Environmental Assessment of WesternGeco's Eastern Newfoundland Offshore Seismic Program, 2015-2024

Prepared by

LGL LIMITED
environmental research associates

For

WesternGeco
(Division of Schlumberger Canada Limited)

May 2015
LGL Project No. FA0035

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1.0 Introduction

This document is an Environmental Assessment (EA) of WesternGeco Canada's (WesternGeco) proposed 2015-2024 2-Dimensional (2D), 3-Dimensional (3D), and/or 4-Dimensional (4D) marine seismic program in the Eastern Newfoundland Offshore area. The EA is intended to enable the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) to fulfill its responsibilities under Section 138 (1)(b) of the *Canada-Newfoundland Atlantic Accord Implementation Act* and Section 134(1)(b) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (Accord Acts). This EA has been guided by the Final Scoping Document (C-NLOPB 2015), as well as by advice and information received, and issues identified through various communications and consultations with other agencies, interest groups, stakeholders and beneficiaries.

The temporal scope of the Project is a 10-year period (2015-2024) with seismic operations potentially occurring between May and November in any given year. The Project Area identified in Figure 1.1 includes portions of the Northern Grand Banks and the Northeast Slope of Newfoundland, as well as the Flemish Pass, the Flemish Cap and Orphan Basin. WesternGeco will be the Operator and may conduct 2D, 3D, and/or 4D seismic surveys in one or more years within the 2015-2024 timeframe.

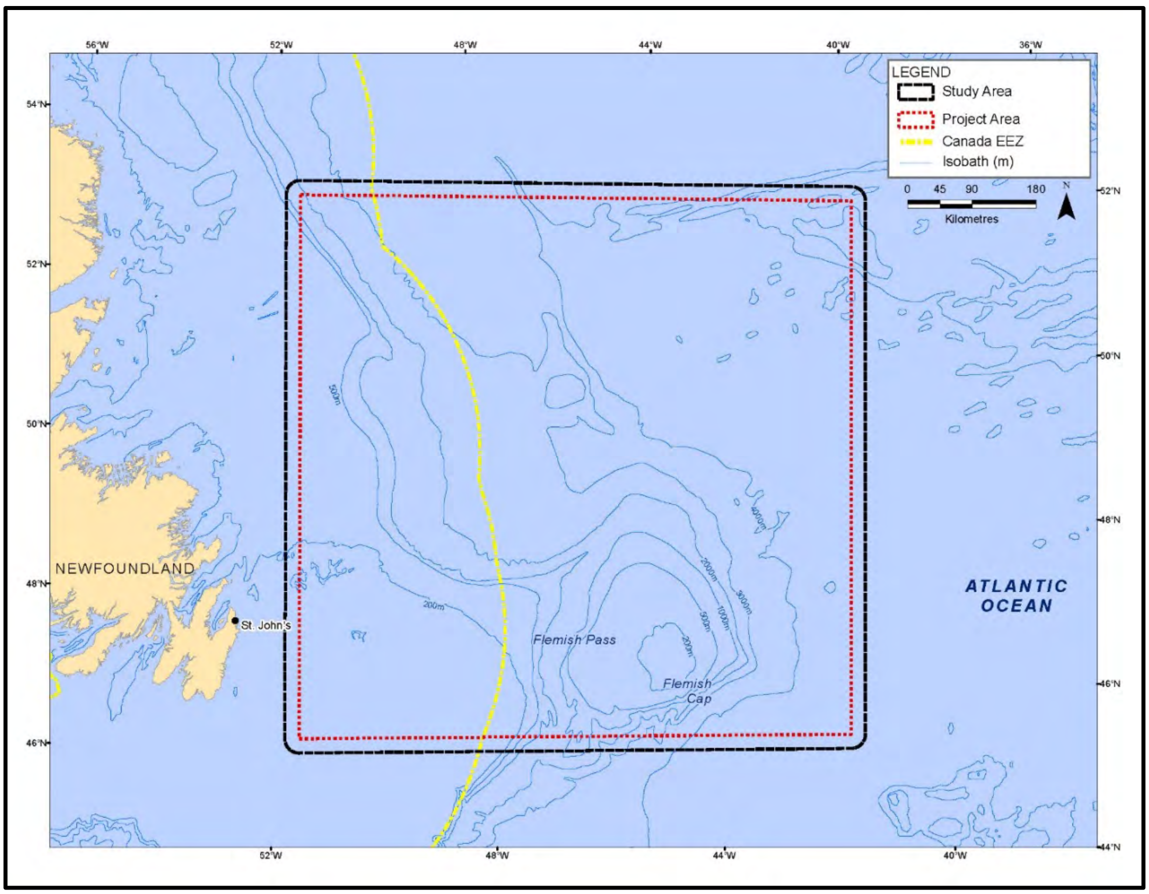

Figure 1.1 Locations of the Project Area and Study Area for WesternGeco's Proposed Eastern Newfoundland Offshore Seismic Program, 2015–2024.

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 seabirds, marine mammals, sea turtles, and fish and fisheries, Fisheries and Oceans Canada (DFO) and Environment Canada (EC) are the agencies that have most involvement in the EA process. Legislation that is relevant to the environmental aspects of the Project includes:

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

WesternGeco will follow guidelines issued by the C-NLOPB, the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012), which include DFO's *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*. The Project will also follow other relevant advice received during the consultations for this Project.

1.2 The Operator

WesternGeco, the world's largest seismic company, provides advanced acquisition and data processing services. WesternGeco's parent company, Schlumberger, employs approximately 120,000 people, representing over 140 nationalities, working in more than 85 countries. WesternGeco Canada has offices in Calgary, Alberta and Halifax, Nova Scotia, as well as a Project Office in St. John's, Newfoundland and Labrador. WesternGeco Canada employs 60 permanent, full time Canadians in its regional offices, and many more on its vessels.

1.3 Canada-Newfoundland and Labrador Benefits

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

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

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2.0 Project Description

The official name of the Project is the Eastern Newfoundland Offshore Seismic Program, 2015-2024. WesternGeco is proposing to conduct one or more 2D, 3D, and/or 4D seismic surveys within its proposed Project Area (see Figure 1.1) between 2015 and 2024, starting as early as July 2015. The timing of the surveys is subject to WesternGeco priorities and circumstances, weather conditions, contractor availability and regulatory approvals.

2.1 Spatial and Temporal Boundaries

The proposed Project Area includes space to account for ship turning and streamer deployment (see Figure 1.1). The areas of the Study and Project areas are 643,553 km^2 and 581,299 km^2, respectively. More than half of the Study and Project area is located outside of Canada's Exclusive Economic Zone (EEZ) (200 nm limit). Water depth within the Project Area ranges from <100 m to > 4,000 m.

The "corner" coordinates (decimal degrees, WGS84 projection) of the extents of the Project Area are as follows:

- Northwest: 53.008°N, 51.560°W;
- Northeast: 52.436°N, 40.206°W;
- Southeast: 45.828°N, 41.566°W; and
- Southwest: 46.160°N, 51.514°W.

The temporal boundaries of the proposed Project Area are between 1 May and 30 November, from 2015-2024. The maximum duration of a seismic survey in any given year is 210 days. In 2015, the seismic survey is anticipated to require 120 to 150 days.

2.2 Project Overview

The proposed Project is a ship-borne geophysical program. There is a slight possibility that WesternGeco may conduct some 2D seismic surveying in the Project Area in 2015. If so, operations would be conducted in the southern portion of the Project Area in the vicinity of the Flemish Pass. Data acquisition plans for 2D, 3D, and/or 4D surveys during 2016-2024 are not yet determined.

For the potential 2D surveying in 2015, the seismic survey vessel would most likely be the MV *WG Tasman* (see Section 2.2.6 for more details) or a similar vessel. The seismic survey vessel(s) used during subsequent 2D/3D/4D surveys are unknown at present 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 below.

The C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2012) will be used as the basis for the marine mammal monitoring and mitigation program for the seismic surveys. Dedicated Marine Mammal Observers (MMOs) will monitor for marine mammals and sea turtles and implement mitigation measures as appropriate. 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 an Endangered or Threatened (as listed on Schedule 1 of *SARA*) marine mammal or sea turtle is detected within the safety zone. These measures are designed to minimize disturbance to marine life, particularly marine mammals and species considered at risk under the *SARA*. In addition, the MMOs will conduct a monitoring and release program for seabirds which may strand on board Project vessels. A Fisheries Liaison Officer (FLO) provided by the Fish, Food and Allied Workers (FFAW) 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 quality 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 Phases

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

1. Phase 1 may include a 2D survey in 2015 in the Project Area; and
2. Phase 2 may include 2D, 3D and/or 4D seismic surveys in the Project Area, depending on the results of analyses of existing and acquired data.

2.2.3 Project Scheduling

The seismic surveys will be conducted between 1 May and 30 November of any given year from 2015-2024. The approximate duration of the proposed 2015 survey is 120 to 150 days.

2.2.4 Site Plans

In 2015, it is possible that WesternGeco will conduct some 2D seismic surveying in the southern part of the Project Area in the vicinity of the Flemish Pass.

2.2.5 Personnel

A typical seismic vessel can accommodate ~35-60 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 a FLO and MMOs on board. All project personnel will have all of the required certifications as specified by the relevant Canadian legislation and the C-NLOPB.

2.2.6 Seismic Vessel

If there is seismic surveying conducted in 2015, WesternGeco will likely use the MV *WG Tasman* or a similar vessel as the seismic vessel. The MV *WG Tasman* (Figure 2.1) was built in Dubai in 2010 and is registered in Cyprus. The vessel is 89.8 m long, 21 m wide and has a mean draft of 6.0 m. The vessel is equipped with six Wartsila engines and has a maximum cruising speed of 14.5 knots. It is also equipped with a helideck.

For seismic surveys in 2016-2024, vessel specifics will be provided once the vessel has been identified.

Figure 2.1 MV *WG Tasman.*

2.2.7 Seismic Energy Source Parameters

If a 2D survey is conducted in 2015, the survey sound source will consist of one or two airgun arrays, each 5,085 in^3 in total volume, which will operate at towed depths between 6 and 15 m. If two airgun arrays are used, they will not be operated simultaneously but in a “flip-flop” arrangement. The array will be operated with compressed air at pressures of 2,000 psi, producing an approximate peak-to-peak pressure value that is between 104 and 141 bar-m, depending on which source filter is used by WesternGeco.

Detailed specifications of the airgun array will be provided once the project design is completed and parameters are selected.

2.2.8 Seismic Streamers

If a 2D survey is conducted in 2015, the seismic survey vessel will tow a single solid streamer that is 8,000-12,000 m in length at a depth of 10-45 m. In subsequent 2D, 3D, and/or 4D seismic surveys (2016-2024), streamer equipment specifications will be provided when program design is complete. The solid streamers will be deployed at depths ranging from 10-45 m. As many as 16 streamers may be towed during a 3D or 4D seismic survey.

2.2.9 Logistics/Support

2.2.9.1 Vessels

Primary support and supply will be provided by a chartered vessel. During the possible 2015 2D seismic survey, it is anticipated that one local picket vessel will accompany the seismic vessel. The guard vessel will be used to scout ahead of the seismic vessel for fishing vessels and gear, as well as for hazards such as ice and floating debris.

2.2.9.2 Helicopters

The seismic vessel will be equipped with a helicopter deck. Helicopters are often used for crew changes and light re-supply. It is not known at this time whether helicopters or vessel-to-vessel transfers will be used for crew changes during seismic program(s) in 2016-2024. WesternGeco will not do port calls during the program.

2.2.9.3 Shore Base, Support and Staging

WesternGeco will have a shore representative based in St. John’s for the duration of seismic programs. No new shore base facilities will be established as part of the Project.

2.2.10 Waste Management

Waste management will be consistent with industry best practices in offshore Newfoundland and Labrador.

2.2.11 Air Emissions

Air emissions will be those associated with standard operations for marine vessels, including the seismic vessel and any potential picket and/or supply vessel.

2.2.12 Accidental Events

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

2.3 Mitigation and Monitoring

Project mitigations are detailed in this EA and 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 dedicated MMOs and FLOs, and a fisheries compensation program. In addition, the MMOs will conduct a monitoring (systematic seabird counts based on protocols issued by the Canadian Wildlife Service [CWS]) and release program for seabirds which may strand on board Project vessels.

2.4 Project Site Information

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

2.4.1 Environmental Features

The physical and biological environments of the general area have been described in the recently completed Eastern Newfoundland Strategic Environmental Assessment (SEA; C-NLOPB 2014) as well as in numerous EAs prepared during recent years (e.g., LGL 2013a,b, 2014a,b). A review of the physical and biological environments, based on the Eastern Newfoundland SEA, previous EAs and any available new information, are provided in Sections 3.0 and 4.0 of this EA, respectively.

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 Eastern Newfoundland SEA (C-NLOPB 2014) and recent EAs prepared for other seismic programs in the general area. The seismic surveys could be conducted in areas with water depth ranging from

<100 m to >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 to November) when NW Atlantic operating conditions are relatively good compared to the late fall/winter/early spring period, should lessen the risk of any 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 Eastern Newfoundland SEA (C-NLOPB 2014), previous EAs, and any new available information, is provided in Section 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 Section 4.0 on the basis of Valued Environmental Components (VECs) which include the following:

- 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 as well as accidental events (such as an 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, WesternGeco consulted with stakeholders with an interest in the Project. Those consulted and the results of those consultations are presented in Section 5.1.1 and Appendix 1.

In order to assist in scoping the effects assessment and mitigation plan, and to aid in addressing any issues of concern, WesternGeco consulted with the following stakeholders:

- Fisheries and Oceans Canada;
- Environment Canada;
- Nature Newfoundland and Labrador (NNL) (and various member organizations);
- One Ocean;
- Fish, Food and Allied Workers Union/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).

2.6 Effects of the Project on the Environment

The proposed Project will be well within the scope of other seismic programs routinely conducted offshore Newfoundland and elsewhere in eastern Canada, and is not expected to produce adverse significant environmental effects on the marine environment in or adjacent to the Project Area. Nonetheless, potential environmental effects are examined in detail with focus on the VECs listed above (Section 2.4.1.2) and the cumulative effects associated with other marine users.

2.7 Environmental Monitoring

MMOs will be on board the vessel(s) to monitor for and implement mitigation measures specific to marine mammals and sea turtles, and to collect opportunistic data on marine mammal behaviour and distribution with and without airguns operating. Information on marine-associated bird occurrence and distribution will also be collected during the seismic surveys.

3.0 Physical Environment

The Final Scoping Document (C-NLOPB 2015) required 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 recently described in the Eastern Newfoundland Strategic Environmental Assessment (SEA) (C-NLOPB 2014) and in EAs for Electromagnetic Geoservices' East Canada CSEM Survey (LGL 2014b), Suncor Energy's Eastern Newfoundland Seismic Program (LGL 2013c), and Husky Energy's White Rose Extension Project (Husky 2012). An overview of the physical environment of the Study Area is provided below, including updated information from recent EAs (LGL 2013c, 2014b).

3.1 Bathymetry and Geology

The bathymetry and geology of the Study Area is highly diverse. The following nine areas reflect the bathymetric and geological diversity within the Study Area.

1. Northern Grand Banks (< 200 m, average 75 m);
2. Jeanne d'Arc Basin (≤ 200 m);
3. Eastern portion of the northeast Newfoundland Shelf (200 to 300 m);
4. Northeast Newfoundland Shelf Slope and Flemish Cap Shelf (>200 to 2,000 m);
5. Flemish Pass (deep water in excess of 1,000 m confined between the Grand Banks and the Flemish Cap (~130 m));
6. Sackville Spur (≤ 1,000 m);
7. Orphan Basin proper (1,200 to 3,500 m);
8. Orphan Knoll (rising steeply from 3,000 to 1,800 m); and
9. Southwestern portion of the Labrador Basin (3,000 to 4,000 m).

The characterization of surficial sediment in the Study Area ranges from fine (mud and clay) to extremely coarse (boulders and bedrock). The Study Area contains several fault zones in the Flemish Pass area. The Flemish Pass is a saddle-shaped, mid-slope basin (>1,000 m) bounded on the west by the Grand Banks and on the east by the Flemish Cap. Considerable geological data have been collected for the Flemish Pass by the Geological Survey of Canada (GSC) whose work has included over 70 sediment samples in the Flemish Pass using box cores, gravity and piston cores, and extensive surveys with side scan sonar and high resolution seismic (Campbell et al. 2002). The topography of the Flemish Pass is unusual in that it allows the trapping of sediments that elsewhere in most areas of the East Coast would be transported across the slope to the abyssal plain (Piper and Pereira 1992 *in* Campbell et al. 2002). The bottom is overlain by Miocene sediments over a thick Mesozoic sequence (Kennard et al. 1990 *in* Campbell et al. 2002). The Orphan Knoll is a fragment of continental crust that detached from North America during continental rifting (Keen and Beaumont 1990 *in* Toews and Piper 2002). Surficial sediments in the area are primarily hemipelagic, ice-rafted, and from glacial plume deposits (Toews and Piper 2002).

3.2 Climatology

Every marine seismic survey program is influenced by weather conditions, both from routine operational and environmental safety perspectives. During routine activities, data quality can be affected by weather, particularly wind and wave conditions. This section, based primarily on the Eastern Newfoundland SEA (C-NLOPB 2014) with updated information from recent EAs (LGL Limited 2013c, 2014b), provides a general overview of climatic conditions in the Study Area, including wind, waves, temperature, precipitation, visibility, and weather systems, with a more detailed description of extreme events.

The wind and wave climatology of the Study Area was prepared using the 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 four grid points to represent the Study Area: (1) grid point 11595 on the Northern Grand Banks; (2) grid point 17801 in the Orphan Basin; (3) grid point 13912 in the Flemish Pass; and (4) grid point 13451 on the Flemish Cap (Table 3.1, Figure 3.1). Continuous wind and wave hindcast data for grid points 17801, 11595, and 13451 are one-hour time steps from January 1954 to December 2011 (C-NLOPB 2014). Hindcast data for grid point 13912 are one-hour time steps from January 1954 to December 2005 (LGL 2014b).

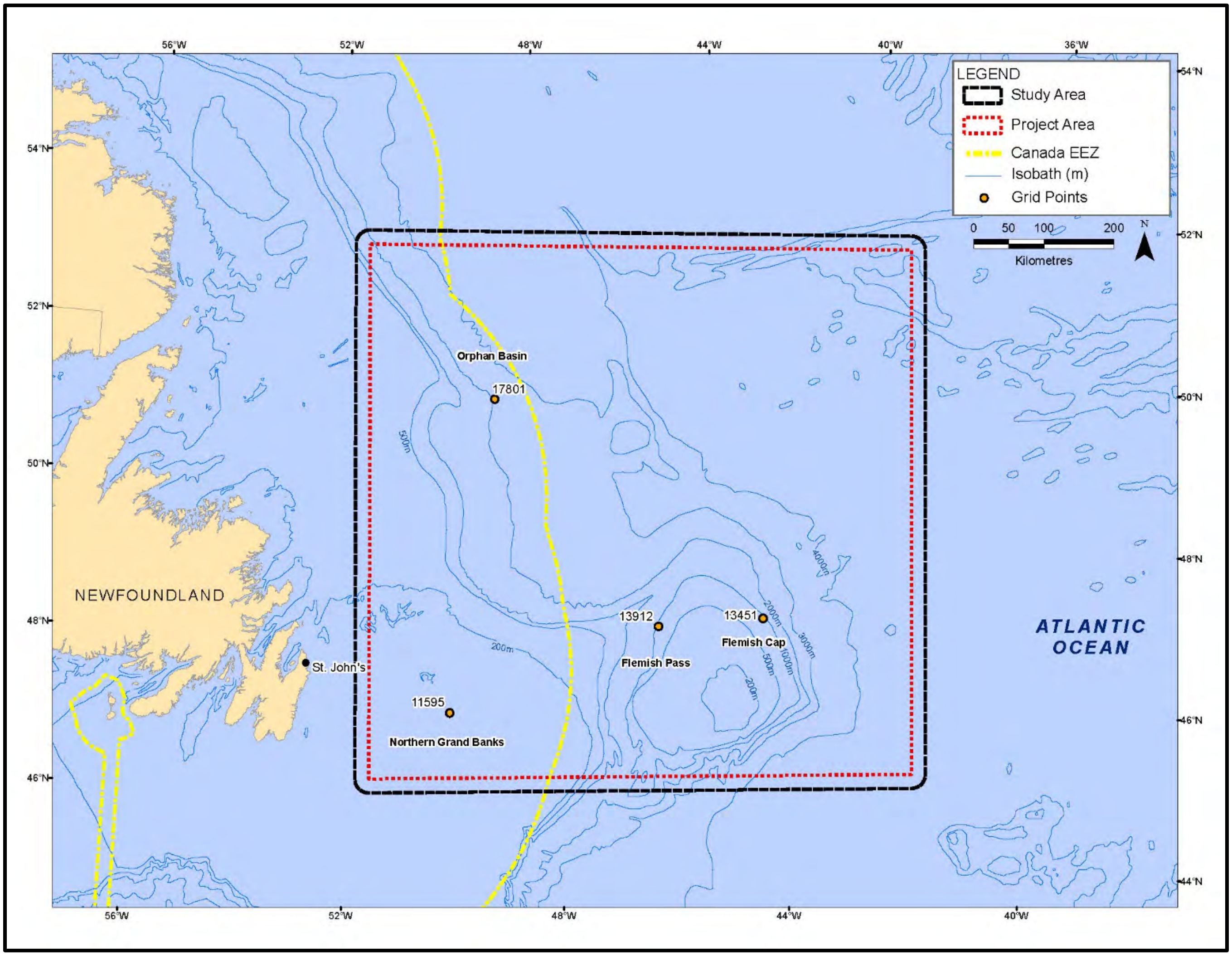
Table 3.1 MSC50 Grid Point Locations.

Region	Grid Point	Latitude	Longitude
Northern Grand Banks	11595	47°N	50°W
Orphan Basin	17801	51°N	49°W
Flemish Pass	13912	48°N	46°W
Flemish Cap	13451	48°N	44°W

Data related to air temperature, sea surface temperature, visibility, and precipitation were compiled using the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). 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 Northern Grand Banks, the Orphan Basin, and the Flemish Pass (C-NLOPB 2014). A subset of observations covering the period from January 1980 to December 2010 was used in the analysis for the Flemish Pass (LGL Limited 2014b).

3.2.1 Wind

Much of the Study Area experiences primarily southwest to west winds throughout the year; however, there is a strong annual cycle in wind directions. West to northwest winds are prevalent during the winter months but 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. Mean hourly wind speeds for grid points within the Study Area are presented in Table 3.2. Mean wind speeds peak during the winter and are highest during January and February in all regions. From May to November, the highest mean wind speeds occur during November and the lowest during July, ranging from 9.7 to 11.1 m/s and 6.2 to 6.7 m/s, respectively.



Sources: C-NLOPB 2014; LGL 2014b.

Figure 3.1 Location of MSC50 Grid Points and Regions used in the Physical Environment Analyses.

Table 3.2 Mean Hourly Wind Speed Statistics for Offshore Eastern Newfoundland.

Month	Mean Wind Speed (m/s)			
	Northern Grand Banks (11595)	Orphan Basin (17801)	Flemish Pass (13912)	Flemish Cap (13451)
January	11.0	12.4	12.0	12.5
February	10.8	12.0	11.6	12.2
March	9.8	11.0	10.5	11.0
April	8.4	9.6	8.8	9.3
May	7.1	8.1	7.6	8.1
June	6.6	7.1	6.9	7.4
July	6.2	6.6	6.4	6.7
August	6.6	7.3	6.7	7.1
September	7.7	8.6	8.1	8.6
October	8.9	10.0	9.5	10.1
November	9.7	11.1	10.3	10.8
December	10.6	12.0	11.4	11.9

Sources: C-NLOPB 2014; LGL 2014b.

3.2.2 Waves

The wave climate of the Grand Banks is dominated by extratropical storms (discussed in Section 3.2.5), primarily during October through March. Tropical storms may occur during the early summer and early winter, but most often occur from late August through October. 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.

During autumn and winter, the predominant direction of the combined significant wave heights is from the west, corresponding to a high frequency of occurrence of wind waves during these months. During March and April, the wind waves remain primarily westerly, while the swell begins to back to southerly. During the summer, the mean direction of the combined significant wave heights is from the southwest, as a result of both southwesterly wind waves and southwesterly swell. During September and October, the wind waves veer again to the west and become the predominant component of the combined significant wave heights.

Wave conditions are described 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 roughly approximates the characteristic height observed visually. Significant wave heights for grid points within the Study Area are presented in Table 3.3. From May to November, the highest waves occur during November and the lowest during July in all regions, ranging from 3.2 to 3.8 m and 1.7 to 1.8 m, respectively.

Table 3.3 Combined Significant Wave Height Statistics for Offshore Eastern Newfoundland.

Month	Significant Wave Height (m)			
	Northern Grand Banks (11595)	Orphan Basin (17801)	Flemish Pass (13912)	Flemish Cap (13451)
January	3.7	4.3	4.6	4.9
February	3.3	3.6	4.2	4.6
March	2.8	3.3	3.6	4.0
April	2.5	2.9	3.0	3.2
May	2.2	2.3	2.4	2.5
June	1.9	1.9	2.0	2.1
July	1.7	1.7	1.8	1.8
August	1.8	1.8	1.9	2.0
September	2.3	2.6	2.6	2.7
October	2.9	3.2	3.2	3.4
November	3.2	3.7	3.6	3.8
December	3.8	4.3	4.3	4.5

Sources: C-NLOPB 2014; LGL 2014b.

Maximum wave height is defined as the greatest vertical distance between a wave crest and adjacent trough. Maximum wave heights for grid points within the Study Area are presented in Table 3.4. From May to November, the most severe sea states occur during September on the Northern Grand Banks (11595) and in the Flemish Pass (13912) and November in the Orphan Basin (17801) and on the Flemish Cap (13451).

3.2.3 Wind and Wave Extreme Value Analysis

An analysis of extreme wind and waves was performed using the four grid points already indicated to represent the Study Area (see Table 3.1, Figure 3.1). The extreme value analysis was based on the Gumbel distribution, to which data were fitted using the maximum likelihood method for grid points 11595, 17801, and 13451 (C-NLOPB 2014) and the peak-over threshold method for grid point 13912 (LGL 2014b).

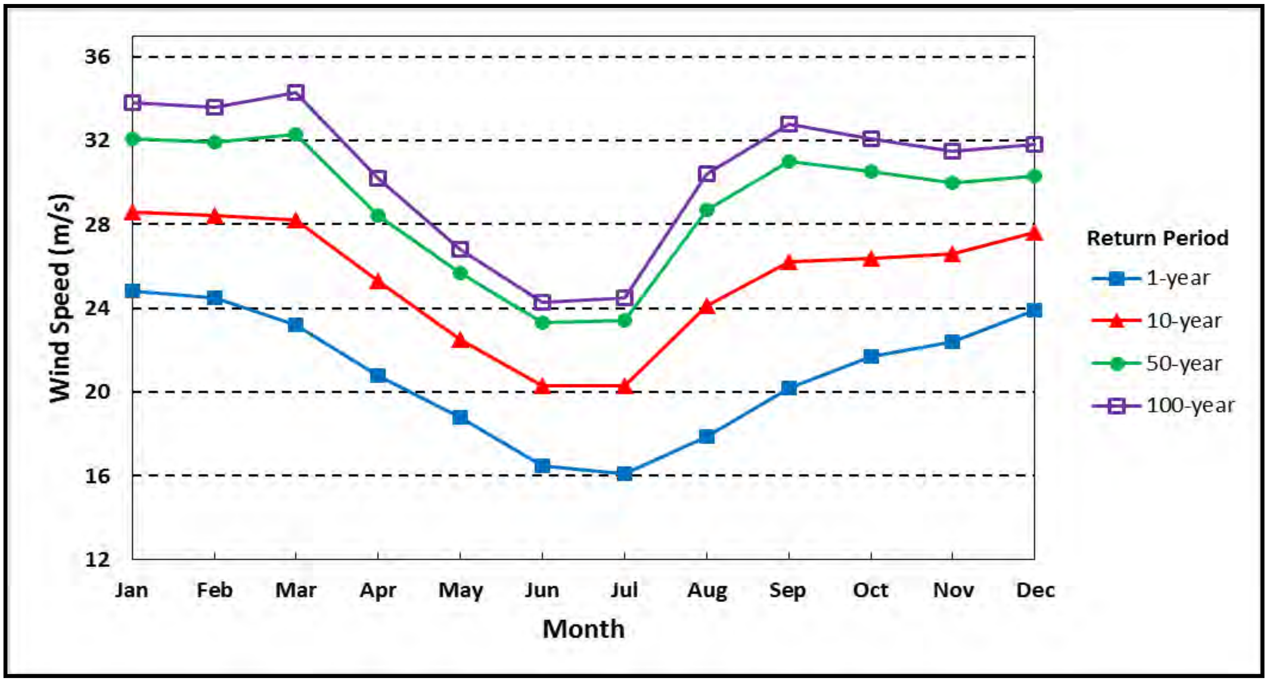
Table 3.4 Combined Maximum Wave Height Statistics for Offshore Eastern Newfoundland.

Month	Maximum Wave Height (m)			
	Northern Grand Banks (11595)	Orphan Basin (17801)	Flemish Pass (13912)	Flemish Cap (13451)
January	11.5	15.9	14.2	14.8
February	13.3	13.4	15.3	15.8
March	10.4	12.1	13.1	15.6
April	10.3	11.5	11.0	11.7
May	9.6	10.9	11.7	11.8
June	9.1	8.7	10.5	11.4
July	6.0	6.3	7.1	6.8
August	8.5	11.1	8.2	9.8
September	12.8	12.1	13.3	12.9
October	10.5	12.7	12.5	13.8
November	10.7	13.1	13.2	14.2
December	12.1	15.1	15.3	16.5

Sources: C-NLOPB 2014; LGL 2014b.

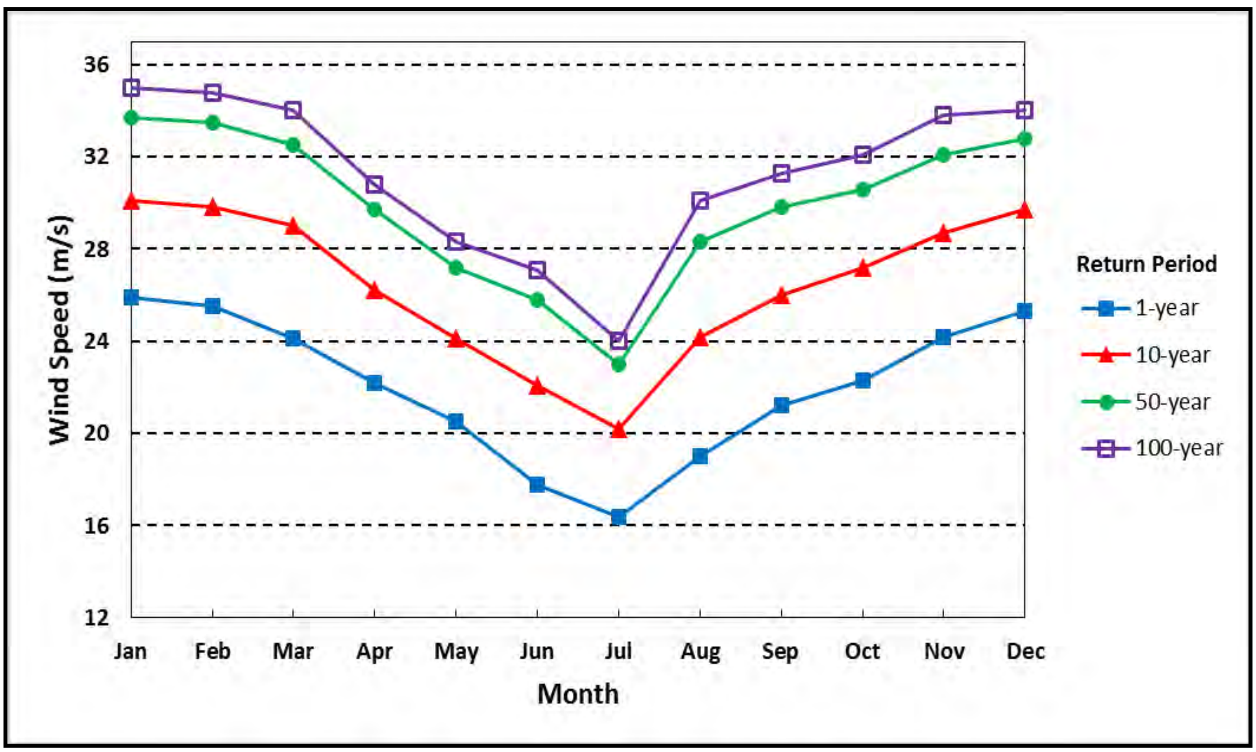
3.2.3.1 Extreme Value Estimates for Winds from the Gumbel Distribution

The extreme value estimates for wind were calculated using Oceanweather's Osmosis software for return periods of 1-year, 10-years, 50-years, and 100-years. 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 analysis used hourly mean wind speeds for a reference height of 10 m above sea level (C-NLOPB 2014, LGL 2014b). The calculated monthly extreme 1-hour wind speed estimates for grid points within the Study Area are presented in Figures 3.2 to 3.5. The calculated annual 100-year extreme 1-hour wind speed ranged from 33.1 to 35.8 m/s, and was determined to be 33.1 m/s for the Flemish Pass (13912), 34.8 m/s for the Northern Grand Banks (11595), and 35.8 m/s for the Orphan Basin (17801) and the Flemish Cap (13451). From May to November, the highest 100-year extreme 1-hour wind speeds occur from September to November, while the lowest occur during June and July.



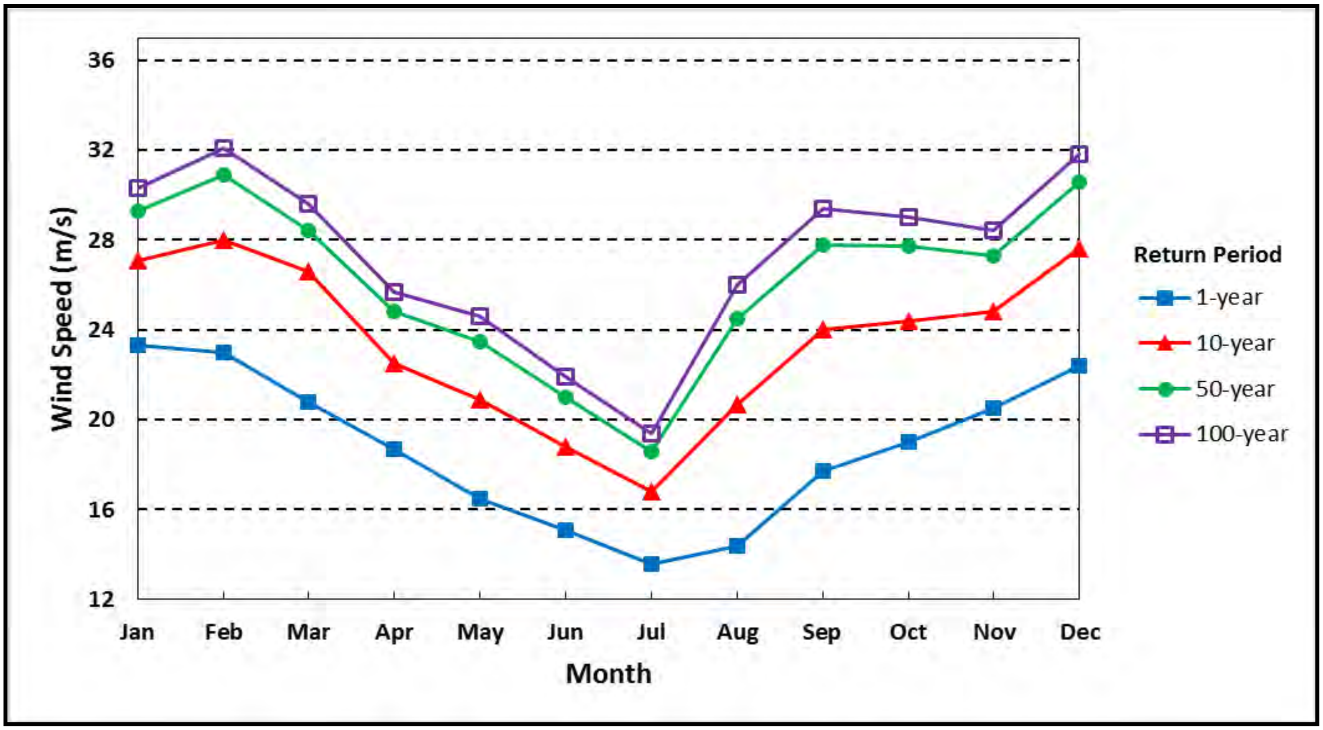
Sources: C-NLOPB 2014.

