The potential effects of sound from airgun arrays on marine mammals and sea turtles constitute a common concern associated with seismic programs. Airgun arrays used during marine seismic operations introduce strong sound pulses into the water. These sound pulses could have several types of effects on marine mammals and sea turtles, and are the main issues associated with the proposed seismic surveys. The effects of human-generated noise on marine mammals are quite variable and depend on numerous factors, including species, activity of the animal when exposed to the noise, and distance of the animal from the sound source. This section includes only a review of new information regarding the potential effects of airgun sounds on marine mammals and sea turtles. More comprehensive reviews of the relevant background information for marine mammals and sea turtles are provided in § 5.7.7.1 and Appendices 4 and 5 of LGL (2015a,b), § 5.3.1 of the Eastern Newfoundland SEA (C-NLOPB 2014), and § 4.5.1.5 and 4.5.1.6 of the Southern Newfoundland SEA (C-NLOPB 2010). The characteristics of airgun sounds are also summarized in Appendix 4 of LGL (2015a,b). Descriptions of the hearing abilities of marine mammals and sea turtles are also provided in Appendices 4 and 5, respectively, of LGL (2015a,b).

The potential effects of airgun sounds considered in this assessment include: (1) masking of natural sounds; (2) behavioural disturbance; (3) non-auditory physical or physiological effects; and (4) at least in theory, temporary or permanent hearing impairment (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Peng et al. 2015). Although the possibility cannot be entirely excluded, it is unlikely that the program would result in any cases of permanent hearing impairment or any significant non-auditory physical or physiological effects. If marine mammals or sea turtles encounter the survey while it is underway, behavioural effects may occur but effects are generally expected to be localized and short-term.

Table 5.11   Potential Interactions of the Project Activities and the Marine Mammal and Sea Turtle VEC.

Valued Environmental Component - Marine Mammal and Sea Turtle				
Project Activities	**Toothed Whales**	**Baleen Whales**	**Seals**	**Sea Turtles**
Sound				
Airgun Array (2D, 3D and 4D)	X	X	X	X
Seismic Vessel	X	X	X	X
Supply Vessel	X	X	X	X
Escort Vessel	X	X	X	X
Helicopter	X	X	X	X
Echo Sounder	X	X	X	X
Side Scan Sonar	X	X	X	X
Vessel/Equipment Presence				
Seismic Vessel/Gear (2D, 3D and 4D)	X	X	X	X
Supply Vessel	X	X	X	X
Escort Vessel	X	X	X	X
Vessel Lights				
Helicopter Presence	X	X	X	X
Sanitary/ Domestic Wastes	X	X	X	X
Atmospheric Emissions	X	X	X	X
Accidental Releases	X	X	X	X
Garbage[a]				
Shore Facilities[b]				
Other Projects and Activities in Regional Area				
Oil and Gas Activities	X	X	X	X
Fisheries	X	X	X	X
Marine Transportation	X	X	X	X

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

Masking

Erbe et al. (2015) recently reviewed communication masking in marine mammals. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Guan et al. (2015) indicated that, in very shallow water environments (<15 m), the airgun inter-pulse sound field can exceed ambient noise levels by as much as 9 dB during relatively quiet conditions. The inter-pulse noise levels can also be related to the distance to the source, probably as a result of higher reverberant

conditions in shallow water. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales occurring 2,000 km from a seismic source. However, based on past and current reviewed research, the potential for masking of marine mammal calls and/or important environmental cues from the proposed seismic program is considered low. Thus, masking is unlikely to be a significant issue for either marine mammals or sea turtles exposed to the sounds from the proposed seismic survey.

In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, shift their peak frequencies, or otherwise change their vocal behaviour in response to airgun sounds (e.g., Blackwell et al. 2015) and shipping (e.g., Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Heiler et al. 2016; O'Brien et al. 2016; Parks et al. 2016a,b). Nonetheless, for humpback whales, Dunlop (2015) suggested a potential for masking with an increase in anthropogenic noise. Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. Harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

Disturbance

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal or sea turtle does react briefly 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 or sea turtles from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Nowacek et al. 2015).

Although baleen whales generally tend to avoid operating airguns, avoidance radii are variable. Stone (2015) examined data from 1,196 seismic surveys in the UK and adjacent waters and reported significant responses to airgun arrays of 500 in^3 or more in volume for minke and fin whales. This included lateral displacement, change in swimming or surfacing behaviour, and indications that cetaceans remained near the water surface. Dunlop et al. (2015, 2016) reported that humpback whales responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration. However, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. Matos (2015) reported no change in sighting rates of minke whales in Vestfjorden, Norway during ongoing seismic surveys outside of the fjord. Similarly, no large changes in grey whale movement, respiration, or distribution patterns were observed during a 4D seismic survey off Sakahlin Island, Russia (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a two-week seismic survey,

this result was not significant (Muir et al. 2015). However, there may have been a possible avoidance response to high sound levels in the area (Muir et al. 2016). Vilela et al. (2016) cautioned that environmental conditions should be taken into account when comparing sighting rates during seismic surveys, given that spatial modeling showed that differences in sighting rates of rorquals (fin and minke whales) during seismic periods and non-seismic periods during a survey in the Gulf of Cadiz could be explained by environmental variables.

Subtle but statistically significant changes in surfacing–respiration–dive cycles were shown by traveling and socializing bowheads exposed to airgun sounds in the Beaufort Sea, including shorter surfacings, shorter dives, and decreased number of blows per surfacing (Robertson et al. 2013). Bowhead whales continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2015). Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2015).

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive mysticetes and some other odontocetes. Small and medium-sized odontocetes, including beaked whales, showed a significant response (e.g., lateral displacement, localized avoidance, or change in behaviour) to large airgun arrays of 500 in^3 or more in volume, with the exception of Risso's dolphin (Stone 2015). When investigating the auditory effects of multiple underwater impulses on bottlenose dolphins, Finneran et al. (2015) reported that at the highest exposure condition (peak sound pressure levels from 196–210 dB re 1 µPa), two of three dolphins tested exhibited anticipatory behavioural reactions to impulse sounds presented at fixed time intervals. Preliminary data from the Gulf of Mexico showed a correlation between reduced sperm whale acoustic activity during periods with airgun operations (Sidorovskaia et al. 2014). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbour porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013).

Pinnipeds tend to be less responsive to airgun sounds than many cetaceans and are not likely to show a strong avoidance reaction to the airgun array. Stone (2015) found that grey seals were displaced by large airgun arrays of 500 in^3 or more in volume as indicated by the lower detection rate during periods of seismic activity. Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3,090 in^3 airgun array in New Zealand during 2009. The results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. When Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses, only mild behavioural responses were observed.

Based on available data, it is likely that sea turtles would exhibit behavioural changes and/or localized avoidance near a seismic vessel. In addition, Nelms et al. (2016) suggested that sea turtles could be excluded from critical habitats. However, turtles are considered rare in the Study Area.

Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels. Historically, research has focused on the low-frequency component of ship noise. Recent studies have also examined the medium- to high-frequency components of ship noise on small toothed whales (Hermannsen et al. 2014; Dyndo et al. 2015; Li et al. 2015). Hermannsen et al. (2014) reported that the noise from vessels passing at a distance of 1,190 m can result in a reduction of the hearing range of >20 dB for harbour porpoise (at 1 and 10 kHz) and >30 dB (at 125 kHz) from vessels passing at a distance of 490 m or less. Dyndo et al. (2015) showed that low levels of high frequency components in vessel noise can result in stereotyped porpoising behavioural responses in harbour porpoise in almost 30% of passages. Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016) and porpoise (Teilmann et al. 2015). A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016).

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.

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 (recently reviewed in Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage (i.e., Permanent Threshold Shift [PTS]), in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

There is recent evidence supporting the idea that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (e.g., Finneran 2015; Kastelein et al. 2015, 2016; Supin et al. 2016). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioural tests, Finneran et al. (2015) reported no measurable TTS in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun. However, auditory evoked potential measurements were more variable, with one dolphin showing a small (9 dB) threshold shift at 8 kHz.

Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbour porpoise. Several studies on TTS in porpoises indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes (e.g., Kastelein et al. 2015; Tougaard et al. 2016). Popov et al. (2017) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2014, 2015).

When Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa, no low-frequency TTS was observed. Hermannsen et al. (2015) concluded that there is little risk of hearing damage to pinnipeds and porpoises when using a single airgun in shallow water. Similarly, it is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns.

There is substantial overlap in the frequencies that sea turtles detect vs. the frequencies in airgun pulses. Sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the immediate area around the airguns. However, monitoring studies show that some sea turtles exhibit localized movement away from approaching airguns.

According to Nowacek et al. (2013), current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals and sea turtles occurring near the airgun array and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. In addition, many cetaceans and, to a limited degree, pinnipeds and sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce the possibility of hearing impairment.

Non-auditory Physical Effects

Non-auditory physical effects may also occur in marine mammals and sea turtles exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might theoretically occur include stress (e.g., Lyamin et al. 2016), neurological effects, and 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.

However, there is no definitive evidence that any of these effects occur even for marine mammals or sea turtles in close proximity to large arrays of airguns. Nonetheless, 10 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 (Castellote and Llorens 2016).

Sound Criteria for Assessing Impacts

Impact zones for marine mammals are commonly defined by the areas within which specific received sound level thresholds are exceeded. For the last two decades, the U.S National Marine Fisheries Service regulated 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 was set at 190 dB re 1 μPa_{rms} (NMFS 1995, 2000). According to NMFS, these sound levels were the received levels above which one cannot be certain that there will be no injurious effects, auditory or otherwise, to marine mammals. Since these regulations came into effect, it has been common for marine seismic surveys conducted in U.S. waters and some areas of Canada (Canadian Beaufort Sea and the Scotian Shelf) to include a "shutdown" requirement for cetaceans based on the distance from the airgun array at which the received level of underwater sounds is expected to diminish below 180 dB re 1 μPa_{rms}. An additional criterion that is often used in predicting "disturbance" impacts is 160 dB re 1 μPa. At this received level, some marine mammals exhibit behavioural effects.

Recommendations for science-based noise exposure criteria for marine mammals were published by Southall et al. (2007). Those recommendations were never formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys, although some aspects of the recommendations were taken into account in certain environmental impact statements and small-take authorizations. However, new guidance for assessing the effects of anthropogenic sound on marine mammals has now been released by NMFS (2016). The new noise exposure criteria for marine mammals account for the now-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such airgun pulses, the thresholds use dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). DFO has not yet adopted any noise exposure criteria (DFO 2015d; Theriault and Moors-Murphy 2015).

For marine seismic programs in Newfoundland and Labrador, the C-NLOPB (2017) requires that seismic operators follow the "Statement of Canadian Practice with Respect to the Mitigation of

Seismic Sound in the Marine Environment" (hereafter referred to as the Statement) issued by the DFO. The Statement does not include noise criteria as part of the recommended mitigation measures; rather it defines (see Point 6.a) a safety zone as "a circle with a radius of at least 500 metres as measured from the centre of the air source array(s)".

Assessment of Effects of Sound on Marine Mammals

The marine mammal effects assessment is discussed in detail below. The effects of underwater sound from vessels, the echo sounder, and the side scan sonar are not further discussed as their effects are generally considered minimal relative to sounds from airgun arrays.

<u>Toothed Whales</u>

Despite the relatively poor hearing sensitivity of toothed whales (at least the smaller species that have been studied) at the low frequencies that contribute most of the energy in seismic pulses, sounds are sufficiently strong that they remain above the hearing threshold of odontocetes at tens of kilometres from the source. Species of most concern are those that are designated under *SARA* Schedule 1 and that may occur in and near the Project Area (i.e., northern bottlenose and Sowerby's beaked whales). The killer whale and harbour porpoise have special status under COSEWIC (the harbour porpoise is also listed as threatened under Schedule 2 of *SARA*), but are not expected to occur in large numbers in the Project Area. Until recently (July 2016), the received sound level of 180 dB re 1 μPa_{rms} criterion was accepted by NMFS as a level that below which there is no physical effect on toothed whales. The new PTS onset acoustic thresholds for impulsive sounds for mid-frequency (MF) cetaceans consist of a peak SPL_{flat} of 230 dB and a SEL_{cum} of 185 dB. The PTS onset thresholds for high-frequency (HF) cetaceans are a peak SPL_{flat} of 202 dB and a SEL_{cum} of 155 dB. NMFS assumes that disturbance effects for toothed whales may occur at received sound levels at or above 160 dB re 1 μPa_{rms}. However, there is no good scientific basis for using this 160 dB criterion for odontocetes, rather 170 dB re 1 μPa_{rms} is likely a more realistic indicator of the isopleth within which disturbance is possible, at least for delphinids.

Hearing Impairment and Physical Effects

Table 5.12 provides the details of the assessment of the effects of exposure to Project-related sound on marine mammals. As indicated in Table 5.12, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual hearing impairment/physical effects on toothed whales that are *negligible* to *low* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual hearing impairment/physical effects of sound associated with MKI's proposed 2D/3D/4D seismic program on toothed whales are predicted to be *not significant* (Table 5.13). The level of confidence associated with this prediction is *medium* (Table 5.13).

Table 5.12   Assessment of Effects of Project Activities on Marine Mammals.

Valued Environmental Component: Marine Mammals								
			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound								
Airgun Array (2D, 3D and 4D)	Hearing Impairment (N) Physical Effects (N)	Pre-watch; Ramp-up; Delay start[a]; Shutdown[b]	0-1	1-2	6	1-2	R	2
Airgun Array (2D, 3D and 4D)	Disturbance (N)	Pre-watch; Ramp-up; Delay start[a]; Shutdown[b]	1-2	1-5	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	1	1	R	2
Escort Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Helicopter	Disturbance (N)		0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)		0-1	1	6	1-2	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1-2	R	2
Vessel/Equipment Presence								
Seismic Vessel/Gear (2D, 3D and 4D)	Disturbance (N)		0-1	1-3	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1	1	1	R	2
Escort Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1	1	1	R	2
Sanitary/Domestic Waste	Increased Food (N/P)	Treatment; containment	0	1	4	1-2	R	2
Atmospheric Emissions	Surface Contaminants (N)	Low sulphur fuel	0	1	6	1-2	R	2
Accidental Releases	Injury/Mortality (N)	Solid streamer[c]; Spill response	1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

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

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

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

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

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

[a] Ramp-up will be delayed if any marine mammal is sighted within the 500 m safety zone.
[b] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal is sighted within 500 m of the array.
[c] A solid streamer will be used for all seismic surveys

Table 5.13   Significance of Potential Residual Environmental Effects of Project Activities on the Marine Mammal VEC.

Project Activity	Significance of Predicted Residual Environmental Effects		Likelihood[a]	
	Residual Environmental Effect Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Sound				
Airgun Array (2D, 3D and 4D) – hearing/physical effects	NS	2	-	-
Airgun Array (2D, 3D and 4D) – behavioural effects	NS	1-2	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Vessel/Equipment Presence				
Seismic Vessel/Gear (2D, 3D and 4D)	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Helicopter Presence	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	NS	2	-	-
Key: Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.				

Key:
Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.

Residual Environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Level of Confidence: based on professional judgment:
1 = Low
2 = Medium
3 = High

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

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

Disturbance

Table 5.12 provides the details of the assessment of the effects of exposure to Project-related sound on marine mammals. As indicated in Table 5.12, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual disturbance effects on toothed whales that are *low* to *medium* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1* to *1001–10,000 km²*. Based on these criteria ratings, the *reversible* residual disturbance effects of sound associated with MKI's proposed 2D/3D/4D seismic program on toothed whales are predicted to be *not* significant (see Table 5.13). Given the data gaps in baseline scientific data and the uncertainties of the effects of multiple simultaneous seismic surveys, the level of confidence associated with this prediction is *low to medium* (Table 5.13).

Baleen Whales

Baleen whales are thought to be sensitive to low-frequency sounds such as those that contribute most of the energy in seismic pulses. Species of most concern are those that are designated under *SARA* Schedule 1 and that may occur in and near the Project Area (i.e., North Atlantic right, blue, and fin whale). Until recently, as with toothed whales, the 180 dB re 1 μPa_{rms} criterion was used by NMFS when estimating the area within which hearing impairment and/or physical effects may occur for baleen whales (although there are no data to support this criterion for baleen whales). The new PTS onset acoustic thresholds for impulsive sounds for low-frequency (LF) cetaceans consist of a peak SPL_{flat} of 219 dB and a SEL_{cum} of 183 dB. For all baleen whale species, NMFS assumes that disturbance effects (avoidance) may occur at sound levels greater than 160 dB re 1 μPa_{rms}.

