# Environmental Assessment of StatoilHydro's Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016

**Prepared by**

LGL LIMITED
environmental research associates

**for**

StatoilHydro

**January 2008**
**Project No. SA947a**

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**Prepared by**

**LGL Limited**
**environmental research associates**
**388 Kenmount Road, Box 13248, Stn. A., St. John's, NL  A1B 4A5**
**Tel: 709-754-1992**
**rbuchanan@lgl.com**
**www.lgl.com**

**In Association With**

**Canning & Pitt Associates, Inc.**
**Box 21461, St. John's, NL  A1A 5G2**
**Tel: 709-738-0133**
**www.canpitt.ca**

**and**

**Oceans Limited**
**65A LeMarchant Road**
**St. John's, NL  A1C 2G9**
**Tel: 709-753-5788**

**Prepared for**

**StatoilHydro Canada Ltd.**
**Suite 600, Scotia Centre**
**235 Water Street**
**St. John's, NL   A1C 1B6**

**January 2008**
**Project No. SA947a**

**Suggested format for citation:**

LGL Limited. 2008. Environmental assessment of StatoilHydro's Jeanne d'Arc Basin area seismic and geohazard program, 2008-2016. LGL Rep. SA947a. Rep. by LGL Limited, Canning & Pitt Associates Inc., and Oceans Ltd., St. John's, NL, for StatoilHydro Canada Ltd., St. John's, NL. 174 p. + appendices.

# Table of Contents

Page

# List of Figures

Page

# List of Tables

Page

# 1.0 Introduction

This document is a screening level environmental assessment (EA) as defined by the *Canadian Environmental Assessment Act* (*CEAA*) for a multiyear seismic and geohazard program (2008-2016) proposed for the Jeanne d'Arc Basin by StatoilHydro Canada Ltd. (SHC; the Proponent). SHC proposes conducting an initial 3-D (and potential 4-D extension in cooperation with Petro-Canada) seismic survey in 2008 and subsequent surveys (3-D and potentially 2-D and/or 4-D), as well as geohazard surveys, over the remaining eight years.

The temporal scope of the Project is for nine years (2008-2016) although the present document focuses primarily on the proposed 2008 seismic program. It is currently uncertain how many and in which years SHC will undertake seismic and geohazard surveys in the Jeanne d'Arc Basin in 2008-2016 as numbers and types will depend on results of initial surveys and other factors. In addition, SHC may perform seismic programs on behalf of other operators within the Project Area. The geographic scope of the Project is the Project Area as defined in Figure 1.1. The proposed operations in 2008 may begin as early as May and will occur in and near Exploration Licenses (ELs) 1100 and 1101 and potentially in the Terra Nova field (Figure 1.1).