Figure 3.2 Extreme 1-hour Wind Speed Estimates for the Northern Grand Banks (11595).



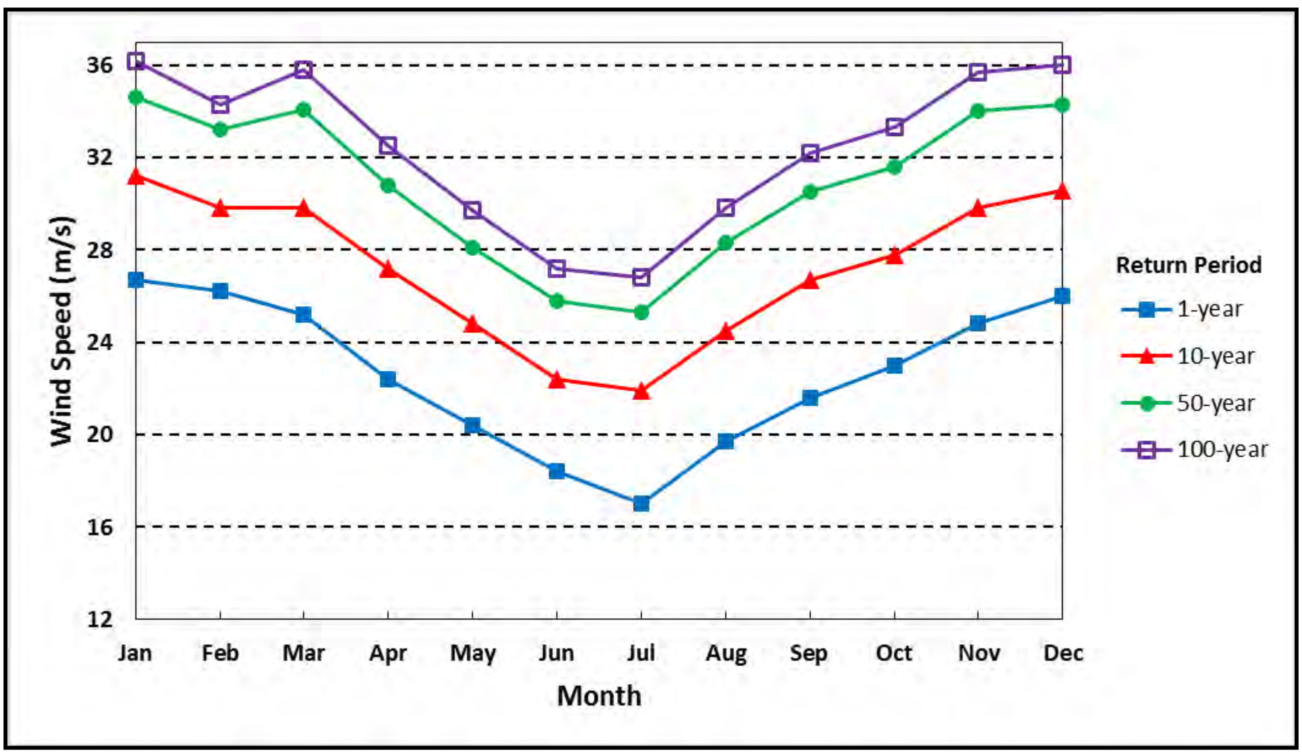
Sources: C-NLOPB 2014.

Figure 3.3 Extreme 1-hour Wind Speed Estimates for the Orphan Basin (17801).



Sources: LGL 2014b.

Figure 3.4 Extreme 1-hour Wind Speed Estimates for the Flemish Pass (13912).

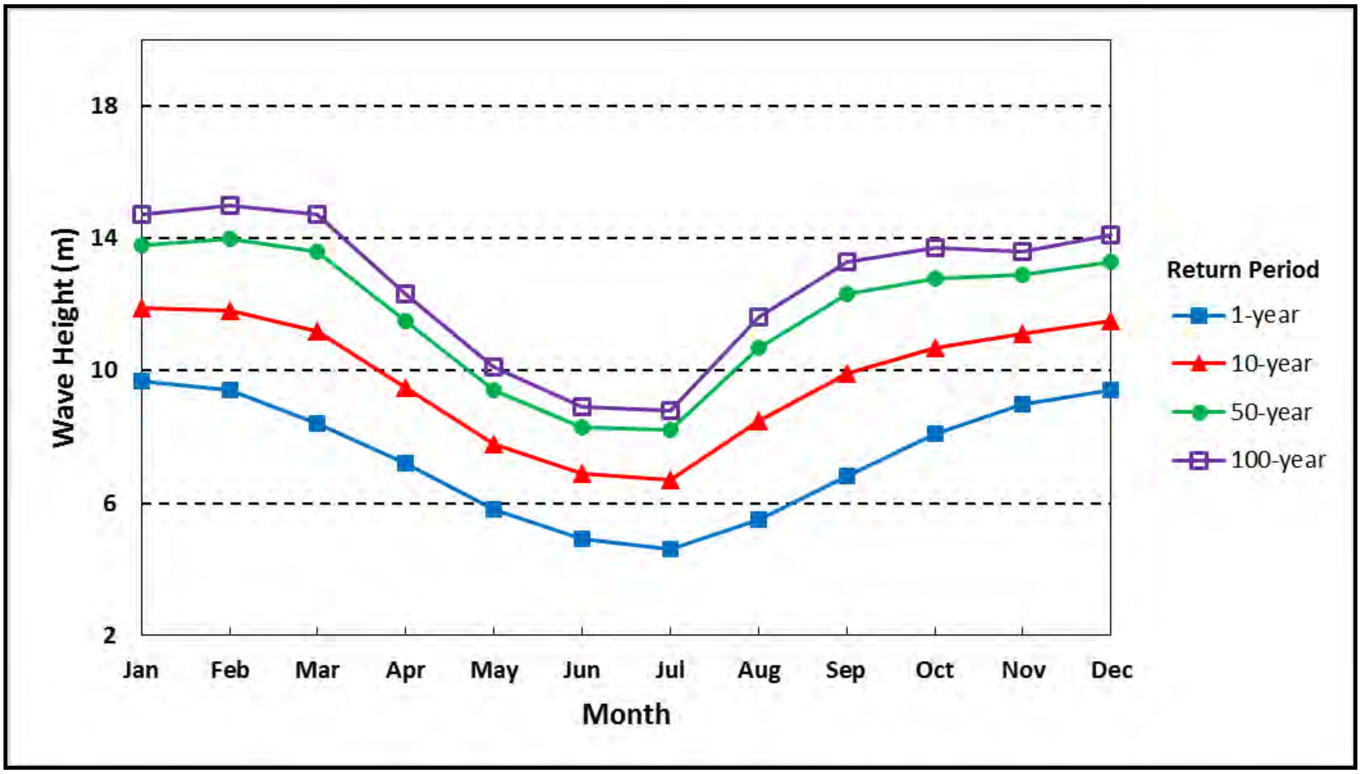


Sources: C-NLOPB 2014.

Figure 3.5 Extreme 1-hour Wind Speed Estimates for the Flemish Cap (13451).

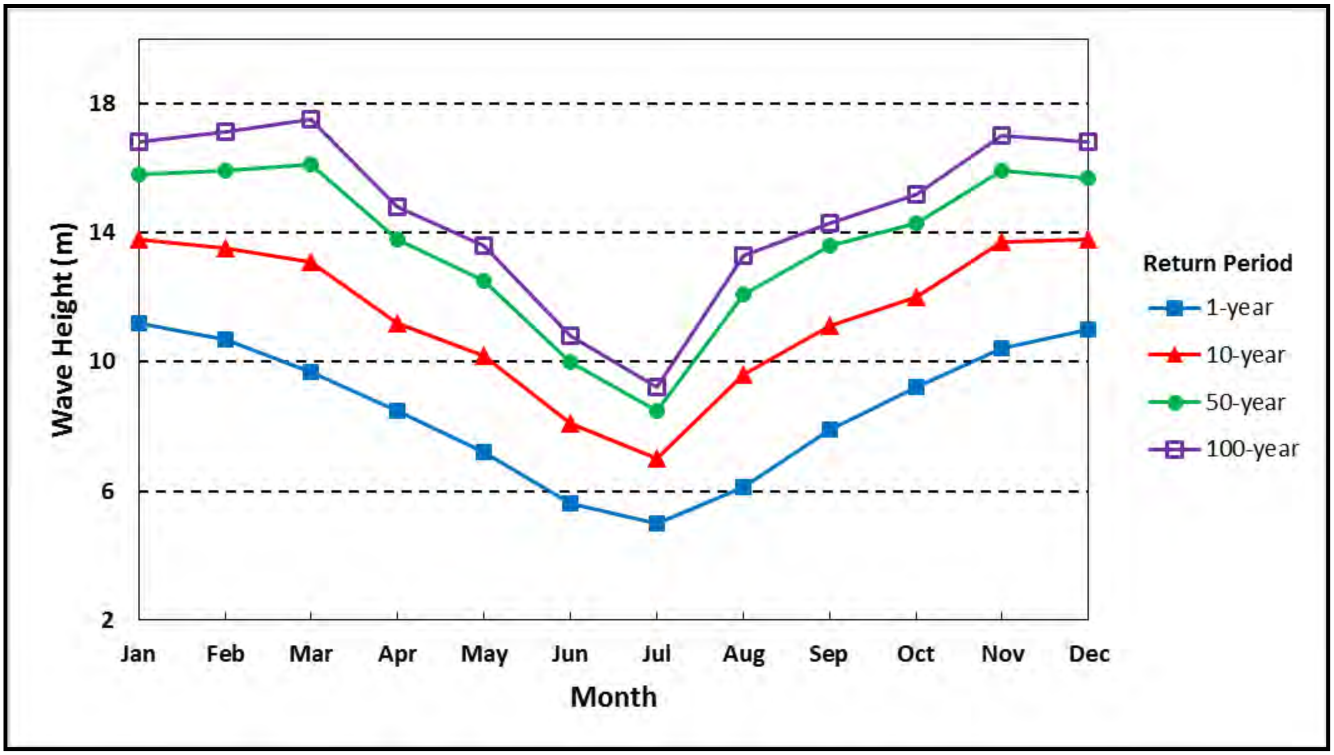
3.2.3.2 Extreme Value Estimates for Waves from a Gumbel Distribution

The monthly extreme value estimates for significant wave height for return periods of 1-year, 10-years, 50-years, and 100-years for grid points within the Study Area are presented in Figures 3.6 to 3.9, respectively. A storm with a return period of 100-years means that the calculated significant wave height will occur once every 100-years, averaged over a long period of time. The calculated annual 100-year extreme significant wave height ranged from 14.1 to 15.0 m, and was determined to be 14.3 m for the Northern Grand Banks (11595), 16.0 m for the Flemish Pass (13912), 16.3 m for Orphan Basin (17801), and 18.6 m for the Flemish Cap (13451). From May to November, the highest 100-year extreme significant wave heights occur during October and November, while the lowest occur during July.



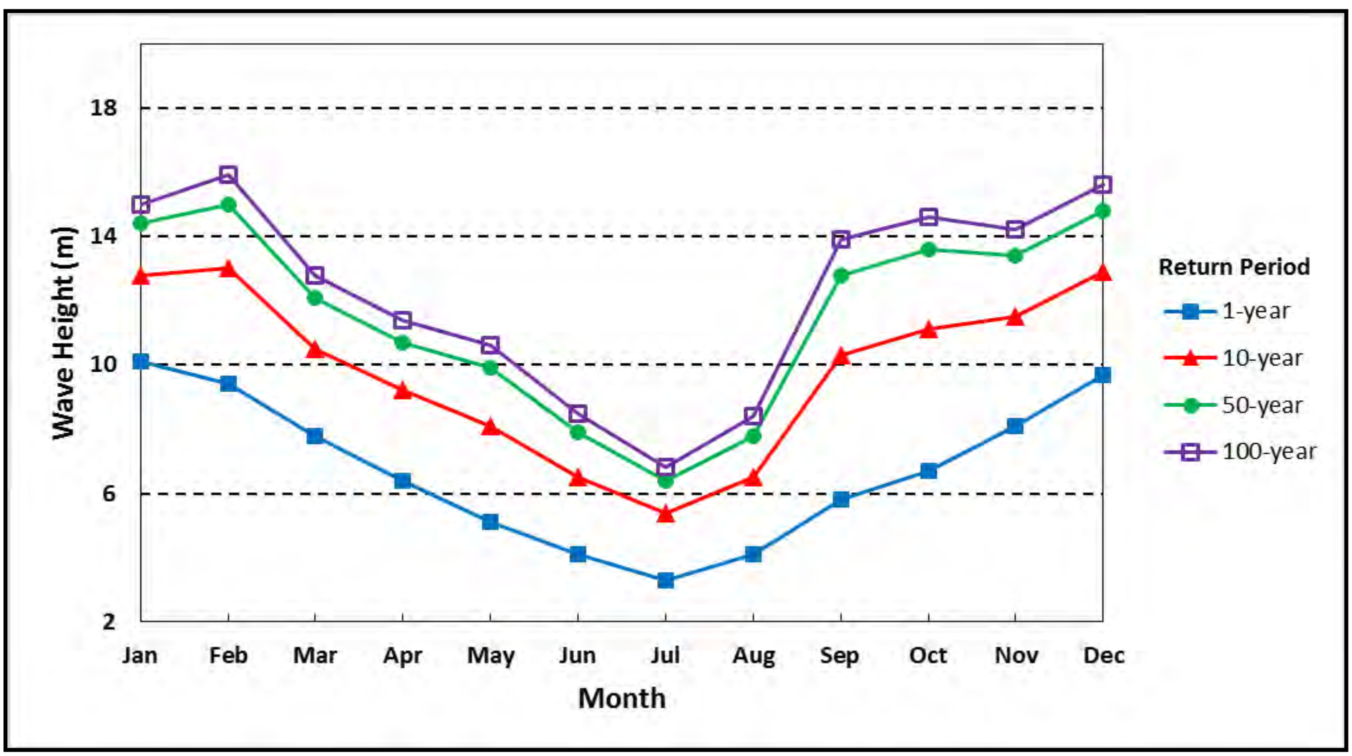
Sources: C-NLOPB 2014.

Figure 3.6 Extreme Significant Wave Height Estimates for the Northern Grand Banks (11595).



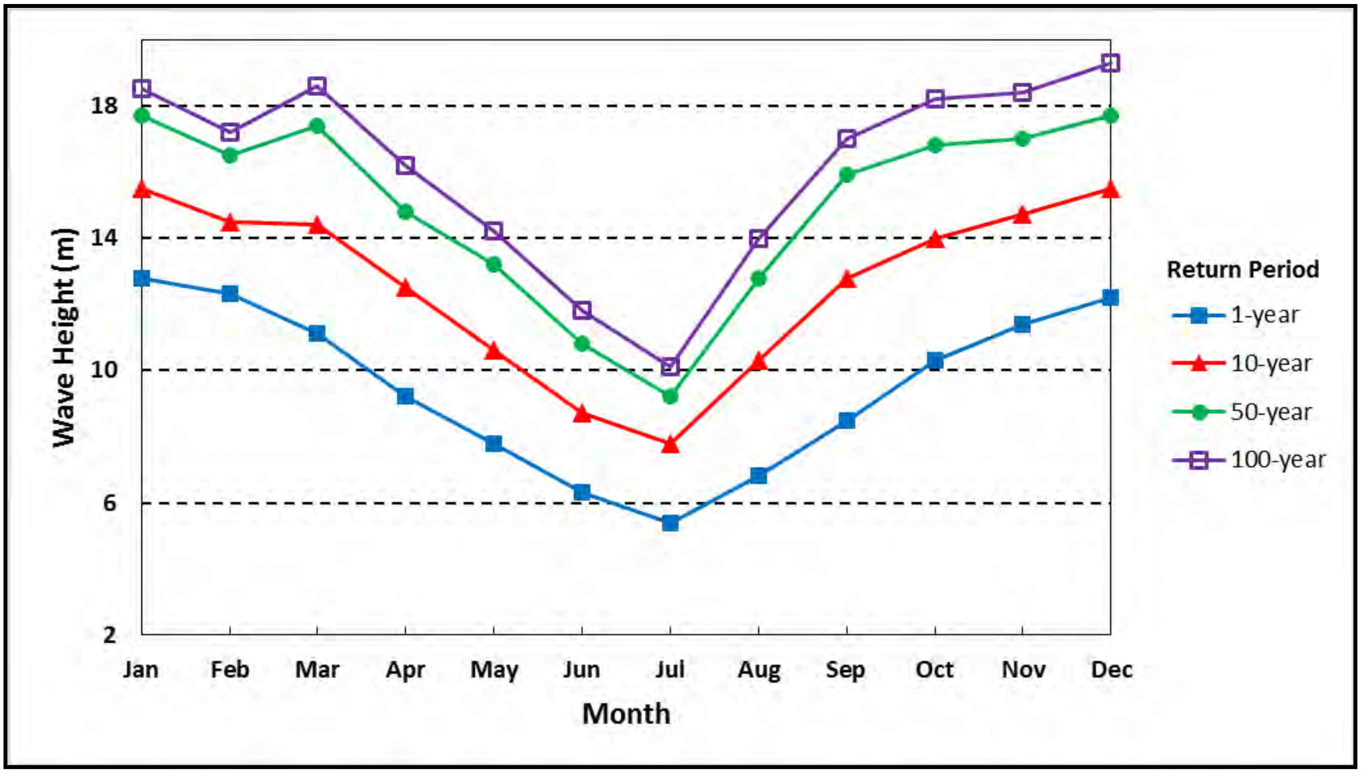
Sources: C-NLOPB 2014.

Figure 3.7 Extreme Significant Wave Height Estimates for the Orphan Basin (17801).



Sources: LGL 2014b.

Figure 3.8 Extreme Significant Wave Height Estimates for the Flemish Pass (13912).



Sources: C-NLOPB 2014.

Figure 3.9 Extreme Significant Wave Height Estimates for the Flemish Cap (13451).

3.2.4 Weather Variables

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. Air and sea surface temperatures for each region (see Figure 3.1) were extracted from the ICOADS data set (C-NLOPB 2014, LGL Limited 2013c). Mean monthly air temperatures and sea surface temperatures for the Study Area are presented in Tables 3.5 and 3.6, respectively, and are the mean of all recorded temperatures for a particular region during that month.

The temperature data indicate that the air is warmest during August and coldest during February in all regions. Sea surface temperature is also warmest during August and coldest during February in all regions.

Table 3.5 Mean Monthly Air Temperatures for Offshore Eastern Newfoundland.

Month	Air Temperature (°C)			
	Northern Grand Banks	Orphan Basin	Flemish Pass	Flemish Cap
January	0.4	-1.4	3.9	3.1
February	-0.1	-2.9	3.1	2.6
March	0.7	-0.4	3.7	3.4
April	2.3	1.3	3.8	5.1
May	4.4	3.5	5.2	7.0
June	7.6	6.6	6.7	9.2
July	12.1	10.1	9.3	12.4
August	14.6	11.7	11.5	14.2
September	12.8	10.3	11.3	13.3
October	9.2	6.6	9.4	10.4
November	5.6	3.7	7.4	7.8
December	2.5	1.1	5.8	5.4

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.6 Mean Monthly Sea Surface Temperatures for Offshore Eastern Newfoundland.

Month	Sea Surface Temperature (°C)			
	Northern Grand Banks	Orphan Basin	Flemish Pass	Flemish Cap
January	0.9	0.9	4.0	4.8
February	0.0	0.4	2.9	3.8
March	0.1	0.7	3.3	4.1
April	0.7	1.2	3.3	4.8
May	2.6	2.5	4.7	6.3
June	5.5	4.8	6.6	8.4
July	10.3	8.4	9.2	11.4
August	14.0	11.3	11.8	13.7
September	13.5	10.6	11.6	13.7
October	10.5	7.7	9.9	11.4
November	6.8	4.7	7.2	9.2
December	3.5	2.5	5.6	6.5

Sources: C-NLOPB 2014; LGL 2014b.

3.2.4.2 Precipitation

Precipitation may occur in three forms, classified as liquid, freezing, or frozen. Included in these classifications are:

- Liquid precipitation
  - Drizzle
  - Rain
- Freezing precipitation
  - Freezing drizzle
  - Freezing rain
- Frozen precipitation
  - Snow
  - Snow pellets
  - Snow grains
  - Ice pellets
  - Hail
  - Ice crystals

The migratory high and low pressure systems transiting the middle latitudes of the Northern Hemisphere result in a variety of precipitation types. The frequency of occurrence of each precipitation type was calculated as a percentage of the total monthly and annual weather observations from the ICOADS data set, with each occurrence counting as one event. The frequencies of occurrence of precipitation types for regions within the Study Area are presented in Tables 3.7 to 3.10.

Most of the observed precipitation events are in the form of rain or snow. From May to November, the monthly occurrence of rain events is lowest during July and highest during October and November. The minimum frequency of snow events occurs from May to November, ranging from 0.0 to 4.6%, and is lowest during the summer months. Other types of precipitation, such as freezing rain/drizzle, mixed rain/snow, and hail, occur less frequently than rain or snow. Thunderstorms occur infrequently over the Study Area, although there is a year-round potential of occurrence. In general, thunderstorms are most frequent during the summer months.

Table 3.7 Frequency of Occurrence of Precipitation for the Northern Grand Banks.

Month	Frequency of Occurrence (%)					
	Rain/Drizzle	Freezing Rain/Drizzle	Rain/Snow Mixed	Snow	Hail	Thunder Storm
January	10.1	0.4	0.7	14.4	0.5	0.1
February	8.2	0.6	0.6	14.8	0.3	0.0
March	8.8	0.7	0.5	9.8	0.3	0.1
April	10.2	0.2	0.3	3.7	0.2	0.1
May	10.0	0.1	0.1	0.8	0.2	0.1
June	9.6	0.0	0.1	0.1	0.2	0.2
July	8.4	0.0	0.1	0.1	0.3	0.4
August	9.6	0.0	0.1	0.1	0.3	0.4
September	10.6	0.0	0.1	0.1	0.1	0.1
October	14.1	0.0	0.1	0.3	0.3	0.3
November	14.2	0.1	0.4	2.8	0.4	0.1
December	12.0	0.1	0.8	8.5	0.4	0.1
Annual	10.4	0.2	0.3	4.4	0.3	0.2

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.8 Frequency of Occurrence of Precipitation for the Orphan Basin.

Month	Frequency of Occurrence (%)					
	Rain/Drizzle	Freezing Rain/Drizzle	Rain/Snow Mixed	Snow	Hail	Thunder Storm
January	6.7	0.3	1.9	21.5	0.5	0.1
February	4.0	0.3	0.8	18.6	0.3	0.1
March	6.2	0.2	1.2	14.2	0.5	0.3
April	8.0	0.2	0.8	7.2	0.3	0.2
May	9.1	0.1	0.5	2.0	0.3	0.3
June	8.2	0.0	0.1	0.1	1.4	1.4
July	7.3	0.0	0.0	0.1	0.6	0.7
August	8.5	0.0	0.0	0.0	0.3	0.2
September	9.9	0.0	0.1	0.1	0.2	0.2
October	12.6	0.0	0.3	0.9	0.3	0.2
November	11.1	0.1	0.8	4.6	0.4	0.1
December	8.4	0.2	1.5	12.7	0.5	0.1
Annual	8.2	0.1	0.6	7.0	0.5	0.3

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.9 Frequency of Occurrence of Precipitation for the Flemish Pass.

Month	Frequency of Occurrence (%)					
	Rain/Drizzle	Freezing Rain/Drizzle	Rain/Snow Mixed	Snow	Hail	Thunder Storm
January	12.3	0.1	1.7	20.8	0.3	0.1
February	11.6	0.2	1.5	20.5	0.0	0.1
March	11.2	0.1	1.0	14.2	0.0	0.1
April	9.9	0.1	0.4	6.0	0.1	0.0
May	13.5	0.0	0.2	2.2	0.0	0.1
June	14.9	0.0	0.0	0.2	0.0	0.1
July	12.2	0.0	0.0	0.1	0.0	0.4
August	14.5	0.0	0.0	0.1	0.1	0.3
September	21.1	0.0	0.0	0.6	0.0	0.2
October	19.7	0.0	0.0	0.6	0.0	0.2
November	17.9	0.0	1.6	3.6	0.8	0.2
December	14.6	0.0	2.5	11.5	0.4	0.2
Annual	13.4	0.1	0.7	7.3	0.1	0.1

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.10 Frequency of Occurrence of Precipitation for the Flemish Cap.

Month	Frequency of Occurrence (%)					
	Rain/Drizzle	Freezing Rain/Drizzle	Rain/Snow Mixed	Snow	Hail	Thunder Storm
January	12.3	0.2	1.4	9.0	1.0	0.2
February	10.3	0.1	1.2	10.1	0.8	0.1
March	10.6	0.1	0.8	6.1	0.7	0.2
April	10.9	0.1	0.5	2.0	0.3	0.1
May	11.0	0.1	0.2	0.4	0.2	0.1
June	9.6	0.0	0.1	0.1	0.2	0.2
July	8.3	0.0	0.1	0.1	0.9	0.9
August	8.5	0.0	0.1	0.1	0.2	0.2
September	11.0	0.0	0.1	0.1	0.9	0.1
October	13.6	0.0	0.1	0.3	0.2	0.1
November	13.5	0.1	0.4	1.1	0.3	0.1
December	12.6	0.1	1.0	4.7	0.9	0.1
Annual	10.9	0.1	0.5	2.9	0.5	0.2

Sources: C-NLOPB 2014; LGL 2014b.

3.2.4.3 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.

The frequency distributions of visibility states from the ICOADS data set for each region within the Study Area are presented in Tables 3.11 to 3.14. The visibility states have been defined as very poor (less than 1 km for the Flemish Pass and less than 0.5 km for all other regions), poor (1 to 2 km for the Flemish Pass and 0.5 to 2 km for all other regions), fair (2 to 10 km), and good (greater than 10 km). Annually, the Northern Grand Banks has the highest occurrence of reduced visibility, with poor to very poor visibility (less than 2 km) occurring 23.7% of the time, followed by the Flemish Pass (~23.0%), the Orphan Basin (19.5%), and the Flemish Cap (16.6%). In all regions, visibility is poorest during July, with poor to very poor visibility occurring ~56.0% of the time in the Flemish Pass, 51.8% on the Northern Grand Banks, 41.5% in the Orphan Basin, and 40.0% on the Flemish Cap.

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 the 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 narrow and by September, the air temperature begins to fall below the sea surface temperature and the occurrence of fog decreases. During the May to November period, September and October has the lowest occurrence of reduced visibility since the air temperature has, on average, decreased below the sea surface temperature, but it 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.

Table 3.11 Frequency of Occurrence of Visibility States for the Northern 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

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.12 Frequency of Occurrence of Visibility States for the 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

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.13 Frequency of Occurrence of Visibility States for the Flemish Pass.

Month	Frequency of Occurrence (%)			
	Very Poor (<1 km)	Poor (1 – 2 km)	Fair (2 – 10 km)	Good (>10 km)
January	8	4	21	67
February	9	5	22	64
March	12	4	18	66
April	23	3	13	61
May	26	2	13	59
June	28	4	15	53
July	52	4	11	33
August	31	3	14	52
September	13	3	13	71
October	9	2	14	75
November	12	2	16	70
December	7	3	17	73
Annual	20	3	15	62

Sources: C-NLOPB 2014; LGL 2014b.

Table 3.14 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

Sources: C-NLOPB 2014; LGL 2014b.

3.2.5 Weather Systems

The Study Area, including the northeast Newfoundland Shelf, the northern Grand Banks, the Orphan Basin, the Jeanne d'Arc Basin, and the Flemish Pass, experiences weather conditions typical of a marine environment that moderates air temperatures. In general, marine climates experience cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Furthermore, a marine climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and significant amounts of precipitation.

The climate of the Study Area is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in and steered by the prevailing westerly flow that 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. [Meteorological convention defines seasons by quarters; e.g., winter is December, January, February, etc.]

During the winter months, an upper level trough tends to lie over central Canada and an upper ridge over the North Atlantic, resulting in three main storm tracks affecting the region: (1) one from the Great Lakes Basin; (2) one from Cape Hatteras, North Carolina; and (3) one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area. The intensity of these systems ranges from relatively weak features to major winter storms. With increasing solar radiation during spring, there is a general warming of the atmosphere that is relatively greater at higher latitudes. This decreases the north-south temperature contrast, lowers the kinetic energy of the westerly flow aloft, and decreases the potential energy available for storm development. By summer, the main storm tracks have moved further north than in winter, and storms are less frequent and much weaker. During the summer months, with low pressure systems normally passing to the north of the region, in combination with the northwest sector of the sub-tropical high to the south, the prevailing wind direction across the Grand Banks is from the southwest to south. Wind speed is lower during the summer, and gale or storm force winds are relatively infrequent. There is also a corresponding decrease in significant wave heights.

Frequently, intense low pressure systems become 'captured' and slow down or stall off the coast of Newfoundland and Labrador. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity, and size of the system, from relatively benign to heavy weather conditions.

Rapidly deepening storms are a problem south of Newfoundland in the vicinity of the warm water of the Gulf Stream. Sometimes explosively deepening oceanic cyclones develop into a "weather bomb"; defined as a storm that undergoes central pressure decreases greater than 24 mb over 24 hours. Typical features of weather bombs include hurricane force winds near the center, the outbreak of convective clouds to the north and east of the center during the explosive stage, and the presence of a clear area near the center in its mature stage. After development, these systems will either move across Newfoundland or near the southeast coast producing gale to storm force winds from the southwest to south.

In addition to extratropical cyclones, tropical cyclones often retain their tropical characteristics as they enter the Study Area. Tropical cyclones account for the strongest sustained surface winds observed anywhere 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. Once formed, a tropical storm or hurricane will maintain its energy as long as a sufficient supply of warm, moist air is available. These systems typically move east to west over the warm water of the tropics; however, some of these systems turn northward, moving towards Newfoundland and the Orphan Basin. Since the capacity of the air to hold water vapour is dependent on temperature, as the hurricanes move northward over the colder ocean waters, they begin to lose their tropical characteristics. By the time these weakening cyclones reach Newfoundland, they are generally embedded into a mid-latitude low and are classified as post-tropical, either as an extratropical cyclone or a remnant low. Occasionally, conditions are favourable for tropical cyclones to retain their tropical characteristics long enough to reach the Orphan Basin.

A significant number of tropical cyclones that move into the mid-latitudes will undergo transition into extratropical cyclones. On average, 46% of tropical cyclones formed in the Atlantic transform into extratropical cyclones. During this transformation, the system loses tropical characteristics and becomes more extratropical in nature. These systems frequently produce large waves, gale to hurricane force winds, and intense rainfall. The likelihood that a tropical cyclone will undergo transition into an extratropical cyclone increases toward the second half of the tropical season, with October having the highest probability of transition. In the Atlantic, extratropical transition occurs at lower latitudes in the early and late hurricane season and at higher latitudes during the peak of the season.

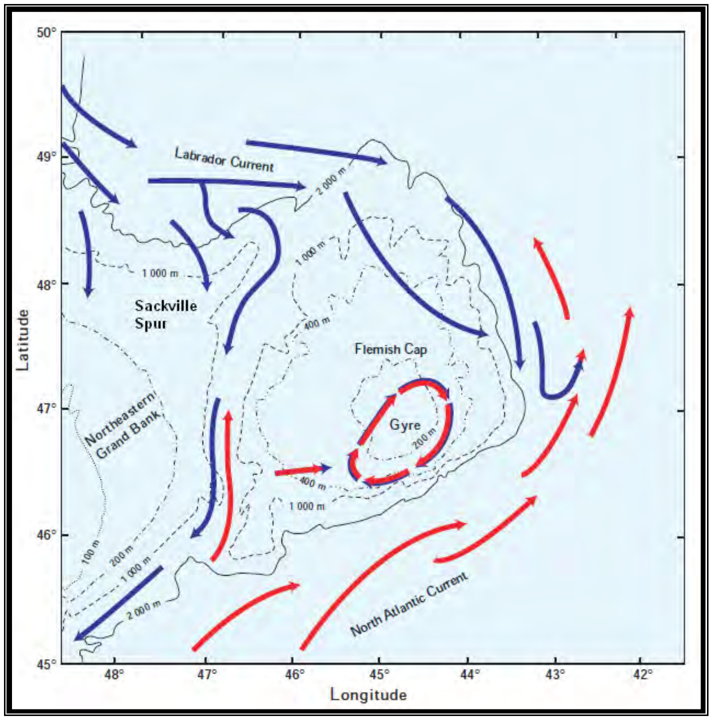
3.3 Physical Oceanography

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 Eastern Newfoundland SEA (C-NLOPB 2014). A summary of the major currents in the Study Area is provided below, with additional information from LGL (2014b).

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. The two major current systems in the area are the Labrador Current and the North Atlantic Current (Figure 3.10).

The Labrador Current is the major current on the Grand Banks and is a continuation of the Baffin Island Current, which transports the cold and relatively low salinity water flowing out of Baffin Bay and a branch of the warmer and more saline waters of the West Greenland Current. 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.



Source: Modified from Colborne and Foote 2000.

Figure 3.10 Major Ocean Currents and Circulation Features Offshore Eastern Newfoundland.

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

The Gulf Stream and its associated eddies play an important role in the region south of the Study Area. When it reaches the Grand Banks, the structure of the Gulf Stream changes from a single, meandering front to multiple, branching fronts. 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 interaction among these circulations is known to correlate with the behaviour of the North Atlantic Oscillation (NAO) index. The NAO index is the difference in winter sea level atmospheric pressures between the Azores and Iceland, and 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.