Hearing Impairment and Physical Effects

Table 5.12 provides the details of the assessment of the effects of exposure to Project-related sound on marine mammals. As indicated in Table 5.12, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual hearing impairment/physical effects on baleen whales that are *negligible* to *low* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual hearing impairment/physical effects of sound associated with MKI's proposed 2D/3D/4D seismic program on baleen whales are predicted to be *not significant* (see Table 5.13). The level of confidence associated with this prediction is *medium* (see Table 5.13).

Disturbance

Table 5.12 provides the details of the assessment of the effects of exposure to Project-related sound on marine mammals. As indicated in Table 5.12, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being

the worst-case scenario) is predicted to have residual disturbance effects on baleen whales that are *low* to *medium* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1* to *1001–10,000 km²*. Based on these criteria ratings, the *reversible* residual disturbance effects of sound associated with MKI's proposed 2D/3D/4D seismic program on baleen whales are predicted to be *not* significant (see Table 5.13). Given the data gaps in baseline scientific data and the uncertainties of the effects of multiple simultaneous seismic surveys, the level of confidence associated with this prediction is *low to medium* (Table 5.13).

Seals

Until recently, the 190 dB re 1 μPa_{rms} criterion was used by NMFS when estimating the area within which hearing impairment and/or physical effects may occur for pinnipeds. The new PTS onset acoustic thresholds for impulsive sounds for pinnipeds in water (PW) consist of a peak SPL_{flat} of 218 dB and a SEL_{cum} of 185 dB. For all pinnipeds, NMFS assumes that disturbance effects (avoidance) may occur at sound levels greater than 160 dB re 1 μPa_{rms}. However, seals are not expected to be abundant within the Study Area, particularly during the time period when seismic operations will likely occur.

Hearing Impairment and Physical Effects

Table 5.12 provides the details of the assessment of the effects of exposure to Project-related sound on marine mammals. As indicated in Table 5.12, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual hearing impairment/physical effects on seals that are *negligible* to *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual hearing impairment/physical effects of sound associated with MKI's proposed 2D/3D/4D seismic program on seals are predicted to be *not significant* (see Table 5.13). The level of confidence associated with this prediction is *medium* (see Table 5.13).

Disturbance

Table 5.12 provides the details of the assessment of the effects of exposure to Project-related sound on marine mammals. As indicated in Table 5.12, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual disturbance effects on seals that are *low* to *medium* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *101–1000 km²*. Based on these criteria ratings, the *reversible* residual disturbance effects of sound associated with MKI's proposed 2D/3D/4D seismic program on seals are predicted to be *not significant* (see Table 5.13). The level of confidence associated with this prediction is *medium* (see Table 5.13).

Assessment of Effects of Sound on Sea Turtles

Sea turtles have received very little research attention when compared to marine mammals and fishes (Nelms et al. 2016). Although it is possible that exposure to airgun sounds could cause either mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 dB_{peak} for sounds from seismic airguns. The effects of underwater sound from vessels, the echo sounder, and the side scan sonar are not further discussed as their impact is minimal relative to airguns.

Hearing Impairment and Physical Effects

Table 5.14 provides the details of the assessment of the effects of exposure to Project-related sound on sea turtles. As indicated in Table 5.14, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual hearing impairment/physical effects on sea turtles that are *negligible* to *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual hearing impairment/physical effects of sound associated with MKI's proposed 2D/3D/4D seismic program on sea turtles are predicted to be *not significant* (Table 5.15). The level of confidence associated with this prediction is *medium* (Table 5.15).

Disturbance

Table 5.14 provides the details of the assessment of the effects of exposure to Project-related sound on sea turtles. As indicated in Table 5.14, sound produced as a result of the proposed Project (airgun array sound during three concurrent 3D surveys and a 2D survey being the worst-case scenario) is predicted to have residual disturbance effects on sea turtles that are *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *101–1000 km²*. Based on these criteria ratings, the *reversible* residual disturbance effects of sound associated with MKI's proposed 2D/3D/4D seismic program on sea turtles are predicted to be *not significant* (Table 5.15). The level of confidence associated with this prediction is *medium* (Table 5.15).

Table 5.14   Assessment of Effects of Project Activities on the Sea Turtle VEC.

Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Valued Environmental Component: Sea Turtles			**Evaluation Criteria for Assessing Environmental Effects**					
Sound								
Airgun Array (2D, 3D and 4D)	Hearing Impairment (N); Physical Effects (N)	Pre-watch; Ramp-up; Delay start[a]; Shutdown[b]	0-1	1-2	6	1-2	R	2
Airgun Array (2D, 3D and 4D)	Disturbance (N)	Pre-watch; Ramp-up; Delay start[a]; Shutdown[b]	1	1-4	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	1	1	R	2
Escort Vessel	Disturbance – (N)		0-1	1-2	6	1-2	R	2
Helicopter	Disturbance (N)		0-1	1-2	1	1	R	2
Echo Sounder	Disturbance (N)		0-1	1	6	1-2	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1-2	R	2
Vessel Presence								
Seismic Vessel/Gear (2D, 3D and 4D)	Disturbance (N)		0-1	1-3	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1	1	1	R	2
Escort Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Helicopter Presence	Disturbance (N)	Maintain high altitude	0	1	1	1	R	2
Sanitary/Domestic Waste	Increased Food (N/P)	Treatment; containment	0	1	4	1-2	R	2
Atmospheric Emissions	Surface Contaminants (N)	Low sulphur fuel	0	1	6	1-2	R	2
Accidental Releases	Injury/Mortality (N)	Solid streamer[c]; Spill response	1	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

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

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

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

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

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

[a] Ramp-up will be delayed if a sea turtle is sighted within the 500 m safety zone.
[b] The airgun arrays will be shutdown if an *endangered* or *threatened* sea turtle is sighted within 500 m of the array.
[c] A solid streamer will be used for all seismic surveys.

Table 5.15   Significance of Potential Residual Environmental Effects of Project Activities on Sea Turtles.

| Project Activity | Significance of Predicted Residual Environmental Effects | | Likelihood[a] | |
	Residual Environmental Effect Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Sound				
Airgun Array (2D, 3D and 4D) – hearing/physical effects	NS	2	-	-
Airgun Array (2D, 3D and 4D) – behavioural effects	NS	2	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echo Sounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Vessel/Equipment Presence				
Seismic Vessel/Gear (2D, 3D and 4D)	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Helicopter Presence	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Accidental Releases	NS	2	-	-
Key: Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km². Residual Environmental Effect Rating: S = Significant Negative Environmental Effect NS = Not-significant Negative Environmental Effect P = Positive Environmental Effect Level of Confidence: based on professional judgment: 1 = Low 2 = Medium 3 = High		Probability of Occurrence: based on professional judgment: 1 = Low Probability of Occurrence 2 = Medium Probability of Occurrence 3 = High Probability of Occurrence Scientific Certainty: based on scientific information and statistical analysis or professional judgment: 1 = Low 2 = Medium 3 = High		
[a] Considered only in the case where 'significant negative effect' is predicted.				

5.7.7.2 Helicopter Sound

Information on interactions between helicopter sound and marine mammals and sea turtles is available in § 5.7.7.2 of the WesternGeco Eastern Newfoundland EA (LGL 2015a) and WesternGeco Southeastern Newfoundland EA (LGL 2015b), and § 5.3.1 of the Eastern Newfoundland SEA (C-NLOPB 2014).

Tables 5.12 and 5.14 provide the details of the assessment of the effects of exposure to Project-related helicopter sound on marine mammals and sea turtles, respectively, including appropriate mitigations. As indicated in Tables 5.12 and 5.14, sound produced by helicopters associated with the proposed Project is predicted to have residual disturbance effects on marine mammals and sea turtles that are *negligible* to *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual disturbance effects of helicopter sound associated with MKI's proposed 2D/3D/4D seismic program on marine mammals and sea turtles are predicted to be *not significant* (see Tables 5.13 and 5.15. The level of confidence associated with this prediction is *high* (see Tables 5.13 and 5.15).

5.7.7.3 Vessel/Equipment Presence

Information on interactions between vessel/equipment presence and marine mammals and sea turtles is available in § 5.7.7.3 of the WesternGeco Eastern Newfoundland EA (LGL 2015a) and WesternGeco Southeastern Newfoundland EA (LGL 2015b), § 5.3.1 of the Eastern Newfoundland SEA (C-NLOPB 2014), and § 4.5.9.3 of the Southern Newfoundland SEA (C-NLOPB 2010). This section includes only a review of new information regarding the potential effects of vessel/equipment presence on marine mammals and sea turtles.

During the proposed seismic program, there will be one seismic ship and an escort vessel on site during most of the program. A supply vessel will also regularly be present during the program. There is some risk for collision between marine mammals and vessels, but given the slow surveying speed (~4.5 knots; 8.3 km/h) of the seismic vessel (and its support vessels), this risk is likely to be minimal in spite of the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species (McKenna et al. 2015). Wiley et al. (2016) also concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. Marine mammal responses to ships are presumably responses to noise.

Sea turtles may also become entangled with seismic gear, such as cables, buoys, or streamers (Nelms et al. 2016) or collide with the vessel.

Tables 5.12 and 5.14 provide the details of the assessment of the effects of exposure to Project-related vessel/equipment presence on marine mammals and sea turtles, respectively, including appropriate mitigations. As indicated in Tables 5.12 and 5.14, vessel/equipment

presence associated with the proposed Project is predicted to have residual effects on marine mammals and sea turtles that are *negligible* to *low* in magnitude for a duration of *<1* to *1–12 months* over a geographic area of *<1 km²* to *11-100 km²*. Based on these criteria ratings, the *reversible* residual effects of vessel/equipment presence associated with MKI's proposed 2D/3D/4D seismic program on marine mammals and sea turtles are predicted to be *not significant* (see Tables 5.13 and 5.15). The level of confidence associated with this prediction is *high* (see Tables 5.13 and 5.15).

5.7.7.4 Other Project Activities

There is potential for marine mammals and sea turtles to interact with domestic and sanitary wastes, and atmospheric emissions from the seismic ship and the support vessels. Any effects from these interactions are predicted to be *negligible* (see Tables 5.13 and 5.15).

Accidental Releases

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with MKI's policy, and handling and reporting procedures. A fuel spill may occur from the seismic ship and/or the support vessels. 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 § 5.7.7.4 of the WesternGeco Eastern Newfoundland EA (LGL 2015a), § 5.7.7.5 of the WesternGeco Southeastern Newfoundland EA (LGL 2015b), § 5.3 of the Eastern Newfoundland SEA (C-NLOPB 2014), § 4.6.4.5 and 4.6.4.6 of the Southern Newfoundland SEA (C-NLOPB 2010). Dupuis and Ucan-Marin (2015) and Helm et al. (2015) also reviewed the effects of oil on marine mammals and/or sea turtles. Whales and seals generally do not exhibit large behavioural or physiological responses to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil. However, lung disease, adrenal toxicity, and low reproductive success were reported for bottlenose dolphins exposed to oil during the Deepwater Horizon spill (Schwacke et al. 2014; Lane et al. 2015; Venn-Watson et al. 2015). Acoustic data suggests that sperm whales foraged farther away from the spill site than before the spill, whereas Ziphiidae returned to the spill site to feed (Sidorovskaia et al. 2016). Sea turtles are thought to be more susceptible to the effects of oiling than marine mammals, but effects are believed to be primarily sublethal. Biomarkers showed that loggerhead turtles remained in the oiled areas after the Deepwater Horizon spill (Vander Zanden et al. 2016).

Tables 5.12 and 5.14 provide the details of the assessment of the effects of exposure to Project-related accidental releases of hydrocarbons on marine mammals and sea turtles, respectively, including appropriate mitigations. As indicated in Tables 5.12 and 5.14, accidental releases of hydrocarbons associated with the proposed Project are predicted to have residual effects on marine mammals and sea turtles that are *low* in magnitude for a duration of *<1 month* over a geographic area of *<1* to *1–10 km²*. Based on these criteria ratings, the *reversible* residual effects of accidental releases of hydrocarbons associated with MKI's proposed 2D/3D/4D

seismic program on marine mammals and sea turtles are predicted to be *not significant* (see Tables 5.13 and 5.15). The level of confidence associated with this prediction is *medium* (see Tables 5.13 and 5.15).

5.7.8 Species at Risk VEC

Biological summaries of all species with an *endangered* or *threatened* status under Schedule 1 of the *SARA* and with reasonable likelihood of occurrence in the Study Area were provided in § 4.6, while overviews of species with *special concern* status under Schedule 1 of *SARA* were provided in § 4.2, § 4.4 and § 4.5 on fish and fish habitat, marine-associated birds and marine mammals and sea turtles, respectively. No critical habitat for any of these species/populations has been identified within the Study Area. As indicated in Table 4.16 in § 4.6, *SARA* Schedule 1 species/populations of relevance to the Study Area include:

- White Shark (Atlantic population), and northern, spotted and Atlantic wolffishes;
- Ivory Gull, Red Knot *rufa* spp., Harlequin Duck (Eastern population), and Barrow's Goldeneye (Eastern population);
- Blue whale (Atlantic population), North Atlantic right whale, northern bottlenose whale (Scotian Shelf population), fin whale (Atlantic population), and Sowerby's beaked whale; and
- Leatherback and loggerhead sea turtles.

Species/populations currently without status on Schedule 1 of *SARA*, but listed on Schedules 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 this assessment of potential effects on the Species at Risk VEC. Instead, potential effects on these species/populations have been assessed in the appropriate VEC assessment section (i.e., § 5.7.4 [Fish and Fish Habitat], § 5.7.6 [Marine-associated Birds] and § 5.7.7 [Marine Mammals and Sea Turtles]) of this EA.

If species/populations currently without status do become listed on Schedule 1 of *SARA* during the temporal scope of the Project (2018–2023), the Proponent will re-assess these species/populations considering the prohibitions of *SARA* (including *SARA* sections 32(1) [Killing, harming, etc., listed wildlife species], 33 [damage or destruction of residence], and 58(1) [Destruction of critical habitat]), and any recovery strategies or action plans that may be in place. Possible mitigation measures as they relate to species at risk will be reviewed with DFO and ECCC. Potential interactions between Project activities and the Species at Risk VEC are indicated in Table 5.16. Only those species species/populations with either *endangered* or *threatened* status under Schedule 1 of *SARA* (see Table 4.20) are included in the interactions table (Table 5.16). The potential effects of activities associated with MKI's seismic program are not expected to contravene the aforementioned prohibitions of *SARA*.

Table 5.16   Potential Interactions of Project Activities and the Species at Risk VEC.

Project Activities	Valued Environmental Component: Species at Risk				
	White Shark	Northern Wolffish Spotted Wolffish	Ivory Gull Red Knot	Blue Whale North Atlantic Right Whale Northern Bottlenose Whale	Leatherback Sea Turtle Loggerhead Sea Turtle
Sound					
Airgun Array (2D, 3D and 4D)	X	X	X	X	X
Seismic Vessel	X	X	X	X	X
Supply Vessel	X	X	X	X	X
Escort Vessel	X	X	X	X	X
Helicopter			X	X	X
Echosounder	X	X	X	X	X
Side Scan Sonar	X	X	X	X	X
Vessel Lights	X		X		
Vessel/Equipment Presence					
Seismic Vessel/Gear (2D, 3D and 4D)			X	X	X
Supply Vessel			X	X	X
Escort Vessel			X	X	X
Sanitary/ Domestic Waste	X	X	X	X	X
Atmospheric Emissions	X	X	X	X	X
Garbage[a]					
Helicopter Presence			X	X	X
Shore Facilities[b]					
Accidental Releases	X	X	X	X	X
Other Projects and Activities in Regional Area					
Oil and Gas Activities	X	X	X	X	X
Fisheries	X	X	X	X	X
Marine Transportation	X	X	X	X	X

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

5.7.8.1   Fish Species at Risk

The mitigation measure of ramping up the airgun array over a 30 minute period is expected to minimize the potential effects on white sharks and wolffishes. As per the detailed effects assessment contained in § 5.7.4, physical effects of Project activities on the various life stages of the white shark and wolffishes will have *negligible* to *low* magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1 km^2* (Table 5.17). Based on these criteria ratings, the residual physical effects of activities associated with MKI's proposed seismic program on white sharks and wolffishes are predicted to be *not significant* (Table 5.18). The level of confidence associated with this prediction is *high* (Table 5.18).

Table 5.17   Assessment of Effects of Project Activities on the Species at Risk VEC.

