NEXEN ENERGY ULC
Eastern Newfoundland Offshore Geophysical, Geochemical, Environmental and Geotechnical Program (2018 – 2027)

Environmental Assessment

FINAL REPORT

Submitted by:

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LIST OF ACRONYMS AND ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
4D	Four-dimensional
Accord Acts	*Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*
ACSS	Atlantic Canada Shorebird Survey
bar-m	bar-metres
BLM	Bureau of Land Management
CAPP	Canadian Association of Prawn Producers
CCG	Canadian Coast Guard
CETAP	Cetacean and Turtle Assessment Program
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CNOOC	China National Offshore Oil Corporation
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPAWS	Canadian Parks and Wilderness Society
CTD	Conductivity, Temperature and Depth
CWS	Canadian Wildlife Service
DFO	Fisheries and Oceans Canada
DND	National Defense Canada
EA	Environmental Assessment
EBSA	Ecologically and Biologically Significant Areas
ECCC	Environment and Climate Change Canada
ECSAS	Eastern Canada Seabirds at Sea
EEZ	Exclusive Economic Zone
EL	Exploration License
EMCP	ExxonMobil Canada Properties
EU	European Union
FCA	Fishery Closure Area
FFAW-Unifor	Fish, Food and Allied Workers
FISH-NL	Federation of Independent Sea Harvesters of Newfoundland and Labrador
FLO	Fisheries Liaison Officer
FPSO	Floating Production Storage and Offloading
GBS	Gravity Based Structure

GEAC	Groundfish Enterprise Allocation Council
GIS	Geographic Information Systems
GPA	Geophysical Program Authorization
HMDC	Hibernia Management and Development Company
HSE&A	Health, Safety, Environment & Assurance
IBA	Important Bird Area
ICCAT	International Commission for the Conservation of Atlantic Tuna
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IFMP	Integrated Fisheries Management Plan
IIP	International Ice Patrol
IUCN	International Union for the Conservation of Nature
MARPOL	International Convention for the Prevention of Pollution from Ships
MBCA	*Migratory Birds Convention Act*
MBS	Migratory Bird Sanctuaries
MCTS	Marine Communications and Traffic Services
MMO	Marine Mammal Observer
MPA	Marine Protected Area
MWA	Marine National Wildlife Areas
NAD	North American Datum
NAFO	North Atlantic Fisheries Organization
NAO	North Atlantic Oscillation
Nexen	Nexen Energy ULC
NHS	National Historic Site
NL ESA	Newfoundland and Labrador *Endangered Species Act*
NL	Newfoundland and Labrador
NMCA	National Marine Conservation Areas
NOAA	National Oceanic and Atmospheric Administration
NOIA	Newfoundland and Labrador Oil and Gas Industries Association
NRA	NAFO Regulatory Area
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NSRF	Northern Shrimp Research Fund
NWA	National Wildlife Areas
OBIS	Ocean Biogeographic Information System
OCI	Ocean Choice International

PBGB LOMA	Placentia Bay Grand Bank Large Ocean Management Area
PERD	Program of Energy Research and Development
PIROP	Programme Integre de Recherches sur les Oiseaux Pelagiques
psi	pounds per square inch
RMA	Representative Marine Area
ROV	Remotely Operated Vehicle
RV	Research Vessel
SARA	*Species at Risk Act*
SEA	Strategic Environmental Assessment
SFA	Shrimp Fishing Area
SOCC	Species of Conservation Concern
SPANS	Spatial Analysis System
SPOC	Single Point of Contact
SSAC	Species Status Advisory Committee
TAC	Total Allowable Catch
TTS	Temporary Threshold Shift
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnances
VEC	Valued Environmental Component
VME	Vulnerable Marine Ecosystems
VMS	Vessel Management System
WGS	World Geodetic System
WWF	World Wildlife Fund

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1 INTRODUCTION

Nexen Energy ULC (Nexen) is proposing to undertake an offshore petroleum exploration program in the eastern portion of the Canada - Newfoundland and Labrador Offshore Area, which will include planned geophysical, geochemical, environmental and geotechnical survey activities in this region between 2018 and 2027 (hereinafter also referred to as the Project).

The proposed Project will require authorizations from the Canada - Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB, or the Board), pursuant to 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* (the *Accord Acts*).

This document provides an Environmental Assessment (EA) of this proposed Project, and has been planned, prepared and is being submitted in compliance with the associated regulatory requirements and processes of the C-NLOPB.

1.1 Project Overview and Scope

Project Name: ***Eastern Newfoundland Offshore Geophysical, Geochemical, Environmental and Geotechnical Program (2018 - 2027)***

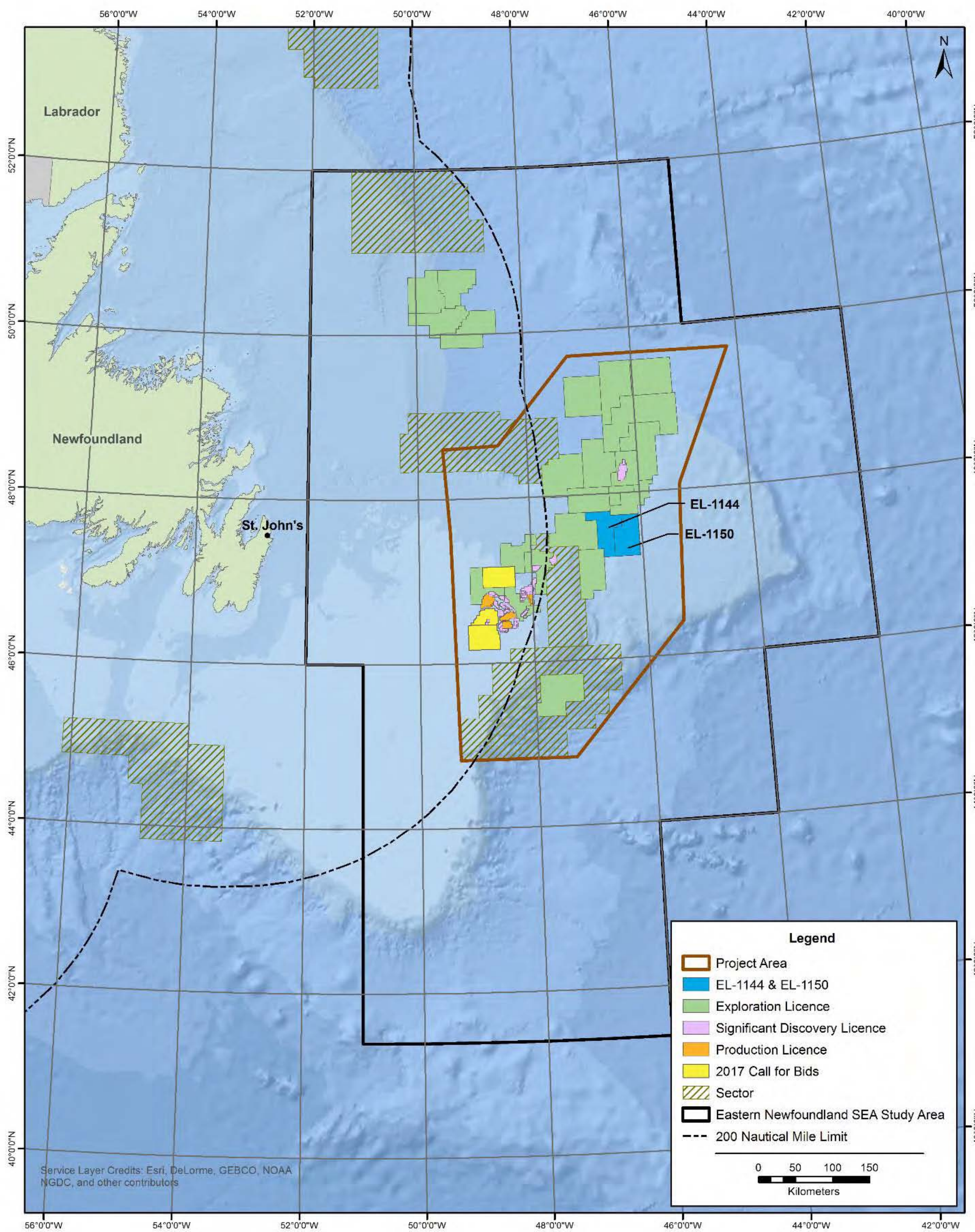
Nexen is an upstream oil and gas company that is responsible for managing its energy resources in Canada and providing management services and oversight to its affiliates including in the UK North Sea, offshore West Africa, and the United States ("manages"). A wholly-owned subsidiary of CNOOC Limited, Nexen manages three principal lines of businesses: 1) Conventional oil and gas, 2) Oil sands, and 3) Shale gas/oil. Although Nexen manages onshore production in several areas around the world, the largest component of the conventional business it manages occurs offshore, with approximately half of the production coming from offshore facilities in the UK North Sea, West Africa, and the Gulf of Mexico. The company is also a significant player in Canada's oil sands industry, and produces shale gas in northeastern British Columbia while also managing working interests in several shale projects in the United States. Further information on Nexen can be found at *www.nexencnoocltd.com*.

Nexen's current offshore interests in Eastern Canada include two existing Exploration Licences (ELs) off Eastern Newfoundland (EL 1144 and EL 1150) which were issued by the C-NLOPB effective January 15, 2016 and January 15, 2017, respectively. Nexen is currently sole interest holder in ELs 1144 and 1150.

Nexen is currently developing its plans for an oil and gas exploration program offshore Eastern Newfoundland, which will involve several types of exploration survey activities over these existing and any forthcoming ELs and other areas of interest in the Project Area (Figure 1.1). These may include two-dimensional (2D), three-dimensional (3D) and possibly four-dimensional (4D) seismic data acquisition, as well as associated geochemical, environmental and geotechnical survey activities.

It should be noted that subject to regulatory approvals, Nexen or any future partners may serve as Operator during the Project. The Operator will honour all commitments, mitigations and regulatory requirements for any Project activities that are the subject of this EA, including any terms and conditions of EA approval.

Figure 1.1 Nexen's Eastern Newfoundland Offshore Geophysical, Geochemical, Environmental and Geotechnical Program, 2018-2027



1.2 Proponent Contact Information

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1.3 Regulatory Context and Environmental Assessment Requirements

The C-NLOPB is responsible, on behalf of the Governments of Canada and Newfoundland and Labrador, for petroleum resource management in the Canada - NL Offshore Area. The *Accord Acts,* administered by the C-NLOPB, provide for joint management of this Offshore Area and govern all oil and gas activities in the region. In the implementation of its mandate, the role of the C-NLOPB is to facilitate the exploration for, and development of, the hydrocarbon resources in this area in a manner that conforms to the statutory provisions for: 1) worker safety; 2) environmental protection; 3) effective management of land tenure; 4) maximum hydrocarbon recovery and value; and 5) Canada-Newfoundland and Labrador benefits. The C-NLOPB's associated regulatory responsibilities include but are not limited to the administration and issuance of specific licences, authorizations and approvals pertaining to offshore oil and gas exploration and production activities in this region.

In planning to carry out offshore geophysical programs for petroleum resources in the Canada-NL Offshore Area, an Operator must apply for and obtain a Geophysical Program Authorization (GPA) from the C-NLOPB. In addition, proposed geological (including geochemical), environmental and geotechnical activities also require a Geological, Geotechnical and Environmental Program Authorization. The application and review processes and information requirements that pertain to these authorizations are outlined in the C-NLOPB's *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (June 2016), which also include various measures and requirements related to environmental planning, mitigation and reporting.

As part of its regulatory responsibilities and processes, the C-NLOPB also requires that project-specific EAs be conducted and submitted by Operators in relation to various types of oil and gas exploration activities in the Canada - NL Offshore Area, including those that are being proposed as part of this Project.

A number of other federal and provincial government departments and agencies also may have regulatory responsibilities, information and advice and/or other interests regarding the proposed Project and its environmental setting and potential effects, pursuant to their associated legislation and mandates. These include:

- Fisheries and Oceans Canada (DFO);
- Environment and Climate Change Canada (ECCC);
- Transport Canada;
- Department of National Defence;
- NL Department of Municipal Affairs and Environment;
- NL Department of Fisheries and Land Resources; and the
- NL Department of Natural Resources

Key legislation and regulations that are or may be relevant to the Project and its EA therefore include:

- The *Accord Acts* and associated Regulations and Guidelines, including the:
    - Geophysical, Geological, Environmental and Geotechnical Program Guidelines (June 2016),
    - Canada-Newfoundland and Labrador Exploration Benefits Plan Guidance (February 2006); and the
    - Offshore Physical Environmental Guidelines (September 2008).
- *Fisheries Act*;
- *Oceans Act*;
- *Navigation Protection Act*;
- *Canada Shipping Act*;
- *Canadian Environmental Protection Act;*
- *Migratory Birds Convention Act*; and the
- *Species at Risk Act* (Canada) and *Endangered Species Act* (NL).

In planning and conducting its oil and gas exploration activities, Nexen will comply with these and other relevant federal and provincial legislation, regulations and guidelines, as well as applicable international conventions and standards. As described in a later section of this EA Report, Nexen also has in place its own comprehensive corporate Health, Safety, Environment & Assurance (HSE&A) policies, plans and procedures for planning and conducting its oil and gas exploration and development projects and activities, and requires its contractors to adhere to these as applicable.

1.4 Canada-Newfoundland and Labrador Benefits

The C-NLOPB's mandate also includes the administration of the various provisions of the *Accord Acts* that pertain to industrial and employment benefits resulting from the exploration for, and development of, oil and gas resources in the Canada-NL Offshore Area. This includes the creation and optimization of such benefits for Canada in general and the Province of Newfoundland and Labrador in particular.

The *Accord Acts* require that before any work or activity is authorized, a Canada-Newfoundland and Labrador Benefits Plan must be submitted to, and approved by, the Board. This Plan must identify and describe the measures to be taken regarding the employment of Newfoundlanders and Labradorians and other Canadians, as well as providing manufacturers, consultants, contractors and service companies in the province and other parts of Canada with full and fair opportunity to participate on a competitive basis in the supply of goods and services to such a project.

Nexen is also committed to creating and optimizing opportunities and benefits for Newfoundland and Labrador and Canadian workers and companies as part of its activities and operations in the Canada-NL Offshore Area, and to carrying out its business in full compliance with relevant *Canada-Newfoundland and Labrador Exploration Benefits Plan Guidance* and other applicable requirements.

1.5 Purpose and Organization of the Environmental Assessment Report

EA is a regulatory review and planning process that is often applied to proposed development projects or other associated activities. Its purpose is to identify and evaluate the potential environmental effects of such proposals, in order to help ensure that these issues can be considered and incorporated into planning and decision making. It involves predicting a project's potential effects and identifying and proposing measures to avoid or reduce adverse outcomes and to enhance any benefits, and often includes public and stakeholder consultation at various stages of the process.

Nexen, as the Proponent of the Project, is submitting this EA Report which was prepared by Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited. The assessment has been planned and undertaken in accordance with the requirements of the C-NLOPB's review process, and in full compliance with the Final EA Scoping Document issued by the Board on March 13, 2017. It has also been guided by the information and input received, and questions and issues identified, through various communications and consultations with other government departments and agencies, industry and interest groups and key stakeholders.

The EA that follows provides the required information about the Project, its existing environmental setting, potential environmental effects, proposed mitigation and any associated residual environmental effects and environmental monitoring and follow-up initiatives. This will form the basis for a review of the Project and its likely environmental effects by the C-NLOPB and other applicable government departments and agencies and non-governmental organizations, and will be an input into associated regulatory decisions about the Project.

This EA Report is structured as follows:

Chapter 1 (this Introduction): Provides a general overview of the Project and its background and scope, identifies the Proponent, outlines the regulatory context for the Project, and describes the purpose of the EA Report and the overall organization of the document.

Chapter 2 (Project Description): Initially sets the overall context for the Project and its EA by discussing its need, purpose, rationale and alternatives. It goes on to describe its proposed location (Project Area) and schedule, and provides a description of the planned survey equipment and activities. This Chapter also describes potential environmental emissions and interactions, possible accidental events and malfunctions, and potential effects of the environment on the Project, including the manner in which environmental conditions have and will influence Project planning and implementation.

Chapter 3 (EA Scope, Focus and Approach): Outlines the scope and focus of the assessment, including its various regulatory requirements and consultative activities and inputs. It also identifies the various Valued Environmental Components (VECs) upon which the EA is focussed and the rationale for same, and describes the overall approach and methods that were used to conduct the assessment.

Chapter 4 (Existing Environment): Describes the existing environmental setting within the Project Area and Study Area, including the natural and human environments that overlap, and may interact with, the proposed Project. This includes relevant aspects of the physical, biological and socioeconomic environments.

Chapter 5 (Environmental Effects Assessment): Provides the detailed results of the environmental effects assessment for the selected VECs, each of which is addressed in a separate section using the overall EA structure and methodology described in Chapter 3.

Chapter 6 (EA Summary and Conclusions): Provides a summary of the key results and overall conclusions of the EA.

Chapter 7 (*References*): Provides a bibliography of all information sources used in the EA Report, including personal communications and literature cited.

Supporting information is provided as *Appendices*.

2 PROJECT DESCRIPTION

The following Chapter provides an overview description of the proposed Project, including its purpose and rationale, alternatives to and within the proposal, the proposed Project Area and survey timing, planned Project equipment and activities, and various associated environmental planning and management considerations and measures. This overview is based on, and reflects, the current stage of the planning and design of this multi-year offshore exploration program, and will therefore be subject to continued definition and refinement as these activities move forward.

2.1 Project Purpose and Rationale

The petroleum industry is an important and valuable component of the Newfoundland and Labrador economy, and one that has been identified as having considerable potential for future growth. Oil and gas exploration has been a key aspect of the province's offshore petroleum industry to date. On-going and future exploration is required in order to identify and further understand the existence of currently unknown and undeveloped hydrocarbon reserves in the region, and in doing so, to help facilitate the further development of this important economic sector. As a new entrant into Newfoundland and Labrador's oil and gas sector, Nexen is seeking to increase its activities in the region through exploration, and if commercially viable hydrocarbon resources are successfully identified, through future development and production activities. In proposing, planning and undertaking this Project, Nexen's primary objectives are to acquire additional geological information to better understand the overall hydrocarbon potential of the Project Area, and to help define and assess prospects for potential future drilling activities.

In order to evaluate the hydrocarbon prospectivity and potential of the region, Nexen is proposing to acquire new 2D and 3D seismic data over the Project Area. Nexen also intends to re-evaluate existing geophysical and geological data and to perform a series of geoscience studies of existing and newly acquired data, including seismic re-processing, biostratigraphic dating and provenance analysis

In the near term, the proposed petroleum exploration activities that comprise this Project and which are the subject of this EA will result in a number of direct and indirect economic benefits, including the creation of employment and business opportunities over the course of its planning and operational phases in 2017 and beyond. As noted earlier, the Project is being planned and will be carried out in full compliance with the C-NLOPB's *Canada-Newfoundland and Labrador Exploration Benefits Plan Guidance*.

Should the exploration program be successful in identifying important and commercially viable oil and/or gas resources in the region, it could also lead to additional economic activity in Newfoundland and Labrador related to further exploration, and possibly, petroleum production activities. An important potential outcome of this Project could therefore be future economic development and growth in the province's offshore oil and gas sector and overall economy.

2.2 Project Area

Offshore exploration survey programs such as those being proposed here are often planned and conducted to get an overall understanding of regional geology and hydrocarbon potential, and to help identify particular sites or zones that may warrant further investigation, such as through eventual exploration drilling activities.

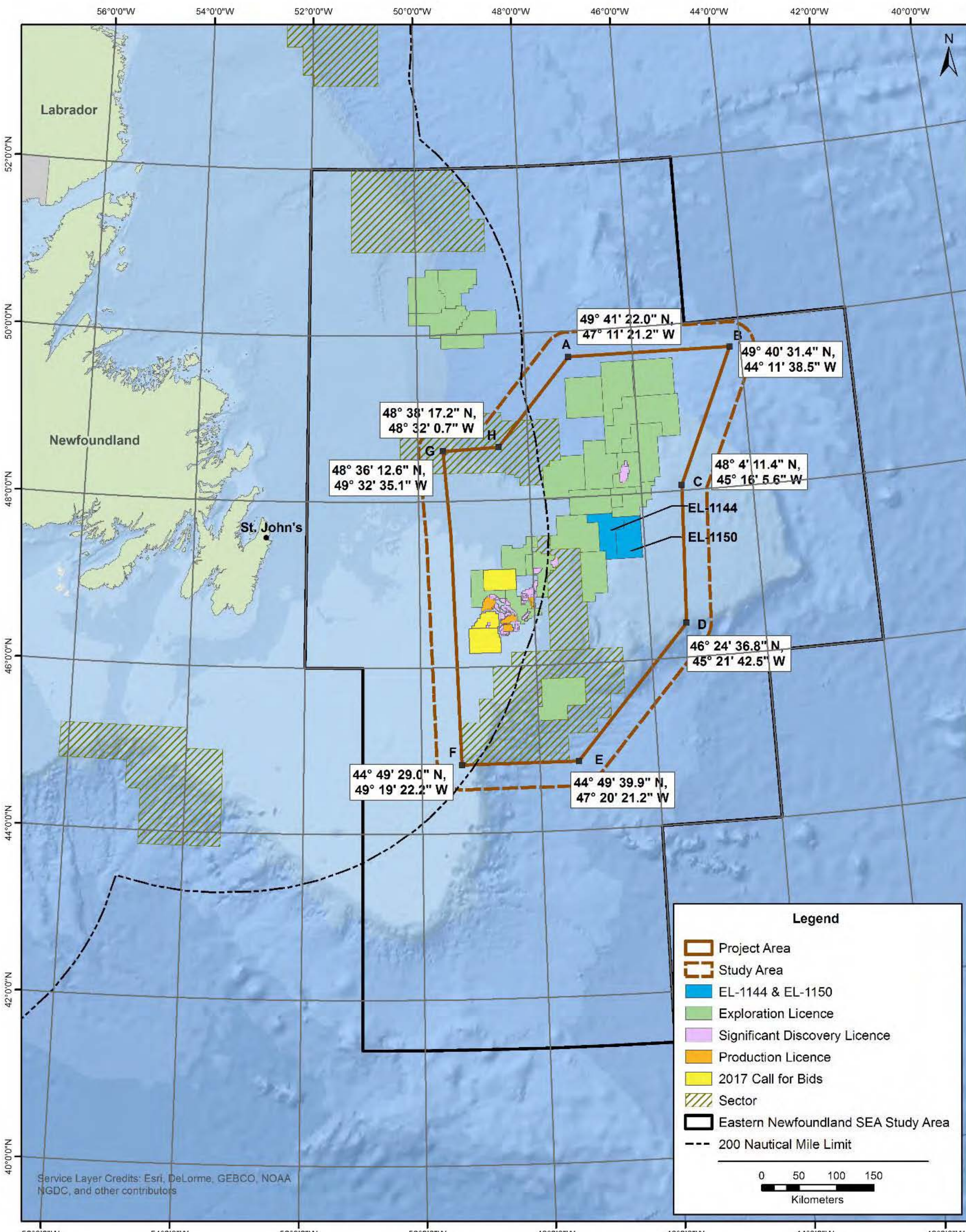
The proposed Project Area is located off the eastern coast of the Island of Newfoundland, with its western edge being approximately 200 km east of St. John's (Figure 2.1). It covers a total area of approximately 147,200 km^2, and encompasses the overall marine area within which all Project-related survey equipment use and data-acquisition activity will take place. Water depths in the Project Area range from approximately 100 m to 4,000 m. Coordinates for each of the identified corner points of the proposed Project Area are provided in Figure 2.1 and Table 2.1.

Table 2.1 Project Area Corner Points and Coordinates

Corner Point ID	Latitude	Longitude	Easting	Northing
A	49° 41' 22.0" N	47° 11' 21.2" W	774830	5511078
B	49° 40' 31.4" N	44° 11' 38.5" W	990852	5524816
C	48° 4' 11.4" N	45° 16' 5.6" W	926910	5339973
D	46° 24' 36.8" N	45° 21' 42.5" W	933306	5155094
E	44° 49' 39.9" N	47° 20' 21.2" W	789391	4970337
F	44° 49' 29.0" N	49° 19' 22.2" W	632589	4964847
G	48° 36' 12.6" N	49° 32' 35.1" W	607405	5384405
H	48° 38' 17.2" N	48° 32' 0.7" W	681701	5390165

* See Figure 2.1
Geodetic parameters (WGS): NAD 83

Figure 2.1 Project Area Corner Points and Coordinates

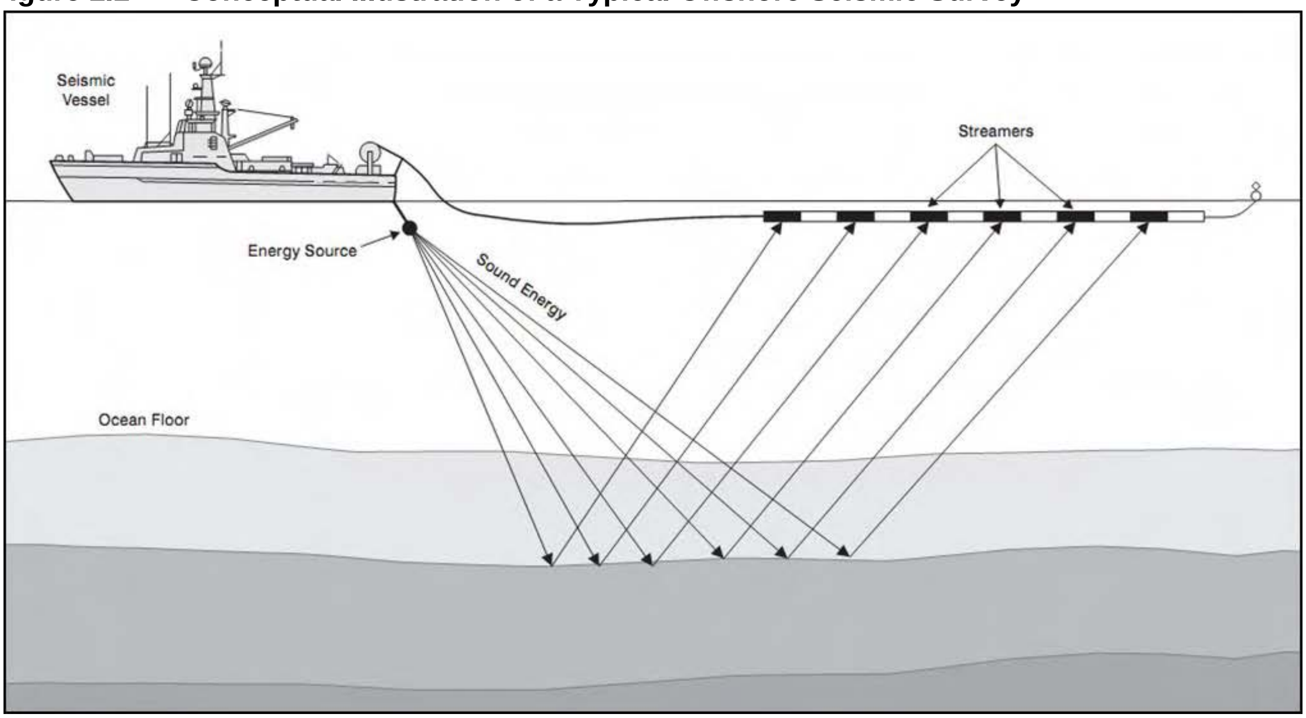


As also illustrated in Figure 2.1, portions of the Project Area are located within Canada's Exclusive Economic Zone (EEZ), whereas other parts are located beyond the 200 nautical mile limit. All Project survey activities and operations, including survey equipment deployment, use and recovery, testing, other data acquisition and seismic survey line turns, will be completed within the identified Project Area boundary.