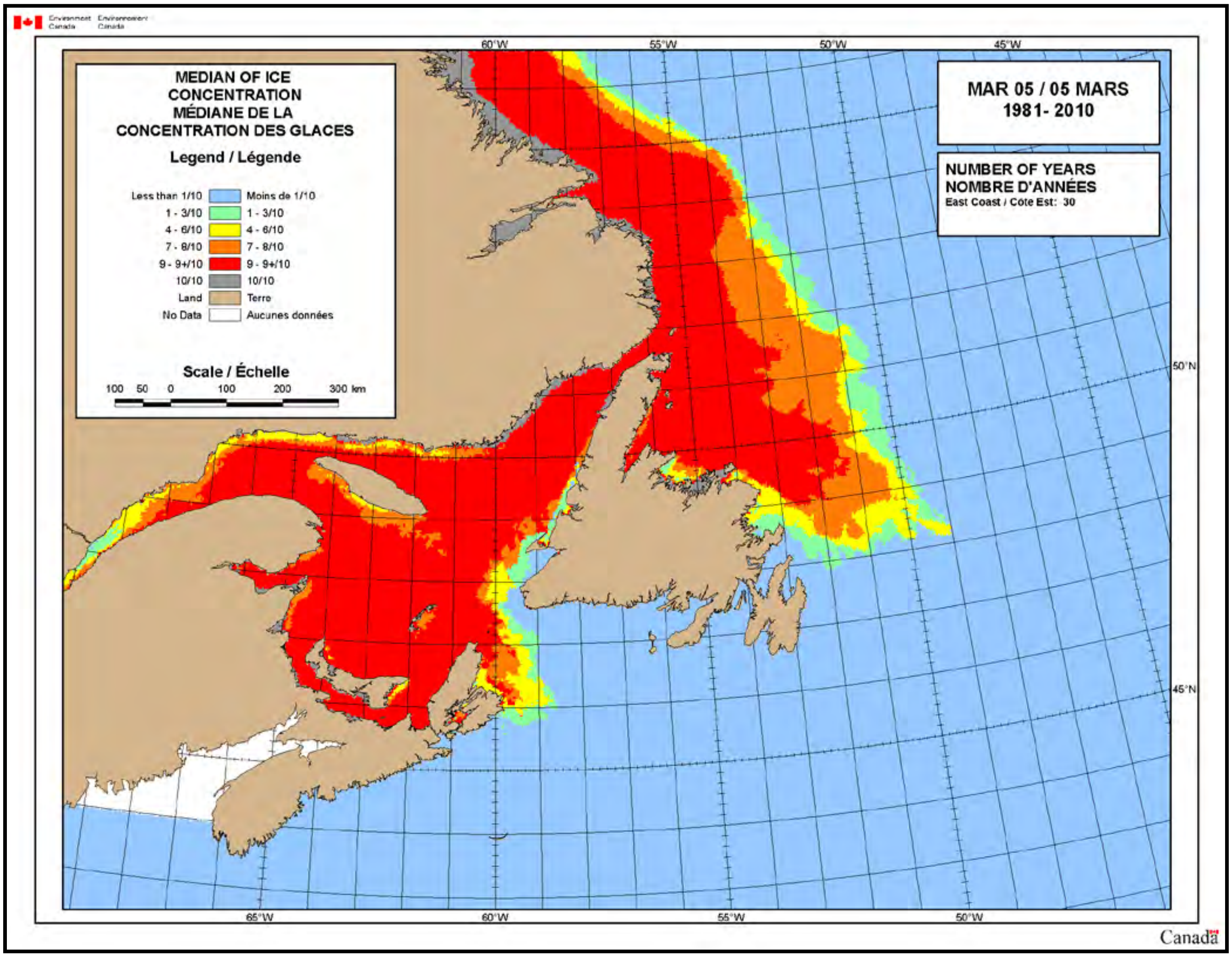
At all locations within the Study Area, the currents vary on different time scales related to tides, wind stress, atmospheric pressure changes from the passage of storm systems, volume transport of the Labrador Current, seasonal temperature changes, salinity variations, etc. The current variability in 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 impact 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 often directly affect offshore activities along the coast of Newfoundland and Labrador. A review of ice conditions in the Study Area has been provided in the Eastern Newfoundland SEA (C-NLOPB 2014) and recent EAs (LGL Limited 2013c, 2014b); a summary is provided below. The classification of ice commonly found along Canada's eastern seaboard is based on internationally accepted terminology (CIS 2011).

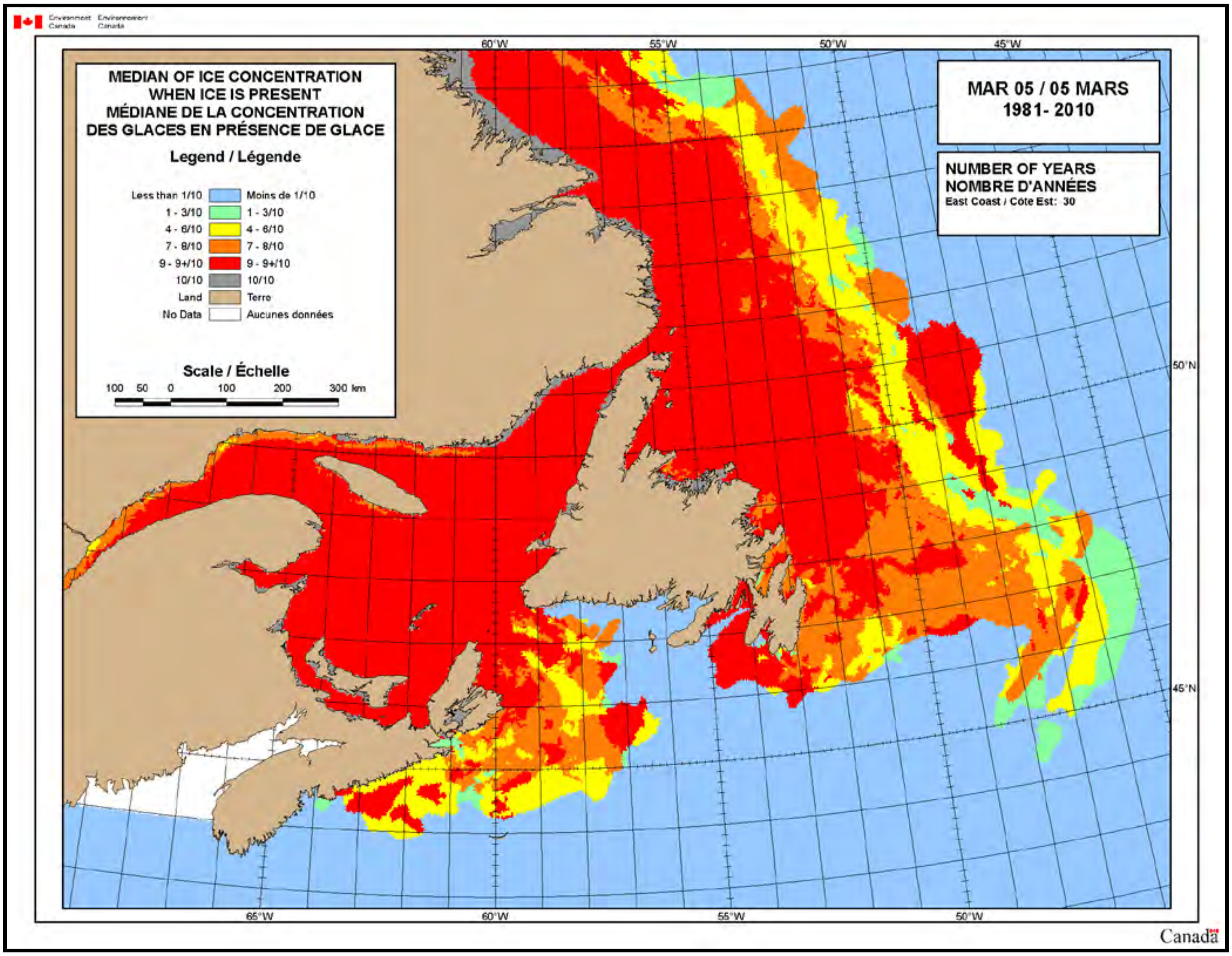
3.4.1 Sea Ice

Sea ice begins to form on the coast of southern Labrador in mid-December and spreads south to Newfoundland waters in early January. The 30-year median concentration of sea ice reaches its maximum during the week of 5 March (Figure 3.11). The maximum median sea ice extent reaches to approximately 48°N, 50°W. During median years, only the northwestern portion of the Study Area would have some ice cover (Figure 3.11). During extreme years, sea ice could occur throughout the Study Area (Figure 3.12). A majority of the Study Area will be free of sea ice from mid-April until January, with the exception of the northeastern portion where sea ice may persist until early July.



Source: Canadian Ice Service 30-Year Ice Atlas, accessed January 2015.

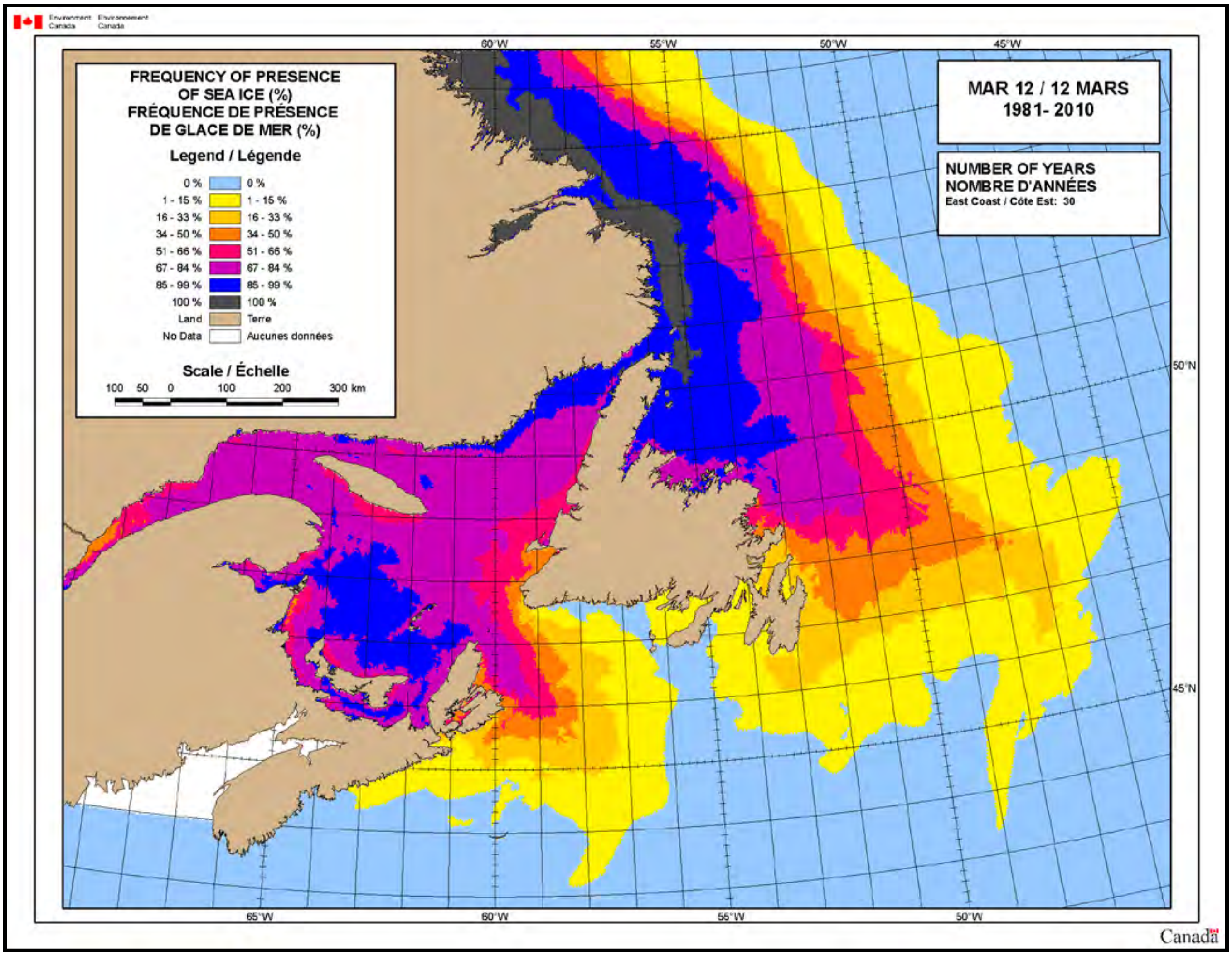
Figure 3.11 30-Year Median Concentration of Sea Ice, 1981–2010 (5 March).



Source: Canadian Ice Service 30-Year Ice Atlas, accessed February 2015.

Figure 3.12 30-Year Median Concentration of Sea Ice when Ice is Present, 1981–2010 (5 March).

A weekly analysis of the Canadian Ice Service's 30-Year Frequency of Presence of Sea Ice indicates that the Study Area is first affected by sea ice beginning the week of 1 January and lasting until the week beginning 9 July. Figure 3.13 depicts the week of 12 March, the period when the frequency of presence of sea ice is the greatest over the Study Area. When sea ice is present, the predominant ice type within the Study Area from 1 January until the week of 12 February is a mixture of grey and grey-white. By the week of 19 February, thin first-year ice begins to form and is the predominant ice type until the week of 2 April, with small amounts of grey-white and new ice also present. Medium first-year ice begins to appear by the week of 5 March, and some thick first-year by the week of 26 March. Small amounts of old ice are present within the Study Area by the week of 26 March.



Source: Canadian Ice Service 30-Year Ice Atlas, accessed January 2015.

Figure 3.13 30-Year Frequency of Presence of Sea Ice, 1981–2010 (12 March).

3.4.2 Icebergs

Icebergs often cause concern with regard to navigation and offshore activities along the coast of Newfoundland and Labrador. The major source, contributing ~90% of icebergs in Canadian waters, is 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 influence the number of icebergs that move into the coast or remain offshore. Major iceberg drift patterns branch in the northwest corner of the Study Area, flowing southward along the western border, and through the center from the northwest corner to the southeast. In the Newfoundland offshore area, with the exception of the Flemish Pass, the highest numbers of icebergs are sighted along the northeast coast. Iceberg sightings generally decrease to the east and south.

An analysis was performed to determine the threat posed by icebergs in the Study Area. The International Ice Patrol (IPP) 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 2001 – 2013, a total of 13,775 icebergs were observed in the Study Area (between approximately 46 to 53°N and 40 to 52°W). Only months with recorded iceberg sightings have been included (February to September). These observed sightings may not include all icebergs passing through the Study Area but indicate the relative abundance by month and year. Of the 13,775 icebergs sighted, 51.6% were observed during the period from May to November. Most were sighted in May (36.9%), followed by June (11.8%), and July (2.6%). There were no icebergs observed in October or November. Additionally, there was a great deal of inter-annual variability in the numbers of iceberg sightings. For example, during May to November of 2003, there were 2,490 icebergs observed in the Study Area. During the same time period of 2004 and 2005, there were 813 and 29 icebergs observed, respectively.

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 2001 – 2013, 42.6% of the 13,775 icebergs 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, 2001–2013.

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	% of Total
2001	41	57	33	34	93	28	-	-	286	2.1
2002	47	393	780	705	204	29	-	-	2,158	15.7
2003	4	198	880	1,188	184	21	-	-	2,490	18.1
2004	-	5	185	458	138	36	6	-	813	5.9
2005	1	8	13	2	5	-	-	-	29	0.2
2006	-	1	-	2	6	-	-	-	9	0.1
2007	-	4	42	101	270	88	-	-	442	3.2
2008	9	291	2,182	100	95	16	-	-	2,693	19.6
2009	39	154	530	1,450	528	107	3	-	2,811	20.4
2010	-	9	20	-	3	1	-	-	33	0.2
2011	-	-	6	4	22	-	-	-	32	0.2
2012	-	163	564	969	29	-	1	-	1,726	12.5
2013	7	-	6	74	117	34	14	1	253	1.8
Total	148	1,283	5,241	5,087	1,631	360	24	1	13,775	
% of Total	1.1	9.3	38.1	36.9	11.8	2.6	0.2	0.0		

Source: NSIDC 1995, IPP Iceberg Sightings Database, accessed January 2015.

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), and in EAs for Electromagnetic Geoservices' East Canada CSEM Survey (LGL 2014b), Suncor Energy's Eastern Newfoundland Seismic Program (LGL 2013c), and Husky Energy's White Rose Extension Project (Husky 2012). In addition to updated information, overviews of relevant information are presented in the following subsections for fish and fish habitat, fisheries, seabirds, marine mammals, sea turtles, species at risk and sensitive areas.

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 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, seabirds and marine mammals that are important ecologically, economically, and/or socially, with potential to interact with the Project. This is the VEC approach to environmental assessment which is detailed in Section 5.0. The VECs and/or their respective groups are discussed in the following sections.

4.2 Fish and Fish Habitat VEC

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

Phytoplankton distribution, productivity, and growth regulation in high-latitude ecosystems constitute a complex system with light, nutrients, and herbivore grazing being the principal factors limiting phytoplankton regulations (Harrison and Li 2008). In the NW Atlantic, there is generally a spring plankton bloom (May/June) which is often followed by a smaller bloom in the fall (September/October). This general pattern likely applies to the Study Area. There may be areas of enhanced production in the Study Area, similar to other slope areas that have been studied. For example, Moderate Resolution Imaging Spectroradiometer (MODIS) chlorophyll 'a' concentration images from August 2009 to 2011 (DFO 2011a) indicate the highest chlorophyll 'a' concentrations occurred around the slopes in the Study Area between March and May, with the second highest occurring in October and November. Typically, the spring bloom of phytoplankton is the driving force of high-latitude marine ecosystem dynamics, at least offshore. Sunlight has been considered the limiting factor for development of the spring bloom; however, factors such as nutrients, latitude and water column stratification are also important (Wu et al. 2008).

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

The information on plankton of the southern Grand Banks area has been reviewed extensively in the Eastern Newfoundland SEA (C-NLOPB 2014) and is summarized briefly in the current section. Some of the key points concerning the various components of planktonic communities for the eastern Grand Banks 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, usually 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 temperature 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.
- Nitrate levels are limited in the SEA Study Area relative to other areas of the NW Atlantic and favour the growth of diatoms.
- 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 make up a large 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 an important prey species 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 to increase survivorship.
- Ichthyoplankton assemblages (fish eggs and larvae) on the Northeast Newfoundland Shelf are primarily dominated by capelin (*Mallotus villosus*), sand lance (*Ammodytes* sp.), lanternfishes, and Arctic cod (*Boreogadus saida*).

The Atlantic Zone Monitoring program (AZMP) was implemented by DFO in 1998 in an attempt 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 2014a). The AZMP findings in relation to oceanographic conditions in the Study Area for 2013 are summarized below.

- Sea-surface temperatures were at record highs in September 2013 on the Grand Banks, and generally above normal during ice-free months, across the zone. Bottom temperatures were generally above normal across the zone.
- Nitrate inventories in both surface and subsurface waters were below normal on the Newfoundland and Labrador Shelf and Grand Banks.
- Overall abundance of phytoplankton was near the long-term (1999-2010) average throughout much of the Atlantic Zone in 2013. Chlorophyll anomalies have been below normal across much of the Newfoundland & Labrador Shelf since 2011 but increased slightly on the Grand Banks in 2013.
- 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 2013.
- The abundance levels of zooplankton species Pseudocalanus spp. and Calanus finmarchicus have demonstrated above normal levels since 2009.

Planktonic organisms are so ubiquitous and abundant, and many have such rapid generation times that there will be essentially no or negligible effect on planktonic communities from the proposed seismic 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 following sections because of their VEC status.

More information on phytoplankton within and around the Study Area is available in the Eastern Newfoundland SEA (C-NLOPB 2014), as well as in recent EAs (LGL 2012a, 2013c, 2014b).

4.2.1.2 Benthic Invertebrates

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

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

1. Continental shelf where the biomass is higher at the shelf edge; and
2. Upper slope areas where the biomass begins to decrease.

The benthic invertebrate communities of portions of the Study Area have been described extensively in the Eastern Newfoundland SEA (C-NLOPB 2014) and are briefly summarized below. 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 relating to the benthos. The information presented in this section 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, Iceland scallops (*Chlamys islandica*), sea scallops (*Placopecten magellanicus*), northern shrimp, striped pink shrimp (*Pandalus montagui*), Atlantic surf clams (*Spisula* *solidissima*), propeller clams (*Cyrtodaria silique*), pale sea urchin (*Strongylocentrotus pallidus*), hooded shrimp (Cumacea), and whelks (*Buccinum* sp.).

- 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 brittlestars, 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 RV trawl surveys were 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, 2013c).
- Many benthic communities in the SEA Study Area are quite diverse compared to higher trophic levels and can be expected to vary over time and with changing environmental conditions.

For more information on the life history and biology of some of the key benthic species in the SEA 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), such as large gorgonian corals (Breeze et al. 1997). Others, such as small gorgonians, cup corals, and sea pens, prefer sand or mud substrates (Edinger et al. 2007). The distribution of various corals along the continental shelf and slope regions of the Grand Banks, Flemish Pass, and Flemish Cap, 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, most found deeper than 200 m.

Several recently published reports present information on the ecology of deep cold-water corals of Newfoundland and Labrador waters, including information on biogeography, life history, biochemistry, and relation to fishes (e.g., Gilkinson and Edinger 2009; Kenchington et al. 2010a,b; Baillon et al. 2012; Baker et al. 2012). Wareham (2009) updated deep-sea coral distribution data for the Newfoundland and Labrador and Arctic Regions to partially fill information gaps previously identified by Wareham and Edinger (2007). Their study area encompassed the continental shelf, edge, and slope ranging from Baffin Bay to the Grand Banks. Distributional maps were compiled by Wareham (2009) using DFO Newfoundland and Labrador Region Multispecies Surveys (2000 to 2007), DFO Arctic Multispecies Surveys (2006 to 2007), Northern Shrimp Survey (2005), and from Fisheries Observers aboard commercial fishing vessels (2004 to 2007). The maps provided by Wareham (2009) show the distribution of several coral groups occurring along the continental edge and slope from Baffin Bay to the Grand Banks. The groups profiled include antipatharians, alcyonaceans, scleractinians, and pennatulaceans. Six previously undocumented coral species, composed of one alcyonacean, two scleractinians, and three pennatulaceans, were identified in the Newfoundland and Labrador and Arctic Regions (Wareham 2009).

According to distribution maps included in Wareham (2009), there are numerous species of corals occurring within or adjacent to the Study Area. The species identified include large gorgonians (*Keratoisis ornata*, *Paragorgia arborea*, *Primnoa resedaeformis*, 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 one scleractinian species (*Flabellum alabastrum*) and several pennatulacean species (*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. 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 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, 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 Northwest Atlantic contained 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 higher fauna. Live glass sponge reefs have been shown to provide nursery habitat for juvenile rockfish, and high-complexity reefs are associated with higher species richness and abundance (DFO 2010a).

Since 2008, the North Atlantic Fisheries Organization (NAFO) Scientific Council has identified various areas of significant coral and sponge concentrations within the NAFO Regulatory Area. These areas that have been deemed closed to fishing with bottom gear are shown in Section 4.7 on Sensitive Areas (NAFO 2015a).

As indicated by data collected during DFO RV surveys during 2008-2012, the highest coral and sponge catches in the Study Area occurred along the northeastern Newfoundland slope and Northern Grand Banks slope (see Figures 4.37 and 4.40 in Section 4.3.7). The most concentrated sponge collections occurred in the Flemish Pass area and along the slope area in the northwest portion of the Study Area (Figure 4.37).

4.2.2 Fish

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

4.2.2.1 Macro-invertebrate and Fish Species Harvested during Commercial Fisheries

This section 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 section.

Macroinvertebrates

<u>Snow Crab</u>

The snow crab, a decapod crustacean, occurs over a broad depth range in the NW Atlantic from Greenland south to the Gulf of Maine (DFO 2014b). Snow crab distribution is widespread and continuous in waters off Newfoundland and southern Labrador. Generally, snow crabs undertake a migration from shallow cold areas with hard substrates to warmer deeper areas with soft substrates as they develop. Large males are most commonly found on mud or mud/sand, while smaller crabs are more common on harder substrates (DFO 2014b).

After spring hatching, snow crab undergo a multi-stage life cycle including a 12 to 15 week planktonic larval period before settlement. Benthic juveniles of both sexes molt frequently, becoming sexually mature at about 40 mm CW (~ 4 years of age). Female crabs carry fertilized eggs for about two years (DFO 2014b). Snow crab are believed to be recruited to the fishery at approximately 10 years of age in warmer areas (e.g., Div. 2J3K) while those in colder areas (e.g., Subdiv. 3LNOPs) are recruited at higher ages owing to less frequent molting in colder temperatures (Dawe et al. 2012 *in* DFO 2014b).

Snow crab typically feed on fishes, clams, benthic worms, brittle stars, shrimps and crustaceans, including smaller snow crabs. Their predators include various groundfish, other snow crabs, and seals (DFO 2014b).

Snow crab landings in NAFO Div. 3LNO (offshore) between 2009 and 2013 have increased by 20% (DFO 2014b). However, long-term recruitment prospects in these NAFO Divisions are considered unfavourable due to a recent warming oceanic regime (DFO 2014b).

In the commercial fishery conducted within the Study Area, snow crab catches during the 2005-2013 period were most concentrated in the western and southwestern portions of the Study Area inside of the 200 m isobaths (see Figures 4.21 to 4.24 in Section 4.3).

Northern Shrimp

The primary cold-water shrimp resource in the N Atlantic, the northern shrimp is distributed from Davis Strait to the Gulf of Maine. It usually occupies areas with soft muddy substrates, depths ranging from 150 to 600 m, and water temperatures ranging from 1 to 6°C (DFO 2013a). Larger individuals generally occur in deeper waters (DFO 2013b). During the day, shrimp generally rest and feed on or near the ocean floor. They commence a diel vertical migration at night with large abundances of shrimp moving off the bottom into the water column to feed on zooplankton. Female shrimp also undergo a seasonal migration to shallower areas to spawn (DFO 2013b).

Northern shrimp are protandric hermaphrodites. They first mature as males, mate as males for one to several years and then permanently change to mature females (DFO 2013a). Eggs are typically extruded in the summer and remain attached to the female until the following spring, when the female migrates to shallow coastal waters to spawn (Nicolajsen 1994 *in* Ollerhead et al. 2004). The hatched larvae float to the surface feeding on planktonic organisms (DFO 2013b). Northern shrimp are known to live for more than eight years in some areas and are thought to begin recruitment to the fishery as early as at age three. Some northern populations exhibit slower rates of growth and maturation but greater longevity that results in larger maximum size (DFO 2013b).

As with most crustaceans, northern shrimp grow by moulting their shells. During this period, the new shell is soft, causing them to be highly vulnerable to predators such as Greenland halibut, cod, Atlantic halibut (*Hippoglossus hippoglossus*), skates (*Raja* sp.), wolffishes and harp seals (*Pagophilus groenlandicus*). Northern shrimp are vulnerable to these predators regardless of whether they have a soft shell or not (DFO 2013a).

The northern shrimp fishery in NAFO Div. 3LNO within the Study Area has seen a reduction in shrimp catch and declining TAC levels in recent years. TACs increased from 6,000 t in 2000 to 30,000 t in 2009 and 2010 but has 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 has decreased, from as many as 16 in 2006 to only one country in 2013. The majority (over 92.7%) of total biomass in NAFO Div. 3LNO from 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 declining in NAFO Div. 3M with biomass and abundance decreasing by 20% and 21% respectively in 2013 from the previous year (Casas 2013). This decline has been attributed to a lack of strong year classes and poor recruitment in recent years.

In the commercial fishery conducted within the Study Area, northern shrimp catches during the 2005-2013 period were most concentrated in the western and southwestern portions of the Study Area along the slope outside of the 200 m isobaths (see Figures 4.15 to 4.18 in Section 4.3). This spatial trend is also reflected in the DFO RV survey data collected during 2008-2012 (Figure 4.34 in Section 4.3.7).

Note that NAFO Div. 3L is closed to commercial shrimp fishing during 2015 due to the decline of the stock. The decision was made during the NAFO Annual Meeting in September 2014 (NAFO 2014a) [NAFO Press Release].

Fishes

<u>Greenland Halibut (Turbot)</u>

Greenland halibut (*Reinhardtius hippoglossoides*), often referred to as turbot, is distributed throughout the cold, deep waters of the Labrador-eastern Newfoundland area, inhabiting the continental shelf and slope at depths of 200 to >2,200 m (Smidt 1969; Morgan et al. 2013). High abundances in shelf channels have been attributed to high concentrations of available prey, namely northern shrimp (Bowering 1983). Greenland halibut feed on a variety of species, including shrimp, small pelagic crustaceans, small fish (e.g., Arctic cod, capelin), larger fish (e.g., redfish, grenadier), and squid (DFO 2008a).

Greenland halibut are highly mobile and capable of travelling long distances (Boje 2002). In addition, movements and changes in distribution of Greenland halibut may be due to fluctuations in oceanic temperatures (Morgan et al. 2013). Small-scale localized spawning may also occur along the deep slopes of the continental shelf throughout its range (Bowering and Brodie 1995).

Greenland halibut are distributed over areas of the Grand Bank and Flemish Pass. The biomass index from NAFO's Canadian research vessel fall survey of Divs. 2J3K increased from 2010 to 2013 to reach the second highest levels of the time series (1996-2013) while the biomass index from the spring survey of Divs. 3LNO (1996-2013) has been variable without trend since 2009, though generally at a lower level. Recruitment in the most recent years appears to be low in these areas (Morgan et al. 2014).

In the commercial fishery conducted within the Study Area, Greenland halibut catches during the 2005-2012 period were most concentrated in the western and southwestern portions of the Study Area along the slope outside of the 200 m isobaths (see Figures 4.27 to 4.29 in Section 4.3). In 2013, harvest locations were still concentrated in slope areas but more so in the Flemish Pass area (Figure 4.30 in Section 4.3) This spatial trend is also reflected in the DFO RV survey data collected during 2008-2012 (Figure 4.39 in Section 4.3.7).

<u>Redfish</u>

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

Redfish typically inhabit cool waters (3 to 8°C) along the slopes of banks and deep channels in depths of 100 to 700 m (Scott and Scott 1988; DFO 2012a). Although generally found near the bottom, redfish are known to undertake diel vertical migrations, moving off the bottom at night to follow the migration of their prey (DFO 2012a). Redfish are pelagic or bathypelagic feeders, feeding primarily on zooplankton such as copepods, amphipods and euphausiids. Fishes and crustaceans become more important in the diet of larger redfish (Scott and Scott 1988). Greenland halibut and skate are the primary predators of redfish on the Labrador shelf (DFO 2012a).

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

Redfish are generally slow growing and long-lived fishes (DFO 2012a). Maturation in redfish occurs between 8-10 years of age with Acadian redfish maturing, on average, 1-2 years earlier than deepwater redfish. Males also mature, on average, 1-2 years earlier than females within the same species. The reproductive cycle of redfish is quite different than those of most other fish species. Redfish are ovoviviparous, meaning fertilization is internal and females bear live young. Mating takes place in the fall, most likely between September and December, and females carry the developing embryos until they are extruded as free swimming larvae in spring. Larval extrusion takes place from April to July, the timing being dependent on location and species. Mating and larval extrusion do not necessarily occur in the same locations.

Two species of redfish have been fished in NAFO Div. 3NO: (1) the deepwater redfish; and (2) the Acadian redfish. These species have been collectively reported as “redfish” in commercial fishery statistics. There was a redfish fishery moratorium in 3N from 1998-2009, followed by a re-opening of the fishery in 2010. The TAC in 2012 was 6,000 t. In surveys completed by NAFO, biomass has always been greater in 3N than in 3O. Since 2005, over 83% of redfish catches have occurred in 3N (González-Troncoso and Paz 2014) A fishery for redfish on the shallower region of the Flemish Cap (i.e., <300 m depth) opened in 2005, prosecuted primarily by pelagic and bottom trawl (Ávila de Melo et al. 2013).

DFO RV data collected during the 2008 to 2012 period indicated highest deepwater redfish catches in slope areas of the western and southwestern portions of the Study Area, including the Flemish Pass, the Sackville Spur and the Northeast Newfoundland slope (see Figure 4.33 in Section 4.3.7).

Witch Flounder

Witch flounder (*Glyptocephalus cynoglossus*) range from the Hamilton Inlet Bank to North Carolina in the NW Atlantic (DFO 2011b). They preferentially inhabit gullies with clay, muddy sand, or pure mud bottoms, and usually move from shallower, soft mud bottoms in the summer to deeper gullies in the winter, with bottom temperatures ranging from -1 to +11ºC (DFO 2011b). A deepwater species, witch flounder is most abundant between 185 and 400 m, although some have been caught deeper than 1,500 m (DFO 2011b). Witch flounder form dense prespawning concentrations between winter and spring, and spawning occurs in shallow water and on the slopes of the Grand Banks area, in late spring to late summer or early fall (DFO 2011b). Eggs and larvae of witch flounder are pelagic, while juveniles can be either pelagic or deepwater fishes. Witch flounder have a very small mouth, and their diet consists mainly of polychaetes, small crustaceans and shellfish (DFO 2011b). Although a considerable portion of witch flounder catch occurs as by-catch of other fisheries, it has been a component of the Canadian Atlantic groundfisheries since the early 1940s (DFO 2011b).

Atlantic Halibut

Atlantic halibut, the largest of the flatfishes, is typically found along the slopes of the continental shelf. Atlantic halibut move seasonally between deep and shallow waters, apparently avoiding temperatures below 2.5ºC (Scott and Scott 1988) and prefer sandy soft bottoms that they can bury themselves in (DFO 2013c). Fish tagging studies in the Gulf of St. Lawrence have shown that Atlantic halibut can migrate long distances; up to 1,000 km, but often prefer to remain in the area that they were born. Atlantic halibut migrate horizontal as well as vertical, halibut hunt for their prey by swimming up in the water column at sunset, and return to the bottom at dawn (DFO 2013c). The spawning grounds of the Atlantic halibut are not clearly defined; however in the Gulf of St. Lawrence the Magdalen Shallows is thought to be a region favourable to the reproduction of Atlantic halibut (DFO 2013c). The fertilized eggs are slightly positively buoyant so that they naturally disperse and only gradually float toward the ocean's surface. Once hatched, the developing larvae live off their yolk for the next six to eight weeks while their digestive system develops so they can begin feeding on natural zooplankton. After a few weeks of feeding, they metamorphose from a bilaterally symmetrical larva to an asymmetrical flatfish, and are ready to assume a bottom-living habit. At this point they are ~20 mm long. As juveniles, Atlantic halibut feed mainly on invertebrates, including annelid worms, crabs, shrimps, and euphausiids. Young adults (between 30 to 80 cm in length) consume both invertebrates and fishes, while mature adults (>80 cm) feed entirely on large fishes such as other redfish, cod, haddock (*Melanogrammus aeglefinus*), small halibut and lumpfish (*Cyclopterus lumpus*) (Scott and Scott 1988; DFO 2013c). Juveniles are preyed upon mostly by cod and other large fish while full size adults are preyed on by sharks, killer whales (*Orcinus orca*), and seals (DFO 2013c).