Valued Environmental Component: Species At Risk								
			Evaluation Criteria for Assessing Environmental Effects					
Project Activity	Potential Positive (P) or Negative (N) Environmental Effect	Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Sound								
Airgun Array (2D, 3D and 4D)	Disturbance (N) Hearing Impairment (N) Physical Effects (N)	Ramp-up; delay start[a]; shutdown[b]	0-2	1-5	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	1	1	R	2
Escort Vessel	Disturbance (N)		0-1	1-2	6	1-2	R	2
Helicopter	Disturbance (N)	Maintain high altitude	0-1	1-2	1	1	R	2
Echosounder	Disturbance (N)		0-1	1	6	1	R	2
Side Scan Sonar	Disturbance (N)		0-1	1	6	1	R	2
Vessel Lights	Attraction (N); Mortality (N)	Reduce lighting (if safe); release protocols	0-1	1-2	2-3	1-2	R	2
Vessel/Equipment Presence								
Seismic Vessel/Gear (2D, 3D and 4D)	Disturbance (N)		0-1	1-3	6	1-2	R	2
Supply Vessel	Disturbance (N)		0-1	1	1	1	R	2
Escort Vessel	Disturbance (N)		0-1	1	6	1-2	R	2
Sanitary/Domestic Waste	Increased food (N/P)	-	0-1	1	4	1-2	R	2
Atmospheric Emissions	Surface contaminants (N)	-	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[c]; Spill Response	0-2	1-2	1	1	R	2

Key:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

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

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

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

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

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

[a] Ramp-up will be delayed if a sea turtle is sighted within the 500 m safety zone.
[b] The airgun arrays will be shutdown if an *endangered* (or *threatened*) marine mammal or sea turtle is sighted within 500 m of the array.
[c] A solid streamer will be used for all seismic surveys.

Table 5.18   Significance of Potential Rsidual Environmental Effects of Project Activities on the Species at Risk VEC.

Project Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Valued Environmental Component: Species At Risk				
Sound				
Airgun Array (2D, 3D and 4D)	NS	1-3	-	-
Seismic Vessel	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	3	-	-
Side Scan Sonar	NS	3	-	-
Vessel Lights	NS	3	-	-
Vessel/Equipment Presence				
Seismic Vessel (2D, 3D and 4D)	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Key:
Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.

Residual Environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect
Level of Confidence (based on professional judgment):
1 = Low
2 = Medium
3 = High

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

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

Behavioural effects of Project activities on the various life stages of the white shark and wolffishes will have *negligible* to *low* magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1 to 1001–10,000 km^2* (Table 5.17). Based on these criteria ratings, the residual behavioural effects of activities associated with MKI's seismic program on white sharks and wolffishes are predicted to be *not significant* (Table 5.18). The level of confidence associated with this prediction is *low* to *medium* (see Table 5.18) given the scientific data gaps.

5.7.8.2 Marine-associated Bird Species at Risk

Ivory Gull and Red Knot foraging behaviour would not likely expose them to underwater sound, and these species are unlikely to occur in the Study Area, particularly during the time when

seismic surveys are likely to be conducted. Furthermore, Ivory Gulls and Red Knots are not known to be prone to stranding on vessels. The mitigation measures of monitoring the seismic vessel, releasing stranded birds (in the unlikely event that an Ivory Gull or Red Knot did strand on the vessel) and ramping up the airgun array will minimize the potential effects on these seabird species at risk. With mitigation measures in place and as per the detailed effects assessment in § 5.7.6, the predicted effects of the Project on Ivory Gull and Red Knot will range from *negligible* to *medium* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1* to *11–100 km²* (see Table 5.17). Based on these criteria ratings, the predicted effects of activities associated with MKI's proposed seismic program on Ivory Gull and Red Knot are predicted to be *not significant* (see Table 5.18). The level of confidence associated with this prediction is *medium* to *high* (see Table 5.18).

5.7.8.3 Marine Mammal and Sea Turtle Species at Risk

Based on available information, blue whales, North Atlantic right whales, and leatherback and loggerhead sea turtles are not expected to occur regularly in the Study Area. Relatively speaking, northern bottlenose whales (possibly the Scotian Shelf population) are likely to occur more regularly in the Study Area, particularly in the slope and deep basin waters including off southern Newfoundland and the Flemish Pass area. Northern bottlenose whales have also been observed during seismic monitoring programs in the Orphan Basin (e.g., Moulton et al. 2005, 2006). However, it is uncertain which population of northern bottlenose whales occurs in the Study Area. No critical habitat for these species/populations has been identified in the Study Area. Mitigation and monitoring designed to minimize potential effects of airgun array noise on *SARA*-listed marine mammals and sea turtles will include:

- Ramp-up of the airgun array over a 30 min period;
- Monitoring by MMO(s) (with assistance from a FLO) during daylight hours that the airgun array is active and the 30 minutes pre-ramp up;
- Shutdown of the airgun array when an *endangered* or *threatened* marine mammal or sea turtle is detected within the 500 m safety zone;
- Delay of ramp-up if any marine mammal or sea turtle is detected within the 500 m safety zone.
- Use of PAM to detect cetaceans (details to be provided in EA Updates).

With these mitigation measures in place and as per the detailed effects assessment in § 5.7.7, the predicted effects of the Project on blue whales, North Atlantic right whales, northern bottlenose whales, leatherback sea turtles, and loggerhead sea turtles will range from *negligible* to *medium* in magnitude for a duration of *<1 month* to *1–12 months* over a geographic area of *<1* to *1001–10,000 km²* (see Table 5.17). Based on these criteria ratings, the predicted effects of activities associated with MKI's proposed seismic program on blue whales, North Atlantic right whales, northern bottlenose whales, leatherback sea turtles, and loggerhead sea turtles are predicted to be *not significant* (see Table 5.18). The level of confidence associated with this prediction is *low* to *medium* (see Table 5.18) given the data gaps.

5.7.9 Sensitive Areas VEC

An overview of sensitive areas located either entirely or partially within the Study Area was provided in § 4.7. The habitat preferences of biota potentially inhabiting these sensitive areas, including invertebrates, fishes, marine mammals, sea turtles and marine-associated birds, were detailed in § 4.2 to 4.5, and species at risk were described in § 4.6.

Based on the conclusions of § 5.7.4 to 5.7.8, the residual effects of activities associated with MKI's seismic program on the Sensitive Areas VEC within the Study Area are predicted to be *not significant*. The level of confidence associated with this prediction is *medium*.

5.8 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 resulting from the MKI seismic program activities in the Project Area. This includes the residual effects of three concurrent 3D surveys and a 2D survey being conducted by MKI (see § 2.0). Considering the size of the Project Area, the likely considerable separation of the concurrent surveys, and the predictions of significance presented in § 5.7, the within-Project cumulative residual effects associated with concurrent MKI seismic surveys are predicted to be *not significant*. The level of confidence associated with this prediction ranges from low to high, depending on the Project activity and VEC.

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

- Fisheries (commercial and research survey fishing);
- Marine transportation (e.g., cargo, defense, yachts, cruise ships); and
- Offshore oil and gas industry activities.

Duinker et al. (2012), in their review of work to date on the scientific dimensions of cumulative effects assessment (CEA), concluded that it is particularly difficult to properly implement CEA in project-specific EAs. They made several recommendations regarding revisions to guidance materials for science in CEA, including the following:

- A much richer and nuanced conceptual framework for a cumulative effect is required in order to describe how effects become cumulative;
- Clearer guidance regarding CEA analytical methods is required; and
- Better definitions of thresholds, without which it is really impossible to judge the significance of cumulative effects.

Duinker et al. (2012) concluded by saying that lack of competent CEA impairs our ability to determine the degree to which particular activities jeopardize the sustainability of VECs, and that improvements in CEA practice are desperately needed.

Until more robust methods of CEA are developed, the qualitative method used for EAs to date is again applied in this EA.

5.8.1   Fisheries

Fishing has been discussed and assessed in detail in § 4.3 and § 5.7.5. 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 *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 as much as possible. The seismic surveying will also spatially and temporally avoid DFO research vessels during multi-species trawl surveys. Any cumulative effects associated with fisheries are predicted to be *not significant*. The level of certainty associated with this prediction is *medium*.

5.8.2   Marine Transportation

Marine transportation within the Study Area is discussed in the Eastern Newfoundland SEA (§ 4.3.5.1 of C-NLOPB 2014), the Southern Newfoundland SEA (§ 5.3 of C-NLOPB 2010), and the two WesternGeco EAs (§ 5.8.2 of LGL 2015a,b).

The seismic survey vessels are not likely to add much marine traffic congestion. Ships may need to divert around the immediate seismic survey area, but this will not prevent or impede the passage of either vessel as the *Shipping Act* and standard navigation rules will apply. Thus, potential for cumulative effects with other shipping is predicted to be *low* and *not significant*. The level of certainty associated with this prediction is *medium*.

5.8.3   Other Oil and Gas Activities

Potential offshore oil and gas industry activities in the Regional Area during 2017, based on current completed 'in-effect' EAs listed on the C-NLOPB public registry (www.cnlopb.nl.ca) include the following:

- Seitel Canada Ltd. East Coast Offshore Seismic Program, 2016–2025;
- CGG Services (Canada) Inc. Newfoundland Offshore 2D, 3D and 4D Seismic Program, 2016–2025;

- ExxonMobil Canada Ltd. Eastern Newfoundland Offshore Geophysical, Geochemical, Environmental and Geotechnical Program, 2015–2024;
- WesternGeco Canada Eastern Newfoundland Offshore Seismic Program, 2015–2024;
- WesternGeco Canada Southeastern Newfoundland Offshore Seismic Program, 2015–2024;
- Suncor Energy Eastern Newfoundland Offshore Area 2D/3D/4D Seismic Program, 2014–2024;
- Bridgeporth Holdings Ltd. and JEBCO Seismic Company North Flemish Pass Gravity Survey, 2015–2019;
- MG3 (Survey) UK Limited Offshore Labrador Geochemical and Seabed Sampling Program, Newfoundland and Labrador Offshore Area, 2015–2024;
- HMDC Ltd. 2D/3D/4D Seismic Projects for the Hibernia Oil and Gas Production Field, 2013 to Remaining Life of Field;
- GXT Technology Canada Ltd. GrandSPAN Marine 2D Seismic, Gravity and Magnetic Survey, 2014–2018;
- TGS NOPEC Geophysical Company ASA and Multiklient Invest AS Offshore Labrador Seafloor and Seabed Sampling Program, Newfoundland and Labrador Offshore Area, 2014–2019;
- Electromagnetic Geoservices Canada Inc. East Canada Controlled Source Electromagnetic Survey, 2014–2018;
- Husky Energy Jeanne d'Arc Basin/Flemish Pass Regional Seismic Program, 2012–2020;
- Statoil Canada Limited 2011-2019 Jeanne d'Arc and North Ridge/Flemish Pass Basin Geophysical Program;
- ExxonMobil Canada Properties Hebron Development Project;
- Husky Energy Sydney Basin Seismic Program, 2010–2018;
- Hibernia Drill Centres Construction and Operations Program, 2009–2036;
- Husky Energy Delineation/Exploration Drilling Program for Jeanne d'Arc Basin Area, 2008–2017;

Statoil are currently in the process of proposing a three-year extension to its EA of exploration and appraisal/delineation drilling program for offshore Newfoundland, 2008–2016. If the EA Amendment receives a positive determination from the C-NLOPB, the temporal scope will be extended to 2019.

In addition, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. A fourth development (Hebron) commenced installation in 2017 and began production in January 2018. The existing developments fall inside of the boundaries of MKI's Regional Area but do not create the same types and levels of underwater noise as seismic, geohazard, or VSP programs.

There is potential for cumulative effects with other seismic programs that could operate in future years (see above list). 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 to arrange for good coordination between programs in order to provide sufficient buffers and to minimize acoustic interference. 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, marine-associated birds, marine mammals, sea turtles, species at risk and sensitive areas are predicted to be *not significant*. However, there are uncertainties regarding this prediction, particularly regarding effects of masking on marine mammals from sound produced during multiple seismic surveys. The potential for temporal and spatial overlap of future activity of seismic programs (2018 and beyond) in the area will be considered in the EA update process. Uncertainty due to the large Study Area will be reduced as specific survey designs that likely cover smaller areas become available.

As discussed in this EA, negative effects (auditory, physical, and behavioural) 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, shutdowns of the airgun arrays, and spatial separation between seismic surveys.

Cumulative effects associated with other oil and gas activities in the Regional Area are predicted to be *not significant*. The level of certainty associated with this prediction is *low* to *medium*. The cumulative effects associated with this Project will be re-visited in each subsequent EA Update.

5.9   Mitigation Measures and Follow-up

Project mitigations are summarized in this section, both in the text and in Table 5.19. MKI will adhere to mitigations detailed in Appendix 2 of the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2017b) including those in the *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*.

Fishers who may be operating in the area will be notified of the timing and location of planned activities by means of a CCG "Notice to Mariners". If necessary, individual fixed gear fishers will be contacted to arrange mutual avoidance. Any incidents of contact with fishing gear with any identifiable markings will be reported to the C-NLOPB within 24 h of the contact (in accordance with the C-NLOPB Incident Reporting and Investigation Guidelines). Fishing gear may only be retrieved from the water by the gear owner (i.e., fishing license owner). This includes buoys, radar reflectors, ropes, nets, pots, etc., associated with fishing gear and/or activity. If gear contact is made during seismic operations, it should not be retrieved or retained

Table 5.19   Summary of Mitigations Measures by Potential Effect.

VEC, Potential Effects	Primary Mitigations
Fisheries VEC: Interference with fishing vessels/mobile and fixed gear fisheries	• Pre-survey communications, liaison and planning to avoid fishing activity • Continuing communications throughout the program • FLOs • SPOC • Advisories and communications • VMS data • Avoidance of actively fished areas • Start-up meetings on ships that discuss fishing activity and communication protocol with fishers
Fisheries VEC: Fishing gear damage	• Pre-survey communications, liaison and planning to avoid fishing gear • Use of escort vessel • SPOC • Advisories and communications • FLOs • Compensation program • Reporting and documentation • Start-up meetings on ships that discuss fishing activity, communication protocol with fishers, and protocol in the event of fishing gear damage
Interference with shipping [a]	• Advisories and at-sea communications • FLOs (fishing vessels) • Use of escort vessel • SPOC (fishing vessels) • VMS data
Fisheries VEC: Interference with DFO/FFAW research program	• Communications and scheduling • 7-day/30-km temporal/spatial avoidance protocol [b]
Fish and Fish Habitat, Marine Mammal and Sea Turtle, and Marine-associated Bird VECs: Temporary or permanent hearing damage/disturbance to marine animals (marine mammals, sea turtles, seabirds, fish, invertebrates)	• "Pre-watch" (30 minute) of 500 m safety zone using visual and PAM • Delay start-up if any marine mammals or sea turtles are detected within 500 m with visual and PAM • Ramp-up of airguns • Use of experienced, qualified MMO(s) to monitor for marine mammals and sea turtles during all daylight periods when airguns are in use • Minimum separation distance of 30 km for simultaneous seismic surveys in the Project Area based on separation distances required in other jurisdictions (i.e., Gulf of Mexico [G. Morrow, PGS, Senior Contract Manager, pers. comm., June 2017] and Greenland [LGL 2012]).
Species at Risk and Sensitive Areas VEC: Temporary or permanent hearing damage/ disturbance to Species at Risk or other key habitats	• "Pre-watch" (30 minute) of 500 m safety zone using visual and PAM • Delay start-up if any marine mammals or sea turtles are detected within 500 m with visual and PAM • Ramp-up of airguns • Shutdown of airgun arrays for *endangered* or *threatened* marine mammals and sea turtles within 500 m • Use of experienced, qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations. • Use of PAM for cetaceans (details to be provided in EA Updates) • Minimum separation distance of 30 km for simultaneous seismic surveys in the Project Area based on separation distances required in other jurisdictions (see above).
Marine-associated Bird VEC: Injury (mortality) to stranded seabirds	• Daily search of seismic and support vessels • Implementation of handling and release protocols • Minimize lighting if safe
Marine-associated Bird VEC: Seabird oiling	• Adherence to MARPOL • Adherence to conditions of ECCC-CWS migratory bird permit • Spill contingency and response plans • Use of solid streamer

[a]   MKI will engage CTF 84, through Director General Naval Strategic Readiness (DGNSR), to ensure de-confliction with possible Allied submarine activities.

[b]   DFO does not indicate an official spatial and/or temporal buffer mitigation method for seismic operations in the vicinity of survey stations. MKI will work cooperatively with FFAW|Unifor and DFO in an effort to avoid survey stations prior to their sampling to the best extent possible.

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).   MKI will advise the C-NLOPB prior to compensating and settling all valid lost gear/income claims promptly and satisfactorily.

MKI will also ensure that a "Notice to Mariners" would be issued for all underwater activities and any significant surface ventures as defined by the DND in LGL (2017b), such as the use of flares, buoys or unconventional night lighting. Although there are currently no plans for such activities, a "Notice to Airmen" would also be issued for all activities that could affect air safety, such as the use of balloons, Unmanned Aerial Vehicles (UAVs) or tethered airborne devices.