2.3 Seismic Surveys

The main equipment associated with an offshore seismic program for petroleum exploration includes a survey vessel, a sound source (typically compressed air), receivers (streamers) and associated supporting components and activities (Figure 2.2). In a marine seismic survey, one or more sound source arrays are towed behind a vessel while it travels along pre-determined survey lines. The sound source is fired at regular intervals and directs high energy (low frequency) sound pulses toward the seafloor which can penetrate below the surface. The reflected acoustic energy is then recorded by sensitive hydrophones in the streamer(s) which are towed behind the vessel. Computer-based data processing systems then convert the reflected acoustic signals into seismic data that can be used to map geological features and structures of interest within the survey area.

Figure 2.2 Conceptual Illustration of a Typical Offshore Seismic Survey



2D seismic programs tend to cover relatively large geographical areas, in order to identify sites or zones that may warrant further investigation, and they are therefore of relatively short-term duration at any given location. These surveys typically use one sound source array and often employ a single streamer, with survey lines being widely spaced (usually several kilometers apart) and laid out in various directions. A number of 2D surveys may be designed and undertaken as part of the Project over its planned 10 year duration, and it is currently anticipated that this could involve approximately 2,200 to 5,000 km^2 of survey coverage within the Project Area. Each 2D survey would involve the collection of approximately 1,000–3,000 line-kilometers of seismic data, and would range from approximately 10-30 days in duration. Seismic survey locations and associated survey line numbers, lengths and layouts have yet to be determined and will be defined each year as Project planning and implementation progress. More narrowly spaced (high resolution) 2D seismic survey work may also be undertaken at particular locations to evaluate potential wellsite drilling locations identified through the geophysical survey program.

It is also anticipated that a number of 3D seismic surveys may be completed over parts of the Project Area within this 10 year period. 3D seismic activities are typically more focussed and tend to cover smaller geographical areas than 2D surveys, and may use multiple sound source arrays and streamers which enable a greater resolution of potential oil and gas bearing geological structures. Although the specific number and size of 3D survey areas and associated line lengths and layouts have yet to be defined, it is currently expected that the surveys would range in area from 500-3,000 km^2 full-fold coverage. The duration of each 3D seismic survey would typically range from approximately 30-100 days.

It is also possible that 4D seismic survey activity will be carried out as part of the Project. Also known as “time lapse seismic”, 4D surveys incorporate multiple 3D seismic surveys over the same area at specified intervals. If conducted, any such 4D surveys would likely take place around the vicinity of any Nexen wellsites that have provided an indication of a significant petroleum discovery or other specific areas of identified interest and hydrocarbon potential in the Project Area.

Although the particular seismic survey vessel(s) that would be used for the Project has yet to be selected and contracted, it would be a fully equipped, modern vessel suited to the operating environment and task, which would be approximately 75 – 90 m in length. The seismic source arrays, streamers and other equipment to be used during the surveys are contractor and vessel dependent.

A typical seismic source consists of air source arrays, ranging in volume from 3,000 in^3 to 6,000 in^3 which operate at towed depths between 5 m and 15 m. The towed array operates on compressed air at pressures of approximately 2,000-2,500 pounds per square inch (psi), and produces approximate peak-to-peak pressures of 100 to 150 bar-metres (bar-m). The array configurations are optimized to direct the signal downward towards and into the seafloor. If two source arrays are used for the 3D/4D survey activities, they will not fire simultaneously but rather will have an alternate firing pattern (“flip-flop” mode). The source arrays’ discharge frequency is based on vessel speed and distance along the survey line. Firing of the complete source array will be stopped during the turns from line to line.

The planned 2D seismic surveys would use a single towed streamer, with a length ranging from 6,000 - 10,000 m which would be deployed at a depth of about 5 - 80 m. Streamer design may be flat, slanted or curved, depending on acquisition requirements. Where multiple streamers are planned to be used (such as for 3D survey activity), their specific numbers (up to an estimated 15), tow depths, and separation distances will be determined according to survey data collection objectives and other parameters and technical considerations. Streamers are planned to be solid or gel-filled to minimize any potential for environmental effects in the case of breaks or tears. Hydrophones in the streamers will receive the sound waves reflected from structures underneath the ocean floor and transfer the data to an on-board recording and processing system. The seismic survey vessel would also passively collect and record gravity and magnetic data at the same time, and have an echosounder for depth soundings.

As survey vessel(s), source array and streamer characteristics and equipment configurations are contractor-specific, the particular vessels and equipment used may therefore vary somewhat from those described above, and from year to year. The overall characteristics of the seismic survey vessels and equipment used would, however, be generally in keeping with the parameters described above.

2.4 Geochemical, Environmental, Geotechnical and Wellsite Surveys

Geochemical, environmental, geotechnical and wellsite survey activities may also be conducted as part of the Project, in order to collect additional information to help determine the hydrocarbon potential of, and/or environmental and seabed conditions within, relevant parts of the Project Area. The specific nature, location and timing of these activities in any year will be subject to regulatory approvals, information requirements and data collection objectives, as well as such factors as weather and ice conditions, the location of other marine activities in the region and other considerations.

Geochemical surveys are associated with exploration for hydrocarbon prospects. Data acquisition may be undertaken using a towed or Remotely Operated Vehicle (ROV) mounted seabed camera/video system, grab samplers, gravity or piston core, box corer and water sampler.

Environmental surveys could include the collection of meteorological and oceanographic information within parts of the Project Area, as well as other environmental data collection activities focussed on specific physical or biological components at particular sites. Associated equipment may include water samplers, current, temperature and depth (CTD) measuring devices, wave rider buoys, seabed grab and core samples and fish sampling gear.

Geotechnical surveys may also be undertaken to better understand sea bottom conditions at particular locations within the Project Area. These can range from seabed sampling from a vessel of opportunity using core, grab and seabed sampling equipment, to in-situ sampling well below the seabed using a dedicated geotechnical drillship. Specific geotechnical activities may include, but not be limited to, cone penetration tests and vibrocorers.

An objective of regional survey programs such as this proposed Project is often to help identify particular locations that may warrant further investigation through future exploration drilling activities. As the proposed survey activities that comprise this Project are initiated and completed and their results are analysed and interpreted, possible future wellsite locations may be identified and evaluated further through wellsite surveys. These site investigations may be carried out using 2D high-resolution reflection seismic, sub-bottom profilers, side-scan sonar, multi-beam echosounder and/or magnetometers. The wellsite surveys are conducted within a block/grid around the identified potential well site, with any final well location within this area being determined and adjusted within the grid based on the interpreted data from the survey and other factors. Core, grab and seabed samples may also be acquired within these locations to further evaluate seabed sediment characteristics at these sites. For each of these activities, the survey vessel could be either a dedicated survey ship or could be a vessel of opportunity from which the appropriate equipment would be deployed. In 2018 (and in future years of the Project), Nexen may conduct one or more of these wellsite surveys, pending the identification of potential drill-worthy prospects in the Project Area.

In conducting each of these types of marine activities, individual surveys would be an estimated 5-20 days in duration.

2.5 Project Logistics and Personnel

Any and all vessels that are used for this Project will fully meet the operational and environmental capabilities needed for the associated exploration activities, including implementing relevant environmental mitigations, pollution prevention, safety and emergency response. All vessels will comply with applicable legislation and regulations, and will be inspected by Transport Canada and approved for operation by the C-NLOPB before beginning any Project-related work. They will have appropriate oil spill/pollution prevention and emergency response plans in place, and each will be fully compliant with the International Convention for the Prevention of Pollution from Ships (MARPOL).

A typical seismic acquisition vessel can accommodate approximately 50-100 personnel, depending on project requirements. Personnel on a seismic vessel typically include the vessel owner/operator (ship's officers and marine crew), and technical and scientific personnel from the main seismic contractor. The seismic vessel will also have a Fisheries Liaison Officer (FLO) and Marine Mammal Observer(s) on board, as well as Nexen representative(s). All Project personnel will have all required certifications specified by applicable Canadian legislation and the C-NLOPB. Crew changes will be either by helicopter, ship-to-ship or ship-to-shore transfer. Standby or guard vessel(s) will be used to scout for hazards and for interacting and communicating with other marine users in the area, including fishers.

A typical vessel for the other geochemical, environmental, geotechnical and wellsite survey activities outlined above can typically accommodate 20-40 personnel, made up of technical personnel and the maritime crew and Nexen representatives. All Project personnel will again have all of the required certifications as specified by applicable Canadian legislation and the C-NLOPB.

Logistical and support activities for the surveys will largely depend on the contracted seismic acquisition company. The seismic vessel will likely use shore based facilities in or near St. John's, NL for initial authorization to enter and work in Canadian waters. Resupply of the vessels during the survey will be accomplished with a supply vessel from an Atlantic Canadian port, most likely St. John's. Existing port infrastructure will be used for all support aspects, and fuel and supplies will be sourced from existing, local suppliers. Refuelling will take place offshore, utilizing the offshore supply vessel. Helicopter support may also be used intermittently and as required for the transportation of personnel or materials to and from the vessels.

2.6 Project Schedule

Pending eventual EA approval and the receipt of all other required permits and authorizations from applicable regulatory authorities and other technical and logistical requirements and Nexen internal approvals to proceed, it is currently anticipated that in-field Project work will commence in 2018. Project activity will generally occur within the April to November period for each and all years of the proposed exploration program, which will include survey activity in one or more years within the 2018 to 2027 timeframe. The actual timing of data acquisition in any given year will be determined at that time based on factors such as local weather, sea state and ice conditions, the nature, timing and intensity of commercial fisheries, and associated coordination with other marine activities in this area and elsewhere. Nexen may concurrently conduct multiple surveys in any given year of the program.

2.7 Potential Environmental Emissions and Their Management

Potential environmental emissions and discharges that may be associated with marine-based geophysical, geochemical, environmental, geotechnical and wellsite survey programs include seismic sound and other noise, as well as vessel discharges, atmospheric emissions (exhaust), and the noise and general presence of vessels, equipment and lights associated with these offshore activities.

2.7.1 Underwater Noise

Underwater sound will be generated as a result of the planned Project activities, which will include the noise generated by the survey and support vessels themselves, as well as the sound energy from the source array for 2D/3D/4D seismic data collection.

As described earlier, the seismic source array volumes for this program are expected to range from approximately 3,000 – 6,000 in^3 in volume with operating pressures of approximately 2,000-2,500 psi, producing approximate peak-to-peak pressures of 100 to 150 bar-m. The airguns in the array are strategically arranged to direct most of the energy vertically (downward) rather than in the horizontal plane (sideways or to the front and back). If two source arrays are used for the 3D survey activity, they will not fire simultaneously but rather will fire alternatively along the line ("flip-flop" mode). The source arrays' discharge frequency is based on distance along the survey line. For a typical 2D or 3D seismic survey, Nexen expects the shot-point interval to be in the range of 50 m to 100 m with a source separation of 50 m. Firing of the complete source array will be stopped during the turns from line to line. Due to the length of the streamers, such turns are expected to require several hours to complete. During this period, a single and smallest unit from a source array may be fired at a considerably reduced frequency to act as a mitigation (deterrent) source for marine animals.

The firing of an air source generates an oscillating bubble in the surrounding water. At the time of firing, the pressure of the air inside the cylinder exceeds the outside pressure in the surrounding water. This difference in pressure causes a bubble to expand rapidly in the water around the air source, and it is this initial bubble expansion that generates the relatively broadband seismic pulse. The output of an air source array is a function of the time vs. pressure and frequency involved. During the conduct of an offshore seismic survey, airguns are usually fired at intervals of several seconds, with seismic shots being of short duration, at most a few tens of milliseconds (ms). The frequency characteristics of an air source array signature relate to how the signal sounds, with hertz (Hz) being the unit of measurement for frequency. Air source signatures are referred to as broadband, as they contain a range of frequencies (Amec 2013, 2014).

During a marine seismic survey, the arrays are configured to maximize the amount of seismic energy projected vertically into the geologic formation being studied (a characteristic known as "directivity"). Although the direction of the greatest sound intensity is downwards from the array, some energy is radiated in directions away from the beam axis and into the surrounding environment. Because of the pattern of air source placement in an array, the signature changes as a function of direction (azimuth) and emission angle (angle from the vertical). The firing times for all the air sources in the array are synchronized to ensure that the primary pulses from each gun align exactly with one another along the vertical axis of the array. These differences in the array signature with respect to direction and angle from the vertical are referred to as the array response. This means that the frequency content and sound pressure levels of the array signature will be different at different locations in the water. These differences are known as the acoustic radiation pattern and can be calculated and mapped in three dimensions (Amec 2013, 2014).

The sound from a seismic array diminishes with increasing distance from the source, which is referred to as transmission loss, and it is influenced by geometric spreading losses and attenuation. Pressure measured at some distance away for the air source array is often determined by using a model of spherical and cylindrical spreading. Sound travels out in a progressively large area from the sound source in all directions. This unrestricted spreading in water is called spherical spreading. The loss of sound is described as 20logR dB, where R is distance from the source in metres. This calculates to a transmission loss of about 6 dB with each doubling of distance from the source. There are, however, various other factors that influence the nature and rate of decay in a sound wave in the marine environment, including frequency as well as local conditions such as water temperature, water depth and bottom conditions. The sound can also be compressed between the sea surface and the seafloor and other obstructions (e.g. thermal layers), thus channelling it. Therefore, sound in the marine environment typically spreads in a cylindrical fashion (Davis et al 1998; Thomson et al 2000). The transmission loss is typically half that of spherical spreading, and is then calculated as 10logR dB, a loss of about 3 dB with each doubling of distance (Amec 2014).

At the commencement of each offshore seismic survey line, just prior to arriving at the starting position, the array will be slowly brought up to the specified power, a procedure referred to as a “ramp up” or “soft start”. This procedure is intended to allow mobile marine animals (fish, marine mammals) to vacate an area temporarily if they perceive the sound levels as a disturbance (this standard mitigation measure is discussed further in later sections of this report).

Details about the array and its sound characteristics are provided above, and the characteristics of source array in water and the potential environmental effects of same are described in Chapter 5. Much of the focus of this assessment, and the associated mitigation measures that result from it, is on sound and proposed means of avoiding or reducing its potential effects on the biophysical and socioeconomic environments.

2.7.2 Atmospheric Emissions

Light emissions from the ships will be those typically generated by other ships of similar size, such as a fishing vessel. Since lights can attract marine-associated avifauna, lighting will be kept to a minimum at night, to the extent that it does not affect crew/vessel safety. Project-related air emissions from the seismic vessel and support vessels will be in keeping with those typically associated with marine vessels of similar size and type.

2.7.3 Solid and Liquid Waste Materials

Wastes that are anticipated to be generated during the execution of the Project and the mechanisms in place to ensure that they are managed in an environmentally acceptable manner are described in Sections 2.7.3.1 and 2.7.3.2. This will include compliance with applicable regulations and industry best practices offshore Newfoundland and Labrador. Waste types and volumes will be documented as per applicable regulatory requirements.

2.7.3.1 Liquid and Organic Discharges

The main liquid waste materials that will be generated during the Project include grey water (wastewater from washing, bathing, laundry and food preparation), black water (human wastes), bilge water, deck drainage and possibly others. Vessel discharges will be similar in nature and amount to those associated with standard vessel operations, and will adhere to all applicable regulations. As a best practice, only environmentally friendly products will be used onboard the vessels where possible. Black water (sewage) will be processed through the sewage treatment plants onboard the vessels and disposed of in accordance with applicable regulatory requirements. Grey water will be discharged at sea as far as practical from the nearest land. Galley food waste will be processed and discharged from the vessels in compliance with the requirements of MARPOL.

If discharges of bilge and ballast water are necessary, all such discharges will be conducted in accordance with regulatory requirements described under MARPOL and the *Canada Shipping Act*.

2.7.3.2 Waste Materials and Their Management

All solid and domestic waste will be collected on-board the vessels, and waste materials will be separated and recycled where possible. Solids intended for disposal will be stored in dedicated waste receptacles that will be collected dockside by an approved waste contractor for disposal at an existing on-land waste disposal facility. Any hazardous waste will be directed through an approved hazardous waste collection contractor.

2.7.4 Potential Accidental Events and Malfunctions

Because geophysical surveys do not result in the recovery of hydrocarbons, the potential for and likely environmental effects of any accidental events (particularly spills) that could be associated with these offshore surveys are relatively low. In the unlikely event of the accidental release of hydrocarbons or other materials during the Project, Nexen and its seismic survey contractor will implement the measures outlined in its Oil Spill Response Plan which will be filed with the C-NLOPB. In addition, Nexen has an Emergency Response Plan in place which will apply to the proposed activities that are part of this Project.

2.8 Effects of the Environment on the Project

The nature and timing of offshore oil and gas exploration and other marine activities in the Canada-NL Offshore Area are often influenced by environmental factors such as winds, waves, currents, visibility, fishing activities and other conditions. Sea ice and icebergs are also potential seasonal hazards that must be considered and addressed in Project planning and implementation. The time of year is a key factor in determining the potential for, and possible effects of, these environmental parameters with regard to operational efficiency and safety. An appropriate understanding and consideration of environmental characteristics and phenomena are therefore required so that offshore activities can be designed and implemented appropriately, and in a manner that helps ensure that human health and safety, equipment and infrastructure and the environment are protected.

The timing of offshore exploration operations is at times affected by wind or sea conditions, which may disrupt vessel operations, and can interfere with the deployment, use and retrieval of seismic equipment (particularly, the streamers).The proposed Project may include survey activities within the April to

November period in any Project year. Although this will avoid the winter period (which often produces the most severe weather and oceanographic conditions in the Project Area), such conditions are a required consideration in planning and implementing survey work from day to day. In addition to the general overview of past and recent climate and weather conditions provided in this EA (Chapter 4), future Project planning will include the review and analysis of additional, area-specific information on forecasted meteorological conditions (winds, waves, precipitation, fog/visibility, and temperatures) and oceanographic characteristics (waves, currents, sea ice and icebergs). Up-to-date weather forecasting and analysis will be accessed throughout the program to address and respond to any severe environmental conditions. Vessels, equipment and materials used by the Project will have the capacity to function within the environmental conditions that are known or likely to be encountered in the Study Area, and will adhere to all applicable regulatory requirements for safety and data quality.

Icebergs usually occur within the Project Area off Eastern Newfoundland from spring to mid-summer each year, and seasonal outlooks and regular ice surveillance is undertaken for these portions of the region. Forecasting and monitoring the presence and movements of icebergs is also part of routine operational procedures during offshore operations in areas which are subject to such seasonal intrusions of ice. Given the very mobile nature of the equipment that will be used for this Project, interactions with icebergs can be avoided through appropriate operational and safety procedures. The presence, timing, duration and thickness of sea ice are also important considerations in planning and implementing any future offshore oil and gas activities in the region. The sea ice climatology for the East Coast of Canada has been extensively documented, and current conditions and ice forecasts are prepared by the Canadian Ice Service of ECCC on an ongoing basis. There is therefore considerable information and knowledge available for the Project Area to form the basis for Project-specific ice avoidance.

Other aspects of the existing biophysical and socioeconomic environments will also be a key consideration in the planning and conduct of the proposed Project. The information, analysis, and findings of this EA will also therefore play a key role in such planning as the Project moves forward, in order to avoid or reduce the potential for adverse effects.

3 ENVIRONMENTAL ASSESSMENT SCOPE, FOCUS AND APPROACH

This Chapter outlines the scope and focus of the EA, as well as providing an overview of the approach and methods used to conduct the assessment and its associated analyses. This is followed (in Chapter 4) by a focussed description of the existing environmental setting within and adjacent to the Project Area, which forms the environmental baseline for the eventual prediction and evaluation of the Project's potential environmental effects and the associated identification of mitigation (Chapter 5).

3.1 Environmental Assessment Initiation and Scoping Document

The EA review process for this Project was formally initiated with Nexen's submission of a *Project Description* document to the C-NLOPB on February 1, 2017. The Board subsequently determined that the Project would require authorizations pursuant to various provisions of the *Accord Acts* (see Chapter 1), and on February 8, 2017 C-NLOPB staff issued a Draft Scoping Document for review and comment by relevant provincial and federal government departments and agencies and a number of non-governmental organizations. At that time, the Board:

> *[F]ormally delegate[d] the responsibility for preparation of an acceptable environmental assessment report and any supporting documents to Nexen Energy ULC, the project proponent* (Scoping Document, Section 2.0).

That Scoping Document was subsequently finalized and provided to Nexen on March 13, 2017 to guide the scope and content of the EA.

This EA Report has been planned, completed and submitted in compliance with the associated regulatory requirements and processes of the C-NLOPB, as well as that Project-specific Scoping Document which outlines the factors to be considered in the assessment, the scope of those factors, and various requirements for specific environmental information and analysis.

Section 3.0 of the Scoping Document sets out the scope of the Project for EA purposes, as follows:

> *3.1 The conduct of 2D, 3D, and/or 4D seismic, wellsite, geochemical, geotechnical and environmental surveys between April 1 and November 30 in one or more years between 2018 and 2027 within the Project Area; and*
>
> *3.2 Operation of a program vessel and picket/escort/scout/supply vessel associated with the above activities.*

Section 4.0 of the Scoping Document outlines the particular factors that are to be considered in the EA Report, which include:

> *4.1 The purpose of the project;*
>
> *4.2 The environmental effects of the Project, including those due to malfunctions or accidents that may occur in connection with the Project and any change to the Project that may be caused by the environment, whether any change occurs within or outside Canada. Environmental effect is defined as: any change that the project may cause in the environment, including any effect of any such change on health and socioeconomic conditions, on physical and cultural heritage, on*

the current use of lands and resources for traditional purposes by aboriginal persons, or on any structure, site or thing that is of historical, archaeological, paleontological or architectural significance;

4.3 Cumulative environmental effects of the Project that are likely to result from the project in combination with other projects or activities that have been or will be carried out;

4.4 The significance of the environmental effects described in 4.2 and 4.3;

4.5 Measures, including contingency and compensation measures as appropriate, that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project;

4.6 The significance of adverse environmental effects following the employment of mitigative measures, including the feasibility of additional or augmented mitigative measures; and

4.7 Report on consultations undertaken by Nexen with interested other ocean users who may be affected by program activities and/or the general public respecting any of the matters described above. The One Ocean documents Fact Sheet for Non-One Ocean Petroleum Members and One Ocean Protocol for Consultation Meetings: Recommendations for the Fish and Petroleum Industries in Newfoundland and Labrador can assist in planning these consultations.

Section 5.0 of the Scoping Document specifies a number of requirements for environmental information and analysis that are to be included in the assessment.

A detailed Table of Concordance which outlines these requirements and an indication of where and how each of them has been addressed in this EA Report is included as Appendix A of this document.

3.2 Consultation Activities and Outcomes

Consultation is a cornerstone of the EA process, and is a key aspect of Nexen's approach to planning and implementing its business activities. A number of engagement initiatives have been undertaken or are on-going in relation to the proposed Project and its EA, including discussions with relevant government departments and agencies and applicable stakeholder organizations.

3.2.1 Governmental Consultation

As noted in Chapter 1, a number of provincial and federal government departments and agencies may have regulatory responsibilities or other mandates and interests related to the Project and its potential environmental effects. As part of the planning and preparation of this EA, Nexen has met with a number of such government organizations, including the C-NLOPB, Canadian Environmental Assessment Agency, NL Department of Natural Resources, and the NL Department of Municipal Affairs and Environment. A number of other provincial and federal government departments and agencies were also contacted as part of the preparation of the EA Report, including in the identification and compilation of environmental baseline data and other information for use in the EA (see Section 7.0), including DFO (NL and Maritimes Regions), ECCC, the Department of National Defence, Transport Canada, Natural Resources Canada; and the NL Department of Fisheries and Land Resources. Relevant departments and agencies will also be involved in the review of the Project's EA Report, and at other stages of the review process being administered by the C-NLOPB.

Nexen will continue to consult directly with relevant government departments and agencies throughout the Project's EA review, as well as in any subsequent environmental permitting and overall environmental management initiatives during the Project's eventual implementation.

3.2.2 Stakeholder Consultation

As part of the planning and completion of this EA, Nexen has also undertaken a stakeholder consultation program that has provided various mechanisms and opportunities for interested groups and individuals to receive and review information, as well as to provide information and perspectives related to the Project and its potential effects. The results of these consultations were used to identify key issues and questions to be considered and addressed in the EA, and thus, to appropriately focus and frame the analysis.

This included writing to each of the following organizations in early March 2017 to provide an initial overview description of the proposed Project (see Appendix B), and an opportunity for these groups to identify any questions or comments regarding the Project and its potential environmental effects for consideration in the EA, as well as inviting further information sharing and engagement as the EA review progressed:

Fisheries Organizations and Interests

- One Ocean
- Fish, Food and Allied Workers Union (FFAW-Unifor)
- Association of Seafood Producers
- Canadian Association of Prawn Producers (CAPP)
- Groundfish Enterprise Allocation Council (GEAC)
- NL Aquaculture Industry Association
- Atlantic Shark Association
- Nova Scotia Swordfish Association
- Clearwater Seafoods
- Harbour Grace Shrimp Company
- Icewater Seafoods
- Nataaqnaq Fisheries Inc
- Netukulimk Fisheries Limited
- Newfound Resources Ltd.
- Ocean Choice International (OCI)
- Seafreez Foods Inc. (Barry Group Inc.)
- Davis Strait Fisheries
- MV Osprey Ltd.
- Sambro Fisheries

Industry/Business Organizations

- Canadian Association of Petroleum Producers
- Newfoundland and Labrador Oil and Gas Industries Association (NOIA)
- St. John's Board of Trade

Environmental Groups

- Nature NL
- Canadian Parks and Wilderness Society (CPAWS) Newfoundland and Labrador
- World Wildlife Fund (WWF) Canada
- Protected Areas Association of NL
- NL Wildlife Federation

Aboriginal Groups

- Nunatsiavut Government
- Innu Nation
- NunatuKavut Community Council
- Miawpukek First Nation
- Qalipu First Nation
- Mi'kmaq Alsumk Mowimsikik Koqoey Association

As also reflected in Section 7.0, a number of these organizations were also otherwise contacted as part of the preparation of the EA Report, including in the identification and compilation of environmental baseline data and other information for use in the EA.

Nexen has also met directly with a number of key organizations to provide further information on the Project and to discuss any associated questions or issues related to the potential effects of the Project and associated mitigation approaches. This included:

- One Ocean: Teleconference meeting (February 3, 2017) and an in-person meeting (February 28, 2017);

- FFAW-Unifor: In-person meeting (St. John's, March 2, 2017)

These meetings included a short overview/presentation by Nexen outlining its planned Project Area, proposed survey activities, key environmental components and associated mitigations. This was followed by a general discussion and question and answer session.

3.2.3 Consultation Outcomes and Associated Questions and Issues Raised

Questions and items that were raised and discussed through the above described consultation initiatives were fairly typical of any offshore exploration program. Table 3.1 below provides a list of these questions and issues raised, and indicates where each of these have been addressed in this EA Report.

Table 3.1 Questions and Issues Raised through EA Related Consultations

Question/Issue	Where Addressed in EA Report
Potential effects of seismic survey activities on fish and fish catch rates	Sections 5.4 and 5.9
Potential operational conflicts, associated interference with fishing activity, and possible gear damage	Section 5.9
Measures and procedures for on-going communication and planning with fisheries activities to avoid potential interactions	Sections 5.3 and 5.9
The presence and role of the FLO	Sections 5.3 and 5.9

Question/Issue	Where Addressed in EA Report
Compensation policies and procedures in the event of fishing gear damage	Sections 5.3 and 5.9
Fisheries statistics and geo-spatial data for use in the EA	Section 4.3.1.2
Presence of corals and potential interactions of Project activities and equipment with these (including associated fisheries closure areas)	Sections 4.2.1.6, 4.2.4
Importance of the Flemish Cap and Pass and other areas for ocean productivity, including for seabirds and marine mammals in particular	Section 4.2
Potential effects of lights and noise on marine biota	Sections 5.4, 5.5, 5.6, 5.7
Temporal duration of the proposed Project	Section 2.6
Likely offshore activity levels in the area in the coming years, and potential cumulative effects in certain areas including the Flemish Pass	Sections 3.4.7, 5.4.4, 5.5.4, 5.6.4, 5.8.4, 5.9.4

As indicated, each of these items has been considered as part of the planning and conduct of this EA, and is addressed throughout the associated environmental effects assessment (Chapter 5).