Atlantic Cod

The NL population of Atlantic cod has *endangered* status under COSEWIC but no status under Schedule 1 of *SARA* (COSEWIC 2010a). Cod in the NL population inhabit waters ranging from immediately north of Cape Chidley on the northern tip of Labrador southeast to Grand Bank off eastern

Newfoundland. For management purposes, cod in this population are treated as five separate stocks by DFO: (1) northern Labrador cod (NAFO Divisions 2GH), (2) “northern cod” i.e., those found off southeastern Labrador, the northeast Newfoundland Shelf, and the northern half of Grand Bank (NAFO Divisions 2J3KL, (3) southern Grand Bank cod (NAFO Divisions 3NO), (4) southern Newfoundland cod (3Ps), and (5) northern Gulf cod (4RS3Pn). Cod in the Study Area are considered to be those of the southern Grand Bank (3NO) cod stock and the ‘northern cod’ (3L). The following paragraphs provide an overall summary of the life history and ecology of Atlantic cod in Canadian waters, regardless of cod population or stock (Brattey et al. 2011).

The Atlantic cod is a demersal fish that inhabits cold (10 to 15°C) and very cold (<0 to 5°C) waters in coastal areas and in offshore waters overlying the continental shelf throughout the NW and NE Atlantic Ocean (COSEWIC 2010a). The species is found contiguously along the east coast of Canada from Baffin Island to Georges Bank. During the first few weeks of life, cod eggs and larvae are found in the upper 50 m of the water column. As juveniles, cod are settled on the bottom and tend to occur in nearshore habitats with vertical structure such as eelgrass (*Zostera marina*) and macroalgae. As adults, the habitat requirements of cod are increasingly diverse.

Atlantic cod typically spawn over a period of less than three months in water that may vary in depth from tens to hundreds of metres (COSEWIC 2010a). Cod are described as batch spawners because only a small percentage (5 to 25%) of the female’s egg total is released at any given time during a three to six week period. After hatching, larvae obtain nourishment from a yolk sac until they have reached a length of 1.5 to 2.0 mm. During the larval stage, the young feed on phytoplankton and small zooplankton in the upper 10 to 50 m of the water column. After the larval stage, the juveniles settle to the bottom where they appear to remain for a period of 1 to 4 years. These settlement areas are known to range from very shallow (<10 to 30 m) coastal waters to moderately deep (50 to 150 m) waters on offshore banks. After this settlement period, it is believed that the fish begin to undertake seasonal movements and migrations characteristic of adults.

Dispersal in Atlantic cod appears to be limited to the egg and larval phases of life, during which surface and near-surface water currents and turbulence are the primary determinants of horizontal and vertical displacement in the water column (COSEWIC 2010a). For some cod populations, eggs and larvae are capable of dispersing very long distances. For example, cod eggs spawned off southeastern Labrador (NAFO Division 2J) may possibly disperse as far south as Grand Bank. By contrast, eggs spawned by cod in inshore, coastal waters, especially at the heads of large bays, may experience dispersal distances of a few kilometres or less.

Long-term movements by cod take the form of seasonal migrations (COSEWIC 2010a). These migrations can be attributed to geographical and seasonal differences in water temperature, food supply, and possibly spawning grounds. At one extreme, some inshore populations are suspected to have extremely short migrations, possibly limited to tens of kilometres or less. In contrast, cod in other populations are known to move hundreds of kilometres during their seasonal migrations.

According to COSEWIC (2010a), cod abundance in the inshore and offshore waters of Labrador and northeastern Newfoundland have declined by 97-99% since the 1960s and are currently at historical lows. Virtually no recovery of either abundance or age structure of offshore cod has been observed since the moratoria were imposed in the early 1990s and threats to persistence include fishing, predation by fish and seals, and natural and fishing-induced ecosystem changes.

In NAFO Divs. 3NO, cod are generally distributed over the shallower parts of the bank in the summer, commonly in the Southeast Shoal region in Div. 3N, and distributed on the slopes of the bank in the winter. It is possible that seasonal mixing occurs between cod in 3O and 3Ps (Rideout et al. 2013). RV surveys from DFO have reported continuing low abundances of cod in the central and southern region of 3L (DFO 2013d).

DFO RV data collected during the 2008 to 2012 period indicated highest Atlantic cod catches in slope areas of the western and southwestern portions of the Study Area, including the Flemish Pass and the Northeast Newfoundland slope (see Figure 4.35 in Section 4.3.7).

American Plaice

The Newfoundland and Labrador population of American plaice (*Hippoglossoides platessoides*) currently has no status under Schedule 1 of *SARA* but it does have *threatened* status under COSEWIC (COSEWIC 2009; DFO 2012b).

The American plaice is a bottom-dwelling flatfish that resides on both sides of the Atlantic (COSEWIC 2009). American plaice that reside in the W Atlantic region range from the deep waters off Baffin Island and western Hudson's Bay southward to the Gulf of Maine and Rhode Island (Scott and Scott 1988). In Newfoundland waters, plaice occur both inshore and offshore over a wide variety of bottom types (Morgan 2000) but seem to prefer fine sand and gravel substrates (DFO 2012b). It is tolerant of a wide range of salinities and has been observed in estuaries (Scott and Scott 1988; Jury et al. 1994). Adult and juvenile plaice typically inhabit similar areas at depths ranging from 20 to 700 m but primarily at depths of 100 to 300 m (DFO 2012b). Most commercially harvested plaice are taken at depths of 125 to 200 m. It is a coldwater species, preferring water temperatures of -1.5°C to 13°C, but is most abundant at temperatures ranging from just below zero to -1.5°C (DFO 2012b). Tagging studies in Newfoundland waters suggest that, once settled, juveniles and adults are rather sedentary and do not undertake large scale migrations (DFO 2008b). However, older plaice have been known to move up to 160 km (Powles 1965). Migrations have been observed in Canadian waters to deeper offshore waters in the winter, returning to shallower water in the spring (Hebert and Wearing-Wilde 2002 *in* Johnson 2004).

In Newfoundland waters, American plaice spawn during the spring (Scott and Scott 1988). Within the Study Area, there is limited data with respect to the actual spawning times. American plaice in the Newfoundland Region spawn over the entire area within which they occur (DFO 2008b) with the most intense spawning coincident with areas with the highest abundance of adults (Busby et al. 2007; DFO 2012b). Limited data in southern areas (e.g., Burgeo Bank, St. Pierre Bank and along the slopes of the Laurentian Channel and Hermitage Channel) indicate that spawning does occur in April and possibly other months (Ollerhead et al. 2004). In addition, spawning in southern areas (e.g., St. Pierre Bank) typically occurs in water temperatures of about 2.7°C (Scott and Scott 1988). American plaice are group synchronous, batch spawners that generally release eggs in batches every few days (DFO 2012b). Large quantities of eggs are released and fertilized over a period of days on the seabed (Johnson 2004). Eggs are buoyant and drift into the upper water column where they are widely dispersed. Hatching time is temperature dependent, occurring in 11 to 14 days at temperatures of 5°C (Scott and Scott 1988). Larvae are 4 to 6 mm in length at hatch and subsequent settlement to the seabed occurs when they reach 18 to 34 mm in length and their body flattens (Fahay 1983).

American plaice has been under moratorium since 1995. Biomass and spawning stock biomass remain at very low levels but have increased since the onset of the moratorium. NAFO surveys in 3LNO have demonstrated low recruitment since the late 1980s. Bottom trawl surveys conducted by NAFO on the Flemish Cap (3M) have indicated that the stock has slightly increased in recent years due to improved recruitment since 2009, however the stock still remains at a low level (Mandado 2014).

DFO RV data collected during the 2008 to 2012 period indicated highest American plaice catches in the southwestern portion of the Study Area, in both the shelf and slope areas (see Figure 4.38 in Section 4.3.7).

Roughhead Grenadier

The roughhead grenadier occurs in deep water along coasts in subarctic to temperate waters on both sides of the North Atlantic. In the Northwest Atlantic, this species of grenadier occurs from Davis Strait along the continental slope, off Newfoundland, off Nova Scotia on Banquereau, Sable Island and Browns Bank, and on Georges Bank (Scott and Scott 1988). The roughhead grenadier is predominant at depths ranging from 800 to 1,500 m, although it may inhabit depths between 200 and 2,000 m (Murua and De Cardenas 2005 *in* González-Costas 2013). Catches tend to be highest at water temperatures ranging between 2.0 and 3.5ºC (Scott and Scott 1988). The roughhead grenadier is an abundant and widespread species in the Northwest Atlantic. This fish generally occurs both on the shelf and on the continental slope at depths ranging from 400 to 1,200 m. It has been found at depths as shallow as 200 m and as deep as 2,700 m.

Spawning is thought to occur during the winter and early spring. Little is known about the spawning grounds of this fish off Newfoundland although it is believed that some spawning does occur on the southern and southeastern slopes of the Grand Banks (Scott and Scott 1988; COSEWIC 2007). Food for the roughhead grenadier consists of a variety of benthic invertebrates including bivalve molluscs, shrimp, sea stars, polychaetes, and some fish. Roughhead grenadier has been found in the stomachs of Atlantic cod. This grenadier species is quickly becoming an important commercial fish in the Northwest Atlantic. Presently its fishery is unregulated since it is usually taken as bycatch in the Greenland halibut fishery in Div. 3LMN (Róman et al. 2014).

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

4.2.2.2 Other Fishes of Note

Capelin

Capelin is a small pelagic species that has a circumpolar distribution in the northern hemisphere (DFO 2013e). Capelin are often found along the coasts during the spawning season and occur pre-dominantly in offshore waters (e.g., Grand Banks) while immature and maturing. Migration towards the coast precedes spawning on beaches or in deeper waters (Nakashima and Wheeler 2002; DFO 2013e). The preferred spawning substrate is usually fine to coarse gravels. Capelin beach spawning typically occurs at a water temperature range of 5 to 8.5°C, but they have been observed to spawn at 4 to 10°C. Beach spawning is more prevalent at night. On the bottom, spawning temperatures can be as low as 2°C as observed on the Southeast Shoal, located far south of the Study Area. Capelin are able to spawn at the age of two; males and most females usually die following spawning. Spawning commences in early June and may continue through July or August depending on tides, winds, and water temperatures (Scott and Scott 1988; Nakashima and Wheeler 2002, DFO 2013e). Incubation varies with ambient temperature and lasts ~15 days at 10°C (Scott and Scott 1988). Once hatched, larval capelin can be found at the surface to depths >40 m (Frank et al. 1993).

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

Capelin is a major component in marine ecosystem dynamics as they are a key forage species that facilitate the transfer of energy between trophic levels, principally between primary and secondary producers to higher trophic levels (DFO 2013e). Capelin predators comprise most major fish species including Atlantic cod, haddock, herring (*Clupea harengus*), flatfish species, dogfish (*Squalus* sp.), and others. Several marine mammal species including minke whales (*Balaenoptera acutorostrata*), fin whales (*Balaenoptera physalus*), harp seals (*Pagophilus groenlandicus*), ringed seals (*Pusa hispida*), and a variety of seabirds also prey on capelin.

Other than the fishery the primary cause of capelin mortality is predation, and as such, variations in capelin abundances are directly linked to natural causes (DFO 2013e). Capelin have a short life span (usually five years or less), and abundances are linked to a few age classes. Management of capelin fisheries tends to be conservative as a result of the prominent role of capelin in the marine ecosystem.

DFO RV data collected during the 2008 to 2012 period indicated highest capelin catches in the southwestern portion of the Study Area, in both the shelf and slope areas (see Figure 4.36 in Section 4.3.7).

Wolffishes

Three species of wolffish (i.e., northern *Anarhichas denticulatus*, spotted *A. minor*, and Atlantic *A. lupus)* are currently listed on Schedule 1 of *SARA*. Both the northern and spotted wolffishes are designated as *threatened* on Schedule 1 of *SARA* and under COSEWIC. The Atlantic wolffish is designated as *special concern* on Schedule 1 of *SARA* and under COSEWIC.

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

<u>Atlantic Wolffish</u>

The Atlantic wolffish is primarily demersal and it inhabits shallower areas than the northern and spotted wolffishes. This species has been observed from near shore to a depth of 918 m at water temperatures ranging from -1 to 10°C, but are most common at water depths of 150 to 350 m with water temperatures ranging from 1.5 to 4°C. During 1980-1984, this species was most concentrated in the same areas as the northern wolffish, with additional concentrations on the southern Grand Banks and the Gulf of St. Lawrence. More recently, the area occupied and density within the area was considerably reduced in the northern part of its confirmed range, but has remained relatively constant in the Gulf of St. Lawrence. Unlike the northern and spotted wolffishes, Atlantic wolffish are often observed by divers close to shore, and they form dense concentrations offshore. During its feeding period, this wolffish species appear to prefer complex reliefs of rocks without algal growth and sand. Shelters in these rock reliefs are typically situated on 15-30° slopes with good water circulation. There is some indication that Atlantic wolffish form colonial settlements during the feeding period (Kulka et al. 2007).

Prey of Atlantic wolffish are primarily benthic (>85%), typically including echinoderms (e.g., sea urchins), crustaceans (e.g., crabs) and molluscs (e.g., scallops) associated with both sandy and hard bottom substrates. This species is referred to as a mollusc specialist (i.e., benthivore) (DFO 2011c). Fish also constitutes part of the spotted wolffish diet (<15%) (e.g., redfish). Migration by Atlantic wolffish is also limited, with seasonal inshore movement in the spring when mature fish are found in areas with water depths <15 m. These wolffish seem to prefer stony bottom substrate for spawning in September and October in Newfoundland and Labrador waters. After internal fertilization, cohesive masses of eggs are deposited in crevices on the bottom, remaining unattached to the substrate. The egg mass is guarded and maintained by the male Atlantic wolffish for the 7 to 9 month incubation time, after which pelagic larvae hatch and commence to feed on crustaceans, fish larvae and fish eggs within a few days of hatching (Kulka et al. 2007).

DFO RV data collected during the 2008 to 2012 period indicated that 2,780 individuals were caught within the Study Area (see Table 4.7 in Section 4.3.7). The highest Atlantic wolffish catches occurred in the western and southwestern portions of the Study Area, primarily in slope areas but also at certain locations on the shelf (see Figure 4.41 in Section 4.3.7).

4.2.3 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 to 10 months and larvae hatch in the spring	12 to 16 weeks
Snow crab	On banks and possibly along some upper slope regions over the extent of its distribution	Mating in early spring Fertilized eggs carried by female for 2 years and larvae hatch in late spring/early summer	12 to 15 weeks
Greenland halibut	Spawning grounds extend from Davis Strait (south of 67°N) to south of Flemish Pass between 800 m and 2,000 m depth	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 to 8 weeks
American plaice	Spawning generally occurs throughout the range the population inhabits.	April to May	12 to 16 weeks
Redfish	Primarily along edge of shelf and banks, in slope waters, and in deep channels	Mating in late winter and release of young between April and July (peak in April)	No planktonic stage
Atlantic cod	Spawn along outer slopes of the shelf in depths from tens to hundreds of metres	March to June	10 to 12 weeks
Wolffishes	Along bottom in deeper water, typically along continental slope	Summer to early winter (species dependent)	Uncertain
Porbeagle shark	Very little known about the location of the pupping grounds; likely southern Grand Banks	Mating in late summer/fall and pupping between early April and early June	Uncertain
Sand lance	On sand in shallow water of the Grand Banks	November to January	Several weeks

4.3 Fisheries

This section primarily describes the commercial fishery in the Study Area between 2005–2013. Figure 4.1 shows the locations of the Study and Project Areas in relation to the regional fisheries management areas. As the figure indicates, the Study Area overlaps portions of NAFO Divisions 2J, 1F, 3K, 3L and 3M.

This section also briefly describes recreational fisheries, traditional fisheries, aquaculture activity, and fisheries research surveys in the Study Area. The biology and status of the principal macro-invertebrate and fish species included in this section were discussed in the Section 4.2 on fish and fish habitat.

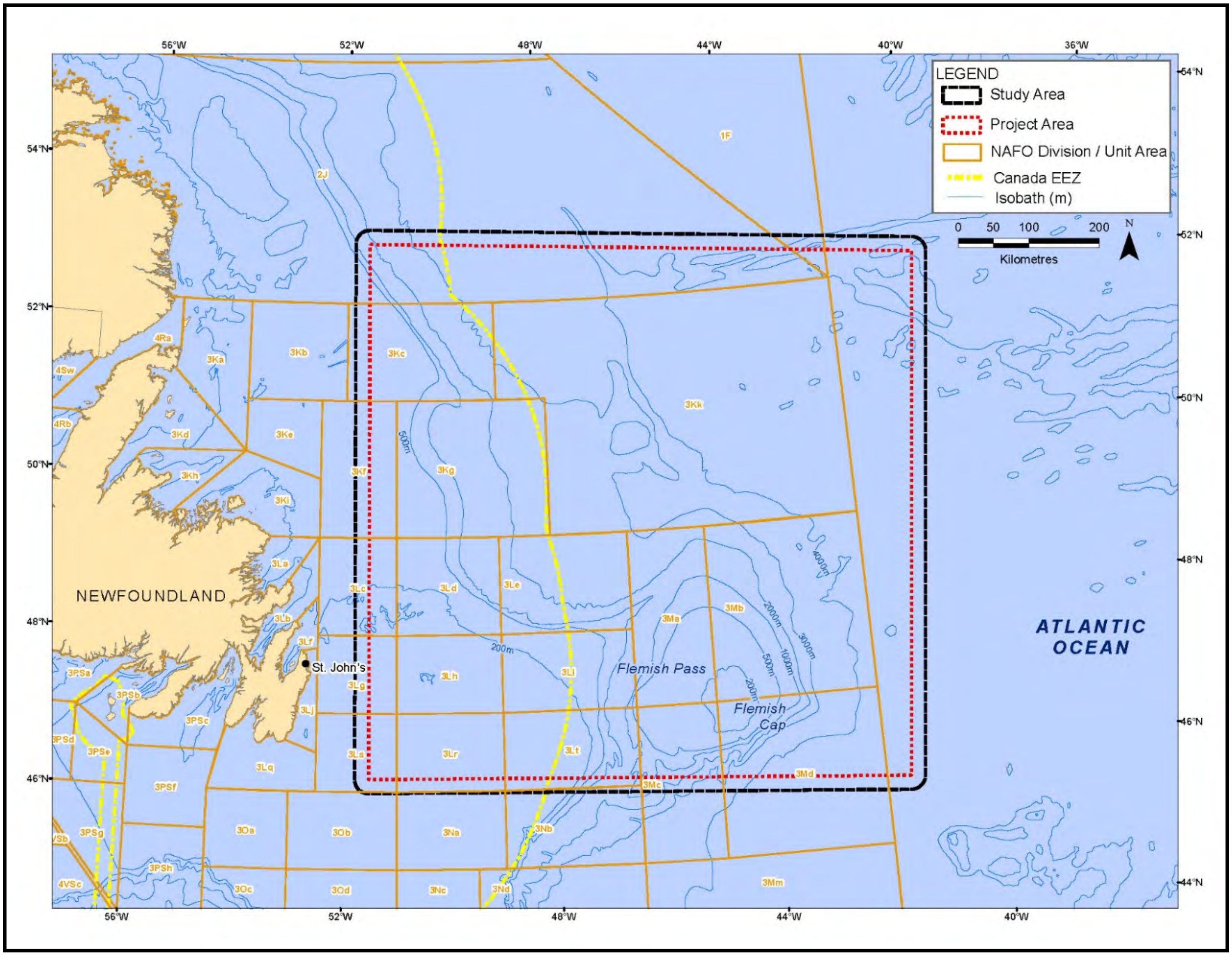


Figure 4.1 Study Area and Project Area in Relation to Regional Fisheries Management Areas (NAFO Divisions and Unit Areas).

4.3.1 Information Sources

NAFO catch weight data are used to describe both domestic and foreign fisheries prosecuted beyond the 200 nm EEZ. Most of the Study Area is located outside of the 200 nm limit (see Figure 4.1). The NAFO data are derived from the STATLANT 21 data set for 2005–2013. The STATLANT reporting system of questionnaires is a long-standing standardized statistical inquiry for submission of national catch data to international fisheries agencies by national reporting offices. Rather than being georeferenced, these STATLANT data are geographically resolved at the NAFO Division level only. Thus the analysis of these data quantifies harvesting for portions of NAFO Divisions 2J, 1F, 3K, 3L and 3M (see Figure 4.1).

The primary fisheries data analyses use all DFO Atlantic Regions georeferenced landings data for the 2005–2010 time period. The 2011, 2012 and 2013 landings data were provided as ranges of catch weight and catch value within 6 min x 6 min cells (latitude x longitude). Figures based on the 2005-2013 commercial fishery landings data are included in the EA. The DFO datasets record domestic harvest and foreign harvest landed in Canada.

The 2005–2010 DFO data are georeferenced in two ways: (1) by latitude and longitude (degrees and minutes) of the gear set location; and (2) by NAFO Unit Area (UA) in which the catch was harvested. Georeferencing by latitude and longitude allows the mapping of specific harvesting locations. Areas farther from shore, generally fished by larger vessels, tend to have a greater proportion of their catches georeferenced than those closer to shore. Certain inshore species (e.g., lobster) are not georeferenced. While most of the data have associated latitude and longitude information, virtually all of the data have a UA designation. The UA designation allows all the harvesting data to be tabulated according to these fisheries management areas. It is important to note that some of the UAs occur only partially within the boundaries of the Study Area. For these UAs, the harvesting locations occurring outside of the Study Area were excluded from analysis for the detailed overview of the 2005–2010 fishing seasons.

The maps in this section show harvesting locations for 2005–2010, based on the latitude and longitude (lat/long) data, as dark points. The data coordinates provided are those recorded in the vessel's fishing log, and are reported in the DFO datasets by degree and minute of latitude and longitude; thus the position should be accurate to within approximately 925 m [0.5 nm] of the reported coordinates. The points are not "weighted" by quantity of harvest, but show where fishing effort was recorded. Such location data have been groundtruthed with fishers during consultations conducted for previous EAs. They have proven to be particularly useful in understanding the likely location of gear concentrations and timing of fisheries in order to minimize potential conflict between the fishers and other marine users. DFO catch data for 2011, 2012 and 2013, based on 6 min x 6 min cells, are displayed as uniformly coloured grid cells representing cells within which harvesting was reported. Samples of fishery harvest location maps were presented during consultations.

The data primarily used to characterize the fisheries in this EA are harvest catch weights. Catch value is used to demonstrate that some species have lower ranked catch weights but are highly ranked in terms of value. Catch values are important in the case of a gear damage incident and would be carefully evaluated at that time, based on current numbers, to calculate compensation.

Various groups were involved in consultations that included discussions related to fisheries (see Section 5.1.1). One purpose of the consultations was to gather both spatial and temporal information about fisheries and to determine any issues or concerns to be considered in the EA. In addition, the consultations provided a means for discussion about potential mitigations meant to minimize the potential impacts of activities on the fisheries (see Consultation Report in Appendix 1).

Other sources used for this assessment include DFO species management plans, DFO stock status reports and other internal documents, previous EAs relevant to the Study Area, and the Eastern Newfoundland SEA (C-NLOPB 2014).

4.3.2 Regional NAFO Fisheries

NAFO manages 19 stocks comprised of 11 species: Atlantic cod (3L, 3M, 3NO stocks), redfish (3LN, 3M, 3O, Sub-area 2 and Div. 1F+3K stocks), American plaice (3LNO, 3M stocks), yellowtail flounder (*Limanda ferruginea*) (3LNO stocks), witch flounder (3L, 3NO stocks), white hake (*Urophycis tenuis*) (3NO stock), capelin (3NO stock), skates (3LNO stock), Greenland halibut (3LMNO stock), squid (*Illex* sp.; Sub-areas 3+4 stock), and shrimp (3L and 3NO stocks). Of the 19 stocks managed by NAFO, 16 straddle the EEZ; only the 3M cod, redfish and American plaice stocks occur entirely outside of the EEZ. Most fishing for relevant species in the NAFO Convention Regulatory Area is conducted using bottom trawlers.

The Study Area overlaps portions of NAFO Divisions 2J, 1F, 3K, 3L and 3M (see Figure 4.1). During the 2005–2013 period, commercial harvesting within the Study Area beyond the 200 nm EEZ, in terms of catch weight, was dominated by northern shrimp (41% of total catch weight; primarily in NAFO Division 3K), snow crab (17%; primarily in 3L), capelin (11%; exclusively and approximately equally in 3K and 3L), and Greenland halibut (6%; primarily in 3L). The highest catch weights during the nine year period were reported in NAFO Divisions 3K (35%), and 3L (34%), followed by 2J (14%), 3M (11%) and 1F (5%). Canadian vessels accounted for 77% of the commercial catch weight reported for this area during 2005–2013. Only in Divisions 3M and 1F did the foreign vessels dominate catches (>99% of total catch weight in these Divisions). Catches in 3M were dominated by northern shrimp, Atlantic redfishes, Atlantic cod, and Greenland halibut. Catches in 1F were dominated by Atlantic cod, Atlantic redfishes, deepwater beaked redfish, and northern shrimp.

4.3.3 Domestic Fisheries

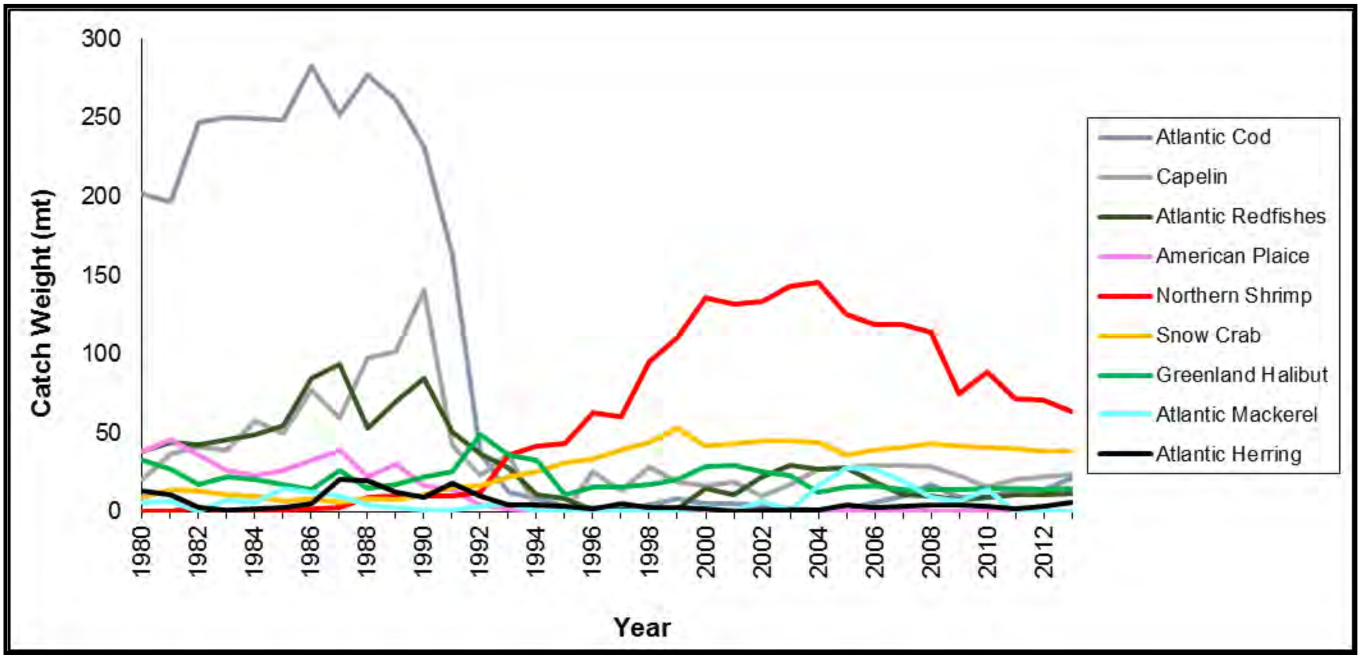
This section provides an overview of the commercial fisheries within and/or adjacent to the Study Area. The first part of this section provides the historical context. The second part of this overview provides recent information for the georeferenced (lat/long) data recorded specifically within the Study Area for 2005–2010, and gridded cell (6 min x 6 min) data for 2011, 2012 and 2013. Statistical summaries of the commercial catch data are provided for the Study and Project areas.

4.3.3.1 Historical Fisheries

A historical overview of fisheries was given in Section 4.3.4.2 of the Eastern Newfoundland SEA (C-NLOPB 2014). Commercial fish harvesting in many parts of Newfoundland and Labrador has changed considerably over the last two decades, shifting from a groundfish-based to a shellfish-based industry. In the early 1990s, a harvesting moratorium was imposed on several commercially important groundfish species so that directed fisheries for Atlantic cod and other groundfish were no longer permitted in most areas. The shifting environmental conditions were favourable for crustaceans (e.g., colder water temperature) and rapid declines in Newfoundland and Labrador's groundfish stocks resulted in the rapid growth of crustacean populations such as northern shrimp and snow crab. All fish have physiological limits within which they can survive, such as sea temperatures and salinities (Rose 2005). Frank et al. (1990) analyzed the effects of changes in oceanographic conditions induced by a global increase in atmospheric CO_2, and their models predicted a general warming and freshening of the continental shelf waters, leading to shifts in the geographic distribution of important commercial groundfish stocks, earlier arrival and later departure times for highly migratory large pelagics, and, in combination with increased water column stratification, decreased organic material accumulating on the seabed. Rose (2005) inferred that capelin and Atlantic herring react strongly and quickly to climate change, owing to their physiological limits and potential for fast population growth. This was verified through examination of historical data from Icelandic and Greenland waters which warmed considerably between 1920 and 1940, resulting in capelin, Atlantic herring, Atlantic cod, and other species quickly shifting northwards.

The Study Area fisheries were not exceptions to this trend away from groundfish and towards crustacean harvesting (e.g., LGL 2013b, 2014a,b). In the late 1980s, the fisheries in NAFO Divisions 2J, 1F, 3K, 3L and 3M largely targeted Atlantic cod, capelin, Atlantic redfishes and American plaice (Figure 4.2). After large groundfish catches in NAFO Divisions in and around the Study Area in the 1970s and 1980s, the fishery was considerably reduced in the early 1990s at the time of the moratorium (Figure 4.2). Since the early 1990s, much lower quotas have been allocated, based on scientific advice and other considerations. Atlantic cod and American plaice remain priority species for Canada in a number of NAFO Divisions, and Integrated Fisheries Management Plans (IFMPs) are currently in place for these and several other species in the Newfoundland and Labrador region, including several groundfish species, northern shrimp, snow crab, yellowtail flounder, Atlantic mackerel, Atlantic swordfish and various tunas (DFO 2014c). Today, there is limited directed fishery for Atlantic cod and only a modest by-catch is allowed (DFO 2013f).

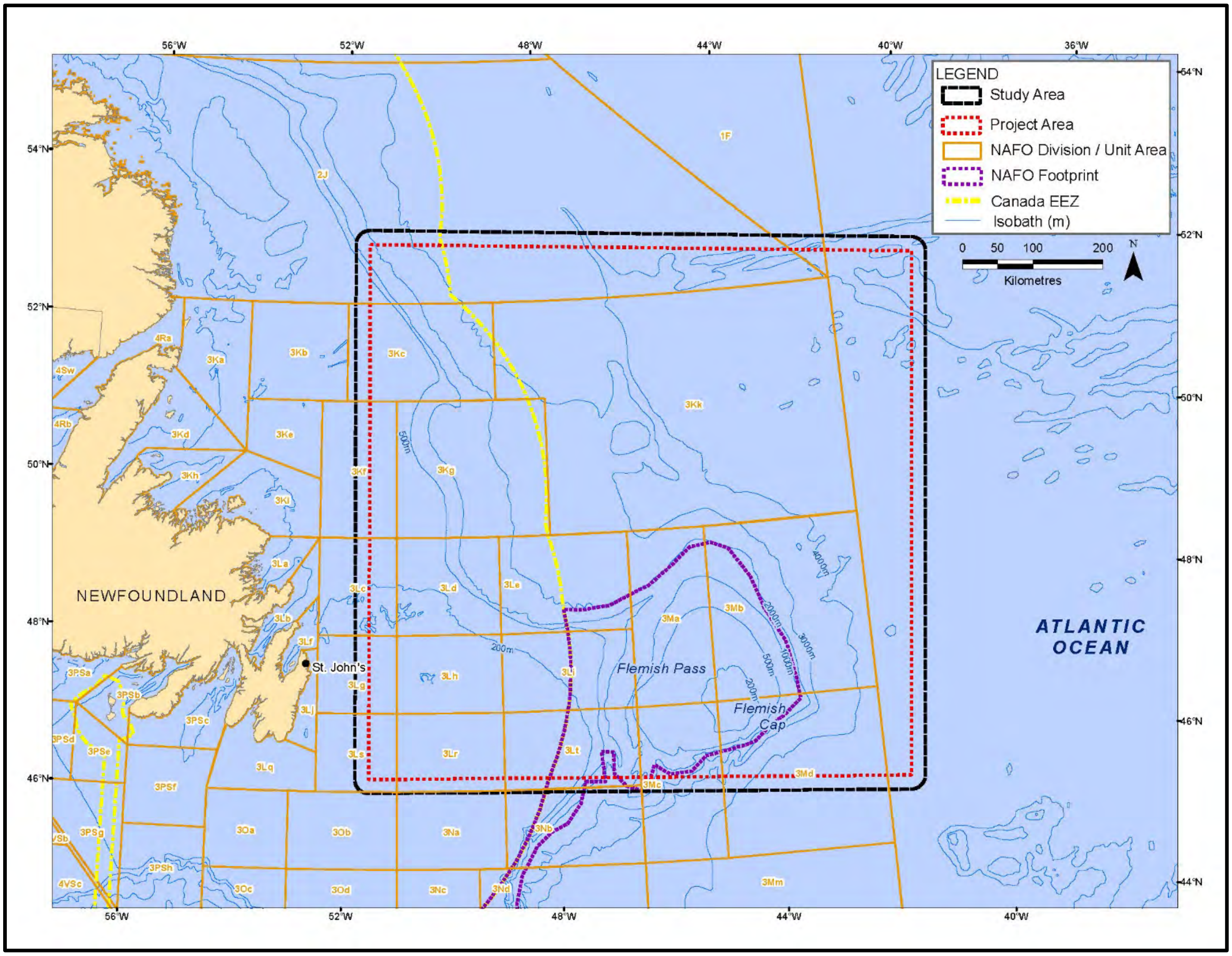
Overall, the Study Area groundfish fishery has been greatly reduced while the invertebrate fisheries have grown in importance. Invertebrate catches, most notably northern shrimp and snow crab, have become increasingly important within the Study Area, particularly since the mid-1990s. However, northern shrimp stocks have recently begun to decline, with poor recruitment and drastic declines in shrimp biomass in NAFO Divisions 3M and 3LNO since 2007 (NAFO 2013). There has been a moratorium on the shrimp fishery in Division 3M since 2010 (NAFO 2014b), and there will be no shrimp fishery permitted within Division 3L in 2015 (NAFO 2015b). The decrease in shrimp biomass in 3M has been correlated with an increase in the cod stock in that Division; however, it is currently unclear whether this relationship is causal and/or the result of other environmental factors (NAFO 2013).



Source: NAFO STATLANT 21A Data Extraction Tool.

Figure 4.2 Historical Catch Weights for Predominant Species in the Commercial Fisheries in NAFO Divisions 2J, 1F, 3K, 3L and 3M, all Countries, 1980–2013.