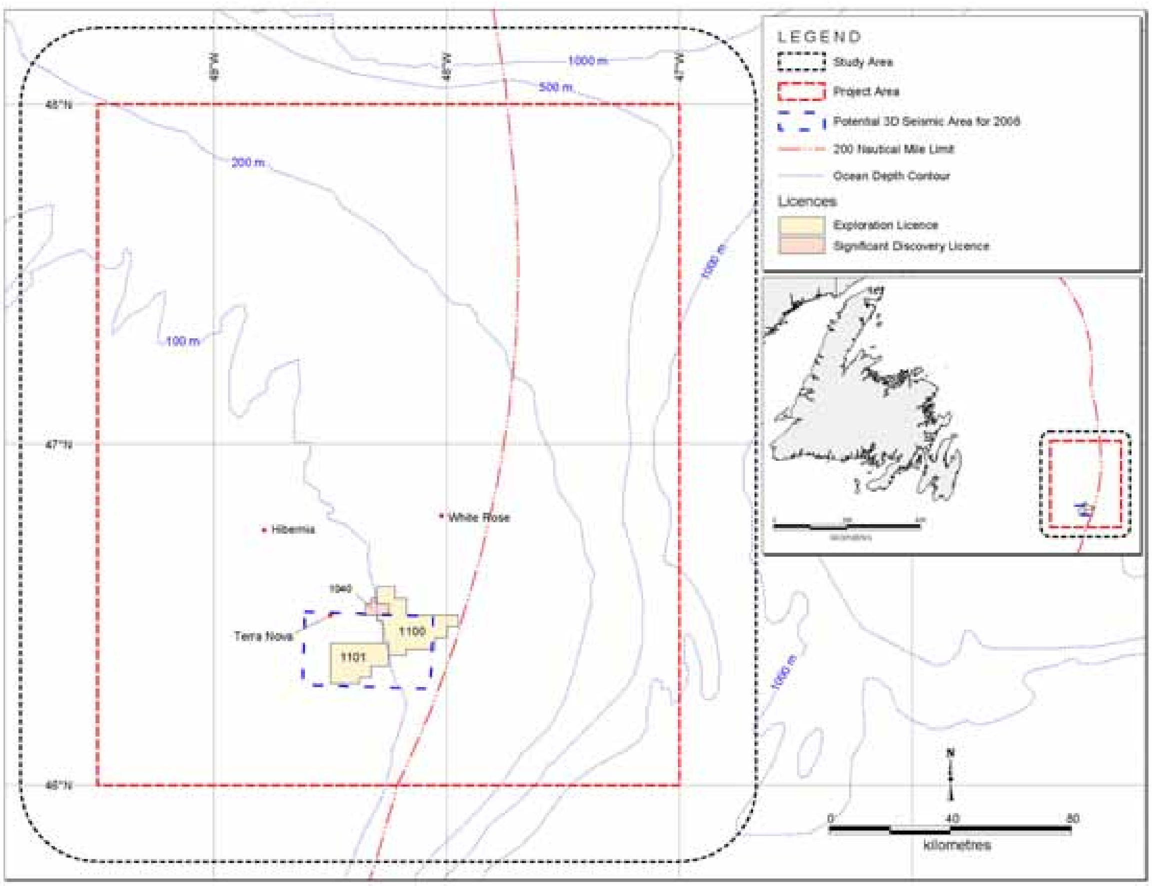



**Figure 1.1. Locations of proposed 3-D seismic program for StatoilHydro in 2008, the Project Area and corresponding Study Area for other potential seismic and geohazard surveys.**

## 1.1. Relevant Legislation and Regulatory Approvals

An *Authorization to Conduct a Geophysical Program* will be required from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). The C-NLOPB is mandated by the *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*. Offshore geophysical surveys (including geohazard surveys) on federal lands are subject to screening under the *CEAA.* In addition, the *CEAA* specifies that a marine seismic survey with an output level of 275.79 kPa at a distance of one metre from the seismic energy source (i.e., ~228.69 dB//1µPa@1m) requires an EA. The seismic survey activities described as part of the Project typically exceed the defined threshold level (if considering instantaneous levels). The C-NLOPB is the lead Responsible Authority (RA) for the EA and acts as the federal environmental assessment coordinator or FEAC. Because seismic survey activities have the potential to affect seabirds, marine mammals, sea turtles, and fish and fisheries, the Fisheries and Oceans Canada (DFO) and Environment Canada are the primarily interested agencies. Legislation that is relevant to the environmental aspects of the Project includes:

- *Canada-Newfoundland Atlantic Accord Implementation Act*
- *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act*
- *Canadian Environmental Assessment Act*
- *Oceans Act*
- *Fisheries Act*
- *Navigable Waters Act*
- *Canada Shipping Act*
- *Migratory Bird Act*
- *Species at Risk Act*

### 1.1.1. Environmental Assessment Validation Process

The issuance of a geophysical/geotechnical work authorization under the *Atlantic Accord Implementation Act* requires a screening level environmental assessment pursuant to the *CEAA.*

The seismic and geohazard survey activities described in this environmental assessment will be undertaken at various times over the coming nine years. This environmental assessment has been developed taking into account the expected period of time during which these project activities will occur.

Authorizations issued under the *Atlantic Accord Implementation Act* for the kinds of activities described in this assessment may be valid for one to five years at the discretion of the C-NLOPB. Therefore, notwithstanding the fact that this environmental assessment has been written to cover a period of nine years based on the best available knowledge at this time SHC recognizes that should any authorizations need to be renewed during that time period that there will be a regulatory requirement to ensure that the environmental assessment is still current and valid to support the renewal of any applicable authorizations. To that end SHC will during the first quarter of each year for which this environmental assessment applies submit documentation to the C-NLOPB to attest that:

- the scope and nature of activities planned and addressed under this environmental assessment have not changed;
- the nature of the species at risk in the Project and Study areas have been validated and have not changed;
- the nature and extent of the fishing activities being undertaken in the Project Area have been validated and have not changed such that project activities pose any potential effects not previously assessed; and,
- the mitigation measures defined and committed to in the environmental assessment are still valid and will continue to be implemented.