3.3 Selection of Valued Environmental Components

EAs typically identify and focus on components of the environment that are of particular ecological or socioeconomic importance and/or which can serve as indicators of environmental change, and which have the potential to be materially affected in some way by the proposed project under assessment. These are known as VECs, and include both biophysical and socioeconomic aspects of the environment.

VECs are typically identified early in an EA as a result of experience with similar assessments in the past, questions and issues raised through consultations with government departments and agencies, stakeholder groups and resource users, and through other scoping exercises. The VEC approach is a useful, effective and widely accepted way of ensuring that an EA focuses on important and relevant environmental components and issues, and is specified and suggested for use in this assessment by the C-NLOPB in its Scoping Document (Section 5).

Initial direction and input into VEC selection was obtained through the Final Scoping Document issued to Nexen by the C-NLOPB in March 2017, with further consideration and analysis by the EA Study Team and as a result of Nexen's consultation activities and previous experience.

In keeping with most recent EAs for oil and gas related projects in the Canada-NL Offshore Area, the following VECs are considered in this assessment:

- Marine Fish and Fish Habitat;
- Marine/Migratory Birds;
- Marine Mammals and Sea Turtles;
- Species at Risk;
- Special Areas; and

- Marine Fisheries and Other Activities.

The rationale for the selection of these VECs is generally described below:

Marine Fish and Fish Habitat: Fish resources are an important consideration in the EA of any proposed activities that occur within, and that may affect, the marine environment. This VEC includes relevant fish species (finfish and invertebrates), as well as marine plants, plankton, algae, benthos and relevant components of their habitats (such as water and sediment), given the clear interrelationships between these environmental components. The consideration of marine fish and fish habitat within a single VEC is in keeping with current and standard practice, and provides for a more comprehensive, holistic approach while at the same time reducing unnecessary repetition.

Marine/Migratory Birds: A variety of avifauna species inhabit the marine and coastal environments off Eastern Newfoundland at various times of the year. Birds are important from an ecological, social and economic perspective, as they often function near the top of the food chain, may be relatively vulnerable to certain types of environmental disturbance, and are an important resource for recreational and tourism related pursuits.

Marine Mammals and Sea Turtles: Whales, dolphins and seals have been and remain an important element of the environmental and socio-cultural settings of the province. These species are especially important from an ecological perspective, and due to current consumptive (seal harvests) and non-consumptive (whale watching) activities which are important tourism attractions in some areas. A number of marine mammal species have been designated as species at risk under Canadian legislation and other processes. Although sea turtles are generally uncommon in the region, they are also typically included as part of this VEC given their rare and often protected status, and sensitivity to certain types of disturbances.

Species at Risk: A number of marine fish, bird, mammal and turtle species that occur off Eastern Newfoundland have been designated as being species at risk under federal and/or provincial legislation, or have been otherwise identified as being of special conservation concern under applicable processes. These species are identified and their known or likely presence, abundance and geographic and temporal distribution is described integrally under the existing environment sections for each of the above components, as well as in the environmental effects assessment for each of these VECs. These species are, however, given special attention and emphasis in the identification and analysis of potential environmental effects and mitigation.

Special Areas: Several locations within and off Eastern Newfoundland have been designated as protected under provincial, federal and/or other legislation and processes, due to their ecological, historical and/or socio-cultural characteristics and importance. In addition to areas that have existing and formal protections, a number of other locations have been identified as being important ecologically and/or for associated human activities and values as well as particularly sensitive to environmental disturbances. These areas are also given special attention in the identification and analysis of potential environmental effects and mitigation.

Marine Fisheries and Other Activities: Fisheries have been key elements in shaping the history and socioeconomic character of Newfoundland and Labrador and are important aspects of the current economic and socio-cultural fabrics of the province and other parts of Canada.

Commercial fisheries off Eastern Newfoundland are extensive and diverse, and involve a variety of participants, fish species, gear types and other characteristics at various times of the year. Fishing activities are undertaken in and around the Project Area by fishing interests from Newfoundland and Labrador, elsewhere in Canada and by various other countries. A variety of other human activities also take place in parts of the Project Area on either a year-round or seasonal basis, including other oil and gas related activities, general vessel traffic and others. These and other marine uses and users may be affected both directly (through possible interactions and disturbance) and indirectly (due to any negative changes in the biophysical environment).

3.4 Environmental Assessment Approach and Methods

The following sections describe the EA approach and methodology that have been used to conduct the environmental effects assessment presented in this EA Report, including each of its key stages and components (Figure 3.1). The methods used are in keeping with current EA approaches and practice, and have been developed and used to ensure a thorough and rigorous analysis, while presenting the results of the assessment in a clear, concise and well-organized manner.

An overview description of the proposed Project was provided in Chapter 2, including its proposed location, survey equipment, activities, schedule, emissions and other components. The existing natural and human environmental setting for the Project is subsequently described in Chapter 4, including a focussed description of the key components of the environment that overlap, and may interact with, the proposed Project. This includes relevant elements of the physical (geology, climate, oceanography, ice), biological (fish, birds, mammals, turtles) and socioeconomic (fisheries, other marine activities) environments. In the EA, this overview of the existing environment is used as a further basis for identifying potential environmental issues and interactions, and mitigation to avoid or reduce potential adverse environmental effects.

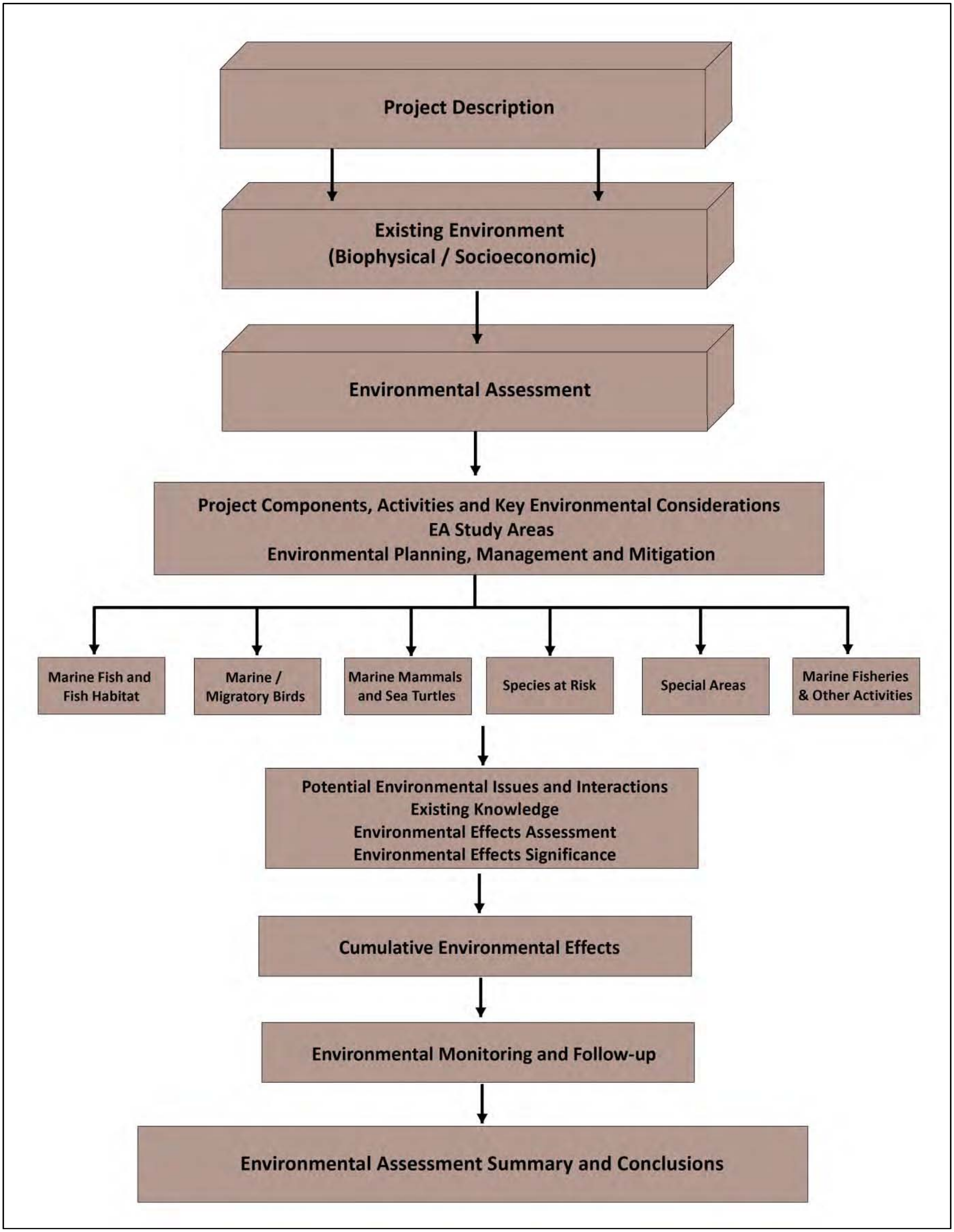
The environmental effects assessment aspect of this EA involves predicting and evaluating the potential environmental effects of the Project, which are generally defined as detectable changes that the Project may cause in the environment. The assessment of potential environmental effects is therefore generally based on the approach of “overlaying” a proposed project on its existing environment to identify and describe whether, how and to what degree the identified VEC may change as a result (Figure 3.1).

The environmental effects assessment is provided in Chapter 5, and is organized and presented on a VEC-by-VEC basis, with each stage of the analysis completed for each VEC in its own separate sub-section. This includes each of the stages outlined in the subsections that follow.

3.4.1 Project Components, Activities and Key Environmental Considerations

This initial and generic section of Chapter 5 provides a brief introduction to, and overview of, the primary components and activities that will be associated with the proposed Project and the likely (general, non-VEC specific) environmental interactions and considerations that may be associated with these, as initial background and context for the environmental effects assessment.

Figure 3.1 Environmental Assessment Structure and Approach



3.4.2 Environmental Planning, Management and Mitigation

This section of Chapter 5 (Section 5.3) provides a listing and description of the various environmental planning, management and mitigation measures that Nexen and/or its contractors will implement in order to prevent or reduce adverse effects. These are then considered in a fully integrated manner within and throughout the environmental effects analysis for each VEC, as applicable.

Each VEC-specific effects assessment is then addressed in a separate sub-section of Chapter 5, which begins with a brief overview of the VEC, further defining what it comprises and why it is being considered in this EA.

3.4.3 Environmental Assessment Study Areas

Study Areas (spatial and temporal boundaries) have been established to direct and focus the environmental effects assessment. As noted in the Scoping Document issued by the C-NLOPB, they reflect a consideration of:

- The proposed schedule/timing of the program and related activities;
- The natural variation of a VEC or subset thereof;
- The timing of sensitive life cycle phases in relation to the scheduling of survey activities;
- Interrelationships/interactions between and within VECs;
- The time required for recovery from an effect and/or return to a pre-effect condition, including the estimated proportion, level, or amount of recovery; and
- The area within which a VEC functions and within which a project effect may be felt.

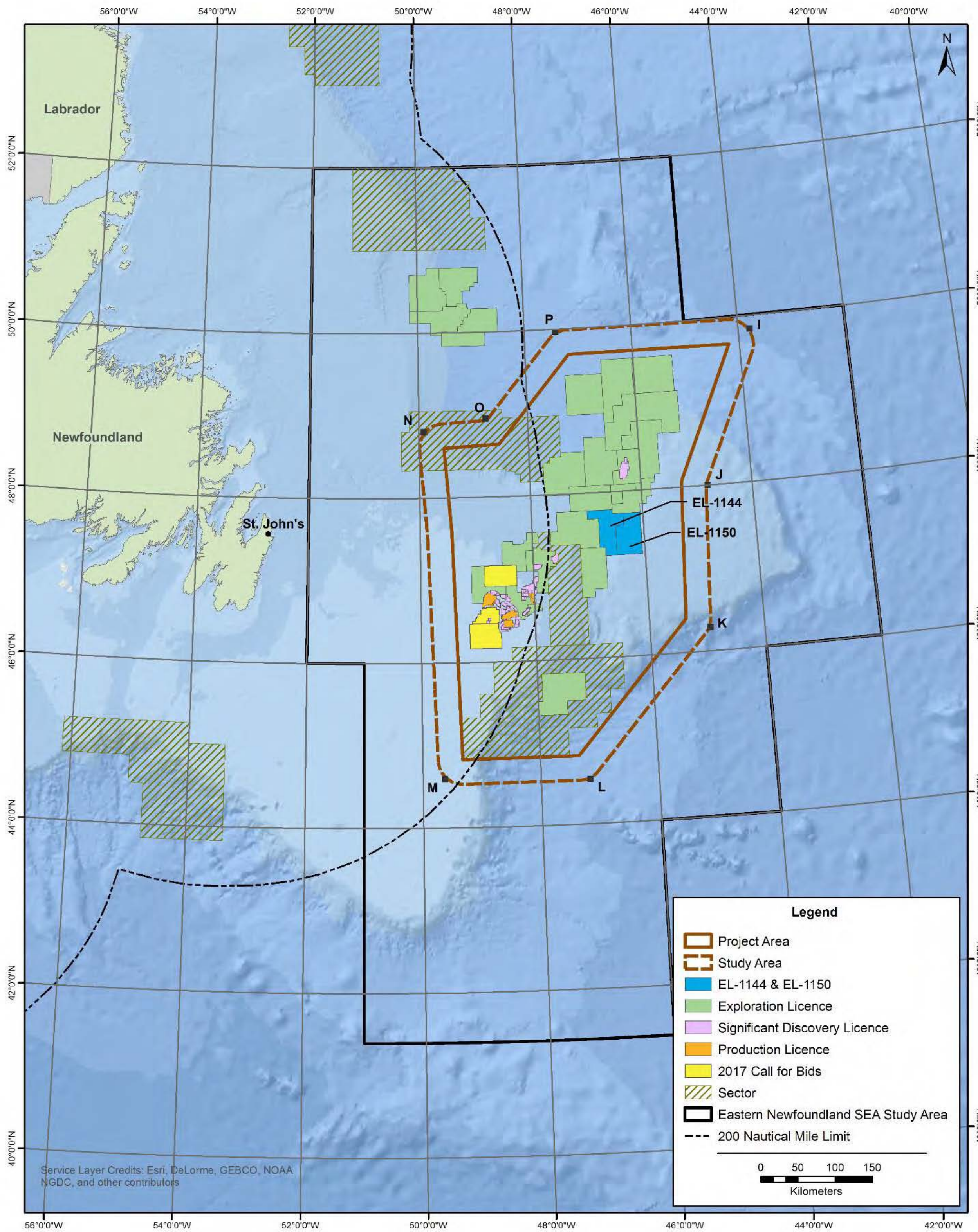
A number of these established study boundaries are generic (i.e., for the Project and EA as a whole) with VEC-specific (Regional) Study Areas also considered given the differences between the VECs in terms of their overall characteristics and in the manner in which they may interact with the Project. These Study Areas have also been defined and used with a flexible and adaptive approach, based on the nature of the VEC and the associated environmental information and processes which influence the analysis.

1) ***Spatial Boundaries***: Three types of spatial boundaries have been identified and considered in conducting the environmental effects assessment for each VEC (Figure 3.2):

   Project Area: This area encompasses all Project-related data acquisition activities (equipment deployment and surveys), and all associated vessel movements and vessel turning activities with this equipment deployed (see corner point coordinates provided in Table 3.2).

   Study Area: The geographic area over which the Project and its potential emissions and other possible disturbances and environmental interactions may occur and extend, which for EA purposes is conservatively defined as an area that encompasses the Project Area plus appropriately 40 km (Table 3.2).

Figure 3.2 Environmental Assessment Study Area



Regional Areas: In addition to the Project Area and Study Area, the environmental effects assessment also considers the particular characteristics and larger distributions of the individual VECs under consideration. This includes the migratory nature and movement patterns of affected fish or other wildlife (both within the water column and/or across larger geographic areas), as well as the overall extent and distribution of fishing and other marine components and activities in the region.

For some environmental components, possible environmental interactions may be limited to the immediate locations of proposed Project activities, whereas others may extend beyond the immediate area of disturbance as the distribution and/or movement of an environmental component can be local, regional, national or even international in extent. Such factors as population characteristics, migration patterns and other factors are therefore important considerations in determining the potential for, and the extent and distribution of, an environmental effect. These Regional Study Areas are defined generally and applied flexibly in the environmental effects assessment for each VEC to account for these larger ecological and socioeconomic factors and considerations.

Table 3.2 Project Area and Study Area Corner Points and Coordinates

Corner Point ID *	Latitude	Longitude	Easting	Northing
Project Area (See earlier Figure 2.1)				
A	49° 41' 22.0" N	47° 11' 21.2" W	774830	5511078
B	49° 40' 31.4" N	44° 11' 38.5" W	990852	5524816
C	48° 4' 11.4" N	45° 16' 5.6" W	926910	5339973
D	46° 24' 36.8" N	45° 21' 42.5" W	933306	5155094
E	44° 49' 39.9" N	47° 20' 21.2" W	789391	4970337
F	44° 49' 29.0" N	49° 19' 22.2" W	632589	4964847
G	48° 36' 12.6" N	49° 32' 35.1" W	607405	5384405
H	48° 38' 17.2" N	48° 32' 0.7" W	681701	5390165
Study Area (Figure 3.2)				
I	49° 50' 20.231" N	43° 46' 50.144" W	587682	5521438
J	47° 59' 52.801" N	44° 48' 14.533" W	514619	5316097
K	46° 17' 4.091" N	44° 56' 45.626" W	504159	5125656
L	44° 32' 20.695" N	47° 9' 48.076" W	328132	4934027
M	44° 35' 35.343" N	49° 37' 20.473" W	133113	4948158
N	48° 48' 16.082" N	49° 54' 33.191" W	139582	5417352
O	48° 56' 45.648" N	48° 46' 2.456" W	224176	5428297
P	49° 58' 9.386" N	47° 24' 40.513" W	327091	5538001
* See Figure 3.2 Easting and Northings are NAD83 UTM Zone 23				

2) ***Temporal Boundaries***: In all cases, the temporal boundaries include and encompass the overall potential timing of Project related activities, as well as the likely duration of any resulting environmental effects. In conducting the environmental effects assessment, consideration is also given to the relevant temporal characteristics of the VECs, including the timing of their presence/conduct and activities within the Project Area and Study Area, any particularly

sensitive or critical periods, likely response and recovery times to potential effects, and any natural (without-Project) variation in that environmental component.

The Project's potential environmental effects are assessed and their significance is evaluated based on the above described spatial and temporal boundaries.

3.4.4 Definition and Determination of Environmental Effect Significance

Evaluating the significance of the predicted environmental effects of a proposed project is one of the most important and fundamental stages of any EA. It involves first defining what a significant environmental effect is, and then evaluating whether a project's potential environmental effects are significant or not significant.

In this EA Report, the definition and determination of effects significance is based largely on the guidance provided in the Canadian Environmental Assessment Agency's *Operational Policy Statement, Determining Whether a Designated Project is Likely to Cause Significant Adverse Environmental Effects under the Canadian Environmental Assessment Act, 2012* (Canadian Environmental Assessment Agency 2015), as specified in Section 5.3 of the EA Scoping Document.

Significant environmental effects are those adverse effects that will cause a change in the VEC that will alter its status or integrity beyond an acceptable and sustainable level. An environmental effect that does not meet these criteria is considered not significant. Significance definitions are developed and used on a VEC-specific basis within this assessment.

The development of the significance criteria used in this assessment includes consideration of (where available and relevant) any applicable legislation and regulations, standards, guidelines, objectives and/or policies and management plans relevant to such determinations. For the biophysical VECs, the significance definitions used generally incorporate consideration of such factors as potential adverse effects to species at risk and/or their habitats, as well as to the size, health, ecological function and/or sustainability of populations of any species, and to the ecological and socio-cultural characteristics of any special marine areas and thus to their overall integrity or value. For socioeconomic components, significance is linked to the potential for, and degree and duration of, any detectable economic effects on these users and uses, on overall activity levels, on the enjoyment or cultural value of human activities, and other relevant concepts and considerations as appropriate.

3.4.5 Potential Environmental Issues, Interactions and Existing Knowledge

To identify and focus on key environmental issues, and to ensure that these are fully considered and addressed in the assessment, this section summarizes the various questions and issues associated with the Project and its potential effects on the VEC. This includes those issues that have been referenced in the Scoping Document, as well as those identified through Nexen's associated consultation process, by the Study Team, and/or through other Project-related environmental issues scoping activities.

Based on these identified issues and the description of the existing environment for each VEC (Chapter 4), the environmental effects assessment for each VEC then identifies and focuses on relevant *Key Indicators and Parameters*, which are generally defined as an important aspect of the VEC and/or its environment which, if changed as a result of the Project, may result in an adverse effect to the VEC (and to which such changes could conceivably be detected and measured).

A Table (sample provided below, for illustration) is then used to summarize the potential interactions between each of the main Project components and activities and each of these identified Key Indicators and Parameters:

Table 3.3 Potential Project-VEC Interactions

Project Component/Activity	**Key Indicators and Parameters ***				
	1	**2**	**3**	**4**	**#**
Presence and Use of Vessels/Aircraft and Equipment					
Seismic Sound					
Seabed and Environmental Sampling Activities					
Air Emissions					
Lighting					
Solid Waste					
Liquid Waste					
Potential Accidental Spills					
Onshore Supply and Servicing					
* These indicators and parameters are identified and listed on a VEC-specific basis in the relevant Table/section of Chapter 5					

This section also provides a brief overview of existing knowledge and what is understood about the potential effects of offshore exploration activities such as those being proposed and assessed herein on the VEC in question. This includes relevant information and findings from the literature, reported environmental monitoring of other similar projects, and other sources, which is then used to guide and inform the assessment and evaluation of environmental effects and the identification and proposal of mitigation.

3.4.6 Environmental Effects Assessment

This section provides an analysis (prediction) and description of the likely environmental effects of the Project on the VEC. The environmental effects assessment considers the nature, degree, extent and timing of potential Project-induced change from the existing (baseline) environment (as described in Chapter 4).

Within this section, potential environmental effects are assessed and evaluated for both planned Project components and activities, as well as for any potential accidents and malfunctions that may occur as a result of the Project. Environmental effects management (mitigation) measures are considered integrally and iteratively in the effects assessment. This includes those that will be "built-in" to the Project through its planning and design, so as to avoid or reduce potential environmental issues proactively (Chapter 2) as well as other environmental protection (mitigation) measures identified by Nexen (see Section 5.3). From there, and with this base of general mitigation and optimization in place, the environmental effects assessment identifies and predicts the likely environmental effects of the Project on the VEC, with the additional identification of further VEC-specific mitigation as required and appropriate.

As a result, and in keeping with standard approaches and to optimize efficiency, the environmental effects assessment is therefore focussed upon assessing and describing the likely residual environmental effects of the Project – namely, those which might occur after the implementation of the effects management/mitigation measures identified and proposed in the EA.

These predicted (residual) environmental effects of the Project are described based on a number of standard and widely accepted environmental effects criteria or "descriptors", as listed and defined in Table 3.4.

Table 3.4 Environmental Effect Descriptors

Descriptor	Definition
Nature/Direction of the Effect	Positive, Adverse or Neutral (as compared to baseline environment)
Magnitude	The degree of change from baseline conditions in the affected area, as defined below. *For all VECs:* *Negligible*: Although there is potential for a Project-VEC interaction, there would be no detectable effect *For the biophysical VECs:* *Low*: A detectable change that is within the range of natural variability, with no associated adverse effect on the viability of the affected population *Medium*: A detectable change that is beyond the range of natural variability, but with no associated adverse effect on the viability of the affected population *High*: A detectable change that is beyond the range of natural variability, with an adverse effect on the viability of the affected population *For the Fisheries and Other Marine Activities VEC* *Low*: A detectable change that is within the range of natural variability, with no associated adverse effect on the overall nature, intensity or value of the affected component or activity. *Medium*: A detectable change that is beyond the range of natural variability, but with no associated adverse effect on the overall nature, intensity or value of the affected component or activity. *High*: A detectable change that is beyond the range of natural variability, with an adverse effect on the overall nature, intensity or value of the affected component or activity.

Descriptor	Definition
Geographic Extent	The spatial area within which a particular environmental effect will likely occur.
Duration	The period of time over which an environmental effect will likely be evident.
Frequency	How often an environmental effect will likely occur (continuous, or at specific time intervals).
Reversibility	The ability of an environmental component to return to an equal or improved condition once the disturbance(s) that caused it has ended.
Certainty	The level of confidence in the effects prediction.

Specific definitions/ratings for each of these "criteria" are included in the Environmental Effects Summary Tables included in each VEC section (see example presented below).

The current condition of an environmental component as a result of natural and/or anthropogenic factors, and thus, its resulting resiliency or sensitivity to further change (ecological/socioeconomic context) is again considered integrally as part of the prediction of environmental effects.

The level of confidence (certainty) in each environmental effects prediction is also indicated throughout, along with an associated discussion of any key sources of uncertainty, data gaps, issues of reliability, sensitivity and approaches to conservativeness in effects prediction and the identification of mitigation. Any assumptions made are also clearly defined and discussed and justified where relevant, and any data gaps that may have implications for the prediction and evaluation of effects and for the identification and likely effectiveness of mitigation are also described and evaluated as applicable.

The following Table is then used to summarize the predicted residual environmental effects of the Project on the VEC.

Table 3.5 Environmental Effects Assessment Summary Table

Project Activity and Potential Effect(s)	Environmental Effect Descriptors						
	Nature	Magnitude	Extent	Duration	Frequency	Reversibility	Certainty
Presence and Use of Vessels/Aircraft and Equipment							
Seismic Sound							
Seabed and Environmental Sampling Activities							
Air Emissions							
Lighting							

Project Activity and Potential Effect(s)	**Environmental Effect Descriptors**						
	Nature	**Magnitude**	**Extent**	**Duration**	**Frequency**	**Reversibility**	**Certainty**
Solid Waste							
Liquid Waste							
Potential Accidental Spills							
Onshore Supply and Servicing							
Overall, Resulting Effect(s) of Project on the VEC				**Evaluation of Significance**			

Nature/Direction:
A = Adverse
N = Neutral or No Effect
P = Positive

Magnitude:
N = Negligible or No Effect
L = Low
M = Medium
H = High

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

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

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

Reversibility:
R = Reversible
I = Irreversible

Certainty in Prediction:
L Low
M Moderate
H High

NOTES

- In all cases, the above referenced effect descriptors refer to the resulting environmental effect to a particular environmental receptor, not to the Project activity or associated disturbance that creates the effect.
- The residual environmental effects predictions that are summarized above include integral consideration of the mitigation measures described in detail in Section 5.3.

For the biological VECs (marine fish and fish habitat, marine/migratory birds, and marine mammals and sea turtles), any associated species at risk are identified and addressed in an integrated manner within the larger VECs themselves. Following these VEC sections, however, there is a summary discussion of the various relevant species at risk, including an overview of those that have the potential to interact with the Project, and a species by species summary of the Project's potential effects on these protected species.

3.4.7 Cumulative Environmental Effects

As also specified in the Scoping Document, the EA Report assesses and evaluates any cumulative environmental effects that are likely to result from the Project in combination with other projects or activities that have been or will be carried out. The cumulative effects assessment for all VECs is based on the guidance provided in the Canadian Environmental Assessment Agency's documents entitled:

- *Operational Policy Statement Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012*; and
- *Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012*.

The cumulative environmental effects assessment considers the overall (total) effect on the VECs as a result of the Project's potential residual environmental effects (as described in the preceding sections) and those of other relevant projects and activities, using the following approach:

1) Past and on-going projects and activities and their effects are reflected in the existing (baseline) environmental conditions for each VEC (Chapter 4). The current condition of the VEC as a result of these natural and/or anthropogenic factors, and thus its overall sensitivity or resiliency to further disturbance or change, has been integrally considered throughout the environmental effects assessment.