In 2007, the United Nations General Assembly (UNGA 2007 *in* NAFO 2009) requested Regional Fisheries Management Organizations to "regulate bottom fisheries that cause a significant adverse impact on vulnerable marine ecosystems" (NAFO 2009). Implementation guidelines drafted by the Food and Agriculture Organization of the United Nations (FAO) in 2007–2009 called for the mapping of existing bottom fisheries (FAO 2009 *in* NAFO 2009). Participant Flag-states (ten in total) were called upon to submit maps identifying bottom fishing areas within NAFO's Regulatory Area (NRA) from 1987–2007, with priority given to trawl activity (NCEM 2009 *in* NAFO 2009). From these data, NAFO's bottom fishing footprint was developed, including the most highly bottom-fished areas beyond Canada's EEZ (Figure 4.3). Note that the footprint does not represent harvesting areas that are used every year, rather an aggregate of harvesting areas during the 20-year period. The footprint may be revised regularly to incorporate any new relevant information (NAFO 2015b). The NAFO footprint currently has an area of 120,048 km^2, of which ~5.4% is closed to bottom fishing (includes portions of the Coral and Sponge Closures; see Section 4.7.



Source: NAFO 2015a.

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

4.3.3.2 Study Area Catch Analysis, 2005–2013

The May–November, 2005–2010, domestic harvests reported within the Study Area and Project Area are shown in Table 4.2. Domestic harvests from within the Study Area, May–November, 2011–2013, are shown in Tables 4.3–4.5. As indicated, the principal fisheries (by catch weight and value; in order of descending importance) are for northern shrimp, snow crab and Greenland halibut, which combined accounted for >98% of the average annual catch weight in these areas during May–November, 2005-2010. Snow crab replaced northern shrimp as the predominant species caught in 2013. Other notable species in commercial fisheries in the Study Area include redfishes, American plaice, yellowtail flounder, roughhead grenadier, witch flounder, Atlantic cod, capelin, and Atlantic halibut (see Section 4.2 for species descriptions). The total annual commercial fisheries catch weights of all species in the Study Area during May–November, 2005–2010, remained relatively constant, between ~60,000–71,000 mt per year, with the exception being 2009 when it dropped to ~45,000 mt (Figure 4.4).

Table 4.2 Study Area and Project Area Average Annual Catch Weight and Value by Species, May–November, 2005–2010.

Species	Study Area				Project Area			
	Quantity		Value		Quantity		Value	
	mt	% of Total	$	% of Total	mt	% of Total	$	% of Total
Northern Shrimp	43,918	70.4	48,070,247	48.6	37,496	70.9	41,228,173	49.1
Snow Crab	14,686	23.6	44,669,044	45.2	12,189	23.1	37,098,821	44.2
Greenland Halibut	2,935	4.7	5,592,399	5.7	2,816	5.3	5,371,515	6.4
Yellowtail Flounder	482	0.8	320,815	0.3	106	0.2	68,641	0.1
Redfish	87	0.1	46,460	<0.1	79	0.1	41,997	0.1
American Plaice	65	0.1	41,055	<0.1	22	0.0	13,317	<0.1
Roughhead Grenadier	46	0.1	18,571	<0.1	45	0.1	18,118	<0.1
Mackerel	41	0.1	13,603	<0.1	32	0.1	10,720	<0.1
Witch Flounder	28	<0.1	12,860	<0.1	28	0.1	12,832	<0.1
Atlantic Cod	21	<0.1	27,632	<0.1	16	<0.1	21,589	<0.1
Capelin	11	<0.1	2,757	<0.1	11	<0.1	2,757	<0.1
Skate	7	<0.1	1,993	<0.1	7	<0.1	1,967	<0.1
Herring	6	<0.1	1,164	<0.1	6	<0.1	1,164	<0.1
Swordfish	3	<0.1	20,964	<0.1	3	<0.1	19,574	<0.1
Bigeye Tuna	1	<0.1	12,661	<0.1	1	<0.1	12,661	<0.1
Atlantic Halibut	1	<0.1	6,606	<0.1	1	<0.1	6,328	<0.1
Bluefin Tuna	1	<0.1	6,032	<0.1	1	<0.1	6,032	<0.1
Albacore Tuna	0.5	<0.1	5,639	<0.1	0.5	<0.1	5,604	<0.1
Mako Shark	0.2	<0.1	256	<0.1	0.2	<0.1	256	<0.1
Icelandic Scallops	0.1	<0.1	164	<0.1	0.1	<0.1	164	<0.1
Sea Scallops	0.1	<0.1	254	<0.1	0.1	<0.1	254	<0.1
Rock Crab	0.1	<0.1	74	<0.1	0.1	<0.1	74	<0.1
Atlantic Wolffish	<0.1	<0.1	4	<0.1	0	0.0	1	<0.1
White Marlin	<0.1	<0.1	11	<0.1	<0.1	<0.1	11	<0.1
Dolphinfish	<0.1	<0.1	4	<0.1	<0.1	<0.1	4	<0.1
Yellowfin Tuna	<0.1	<0.1	25	<0.1	<0.1	<0.1	25	<0.1
Roundnose Grenadier	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1
White Hake	<0.1	<0.1	0	0.0	<0.1	<0.1	0.4	<0.1
Totals	**62,340**	**100**	**98,871,293**	**100**	**52,860**	**100**	**83,942,599**	**100**

Source: DFO commercial landings database, 2005–2010.

The list of species harvested in the Study Area was consistent during May–November, 2005–2013, with the following exceptions:

- Fewer species recorded in 2011–2013 as compared to 2005–2010;
- Fewer species recorded (and lower catch weights – see Figure 4.4) in each consecutive year from 2011–2013;
- Fewer total catch counts recorded in 2013 than 2011 or 2012;

- The following species were reported as harvested during 2005–2010 but not during 2011-2013: albacore tuna, Atlantic wolffish, bigeye tuna, bluefin tuna, dolphinfish, Icelandic scallops, mako shark, rock crab, roundnose grenadier, swordfish, white hake, white marlin, and yellowfin tuna;
- The following species were reported as harvested during 2005–2012 but were not in 2013: roughhead grenadier, skate, and yellowtail flounder; and
- The following species were sporadically reported as harvested between 2005–2013: herring (2005–2010 and 2013), mackerel (2005–2010 and 2011), winter flounder (2011), and whelks (2012).

Table 4.3 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	
Northern Shrimp	424	476	609	661	538	549	693	390	2,170
Snow Crab	160	383	650	185	100	306	565	407	1,378
Greenland Halibut	93	220	177	54	77	217	182	68	544
Redfish	44	81	114	49	62	81	98	47	288
Witch Flounder	23	47	76	43	39	45	64	41	189
Roughhead Grenadier	14	43	56	17	14	38	55	23	130
American Plaice	14	20	27	23	30	18	24	12	84
Atlantic Halibut	6	18	22	15	10	28	19	4	61
Atlantic Cod	28	13	1	4	37	4	4	1	46
Skate	2	20	19	4	2	18	15	10	45
Yellowtail Flounder	1	10	2	4	11	2	3	1	17
Haddock	2	11	0	4	11	2	3	1	17
Sea Scallops	2	0	0	0	2	0	0	0	2
Capelin	0	1	1	0	1	0	1	0	2
Mackerel	0	1	1	0	0	2	0	0	2
Winter Flounder	1	0	0	0	1	0	0	0	1
Total	**814**	**1,344**	**1,755**	**1,063**	**935**	**1,310**	**1,726**	**1,005**	**4,976**

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 4.4 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	
Northern Shrimp	254	331	357	325	354	321	349	243	1,267
Snow Crab	110	306	545	189	86	225	473	366	1,150
Greenland Halibut	89	163	138	14	82	165	144	13	404
Redfish	27	56	89	15	31	57	90	9	187
Witch Flounder	8	15	48	10	10	20	44	7	81
Roughhead Grenadier	9	24	32	8	9	32	29	3	73
Atlantic Halibut	8	17	31	11	12	24	27	4	67
Skate	3	13	22	0	3	9	24	2	38
Atlantic Cod	8	7	14	7	13	16	7	0	36
American Plaice	3	6	15	4	8	7	11	2	28
Yellowtail Flounder	1	5	4	3	6	6	1	0	13
Haddock	0	1	2	3	1	4	1	0	6
Capelin	0	0	5	1	5	0	1	0	6
Whelks	0	2	0	0	0	2	0	0	2
Sea Scallops	1	0	0	0	1	0	0	0	1
Total	**521**	**946**	**1,302**	**590**	**621**	**888**	**1,201**	**649**	**3,359**

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 4.5 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).

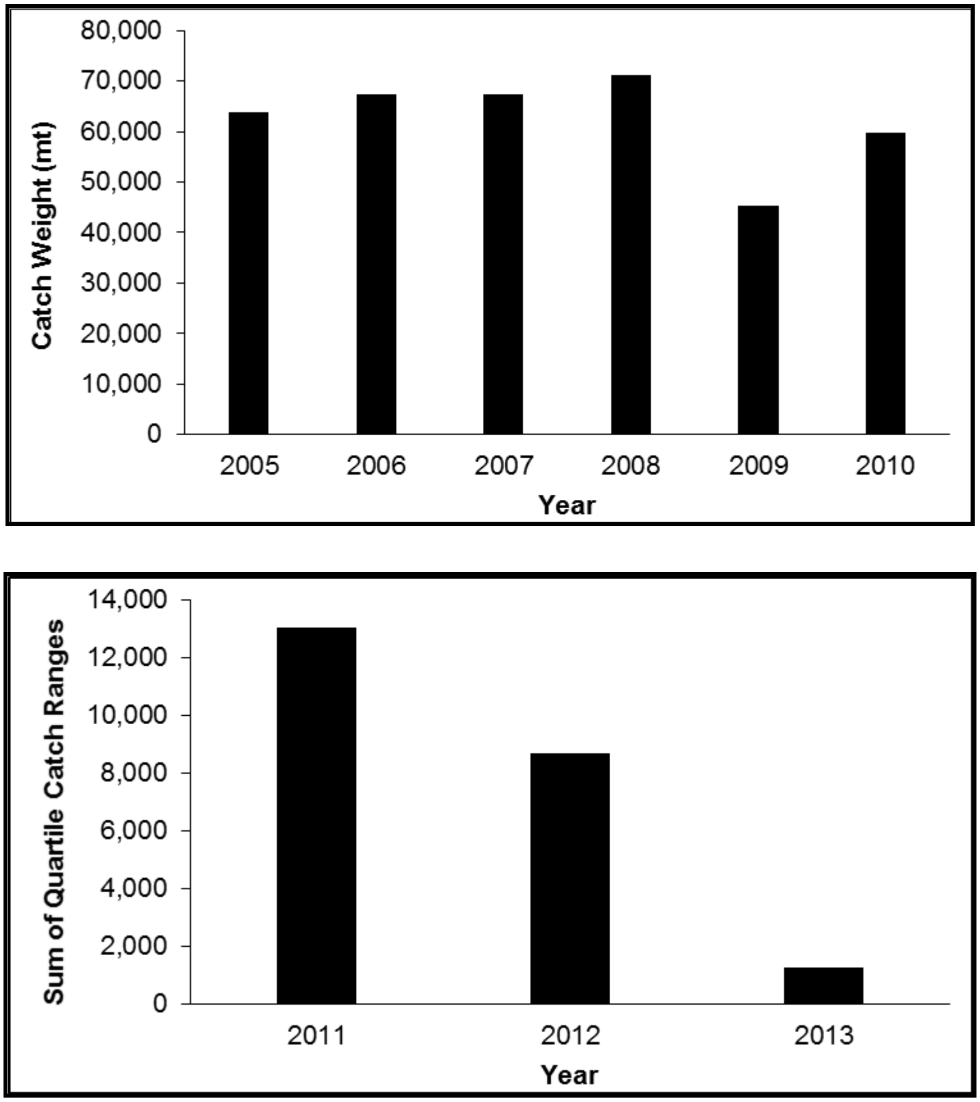
Species	Catch Weight Quartile Code Counts [a]				Catch Value Quartile Code Counts [b]				Total Counts [c]
	1	2	3	4	1	2	3	4	
Snow Crab	61	109	105	21	51	94	107	44	296
Northern Shrimp	87	61	22	3	108	45	18	2	173
Greenland Halibut	35	38	9	0	28	44	10	0	82
Redfish	12	20	12	2	16	15	13	2	46
Atlantic Cod	3	10	6	2	11	4	4	2	21
Atlantic Halibut	1	2	3	1	1	2	3	1	7
American Plaice	1	3	0	0	2	1	1	0	4
Witch Flounder	2	0	1	0	2	0	1	0	3
Capelin	0	1	1	0	2	0	0	0	2
Herring	1	0	0	0	1	0	0	0	1
Total	**203**	**244**	**159**	**29**	**222**	**205**	**157**	**51**	**635**

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.

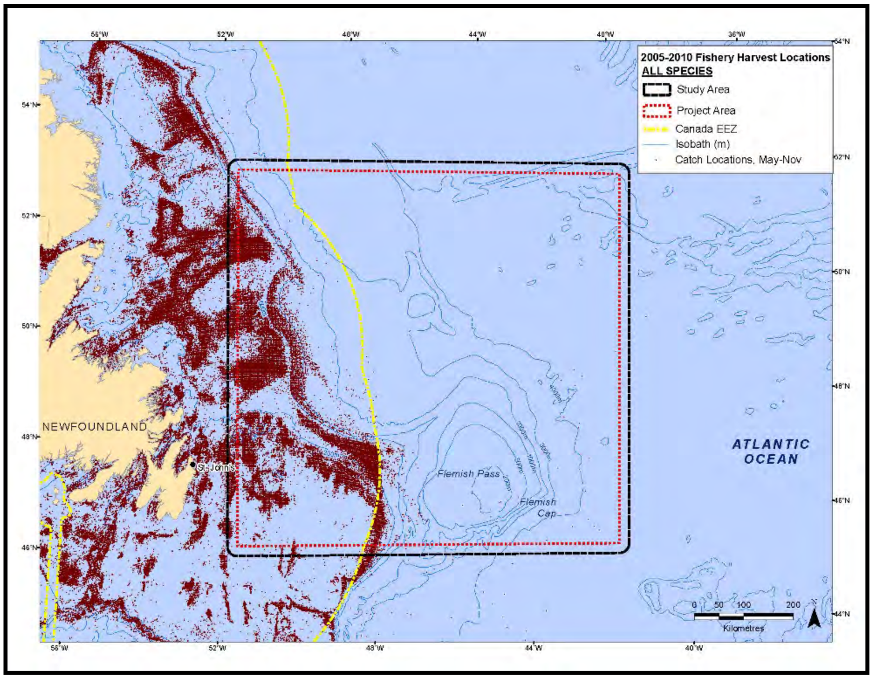


Source: DFO commercial landings database, 2005–2013.
Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.4 Annual Total Catch Weight, May–November, 2005–2010 (top), and Annual Total Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) (all species within the Study Area).

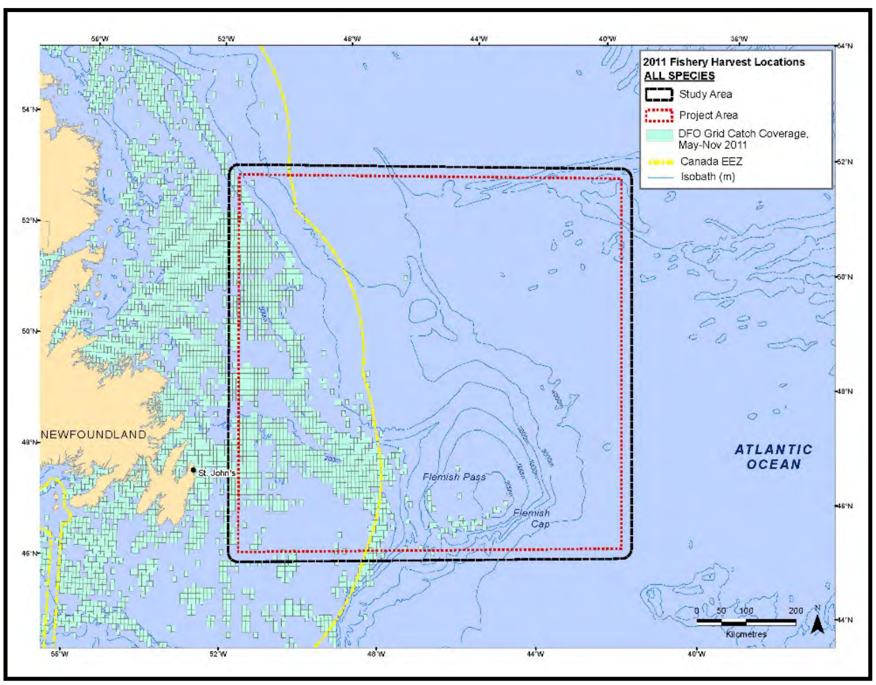
Commercial Harvest Locations in the Study Area

Figure 4.5 shows georeferenced harvest locations and Figures 4.6–4.8 show harvest locations in 6 x 6 minute cells in relation to the Study and Project Areas for all species, May–November, 2005–2010, 2011, 2012 and 2013, respectively. As Figures 4.5–4.8 indicate, most of the fish harvesting occurs in the western part of the Study and Project Areas, principally on the Grand Banks shelf and slope to the 1,000 m isobath. A comparison with fisheries maps in the Eastern Newfoundland Offshore Area SEA (C-NLOPB 2014) indicates that these locations are generally consistent from year to year.



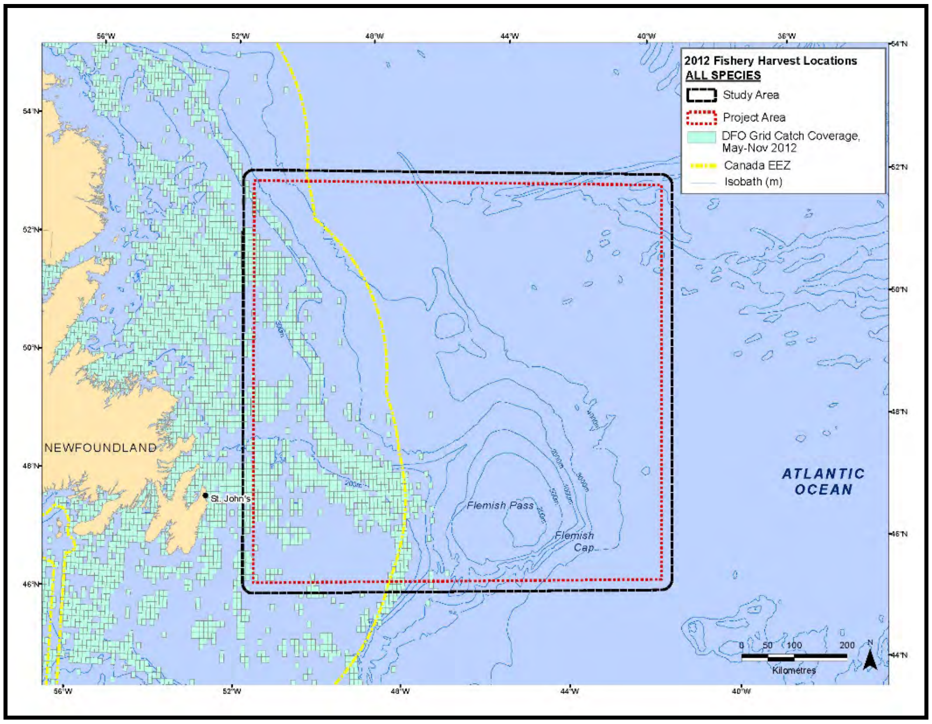
Source: DFO commercial landings database, 2005–2010.

Figure 4.5 Distribution of Harvest Locations, All Species Combined, May–November, 2005-2010.



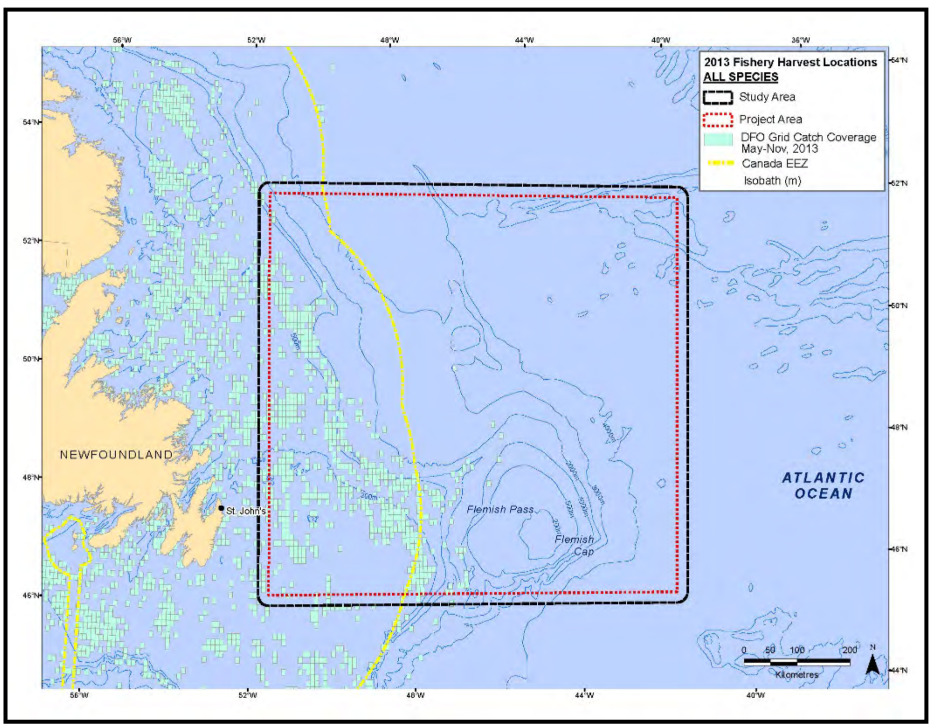
Source: DFO commercial landings database, 2011.

Figure 4.6 Distribution of Harvest Locations, All Species Combined, May–November, 2011.



Source: DFO commercial landings database, 2012.

Figure 4.7 Distribution of Harvest Locations, All Species Combined, May–November, 2012.



Source: DFO commercial landings database, 2013.

Figure 4.8 Distribution of Harvest Locations, All Species Combined, May–November, 2013.

Fishing Gear Used in the Study Area

Various types of fishing gear were used in the Study Area during May–November, 2005–2013. Trawls targeted northern shrimp, snow crab were mainly caught using pots and traps, and Greenland halibut were primarily harvested using gillnets and longlines, with a lesser proportion caught using trawls (Tables 4.6 and 4.7). Yellowtail flounder, redfish, American plaice, roughhead grenadier, witch flounder, Atlantic cod and Atlantic halibut were harvested using gillnets and trawls, along with longlines, pots, or hand lines for roughhead grenadier, witch flounder and Atlantic cod. Capelin were harvested using trawls and seines. Shrimp trawls (mobile gear) accounted for about 70% of the average total catch weight of all species in the Study Area between May–November, 2005–2010. Pots (fixed gear) accounted for about 24% of the average total catch weight during this period. Overall, mobile and fixed gears each accounted for about 72% and 28%, respectively (Table 4.6).

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

Species	Fixed Gear		Mobile Gear	
	mt	% of Total	mt	% of Total
Northern Shrimp	0	0.0	43,918	70.4
Snow Crab	14,686	23.6	0	0.0
Greenland Halibut	2,424	3.9	511	0.8
Yellowtail Flounder	<0.1	<0.1	482	0.8
Redfish	19	<0.1	68	0.1
American Plaice	4	<0.1	61	0.1
Roughhead Grenadier	43	0.1	3	<0.1
Mackerel	0	0.0	41	0.1
Witch Flounder	4	<0.1	24	<0.1
Atlantic Cod	17	<0.1	3	<0.1
Capelin	0	0.0	11	<0.1
Skate	7	<0.1	0.2	<0.1
Herring	0	0.0	6	<0.1
Swordfish	3	<0.1	0	0.0
Bigeye Tuna	1	<0.1	0	0.0
Atlantic Halibut	1	<0.1	0.1	<0.1
Bluefin Tuna	0	0.0	1	<0.1
Albacore Tuna	0.5	<0.1	0	0.0
Mako Shark	0.2	<0.1	0	0.0
Icelandic Scallops	0	0.0	0.1	<0.1
Sea Scallops	0	0.0	0.1	<0.1
Rock Crab	0.1	<0.1	0	0.0
Atlantic Wolffish	<0.1	<0.1	0	0.0
White Marlin	<0.1	<0.1	0	0.0
Dolphinfish	<0.1	<0.1	0	0.0
Yellowfin Tuna	<0.1	<0.1	0	0.0
Roundnose Grenadier	<0.1	<0.1	0	0.0
White Hake	0	0.0	<0.1	<0.1
Subtotal	**17,210**	**27.6**	**45,130**	**72.4**
Grand Total (mt)	**62,340**			

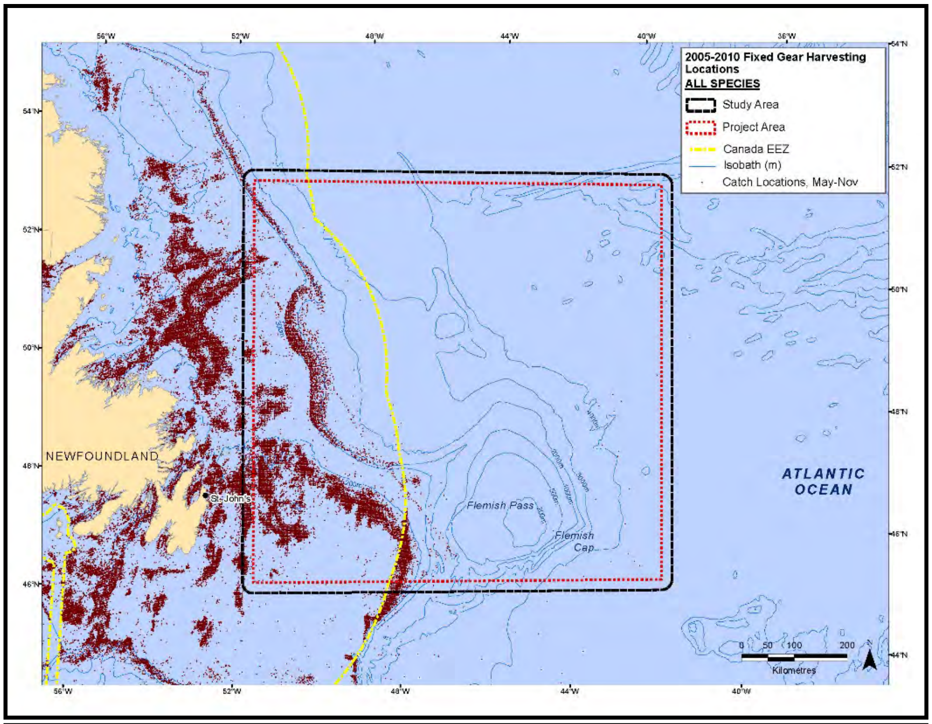
Source: DFO commercial landings database, 2005–2010.

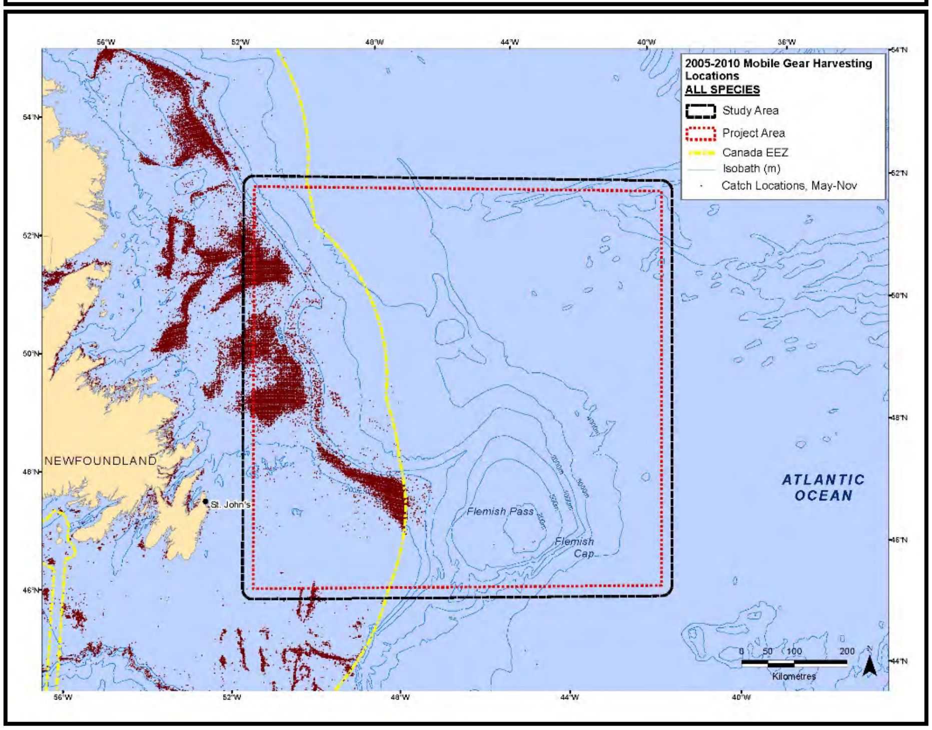
Table 4.7 Summary of Gear Type Used and Timing of the Commercial Fishery in the Study Area, May–November, 2005–2013.

Species	Month Caught				Gear Type	
	2005–2010	2011	2012	2013	Fixed	Mobile
Northern Shrimp	May–Nov	May–Nov	May–Nov	May–Oct	-	Trawl
Snow Crab	May–Nov	May–Aug	May–Aug	May–Jul	Gillnet; Pot; Trap	-
Greenland Halibut	May–Nov	Jun–Nov	May–Nov	May–Aug	Gillnet; Longline	Trawl
Yellowtail Flounder	May–Nov	Jun–Jul	May–Jun	-	Gillnet	Trawl
Redfish	May–Nov	May–Sep; Nov	May–Nov	May–Nov	Gillnet	Trawl
American Plaice	May–Nov	May–Aug; Nov	May–Jul; Nov	May–Jun; Oct	Gillnet	Trawl
Roughhead Grenadier	May–Nov	Jun–Aug; Nov	May–Oct	-	Gillnet; Longline; Pot	Trawl
Mackerel	Sep–Oct	Sep; Oct	-	-	-	Seine
Witch Flounder	May–Nov	May–Sep; Nov	May–Aug; Oct–Nov	May; Jul	Gillnet; Pot	Trawl
Atlantic Cod	May–Nov	May–Jul; Sep; Nov	Jun; Aug–Oct	Jun–Jul; Sep–Nov	Gillnet; Longline; Pot	Trawl; Hand Line
Capelin	May–Nov	Jul	Jul	Jul	-	Trawl; Seine
Skate	May–Nov	Jun–Aug	Jun–Sep	-	Gillnet; Longline	Trawl
Herring	May–Jul; Nov	-	-	May	-	Trawl; Seine
Swordfish	Aug–Sep	-	-	-	Longline	-
Bigeye Tuna	Aug	-	-	-	Longline	-
Atlantic Halibut	May–Oct	Jun–Sep; Nov	May–Aug; Oct	Jun–Jul	Gillnet	Trawl
Bluefin Tuna	Aug–Sep	-	-	-	-	Troller Line; Electric Harpoon
Albacore Tuna	Aug	-	-	-	Longline	-
Mako Shark	Aug–Oct	-	-	-	Gillnet; Longline	-
Icelandic Scallops	Jul–Aug	-	-	-	-	Dredge
Sea Scallops	May; Nov	May	Nov	-	-	Dredge
Rock Crab	Jun	-	-	-	Pot	-
Atlantic Wolffish	May–Oct	-	-	-	Gillnet; Pot	Trawl
White Marlin	Aug	-	-	-	Longline	-
Dolphinfish	Aug	-	-	-	Longline	-
Yellowfin Tuna	Aug	-	-	-	Longline	-
Roundnose Grenadier	May; Aug	-	-	-	Longline	-
White Hake	Aug–Oct	-	-	-	-	Trawl
Haddock	-	Jun–Jul; Nov	Jun	-	-	Trawl
Winter Flounder	-	Sep		-	-	-
Whelks	-		Jun	-	Pot	-

Source: DFO commercial landings database, 2005–2013.

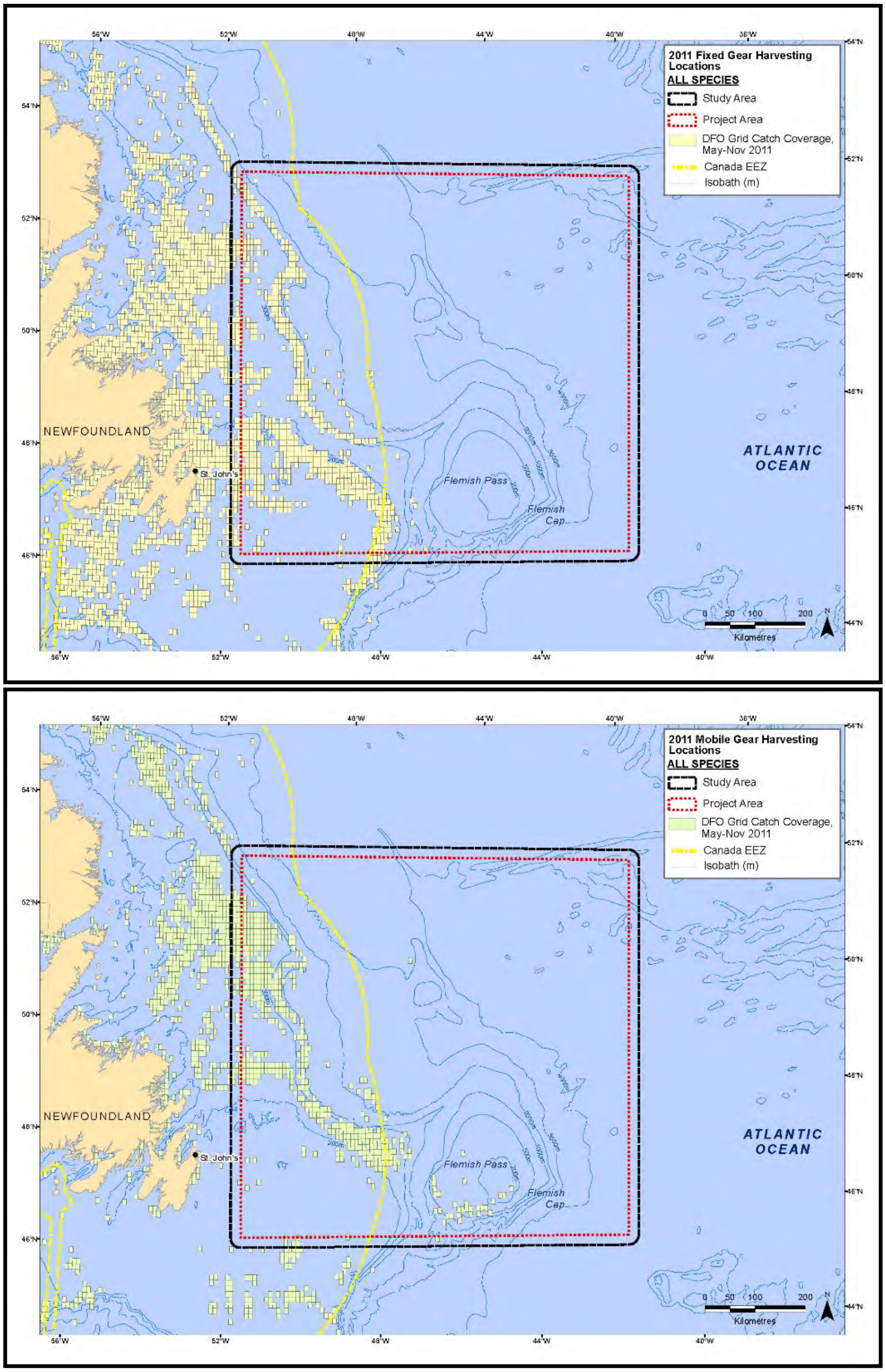
Fishing gears and harvest locations by gear type typically used in the Study Area are provided in Table 4.119 and Figure 4.137 of the Eastern Newfoundland Offshore Area SEA (C-NLOPB 2014). In general, the fixed gears have greater potential for interacting with Project activities than mobile gears, because they use submerged lines attached to buoys at the ocean surface, which can be easily snagged by towed seismic gear, causing damage to both the fishing gear and to the seismic streamer. They are often placed in one location for several days, are difficult to detect and may be set out over long distances in the water. Figures 4.9–4.12 show locations of mobile and fixed gear harvest locations during 2005–2013.