Specific mitigations to minimize potential conflicts and any negative effects with other vessels include:

- Timely and clear communications (VHF, HF Satellite, etc.);
- Utilization of FLOs during 2D/3D/4D seismic programs for advice and coordination in regard to avoiding fishing vessels and fishing gear;
- Utilization of experienced, qualified MMO(s);
- Posting of advisories with the Canadian Coast Guard;
- Compensation program in the event any project vessels damage fishing gear; and
- Single Point of Contact (SPOC).

MKI will also coordinate with the FFAW/Unifor and DFO to avoid any potential conflicts with fishing and research surveys that may be operating in the area. MKI commits to ongoing communications with other operators with active seismic programs within the general vicinity of its seismic program to minimize the potential for cumulative effects on VECs.

As stated earlier in this EA, there will be full opportunity for adaptive mitigation during MKI's proposed six-year program. If there are any new techniques developed during the six-year period that may help to further mitigate environmental effects, they will be investigated and incorporated into the program if deemed useful. Annual updates of the EA that will be prepared during the six-year scope of the Project will include any relevant new information related to mitigation not provided in the EA.

Mitigation measures designed to reduce the likelihood of impacts on marine mammals and sea turtles will include ramp ups (during all periods of day and night), no initiation of airgun array if a marine mammal or sea turtle is detected 30 min prior to ramp up within 500 m safety zone of the energy source, and shutdown of the energy source if an *endangered* or *threatened* whale or sea turtle is detected within the 500 m safety zone. Prior to the onset of the seismic survey, the airgun array will be gradually ramped up, with the intention of providing a warning to marine fauna before they are exposed to the higher sound levels from the full airgun array. One airgun

will be activated first and then the volume of the array will be increased gradually over a recommended 30-min period. An MMO 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 detected within 500 m of the array, then ramp up will not commence until the animal has moved beyond the 500 m zone or 30 min have elapsed since the last detection. MKI will also operate a single airgun (lowest volume) during line changes, and require that a ramp up occurs during the transition from the single airgun to the full array, which exceeds the requirement under the *Statement of Canadian Practice*. The observers will watch for marine mammals and sea turtles during daylight periods and note the location and behaviour of these animals. Visual monitoring and PAM will be implemented. The aspects of the monitoring and mitigation plan include the use of the ship's bridge for MMOs from which to conduct observations (i.e., good sight lines all around the vessel), and the use of reticle binoculars and other distance estimators to accurately estimate the location of the animal with respect to the safety zone. The seismic array will be shut down whenever marine mammals or sea turtles with either *endangered* or *threatened* status under Schedule 1 of *SARA* are detected within the safety zone. Additionally, shut downs will be implemented for all beaked whales that are detected within the 500-m safety zone, which exceeds the requirements in the *Statement of Practice*. The planned monitoring and mitigation measures will minimize the already low probability of exposure of marine animals to sounds strong enough to induce hearing impairment. Any dead or distressed marine mammals or sea turtles will be recorded and reported to the C-NLOPB.

Any seabirds that become stranded on a vessel (most likely Leach's Storm-petrel) will be released using the mitigation methods consistent with *The Leach's Storm-Petrel: General Information and Handling Instructions* by U. Williams (Petro-Canada) and J. Chardine (CWS) (n.d.), and *Procedures for Handling and Documenting Stranded Birds Encountered on Infrastructure Offshore Atlantic Canada [Draft May 2017]* (ECCC 2017b). Data collection for seabirds at sea will be in accordance with Gjerdrum et al. (2012). It is understood by MKI that a ECCC-CWS *Migratory Birds Permit* will be required and that it will be secured as it has been in the past. MKI will adhere to the conditions stipulated on the CWS permit. In the unlikely event that marine mammals, sea turtles or seabirds are injured or killed by Project equipment or accidental releases of hydrocarbons, a report will immediately be filed with the appropriate agencies (ECCC-CWS, C-NLOPB) and the need for follow-up monitoring will be assessed.

Marine mammal and seabird observations will be made during ramp-ups and data acquisition periods, as well as at other times on an opportunistic basis. As per the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2017b), monitoring protocols for marine mammals and sea turtles will be consistent with those developed by LGL and outlined in Moulton and Mactavish (2004). Seabird data collection protocols will be consistent with those provided by CWS in Gjerdrum et al. (2012). Data will be collected by qualified and experienced MMOs and a monitoring report will be submitted to the C-NLOPB.

MKI will also coordinate with DFO, St. John's, and the FFAW/Unifor to avoid any potential conflicts with either survey vessels that may be operating in the area or survey stations in the area (e.g., Industry-DFO-FFAW/Unifor Collaborative Post-Season Trap Survey for Snow Crab). MKI 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.

5.10 Assessment Summary

A summary of the significance ratings of residual effects of MKI's proposed seismic program on the environment are shown in Table 5.20. The levels of confidence are also provided in the table. In summary, the residual effects of MKI's proposed seismic program on the VECs are predicted to be *not significant*.

Table 5.20   Significance of Potential Residual Environmental Effects of MKI's Proposed Seismic Program on VECs in the Study Area.

Valued Environmental Components: Fish and Fish Habitat, Fisheries, Marine-associated Birds, Marine Mammals and Sea Turtles, Species at Risk, Sensitive Areas				
Project Activity	**Significance of Predicted Residual Environmental Effects**		**Likelihood[a]**	
	Significance Rating	**Level of Confidence**	**Probability of Occurrence**	**Scientific Certainty**
Sound				
Airgun Array (2D, 3D and 4D)	NS	1-3	-	-
Seismic Vessel	NS	2-3	-	-
Escort vessel	NS	2-3		
Supply Vessel	NS	2-3	-	-
Helicopter	NS	3	-	-
Echosounder	NS	2-3	-	-
Side Scan Sonar	NS	2-3	-	-
Vessel Lights	NS	3	-	-
Vessel/Equipment Presence				
Seismic Vessel/Gear (2D, 3D and 4D)	NS	3	-	-
Supply Vessel	NS	3	-	-
Escort Vessel	NS	3	-	-
Sanitary/Domestic Wastes	NS	3	-	-
Atmospheric Emissions	NS	3	-	-
Helicopter Presence	NS	3	-	-
Accidental Releases	NS	2-3	-	-

Valued Environmental Components: Fish and Fish Habitat, Fisheries, Marine-associated Birds, Marine Mammals and Sea Turtles, Species at Risk, Sensitive Areas				
Project Activity	**Significance of Predicted Residual Environmental Effects**		**Likelihood**[a]	
	Significance Rating	**Level of Confidence**	**Probability of Occurrence**	**Scientific Certainty**
Key: Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.				

Key:

Significance is defined as either a high magnitude, or a medium magnitude with duration greater than 1 year and a geographic extent >100 km^2.

Residual environmental Effect Rating:

S   = Significant Negative Environmental Effect

NS = Not-significant Negative Environmental Effect

P   = Positive Environmental Effect

Level of Confidence: based on professional judgment:

1 = Low

2 = Medium

3 = High

Probability of Occurrence: based on professional judgment:

1 = Low Probability of Occurrence

2 = Medium Probability of Occurrence

3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgment:

1 = Low

2 = Medium

3 = High

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

6.0   Literature Cited

Abgrall, P., A.L. Lang, and V.D. Moulton. 2008a. Marine mammal and seabird monitoring of Husky Energy's 3D seismic program in the Jeanne d'Arc Basin, 2006 and 2005-2006 combined. LGL Rep. SA920. Rep. by LGL Ltd., St. John's, NL, for Husky Energy Inc., Calgary, AB. 98 p. + appendices.

Abgrall, P., V.D. Moulton, and W.J. Richardson. 2008b. Updated review of scientific information on impacts of seismic survey sound on marine mammals, 2004-present. Rep. by LGL Ltd., St. John's, NL, and King City, ON, for Dept. Fisheries and Oceans, Habitat Sci. Branch, Ottawa, ON. 27 p.

Abgrall, P., B.D. Mactavish, and V.D. Moulton. 2008c. Marine mammal and seabird monitoring of Orphan Basin controlled source electromagnetic survey program, 2006 – 2007. LGL Rep. SA904/939. Rep. by LGL Limited, St. John's, NL, for ExxonMobil Canada Ltd., St. John's, NL. 96 p. + appendices.

Abgrall, P., A.L. Lang, B.D. Mactavish, and V.D. Moulton. 2009. Marine mammal and seabird monitoring of StatoilHydro Canada and Husky Energy's 2008 seismic program in the Jeanne d'Arc Basin. Draft LGL Rep. SA984. Rep. by LGL Limited, St. John's, NL, for StatoilHydro Canada Exploration & Production Inc., St. John's, NL and Husky Energy Inc., Calgary, AB. 98 p. + appendices.

Aguilar de Soto, N. 2016. Peer-reviewed Studies on the Effects of Anthropogenic Noise on Marine Invertebrates: From Scallop Larvae to Giant Squid. Advances in Exp. Med. and Biol., November, 2015, p. 17-26. doi: 10.1007/978-1-4939-2981-8_3.

ALTRT (Atlantic Leatherback Turtle Recovery Team). 2006. Recovery strategy for leatherback turtle (*Dermochelys coriacea*) in Atlantic Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vi + 45 p.

Andersen, J.M., Y.F. Wiersma, G.B. Stenson, M.O. Hammill, A. Rosing-Asvid, and M. Skern-Maurizen. 2012. Habitat selection by hooded seals (*Cystophora cristata*) in the Northwest Atlantic Ocean. ICES J. Mar. Sci. 69:1-13.

Andersen, J.M., M. Skern-Mauritzen, L. Boehme, Y.F. Wiersma, A. Rosing-Asvid, M.O. Hammill, and G.B. Stenson. 2013. Investigating annual diving behaviour by hooded seals (*Cystophora cristata*) within the Northwest Atlantic Ocean. PLoS ONE 8(11): e80438. doi:10.1371/journal.pone.0080438.

Andersen, J.M., G.B. Stenson, M. Skern-Mauritzen, Y.F. Wiersma, A. Rosing-Asvid, M.O. Hammill, and L. Boehme. 2014. Drift diving by hooded seals (*Cystophora cristata*) in the Northwest Atlantic Ocean. PLoS ONE 9(7): e103072. doi:10.1371/journal.pone.0103072.

Archibald, D.W. and M.C. James. 2016. Evaluating inter-annual relative abundance of leatherback sea turtles in Atlantic Canada. Mar. Ecol. Prog. Ser. 547:233-246.

Armstrong, D.A., P.A. Dinnel, J.M. Orensanz, J.L. Armstrong, T.L. McDonald, R.F. Cusimano, R.S. Nemeth, M.L. Landolt, J.R. Skalski, R.F. Lee, and R.J. Huggett. 1995. Status of selected bottom fish and crustacean species in Prince William Sound following the Exxon Valdez oil spill. p. 485-547 *In:* P.G. Wells, J.N. Butler, and J.S. Hughes (eds.). Exxon Valdez oil spill: Fate and effects in Alaskan waters, ASTM STP 1219. American Society for Testing and Materials, Philadelphia. 965 p.

Baillie, S.M., G.J. Robertson, F.K. Wiese, and U.P. Williams. 2005. Seabird data collected by the Grand Banks offshore hydrocarbon industry 1999-2002: results, limitations and suggestions for improvement. Canadian Wildlife Service Technical Report Series No. 434. Atlantic Region.

Baillon, S., J.F. Hamel, V.E. Wareham, and A. Mercier. 2012. Deep cold-water corals as nurseries for fish larvae. Front. Ecol. Environ. 10(7): 351-356.

Baker, K.D., R.L. Haedrich, D.A. Fifield, and K.D. Gilkinson. 2012. Grenadier abundance examined at varying spatial scales in deep waters off Newfoundland, Canada, with special focus on the influence of corals. J. Ichthyol. 52(10): 678-689.

Barrie, J.D., B.A. Bennett, S.M. Browne, and A.J. Moir. 1980. Offshore Labrador biological studies, 1979: Benthos. Nearshore studies of marine benthos in the Makkovik Bay and Cartwright regions. Rep. by Atlantic Biological Services Ltd. (LGL-Northland) for Total Eastcan Exploration Ltd. 158 p.

Beauchamp, J., H. Bouchard, P. de Margerie, N. Otis, and J.-Y. Savaria. 2009. Recovery strategy for the blue whale (*Balaenoptera musculus*), Northwest Atlantic population, in Canada [FINAL]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, ON. 62 p.

Beazley, L.I., E.L. Kenchington, F.J. Murillo, and M. Sacau. 2013. Deep-sea sponge grounds enhance diversity and abundance of epibenthic megafauna in the Northwest Atlantic. ICES J. Mar. Sci. 70(7): 1471-1490.

Blackwell, S.B., C.S. Nations, T.L. McDonald, A.M. Thode, D. Mathias, K.H. Kim, C.R. Greene, Jr., and A.M. Macrander. 2015. Effects of airgun sounds on bowhead whale calling rates: Evidence for two behavioral thresholds. PLoS ONE 10(6):e0125720. http://dx.doi.org/10.1371/journal.pone.0125720.

Blair HB, Merchant ND, Friedlaender AS, Wiley DN, Parks SE. 2016 Evidence for ship noise impacts on humpback whale foraging behaviour. Biol. Lett. 12:20160005.

Booman, C., J. Dalen, H. Leivestad, A. Levsen, T. van der Meeren, and K. Toklum. 1996. Effecter av luftkanonskyting på egg, larver og yngel. Fisken Og Havet 1996(3):1-83 (Norwegian with English summary).

Breeze, H., D.S. Davis, M. Butler, and V. Kostylev. 1997. Distribution and status of deep sea corals off Nova Scotia. Ecology Action Centre, Marine Issues Committee Spec. Publ. 1: 58 p.

Breeze, H., D. Fenton, R.J. Rutherford, and M.A. Silva (eds.). 2002. The Scotian Shelf: An ecological overview for ocean planning. Can. Tech. Rep. Fish. Aquat. Sci. 2393.

Bröker, K., G. Gailey, J. Muir, and R. Racca. 2015. Monitoring and impact mitigation during a 4D seismic survey near a population of gray whales off Sakhalin Island, Russia. Endang. Species Res. 28:187-208.

Brown, R.G.B. 1986. Revised atlas of eastern Canadian seabirds. 1. Shipboard surveys. Canadian Wildlife Service, Ottawa, ON. 111 p.

Bunch, J.N. 1979. Microbiological observations in the south Davis Strait. Fish. Mar. Serv. Man. Rep.1515: x + 92 p.

Burke, C.M., G.K. Davoren, W.A. Montevecchi, and F.K. Wiese. 2005. Surveys of seabirds along support vessel transects and at oil platforms on the Grand Banks. pp. 587-614 *In* P.J. Cransford and K. Lee (eds.). Offshore Oil and Gas Environmental Effects Monitoring. Battelle Press, Columbus, Ohio.

Cairns, D.K., W.A. Montevecchi, and W. Threlfall. 1989. Researcher's guide to Newfoundland seabird colonies. Second edition. Memorial University of Newfoundland Occasional Papers in Biology, No. 14. 43 p.

Campana, I., R. Crosti, D. Angeletti, L. Carosso, L. Davis, N. Di-Méglio, A. Moulins, M. Rosso, P. Tepsich, and A. Arcangeli. 2015. Cetacean response to summer maritime traffic in the western Mediterranean Sea. Mar. Environ. Res. 109: 1-8.

Carey, A.G., Jr. 1991. Ecology of North American Arctic continental shelf benthos: A review. Cont. Shelf Res. 11: 865-883.

Carroll, A.G., R. Przeslawski, A. Duncan, M. Gunning, and B. Bruce. 2016. A critical review of the potential impacts of marine seismic surveys & invertebrates. Mar. Poll. Bull. (2016). http://dx.doi.org/10.1016/j.marpolbul.2016.11.038.

Casas, J.M. 2015. Northern shrimp (*Pandalus borealis*) on Flemish Cap surveys 2015. NAFO SCR Doc.15/047.

Castellote, M. and C. Llorens. 2016. Review of the effects of offshore seismic surveys in cetaceans: Are mass strandings a possibility? p. 133-143 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

CCG (Canadian Coast Guard). 2012. Ice navigation in Canadian waters. Fisheries and Oceans Canada. 140 p. + appendices. Accessed in November 2016 at http://www.ccg-gcc.gc.ca/Icebreaking/Ice-Navigation-Canadian-Waters.

Christian, J.R., A. Mathieu, D.H. Thomson, D. White, and R.A. Buchanan. 2003. Effect of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report No. 144. Calgary, AB, Canada.

CIS (Canadian Ice Service). 2011. Sea Ice Climatic Atlas for the East Coast, 1981-2010. Available at http://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=AE4A459A-1.