2) The cumulative effects assessment then summarizes and considers whether and how this existing condition could be changed by the introduction of the Project and its residual (with mitigation) environmental effects.

3) Other projects and activities that are relevant to this VEC and its cumulative effects assessment are then identified and considered. These comprise any reasonably foreseeable future projects or activities for which their effects on the VEC are likely to overlap in space and time with those of the Project (e.g., overlap with the Project area and/or its zone of influence), and/or would affect the same populations, communities, etc. as the Project.

In any cases where the predicted residual environmental effects of the Project on the VEC will likely accumulate or interact with those of one or more other projects and activities, the potential cumulative effects of the Project in combination with those of these other relevant developments are assessed and evaluated (using the same significance definition and approach as used for the Project-specific effects assessment, as described above).

The cumulative effects assessment considers the following other projects and activities, as summarized in Table 3.6.

Table 3.6 Other Projects and Activities Considered in the Cumulative Effects Assessment

Project/Activity	Overview
Hibernia Oilfield	Discovered in 1979, the Hibernia Oilfield is operated by the Hibernia Management and Development Company Ltd. (HMDC), and is located approximately 315 km east-southeast of St. John's, NL. The development phase of that project commenced in late 1990 and continued until the mating of the Gravity Based Structure (GBS) and its topsides at Bull Arm NL in 1997, after which the platform was towed to and installed at its site on the Grand Banks in June of that year. With estimated recoverable reserves of approximately 1.4 billion barrels, commercial production from the Hibernia Oi field commenced in November 1997 and is on-going. In recent years the project has been further expanded to include the Hibernia South Extension Unit, from which production commenced in 2011.
Terra Nova Oilfield	Discovered in 1984 and declared a significant discovery in 1985, this oilfield has reserve estimates of approximately 500 million barrels of recoverable reserves. The Terra Nova Oilfield is currently in operation by Suncor Energy Inc. using a floating production, storage and offloading (FPSO) vessel, and is located approximately 350 km southeast of St. John's and 35 km southeast of Hibernia. Dry-dock construction of the Terra Nova FPSO vessel began in early 1999, and it arrived at Bull Arm in May 2000 where outfitting, hook-up and commissioning of the vessel took place. The FPSO arrived at the location in August 2001 and began producing oil in January 2002.
White Rose Oilfield and Extension Project	Discovered in 1984, a significant discovery licence for the field was issued in January 2004. It is located approximately 350 km east-southeast of St. John's, and approximately 50 km north-east of the Hibernia and Terra Nova fields. The

Project/Activity	Overview
	White Rose oilfield and its satellite extensions are operated by Husky Energy Inc. utilizing a FPSO vessel, and first oil was produced in November 2005 followed by the North Amethyst expansion in May 2010.
Hebron Oilfield	First discovered in 1980, the Hebron Oilfield is estimated to contain in excess of 700 million barrels of recoverable resources. The Hebron Project is currently under development and will utilize a stand-alone concrete GBS which is being constructed at Bull Arm, and which will be designed for a production rate of 150,000 barrels of oil per day. First oil from the Hebron Project is planned for 2017.
Offshore Petroleum Exploration Activity	The Eastern Newfoundland Offshore Area is also subject to on-going and planned offshore oil and gas exploration activities, including a number of offshore programs which are in progress or being subject to EA review or recently approved as of the time of writing (see *http://www.cnlopb.ca/assessments*).
Fishing Activity	Commercial fisheries within and around the Project are extensive and diverse, as described in Chapter 4 of this EA Report.
Other Marine Traffic	Includes tanker traffic and supply vessels associated with the existing offshore oil developments, as well as cargo ships, fishing vessel transits, etc (see Chapter 4).
Hunting Activity	Wildlife (especially seabird) populations off Newfoundland and Labrador are subject to hunting activity. Although little or no hunting activity is expected to occur in the far offshore locations that comprise the Project Area, these activities do affect the bird populations that occur in, and move to and through, the region.

Any other relevant projects and activities are identified and considered on a VEC-specific basis, as required and applicable.

3.4.8 Environmental Monitoring and Follow-up

The EA Report then identifies and describes any proposed environmental monitoring and/or follow-up activities. This includes any monitoring initiatives that may be required or appropriate to meet regulatory and environmental requirements, EA commitments, and any follow-up to address any related issues of uncertainty, such as to verify the environmental effects predictions or the effectiveness of mitigation measures outlined in this assessment.

4 EXISTING ENVIRONMENT

This Chapter provides a description of the existing biophysical and socioeconomic environments that overlap and may interact with the proposed Project, including relevant components of the physical (geology, climate, oceanography, ice), biological (plankton, benthos, fish, marine birds, marine mammals, sea turtles) and socioeconomic (fisheries, other marine activities) environments. In the EA, this overview of the existing environment is used as a basis for identifying potential environmental issues and interactions and required mitigation to avoid or reduce potential adverse environmental effects. The description of the existing environment focuses primarily, but not exclusively, upon the identified VECs, and includes other aspects of the physical, biological and socioeconomic environments which are relevant as background and/or which have been specified in the Scoping Document for the EA.

The description that follows is informed by and draws from the information that was presented in the C-NLOPB's recent Eastern Newfoundland Strategic Environmental Assessment (SEA) (Amec 2014), and as illustrated previously (see Figure 3.2) the Project Area and Study Area are located entirely within the SEA Study Area. This approach is in keeping with the direction provided in the EA Scoping Document, which states that:

> *Program activities are proposed for the eastern portion of the Canada-Newfoundland and Labrador Offshore Area which has been studied in recent EAs and the Eastern Newfoundland & Labrador Offshore Area Strategic Environmental Assessment (August 2014) (Eastern SEA). For the purposes of this assessment, the information provided in the Eastern SEA should support the EA to avoid unnecessary duplication of information. Appropriate references should be included in the EA* (Section 5.0).

The EA Scoping Document also specifies that (Sections 5.2.1, 5.2.2):

> *The Eastern SEA provides information on the Newfoundland and Labrador offshore physical [and] biological environment[s]… [including] descriptions of… marine birds; fish and fish habitat; marine mammals and sea turtles; species at risk; sensitive areas; and human activities, including marine fisheries. Only relevant new information for the Study Area that has become available since the publication of the above noted document should be provided in the EA, in particular species at risk, sensitive areas, and marine fisheries*

And that (Sections 5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.2.7, 5.2.8):

> *The EA shall provide only new or updated information, where applicable, to address any changes to the following and any data and/or information gaps noted with respect to… marine and/or migratory birds…marine fish and shellfish…marine mammals…sea turtles … species at risk … [and] sensitive areas within the Eastern SEA.*

This Chapter therefore provides an overview description of the existing environmental setting in and around the Project Area and Study Area, and focusses upon identifying and describing applicable environmental components and features for which new or updated information has become available since the Eastern Newfoundland SEA was completed in 2014. The degree of attention given to each environmental component is also commensurate to its relevance to the Project and its potential environmental effects, including the likelihood that it will be subject to material interaction with the proposed Project.

4.1 Physical Environment

These sections give an overview description of relevant aspects of the physical environment of the EA Study Area, including its geology, bathymetry, climatology, oceanography and ice conditions.

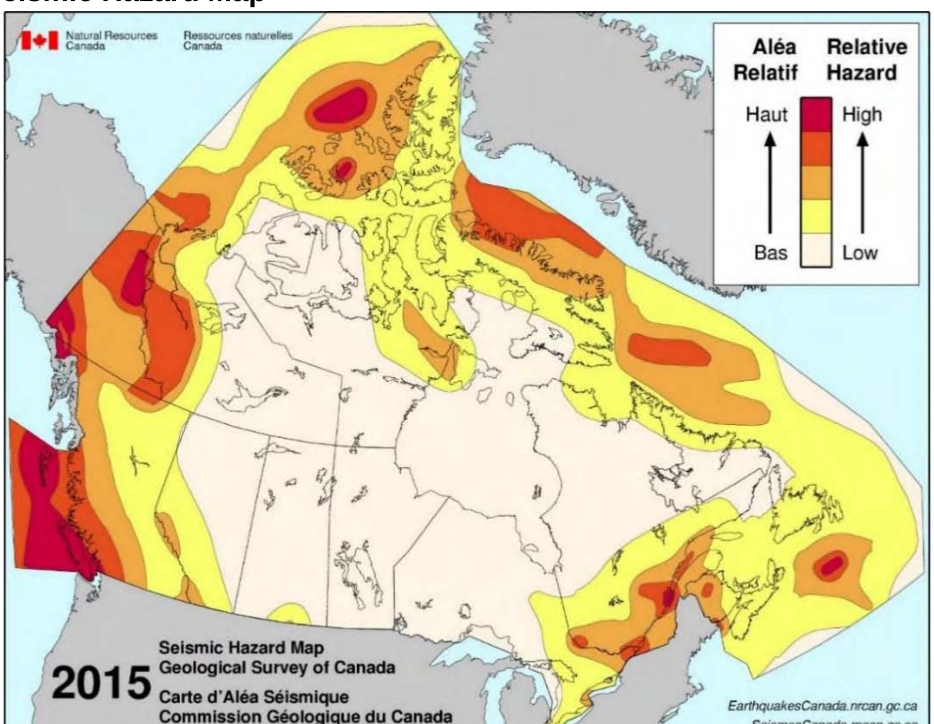
4.1.1 Geology

The geology of the offshore area off Eastern Newfoundland is complex and dynamic, and the current bedrock and surficial characteristics of the Study Area have been shaped by various natural and human factors and processes over time. The Eastern Newfoundland SEA (Amec 2014) provides a regional description of the key geological features and characteristics of the Project Area and Study Area, including information and mapping related to bedrock geology (SEA Section 4.1.1.1), surficial geology and seabed features (SEA Section 4.1.1.2) and geohazards (SEA Section 4.1.1.4). This information is considered adequate and appropriate for the purposes of this EA, and the reader is therefore directed to these sections of the SEA for information on the geology of the area.

Seismicity is one aspect of the existing geological setting for which updated information is available as compared to that which was included in the SEA (see SEA Section 4.1.1.3). An updated overview of this aspect of the existing geological setting of the Project Area is therefore provided here.

Canada’s eastern continental margin is tectonically passive and seismicity is relatively rare throughout much of the region. Natural Resources Canada (NRCan) estimates that approximately 450 earthquakes occur each year in Eastern Canada (NRCan 2017a). Seismicity generally occurs randomly along the Grand Banks margin. The most recent edition of the Seismic Hazard Map prepared by NRCan (Figure 4.1, NRCan 2017b), which illustrates the probability of earthquake occurrences across Canada, indicates that the Project Area has been classified as having a low seismic hazard.

Figure 4.1 Seismic Hazard Map



According to the National Earthquake Database (NRCan 2017c) there have been nine seismic events recorded within the boundaries of the Project Area during the 1985-2017 period (Figure 4.2). The magnitudes of these events have been fairly low, ranging from 2.9 to 4.5 with an average magnitude of 3.7 and a median magnitude of 3.9. All of the recorded events in this area have epicentres in the western and southern portions of the Project Area, and are possibly related to the various tectonic lineaments in the area.

4.1.2 Bathymetry

The marine bathymetry off Eastern Newfoundland exhibits a wide range of physiographic features and associated water depths. A detailed description of the bathymetry of the overall Eastern Newfoundland offshore area is provided in the SEA Report (Amec 2014), Section 4.1.2.

The Project Area and Study Area cover a large expanse of the Northwest Atlantic Ocean, respectively extending approximately 550 km/630 km north to south and 350 km/430 km west to east. The farthest extents of the Project Area boundary from St. John's are about 510 km to the south-southeast, and about 670 km to the northeast. The western boundary is about 250 km east of St. John's.

Some of the key physiographic features of the Project Area and Study Area and surrounding region and its general bathymetry are shown in Figure 4.3.

The western portion contains the Grand Banks, a region with average depths of about 75 m which extend to about 350 km east of St. John's to the 200 m depth contour and then a further 50 km east to the 1,000 m depth contour. To the east of the Grand Banks lies the Flemish Pass, with depths of almost 1,300 m. On the eastern side of the Flemish Pass, water depths rise again to the Flemish Cap, a large bathymetric feature of about 50,000 km^2 with depths rising back up to about 130 m. To the south, on the southeastern portion of the Grand Banks, water depths of about 80 m rapidly descend through numerous canyons off the continental slope into the Newfoundland Basin and deep ocean where depths range from 2,000 to 4,000 m. The Carson Canyon, about 10 km wide, lies at the 110 m isobath at the shelf break at the southern boundary of the area. The Sackville Spur extends the nose of the Grand Banks at depths of up to 1,000 m. This area lies about 250 km east-northeast from the western boundary of the Project Area. The Grand Banks extend north to the Northeast Newfoundland Shelf, with depths there generally of between 200 to 300 m. To the northeast of the shelf, and comprising the northern quarter of the Project Area, lies the Orphan Basin, with water depths ranging from about 1,200 m at the edge of the continental shelf to as deep as 3,500 m. With water depths of around 2,000 m, the Orphan Knoll forms a bathymetric high in the centre of the Orphan Basin. The Labrador Basin and deep ocean lie farther offshore to the north and east of the Orphan Basin and Flemish Cap, with depths from approximately 3,000 m to greater than 4,000 m.

Figure 4.2 Earthquake Epicentres and Seismotechtonic Setting (1985-2017)

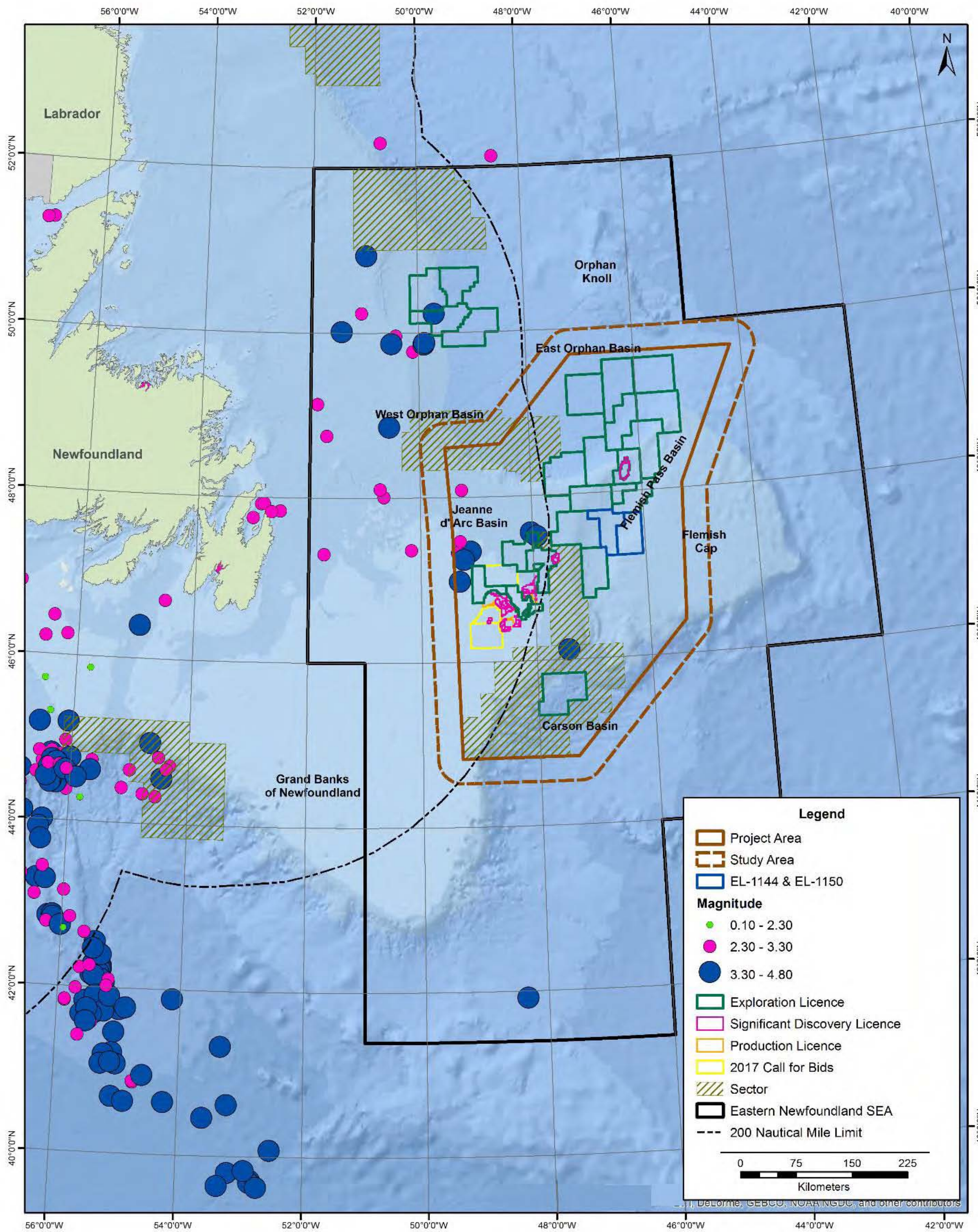
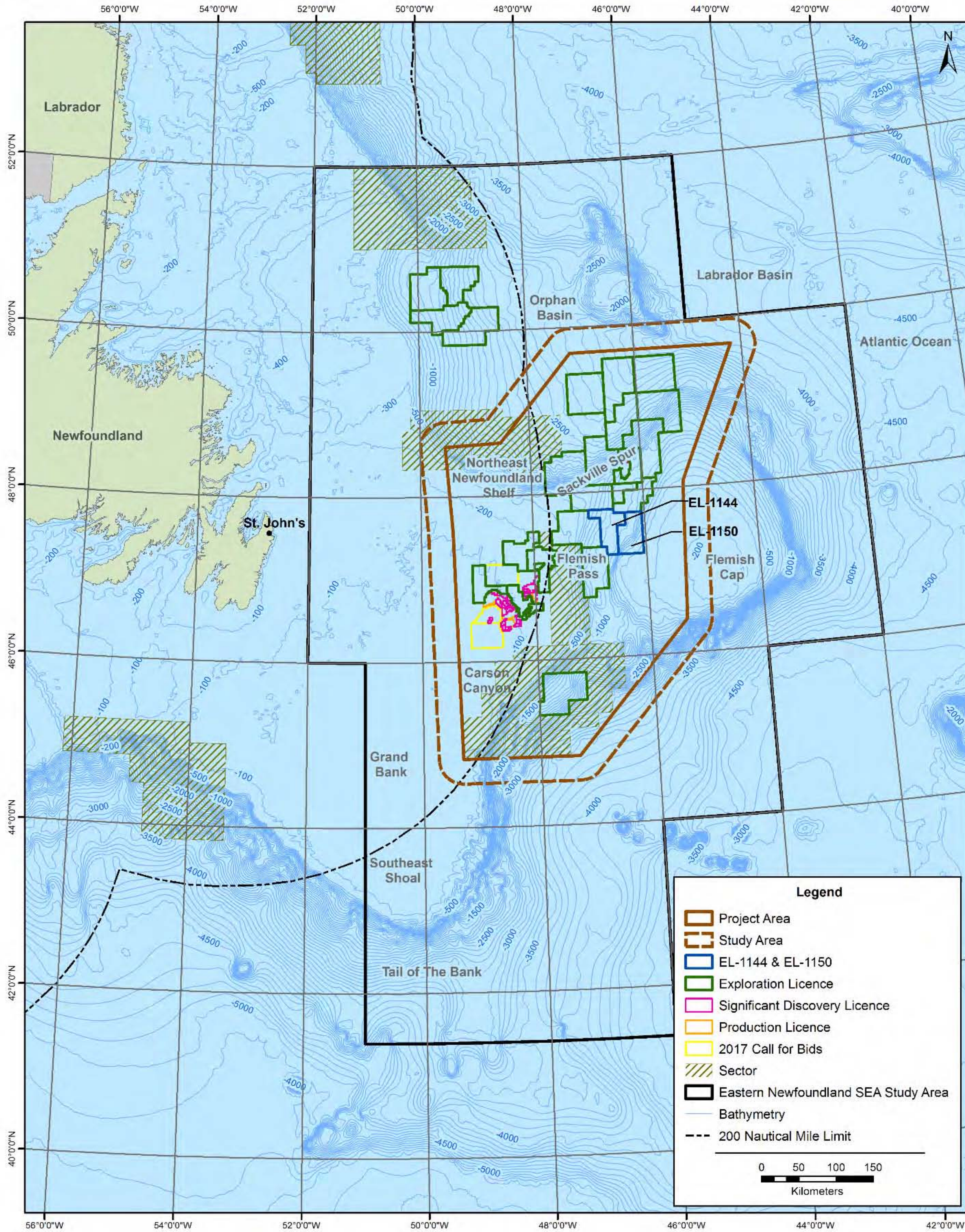


Figure 4.3 General Bathymetry of the Project Area and Study Area



4.1.3 Climatology, Oceanography and Ice Conditions

The sections that follow give an overview description of various aspects of the physical environment of the EA Study Area, including its climatology (wind, air temperatures, precipitation, visibility), oceanography (waves, surface currents, seawater properties) and ice conditions (sea ice, icebergs, potential vessel icing).

Although The Eastern Newfoundland SEA (Amec 2014) provides a considerably more detailed description of these environmental components (see Sections 4.1.3 to 4.1.5), more recent information is available from existing datasets for a number of key parameters. This includes the following updated information and datasets: 1) the availability and use of MSC50 data from 2015 for wind and waves; 2) updated (to 2016) International Comprehensive Ocean-Atmosphere Data Set (ICOADS) data for many of the other parameters; 3) data for up to February 2017 from DFO for currents and sea water properties, and 4) the availability of updated icebergs data with another year (2014) from the National Research Council (NRC) Program of Energy Research and Development (PERD) database and two more years (2013, 2015) from the International Ice Patrol (IIP).

The sections that follow therefore provide some additional and updated information on these components of the physical environment for this EA. Given that the most direct relevance of the physical environment information for this EA is in assessing and evaluating the potential “effects of the environment on the Project” (Section 2.8), and specifically the manner in which physical environmental conditions may eventually affect the planning and conduct of in-field Project activities, the focus of this section is on the Project Area itself.

4.1.3.1 Climatology

ICOADS (NCDC et al 2015) represents the most extensive available database of observations of atmospheric and sea conditions for the Project Area and Study Area. The dataset consists of global marine (ship and rig) data observations spanning the years 1911 to present, compiled by the National Centre for Atmospheric Research (NCAR).

As illustrated in Figure 4.4, four general regions were defined for the purposes of this EA to cover the Project Area, and these were used to query the ICOADS for 1960 to 2016 and assemble statistics of meteorological and marine conditions across this region.

Wind

The prevailing winds over the Project Area are from the west to northwest in winter and from the southwest in summer. Extreme wind gusts greater than 100 knots (51 m/s) have been measured in winter and in association with tropical and post-tropical weather systems. Many storm systems are still strengthening as they pass through the area, and as a result winds over the northeast portion of the Project Area are on average stronger than those over the southwest (Bowyer 1995). Figure 4.5 summarizes seasonal monthly mean and maximum wind speeds for the four ICOADS regions that comprise the Project Area (data from NCDC et al 2015). Mean wind speeds range from 7 to 9 m/s in August to 11 to 13 m/s in February. Winds are generally the greatest in the Northern Grand Banks region. Maximum wind speeds there range from 27 m/s in August to as large as 49.4 m/s (178 km/h) (wind direction from the northwest): an ICOADS observation reported 11 February 2003 at the Hibernia Platform.

Figure 4.4 ICOADS Regions in the Project Area

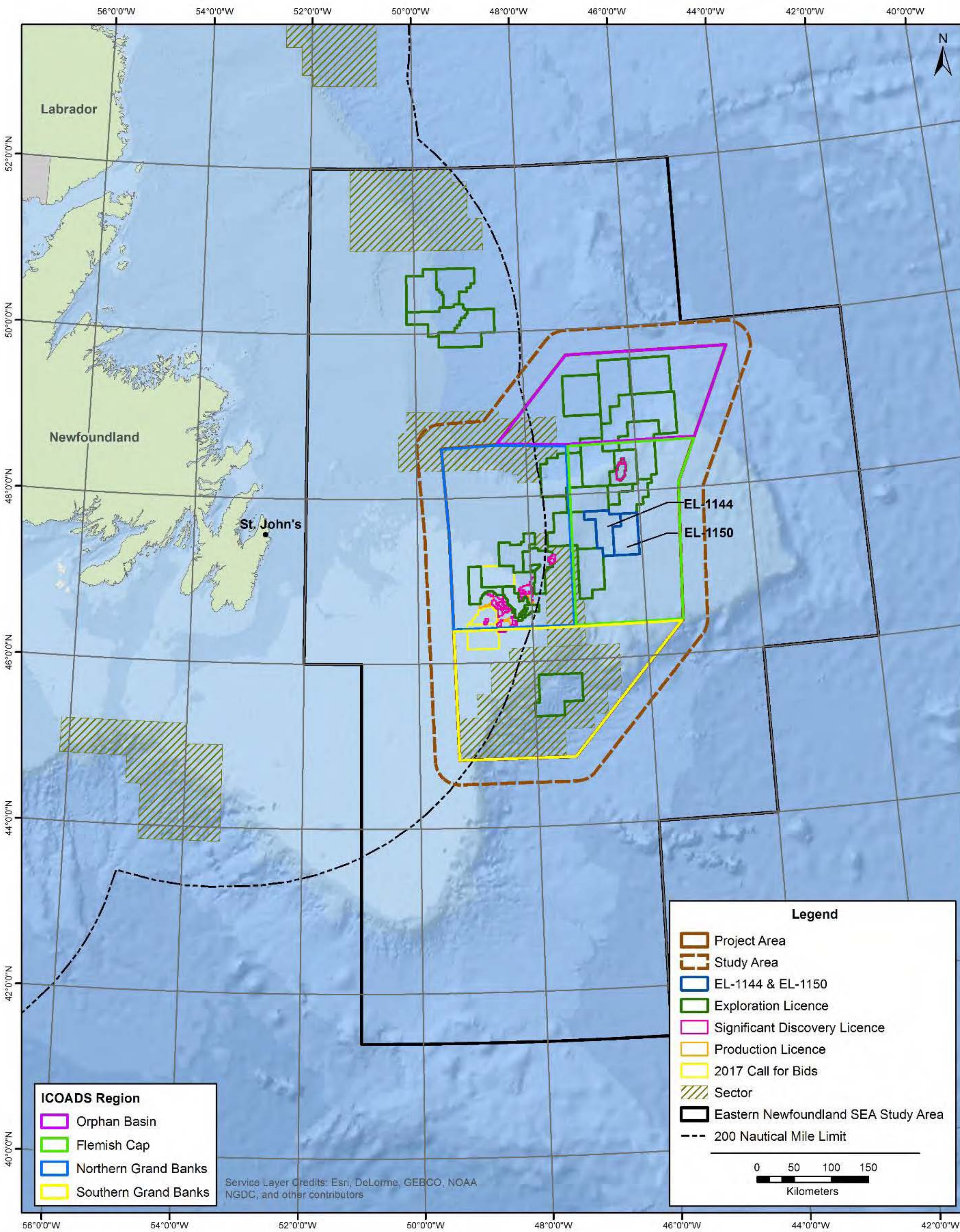
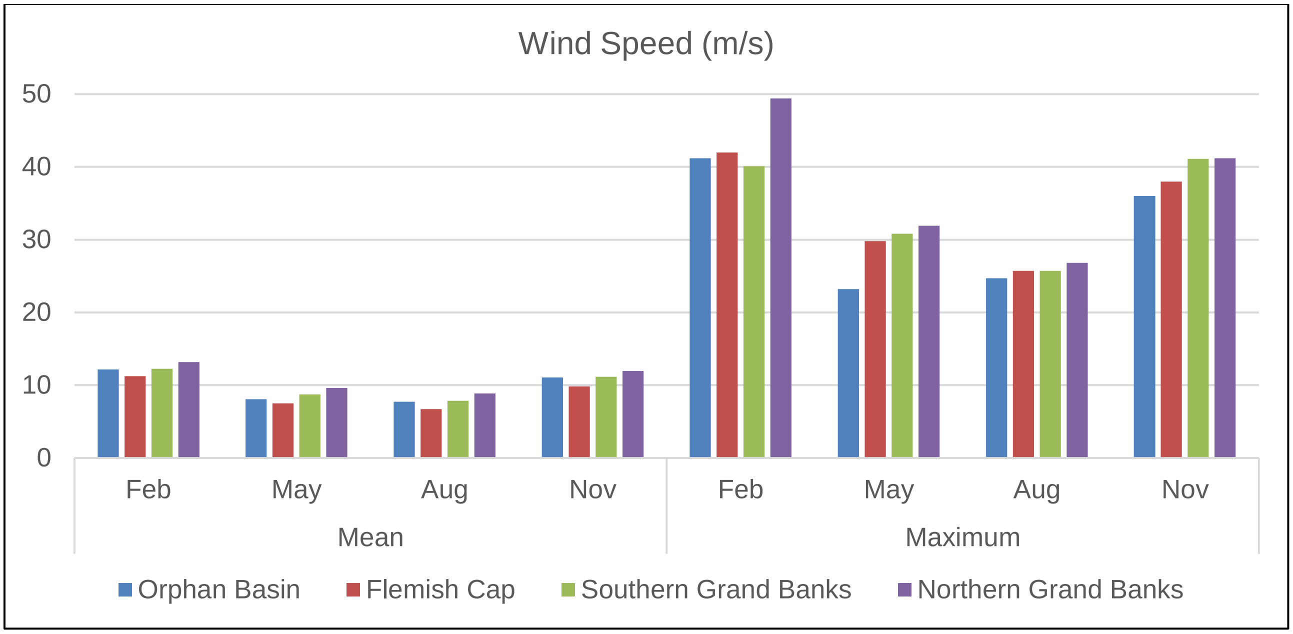