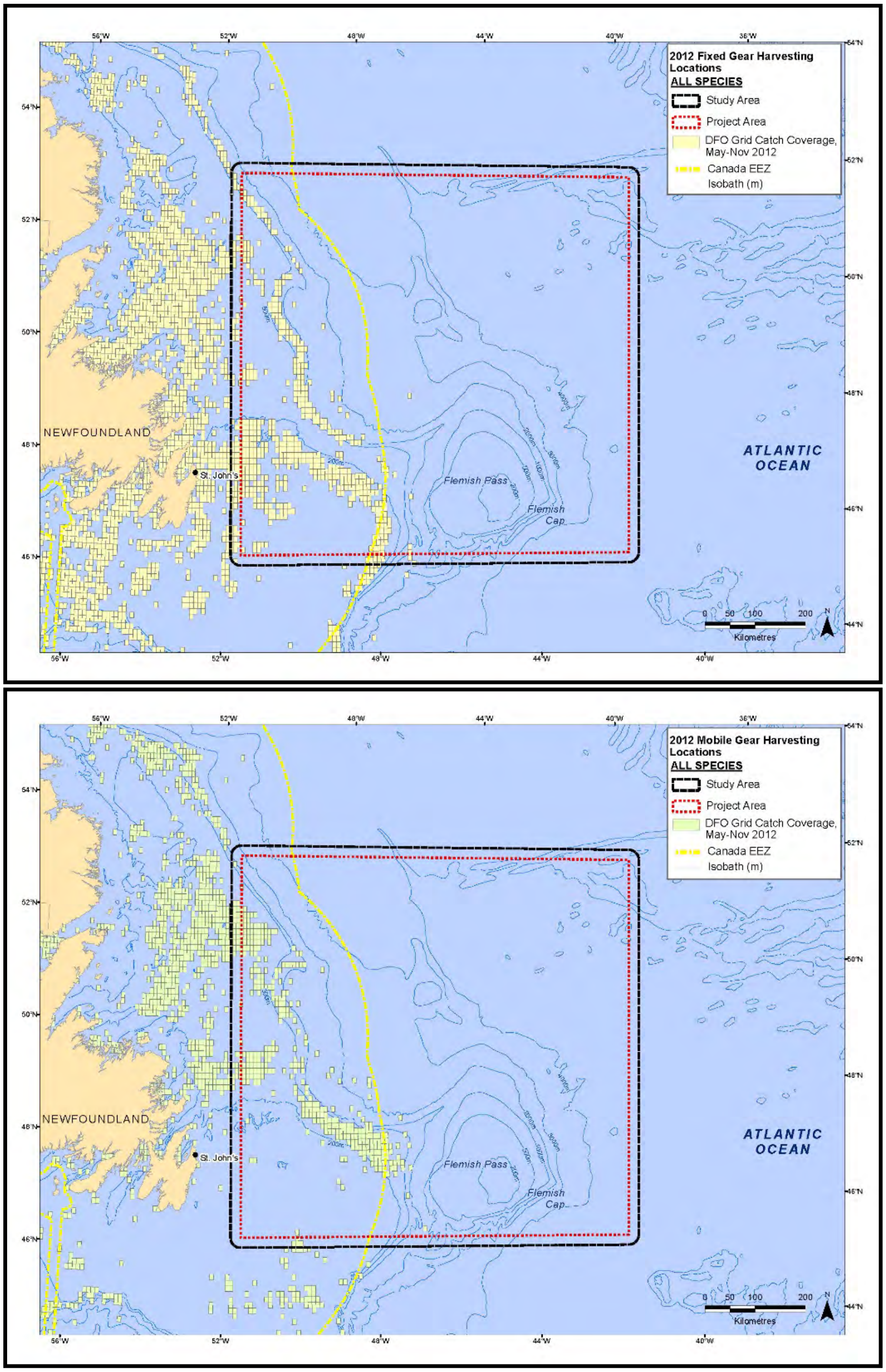
Source: DFO commercial landings database, 2005–2010.

Figure 4.9 Fixed (top) and Mobile (bottom) Gear Harvest Locations, May–November, 2005-2010.



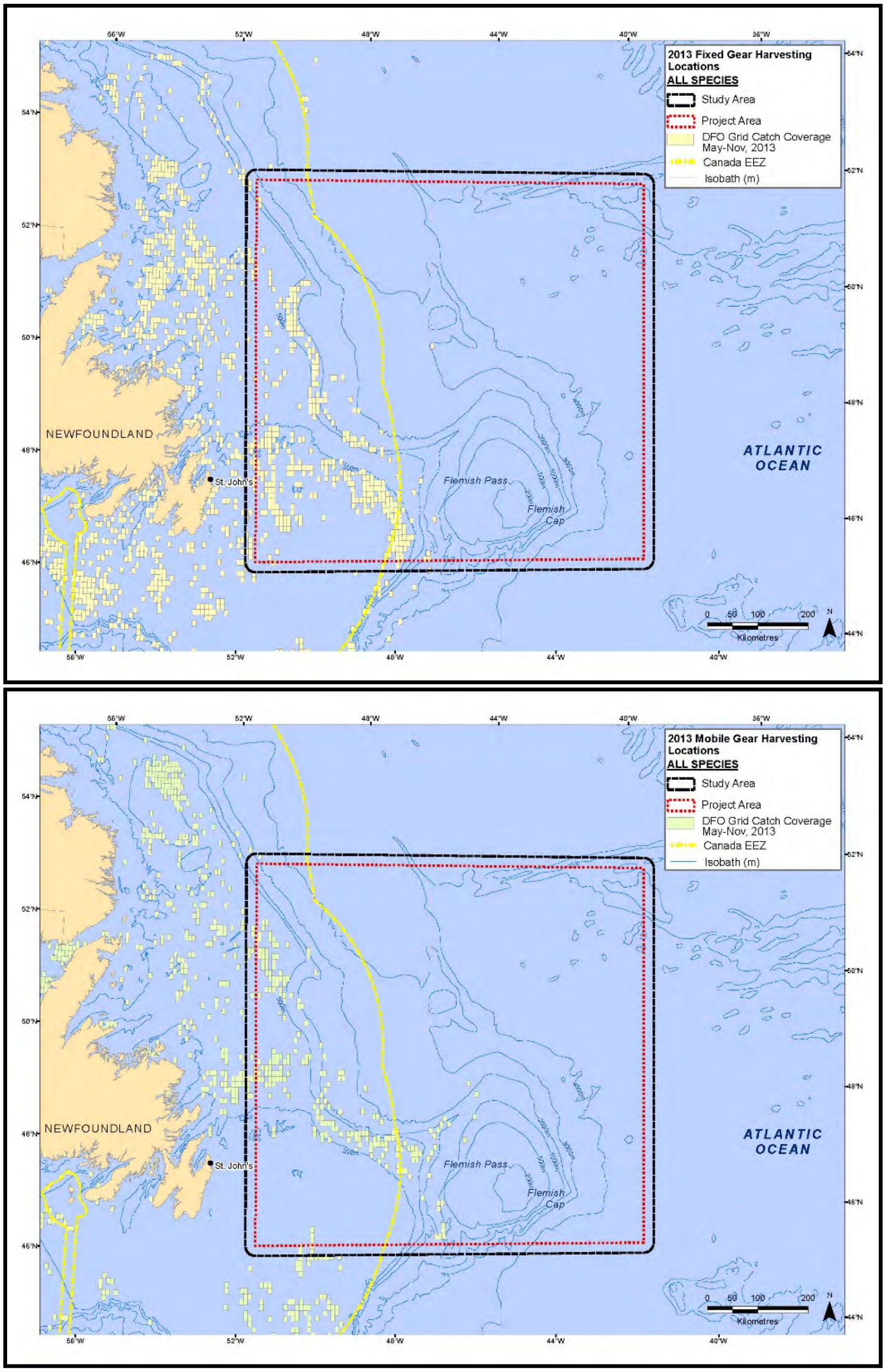
Source: DFO commercial landings database, 2011.

Figure 4.10 Fixed (top) and Mobile (bottom) Gear Harvest Locations, May–November, 2011.



Source: DFO commercial landings database, 2012.

Figure 4.11 Fixed (top) and Mobile (bottom) Gear Harvest Locations, May–November, 2012.

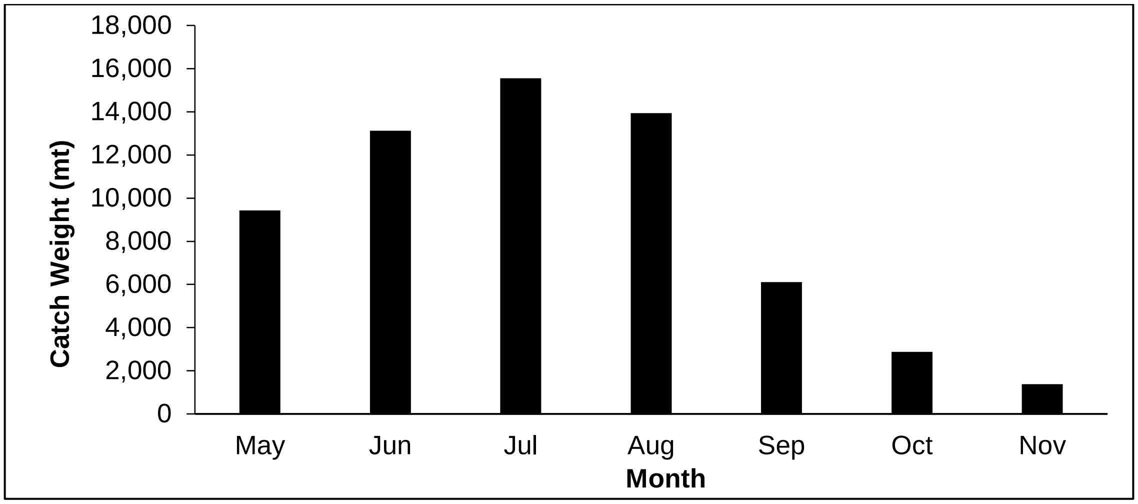


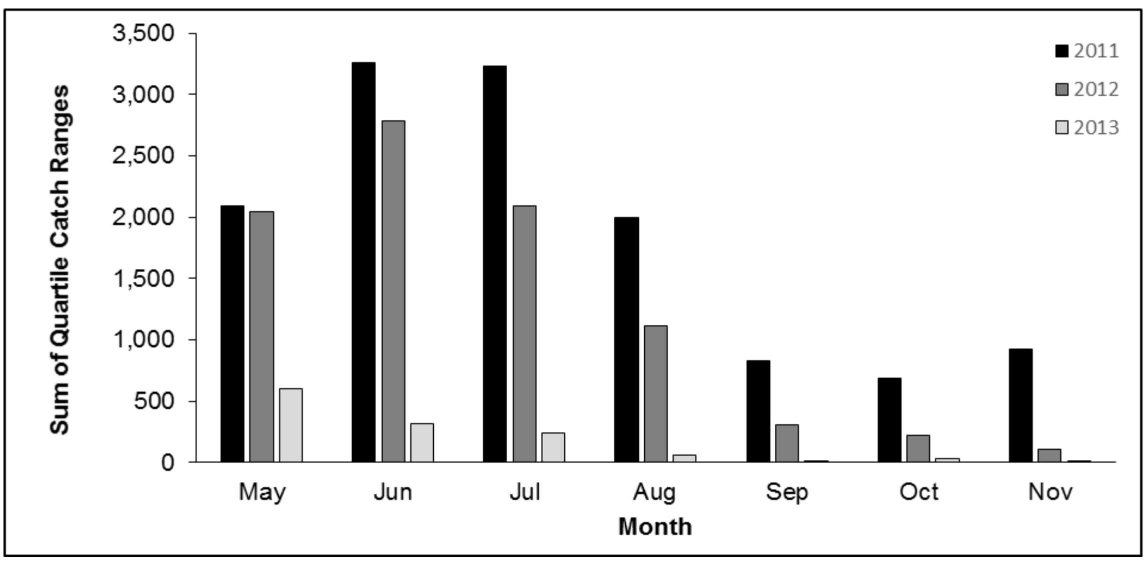
Source: DFO commercial landings database, 2013.

Figure 4.12 Fixed (top) and Mobile (lower) Gear Harvest Locations, May–November, 2013.

Harvest Timing in the Study Area

Average monthly catch weights of all species within the Study Area during May–November, 2005-2010, and total sum of monthly catch weight quartile codes for May-November, 2011–2013, are indicated in Figure 4.13. Monthly catch weight was highest during May-August period and lowest during 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, 2005–2013.
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 Average Monthly Catch Weight during May–November, 2005–2010 (top), and Total Monthly Sum of Catch Weight Quartile Codes, May–November, 2011–2013 (bottom), All Species in the Study Area.

Principal Species in the Study Area

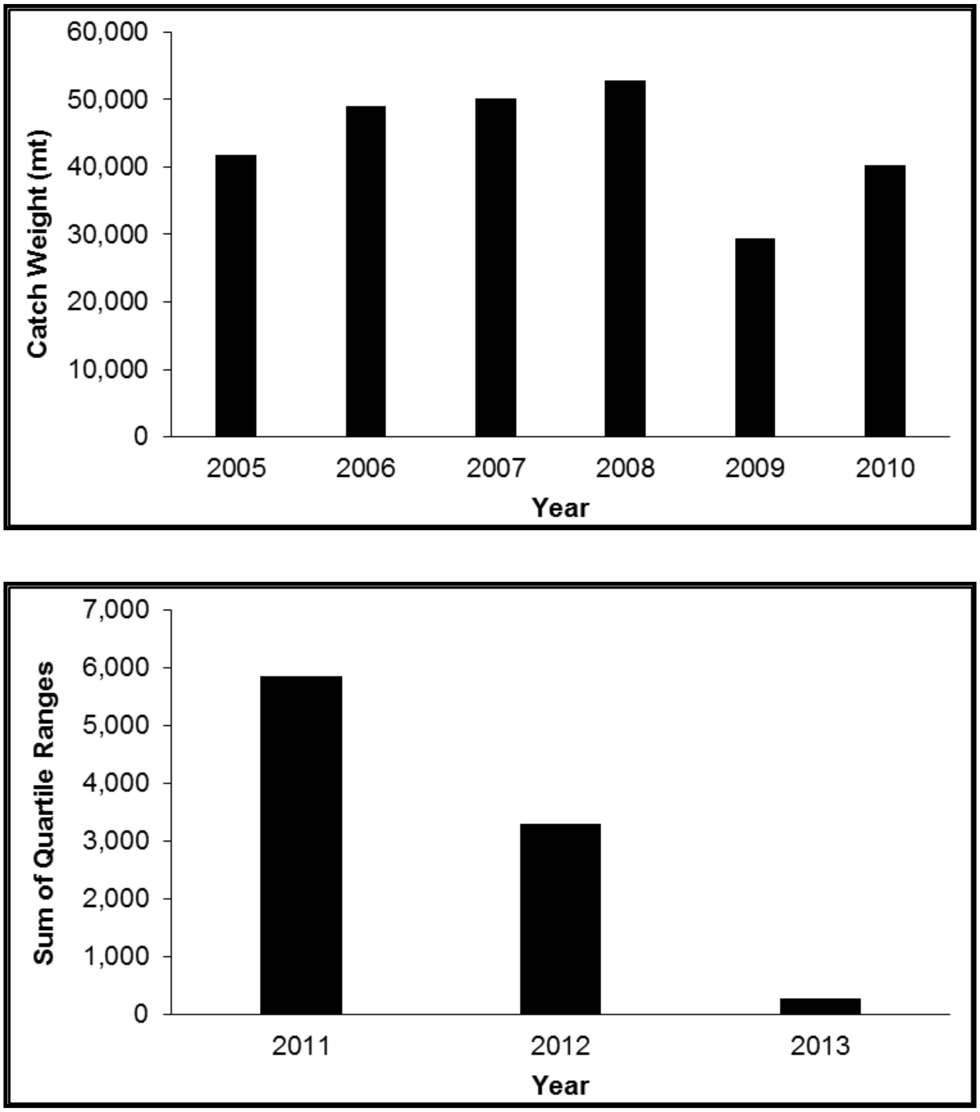
The following section provides information on the principal species caught during fisheries being prosecuted in the Study Area.

Northern Shrimp

Overall, northern shrimp was the most important commercial species in the Study Area, by both quantity and value, during May-November, 2005-2013. The total annual catch weights (2005–2010) and total annual catch weight quartile codes (2011–2013) for northern shrimp in the Study Area between May-November are indicated in Figure 4.14. Figure 4.15 shows the northern shrimp harvest locations during 2005–2010. Figures 4.16–4.18 show harvest location distributions for 2011, 2012 and 2013, respectively. Most of the northern shrimp were harvested in the northwest portion of the Study and Project Areas, between the 200 and 500 m isobaths. The average and total monthly northern shrimp harvests in the Study Area during the May–November, 2005–2010 and 2011–2013 periods, respectively, are shown in Figure 4.19. Most of the northern shrimp was caught in June, July and August.

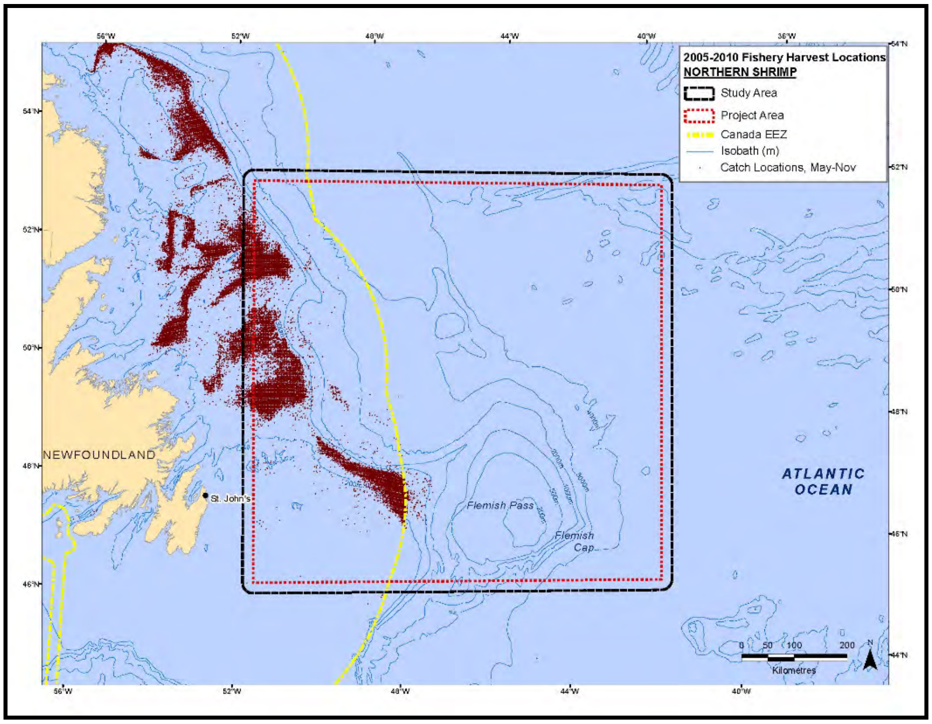
Snow Crab

In terms of catch weight, snow crab was the second most important commercial species in the Study Area during 2005–2012 and the most important in 2013. This crustacean was also the most important commercial species in terms of catch value in 2012 and 2013. Total annual catch weights (2005–2010) and the total sum of catch weight quartile codes (2011–2013) for snow crab in the Study Area between May and November are indicated in Figure 4.20. Figure 4.21 shows the snow crab harvesting locations for 2005–2010 combined. Figures 4.22–4.24 show snow crab harvesting patterns for 2011, 2012 and 2013, respectively. The majority of snow crab were captured in the southwest portion of the Study and Project Areas, in water depths <200 m. The average and total monthly snow crab harvests in the Study Area during the May–November, 2005–2010 and 2011–2013 periods, respectively, are shown in Figure 4.25. Snow crab were almost exclusively caught between May–August in the Study Area, with the majority of catch taken in May–June.



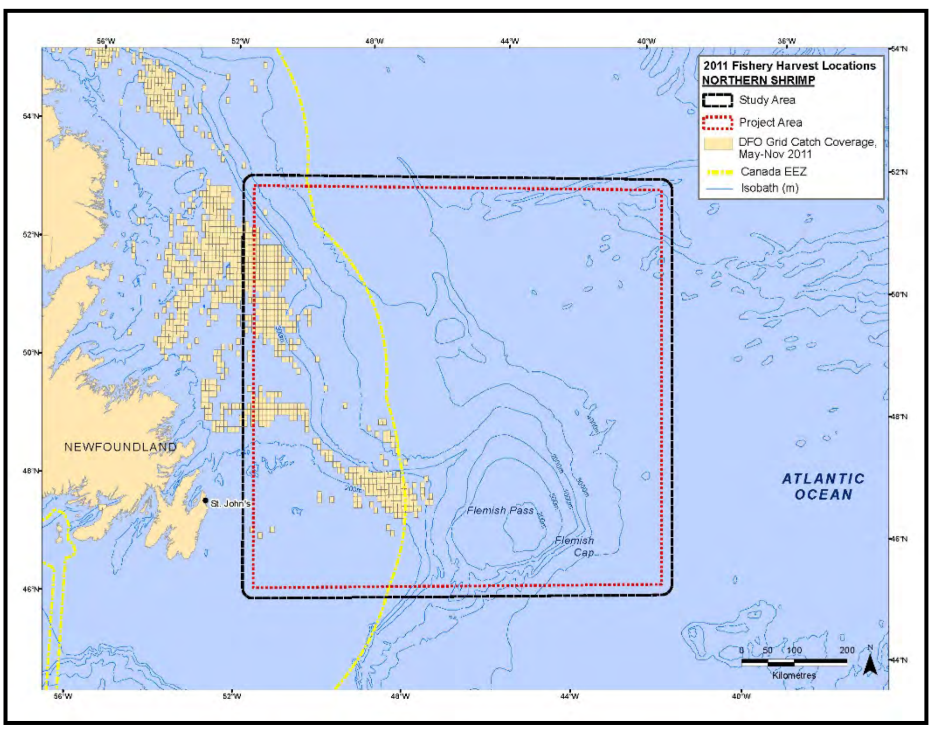
Source: DFO commercial landings database, 2005–2013.
Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.14 Total Annual Catch Weights, May–November, 2005–2010 (top), and Total Annual Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) for Northern Shrimp in the Study Area.



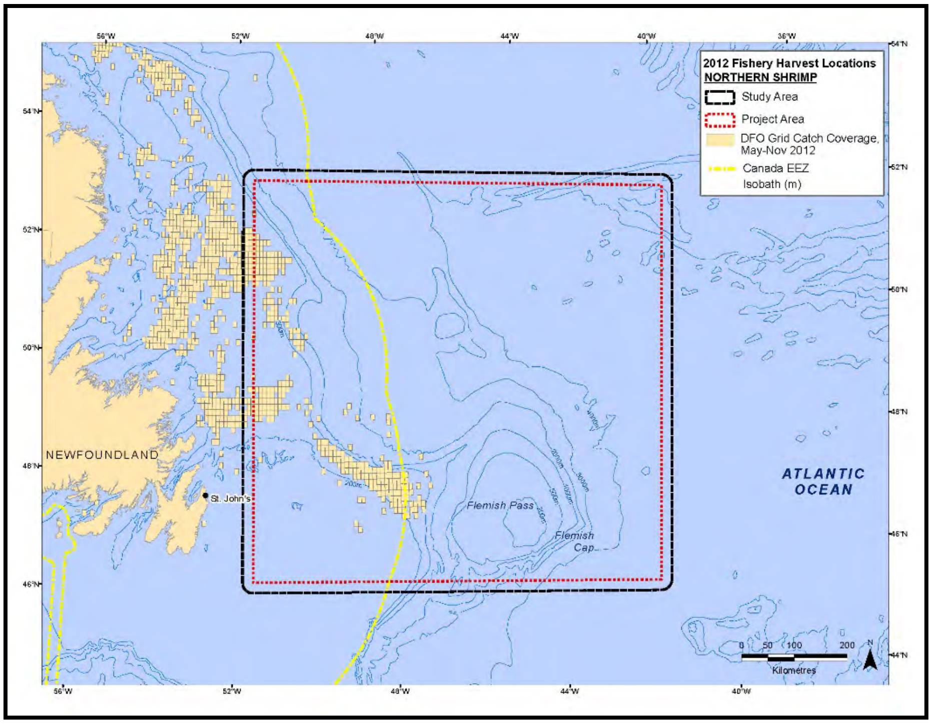
Source: DFO commercial landings database, 2005–2010.

Figure 4.15 Distribution of Harvest Locations for Northern Shrimp, May–November, 2005-2010.



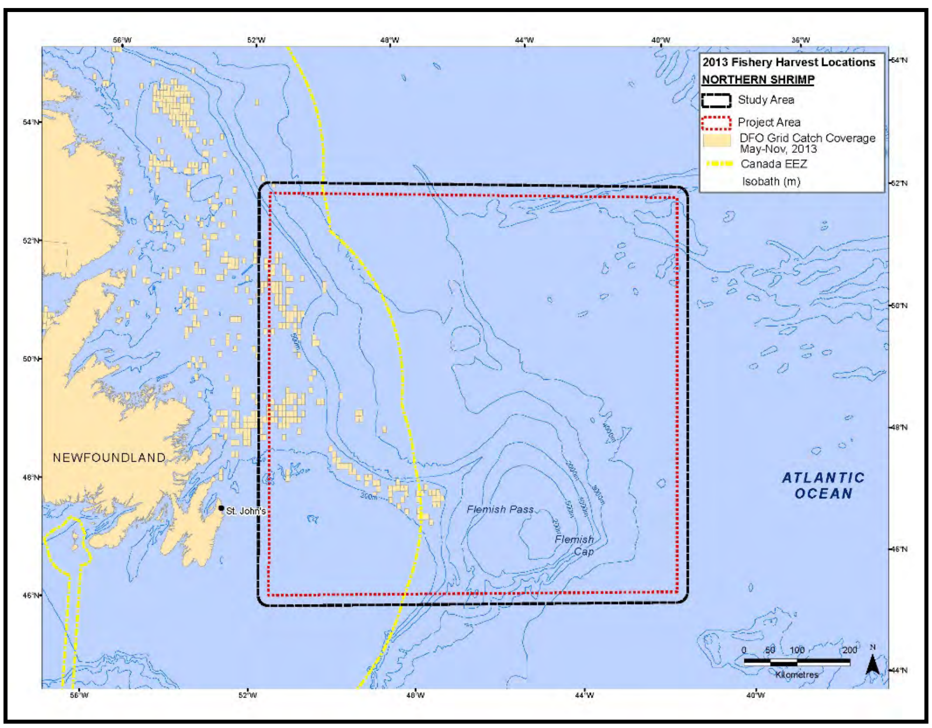
Source: DFO commercial landings database, 2011.

Figure 4.16 Distribution of Harvest Locations for Northern Shrimp, May–November, 2011.



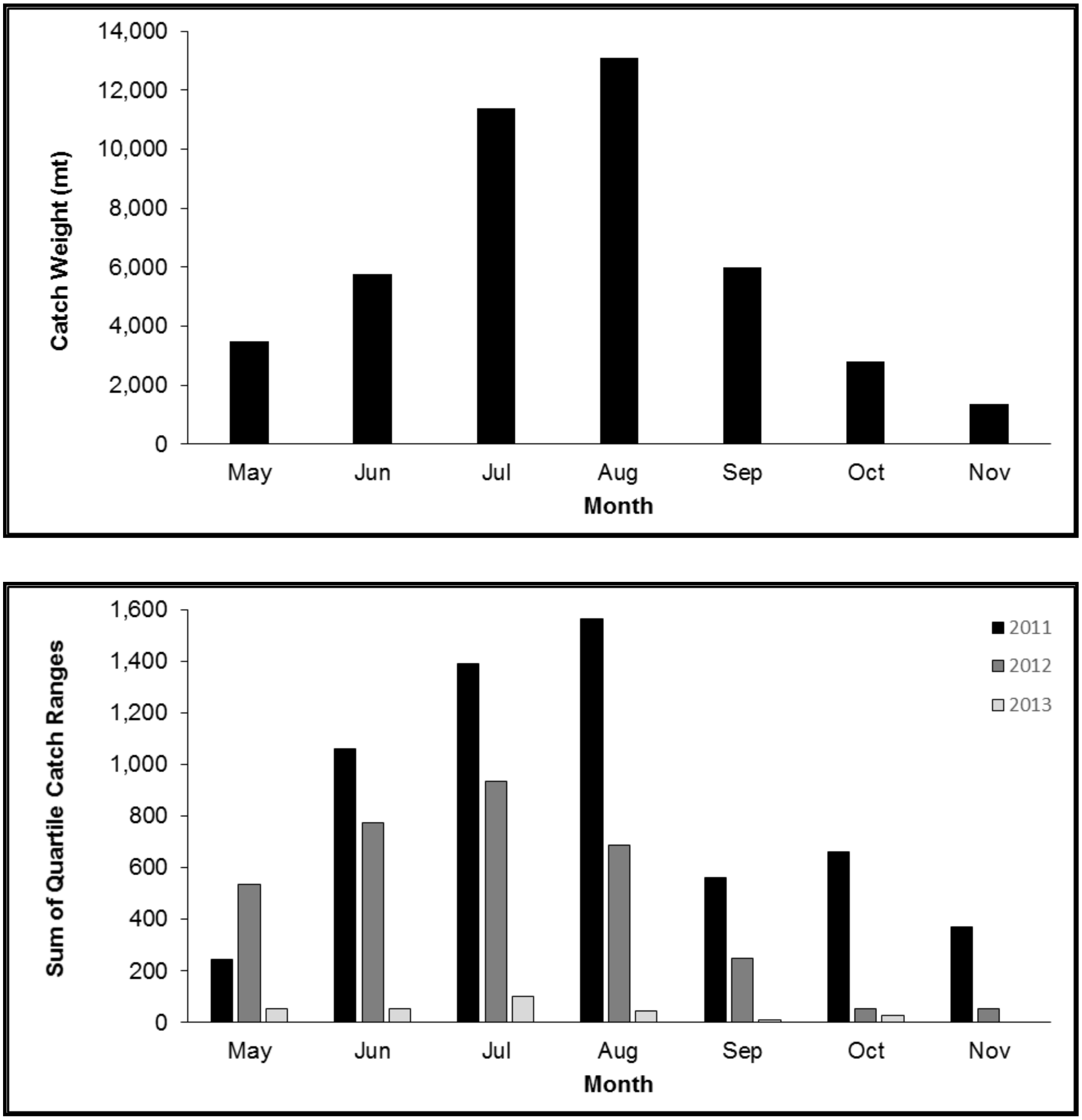
Source: DFO commercial landings database, 2012.

Figure 4.17 Distribution of Harvest Locations for Northern Shrimp, May–November, 2012.



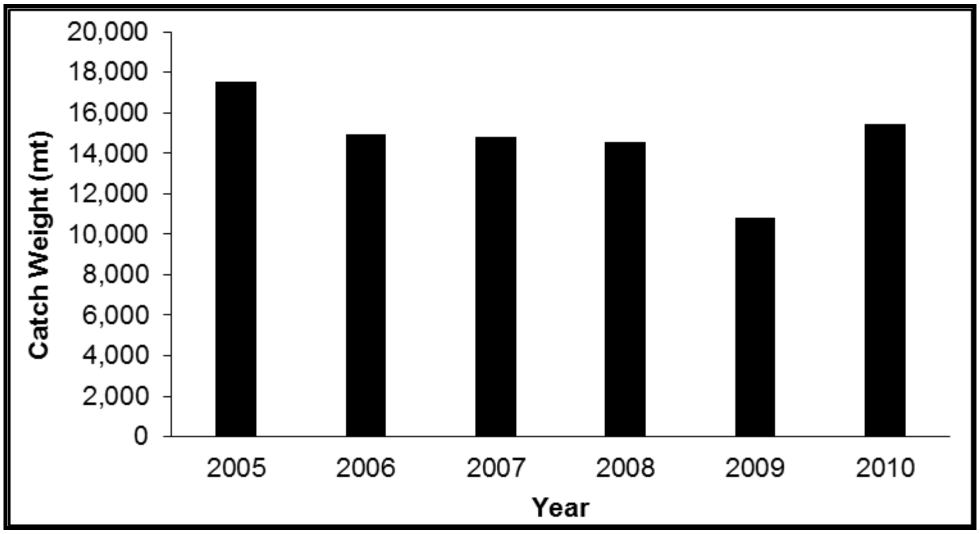
Source: DFO commercial landings database, 2013.

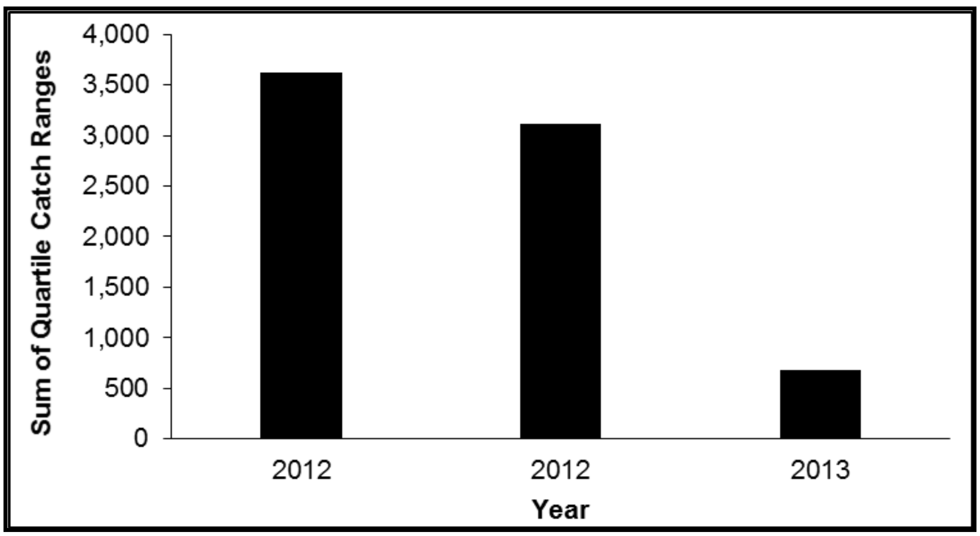
Figure 4.18 Distribution of Harvest Locations for Northern Shrimp, May–November, 2013.



Source: DFO commercial landings database, 2005–2013.
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.