C-NLOPB (Canada-Newfoundland and Labrador Offshore Petroleum Board). 2008. Labrador Shelf Offshore Area Strategic Environmental Assessment. Report by Sikumiut Environmental Management Ltd., St. John's, NL for the C-NLOPB, St. John's, NL. 519 p. + appendices.

C-NLOPB. 2010. Southern Newfoundland strategic environmental assessment. LGL Rep. SA1037. Rep. by LGL Limited, St. John's, NL for the C-NLOPB, St. John's, NL. 332 p. + appendix.

C-NLOPB. 2014. Eastern Newfoundland strategic environmental assessment. Rep. by AMEC Environment & Infrastructure, St. John's, NL for the C-NLOPB, St. John's, NL. 527 p. + appendices.

C-NLOPB. 2017a. Multiklient Invest AS Newfoundland and Labrador Offshore Seismic Program, 2017-2016 scoping document. Canada-Newfoundland and Labrador Offshore Petroleum Board, St. Johns, NL. ISBN: 978-1-927098-71-4. 11 p.

C-NLOPB. 2017b. Geophysical, Geological, Environmental and Geotechnical Program Guidelines, September 2017. 44 p + appendices.

C-NLOPB. 2018. Environmental Assessment of Multiklient Invest Newfoundland and Labrador Offshore Seismic Program, 2017–2026 Addendum (LGL November 2017) Consolidated Comments. 4 p.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2002. COSEWIC assessment and update status report on the northern bottlenose whale *Hyperoodon ampullatus* (Scotian shelf population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. vi + 22 p.

COSEWIC. 2005. COSEWIC assessment and update status report on the fin whale *Balaenoptera physalus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. ix + 37 p.

COSEWIC. 2006. COSEWIC assessment and update status report on the Sowerby's beaked whale *Mesoplodon bidens* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. vi + 20 p.

COSEWIC. 2011. COSEWIC assessment and status report on the northern bottlenose whale *Hyperoodon ampullatus*. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. xii + 31 p.

COSEWIC website. 2017. Committee on the Status of Endangered Wildlife in Canada. Government of Canada. Available at http://www.cosewic.gc.ca/default.asp?lang=en&n=A9DD45B7-1.

COSEWIC website. 2018. Committee on the Status of Endangered Wildlife in Canada. Government of Canada. Available at https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html

Culloch, R.M., P. Anderwald, A. Brandecker, D. Haberlin, B. McGovern, R. Pinfield, F. Visser, M. Jessopp, and M. Cronin. 2016. Effect of construction-related activities and vessel traffic on marine mammals. Mar. Ecol. Prog. Ser. 549: 231-242.

Dahlheim, M. and M. Castellote. 2016. Changes in the acoustic behavior of gray whales *Eschrichtius robustus* in response to noise. Endang. Species Res. 31: 227-242.

Dalebout, M.L., D.E. Ruzzante, H. Whitehead, and N.I. Øien. 2006. Nuclear and mitochondrial markers reveal distinctiveness of a small population of bottlenose whales (*Hyperoodon ampullatus*) in the western North Atlantic. Mol. Ecol. 15: 3115-3129.

Davoren, G.K. 2013. Distribution of marine predator hotspots explained by persistent areas of prey. Mar. Biol. 160(12): 3043-3058.

Day, R.D, R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann and J.M. Semmens. 2016. Assessing the impact of marine seismic surveys on southeast Australian scallop and lobster fisheries. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania. 144 p. + appendices.

Delarue, J., R. Dziak, D. Mellinger, J. Lawson, H. Moors-Murphy, Y. Simard, and K. Stafford. 2014. Western and central North Atlantic fin whale (*Balaenoptera physalus*) stock structure assessed using geographic song variations. J. Acoust. Soc. Am. 135(4): 2240.

Desrosiers, G., C. Savenkoff, M. Olivier, G. Stora, K. Juniper, A. Caron, J.P. Gange, L. Legendre, S. Muslow, J. Grant, S. Roy, A. Grehan, P. Scaps, N. Silverberg, B. Klien, J.E. Tremblay, and J.C. Therriault. 2000. Trophic structure of macrobenthos in the Gulf of St. Lawrence and the Scotian Shelf. Deep-Sea Res. 47: 663-697.

DFFA (Department of Fisheries, Forestry and Agrifoods). 2016. Fisheries and Aquaculture. Government of Newfoundland and Labrador. Available at http://www.fishaq.gov.nl.ca/aquaculture/index.html.

DFO. 2010a. Occurrence, susceptibility to fishing, and ecological function of corals, sponges, and hydrothermal vents in Canadian waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/041.

DFO. 2010b. Recovery strategy for the Northern Bottlenose Whale, Scotian Shelf population, in Atlantic Canadian waters. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada. vi + 61p.

DFO. 2012. Using satellite tracking data to define important habitat for leatherback turtles in Atlantic Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/036.

DFO. 2014. Recovery Strategy for the North Atlantic Right Whale (*Eubalaena glacialis*) in Atlantic Canadian Waters [Final]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 68 p.

DFO. 2015a. Coral & Sponge Conservation Strategy for Eastern Canada 2015. 51 p. + appendices.

DFO. 2015b. Assessment of Capelin in Subarea 2 and Divisions 3KL in 2015. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/036.

DFO. 2015c. Coral and sponge conservation measures in the Maritimes. DFO, Government of Canada. Available at http://www.inter.dfo-mpo.gc.ca/Maritimes/Oceans/OCMD/Coral/Conservation-Measures.

DFO. 2015d. Review of mitigation and monitoring measures for seismic survey activities in and near the habitat of cetacean species at risk. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/005.

DFO. 2016a. Oceanographic conditions in the Atlantic zone in 2015. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/041.

DFO. 2016b. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/013.

DFO. 2016c. An assessment of Northern Shrimp (*Pandalus borealis)* in Shrimp Fishing Areas 4-6 and of Striped Shrimp (*Pandalus montagui)* in Shrimp Fishing Area 4 in 2015. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/028.

DFO. 2016d. Stock Assessment of Northern Cod (NAFO Divs. 2J3KL) in 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/026.

DFO. 2016e. Recovery Potential Assessment for White Hake (*Urophycis tenuis*): Population of the Atlantic and Northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/035.

DFO. 2016f. Decisions for Atlantic Canada, Quebec and the Arctic – 2016. Government of Canada. Available at http://www.dfo-mpo.gc.ca/decisions/fm-2016-gp/index-atl-eng.htm.

DFO. 2016g. Recovery strategy for the northern bottlenose whale, (*Hyperoodon ampullatus*), Scotian Shelf population, in Atlantic Canadian waters [Final]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 70 p. Available at http://www.sararegistry.gc.ca/document/default_e.cfm?documentID=1863.

DFO. 2016h. Action Plan for the North Atlantic Right Whale (Eubalaena glacialis) in Canada: Fishery Interactions [Proposed]. Species at Risk Act Action Plan Series, DFO, Ottawa. v + 35 p.

DFO. 2016i. Action plan for the Atlantic salmon (*Salmo salar*) inner Bay of Fundy populations in Canada [PROPOSED]. *Species at Risk Act* Action Plan Series. Fisheries and Oceans Canada, Ottawa. vi + 58 p. Available at http://www.sararegistry.gc.ca/document/default_e.cfm?documentID=2936.

DFO. 2016j. Recovery document posting plan – Fisheries and Oceans Canada – Fiscal Year 2016-2017. DFO, Government of Canada. 3 p. Available at http://www.sararegistry.gc.ca/document/default_e.cfm?documentID=2661.

DFO. 2016k. Tracking the titans: Research on endangered leatherback turtles informs a recovery strategy. DFO, Government of Canada. Available at http://www.dfo-mpo.gc.ca/science/publications/article/2016/01-29-16-eng.html.

DFO. 2016l. Federal marine protected areas strategy. DFO, Government of Canada. Available at http://www.dfo-mpo.gc.ca/oceans/publications/fedmpa-zpmfed/index-eng.html.

DFO. 2017a. Decisions for Atlantic Canada, Quebec and the Arctic – 2017. DFO, Government of Canada. Available at http://www.dfo-mpo.gc.ca/decisions/fm-2017-gp/index-atl-eng.htm.

DFO. 2017b. Management plan for the fin whale (*Balaenoptera physalus*), Atlantic population in Canada. Species at Risk Act Management Plan Series, DFO, Ottawa. iv + 38 p.

DFO. 2017c. Management plan for the Sowerby's beaked whale (*Mesoplodon bidens*) in Canada. Species at Risk Act Management Plan Series, DFO, Ottawa. iv + 46 p.

DFO. 2017d. Action plan for the Northern Bottlenose Whale (*Hyperoodon ampullatus*), Scotian Shelf population, in Atlantic Canadian waters. Species at Risk Act Management Plan Series, DFO, Ottawa. iv + 37 p.

DFO. 2017e. Laurentian Channel AOI. Fisheries and Oceans Canada. Available at http://www.dfo-mpo.gc.ca/oceans/aoi-si/laurentian-laurentien-eng.html.

Dodge, K.L., B. Galuardi, T.J. Miller, and M.E. Lutcavage. 2014. Leatherback turtle movements, dive behavior, and habitat characteristics in ecoregions of the Northwest Atlantic Ocean. PLoS ONE 9(3): e91726. doi:10.1371/journal.pone.0091726.

Duinker, P.N., E.L. Burbidge, S.R. Boardley, and L.A. Greig. 2012. Scientific dimensions of cumulative effects assessment: toward improvements in guidance for practice. Env. Rev. 21(1): 40-52.

Dunlop, R.A. 2015. The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. Animal Behav. 111: 13-21.

Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, D. Paton, and D.H. Cato. 2015. The behavioural response of humpback whales (*Megaptera novaeangliae*) to a 20 cubic inch air gun. Aquatic Mamm. 41(4): 412-433.

Dunlop, R. A., M. J. Noad, R. D. McCauley, E. Kniest, R. Slade, D. Paton, and D. H. Cato. 2016. Response of humpback whales (*Megaptera novaeangliae*) to ramp-up of a small experimental air gun array. Mar. Poll. Bull. 103: 72-83.

Dupuis, A., and Ucan-Marin, F. 2015. A literature review on the aquatic toxicology of petroleum oil: An overview of oil properties and effects to aquatic biota. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/007. vi + 52 p.

Dyndo, M., D.M. Wiœniewska, L. Rojano-Doñate, and P.T. Madsen. 2015. Harbour porpoises react to low levels of high frequency vessel noise. Scientific Reports 5:11083 doi: 10.1038/srep11083.

ECCC (Environment and Climate Change Canada). 2017a. Recovery strategy and management plan for the Red Knot (*Calidris canutus*) in Canada. *Species at Risk* Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. ix + 67 p. Available at http://www.sararegistry.gc.ca/document/default_e.cfm?documentID=2905.

ECCC. 2017b. Procedures for handling and documenting stranded birds encountered on infrastructure offshore Atlantic Canada (DRAFT May 2017). 17 p.

ECCC-CWS (Environment and Climate Change Canada-Canadian Wildlife Service). 2017. Procedures for handling and documenting stranded birds encountered on infrastructure offshore Atlantic Canada, Draft May 2017. 17 p.

Edinger, E, K. Baker, R. Devillers, and V. Wareham. 2007. Coldwater corals off Newfoundland and Labrador: Distributions and fisheries impacts. World Wildlife Foundation, Toronto, ON.

Edinger, E., V. Wareham, K. Baker, and R. Haedrich. 2009. Relationships between deep-sea corals and groundfish. p. 39-55 *In:* K. Gilkinson and E. Edinger (eds.). The ecology of deep-sea corals of Newfoundland and Labrador waters: Biogeography, life history, biogeochemistry, and relation to fishes. Can. Tech. Rep. Fish. Aquat. Sci. 2830: vi + 136 p.

Edmonds, N.J., C.J. Firmin, D. Goldsmith, R.C. Faulkner, and D.T. Wood. 2016. A review of crustacean sensitivity to high amplitude underwater noise: Data needs for effective risk assessment in relation to UK commercial species. Mar. Poll Bull. (2016). http://dx.doi.org/10.1016/j.marpolbul.2016.05.006.

Edwards, E.F., C. Hall, T.J. Moore, C. Sheredy, and J.V. Redfern, 2015. Global distribution of fin whales *Balaenoptera physalus* in the post-whaling era (1980–2012). Mammal Rev. 45(4): 197-214.

Engås, A., S. Løkkeborg, A.V. Soldal, and E. Ona. 1993. Comparative trials for cod and haddock using commercial trawl and longline at two different stock levels. J. Northw. Atl. Fish. Sci. 19:83-90.

Engås, A, S. Løkkeborg, E. Ona, and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (G. morhua) and haddock (M. aeglefinus). Can. J. Fish. Aquat. Sci. 53(10): 2238-2249.

Erbe, C., C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling. 2015. Communication masking in marine mammals: A review and research strategy. Mar. Pollut. Bull. http://dx.doi.org/10.1016/j.marpolbul.2015.12.007.

Fewtrell, J.L. and R.D. McCauley. 2012. Impact of air gun noise on the behaviour of marine fish and squid. Mar. Poll. Bull. 64(5): 984-993.

FFAW|Unifor (Fish, Food & Allied Workers). 2017. Snow crab post-season trap survey. Available at http://ffaw.nf.ca/en/snow-crab-post-season-trap-survey#.WJTJ530-JEI.

Fifield, D.A., K.P. Lewis, C. Gjerdrum, G.J. Robertson, and R. Wells. 2009. Offshore seabird monitoring program. Environ. Stud. Res. Funds Rep. No. 183. 68 p.

Finneran, J.J. 2015. Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. J. Acoust. Soc. Am. 138(3): 1702-1726.

Finneran, J.J., C.E. Schlundt, B.K. Branstetter, J.S. Trickey, V. Bowman, and K. Jenkins. 2015. Effects of multiple impulses from a seismic air gun on bottlenose dolphin hearing and behavior. J. Acoust. Soc. Am. 137(4): 1634-1646.

Fraser. G.S., J. Russell, G.J. Robertson, R. Bryant, and D.A. Fifield. 2013. Prospects for the Manx Shearwater colony on Middle Island, Newfoundland, Canada. Marine Ornithology 41: 137-140.

Fratantoni, P.S. and R.S. Pickart. 2007. The western north Atlantic shelfbreak current system in summer. J. Phys. Ocean. 37: 2509-2533.

Gailey, G., O. Sychenko, T. McDonald, R. Racca, A. Rutenko, and K. Bröker. 2016. Behavioural responses of western gray whales to a 4D seismic survey off northeastern Sakhalin Island, Russia. Endang. Species Res. 30: 53-71.

Gale, K.S.P. 2013. Ecology of Deep-Sea Asteroidea from Atlantic Canada. M.Sc. Thesis. Memorial University, St. John's, NL, Canada. vii + 114.

Gass, S. 2003. Conservation of deep-sea corals in Atlantic Canada. World Wildlife Fund Canada, Toronto, ON.

Gauthreaux, S.A., Jr. and C.G. Belser. 2006. Effects of artificial night lighting on migrating birds. pp. 67-93 *In:* C. Rich and T. Longcore (editors), Ecological Consequences of Artificial Night Lighting, Island Press, Washington, D.C. 478 p

Gilkinson, K. 2013. Recent DFO (Newfoundland & Labrador Region) studies of the Grand Banks benthos at small and large spatial scales. DFO Canadian Scientific Science Advisory Secretariat Research Document. 2012/114. v + 30 p.

Gilkinson, K. and E. Edinger (eds.). 2009. The ecology of deep-sea corals of Newfoundland and Labrador waters: Biogeography, life history, biogeochemistry, and relation to fishes. Can. Tech. Rep. Fish. Aquat. Sci. 2830: vi + 136 p.

Gjerdrum, C., D.A. Fifield, and S.I. Wilhelm. 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms. Technical Report Services No. 515, Canadian Wildlife Service. Atlantic Region. vi + 37 p. Available at http://www.cnlopb.nl.ca/pdfs/hmdcjdb/ecseabird.pdf.

Gomez, C., J. Lawson, A.D. Wright, A. Buren, D. Tollit, and V. Lesage. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: The disparity between science and policy. Can. J. Zool. 94: 801-819.

Gomez-Salazar, C. and H.B. Moors-Murphy. 2014. Assessing cetacean distribution in the Scotian Shelf Bioregion using habitat suitability models. Can. Tech. Rep. Fish. Aquat. Sci. 3088. iv + 49 p.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. Mar. Technol. Soc. J. 37: 16-34.

Gospić, N.R. and M. Picciulin. 2016. Changes in whistle structure of resident bottlenose dolphins in relations to underwater noise and boat traffic. Mar. Poll. Bull. 105: 193-198.