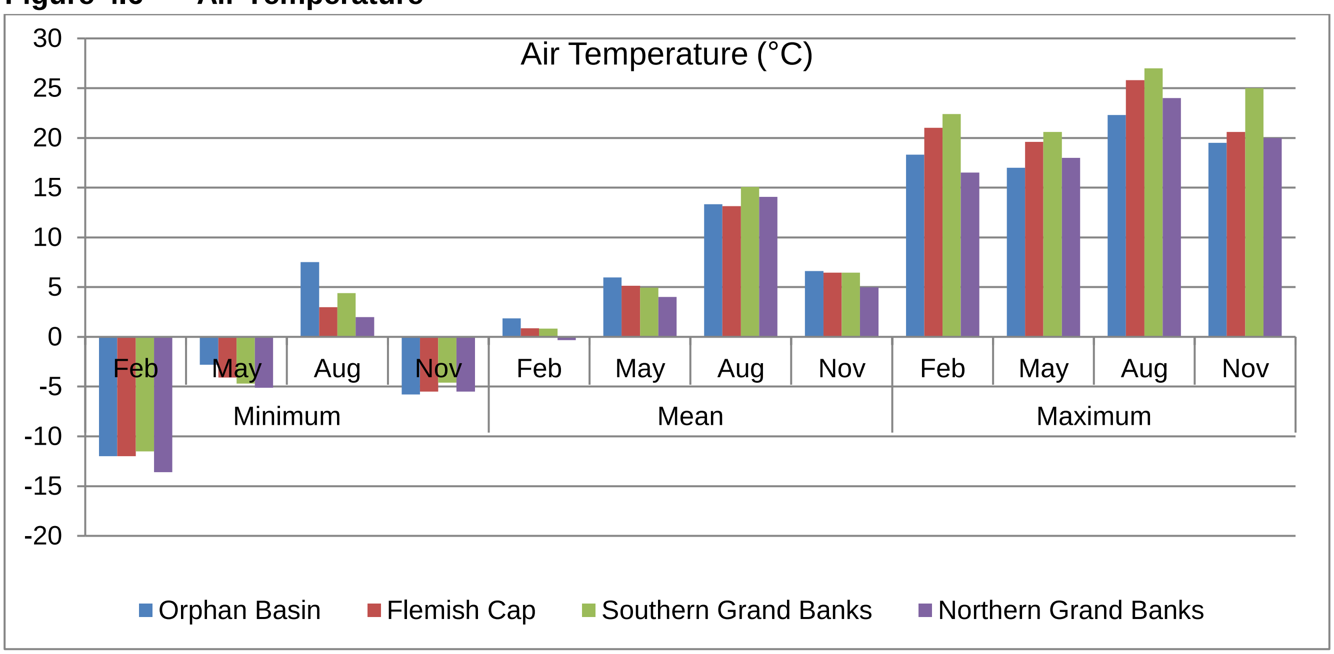
Figure 4.5 Wind Speed



Air Temperature

Air temperatures in the Project Area overall are coolest in January or February and warmest from July through September for all sub-regions. Figure 4.6 (data from NCDC et al 2015) presents minimum, mean and maximum monthly air temperatures for the four (ICOADS) sub-regions that comprise the Project Area. Minimum temperatures range from -11.5°C to -13.6°C in February to as high as 7.5°C in August for the Orphan Basin. Mean temperatures range from -0.3°C in February for the Northern Grand Banks to 14.1°C in August for the Southern Grand Banks. Maximum air temperatures over the Project Area range between 16.5°C and 22.4°C in February to 22.3°C and 27°C in August.

Figure 4.6 Air Temperature



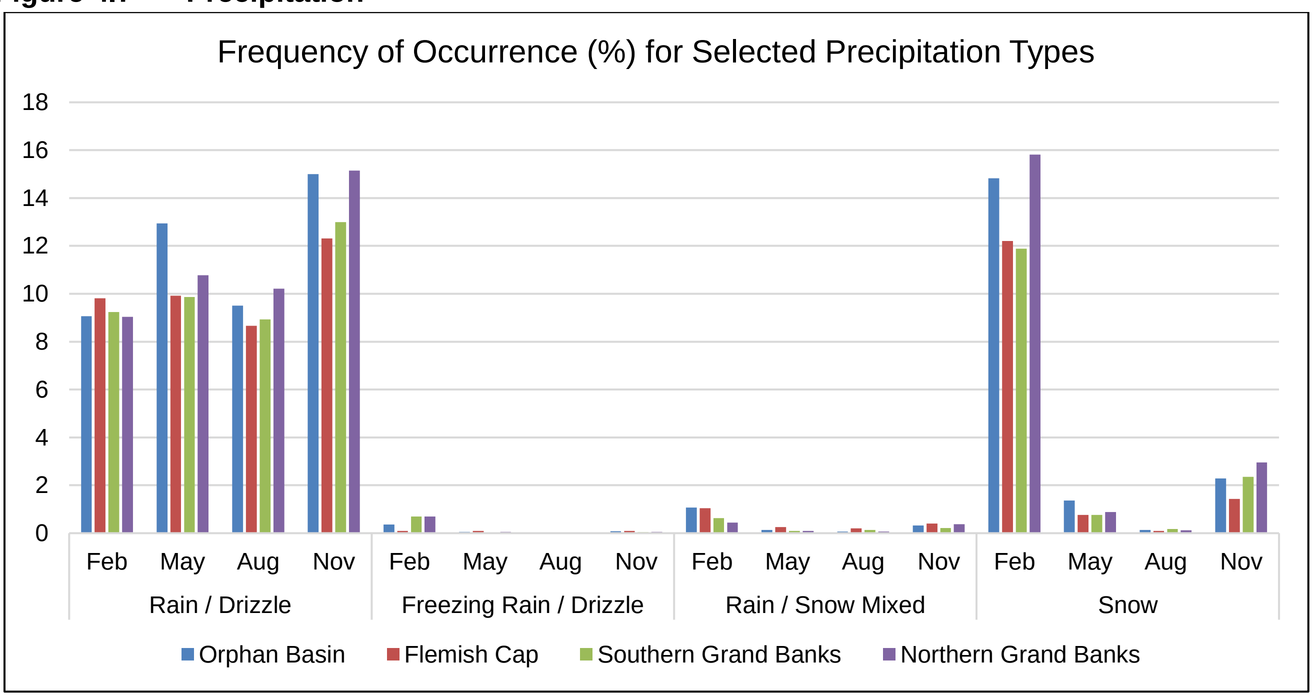
Precipitation

Rain or drizzle can occur at any time of year throughout the Project Area, and is most likely to occur in association with southerly or southwesterly winds. Snow and freezing rain are possible any time from October through May, and snow can accompany winds of any direction. Freezing rain is most common with easterly or north-easterly winds.

Based on the ICOADS data set queried, the total precipitation is the greatest in January and February. Precipitation is lowest in June and is predominantly in the form of rain or drizzle. Figure 4.7 (data from NCDC et al 2015) shows the percent occurrence of different precipitation types for each of the four ICOADS regions for select months of the year. The frequency of occurrence can most closely be characterized as representing unspecified periods of time, for a percentage of all days in the given month.

There is a year-round potential for thunderstorms and hail, with the highest frequency of occurrence of hail occurring in the winter months, and thunderstorms most frequently reported in summer. Annually, the percent occurrence of hail or thunderstorm ranges from about 0.2 percent of the time for the Northern Grand Banks to 0.4 percent for the Orphan Basin. The largest percent occurrence of hail is reported at 1.24 percent in February for the Orphan Basin, while the largest occurrence of thunderstorms is reported at 0.61 percent in July for the Orphan Basin.

Figure 4.7 Precipitation



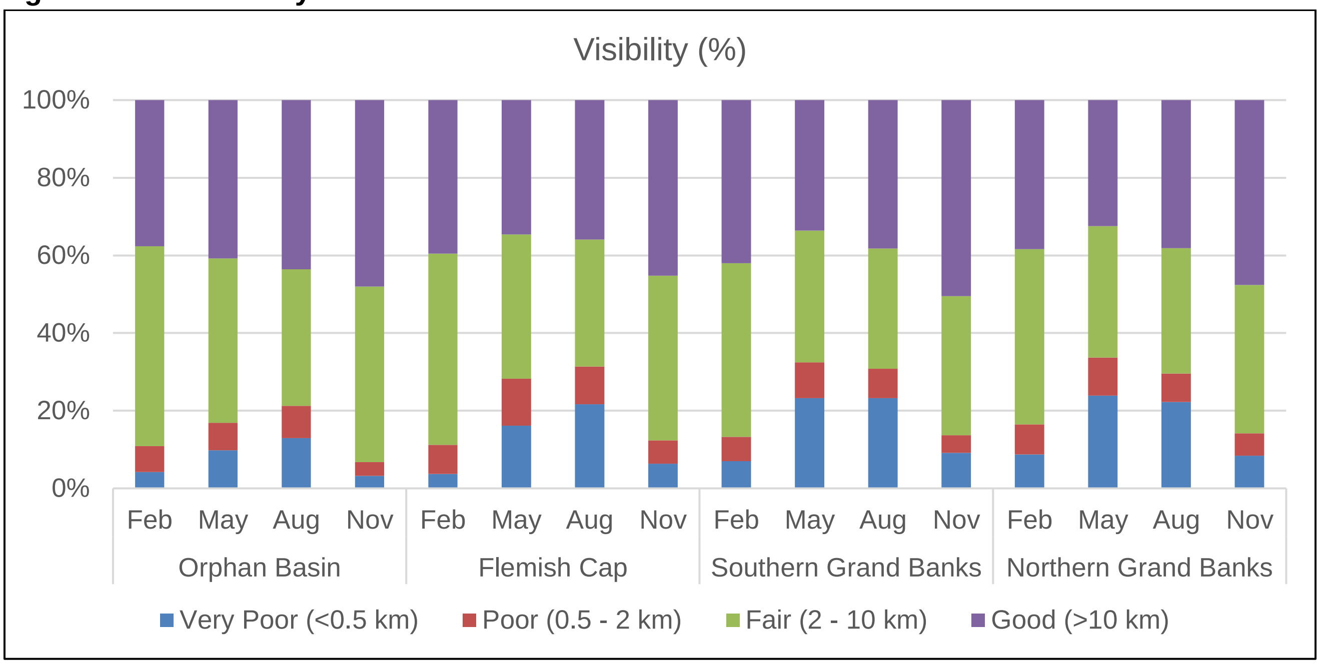
Visibility (Fog)

A summary of visibility conditions based on the ICOADS dataset, with classes defined as very poor (less than 0.5 km), poor (0.5 to 2 km), fair (2 to 10 km) and good (greater than 10 km), is shown in Figure 4.8 (data from NCDC et al 2015).

In general, visibility over the Project Area is the most favourable in fall and winter and most frequently restricted in summer and spring. Good visibility (greater than 10 km) conditions occur annually from about 41 percent of the time for the Orphan Basin to 38-40 percent for the other three regions. On a monthly basis, good visibility conditions range from a minimum of 21 percent of the time in July for the Northern Grand Banks to a maximum of 53 percent of the time in October for the Southern Grand Banks. Fair conditions can be expected about 36 percent (Northern Grand Banks) to 43 percent (Orphan Basin) of the time annually.

Visibility is least favourable for the Northern and Southern Grand Banks, being very poor (less than 0.5 km) 17 percent of the time annually, compared with eight and 12 percent for the Orphan Basin and Flemish Cap, respectively. Visibility conditions are the poorest in July for all regions with the conditions being very poor or poor in that month over half the time (54 percent) for the Northern Grand Banks, 50 percent for the Flemish Cap, 54 percent for the Southern Grand Banks and the least restricted at 37 percent for the Orphan Basin.

Figure 4.8 Visibility



4.1.3.2 Oceanography

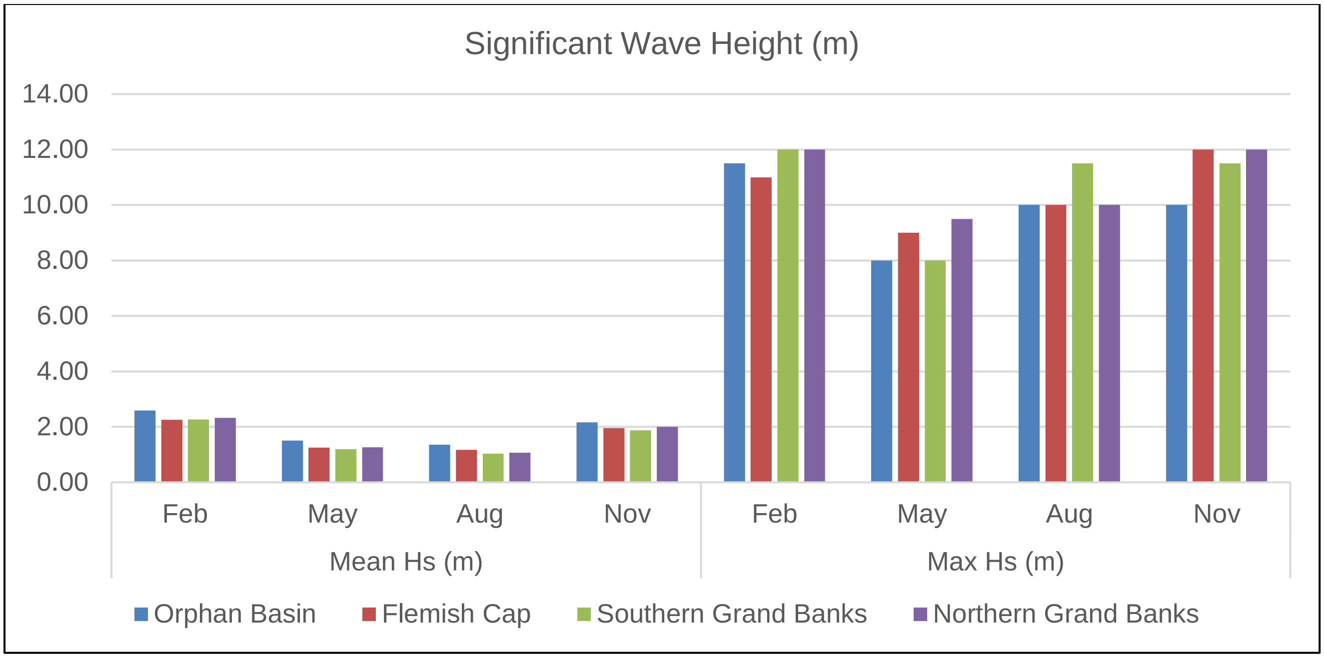
As described above, the ICOADS (1960 to 2016) datasets were used to provide an overview summary of oceanographic conditions across the Project Area, based on each of the subregions described and illustrated above.

Waves

A summary of significant wave height is presented in Figure 4.9 (data from NCDC et al 2015) for the four ICOADS regions that comprise the Project Area. Seasonal monthly mean and maximum significant wave height (Hs), estimated to the nearest 0.1 m are reported.

The largest seas are seen farthest offshore, namely in the Orphan Basin region. Mean significant wave heights in spring and summer (May and August) range from 1.0 to 1.5 m, and in fall and winter (November and February) range from 1.9 to 2.6 m. For maximum Hs values, spring and summer values range from 8.0 to 11.5 m, and winter values from 10.0 to 12.0 m.

Figure 4.9 Significant Wave Height



Ocean Surface Currents

The circulation of the Project Area, which includes the continental shelf waters off Eastern Canada, is dominated by a generally southward flow of the cold Labrador Current and its two streams: 1) an inshore branch that flows along the coast on the continental shelf, and 2) an offshore branch that flows along the outer edge of the Grand Banks.

The current's inshore branch tends to flow mainly in the Avalon Channel along the coast of the Avalon Peninsula, but may sometimes also spread further on the Grand Banks. The offshore branch of the Labrador Current flows over the upper Continental Slope at depth, and through the Flemish Pass with average speeds of approximately 40 cm/s. Over parts of the Grand Banks with water depths less than 100 m, the mean currents are generally weak (less than 10 cm/s) and flow southward, dominated by wind-induced and tidal current variability. The offshore branch meets with the Gulf Stream south of the Project Area near the Tail of the Grand Banks and flows to the east.

Seawater Properties (Temperature, Salinity)

Summaries of winter and summer sea temperature and salinity derived from DFO's Climatology for the Newfoundland Shelf (DFO 2017a) are provided in Tables 4.1 and 4.2, respectively. Four geographic areas have been selected to generally characterize the conditions for the Project Area, which cover a portion of the Newfoundland Shelf:

- Area 34 (Funk Offshore, depth 1,000 m) for Orphan Basin;

- Area 38 (Central Flemish Cap, depth 250 m) for Flemish Cap;
- Area 43 (SW Newfoundland Basin, depth 1,000 m) for Southern Grand Banks; and
- Area 46 (NE Grand Bank, depth 600 m) for Northern Grand Banks

Average sea surface temperatures generally range from about 0°C to 7°C in February and from about 10°C to 16°C in summer, whereas near-bottom sea temperatures generally range from 8°C to 13°C on average year-round (Table 4.1). Average sea surface salinities range from about 32 psu to over 34 psu. Near-bottom salinities are typically around 34 psu in both summer and winter (Table 4.2).

Table 4.1 Sea Temperature

Mean Sea Temperature (°C)	Orphan Basin	Flemish Cap	Southern Grand Banks	Northern Grand Banks
Feb: Surface	2.18	3.10	7.29	0.04
Feb: Mid-Depth	3.75	3.05	5.43	-0.07
Feb: Near-Bottom	3.48	4.05	3.91	--
Aug: Surface	8.82	10.83	12.87	9.14
Aug: Mid-Depth	3.56	3.50	4.98	-0.61
Aug: Near-Bottom	3.38	4.09	3.90	--

Table 4.2 Salinity

Mean Salinity (psu)	Orphan Basin	Flemish Cap	Southern Grand Banks	Northern Grand Banks
Feb: Surface	34.16	33.77	34.18	32.70
Feb: Mid-Depth	34.87	33.88	34.99	33.12
Feb: Near-Bottom	34.88	34.29	34.94	--
Aug: Surface	33.33	33.47	33.24	32.37
Aug: Mid-Depth	34.84	34.15	34.94	33.23
Aug: Near-Bottom	34.86	34.90	34.94	--

4.1.3.3 Ice Conditions

Portions of the Project Area are subject to seasonal intrusions of sea ice and icebergs, as well as vessel icing during particular wind, wave and air temperature conditions. Sea ice and iceberg conditions vary each year and by location, and are influenced by colder or milder winter conditions over Newfoundland and the surrounding waters, and seasonal wind patterns. Cold and dry winds from the west through north have the effect of moving ice further offshore, while northeasterly winds tend to bring ice towards shore. Any of these factors will influence the distribution of ice over the Project Area.

Sea Ice

The Sea Ice Climatic Atlas for the East Coast 1981-2010 (CIS 2011) reports how frequently sea ice is present, its concentration when present, and its predominant ice type and hence thickness. In the northwest portion of the Project Area, sea ice can be present as early as the middle of January and in thicknesses of up to 15-30 cm. By the end of March (Figure 4-10, from CIS 2011), most of the ice over the Project Area is thin first year (30-70 cm), with patches of medium (70-120 cm) and thick (greater than 120 cm) first year. At the end of March there is also potential for some patches of old ice (ice which has survived at least one summer’s melt) at the very southern portion of the Project Area. As illustrated in the companion Figure 4.11 (CIS 2011), sea ice concentrations for the week of March 26th can range from less than 1/10 to as great as 9/10 to 9+/10.

Figure 4.10 Frequency of Presence of Sea Ice (%), Week of March 26 (1981-2010)

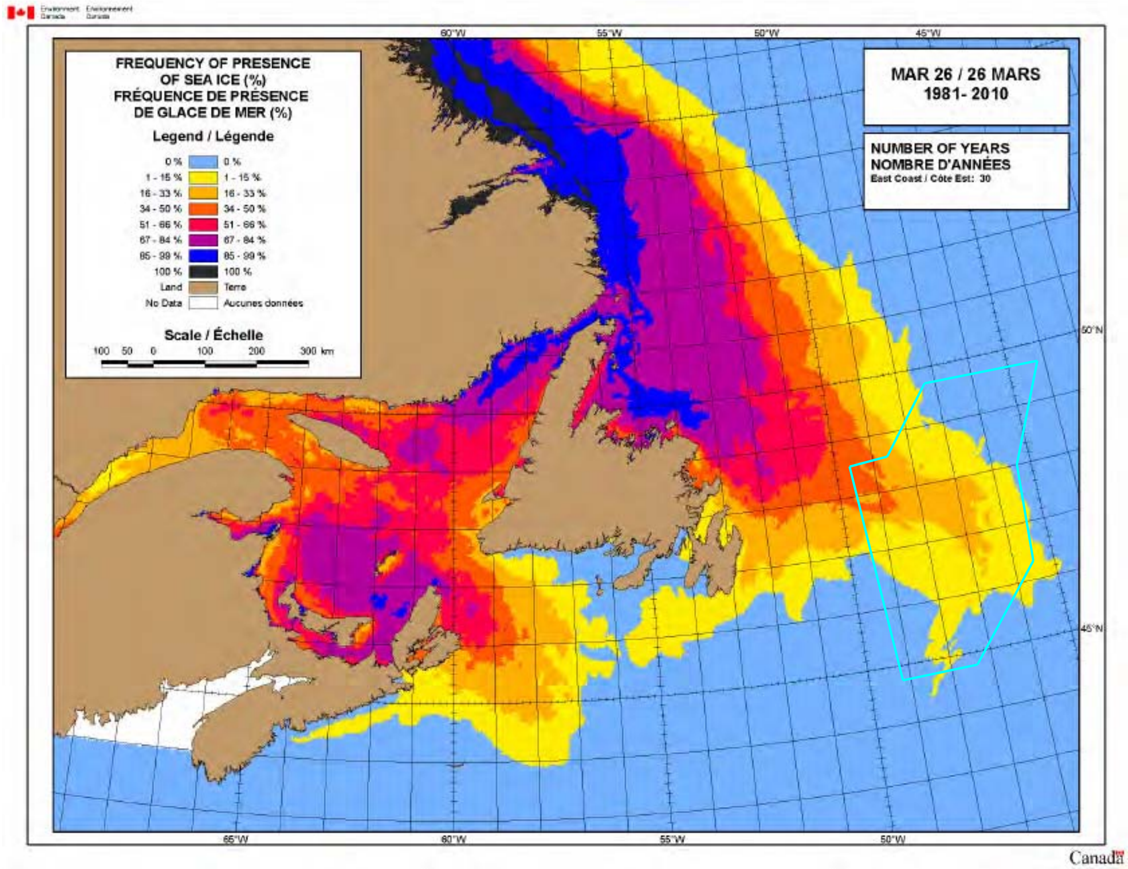
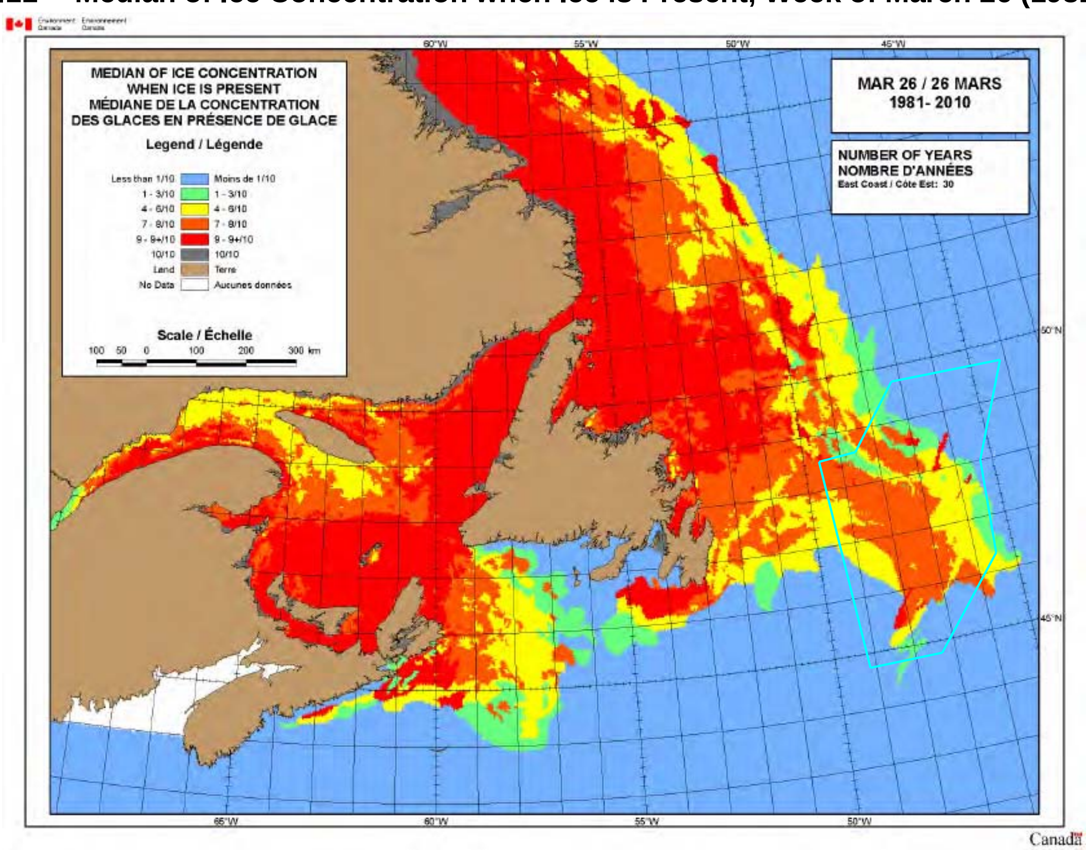


Figure 4.11 Median of Ice Concentration when Ice is Present, Week of March 26 (1981-2010)



The sea ice begins to retreat over the entire region by mid-April, and by the beginning of May the Project Area is generally ice free, with ice presence just 1-15 percent of the time in the outermost northwest portion of the Project Area. At the end of May, small areas of medium or thick first year ice may be found in the northwest in concentrations of 1/10 to 3/10. Occasionally (1-15 percent of the time) old ice may be found in small patches in the southern portions of the Project Area, as late as the first week of June.