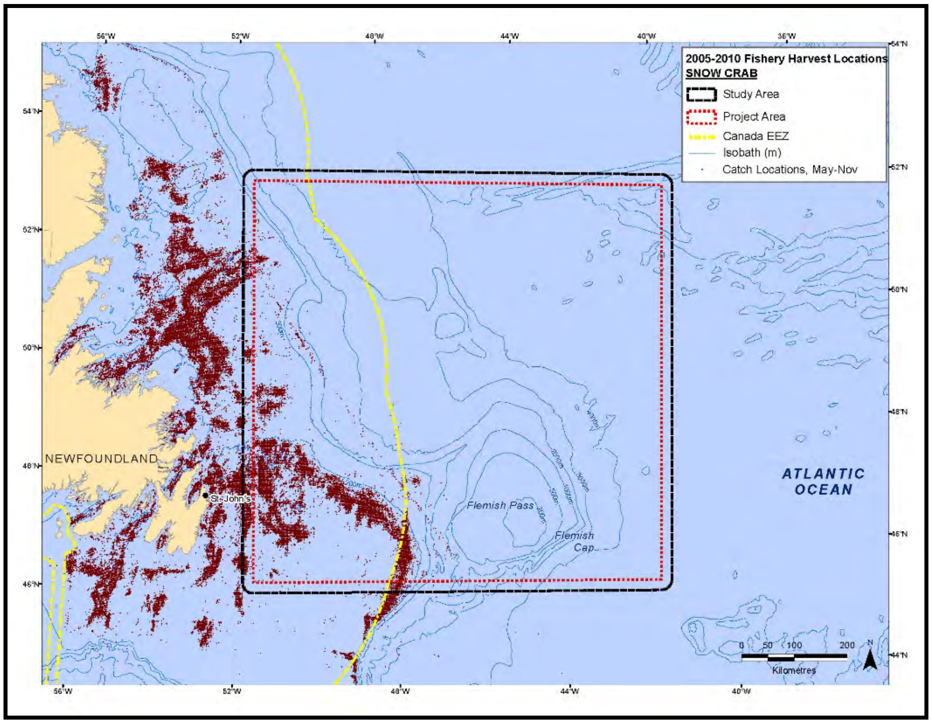
Figure 4.19 Average Monthly Catch Weights, May–November, 2005–2010 (top), and Total Monthly Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) for Northern Shrimp in the Study Area.





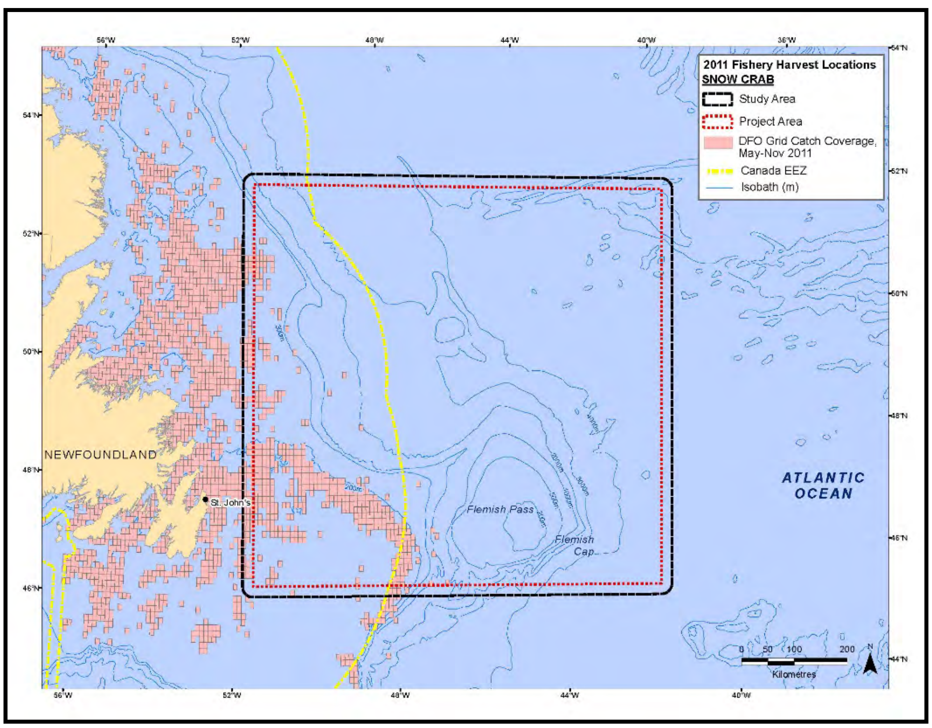
Source: DFO commercial landings database, 2005–2013.
Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.20 Total Annual Catch Weights, May–November, 2005–2010 (top), and Total Annual Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) for Snow Crab in the Study Area.



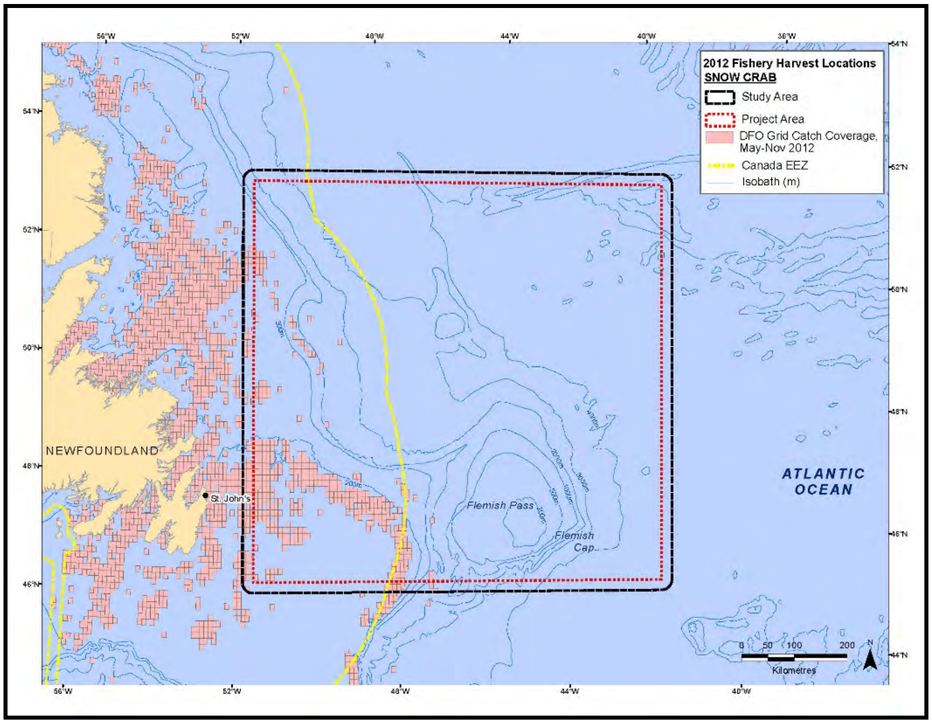
Source: DFO commercial landings database, 2005–2010.

Figure 4.21 Distribution of Harvest Locations for Snow Crab, May–November, 2005–2010.



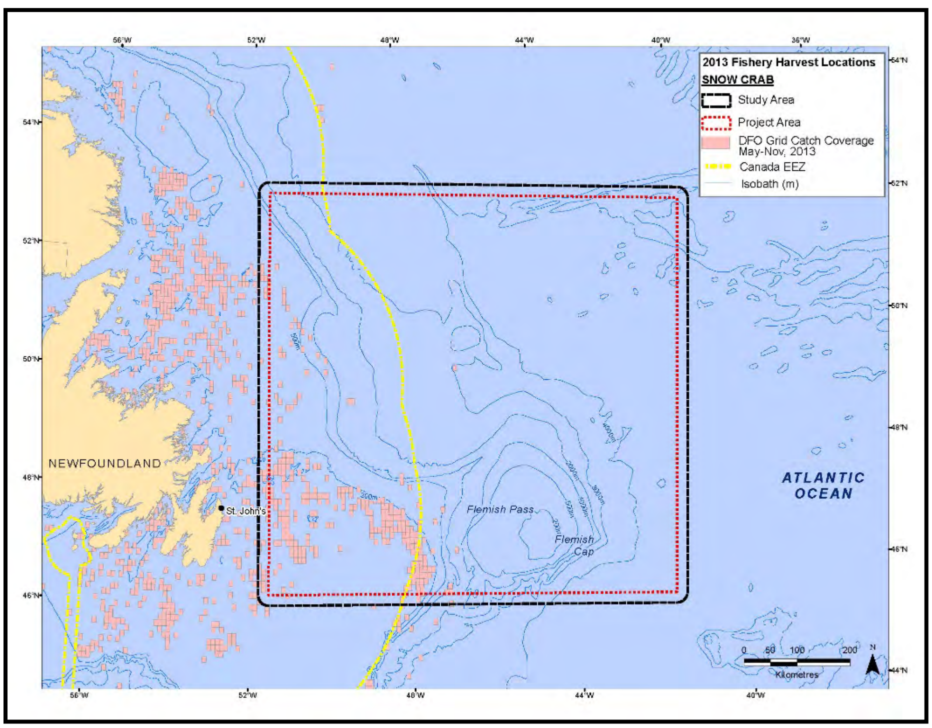
Source: DFO commercial landings database, 2011.

Figure 4.22 Distribution of Harvest Locations for Snow Crab, May–November, 2011.



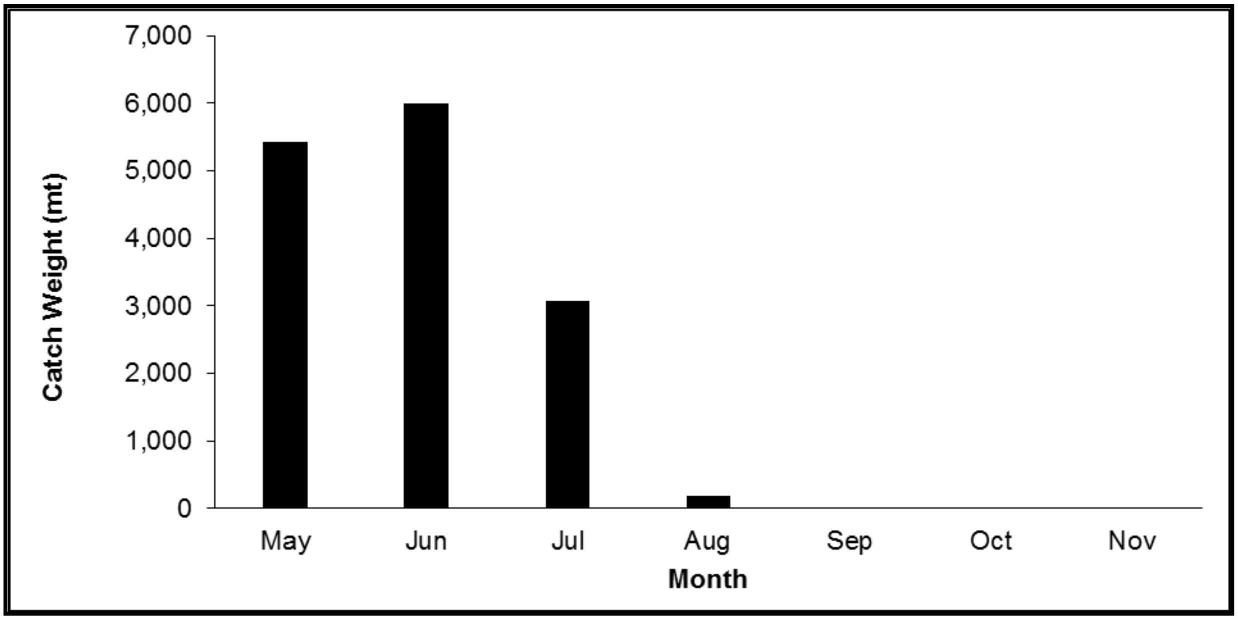
Source: DFO commercial landings database, 2012.

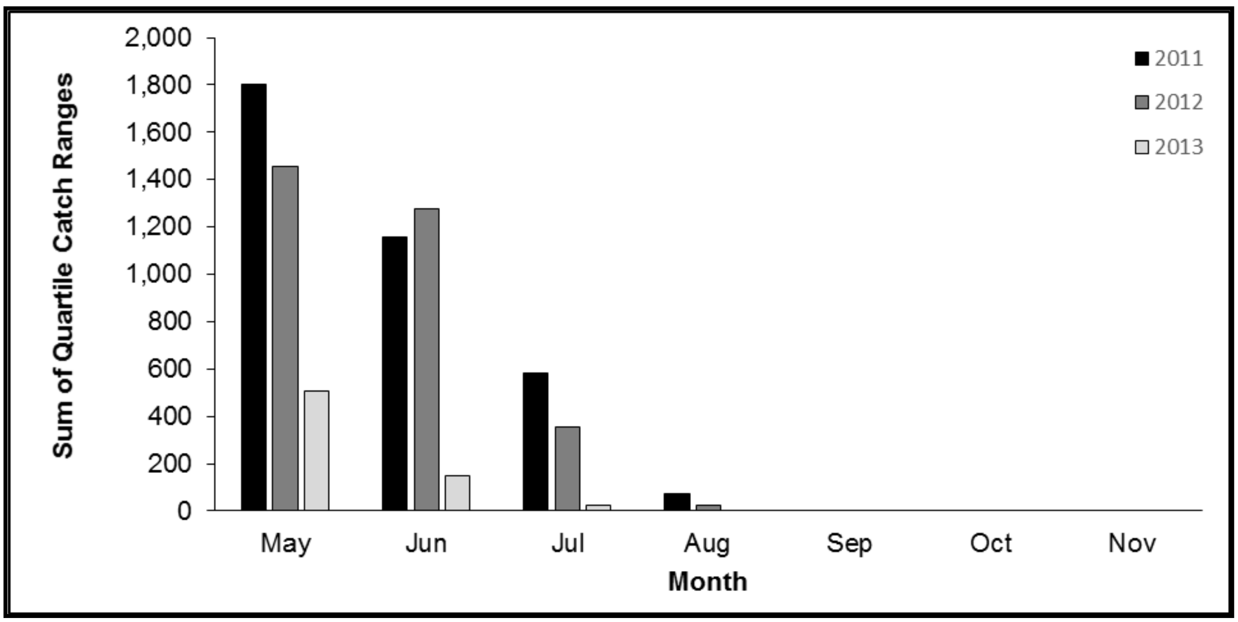
Figure 4.23 Distribution of Harvest Locations for Snow Crab, May–November, 2012.



Source: DFO commercial landings database, 2013.

Figure 4.24 Distribution of Harvest Locations for Snow Crab, May–November, 2013.





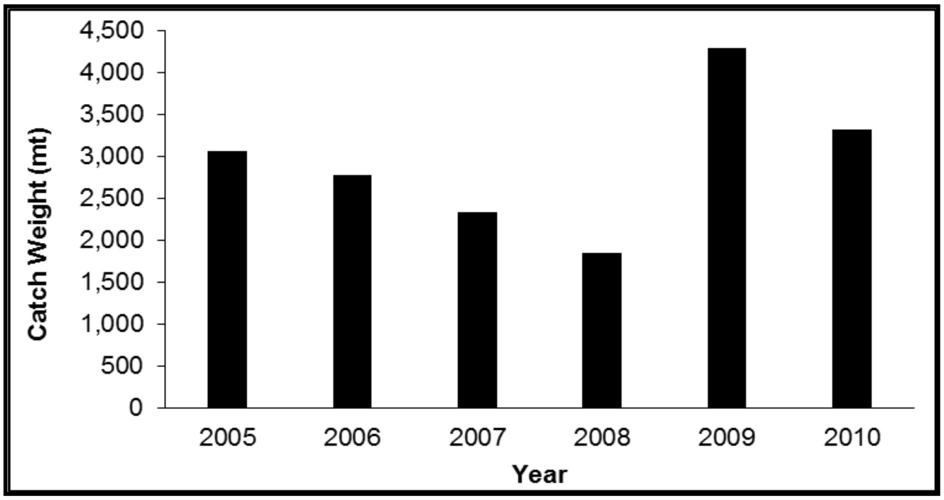
Source: DFO commercial landings database, 2005–2013.
Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given month.

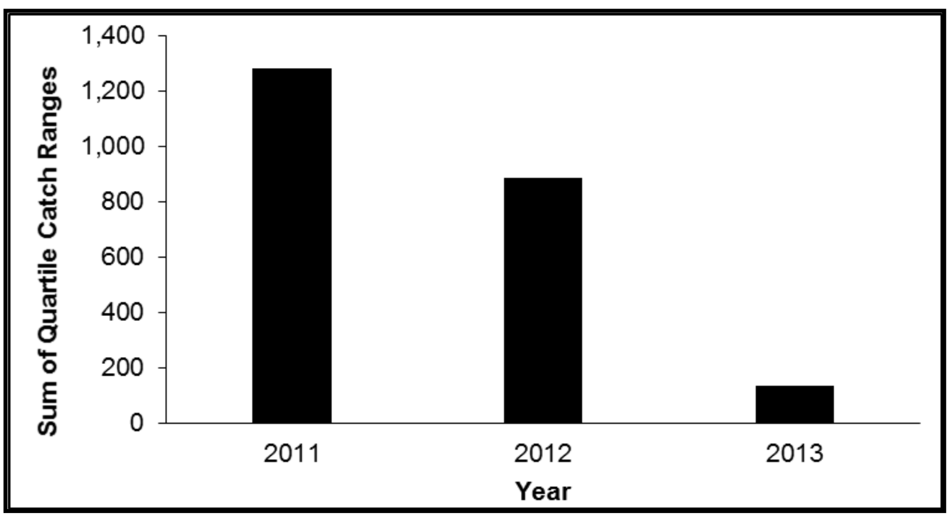
Figure 4.25 Average Monthly Catch Weights, May–November, 2005–2010 (top), and Total Monthly Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) for Snow Crab in the Study Area.

Greenland Halibut

Greenland halibut accounted for the largest portion of groundfish catches in the Study Area during 2005–2013. Total annual catch weights (2005–2010) and the total sum of catch weight quartile codes (2011–2013) for Greenland halibut in the Study Area between May and November are indicated in

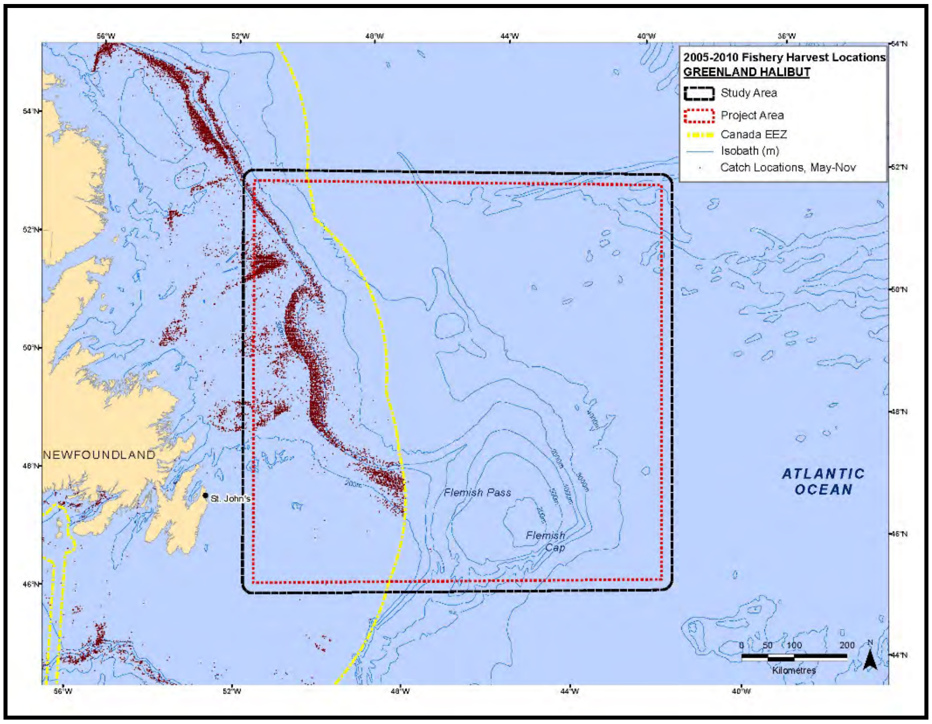
Figure 4.26. Figure 4.27 shows the Greenland halibut harvest locations for 2005–2010 combined. Figures 4.28–4.30 show Greenland halibut harvest locations for 2011, 2012 and 2013, respectively. The majority of Greenland halibut were caught in the southwest portion of the 2015 Survey Area and the western portion of the Project and Study Areas, almost exclusively between the 500 and 1,000 m isobaths. Harvesting of Greenland halibut expanded further east in 2013, into water depths ranging between 500 and 3,000 m. The average monthly Greenland halibut harvests in the Study Area during the May–November, 2005–2010 and 2011–2013 periods are shown in Figure 4.31. Greenland halibut were primarily harvested during the June–August period in the Study Area.





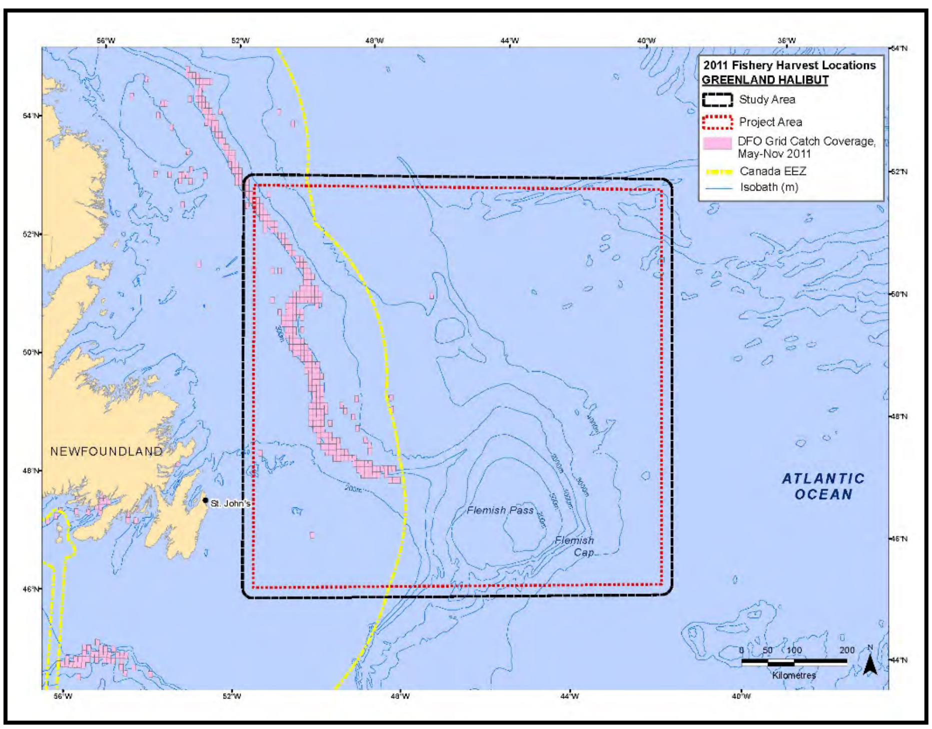
Source: DFO commercial landings database, 2005–2013.
Sum of quartile catch ranges is the summation of catch weight quartile ranges (i.e., 1–4) for all catch records for all species; the greater the sum of quartile range counts, the greater the catch weight for a given year.

Figure 4.26 Total Annual Catch Weights, May–November, 2005–2010 (top), and Total Annual Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) for Greenland Halibut in the Study Area.



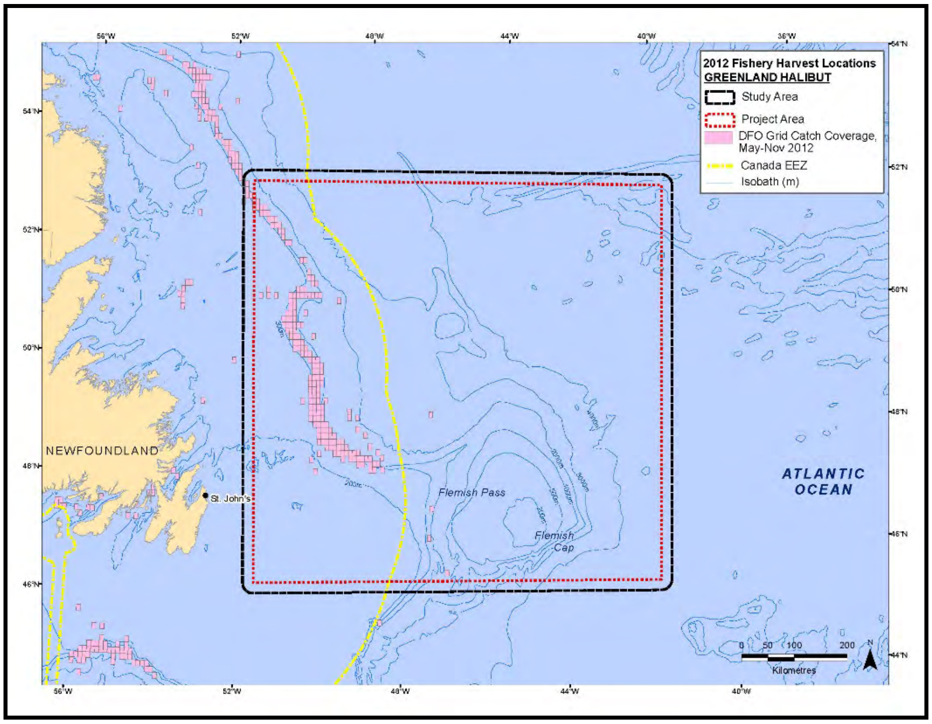
Source: DFO commercial landings database, 2005–2010.

Figure 4.27 Distribution of Harvest Locations for Greenland Halibut, May–November, 2005-2010.



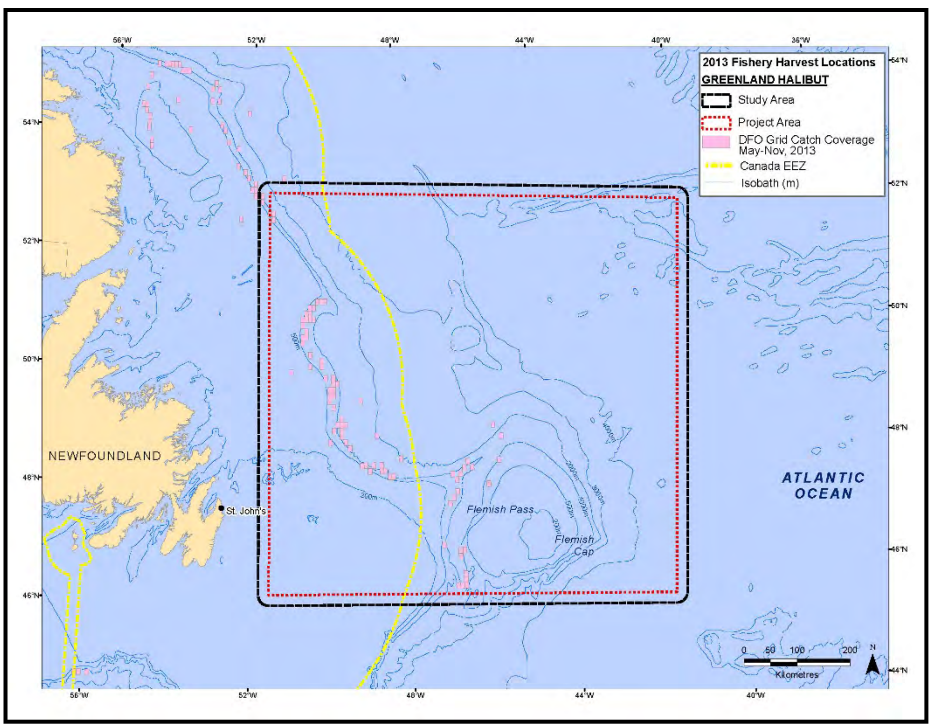
Source: DFO commercial landings database, 2011.

Figure 4.28 Distribution of Harvest Locations for Greenland Halibut, May–November, 2011.



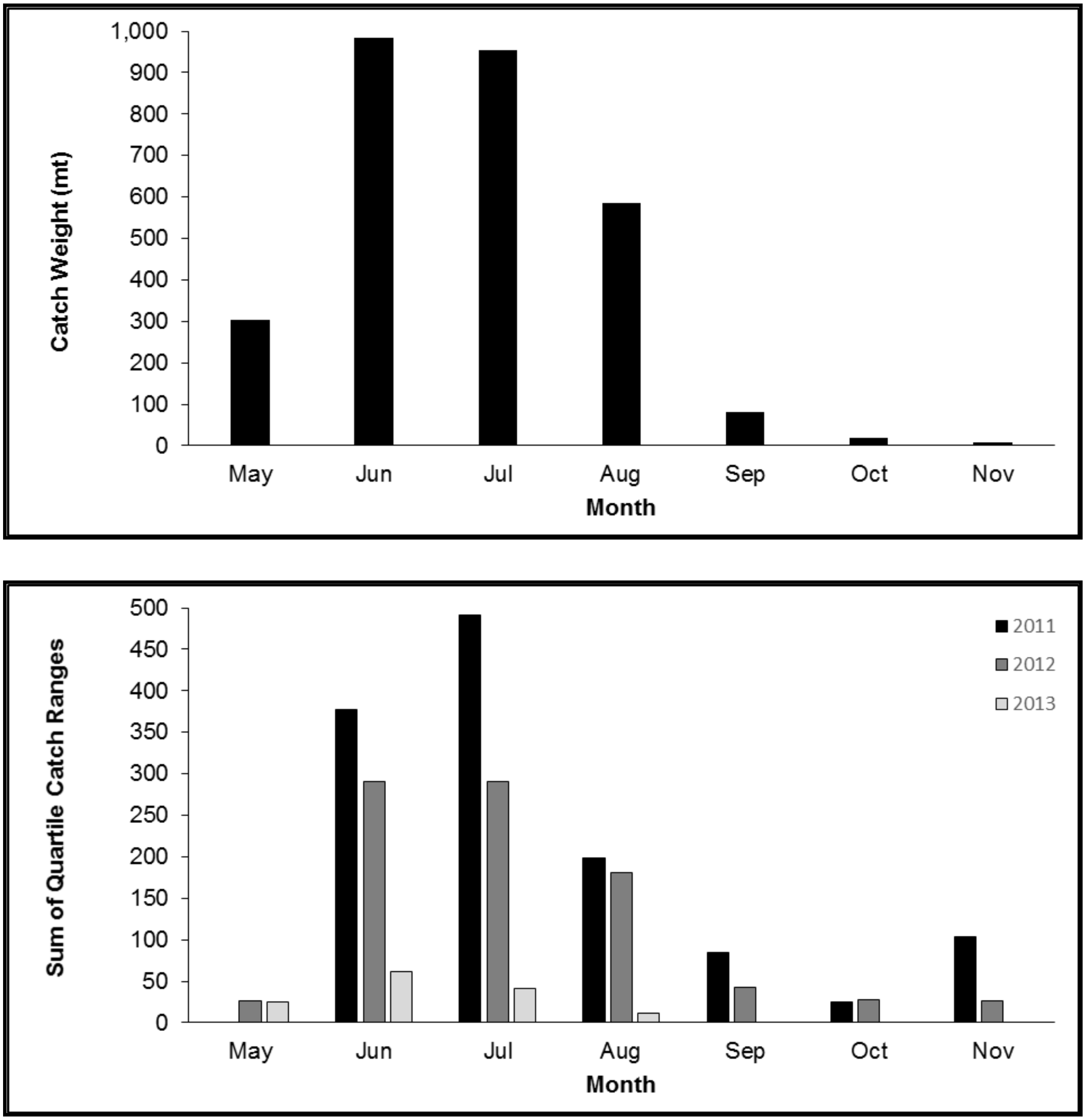
Source: DFO commercial landings database, 2012.

Figure 4.29 Distribution of Harvest Locations for Greenland Halibut, May–November, 2012.



Source: DFO commercial landings database, 2013.

Figure 4.30 Distribution of Harvest Locations for Greenland Halibut, May–November, 2013.



Source: DFO commercial landings database, 2005–2013.
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 4.31 Average Monthly Catch Weights, May–November, 2005–2010 (top), and Total Monthly Catch Weight Quartile Codes, May–November, 2011–2013 (bottom) for Greenland Halibut in the Study Area.

4.3.4 Traditional and Aboriginal Fisheries

According to the Eastern Newfoundland SEA (C-NLOPB 2014), there are no known Aboriginal fisheries that occur within the Study Area. While the Nunatsiavut Government does hold a Communal

Snow Crab licence and allocation within NAFO Divisions 2GHJ, the allocated region is north of 54º40’ N, which is north of the Study Area (DFO 2010b).

4.3.5 Recreational Fisheries

Recreational fisheries in Newfoundland and Labrador are briefly described in Section 4.3.4.4 of the Eastern Newfoundland SEA (C-NLOPB 2014). In 2015, the recreational groundfish fishery will occur in all NAFO areas around Newfoundland and Labrador, including NAFO Divisions 2GH, 2J3KL, 3Ps, 3Pn and 4R (DFO 2014d). Of these NAFO areas, portions of 2J, 3K and 3L are within the Study Area. This fishery is largely conducted in coastal and inshore waters (C-NLOPB 2014), and is open for three weeks in the summer beginning on 18 July 2015, and for nine days in the fall beginning on 19 September 2015 (dates are subject to change) (DFO 2014d). Species that are harvested recreationally typically include brown trout, Atlantic mackerel, squid, capelin, and Atlantic cod (C. Boland, DFO, pers. comm., 2009 *in* LGL 2010). Management measures in place for 2013 to 2015 indicate there is no requirement for licences or tags to fish recreationally for these species (DFO 2014d). Scallops may also be harvested with a recreational license (LGL 2010). Atlantic salmon, trout (brook, brown, rainbow and ouaniche), Arctic char and smelts are fished in freshwater in Newfoundland and Labrador (FWE 2014).

The retention of Atlantic halibut, spotted and northern wolfish, and any species of shark is prohibited in Newfoundland and Labrador recreational fisheries (DFO 2014d). Sculpins and cunners may be released, but all other groundfish captured must be retained (DFO 2014d).

It is highly unlikely that any recreational fisheries will be conducted within this Project’s Study Area.

4.3.6 Aquaculture

Aquaculture operations in Newfoundland and Labrador are described in Section 4.3.4.3 of the Eastern Newfoundland SEA (C-NLOPB 2014). Currently, all aquaculture sites in eastern Newfoundland are coastally-based, and there are no approved aquaculture sites within the Study Area (C-NLOPB 2014; DFA 2014).

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

DFO RV data collected during annual multi-species trawl surveys provide distributional information for invertebrate and fish species not discussed in Section 4.3.3 as well as additional distributional information for some of the commercial species discussed in Section 4.3.3.

The total catch weight during 2008–2012 spring (March, May, June) and fall (October–December) DFO RV surveys in the Study Area was 298 mt. Data collected during these surveys were analyzed, and catch weights, numbers, and mean catch depths of species/groups contributing ≥0.1% of the total catch weight and species at risk (see Section 4.6) are presented in Table 4.8.

Table 4.8 Catch Weights and Numbers of Macroinvertebrates and Fishes Collected during DFO RV Surveys within the Study Area, 2008–2012.