Guan, S., J. Vignola, J. Judge, and D. Turo. 2015. Airgun inter-pulse noise field during a seismic survey in an Arctic ultra-shallow marine environment. J. Acoust. Soc. Am. 138(6): 3447-3457.

Guerra, M., P.J. Dugan, D.W. Ponirakis, M. Popescu, Y. Shiu, and C.W. Clark. 2016. High-resolution analysis of seismic airgun impulses and their reverberant field as contributors to an acoustic environment. p. 371-379 *In:* A.N. Popper and A. Hawkins (eds.). The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Guijarro, J., L. Beazley, C. Lirette, E. Kenchington, V. Wareham, K. Gilkinson, M. Koen-Alonso, and F.J. Murillo. 2016. Species distribution modelling of corals and sponges from research vessel survey data in the Newfoundland and Labrador region for use in the identification of significant benthic areas. Can. Tech. Rep. Fish. Aquat. Sci. 3171: vi + 125p.

Hammill, M.O., C.E. den Heyer, and W.D. Bowen, 2014. Grey seal population trends in Canadian waters, 1960-2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/037. iv + 44 p.

Hammill, M.O., G.B. Stenson, T. Doniol-Valcroze, and A. Mosnier. 2015. Conservation of northwest Atlantic harp seals: Past success, future uncertainty? Biol. Conserv. 192: 181-191.

Harris, L.E., W.E. Gross, and P.E. Emery. 2013. Biology, status and recovery potential of northern bottlenose whales (*Hyperoodon ampullatus*). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/038. v + 35 p.

Harrison, W.G. and W.K.W. Li. 2008. Phytoplankton growth and regulation in the Labrador Sea: Light and nutrient limitation. J. North. Atl. Fish. Sci. 39: 71–82.

Harrison, W.G., K.Y. Børsheim, K.W.L. William, G.L. Maillet, P. Pepin, E. Sakshaug, M.D. Skogen, and P.A. Yeats. 2013. Phytoplankton production and growth regulation in the Subarctic North Atlantic: A comparative study of the Labrador Sea-Labrador/Newfoundland shelves and Barents/Norwegian/Greenland seas and shelves. Progress in Oceanography 114: 26–45.

Hawkins, A.D. and A.N Popper. 2016. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES J. Mar. Sci. (2016). Doi:10.1093/icesjms/fsw205.

Hawkins, A.D., A.E. Pembroke, and A.N. Popper. 2015. Information gaps in understanding the effects of noise on fishes and invertebrates. Rev. Fish. Biol. Fisher. 25(1): 39.

Head, E. and P. Pepin. 2008. Variations in overwintering depth distributions of *Calanus finmarchicus* in the slope waters of the NW Atlantic Continental Shelf and the Labrador Sea. J. North. Atl. Fish. Sci. 39: 49-69.

Head, E.J.H., L.R. Harris, and R.W. Campbell. 2000. Investigations on the ecology of *Calanus* spp. in the Labrador Sea. I. Relationship between the phytoplankton bloom and reproduction and development of *Calanus finmarchicus* in spring. Mar. Ecol. Prog. Ser. 193: 53-73.

Heiler, J., S.H. Elwen, H.J. Kriesell, and T. Gridley. 2016. Changes in bottlenose dolphin whistle parameters related to vessel presence, surface behaviour and group composition. Animal Behav. 117: 167-177.

Helm, R.C., D.P. Costa, T.D. DeBruyn, T.J. O'Shea, R.S. Wells, and T.M. Williams. 2015. Overview of effects of oil spills on marine mammals. p. 455-475 *In:* M. Fingas (ed.), Handbook of Oil Spill Science and Technology.

Hermannsen, L., K. Beedholm, J. Tougaard, and P.T. Madsen. 2014. High frequency components of ship noise in shallow water with a discussion of implications for harbor porpoises (*Phocoena phocoena*). J. Acoust. Soc. Am. 136(4): 1640-1653.

Hermannsen, L., J. Tougaard, K. Beedholm, J. Nabe-Nielsen, and P.T. Madsen. 2015. Characteristics and propagation of airgun pulses in shallow water with implications for effects on small marine mammals. PLoS ONE 10(7): e0133436.

Higgs, D. M., Z. Lu and D. Mann, D. 2006. Hearing and mechanoreception. *In*: D. H. Evans and J. B. Claiborne (eds.). The Physiology of Fishes. Taylor & Francis Group. Boca Raton, FL.

Hoelzel, A.R., C.W. Potter, and P.B. Best. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of bottlenose dolphin. Proc. R. Soc. London, Biol. Sci. 265: 1177-1183.

Holst, M. and T. Lang. 2014. Marine mammal, sea turtle and seabird monitoring of WesternGeco Canada's seismic program in Jeanne d'Arc Basin, 2013. LGL Rep. SA1224. Rep. by LGL Limited, St. John's, NL, for WesternGeco Canada, Calgary, AB. 6 p. + appendix.

Holt, M.M., D.P. Noren, R.C. Dunkin, and T.M. Williams. 2015. Vocal performance affects metabolic rate in dolphins: Implications for animals communicating in noisy environments. J. Exp. Biol. 218(11): 1647-1654. http://dx.doi.org/10.1242/jeb.122424.

Houghton, J., M.M. Holt, D.A. Giles, M.B. Hanson, C.K. Emmons, J.T. Hogan, T.A. Branch, and G.R. VanBlaricom. 2015. The relationship between vessel traffic and noise levels received by killer whales (*Orcinus orca*). PLoS ONE 10(12): e0140119. doi:10.1371/journal.pone.0140119.

Houston, K.A. and R.L. Haedrich. 1984. Abundance and biomass of macrobenthos in the vicinity of Carson Submarine Canyon, northwest Atlantic Ocean. Marine Biology. 82:301-305.

Howard, B. 2012. Assessing and managing the ecological risk of leatherback sea turtles (*Dermochelys ocriacea*) from marine oil pollution in Atlantic Canada. MMM thesis, Dalhousie University, Halifax, NS. 90 p. + appendix.

Huntley, M., K.W. Strong, and A.T. Dengler. 1983. Dynamics and community structure of zooplankton in the Davis Strait and Northern Labrador Sea. Arctic 25(2): 143-161.

Husky (Energy). 2003a. Husky Lewis Hill Prospect Exploration Drilling Program Environmental Assessment. Prepared by LGL Limited, Oceans Limited, Provincial Airlines Limited, and S.R. Ross Environmental Research Ltd. for Husky Oil Operations Limited, St. John's, NL. 324 p.

Husky. 2003b. White Rose baseline addendum draft report January 2003. Prepared by Jacques Whitford Environment Limited for Husky Oil Operations Limited, St. John's, NL. 14 p. + app.

Hutcheson, M., P.L. Stewart, and J.M. Spry. 1981. The biology of benthic communities of the Grand Banks of Newfoundland (including Hibernia area). *In:* MacLaren Plansearch Lavalin. Grand Bank Oceanographic Studies: Volume No. 3. Final Report to Mobil Oil Canada Limited.

Hutchison, L. V., and B. W. Wenzel. 1980. Olfactory guidance in foraging by Procellariiforms. Condor 82: 314-319.

ICOADS (International Comprehensive Ocean-Atmosphere Data Set) 2016. ICOADS Release 3.0 (R3.0). Available at http://icoads.noaa.gov/products.html.

IUCN and UNEP-WCMC (International Union for the Conservation of Nature and United Nations Environment Program World Conservation Monitoring Centre). 2016. The world database on protected areas (WDPA). UNEP-WCMC. Cambridge, UK. Available at http://www.protectedplanet.net.

Jefferson, T.A., C.R. Weir, R.C. Anderson, L.T. Ballance, R.D. Kenney, and J.J. Kiszka. 2014. Global distribution of Risso's dolphin *Grampus griseus*: A review and critical evaluation. Mammal Rev. 44(1): 56-68.

Kastelein, R.A., R. Gransier, M.A.T. Marijt, and L. Hoek. 2015. Hearing frequency thresholds of harbor porpoises (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds. J. Acoust. Soc. Am. 137(2): 556-564.

Kastelein, R.A., R. Gransier, and L. Hoek. 2016. Cumulative effects of exposure to continuous and intermittent sounds on temporary hearing threshold shifts induced in a harbor porpoise (*Phocoena phocoena*). p. 523-528 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Keats, K.F. 2015. Marine mammal, sea turtle, and seabird monitoring during HMDC's 4D M1 seismic program, Newfoundland offshore area, June–August 2015. LGL Rep. FA0050A. Rep. by LGL Limited, St. John's, NL, for WesternGeco Canada, Calgary, AB. 9 p. + appendix.

Kenchington, E.L.R., Prena, J., Gilkinson, K.D., Gordon Jr., D.C., MacIsaac, K., Bourbonnais, C., Schwinghamer, P.J., Rowell, T.W., McKeown, D.L., and Vass, W.P. 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences. 58: 1043-1057.

Kenchington, E., C. Lirette, A. Cogswell, D. Archambault, P. Archambault, H. Benoit, D. Bernier, B. Brodie, S. Fuller, K. Gilkinson, M. Lévesque, D. Power, T. Siferd, M. Treble, and V. Wareham. 2010a. Delineating coral and sponge concentrations in the biogeographic regions of the east coast of Canada using spatial analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/039. vi + 202 p.

Kenchington, E., D. Power, and M. Koen-Alonso. 2010b. Associations of demersal fish with sponge grounds in the Northwest Atlantic Fisheries Organizations Regulatory Area and adjacent Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/039. vi + 27 p.

Kenchington, E., D. Power, and M. Koen-Alonso. 2013. Associations of demersal fish with sponge grounds on the continental slopes of the northwest Atlantic. Marine Ecology Progress Series, 477: 217-230.

Kenchington, E., L. Beazley, C. Lirette, F.J. Murillo, J. Guijarro, V. Wareham, K. Gilkinson, M. Koen Alonso, H. Benoît, H. Bourdages, B. Sainte-Marie, M. Treble, and T. Siferd. 2016. Delineation of Coral and Sponge Significant Benthic Areas in Eastern Canada Using Kernel Density Analyses and Species Distribution Models. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/093. vi + 178 p.

Kennedy, A.S., A.N. Zerbinid, O.V. Vasquez, N. Gandilhon, P.J. Clapham, and O. Adam. 2014. Local and migratory movements of humpback whales (*Megaptera novaeangliae*) satellite-tracked in the North Atlantic Ocean. Can. J. Zool. 92: 8-17.

Kühnhold, W.W. 1978. Effects of the water soluble fraction of a Venezuelan heavy fuel oil (No. 6) on cod eggs and larvae. p. 126-130 *In:* In the Wake of the Argo Merchant, Center for Ocean Management. Univ. of Rhode Island, Kingston, RI.

Kulka, D., C. Hood, and J. Huntington. 2007. Recovery strategy for northern wolffish (*Anarhichas denticulatus*) and spotted wolffish (*Anarhichas minor*), and management plan for Atlantic wolffish (*Anarhichas lupus*) in Canada. Fisheries and Oceans Canada, Newfoundland and Labrador Region. St. John's, NL. x + 103 p.

Lalas, C. and H. McConnell. 2015. Effects of seismic surveys on New Zealand fur seals during daylight hours: Do fur seals respond to obstacles rather than airgun noise? Mar. Mammal Sci. 21 p. doi: 10.1111/mms.12293.

Lane, S.M., C.R. Smith, J. Mitchell, B.C. Balmer, K.P. Barry, T. McDonald, C.S. Mori, P.E. Rosel, T.K. Rowles, T.R. Speakman, F.I. Townsend, M.C. Tumlin, R.S. Wells, E.S. Zolman, and L.H. Schwacke. 2015. Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the *Deepwater Horizon* oil spill. Proc. R. Soc. B 282: 20151944. doi: 10.1098/rspb.2015.1944.

Lang, A.L. 2007. Seabird abundance near Terra Nova offshore oil development during late spring 2006. LGL Rep. SA919. Rep. by LGL Limited, St. John's, NL, for Petro-Canada, St. John's, NL. 11 p.

Lang, A.L. and V.D. Moulton. 2008. Marine mammal and seabird monitoring of Petro-Canada's 3D seismic program in the Jeanne d'Arc Basin, 2007. LGL Rep. SA938. Rep. by LGL Ltd., St. John's, NL, for Petro-Canada, St. John's, NL. 32 p. + appendices.

Lang, A.L., V.D. Moulton, and R.A. Buchanan. 2006. Marine mammal and seabird monitoring of Husky Energy's 3D seismic program in the Jeanne d'Arc Basin, 2005. LGL Rep. SA887. Rep. by LGL Ltd., St. John's, NL, for Husky Energy Inc., Calgary, AB. 63 p. + appendices.

Lawson, J.W. and J.F. Gosselin. 2009. Distribution and preliminary abundance estimates for cetaceans seen during Canada's Marine Megafauna Survey - A component of the 2007 TNASS. DFO Can. Sci. Adv. Sec. Res. Doc. 2009/031. 28 p.

Lawson, J.W. and T.S. Stevens. 2013. Historic and current distribution patterns, and minimum abundance of killer whales (*Orcinus orca*) in the north-west Atlantic. J. Mar. Biol. Assoc. UK 94(6): 1253-1265.

Le Corre, M., A. Ollivier, S. Ribes, and P. Jouventin. 2002. Light-induced mortality of petrels: A 4-year study from Réunion Island (Indian Ocean). Biol. Conserv. 105: 93-102.

Lesage, V., K. Gavrilchuk, R.D. Andrews, and R. Sears. 2016. Wintering areas, fall movements and foraging sites of blue whales satellite-tracked in the Western North Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/078. v + 38 p.

LGL. 2012a. Orphan Basin exploration drilling program environmental assessment: Update 2012. LGL Rep. SA1160. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB. 53 p. + appendix.

LGL. 2012b. Environmental Impact Assessment of the Shell Kanumas A/S 2012 Anu-Napu 3D Seismic Survey in Baffin Bay Blocks 5 and 8. Report prepared by LGL Limited, Canada in association with Grontmij A/S, Denmark for Shell Kanumas A/S, Denmark.

LGL. 2013. Environmental assessment of Suncor Energy's Eastern Newfoundland Offshore Area 2D/3D/4D Seismic Program, 2014–2024. LGL Rep. SA1233. Rep. by LGL Limited, St. John's, NL, for Suncor Energy, St. John's, NL. 210 p. + appendices.

LGL. 2014. Environmental assessment MKI Labrador Sea seismic program, 2014-2018. LGL Rep. SA1245. Rep. by LGL Limited, St. John's, NL, for Multi Klient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, TX. 241 p. + appendices.

LGL. 2015a. Environmental Assessment of WesternGeco's Eastern Newfoundland Offshore Seismic Program, 2015-2024. LGL Rep. FA0035. Prepared by LGL Limited in association with Canning & Pitt Associates Inc., St. John's, NL for WesternGeco (Division of Schlumberger Canada Limited), Calgary, AB. 255 p. + appendices.

LGL. 2015b. Environmental Assessment of WesternGeco's Southeastern Newfoundland Offshore Seismic Program, 2015-2024. LGL Rep. FA0034. Prepared by LGL Limited in association with Canning & Pitt Associates Inc., St. John's, NL for WesternGeco (Division of Schlumberger Canada Limited), Calgary, AB. 283 p. + appendices.

LGL. 2016. Environmental Assessment of Seitel's East Coast Offshore Seismic Program, 2016-2025. LGL Rep. FA0071. Prepared by LGL Limited, St. John's, NL for Seitel Canada Ltd., Calgary, AB. 211 p. + appendix.

LGL. 2017a. Environmental Assessment of Multiklient Invest Newfoundland and Labrador Offshore Seismic Program, 2017–2026. LGL Rep. FA0106. Rep. by LGL Limited, St. John's, NL for Multiklient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, TX. 255 p. + Appendix.

LGL. 2017b. Environmental Assessment of Multiklient Invest Newfoundland and Labrador Offshore Seismic Program, 2017–2026 Addendum. LGL Rep. FA0106-1. Rep. by LGL Limited, St. John's, NL for Multiklient Invest AS, Oslo, Norway, and TGS-NOPEC Geophysical Company ASA, Houston, TX. 32 p.

Li, W.K.W. and G.W. Harrison. 2001. Chlorophyll, bacteria and picophytoplankton in ecological provinces of the North Atlantic. Deep Sea Res. II. 48: 2271-2293.

Li, S., H. Wu, Y. Xu, C. Peng, L. Fang, M. Lin, L. Xing, and P. Zhang. 2015. Mid- to high-frequency noise from high-speed boats and its potential impacts on humpback dolphins. J. Acoust. Soc. Am. 138(2): 942-952.

Lock, A.R., R.G.B. Brown, and S.H. Gerriets. 1994. Gazetteer of marine birds in Atlantic Canada. An atlas of seabird vulnerability to oil pollution. Canadian Wildlife Service, Environmental Conservation Branch, Environment Canada, Atlantic Region. 137 p.