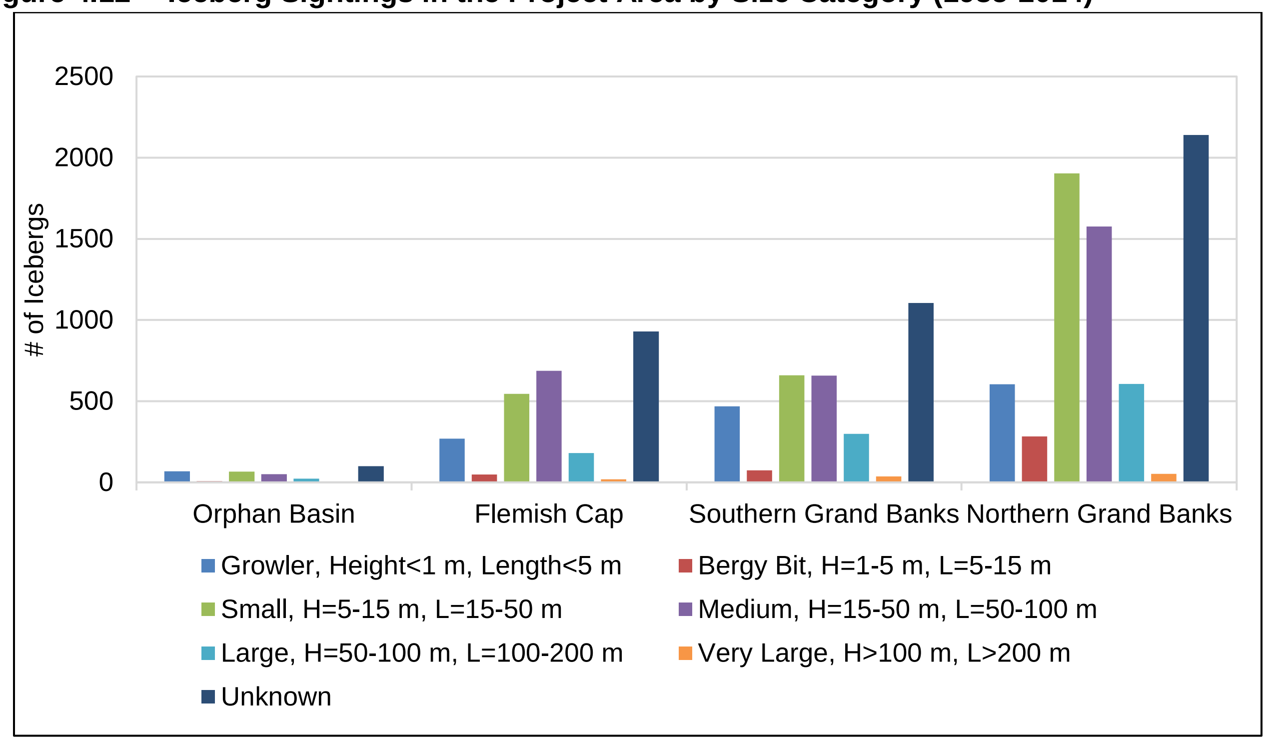
Icebergs

A summary of iceberg sightings from the comprehensive NRC-PERD Iceberg Sighting Database (Sudom et al 2014; NRC 2015) for the years 1985 to 2014 is presented below for four rectangular regions, each corresponding to one of the four ICOADS regions defined above.

The iceberg sightings data are from various sources including industry, aircraft and ship, and include radar, visual and measured observations. Statistics are reported here for first iceberg sightings (excluding any re-sightings of the same iceberg), and include size classes ranging from growlers (those less than 1 m in height, less than 5 m in length and masses of about 500 t) to very large icebergs (greater than 100 m in height, greater than 200 m in length, and mass over 5 Mtonnes). Icebergs of unknown size are also reported. These criteria yield 13,469 iceberg sightings within the Project Area.

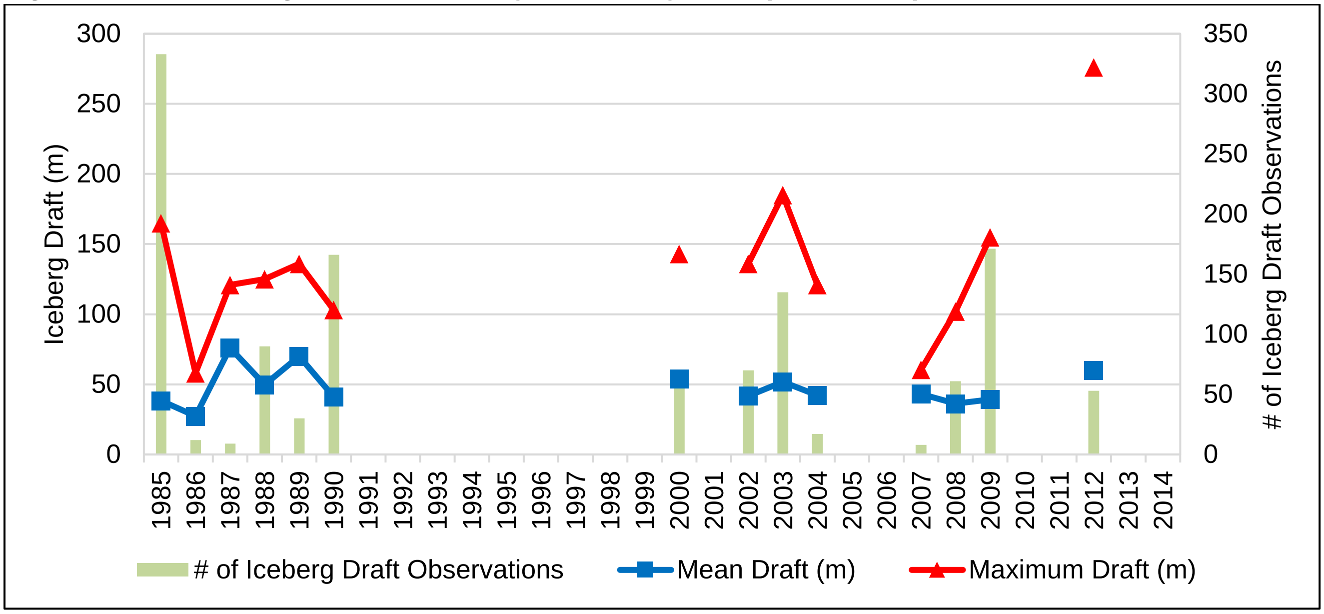
As illustrated in Figure 4.12 (data from NRC 2015), the majority of icebergs are observed in the Northern Grand Banks sub-region: 7,169 over the past 30 years, or 53 percent of the total number of icebergs first observed in all four sub-regions. This is compared with 318 (two percent) for the Orphan Basin, 929 (20 percent) for the Flemish Cap and 3,302 (25 percent) for the Southern Grand Banks. Of the 9,196 first sighting icebergs for which size is known, 20 percent are growlers or bergy bits, 67 percent are small or medium, 12 percent are large, and just over one percent are very large.

Figure 4.12 Iceberg Sightings in the Project Area by Size Category (1985-2014)



Of this subset of icebergs in the Project Area from 1985 to 2014, 1,217 icebergs have draft values, nine percent of these being measurements and the rest being estimates. Observations from the Northern Grand Banks comprise 77 percent of the data set, with no iceberg draft observations from the Orphan Basin. The annual mean, maximum and number of observations for each year are shown in Figure 4.13 (data from NRC 2015). The historical mean draft is 44 m. The maximum draft of 276 m is an estimate for a very large (length=900 m, width=740 m) tabular iceberg reported 23 April 2012 in the Northern Grand Banks. The largest measured draft is 151 m for a large (length=350 m, width=225 m) tabular iceberg reported 18 May 2003 in the Flemish Cap region.

Figure 4.13 Iceberg Draft in the Project Area by Year (1985-2014)



The iceberg season for the Project Area traditionally lasts from January through July, with 86 percent of first sightings during the period March through June (Figure 4.14, data from NRC 2015). Over the 30 year record, 1985-2014, there have been 13 sightings as late as October in the Flemish Cap and Northern Grand Banks regions, and 13 sightings as early as December in all regions except the Orphan Basin (Figure 4.15, note smaller y axis scale, data from NRC 2015).

As illustrated in Figure 4.16 (based on data from NRC 2015), each ice season is quite different. Over the period 1985 to 2014, the number of icebergs reported annually for the Project Area ranged from zero in 2005, 2006, 2010 and 2011 to 1,459 in 2002 and averages 539. For the Northern Grand Banks, between 672 and 755 icebergs were sighted in several years (1985, 1993, 2002, 2003, 2008), with the annual average in that region being 287. The annual average number of icebergs for the other regions are: Orphan Basin, 13; Flemish Cap, 112; and Southern Grand Banks, 138[1].

[1] Data from 2013 are absent from the 2015 PERD database release. However, observations from the International Ice Patrol (IIP) Iceberg Sightings Database (IIP 1995, updated 2016) for 2013 indicate there were numerous icebergs off the coast of Labrador, through the Strait of Belle Isle and into the Gulf of St. Lawrence and off the northeastern coast of NL. There was, however, in 2013 only one iceberg in the Project Area (Southern Grand Banks region).

Figure 4.14 Iceberg Sightings in the Project Area, January to June (1985-2014)

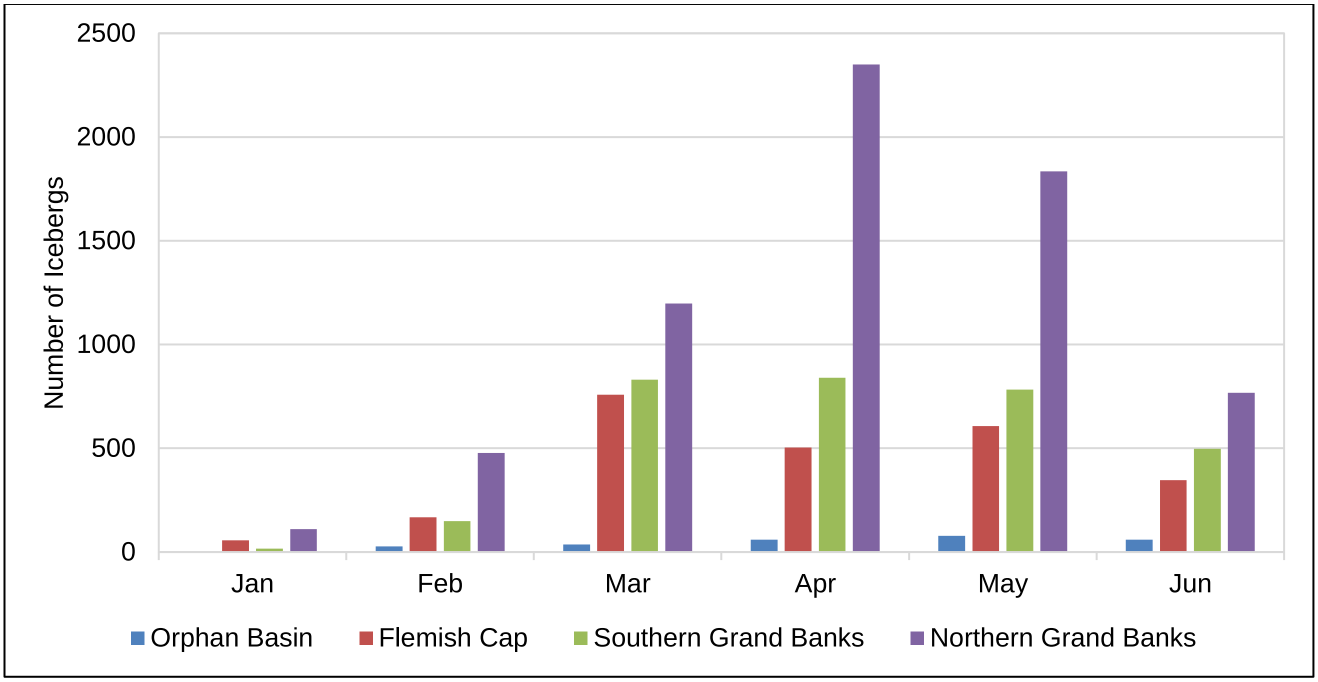


Figure 4.15 Iceberg Sightings in the Project Area, July to December (1985-2014)

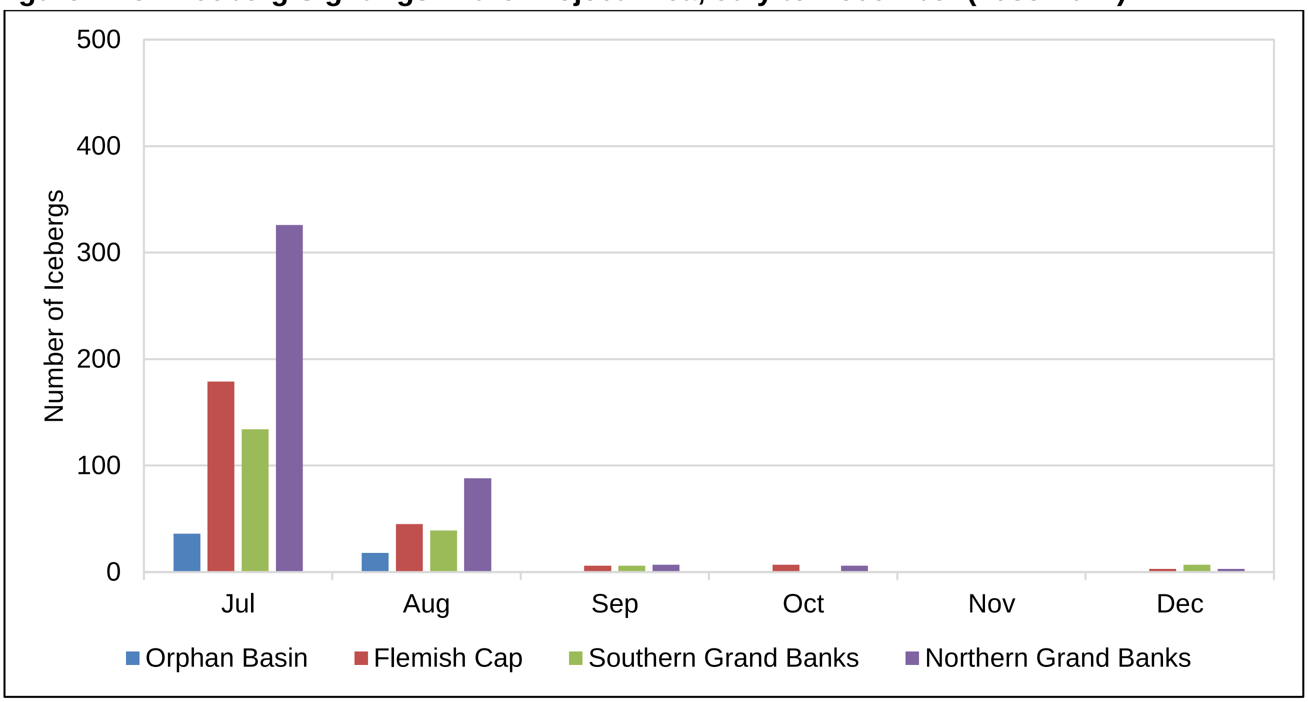
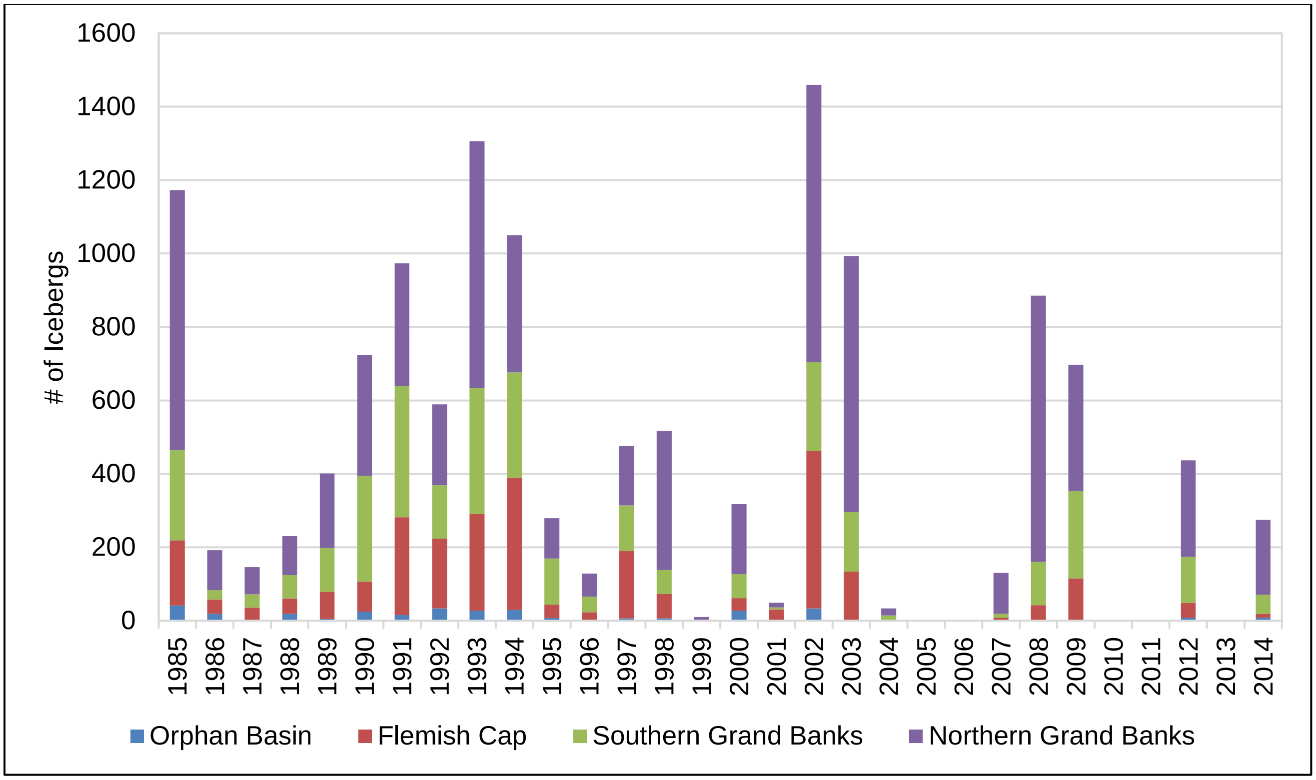


Figure 4.16 Iceberg Sightings in the Project Area by Year (1985-2014)



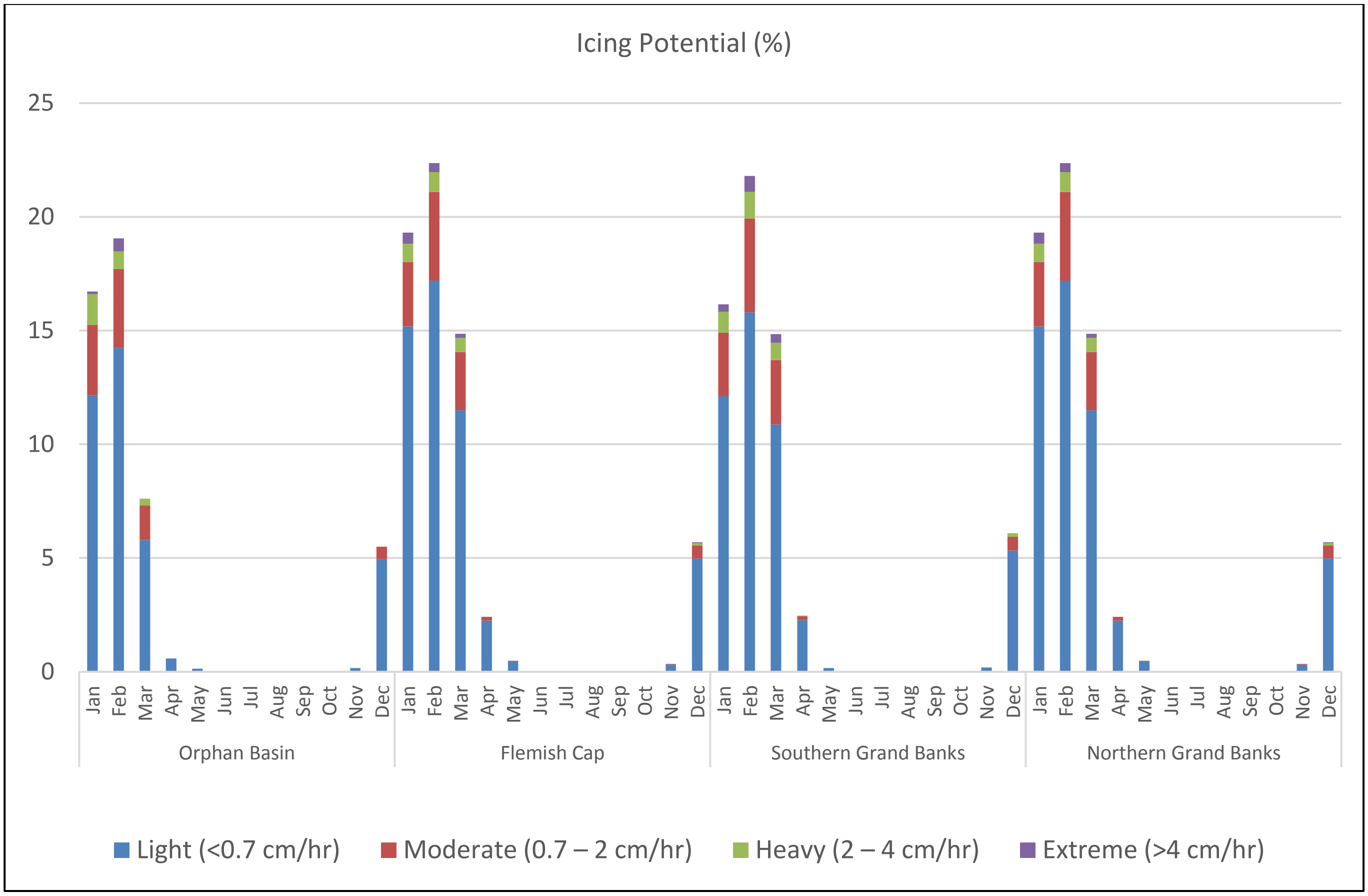
Vessel Icing

Vessel icing, most frequently from freezing spray, is a marine condition that can hinder and limit shipboard activities, increase a vessel's weight and alter its centre of gravity. Freezing spray is most likely to occur from November through April. Air temperatures must be lower than -2°C to produce freezing spray in salt water. Icing conditions are worsened with colder temperatures, high winds and large waves (Bowyer 1995).

A standardized way to determine the potential ice build-up rate has been developed by Overland (1990), who based his algorithm on empirical observations and the heat balance equation of an icing surface. This algorithm has been used to derive an estimate of icing potential in the Project Area by using concurrent air and sea temperature and wind speed data from ICOADS. The results have been sorted into four different categories based on the severity (light, moderate, heavy and extreme), and are summarized in Figure 4.17 (data derived from NCDC et al 2015).

The potential for vessel icing is greatest in the winter months, with total icing potential over 20 percent in February for all regions except Orphan Basin (19 percent). Extreme icing potential for all regions is greatest in January and February.

Figure 4.17 Icing Potential



4.2 Biological Environment

The following sections present an overview of relevant aspects of the biological environment of the Project Area and Study Area, including marine fish and fish habitat, marine/migratory birds, marine mammals and sea turtles.

4.2.1 Marine Fish and Fish Habitat

Marine ecosystems are comprised of physical and biological elements that interact to form complex and often variable patterns across a seascape. The physical elements of fish habitats in the Study Area and surrounding marine environments range from shallow shelf areas and continental slopes to deep abyssal areas, which influence the presence, abundance and distribution of marine organisms and result in various assemblages of species associated with particular habitats. Biological ecosystem elements span primary producers such as phytoplankton to consumers such as zooplankton, invertebrates and fish that have key roles in supporting regional biodiversity and marine productivity.

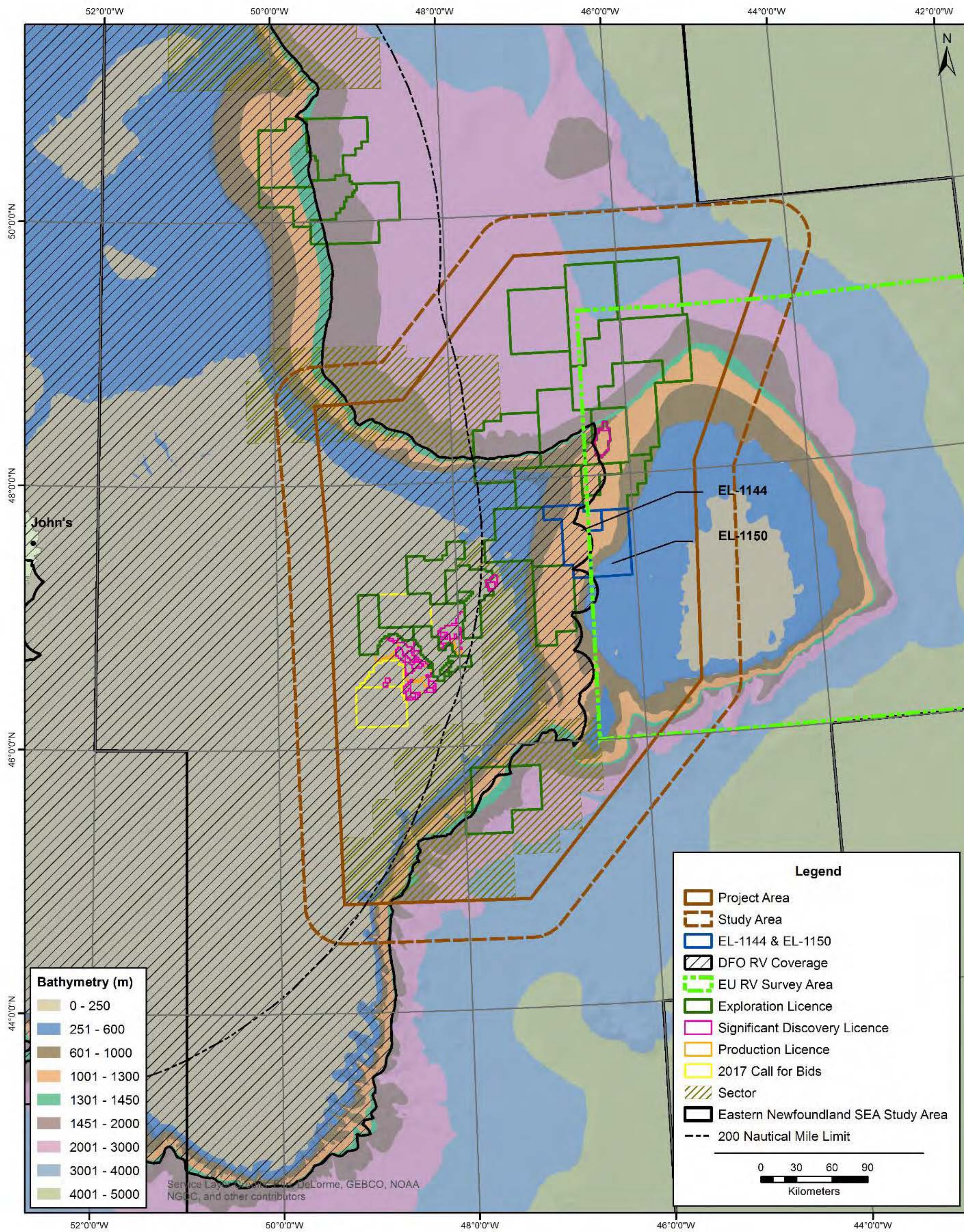
4.2.1.1 Approach, Key Data Sources and Administrative Considerations

The proposed Project Area and the EA Study Area fall within the geographic scope of the Eastern Newfoundland SEA (Amec 2014), which provides a regional overview of the offshore marine ecosystem that includes the Grand Banks, Flemish Cap and adjacent slope and abyssal habitats (Figure 4.18). This chapter builds upon the information presented in the SEA by summarizing critical elements, augmenting SEA knowledge with more recent information available in the literature and from other more recent datasets, and providing additional analyses specific to the proposed Project Area. For more detailed, generic information (including descriptions of the overall characteristics and life histories of marine fish species) or regional ecological context, the reader is directed to the Eastern Newfoundland SEA document itself (Amec 2014), particularly SEA Section 4.2.1.