Species	Catch Weight (mt)	Catch Number	Mean Catch Depth (m)	
			Spring	Fall
Deepwater Redfish (*Sebastes mentella*)	98	460,851	355	318
Northern Shrimp (*Pandalus borealis*)	31	6,593,706	285	247
Atlantic Cod (*Gadus morhua*)	22	19,610	257	214
Capelin (*Mallotus villosus*)	19	1,405,386	171	212
Sponges (Porifera)	19	n/d	319	386
American Plaice (*Hippoglossoides platessoides*)	14	89,123	254	253
Greenland Halibut (*Reinhardtius hippoglossoides*)	11	26,865	344	420
Yellowtail Flounder (*Limanda ferruginea*)	9	29,127	76	75
Roughhead Grenadier (*Macrourus berglax*)	8	18,657	478	503
Thorny Skate (*Raja radiata*)	8	5,978	315	264
Sand Lance (*Ammodytes dubius*)	6	552,787	104	99
Sea Anemone (Actinaria)	4	18,284	301	351
Snow Crab (*Chionoecetes opilio*)	4	20,554	271	207
Shrimp (Natantia)	4	n/d	338	408
Blue Hake (*Antimora rostrata*)	3	22,242	608	884
Basket Star (*Gorgonocephalus arcticus*)	3	69	152	371
Jellyfishes (Scyphozoa)	3	120	471	507
Witch Flounder (*Glyptocephalus cynoglossus*)	2	6,208	370	436
Basket Star (Gorgonocephalidae)	2	168	168	369
Roundnose Grenadier (*Coryphaenoides rupestris*)	2	13,354	634	950
Northern Wolffish (*Anarhichas denticulatus*)	2	465	570	439
Spotted Wolffish (*Anarhichas minor*)	1	549	333	262
Atlantic Wolffish (*Anarhichas lupus*)	1	2,780	293	249
Arctic Argid Shrimp (*Argis dentata*)	1	219,669	135	225
Comb-jelly (Ctenophora)	1	574	75	75
Striped Shrimp (*Pandalus montagui*)	1	336,081	122	171
Longnose Eel (*Synaphobranchus kaupi*)	1	11,074	584	872
Marlin Spike (*Nezumia bairdi*)	1	11,523	485	580
Sea Urchin (Echinoidea)	1	30,321	133	721
Green Sea Urchin (*Strongylocentrotus droebachiensis*)	1	34,631	111	184
Arctic Eelpout (*Lycodes reticulatus*)	1	4,310	179	163
Black Dogfish (*Centroscyllium fabricii*)	1	506	682	940
Vahl's Eelpout (*Lycodes vahlii*)	1	6,785	356	412
Sea Urchin (*Strongylocentrotus* sp.)	1	27,555	107	176
Spinytail Skate (*Bathyraja spinicauda*)	1	66	518	765
Eelpout (*Lycodes* sp.)	1	5,421	289	299
Lanternfishes (Myctophidae)	0.4	65,729	492	527
Sand Dollar (*Echinarachnius parma*)	0.4	19,258	149	239
Moustache Sculpin (*Triglops murrayi*)	0.4	33,605	127	176
Jensen's Skate (*Amblyraja jenseni*)	0.4	131	670	1,022
Large Scale Tapirfish (*Notacanthus nasus*)	0.4	580	608	865
Mailed Sculpin (*Triglops* sp.)	0.4	28,920	225	197
Golden Redfish (*Sebastes marinus*)	0.3	304	390	375
Brittle Star (Ophiuroidea)	0.3	1,202	184	432
Polar Sea Star (*Leptasterias polaris*)	0.3	3,770	92	207
Shrimp (*Sergestes arcticus*)	0.3	288,130	503	823
Longfin Hake (*Urophycis chesteri*)	0.3	2,341	455	502
Eelpout (Zoarcidae)	0.3	4,558	293	405
Toad Crab (*Hyas* sp.)	0.3	31,017	203	182
Shrimp (*Acanthephyra pelagica*)	0.2	39,687	598	1,003
Arctic Cod (*Boreogadus saida*)	0.2	13,883	194	205

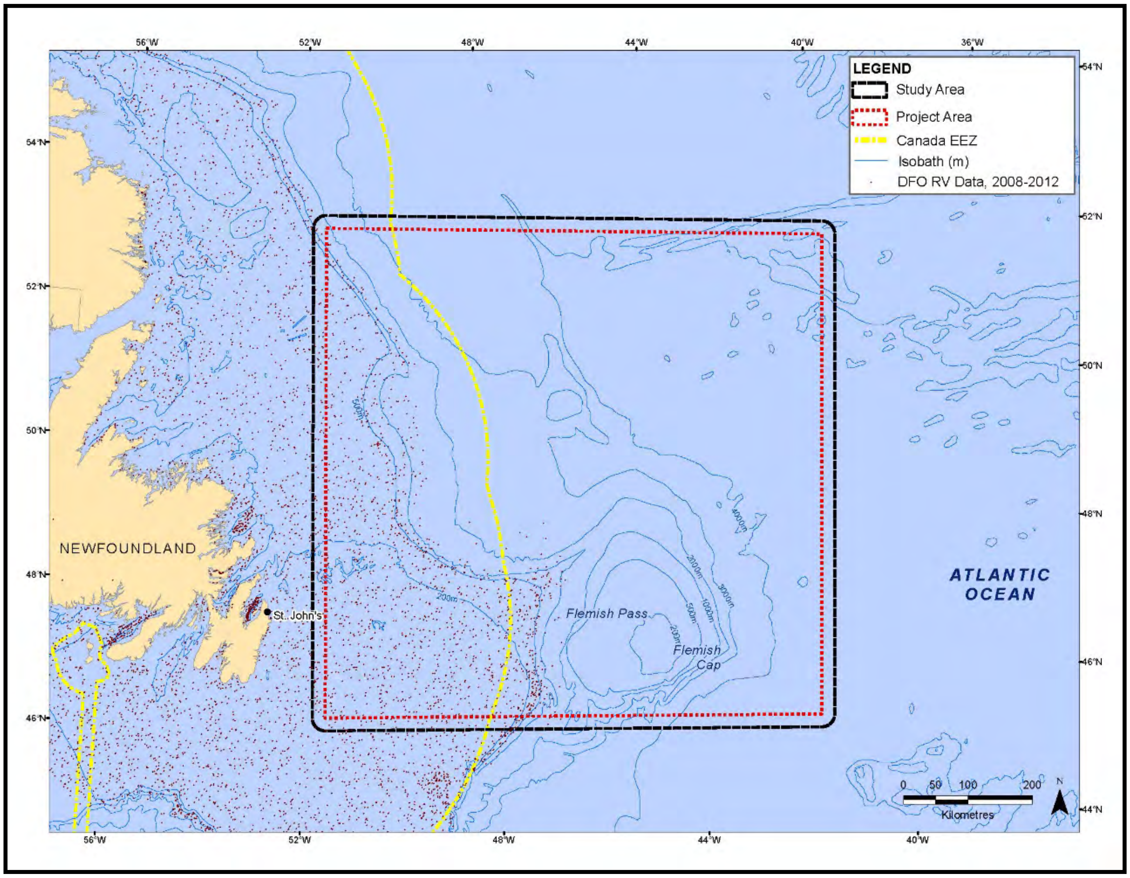
Species	Catch Weight (mt)	Catch Number	Mean Catch Depth (m)	
			Spring	Fall
Atlantic Herring (*Clupea harengus*)	0.2	1,156	228	272
Sand Dollar (Clypeasteroida)	0.2	10,689	189	561
Sculptured Shrimp (*Sclerocrangon boreas*)	0.2	21,879	79	166
Threebeard Rockling (*Gaidropsarus engis*)	0.2	787	453	747
Rigid Cushion Star (*Hippasteria phrygiana*)	0.2	1,060	452	519
Corals	n/d	2,475	259	505
Cusk (*Brosme brosme*)	0.01	5	615	422
White Hake (*Urophycis tenuis*)	0.004	22	359	414
Total	**294**	**10,546,587**	**323**	**420**

Source: DFO RV Survey Data, 2008–2012.
Note: n/d denotes data unavailable.

Deepwater redfish accounted for 33% of the total 2008–2012 catch weight, followed by northern shrimp (11%), Atlantic cod (8%), capelin (6%), sponges (6%), American plaice (5%), Greenland halibut (4%), yellowtail flounder (3%), roughhead grenadier (3%), thorny skate (3%), sand lance (2%), sea anemone (Actinaria; 2%), and snow crab, shrimp (Natantia), blue hake, basket star, jellyfishes, witch flounder, basket star, roundnose grenadier, and northern wolffish (1% each). All other species/groups accounted for less than 1% of the total 2008–2012 catch weight in the Study Area. Principal species captured during the 2008–2012 DFO RV surveys were generally representative of predominant species targeted using similar mobile gear (bottom trawls) in the commercial fishery in recent years. The distribution of georeferenced catch locations reported during the 2008–2012 DFO RV surveys within the Study Area is shown in Figure 4.32. Species were caught in the western portion of the Study Area during the 2008-2012 DFO RV surveys, in water depths <2,000 m. Across all species caught during the 2008-2012 DFO RV surveys in the Study Area, total catch weight ranged from 48–67 mt per year (in 2011 and 2010, respectively).

Spring and fall RV surveys accounted for 32% and 68% of the total catch weight, respectively. The average mean depths of catch during spring and fall surveys from 2008–2012 were 323 m (min: 12 m; max: 727 m) and 420 m (min: 56 m; max: 1,526 m), respectively.

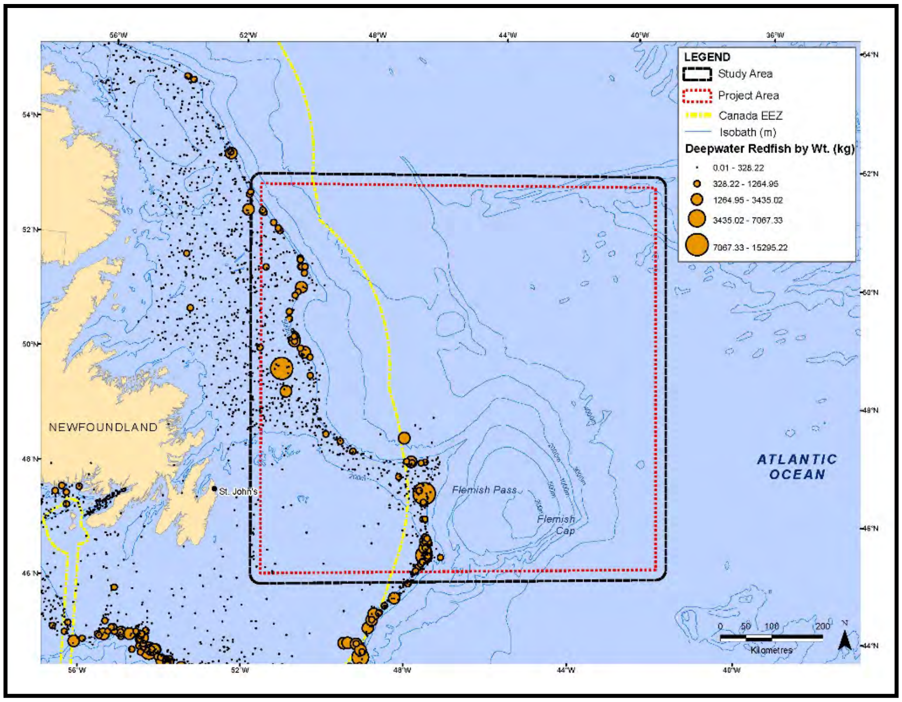
In descending order, the top five species/groups in terms of catch weight during the 2008–2012 spring surveys were capelin, deepwater redfish, northern shrimp, Atlantic cod, and yellowtail flounder. In descending order, the top five species/groups in terms of catch weight during the 2008–2012 fall surveys were deepwater redfish, northern shrimp, sponges, Atlantic cod, and American plaice. Species/groups that were caught predominantly during the spring RV surveys included Atlantic herring, shrimp (*Sergestes arcticus*), capelin, basket star (*Gorgonocephalus arcticus*), sand dollars (*Echinarachnius parma* and Clypeasteroida), mailed sculpin, and yellowtail flounder. Species/groups that were caught in essentially equal amounts during both surveys included sea urchins (*Strongylocentrotus* sp.; *Strongylocentrotus droebachiensis*), hakes (white; longfin) sand lance, and basket star (Gorgonocephalidae). Species/groups that were caught predominantly during the fall RV surveys included black dogfish, grenadiers (roundnose; roughhead), sponges, eelpouts (*Lycodes* sp.; Vahl's; Zoarcidae; *Lycodes reticulatus*), skates (Jensen's, spinytail) longnose eel, blue hake, lanternfishes, threebeard rockling, moustache sculpin, golden redfish, large scale tapirfish, shrimps (Natantia; *Acanthephyra pelagica*; *Argis dentata*), jellyfishes, sea anemone (Actinaria), sea urchin (Echinoidea), marlin spike, witch flounder, wolffishes (northern; spotted), Greenland halibut, and rigid cushion star. The survey depth differences between spring and fall surveys likely account for some of the seasonal differences.



Source: DFO Research Vessel Survey Database, 2008-2012.

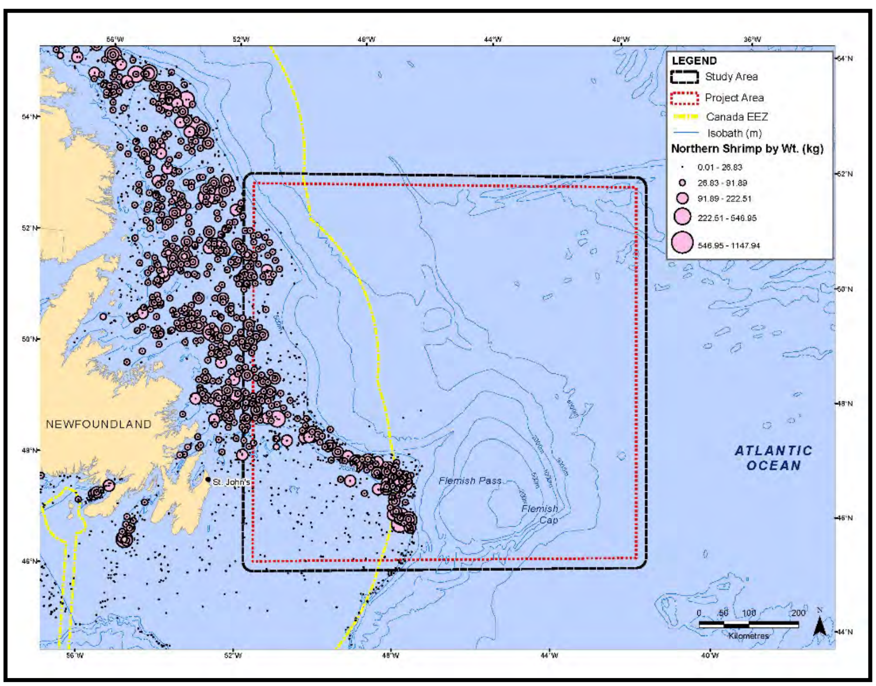
Figure 4.32 Distribution of DFO RV Survey Catch Locations within the Study Area, 2008–2012.

Figures 4.33 to 4.41 indicate 2008-2012 DFO RV survey catch locations for deepwater redfish, northern shrimp, Atlantic cod, capelin, sponges, American plaice, Greenland halibut, corals, and wolffishes, respectively. The sizes of the circular symbols used in these figures are proportional to the catch weight range they represent for each species. Note that there was an insufficient range of catch weights to demonstrate proportional catches for northern and spotted wolffish; catch numbers were used instead (Figure 4.41).



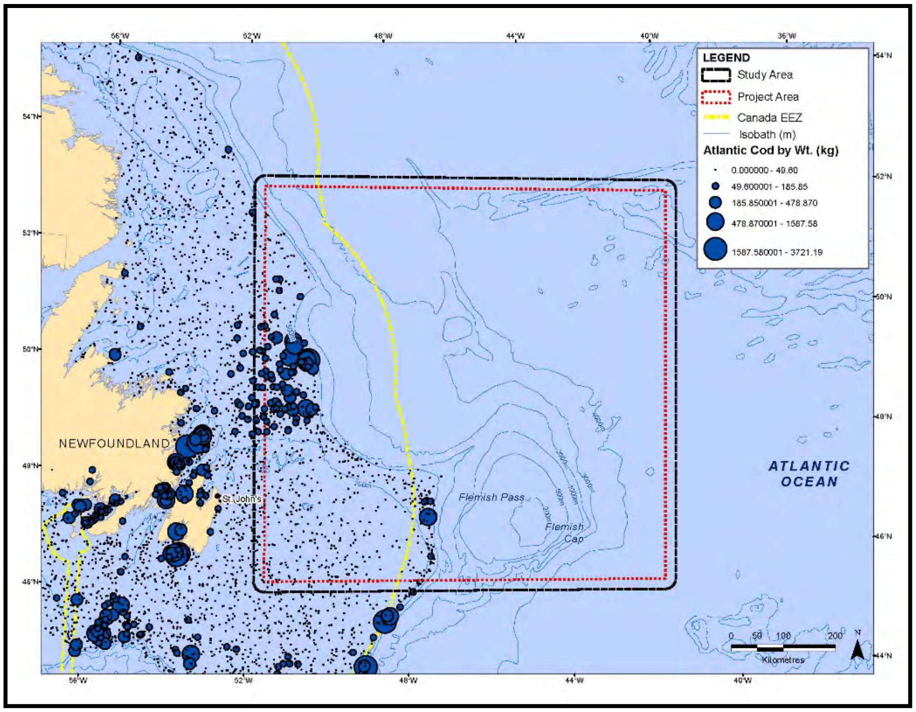
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.33 Distribution of DFO RV Survey Deepwater Redfish Catch Locations in the Study Area, 2008–2012.



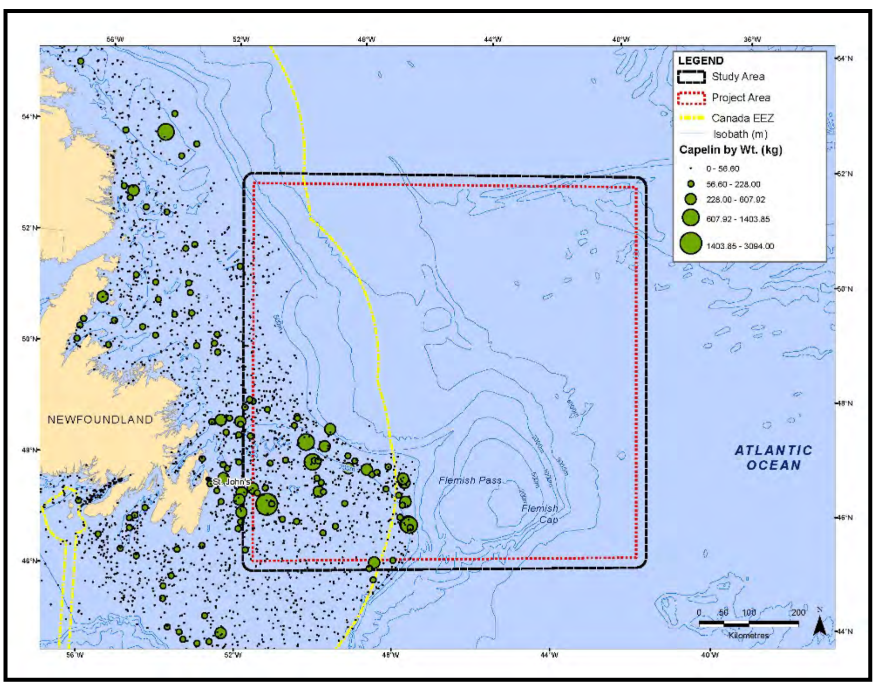
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.34 Distribution of DFO RV Survey Northern Shrimp Catch Locations in the Study Area, 2008–2012.



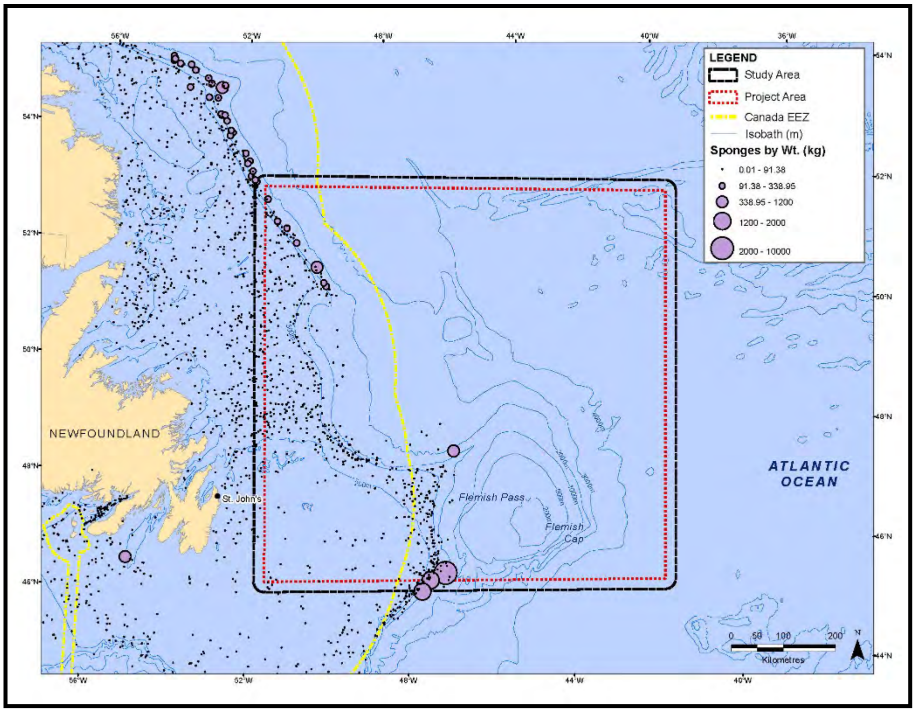
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.35 Distribution of DFO RV Survey Atlantic Cod Catch Locations in the Study Area, 2008–2012.



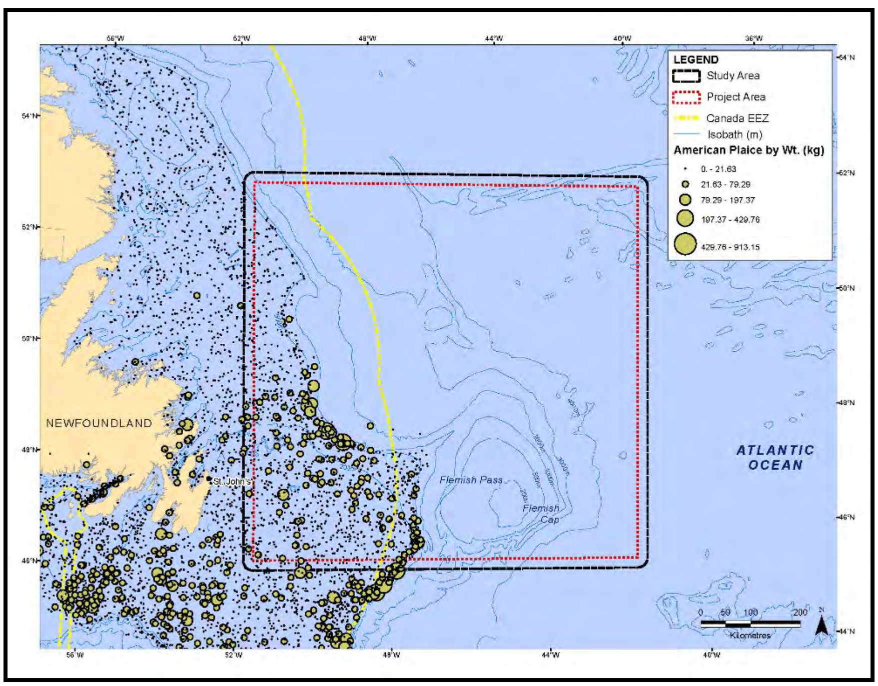
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.36 Distribution of DFO RV Survey Capelin Catch Locations in the Study Area, 2008-2012.



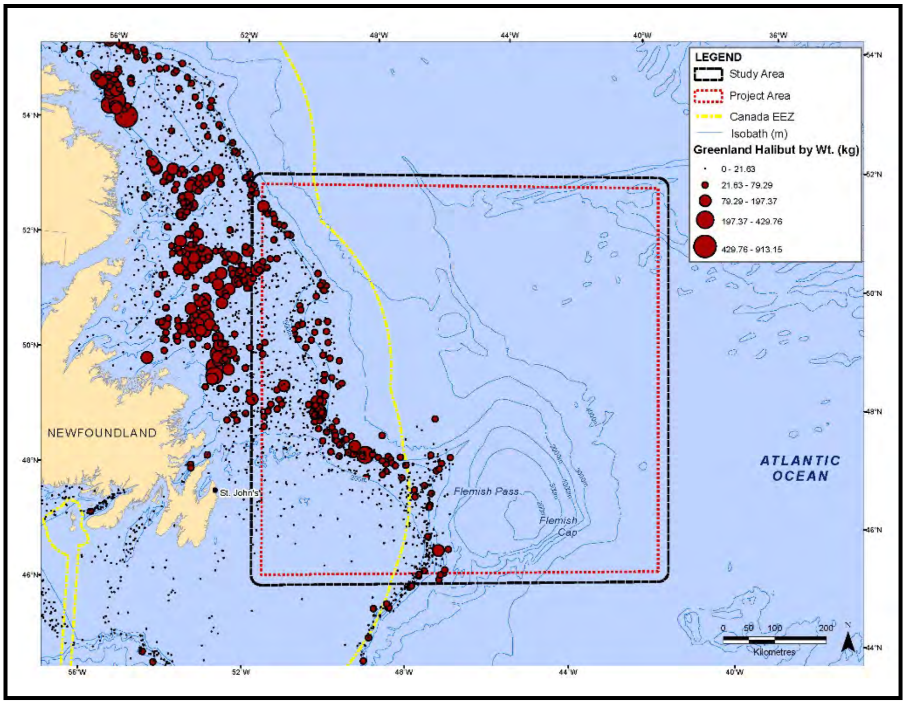
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.37 Distribution of DFO RV Survey Sponge Catch Locations in the Study Area, 2008-2012.



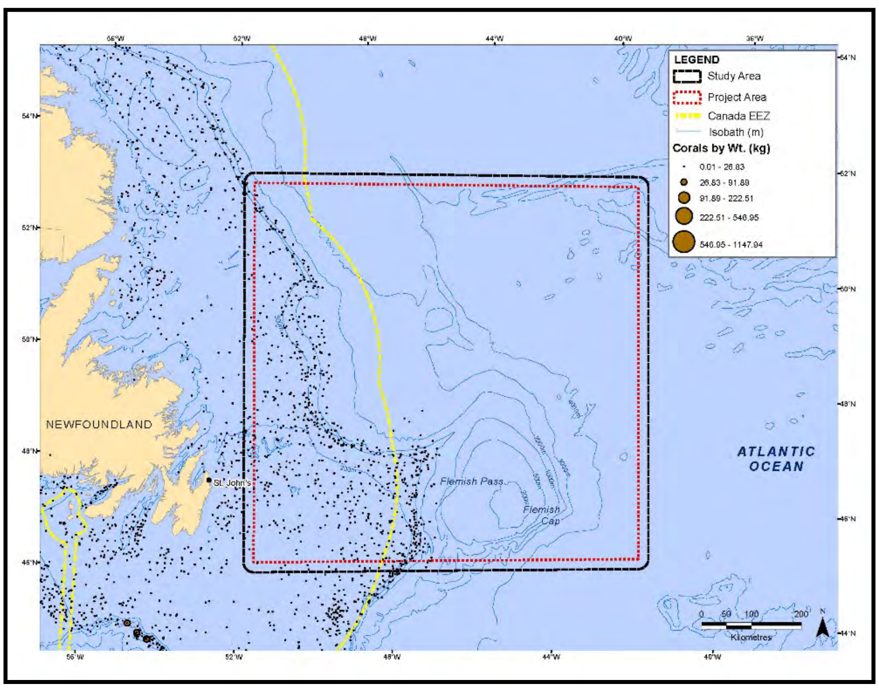
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.38 Distribution of DFO RV Survey American Plaice Catch Locations in the Study Area, 2008–2012.



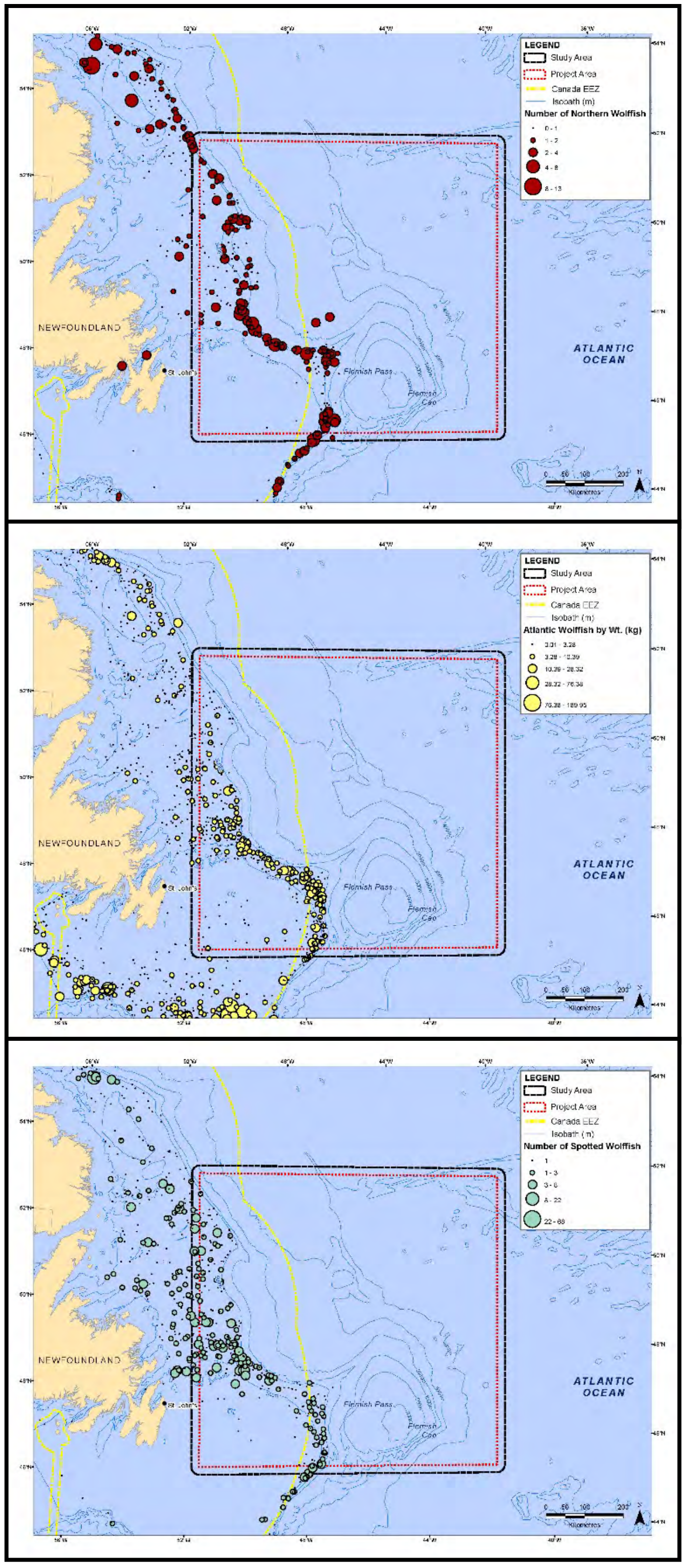
Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.39 Distribution of DFO RV Survey Greenland Halibut Catch Locations in the Study Area, 2008–2012.



Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.40 Distribution of DFO RV Survey Coral Catch Locations in the Study Area, 2008-2012.



Source: DFO Research Vessel Survey Database, 2008–2012.

Figure 4.41 Distributions of DFO RV Survey Northern (top), Atlantic (middle), and Spotted (bottom) Wolffish Catch Locations within the Study Area, 2008–2012.

Catches at various mean depth ranges are also examined in this section. Table 4.9 presents total catch weights and predominant species caught within each mean depth range in the Study Area during the 2008–2012 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 400–500 m, respectively.

Table 4.9 Total Catch Weights and Predominant Species Caught at Various Mean Catch Depth Ranges, DFO RV Surveys, 2008–2012.

Mean Catch Depth Range (m)	Total Catch Weight (mt)	Predominant Species (% of Total Catch Weight)
<100	11	Yellowtail Flounder (83%) Comb Jelly (11%)
≥100 – <200	37	Capelin (52%) Sand Lance (*Ammodytes dubius*; 17%) Snow Crab (11%)
≥200 – <300	76	Northern Shrimp (41%) Atlantic Cod (30%) American Plaice (18%)
≥300 – <400	109	Deepwater Redfish (90%) Sea Anemone (Actinaria; 4%) Shrimp (Natantia; 3%) Vahl`s Eelpout (1%)
≥ 400 – <500	34	Sponges (56%) Greenland Halibut (33%) Witch Flounder (7%)
≥500 – <600	2	Northern Wolffish (77%) Corals (13%)
≥600 – <700	12	Roughhead Grenadier (65%) Jellyfishes (22%) Marlin Spike (8%)
≥700 – <800	1	Spinytail Skate (43%) Shrimp (*Sergestes arcticus*; 23%) Threebeard Rockling (14%)
≥800 – <900	5	Blue Hake (68%) Longnose Eel (22%) Large Scale Tapirfish (8%)
≥900 – <1,000	3	Roundnose Grenadier (64%) Black Dogfish (23%) Shrimp (*Acanthephyra pelagica*; 9%)
≥1,000	1	Jensen`s Skate (40%) Deepsea Catshark (13%) Deepwater Chimaera (12%) Shortnose Snipe Eel (6%)

Source: DFO Research Vessel Survey Database, 2008–2012.

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 any year, there will be spatial overlap between the Study Area and research surveys in NAFO Divisions 2J, 3K, 3L and 3M.

The tentative schedule of DFO RV surveys in the Study Area in 2015 is indicated in Table 4.10. Spring surveys are currently set to begin at the end of March and continue into mid-June, with surveys occurring within the Study Area between the end of May and mid-June. DFO fall research surveys will occur in the Study Area from mid-October until early-December.

Table 4.10 Tentative 2015 Schedule of DFO RV Surveys in the Region of the Study Area.

NAFO Division	Start Date	End Date	Vessel
3P	31 Mar	14 Apr	*Needler*
3P	14 Apr	28 Apr	*Needler*
3P + 3O	29 Apr	12 May	*Needler*
3O + 3N	12 May	26 May	*Needler*
3L + 3N	27 May	13 Jun	*Needler*
3O	16 Sep	29 Sep	*Needler*
3O + 3N	29 Sep	13 Oct	*Needler*
2H	04 Oct	13 Oct	*Teleost*
2H + 2J	14 Oct	27 Oct	*Teleost*
3N + 3L	14 Oct	27 Oct	*Needler*
2J + 3K	27 Oct	10 Nov	*Teleost*
3L	28 Oct	10 Nov	*Needler*
3K	11 Nov	24 Nov	*Teleost*
3K + 3L	11 Nov	24 Nov	*Needler*
3K + 3L Deep	24 Nov	08 Dec	*Teleost*

Start/end dates subject to change as trip plans are finalized.

Members of the FFAW have been involved in a DFO-industry collaborative post-season snow crab trap survey for over ten years. This survey is intended to "allow the fishing industry to more accurately assess and ultimately better manage the valuable snow crab resource" (FFAW|Unifor 2014). 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 2014). This annual survey typically starts in early September, often continuing until November. The station locations, about 1,500 in total, remain constant from year to year. Numerous stations fall within the western and southwestern portions of the Study Area. The survey station locations in relation to the Study Area and Project Area are shown in Figure 4.42.