Løkkeborg, S. and A.V. Soldal. 1993. The influence of seismic explorations on cod (Gadus morhua) behaviour and catch rates. ICES Mar. Sci. Symp. 196:62-67.

Løkkeborg, S., E. Ona, A. Vold and A. Salthaug. 2012. Sounds from seismic air guns: Gear- and species-specific effects on catch rates and fish distribution. Can. J. Fish. Aquat. Sci. 69: 1278-1291.

Lormée, H., K. 2008. Office National de la Chasse et de la Faune Sauvage, internal report.

Lormée, H., K. Delord, B. Letournel, and C. Barbraud. 2012. Population survey of Leach's Storm-Petrels breeding at Grand Colombier Island, Saint-Pierre and Miquelon archipelago. Wilson J. of Ornithology 124(2): 245-252.

Lormée, H., C. Barbraud, et B. Letournel. 2015. Étude des populations d'oiseaux marins nicheurs sur l'Ile du Grand Colombier (Saint Pierre et Miquelon). Rapport interne.

Luís, A.R., M.N. Couchinho, and M.E. Dos Santos. 2014. Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. Mar. Mamm. Sci. 30(4): 1417-1426.

Lyamin, O.I., S.M. Korneva, V.V. Rozhnov, and L.M. Mukhametov. 2016. Cardiorespiratory responses to acoustic noise in belugas. p. 665-672 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Maillet, G.L., P. Pepin, and J.D.C. Craig. 2004. Assessing phytoplankton and zooplankton taxa from the CPR survey in NAFO Subareas 2 and 3 in the Northwest Atlantic. NAFO SCR Doc. 04/30.

Mannocci, L., J.J. Roberts, D.L. Miller, and P.N. Halpin. 2017. Extrapolating cetacean densities to quantitatively assess human impacts on populations in the high seas. Conserv. Biol. 31(3): 601-614.

Mansfield, K.L., J. Wyneken, W.P. Porter, and J. Luo. 2014. First satellite tracks of neonate sea turtles redefine the 'lost years' oceanic niche. Proc. R. Soc. B 281: 20133039. doi:10.1098/rspb.2013.3039.

Matos, F. 2015. Distribution of cetaceans in Vestfjorden, Norway, and possible impacts of seismic surveys. MSc. Thesis, University of Nordland, Norway. 45 p.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin University, Perth, WA, for Australian Petroleum Production Association, Sydney, NSW.

McCordic, J.A., S.K. Todd, and P.T. Stevick. 2014. Differential rates of killer whale attacks on humpback whales in the North Atlantic as determined by scarification. J. Mar. Biol. Assoc. U.K. 94(6): 1311-1315.

McFarlane Tranquilla, L.A., W.A. Montevecchi, D.A. Fifield, A. Hedd, A.J. Gaston, G.J. Robertson, and R.A. Phillips. 2014. Individual winter movement strategies in two species of Murre (*Uria* spp.) in the Northwest Atlantic. PLoS ONE 9(4): e90583. doi:10.1371/journal.

McKenna, M.F., J. Calambokidis, E.M. Oleson, D.W. Laist, J.A. Goldbogen. 2015. Simultaneous tracking of blue whales and large ships demonstrate limited behavioral responses for avoiding collision. Endang. Species. Res. 27: 219-232.

Miles, W., S. Money, R. Luxmoore, and R.W. Furness. 2010. Effects of artificial lights and moonlight on petrels at St. Kilda. Bird Study 57: 244-251.

Montevecchi, W.A. 2006. Influences of artificial light on marine birds. Chapter 5. *In:* C. Rich, and T. Longcore (eds.). Ecological Consequences of Artificial Night Lighting. Island Press, Washington, DC. 478 p.

Montevecchi, W.A., F.K. Wiese, G. Davoren, A.W. Diamond, F. Huettmann, and J. Linke. 1999. Seabird attraction to offshore platforms and seabird monitoring from support vessels and other ships: Literature review and monitoring designs. Prepared for Canadian Association of Petroleum Producers by Memorial Univ. Newfoundland, St. John's, NL, and Univ. New Brunswick, St. John's, NL. 35 p.

Morandin, L.A. and P.D. O'Hara. 2016. Offshore oil and gas, and operational sheen occurrence: Is there potential harm to marine birds? Environmental Reviews 24: 285-318.

Moulton, V.D. and B.D. Mactavish. 2004. Recommended seabird and marine mammal observational protocols for Atlantic Canada. ESRF Rep. No. 156. Rep. by LGL Ltd., St. John's, NL, for Environmental Studies Research Funds, Calgary, AB.

Moulton, V.D., B.D. Mactavish, and R.A. Buchanan. 2005. Marine mammal and seabird monitoring of Chevron Canada Resources' 3D seismic program on the Orphan Basin, 2004. LGL Rep. SA817. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Resources, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB. 90 p. + appendices.

Moulton, V.D., B.D. Mactavish, and R.A. Buchanan. 2006a. Marine mammal and seabird monitoring of Chevron Canada Limited's 3D seismic program on the Orphan Basin, 2005. LGL Rep. SA843. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, Shell Canada Limited, Calgary, AB, and Imperial Oil Resources Ventures Ltd., Calgary, AB. 111 p. + appendices.

Moulton, V.D., B.D. Mactavish, and R.A. Buchanan. 2006b. Marine mammal and seabird monitoring of ConocoPhillips' 3D seismic program, Laurentian Sub-basin, 2005. LGL Rep. SA849. Rep. by LGL Limited, St. John's, NL, for ConocoPhillips Canada Resources Corporation, Calgary, AB. 97 p. + appendices.

MPAtlas. n.d. Milne Seamount Complex MPA. Marine Conservation Institute. Available at http://www.mpatlas.org/mpa/sites/5498/.

Muir, J.E., L. Ainsworth, R. Joy, R. Racca, Y. Bychkov, G. Gailey, V. Vladimirov, S. Starodymov, and K. Bröker. 2015. Distance from shore as an indicator of disturbance of gray whales during a seismic survey off Sakhalin Island, Russia. Endang. Species Res. 29(2): 161-178.

Muir, J.E., L. Ainsworth, R. Racca, Y. Bychkov, G. Gailey, V. Vladimirov, S. Starodymov, and K. Bröker. 2016. Gray whale densities during a seismic survey off Sakhalin Island, Russia. Endang. Species Res. 29(3): 211-227.

Murillo, F.J., P.D. Muñoz, A. Altuna, and A. Serrano. 2011. Distribution of deep-water corals of the Flemish Cap, Flemish Pass, and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): Interaction with fishing activities. ICES J. Mar. Sci. 68(2): 319-332.

Murillo, F.J., A. Serrano, E. Kenchington, and J. Mora. 2016. Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. Deep Sea Res. I. 109: 99-122.

Nachtigall, P.E. and A.Y. Supin. 2014. Conditioned hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). J. Exp. Biol. 217(15): 2806-2813.

Nachtigall, P.E. and A.Y. Supin. 2015. Conditioned frequency-dependent hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). J. Exp. Biol. 218(7): 999-1005.

NAFO. 2017a. Conservation and enforcement measures 2017. FC Doc. 17-01. Serial No. N6638. Available at https://www.nafo.int/Fisheries/Conservation. 188 p.

NAFO. 2017b. Stock advice. Available at https://www.nafo.int/Science/Stocks-Advice.

NAFO. 2017c. NAFO conservation and enforcement measures – Quota tables (Annex I). Available at https://www.nafo.int/Fisheries/Conservation.

NAFO. 2017d. NAFO geographic information. Available at https://www.nafo.int/Data/GIS.

Nelms, S.E., W.E.D. Piniak, C.R. Weir, and B.J. Godley. 2016. Seismic surveys and marine turtles: An underestimated global threat? Biol. Conserv. 193: 49-65.

Nesis, K.I. 1965. Biocoenoses and biomass of benthos of the Newfoundland - Labrador Region. (In Russian). Fisheries Research Board of Canada Translation Series, 1375.

Nevitt, G. A. 1999. Olfactory foraging in Antarctic seabirds: a species-specific attraction to krill odors. Mar. Ecol. Prog. Ser. 177: 235-241.

Nevitt, G. A., and K. Haberman. 2003. Behavioral attraction of Leach's storm-petrels (*Oceanodroma leucorhoa*) to dimethyl sulfide. Journal of Experimental Biology 206: 1497-1501.

NMFS (National Marine Fisheries Service). 1995. Small takes of marine mammals incidental to specified activities; offshore seismic activities in southern California. Fed. Regist. 60(200, 17 Oct.): 53753-53760.

NMFS. 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. Fed. Regist. 65(60, 28 Mar.): 16374-16379.

NMFS. 2016. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic thresholds for onset of permanent and temporary threshold shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55. 178 p.

NOAA (National Oceanic & Atmospheric Administration). 2018. Cetacean & Sound Mapping. Cetacean Data Availability. Accessed January 2018 at http://cetsound.noaa.gov/cda.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Rev. 37(2): 81-115.

Nowacek, D.P., K. Bröker, G. Donovan, G. Gailey, R. Racca, R.R. Reeves, A.I. Vedenev, D.W. Weller, and B.L. Southall. 2013. Responsible practices for minimizing and monitoring environmental impacts of marine seismic surveys with an emphasis on marine mammals. Aquat. Mamm. 39(4): 356-377.

Nowacek, D.P., C.W. Clark, P. Mann, P.J.O. Miller, H.C. Rosenbaum, J.S. Golden, M. Jasny, J. Kraska, and B.L. Southall. 2015. Marine seismic surveys and ocean noise: Time for coordinated and prudent planning. Front. Ecol. Environ. 13(7): 378-386. http://dx.doi.org/10.1890/130286.

NSIDC. 1995, updated annually. International ice patrol (iip) iceberg sightings data base. Boulder, Colorado USA: National Snow and Ice Data Center/World Data Center for Glaciology. Digital media.

O'Brien, J.M., S. Beck, S.D. Berrow, M. Andre, M. vand er Schaar, I. O'Connor, and E.P. McKeown. 2016. The use of deep water berths and the effects of noise on bottlenose dolphins in the Shannon Estuary cSAC. p. 775-783 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

O'Brien, K. and H. Whitehead. 2013. Population analysis of endangered northern bottlenose whales on the Scotian Shelf seven years after the establishment of a marine protected area. Endang. Spec. Res. 21(3): 273-284.

Oceans (Limited). 2014. Physical environmental study for the southern Grand Banks seismic program 2014-2018. Rep. by Oceans Limited, St. John's, NL, for LGL Limited, St. John's, NL. 135 p. + appendices.

OCEARCH website. Global shark tracker. Accessed 8 November 2016 at http://www.ocearch.org/tracker/.

Olsen, E., W.P. Budgell, E. Head, L. Kleivane, L. Nøttestad, R. Prieto, M.A. Silva, H. Skov, G.A. Vikíngsoon, G. Waring, and N. Øien. 2009. First satellite-tracked long-distance movement of a sei whale (*Balaenoptera borealis*) in the North Atlantic. Aquat. Mammals 35(3): 313-318.

One Ocean (Corporation). 2013. One Ocean Protocol for Seismic Survey Programs in Newfoundland and Labrador. One Ocean Corporation. 23 p.

Orr, D.C. and D.J. Sullivan. 2014. The 2014 assessment of the northern shrimp (*Pandalus borealis*, Kroyer) resource in NAFO Divisions 3LNO. NAFO SCR Doc. 14/048.

OSPAR (Oil Spill Prevention, Administration and Response) (Commission). 2010. OSPAR decision 2010/1 on the establishment of the Milne Seamount Complex marine protected area. OSPAR 10/23/1-E, Annex 34. 3 p. Available at www.ospar.org/documents?d=32821.

OSPAR. 2015. 2014 status report on the OSPAR network of marine protected areas. 41 p. + annexes. Available at www.ospar.org/documents?d=33572.

OSPAR. 2016. Milne Seamount Complex MPA – Marine protected area (OSPAR). Available at http://mpa.ospar.org/home_ospar/mpa_datasheets/an_mpa_datasheet_en?wdpaid=555512239&gid=186&lg=0.

Papale, E., M. Gamba, M. Perez-Gil, V.M. Martin, and C. Giacoma. 2015. Dolphins adjust species-specific frequency parameters to compensate for increasing background noise. PLoS ONE 10(4): e0121711. http://dx.doi.org/10.1371/journal.pone.0121711.

Parks, S.E., K. Groch, P. Flores, R. Sousa-Lima, and I.R. Urazghildiiev. 2016a. Humans, fish, and whales: How right whales modify calling behavior in response to shifting background noise conditions. p. 809-813 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Parks, S.E., D.A. Cusano, A. Bocconcelli, and A.S. Friedlaender. 2016b. Noise impacts on social sound production by foraging humpback whales. Abstr. 4th Int. Conf. Effects of Noise on Aquatic Life, July 2016, Dublin, Ireland.

Payne, J.F., A. Mathieu, and T.K. Collier. 2003. Ecotoxicological studies focusing on marine and freshwater fish. p. 191-224 *In:* P.E.T. Douben (ed.). PAHs: An Ecotoxicological Perspective. John Wiley and Sons, London.

Pearson, W.H., J.R. Skalski, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on behavior of captive rockfish (*Sebastes* spp.). Can. J. Fish. Aquat. Sci. 49(7): 1343-1356.

Peng, C., X. Zhao, and G. Liu. 2015. Noise in the sea and its impacts on marine organisms. Intern. J. Environm. Res. Public Health 12(10): 12304-12323.

Pepin, P., E. Colbourne, and G. Maillet. 2011. Seasonal patterns in zooplankton community structure on the Newfoundland and Labrador Shelf. Prog. Ocean. 91: 273-285.

Pepin, P., G. Maillet, S. Fraser, T. Shears, and G. Redmond. 2015. Optical, chemical, and biological oceanographic conditions on the Newfoundland and Labrador Shelf during 2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/027. v + 37p.

Pettis, H.M. and P.K. Hamilton. 2016. North Atlantic Right Whale Consortium annual report card. Report to the North Atlantic Right Whale Consortium, November 2016. 14 p.

Pollet, I.L., R.A. Ronconi, I.D. Jonsen, M.L. Leonard, P.D. Taylor, and D. Shutler. 2014a. Foraging movements of Leach's storm-petrels *Oceanodroma leucorhoa* during incubation. J. Avian Biol. 45: 001-010, 2014.

Pollet, I.L. 2014b. Migratory movements and wintering areas of Leach's Storm-petrels tracked using geolocators. J. Field Ornithol. 85(3): 321-328.

Poot, H., B.J. Ens, H. de Vries, M.A.H. Donners, M.R. Wernand, and J.M. Marquenie. 2008. Green light for nocturnally migrating birds. Ecol. Soc. 113: 47.

Popov, V.V., D.I. Nechaev, E.V. Sysueva, V.V. Rozhnov, and A.Y. Supin. 2015. Spectrum pattern resolution after noise exposure in a beluga whale, *Delphinapterus leucas*: Evoked potential study. J. Acoust. Soc. Am. 138(1): 377-388.

Popov, V.V., E.V. Sysueva, D.I. Nechaev, V.V. Rozhnov, and A.Y. Supin. 2017. Influence of fatiguing noise on auditory evoked responses to stimuli of various levels in a beluga whale, *Delphinapterus leucas*. J. Exp. Biol. Doi:10.1242/jeb.149294.

Popper, A.N., M. Salmon, and K.W. Horch. 2001. Acoustic detection and communication by decapod crustaceans. J. Comp. Physiol. A 187:83-89.

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, M.B. Halvorsen, S. Løkkeborg, P.H. Rogers, B.L. Southall, D.G. Zeddies, and W.N. Tavolga. 2014. Sound exposure guidelines for fishes and sea turtles: a technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. ASA Sc/SC1.4 TR=2014.

Prena, J., P. Schwinghamer, T. Rowell, D. Gordon, K. Gilkinson, W.P. Vass, and D.L. McKeown. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: Analysis of trawl bycatch and effects on epifauna. Mar. Ecol. Prog. Ser. 181: 107-124.

Prieto, R., M.A. Silva, I. Cascão, M.J. Cruz, C.I.B. Oliveira, G. Waring, and J. Gonçalves. 2010. The importance of oceanic fronts in the Labrador Sea to North Atlantic sei whales (*Balaenoptera borealis*). Clues from satellite telemetry. Proc. Arctic Frontiers Conf., Trømso, Norway, 24-29 January 2010.

Prieto, R., M.A. Silva, G.T. Waring, and J.M.A. Gonçalves. 2014. Sei whale movements and behaviour in the North Atlantic inferred from satellite telemetry. Endang. Spec. Res. 26(2): 103-113.