Two regulatory jurisdictions are relevant to marine fish and fish habitat within the proposed Project Area and surrounding marine environments. The Government of Canada manages fish stocks within the 200 mile EEZ and sedentary species across the entire continental shelf. In these areas, the federal *Canadian Fisheries Act* (2012) provides protection to commercial, recreational, and Aboriginal fisheries by managing the fish resources and habitats that support these activities. Groundfish outside the EEZ and the benthic organisms beyond the continental shelf are managed by NAFO (see Section 4.3.1).

Within Canadian waters, the distribution and abundance of demersal fish and invertebrates are relatively well studied through annual standardized multi-species government research vessel (RV) surveys. NAFO and the European Union (EU) also undertake surveys in areas of their jurisdiction, including areas targeted by commercial fisheries on the Flemish Cap and slope within and adjacent to the Study Area. While data sets across the two jurisdictions are often not directly comparable in a quantitative manner and do not necessarily provide comprehensive and comparable coverage in all areas of interest, they collectively provide a sound overall understanding of the key faunal communities in and around the Study Area and the processes that influence their presence and distribution. While it is also recognized that some marine habitats (especially the very deep, abyssal regions) and assemblages (particularly the pelagic groups) are somewhat underrepresented in the available studies, the available data span much of the habitat heterogeneity in and around the Study Area and cover much of the area that is known to be used for commercial fishing purposes.

Figure 4.18 Primary Depth Zones of the Study Area and Surrounding Marine Environments



Data from the Fisheries and Oceans Canada (DFO) RV surveys (2008-2012) were used as the basis for much of the description and analysis that is presented in this section. The data is based on random, stratified sampling from research vessels using a Campelen 1800 trawl and provides the up-to-date and unbiased information available that can be applied in a consistent manner across a large portion of the Study Area. This includes NAFO convention areas 3KLNM within the proposed Project Area. Consequently, these data are used as the foundation for defining focal species and their contemporary distributions. The Canadian (DFO) RV information used in this EA (2008-2012) represents a more up to date data set as compared to that which was available for and used in the Eastern Newfoundland SEA (2005-2008, Amec 2014). Due to the history of ecological regime shifts in the northwest Atlantic ecosystem as established by Nogueira et al (2016, 2017), only five years of recent available data (2008-2012) were utilized for analysis. The data from the Canadian RV surveys were further screened to identify key species that occurred in high abundance within the Study Area (cumulatively exceeded more than 95 percent of individuals captured). From this process, 13 focal taxa (10 fish and three invertebrate species) were identified. The ecology of these species are described in greater detail and maps of their distribution relative to the Study Area are provided in the sections that follow.

Visualizations of Canadian RV-derived species distributions were generated using the GIS Spatial Analysis System (SPANS) potential mapping surface methods utilized in previous research (Han and Kulka 2007; Kulka 2009) and recent strategic and project-specific EAs (e.g., LGL 2003; Amec 2014). The technique makes use of the geo-referenced survey catch rate data to define spatial differences in fish density and biomass. These maps are displayed and described for focal invertebrate and finfish species. Furthermore, aggregate maps are provided and described for total fish biomass, total fish abundance and fish species richness. Where possible and reasonable, inferences have been made for areas not covered by Canadian RV surveys based on distribution within the overall Study Area and respective species biology and ecology.

This information is augmented by NAFO data collected from the Flemish Cap. NAFO RV surveys of the Flemish Cap are also based on a stratified random design (Saborido-Rey and Vázquez 2003) and provide distribution data for a subset of commercially important species (Atlantic cod, American plaice, Greenland halibut, roughhead grenadier and redfish). The area of coverage comprises approximately 20 percent of the Study Area. It is recognized that these surveys do not cover some portions of the Study Area (particularly deep water portions beyond the continental slope under NAFO jurisdiction) and that certain taxa (such as various pelagic, abyssal and infaunal species) within the area surveyed are poorly represented. Nonetheless, these sources provide useful information for a considerable portion of the Study Area on many ecologically and commercially important taxa. The resulting scientific literature has been used to characterize assemblages and distributions of fish (Vázquez et al 2013; Nogueira et al 2014, 2016, 2017) and invertebrate (Murillo et al 2011; 2016) species for the region based on abundance, biomass and occurrence similar to the analysis of Canadian RV survey data. Publication analyses were used to provide comparisons to Canadian surveys and for characterizing fish and fish habitat within the Study Area. From recent publications (Nogueira et al 2017) a total of 10 focal fish taxa were identified and described in greater detail in this section.

4.2.1.2 The Offshore Marine Ecosystem, Ecological Regimes and Assemblages

Marine species have direct or indirect ecological roles in the functioning of their ecosystem (Templeman 2010; Dawe et al 2012) and their community structure may be affected by short and long term shifts in inter-species interactions and fluctuations in environmental parameters. Primary interactions between marine organisms occur through the food chain where widespread variations in predator or prey abundances can cascade to other food chain levels. In the marine environment, primary production is generated by photosynthetic phytoplankton that form the base of the food chain. Nutrients and energy flow through primary consumers such as zooplankton, planktivorous fish and invertebrates, and eventually larger fish, marine mammals and birds. Nutrients are returned to the base of the food chain by detritivores that consume dead flora and fauna.

In the Northwest Atlantic, regime shifts have occurred over the past several decades where declines in groundfish species were linked to cold water temperatures combined with overharvesting in the late 1980s into the mid-1990s (deYoung et al 2004; Koen-Alonso et al 2010; Dawe et al 2012; Nogueira et al 2017). The groundfish stock collapse was followed by a dramatic increase in groundfish prey species abundances including sand lance, herring, shrimp and snow crab. In more recent years, rising water temperatures and restrictions on harvesting are favoring the return of a groundfish dominated system (Koen-Alonso et al 2010; Templeman 2010; Dawe et al 2012; Nogueira et al 2017). Multi-decadal warming trends are also driving greater primary production in the upper layers of the water column and shifting species distributions toward the poles in response to warmer waters (Martinez et al 2016; Sundby et al 2016).

Distributions of species naturally fluctuate over shorter timescales as many species migrate on daily or seasonal cycles. Entire communities may also shift their distributions in response to changing availability or distributions of prey species. For example, on an annual cycle, the Study Area is visited by large pelagics (sharks, tunas, etc.) during the warm water season, while other occupants (e.g. capelin and cod) may leave the area as they migrate inshore to spawn and/or feed (Davoren and Halden 2014). Other species (such as redfish, Greenland halibut and snow crab) are more resident in nature and prefer to remain in more stable thermal habitats on the continental slope.

Marine assemblages represent groups of organisms that through ecological preferences are adapted to coexist within a particular environment in an ecosystem (Murillo et al 2016; Nogueira et al 2017). Assemblages are often associated with specific habitats that are a product of environmental parameters including depth, temperature, pressure, light levels, oceanographic currents, productivity, and substrate type (Gomes et al 1992; Mahon et al 1998; Murillo et al 2016; Noguiera et al 2017). In the vicinity of the Study Area, three general functional units are recognized that have characteristic environmental parameters: 1) The Grand Banks/Newfoundland Shelf, 2) the Flemish Cap, and 3) the oceanic waters beyond the shelf break (Amec 2014). The continental slopes act as transition zones between these functional units and represent important fish habitat in the region (Pepin et al 2010).

The Flemish Cap is a largely distinct marine ecosystem separated from the Grand Bank shelf by the Flemish Pass. A quasi-permanent, anticyclonic gyre dominates the oceanography of the area, leading to local retention of eggs and larvae (Pérez-Rodríguez et al 2012, 2016). The highly oxygenated waters on the Flemish Cap that are strongly influenced by the Labrador Current, are also nutrient rich (Barrio Frojàn et al 2012; Altuna et al 2013). These factors are thought to contribute to the elevated biodiversity found in these areas relative to the Newfoundland Shelf habitats (Altuna et al 2013). The Flemish Cap is highly regulated by fishing activity, as evidenced by population changes to cod size and age at maturity resulting from fisheries removal of immature and early mature individuals (Pérez-Rodríguez et al 2013). The Newfoundland Shelf is relatively shallow, with areas generally less than 100 m deep. The strong influence of the Labrador Current limits the distribution of many “southern” species that occur nearby on the Tail of the Grand Banks. The Grand Banks are considered highly productive due to upwelling of nutrients in the shallow waters resulting from the mixing of the Labrador Current, shelf waters, and the Gulf Stream (Bundy et al 2000; Templeman 2010; Murillo et al 2016). In comparison to the Flemish Cap, the Newfoundland Shelf is more heavily influenced by the state of lower trophic levels and ice dynamics (Buren et al 2014). Assemblages in oceanic waters beyond the shelf and on continental slopes are strongly influenced by depth and associated environmental parameters (Murua and de Cardenas 2005; Barrio Frojàn et al 2012; Nogueira et al 2017). Depth gradients and influence of oceanic currents act as barriers to dispersal for many shelf species into these areas (Murillo et al 2016). Habitat complexity is generally reduced at higher depths (Carter et al 1979) and assemblages may be associated with habitat forming sponges, and corals (Beazley et al 2013a; Kenchington et al 2013; Baillon et al 2014a). The following sections provide more detailed coverage of specific ecosystem elements in the Study Area.

4.2.1.3 Plankton

The plankton community is comprised of small free-floating microscopic marine plants (phytoplankton), invertebrates (zooplankton), vertebrate and invertebrate eggs and larvae, bacteria, fungi and viruses (Legendre and Rassoulzadegan 1995; Suttle 2005). Plankton comprise the most diverse and abundant group in the ocean and form the foundation of marine food webs through primary (phytoplankton) and secondary (zooplankton) production. Many commercially important finfish and invertebrate species occur as plankton early in their life cycle. Their early life cycles may also depend on other plankton for food. Consequently, areas and times of high plankton abundance and concentrations typically correspond with aggregations of animals higher in the food chain and spawning events (Beazley et al 2013a). Plankton also have roles in nutrient (nitrogen) and carbon cycling between the atmosphere and marine environment (biological pump) and within the marine environment (benthic-pelagic coupling) (Amec 2014).

Phytoplankton

Phytoplankton are comprised of microscopic marine plants that depend on both sunlight and nutrients for growth. The combination of these two limiting factors influence phytoplankton abundance. Sunlight decreases in availability with depth. Nutrients can quickly become depleted by plankton in surface waters if not replenished. Therefore highest densities of phytoplankton typically occur in surface waters of frontal zones and areas of upwelling, where nutrients are constantly delivered from deeper water. In western North Atlantic waters, there is a spring phytoplankton bloom where plankton abundance increases in response to strengthening sunlight and interacts with well mixed nutrient rich waters (Maillet et al 2004). A second weaker bloom occurs in the fall associated with nutrient upwelling resulting from a breakdown in the thermocline (Afanasyev et al 2001).

Annual seasonal patterns of phytoplankton dynamics are demonstrated by satellite imagery of surface irradiance from *chlorophyll a* (*chl a*), a photosynthetic pigment in phytoplankton that allows for tracking of phytoplankton abundance and distribution (Figure 4.19). Winter *chl a* concentrations were generally low with higher concentrations towards the southern end of the Study Area corresponding with an earlier spring bloom associated with the northern extension of the Gulf Stream. During Spring in the Study Area, relatively high concentrations of *chl a* are observed on the northeast slopes and southeastern shelf of the Grand Banks, on the Flemish Pass and slopes of the northeastern slopes of the Flemish Cap. Over summer, the blooms dissipate as nutrients are used up in the water column and the second weaker bloom in the Fall is observed on the slopes of the Grand Banks and Flemish Cap.

Phytoplankton abundance may also vary geographically associated with bottom topography and ocean currents that affect nutrient levels. For example, high plankton densities are associated where the Labrador Current and the Gulf Stream meet at the Southeast Shoal and Tail of the Grand Bank (Templeman 2007). Similarly, an anticyclonic gyre near the Flemish Cap contributes to elevated temperatures and relatively higher inorganic nutrients which positively affect both primary and secondary producers (Maillet et al 2004). Plankton levels are also relatively high at shelf break areas where the thermal gradients and enhanced vertical mixing supports upwelling of nutrients (Amec 2014).

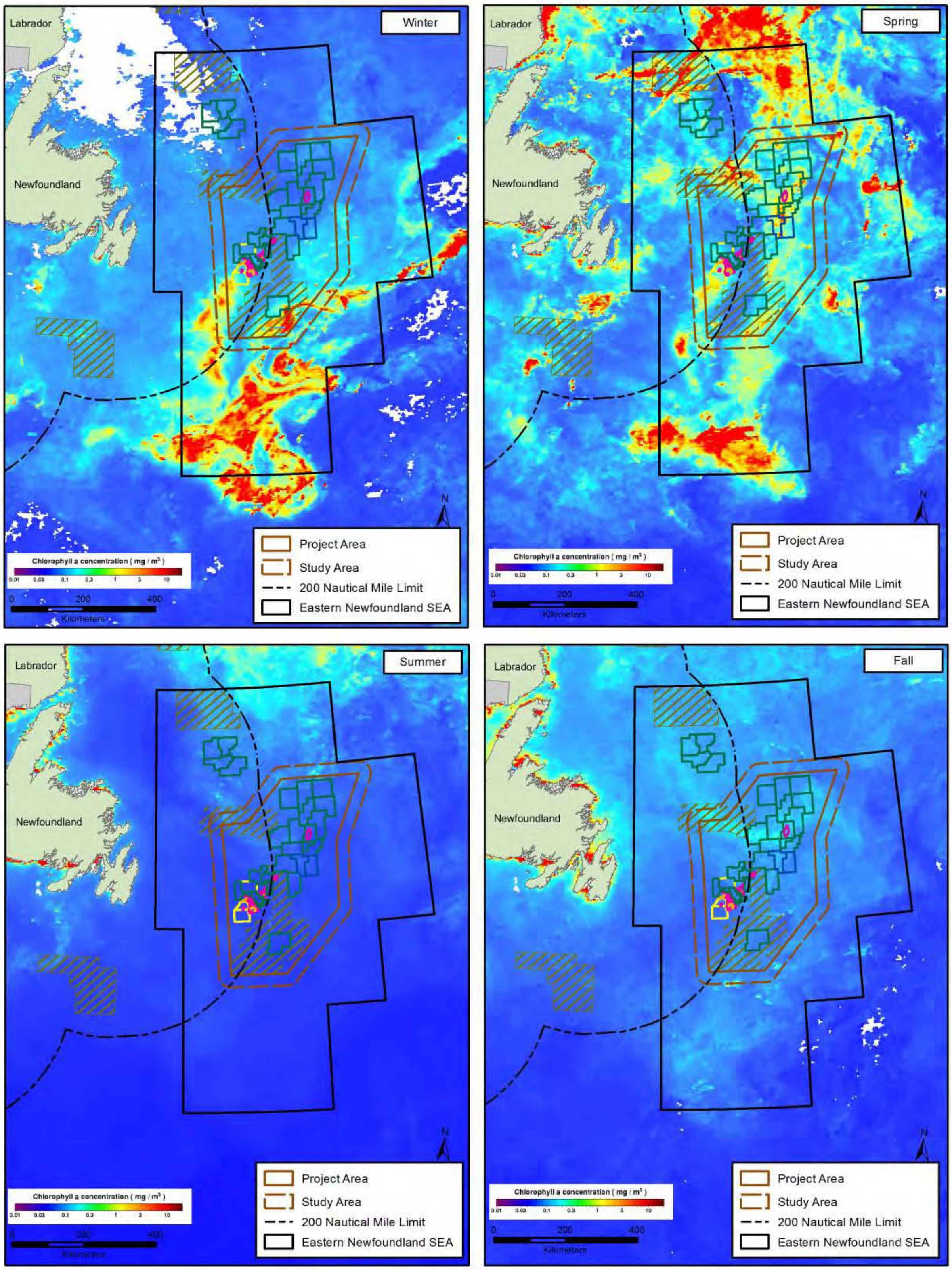
Plankton communities can also vary across longer time scales. In the Study Area and surroundings regions, plankton abundance has been decreasing since a peak in the 1990s (Maillet et al 2004; Head and Sameoto 2007). The observed changes correspond to variations in the Northern Atlantic Oscillation (NAO), a measure of the intensification of northwestern atmospheric flows that in turn cause increased mixing and sea ice extent and colder, fresher ocean conditions. Thus when the NAO intensifies, nutrient levels increase and benefit primary productivity (Maillet et al 2004).

Zooplankton

In the marine food chain, zooplankton provides a key energy pathway between primary producers and the species that occupy higher trophic levels (fish, whales and seabirds) (Maillet et al 2004). The temporal and spatial variation in zooplankton abundance mirrors that of phytoplankton, in that peaks occur in spring and decline afterward as the phytoplankton food base is depleted and the zooplankton community is exposed to continual predation by other zooplankton, fish and marine mammals. The timing and availability of phytoplankton and resulting zooplankton levels have implications for survival of fish and invertebrate larvae and have been associated with condition of stocks in Atlantic cod (Minto et al 2013), capelin (Mullowney et al 2016) and Atlantic mackerel (Plourde et al 2015).

Within the zooplankton community, copepods make over 80 percent of the zooplankton species richness in the Northwest Atlantic (Dalley et al 2001; Pepin et al 2011, 2015). Reproduction of many copepod species are coupled with the spring bloom dynamics such that early larval stages can feed during the optimal phytoplankton growth season. Therefore inter-annual differences in timing and abundance of phytoplankton from changes in physical and biological processes has implications for timing and abundance of copepods. Other important zooplankton taxa include bivalves, cladocerans, barnacles and gastropods (Dalley et al 2001; Plourde and McQuinn 2010; Pepin et al 2011, 2015).

Figure 4.19 Distribution of Chlorophyll Irradiance Measured from NASA Satellite Imagery of the North Atlantic, Winter to Fall 2016.



Zooplankton community structure and abundance may vary across temporal and spatial scales with biomass occurring along a latitudinal gradient on the Newfoundland Shelf. Elevated zooplankton levels are found in northern areas of the Newfoundland Shelf with decreasing biomass towards the tail of the Grand Bank, although there are taxa-specific distributions and trends (Dalley and Anderson 1998; Dalley et al 2001). Water depth and associated environmental parameters has been observed to be a main determinant in zooplankton community structure followed by temperature with distinctions between shelf, slope and deeper waters (Pepin et al 2015). Many zooplankton species undergo daily vertical migrations to mitigate predation risk and for foraging opportunities (Dalley and Anderson 1998). The vertical distribution of zooplankton is also influenced by species specific adaptations of vertical migrations, predator-prey interactions, and ecological niche overlap that support variations in abundance with depth (Pepin et al 2015). Important zooplankton taxa from the Newfoundland Shelf and Grand Bank are summarized in Table 4.3.

Table 4.3 Commonly Observed Zooplankton during the Spring, Summer and Fall on the Newfoundland and Labrador Shelf (2000-2007)

		Spring		Summer		Fall	
Group	**Taxa**	**Occurrence**	**Abund. (ind/m^2)**	**Occurrence**	**Abund. (ind/m^2)**	**Occurrence**	**Abund. (ind/m^2)**
Balanus	-	0.359	12,455	0.168	4,454	0.119	2,875
Bivalvia	-	0.160	3,059	0.056	3,980	0.466	6,392
Cladocera	*Evadne* sp.	-	-	0.043	21,913	0.053	3,954
Copepoda	*Oithona* sp.	0.507	28,756	0.461	64,521	0.603	76,415
	Oithona similis	0.991	41,928	0.993	60,951	0.994	66,055
	Pseudocalanaus sp.	0.878	18,911	0.783	30,534	0.831	25,507
	Calanus finmarchicus	0.985	10,708	1.000	37,212	0.972	23,973
	Temora longicornis	0.368	7,419	0.164	8,112	0.559	29,954
	Centropages sp.	0.092	2,870	0.128	6,522	0.391	16,573
	Microcalanus sp.	0.825	8,570	0.829	6,976	0.703	7,323
	Paracalanus parvus	0.039	8,220	0.030	3,610	0.272	7,026
	Calanus gracialis	0.849	5,047	0.730	6,019	0.325	1,905
	Metridia sp.	0.537	2,215	-	-	0.813	10,131
	Clausocalanus sp.	0.018	5,023	-	-	0.056	2,037
Gastropoda	-	0.837	4,789	0.819	6,525	0.869	6,838

Adapted from Pepin et al (2011).
Occurrence represents the proportion of stations at which the taxa occurred during individual surveys.

Ichthyoplankton

Many marine fish species broadcast spawn, releasing eggs into the water column to be fertilized and passively disperse as they develop. Fish egg and larval abundance may vary annually, temporally and spatially (Frank et al 1992; Dalley and Anderson 1998; Bradbury et al 2008; Ottersen et al 2013) by orders of magnitude (Dalley and Anderson 1998; Bradbury et al 1999; Houde 2008). Mortality of larval stages can be high and therefore the survival of this life stage can define future age-class recruitment success (Cushing 1990; Houde 2008).

Spatially restricted oceanographic features such as thermoclines (Frank et al 1992), upwelling zones (Ings et al 2008) and gyres (Bradbury et al 2008) may retain ichthyoplankton. Therefore, changes in spawning location may highly influence the drift trajectory of larvae (Bradbury et al 1999; 2008). Furthermore, the retentiveness of certain oceanic features can differ across seasons. Ichthyoplankton dispersal dynamics vary spatially across the Study Area. The coastal areas off the northeast coast of Newfoundland are often receiving areas for drifting larvae originating from offshore areas (Ings et al 2008), whereas the gyre associated with the Flemish Cap leaves the potential that the area retains locally produced ichthyoplankton and receives ichthyoplankton on the currents that create the gyre (Dalley and Anderson 1998).

Dalley and Anderson (1998) described ichthyoplankton communities along both the Northeast Newfoundland Shelf and the Grand Bank as dominated by capelin, sand lance, lanternfish and Arctic cod. Other fish larvae that were regularly captured in tows included commercial species such as Atlantic cod, redfish and American plaice (Dalley and Anderson 1998; Dalley et al 2000). Wolffish, which are species at risk, were also captured, but with relatively low abundance. Squid larvae were also documented as being widespread across both locations. Most species (including blennies, sculpins, squid, snailfish, alligatorfish and wolffish) were more abundant on the Newfoundland Shelf than on the Grand Bank while others (such as sand lance and hake) were found predominantly over the Grand Bank (Dalley and Anderson 1998).

4.2.1.4 Plants and Macroalgae

Macroalgae and sea grasses serve as important features for coastal marine habitats where they enhance productivity and provide refuge to marine organisms (Amec 2014). Macroalgae are estimated to be limited to waters less than 50 m in depth due to their reliance on sunlight for photosynthesis (Anderson et al 2002) indicating that the vast majority of the Study Area is too deep to support macroalgae colonization and growth. However, there are localized areas of macroflora reported for the Virgin Rocks on the Grand Banks that hosts a variety of macroalgae resembling assemblages found off Labrador (Amec 2014), including kelps, understory seaweeds, coralline algae and other coldwater species.

4.2.1.5 Benthic Invertebrates

Benthic invertebrates represent a broad group of animals that associate with the seafloor and have key roles in ocean ecosystems. Marine invertebrates, particularly snow crab and shrimp, represent the biggest contributors to commercial landings (Dawe et al 2012), but also play an important trophic role as detrivores, filter feeders and carnivores and facilitate energy transfer through the ecosystem (Amec 2014).

The distribution of benthic invertebrates is highly dependent on environmental parameters as many are sessile in nature or have limited mobility and they will settle in areas that support their growth, feeding and reproduction activities (Murillo et al 2016). Water depth is considered a main predictor of invertebrate community assemblages and distributions due to its association with a host of environmental parameters (substrate, temperature, currents) (Knudby et al 2013; Beazley and Kenchington 2015; Guijarro et al 2016; Murillo et al 2016). There are thus no “typical” species for the Study Area per se, but rather the region contains a suite of species assemblages associated with depth zones and other factors (Table 4.4).

Table 4.4 Overview of Marine Invertebrates Characteristic to Each Area by Depth Zones

Family	Species	NS	FC	FP	OB
Echinodermata – Seastars, Brittlestars, Sand dollars, Sea Urchins and Feather stars	Echinodermata			M,D	
	Brittlestar (Ophiuroidea)				S,M,D
	Brittlestar (*Ophiacantha anomala*)		M,D		
	Brittlestar (*Ophiura sarsi*)	S			
	Sand dollar or sea urchin (Echinoid)				S,M,D
	Sand dollar (*Echinarachnius parma*)	S		D	
	Pale sea urchin (*Strongylocentrotus pallidus*)	S			
	Sea urchin (*Phormosoma placenta*)		M,D		
	Sea cucumber (*Psolus* sp.)		M,D		
	Seastar (*Bathybiaster vexillifer*)		M,D		
	Seastar (*Brisaster fragilis*)		M		
	Seastar (*Ceramaster granularis*)		S,M		
	Seastar (*Ctenodiscus crispatus*)		M		
	Seastar (*Zoroaster fulgens*)		M,D		
Mollusca – Gastropods and Bivalves	Mollusca			M,D	
	Bivalvia				S,M,D
	Boreal astarte (*Astare borealis*)	S			
	Chalky macoma (*Macoma calcarea*)	S			
	Icelandic scallop (*Chlamys islandica*)	S			
	Propeller clam (*Cyrtodaria siliqua*)	S			
	Gastropoda				M,D
	Whelk (Buccinidae)	S			
	Tusk shell (*Dentalium* sp.)				M,D
Arthropoda - Crustaceans	Arthropoda			M,D	
	Amphipod (*Priscillina armata*)	S			
	Crab (Majidae)	S			
	Snow crab (*Chionoecetes opilio*)	S,M			
	Northern shrimp (*Pandalus borealis*)	S,M	S,M	S,M	
	Pink striped shrimp (*Pandalus montagui*)	S,M			
	Sars shrimp (*Sabinea sarsii*)		S		
Cnidaria – Sea anemones and Corals	Cnidaria			M,D	
	Soft coral (*Gersemia* sp.)	S			
	Soft coral (*Heteropylpus* sol)		M		
	Black coral (*Stauropathes artica*)		M		
	Cup coral (*Flabellum alabastrum*)		M		
	Gorgonian coral (*Acanella arbuscula*)		M		
	Sea pen (*Anthoptilum grandiflorum*)		M,D		
	Sea pen (*Funiculina quadrangularis*)		M,D		
	Sea pen (*Halipteris finmarchica*)		M,D		
	Sea pen (*Pennatula aculeata*)		M,D		
	Sea anemone (Actinaria)				M,D
	Subarctic sea anemone (*Hormathia digitata*)		S,M		

Family	Species	NS	FC	FP	OB
Polychaeta - Worms	Polychaeta			M,D	S,M,D
	Polychaete (Sabellidae)	S			
	Polychaete (*Prionospio steenstrupi*)	S			
	Polychaete (*Chaetozone setosa*)	S			
	Polychaete (*Spio filicornis*)	S			
	Polychaete (*Nothria conchylega*)	S			
Porifera - Sponges	Sponge (Porifera)		M,D	M,D	M,D
	Demosponge (*Hexadella dedritifera*)		M,D		
	Demosponge (*Iphon piceum*)		S		
	Sponge (*Craniella cranium*)		M,D		
	Sponge (*Geodia barretti*)		M,D		
	Sponge (*Geodia parva-phlegraei*)		M,D		
	Sponge (*Stelletta normani*)		M,D		
	Sponge (*Stryphnus fortis*)		M,D		
Formanifera – Protists	Foraminiferid		D		
Brachiopoda - Lampshells	Brachiopods			M,D	S,M,D
Bryozoa - Bryozoans	Bryozoan				S,M

Regions: Newfoundland Shelf (NS), Flemish Cap (FC), Flemish Pass (FP), Orphan Basin (OB)
Depths: shallow (S) <250 m, middle depths (M) 250-1,000 m, deep (D) >1,000
Adapted from: Carter et al (1979); Houston and Haedrich (1984); Schneider et al (1987); Prena et al (1999); Kenchington et al (2001); Barrio Froján et al (2012); Beazley et al (2013a, 2013b); Vásquez et al 2013; Murillo et al (2016).