Reed, J.R., J.L. Sincock, and J.P. Hailman. 1985. Light attraction in endangered Procellariiform birds: Reduction by shielding upward radiation. Auk 102: 377-383.

Reichmuth, C., A. Ghoul, J.M. Sills, A. Rouse, and B.L. Southall. 2016. Low-frequency temporary threshold shift not observed in spotted or ringed seals exposed to single air gun impulses. J. Acoust. Soc. Am. 140(4): 2646-2658.

Rice, S.D. 1985. Effects of Oil on Fish. p. 157-182 *In:* F.R. Engelhardt (ed.). Petroleum Effects in the Arctic Environment. Elsevier Science Publishing Co., NY.

Rice, S.D., M.M. Babcock, C.C. Brodersen, M.G. Carls, J.A. Gharrett , S. Korn, A. Moles, and J.W. Short. 1986. Lethal and sub-lethal effects of the water-soluble fraction of Cook Inlet Crude on Pacific herring (*Clupea harengus pallasi*) reproduction. Final Report. Outer Continental Shelf Environmental Assessment Program, NOAA.

Richardson, W.J., C.R.J. Greene, C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Robertson, G.J. and R.D. Elliot. 2002. Changes in seabird populations breeding on Small Island, Wadham Islands, Newfoundland. CWS Technical Report Series No. 381. Atlantic Region. iii + 26 pp.

Robertson, F.C., W.R. Koski, T.A. Thomas, W.J. Richardson, B. Würsig, and A.W. Trites. 2013. Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea. ESR 21(2): 143-160.

Roddick, D. 2013. Precautionary approach reference points for Arctic surfclams (*Mactromeris polynyma*). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/007. v + 11 p.

Roddick, D., J. Brading, L. Carrigan, T. Davignon-Burton, S. Graham, and C. McEwen. 2011. Assessment of the Arctic surfclam (*Mactromeris polynyma*) stock on Grand Bank. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/052. v + 55 p.

Rodríguez, A. and B. Rodríguez. 2009. Attraction of petrels to artificial lights in the Canary Islands: Effects of the moon phase and age class. Ibis 151: 299-310.

Ronconi, R. A., K. A. Allard, and P. D. Taylor. 2015. Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. Journal of Environmental Management 147: 34-45.

Rose, G.A. and S. Rowe. 2015. Northern cod comeback. Can. J. Fish. Aquat. Sci. 72: 1789-1798.

Russell, J. 2008. Population estimate for the colony of Leach's Storm-Petrels (*Oceanodroma leucorhoa*) breeding on Green Island, Fortune Bay, southeastern Newfoundland in 2008. Department of Fisheries and Oceans internal report.

Ryan, C., O. Boisseau, A. Cucknell, M. Romagosa, A. Moscrop, and R. McLanaghan. 2013. Final report for trans-Atlantic research passages between the UK and USA via the Azores and Iceland, conducted from R/V *Song of the Whale* 26 March to 28 September 2012. Final report for trans-Atlantic research passages conducted from R/V Song of the Whale, summer 2012. Prepared by Marine Conservation Research International, Essex, UK for the International Fund for Animal Welfare. 20 p.

Saetre, R. and E. Ona. 1996. Seismiske undersøkelser og skader på fiskeegg og -larver en vurdering av mulige effekter pa bestandsniv. [Seismic investigations and damages on fish eggs and larvae; an evaluation of possible effects on stock level] Fisken og Havet 1996:1-17, 1-8. (in Norwegian with English summary).

Sairanen, E.E. 2014. Weather and ship induced sounds and the effect of shipping on harbor porpoise (*Phocoena phocoena*) activity. M.Sc. Thesis, University of Helsinki. 67 p.

SARA (Species at Risk Act) website. 2018. Species at risk public registry. DFO, Government of Canada. Available at http://www.sararegistry.gc.ca/search/SpeciesSearch_e.cfm.

Schneider, D.C., J.M. Gagnon, and K.D. Gilkinson. 1987. Patchiness of epibenthic megafauna on the outer Grand Banks of Newfoundland. Marine Ecology Progress Series. 39: 1-13.

Schwacke, L.H., C.R. Smith, F.I. Townsend, R.S. Wells, L.B. Hart, B.C. Balmer, T.K. Collier, S. De Guise, M.M. Fry, L.J. Guillette, Jr., S.V. Lamb, S.M. Lane, W.E. McFee, N.J. Place, M.C. Tumlin, G.M. Ylitalo,E.S. Zolman, and T.K. Rowles. 2014. Health of common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. Environm. Sci. Tech. 48(1): 93-103.

Sidorovskaia, N., B. Ma, A.S. Ackleh, C. Tiemann, G.E. Ioup, and J.W. Ioup. 2014. Acoustic studies of the effects of environmental stresses on marine mammals in large ocean basins. p. 1155 *In:* AGU Fall Meeting Abstracts, Vol. 1. Accessed in November 2016 at https://agu.confex.com/agu/fm14/meetingapp.cgi#Paper/.

Sidorovskaia, N.A., A.S. Ackleh, C.O. Tiemann, B. Ma, J.W. Ioup, and G.E. Ioup. 2016. Passive acoustic monitoring of the environmental impact of oil exploration on marine mammals in the Gulf of Mexico. p. 1007-1014 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Sierra-Flores, R., T. Atack, H. Migaud and A. Davie. 2015. Stress response to anthropogenic noise in Atlantic cod *Gadus morhua* L. Aquacultural Engineering 67: 67-76.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R.J. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquat. Mamm. 33: 411-522.

Spencer, N.C., H.G. Gilchrist, H. Strøm, K.A. Allard, and M.L. Mallory. 2016. Key winter habitat of the ivory gull *Pagophila eburnea* in the Canadian Arctic. Endangered Species Research 31: 33-45.

Stenson, G.B. and M.O. Hammill. 2014. Can ice breeding seals adapt to habitat loss in a time of climate change? ICES J. Mar. Sci. 71(7): 1977-1986.

Stewart, K.R., M.C. James, S. Roden, and P.H. Dutton. 2013. Assignment tests, telemetry and tag-recapture data converge to identify natal origins of leatherback turtles foraging in Atlantic Canadian waters. J. Animal Ecol. 82: 791-803.

Stone, C.J. 2015. Marine mammal observations during seismic surveys from 1994-2010. JNCC report, No. 463a. 64 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. J. Cetac. Res. Manage. 8(3): 255-263.

Supin, A., V. Popov, D. Nechaev, E.V. Sysueva, and V. Rozhnov. 2016. Is sound exposure level a convenient metric to characterize fatiguing sounds? A study in beluga whales. p. 1123-1129 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Teilmann, J., D.M. Wisniewska, M. Johnson, L.A. Miller, U. Siebert, R. Dietz, S. Sveegaard, A. Galatius, and P.T. Madsen. 2015. Acoustic tags on wild harbour porpoises reveal context-specific reactions to ship noise. *In:* 18. Danske Havforskermøde.

Telfer, T.C., J.L. Sincock, G.V. Byrd, and J.R. Reed. 1987. Attraction of Hawaiian seabirds to lights: Conservation efforts and effects of moon phase. Wildl. Soc. Bull. 15: 406-413.

Terhune, J.M. and T. Bosker. 2016. Harp seals do not increase their call frequencies when it gets noisier. p. 1149-1153 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Theriault, J.A. and H.B. Moors-Murphy. 2015. Species at Risk criteria and seismic survey noise thresholds for cetaceans. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/078. v + 42 p.

Thomas, P.W., L.A. McFarlane Tranquilla, B.E. Toms, A.W. Boyne, G.J. Robertson, P.M. Regular, and S.I. Wilhelm. 2014a. Second census of terns, gulls, kittiwakes and cormorants along the coast of insular Newfoundland, 2005-2007. CWS Technical Report Series Number 531.

Thomas, T.A., M. Fitzgerald, and A.L. Lang. 2014b. Marine mammal, sea turtle, and seabird monitoring and mitigation for Statoil's Bay du Nord 3D seismic program, 2014b. LGL Limited Report FA0010. Report by LGL Limited, St. John's, NL for Statoil Canada Limited, St. John's, NL. 73 p. + appendices.

Thompson, P.M., K.L. Brookes, I.M. Graham, T.R. Barton, K. Needham, G. Bradbury, and N.D. Merchant. 2013. Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. Proc. Royal Soc. B 280: 20132001. http://dx.doi.org/10.1098/.2013.2001.

Toews, M.W. and D.J.W. Piper. 2002. Recurrence interval of seismically triggered mass-transport deposition at Orphan Knoll, continental margin off Newfoundland and Labrador. Natural Resources Canada, Geological Survey of Canada Current Research, 2002-17. 8 p.

Tougaard, J., A.J. Wright, and P.T. Madsen. 2016. Noise exposure criteria for harbor porpoises. p. 1167-1173 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Vander Zanden, H.B., A.B. Bolten, A.D. Tucker, K.M. Hart, M.M. Lamont, I. Fujisaki, K.J. Reich, D.S. Addison, K.L. Mansfield, K.F. Phillips, M. Pajuelo, and K.A. Bjorndal. 2016. Biomarkers reveal sea turtles remained in oiled areas following the Deepwater Horizon oil spill. Ecol. Appl. 26(7): 2145-2155.

Varo-Cruz, N., J.A. Bermejo, P. Calabuig, D. Cejudo, B.J. Godley, L.F. López-Jurado, S.K. Pikesley, M.J. Witt, and L.A. Hawkes. 2016. New findings about the spatial and temporal use of the Eastern Atlantic Ocean by large juvenile loggerhead turtles. Diversity and Distribution 2016: 1-12. doi:10.1111/ddi.12413.

Venn-Watson S, K.M. Colegrove, J. Litz, M. Kinsel, K. Terio, J. Saliki, S. Fire, R. Carmichael, C. Chevis, W. Hatchett, J. Pitchford, M. Tumlin, C. Field, S. Smith, R. Ewing, D. Fauquier, G. Lovewell, H. Whitehead, D. Rotstein, W. McFee, E. Fougeres, and T. Rowles. 2015. Adrenal gland and lung lesions in Gulf of Mexico common bottlenose dolphins (*Tursiops truncatus*) found dead following the Deepwater Horizon oil spill. PloS ONE 10(5): e0126538. doi:10.1371/journal.pone.0126538.

Vilela, R., U. Pena, R. Esteban, and RW. Koemans. 2016. Bayesian spatial modeling of cetacean sightings during a seismic acquisition survey. Mar. Poll. Bull. 109: 512-520.

Wareham, V.E. 2009. Updates on deep-sea coral distributions in the Newfoundland and Labrador and Arctic Regions, Northwest Atlantic. p. 4-22 *In:* K. Gilkinson and E. Edinger (eds.). The ecology of deep-sea corals of Newfoundland and Labrador waters: Biogeography, life history, biogeochemistry, and relation to fishes. Can. Tech. Rep. Fish. Aquat. Sci. 2830: vi + 136 p.

Wareham, V.E. and E.N. Edinger. 2007. Distribution of deep-sea coral in the Newfoundland and Labrador Region, Northwest Atlantic Ocean. Bull. Mar. Sci. 81(Suppl. 1): 289-313.

Waring, G.T., R.A. DiGiovanni Jr., E. Josephson, S. Wood, and J.R. Gilbert. 2015. 2012 population estimate for the harbor seal (*Phoca vitulina concolor*) in New England waters. NOAA Tech. Memo. NMFS NE-235. 15 p.

Whitehead, H. 2013. Trends in cetacean abundance in the Gully submarine canyon, 1988–2011, highlight a 21% per year increase in Sowerby's beaked whales (*Mesoplodon bidens*). Can. J. Zool. 91(3): 141-148.

Wiese, F.K. and W.A. Montevecchi. 1999. Marine bird and mammal surveys on the Newfoundland Grand Bank from offshore supply vessels. Contract Report Prepared for Husky Oil. 23 p. + appendices.

Wiley, D.N., C.A. Mayo, E.M. Maloney, and M.J. Moore. 2016. Vessel strike mitigation lessons from direct observations involving two collisions between non-commercial vessels and North Atlantic right whales (*Eubaleana glacialis*). Mar. Mamm. Sci. 32(4): 1501-1509.

Wilhelm, S.I., J. Mailhiot, J. Arany, J.W. Chardine, G.J. Robertson, and P.C. Ryan. 2015. Update and trends of three important seabird populations in the western North Atlantic using a geographic information system approach. Marine Ornithology 43: 211–222.

Williams, U. and J. Chardine. n.d. The Leach's Storm-Petrel: General information and handling instructions. 4 p.

Wittekind, D., J. Tougaard, P. Stilz, M. Dähne, K. Lucke, C.W. Clark, S. von Benda-Beckmann, M. Ainslie, and U. Siebert. 2016. Development of a model to assess masking potential for marine mammals by the use of airguns in Antarctic waters. p. 1243-1249 *In:* A.N. Popper and A. Hawkins (eds.). The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Personal Communication

Feyrer, L.J., Ph.D. Candidate, Dalhousie University. 5 February 2018.

Lawson, J., DFO, Research Scientist. January 2017.

Mercier, F., Parks Canada, A/Manager, Marine Establishement, Protected Areas Establishment Branch, 21 February 2018.

Montevecchi, W.A., Memorial University of Newfoundland. 2016.

Moors-Murphy, H., DFO, Biologist. 18 December 2015.

Morrow, G., Senior Contract Manager, PGS, June 2017.

Paddy, N., PGS, Contract Manager. 11 February 2017.

Power, D., DFO, NAFO Senior Science Advisor/Coordinator, Science Branch. 31 January 2018.

Appendix 1

Consultation Report

St. John's

As part of the environmental assessment of Multiklient Invest's (MKI) proposed 2018–2023 seismic program, consultations were undertaken with relevant government agencies, representatives of the fishing industry and other interest groups based in St. John's. The objectives of these consultations were to describe the proposed seismic program, identify any issues and concerns, and gather additional information relevant to the EA process.

Relevant agencies, municipal governments and industry stakeholder groups contacted by MKI in January 2017 are listed below.

- Environment and Climate Change Canada (ECCC);
- Nature Newfoundland and Labrador (NNL);
- One Ocean;
- Fish, Food and Allied Workers Union (FFAW)/Unifor;
- Association of Seafood Producers (ASP);
- Ocean Choice International (OCI);
- Groundfish Enterprise Allocation Council (GEAC) Ottawa;
- Canadian Association of Prawn Producers;
- Clearwater Seafoods;
- Icewater Seafoods; and
- Newfound Resources Ltd. (NRL).

The face-to-face consultations held in St. John's during 31 January-2 February 2017 were organized and coordinated by MKI. Those that requested face-to-face meetings are indicated below. Topics raised at each meeting after the MKI presentation are bulleted below.

Environment Canada (31 January 2017)

- Source array ramp up protocol was explained;
- MARPOL reporting was clarified;
- After-dark lighting on Project vessels was described; and
- Provided details on a typical acquisition season and how weather affects operations.

FFAW/Unifor (31 January 2017)

- Discussion about the post-season snow crab survey, particularly regarding the addition of sampling stations.

Newfound Resources Ltd. (2 February 2017)

- Shrimp harvesting season is complete by the time of onset of seismic activity.

One Ocean (2 February 2017)

- No details from the meeting.

Nature Newfoundland and Labrador (2 February 2017)

- Question about minimizing the level of light being emitted during seismic operation – MKI indicated that lighting on the outside of the seismic vessel is limited to navigation lights and lights in the back deck work areas;
- Question about the effectiveness of source ramp-up to motivate marine mammals to move away from the sound source – MKI indicated that data collected thus far indicates that marine mammals are observed farther from the sound source when it is active than when it is inactive; and
- Request that MKI make metadata collected during seismic operations available for metocean research – MKI indicated that it would look into what archived metadata are available for release.

MKI intends to provide more details about its 2017 activities to all consultees once they are finalized in March 2017.

Agency/Stakeholder Individuals Involved in the St. John's Consultations

The following agencies, managers and fishing industry participants in St. John's were consulted during the preparation of MKI's Environmental Assessment.

<u>Environment Canada</u>

Glenn Troke

<u>Nature Newfoundland and Labrador</u>

Len Zedel

<u>One Ocean</u>

Maureen Murphy-Rustad, Director

FFAW/Unifor

Dwan Street, Petroleum Industry Liaison
Johan Joensen, Industry Liaison

Association of Seafood Producers

Derek Butler, Executive Director

Ocean Choice International

Rick Ellis, Director of Operations

Groundfish Enterprise Allocation Council

Kris Vascotto, Executive Director

Canadian Association of Prawn Producers

Bruce Chapman, Executive Director

Clearwater Seafoods

Catherine Boyd, Acting Director/Sustainability and Public Affairs

Icewater Seafoods Inc.

Alberto Wareham, President

Newfound Resources Ltd.

Joel Hickey, Operations Manager