Shallow areas of the Study Area include the Grand Banks and Flemish Cap at depths of less than 200 m, for which there is existing and available information on benthic communities from research initiatives and offshore oil and gas environmental baseline and environmental effects studies. Substrate on the shelf area has been found to be dominated by sand with areas of gravel and silt and the Flemish Cap is predominantly covered in gravel, sand, and silt (Murillo et al 2016). Echinoderms, crustaceans, bivalves, polychaetes and sipunculans were commonly observed in benthic grab (Kenchington et al 2001; Houston and Haedrich 1984), photograph (Schneider et al 1987), and trawl surveys (Prena et al 1999) in this area. In Canadian RV trawl surveys that mainly focus on commercial species, Northern shrimp represented over 60 percent abundance of species captured at less than 250 m depths and were distributed mainly over the northeast area of the Grand Banks. At this depth, there were also relatively high captures of striped pink shrimp and snow crab. On the Flemish Cap, the sponge *Lophon piceum* and shrimp *Sabinea sarsii* were characteristic species that were widely distributed at shallow depths to 500 m (Murillo et al 2016).

Middle depths (250-1,000 m) within the Study Area include the slopes of the shelf and the Flemish Cap and areas of the Flemish Pass and Orphan Basin. On the Grand Bank, Northern shrimp remain prominent in Canadian RV trawl catches (70 percent of total abundance) at this depth with dramatically reduced catches below 600 m. Many slope areas are characterized by increased presence of echinoderms (sea urchins, seastars and brittlestars), corals and sponges. On the eastern slope of the Grand Bank between 650-700 m, the assemblage is characterized by the presence of sponges *Tentorium semisuberites* and *Polymastia uberima*. Middle slope assemblages on the Flemish Cap between 300-900 m are dominated by seastars (*Brisaster fragilis* and *Ctenodiscus crispatus*) and a variety of corals including a cup coral (*Flabellum alabastrum*), soft coral (*Heteropylpus sol*), sea pen (*Funiculina quadrangularis*), gorgonian coral (*Acanella arbuscula*) and black coral (*Stauropathes artica*) (Murillo et al 2016). As depth increases on the Flemish Cap (700-1,400 m) the macrofauna assemblages become increasingly characterized by various species of sea pens, sponges and echinoderms (sea urchins and seastars). Between the Flemish Cap and Grand Bank is the Flemish Pass that includes middle slopes to deep areas (400-1,400 m). Photograph surveys of this area, which is dominated by mud substrates, indicate the macrofauna assemblage is dominated by sponges, echinoderms, cnidarians, arthropods, chordates, annelids and ectoprocts that comprise 90 percent of total abundance (Beazley et al 2013a). Slope areas of the Orphan Basin from 300-700 m are dominated by gravel and sandy mud substrates where polychaetes, bivalves, and echinoderms (sand dollars and brittlestars) were dominant (Carter et al 1979).

Deeper areas within the Study Area (greater than 1,000 m) include deep slopes of the Flemish Cap and the Orphan Basin. This area is mainly dominated by mud and silt substrates with heterogeneity mainly provided by habitat forming corals and sponges. The Orphan Basin, which exhibits relatively little habitat complexity in deep areas (2,000- over 3,000 m) is dominated by species that are able to thrive in silt habitats including polychaetes, molluscs, sand dollars, brittlestars and brachiopods (Carter et al 1979). Sponges are also distributed in deep areas of the Orphan Basin. Similarly, on the deep slopes around the Flemish Cap (1,000-1,700 m) the area is characterized by burrowing sea cucumbers, brittlestars and sponges (Barrio Froján et al 2012; Murillo et al 2016). Few commercial invertebrates are captured in the Canadian RV trawls at greater than 1,000 m depth, with shrimp species comprising less than one percent of the total catch.

Reproduction

Marine invertebrates use a diverse range of reproduction strategies, often in response to relevant environmental parameters. Environmental cues that trigger reproduction include changing photoperiod, temperature, lunar cycles, and biochemical prompts. Seasonal spawning and or release of larvae is generally associated with elevated food levels in the water column during spring (April to June) and fall (September to November) phytoplankton blooms (Maillet et al 2004). Large numbers of sensitive life history stages across many species would be present in the water column during these periods. However, identifying key spawning periods is confounded by variations in reproduction cycles that can occur across spatial and depth scales within species (Kelly 2000; Mercier and Hamel 2010; Baillon et al 2012). Furthermore, seasonal spawning and multi-year reproduction cycles have been reported.

Key Species Distributions

Species distributions are described below for the three main commercially important benthic/pelagic invertebrate species in the Study Area (northern shrimp, striped pink shrimp and snow crab) based on data from Canadian RV Surveys and other information sources.

Shrimp

Northern shrimp, and to a lesser degree striped pink shrimp, are important commercial species in the Study Area (Dawe et al 2012). Northern shrimp was the most abundant species captured in the Canadian RV survey catches, having benefitted from cooling water temperatures and groundfish collapses of the 1990s (Lilly et al 2000; Ramseier et al 2000). More recently, shrimp stocks are declining in the southern part of their range (Orr et al 2011). Northern shrimp recruitment is affected by the strength of phytoplankton blooms and sea surface temperatures (Ouellet et al 2011) and growth rates are influenced by latitude (Fuentes-Yaco et al 2007) and the availability of particulate organic carbon (such as detritus from decomposing phytoplankton; Ramseier et al 2000). Like many other types of zooplankton, young male Northern shrimp exhibit nocturnal feeding migrations. However, as they age, they morph into females and become more associated with the seafloor (Fuentes-Yaco et al 2007; Templeman 2010). Northern shrimp in the Study Area are concentrated primarily in the Flemish Pass and northern Grand Bank areas (Figure 4.20). High concentrations of Northern shrimp on the northeastern side of the Grand Banks are retained in the area due the anticyclonic gyre associated with the Labrador and North Atlantic Currents (Parsons et al 1998). In comparison, striped pink shrimp are more abundant closer to shore in areas west of the Study Area. Within the Study Area, moderate densities are found on the Grand Bank and the Bonavista Corridor (Figure 4.21).

Snow Crab

Like shrimp, snow crab enjoyed a population resurgence when ocean temperatures in the Study Area cooled in the early 1990s. They have formed a key sector of the commercial fishery, along with shrimp (Dawe et al 2012). Commercial harvests are comprised only of larger mature male crabs (DFO 2008; Mullowney et al 2013) as females never achieve commercial sizes (DFO 2008). The snow crab life cycle includes a number of planktonic larval stages and an ultimate transition to benthic habitats where they grow to maturity (DFO 2008). Juvenile and female crab are often segregated by depth from adult males who can be cannibalistic (Conan et al 1996). Habitat use by crabs varies according to size. Large males are typically found over mud and mud/sand while smaller crabs are more common over harder substrates (DFO 2008). Crabs have a diverse diet that includes polychaetes, brittle stars, crustaceans, shrimp, infaunal clams and fish (Squires and Dawe 2003; DFO 2008), but diet characteristics differ by sex (Squires and Dawe 2003). Snow crab, in turn, serve as prey for groundfish, seals and other snow crabs (DFO 2008).

Snow crab are known to undergo temporal fluctuations in abundance, which are thought to be related to density dependent effects (Conan et al 1996; Ste Marie et al 1996) and/or environmental conditions (Dawe et al 1997). Stocks in the northwest Atlantic have declined in recent years; a trend that is expected to continue as waters warm (Dawe et al 2012; Mullowney et al 2013). In recent years, snow crab have been abundant along the northern slopes of the Grand Bank and the Bonavista Corridor (Figure 4.22). They are much less abundant along the shallows of the southern Grand Bank and the continental slope.

Figure 4.20 Distribution of Northern Shrimp in the Study Area (Canadian RV Surveys, 2008-2012)

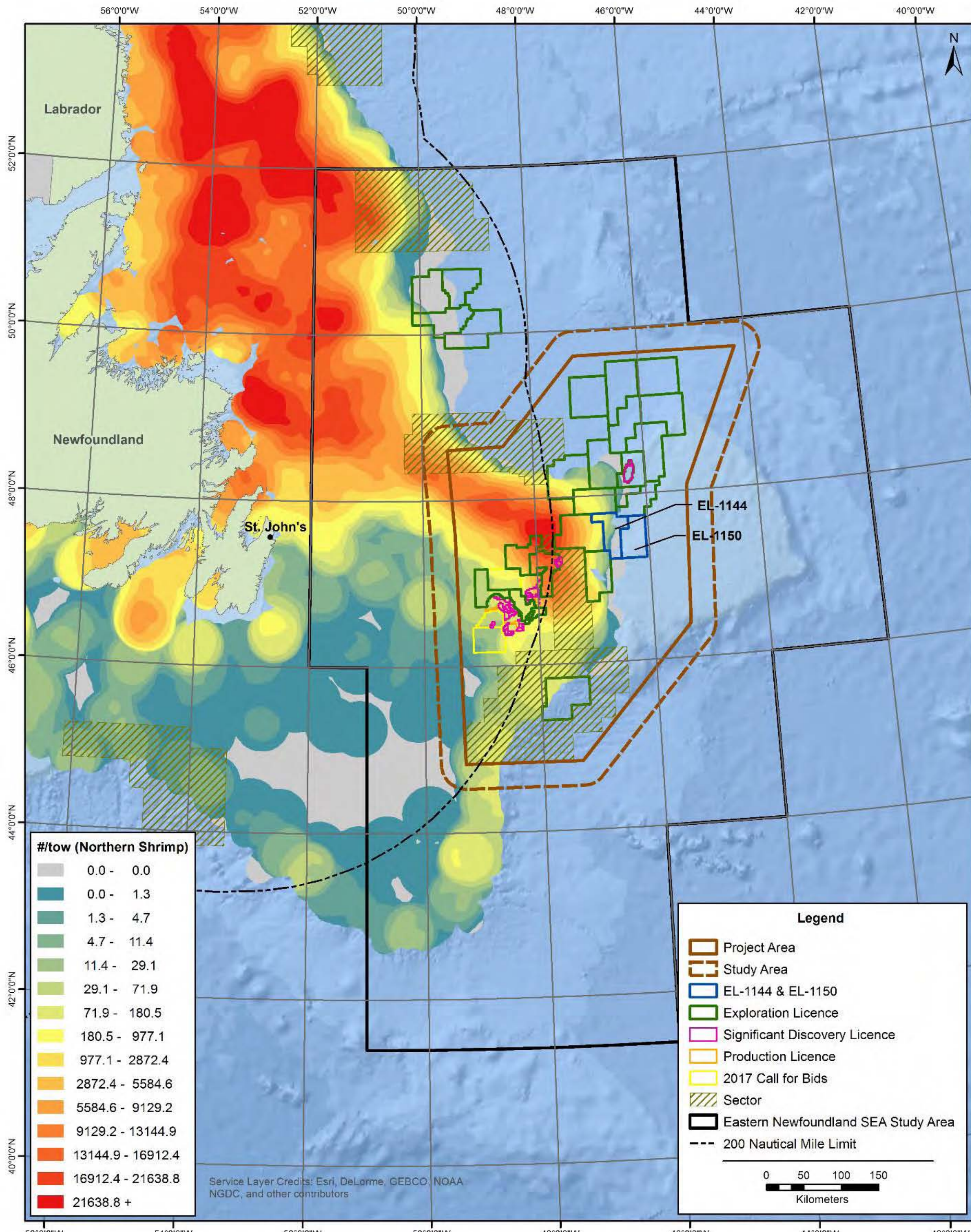


Figure 4.21 Distribution of Striped Pink Shrimp in the Study Area (Canadian RV Surveys, 2008-2012)

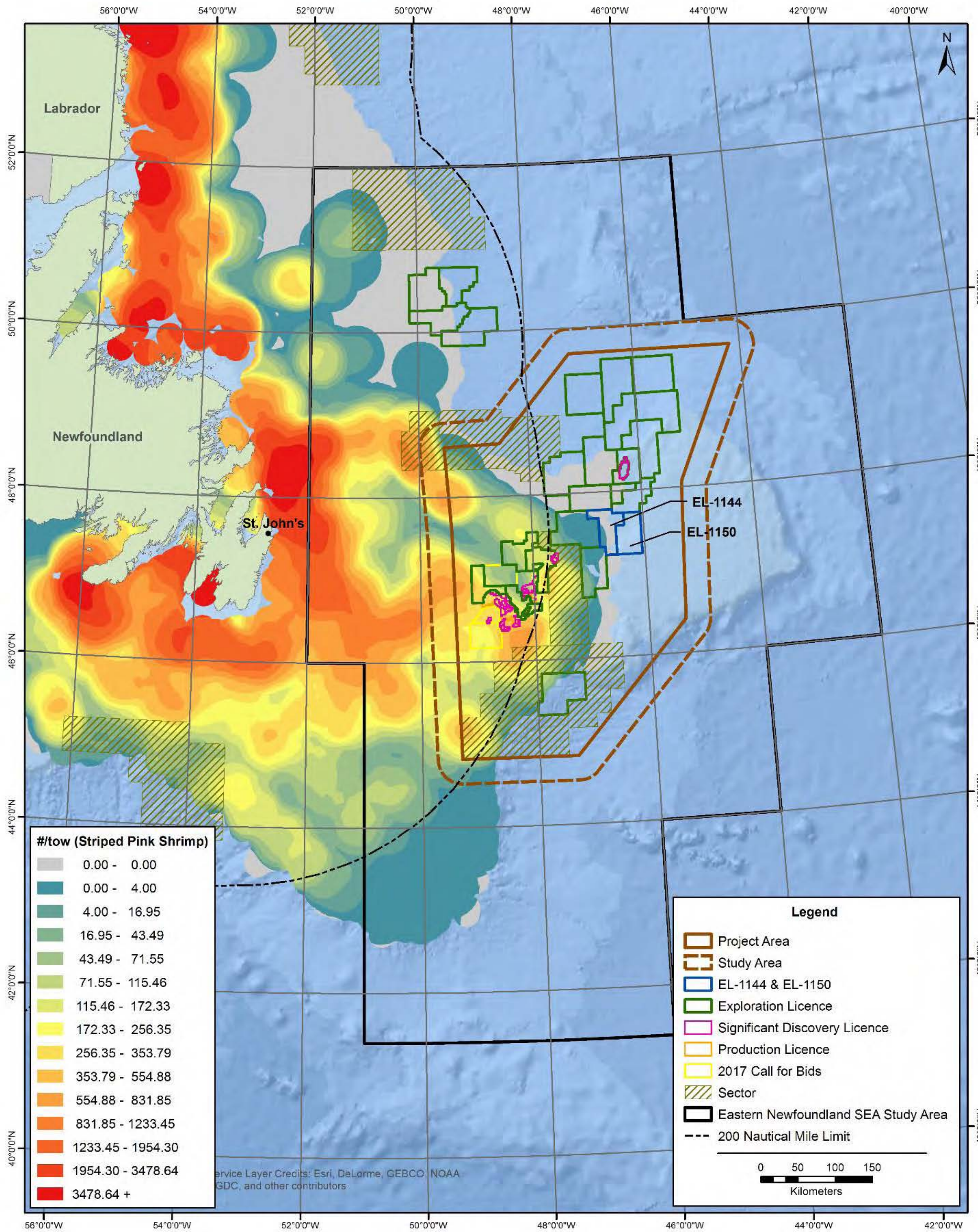
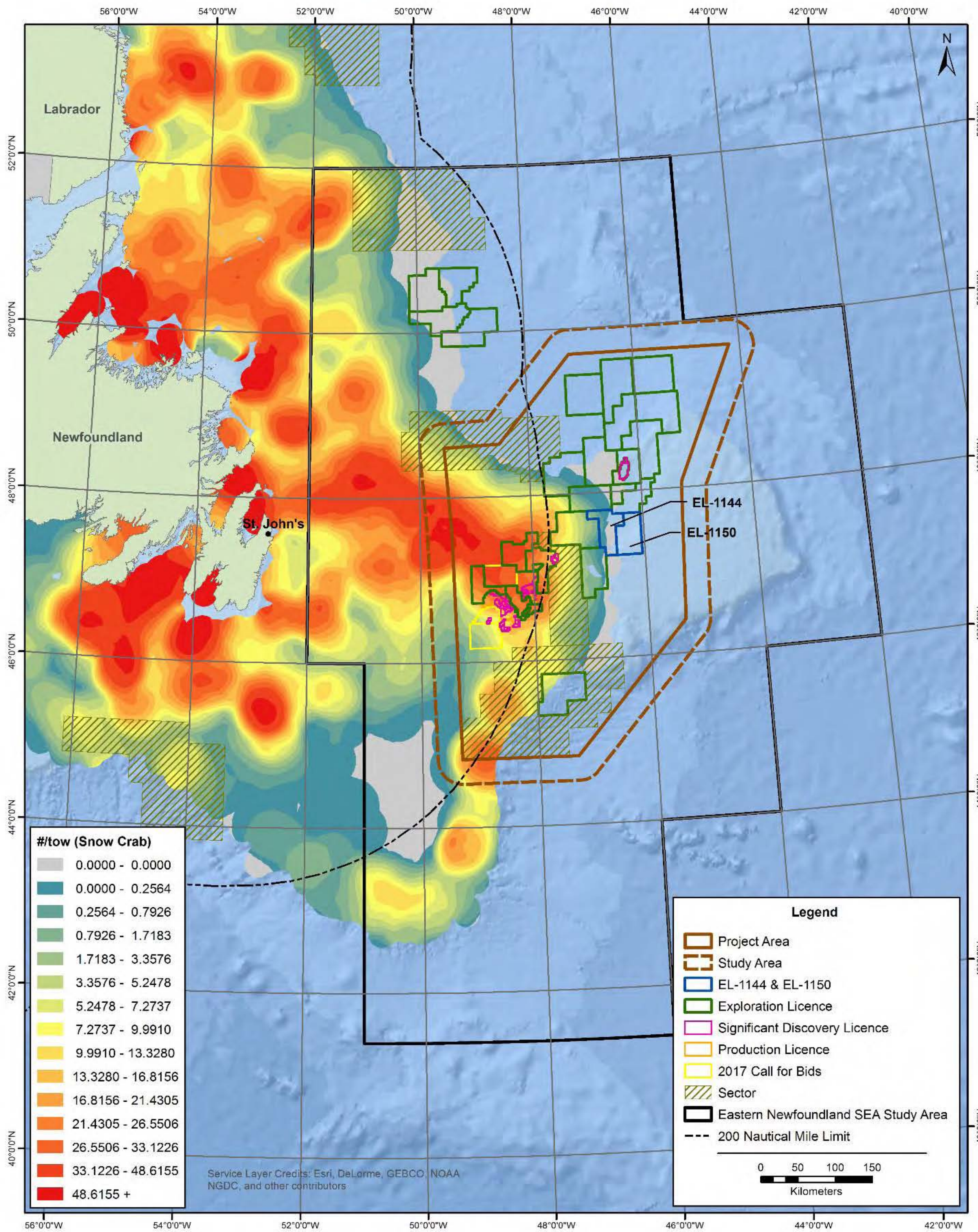


Figure 4.22 Distribution of Snow Crab in the Study Area (Canadian RV Surveys, 2008-2012)



4.2.1.6 Corals, Sea Pens and Sponges

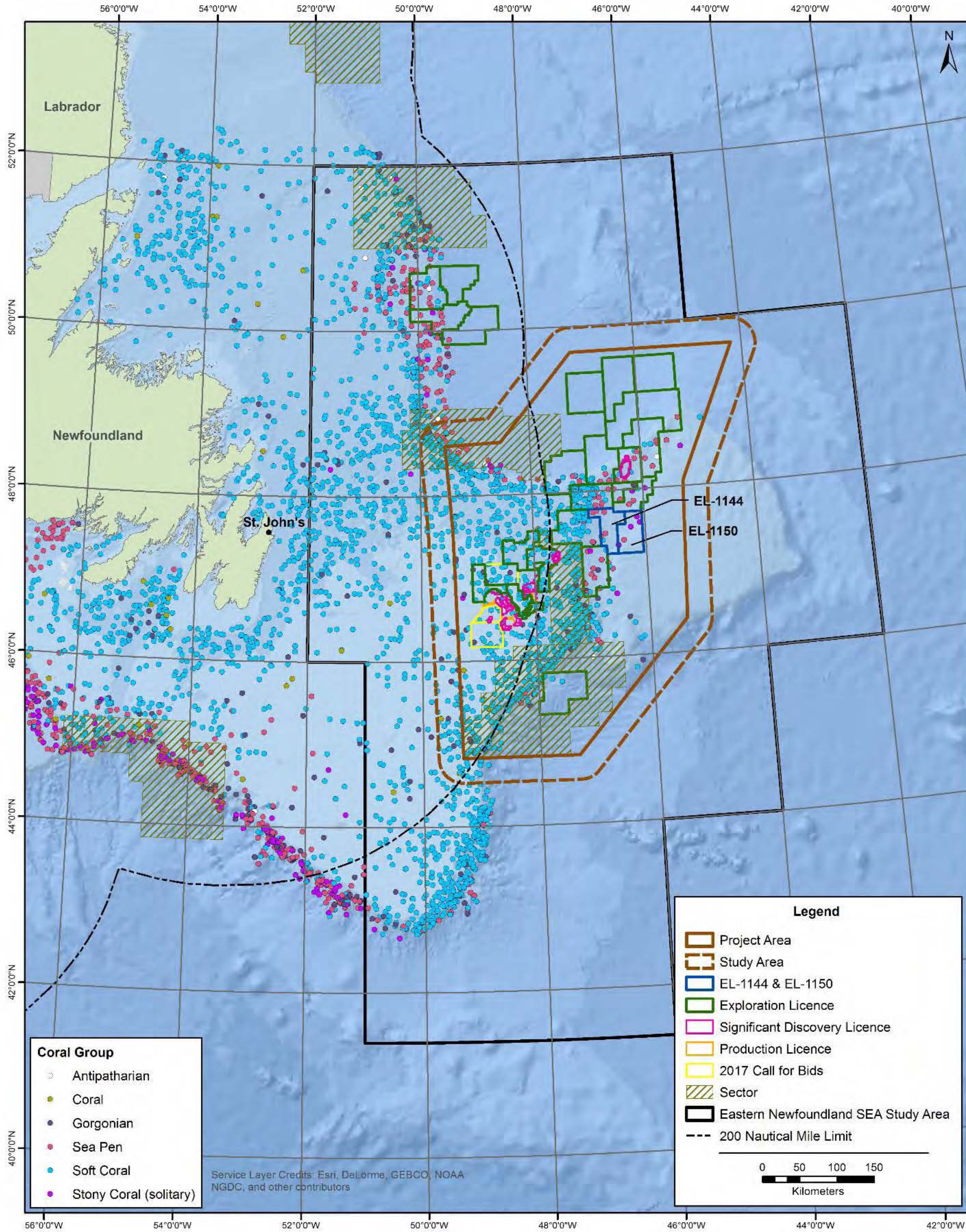
Deep-sea corals, sea pens and sponges are a subset of benthic invertebrates that are of particular conservation interest due to their habitat-forming capacity and their relative sensitivity to certain types of anthropogenic stressors (Murillo et al 2011; Beazley et al 2013a). Deep-sea corals and sponges increase biodiversity and habitat heterogeneity in the deep sea system (WGEFAM 2008; Buhl-Mortensen et al 2010; Beazley et al 2013) by creating vertical structure that is used as refuge and foraging habitat (WGEFAM 2008; Watanabe et al 2009) for a variety of species that include those of commercial importance (Gilkinson and Edinger 2009; Baillon et al 2012). The fragile nature and slow growth of these animals mean that disturbance to bottom habitats (such as trawling, infrastructure placement) can have strong and long lasting effects (Campbell and Simms 2009, Watanabe et al 2009; Barrio-Froján et al 2012). Black corals as well as large and small gorgonian corals, which have carbonate skeletons, are most sensitive to disturbance because they can be permanently dislodged from substrate (Gilkinson and Edinger 2009). This vulnerability has resulted in partial fishing closures to several known coral and sponge areas off Eastern Newfoundland (see Section 4.2.4).

There are at least 56 species of corals and sea pens distributed within and around the Study Area on the Flemish Cap, Flemish Pass and the Grand Banks based on bottom trawling and video surveys (Table 4.5) (Gilkinson and Edinger 2009; Wareham 2009; Beazley et al 2013a, Murillo et al 2012; Vàzquez et al 2013; Baillon et al 2014a, 2014b; Beazley and Kenchington 2015). Along shelf and slope areas, depth along with associated environmental parameters, is considered the greatest predictor for coral presence as determined by distribution models (Guijarro et al 2016). This supports the association of coral species to specific depth ranges, particularly on shelf slopes (Figure 4.23). Coral presence predictions based on the models were limited to areas of known coral distributions (less than 2,000 m depth).

Table 4.5 Numbers of Sponge and Coral Species Known to Occur within the Study Area

Corals (Cnidaria)				
Taxonomic Group	**Group**	**NS**	**FC**	**FP**
Antipatharia	Black-wire corals	1	3	4
Alcyonacea	Large gorgonians	4	13	5
	Small gorgonians	-	5	4
	Soft corals	2	14	7
Scleractinia	Solitary stony corals	1	2	3
Pennatulacea	Sea pens	4	17	13
Total Species		**12**	**54**	**36**
Sponges (Porifera)				
Taxonomic Group	**Group**	**NS**	**FC**	**FP**
Hexactinellida	-	1	5	1
Demospongiae	-	5	8	1
Polymastiida	-	5	8	-
Spirophorida	-	1	2	1
Astrophorida	-	6	10	1
Hadromerida	-	3	5	2
Poecilosclerida	-	11	12	-
Halichondrida	-	3	4	-
Total Species		**35**	**54**	**6**
Regions: Newfoundland Shelf (NS), Flemish Cap (FC), Flemish Pass (FP)				

Figure 4.23 Coral Presence in the Study Area and Adjacent Areas Based on Canadian RV Surveys (2000-2015)



The slopes of the Flemish Pass, the Flemish Cap and Grand Banks have the highest relative abundance of corals in the Study Area. There have been fewer coral observations in shallow shelf and top of the Flemish Cap areas. Areas between 600-900 m depth in the Study Area are dominated by warm saline waters with silty sand substrates and have the highest biomass of corals. These environmental parameters may support increased levels of primary production which is an important predictor of coral biomass (Guijarro et al 2016). Coral presence decreases with depths with few observations in very deep waters within the Study Area (1,500-4,000 m) (Gates et al 2008; Beazley et al 2013a). However, coral presence likely extends to deeper areas as species observed in the study area including gorgonian corals (*Acanella arbuscular and Acanthogorgia armata*), have been observed at depths 2,000 m globally (Buhl-Mortensen et al 2015; Murillo et al 2016).

There are at least 60 sponge species distributed within the Study Area (Table 4.5) (Murillo et al 2012; Beazley et al 2013a; Knudby et al 2013; Beazley and Kenchington 2015; Beazley et al 2015). Sponges are fragile organisms that often disintegrate before reaching the surface for identification and as such many samples are not identified to species in trawl surveys (Knudby et al 2013). Therefore, sponge diversity may be under represented in published reports (Knudby et al 2013). Sponges exhibit a wide depth range (100-1,500 m) with the highest sponge biomass in the Study Area located on the Flemish Cap, followed by the Flemish Pass and the tail of the Grand Banks (Figure 4.24) (Murillo et al 2012). There are concentrated areas of sponges on the northeastern slope of the Grand Banks within the proposed Project Area, however they are generally not well distributed on the shelf (Knudby et al 2013; Guijarro et al 2016). Food availability and depth are considered to be amongst the main predictors of sponge abundance and biomass (Knudby et al 2013; Guijarro et al 2016).

Figure 4.24 Sponge Presence in the Study Area and Adjacent Areas Based on Canadian RV Surveys (2000-2015)