Should SHC determine that changes to the project activities or the environmental aspects noted above have taken place it will consult with the C-NLOPB to determine the need for submission of an amendment to the environmental assessment.

As part of it ongoing continuous improvement and consultation processes SHC will meet with stakeholders in the first quarter of each year in the context of preparing the above-noted submission to the C-NLOPB. This meeting will outline SHC's planned activities for the upcoming year and discuss issues of mutual interest and concern.

## 1.2. The Proponent

StatoilHydro Canada Ltd. (SHC) is a wholly-owned subsidiary of StatoilHydro ASA[1] which has been active in Canada since 1996. SHC has offices in Calgary, Alberta and St. John's, Newfoundland and Labrador (NL). SHC has interests in five exploration licenses (ELs), twenty seven significant discovery licenses (SDLs), and five production licenses (PLs) in the offshore area of NL. On the Grand Banks, SHC is a partner in the Hibernia (5% interest) and Terra Nova (15%) producing oilfields, is a partner in the proposed Hebron (10%) development, and is operator of three ELs and one SDL. SHC's East Coast activities are managed from its St. John's, NL office and operations will be supported by local logistics infrastructure and resources to the extent possible.

SHC is part of a globally active company involved in exploration and development of crude oil and natural gas and is committed to maximizing returns to stakeholders in an ethical, socially and environmentally responsible way.

[1] StatoilHydro ASA was established on 1 October 2007 following the merger between Statoil and Norsk Hydro. The head office is located in Stavanger, Norway with corporate functions in both Stavanger and Oslo. The company has 31,000 employees in 40 countries and is the world's third largest net seller of crude oil, one of the world's largest gas suppliers, and the largest operator of deepwater fields. StatoilHydro is the Operator of 39 producing oil and gas fields worldwide.

## 1.3. Canada-Newfoundland Benefits

SHC is committed to the industrial and employment benefits objectives of the *Canada-Newfoundland Atlantic Accord Implementation Act* (the Act) and C-NLOPB guidelines dated February 2006 including full and fair opportunity and first consideration. In the spirit of the Act, SHC actively seeks to enhance the participation of individuals and organizations from NL and elsewhere in Canada in offshore oil and gas activity on the East Coast. SHC encourages its suppliers and service providers to implement these principles.

SHC is committed to:

- improving the communities in which it operates, including supporting charitable, cultural, and community organizations;
- supporting research and development, education and training, and technology transfer; and
- employing qualified individuals without regard to race, religion, gender, national origin, or disability.

## 1.4. Contacts

Relevant contacts at SHC for the seismic program include:

**Executive Contact Information**
*Mr. Erik Abrahamsen*
Vice President, Operations
StatoilHydro Canada Ltd.
Suite 600, Scotia Centre
235 Water Street
St. John's, NL A1C 1B6

Phone: (709) 738-8472
Fax: (709) 726-9053
ERABR@StatoilHydro.com

**Geophysical Contact**
*Mr. Vegard Gunleiksrud*
Exploration Geophysicist
StatoilHydro Canada Ltd.
Suite 1190, Petro-Canada Centre
111 - 5th Avenue SW
Calgary, AB T2P 3Y6

Phone: (403) 268-9805
Fax: (403) 264-4309
VGUN@StatoilHydro.com

**Environmental Contact**
*Mr. Tor Martin Vikse*
Vice President, HS&E
StatoilHydro Canada Ltd.
Suite 600, Scotia Centre
235 Water Street
St. John's, NL  A1C 1B6

Phone: (709) 738-8472
Fax: (709) 726-9053
toma@statoilhydro.com

# 2.0 Project Description

SHC is proposing to conduct a 3-D seismic program with a potential 4-D extension across the Terra Nova license area in cooperation with Petro-Canada starting as early as 1 May 2008. Seismic surveys (2-D, 3-D, or 4-D[2]) may also occur sometime during the April to October, 2009-2016 timeframe, subject to the Proponent's priorities and circumstances, contractor availability and regulatory approvals. In addition, geohazard surveys will be conducted at potential drilling sites. As many as three geohazard surveys may be conducted in any one year. The geographic area where seismic (and geohazard) surveys, including the area required for turning the seismic vessel, could occur in 2008-2016 is located within the boundaries of the Project Area depicted in Figure 1.1. SHC's current seismic priority is located in and near ELs 1100 and 1101, and near the Terra Nova field (see "Potential 3D Seismic Area for 2008" in Figure 1.1). The 2008 survey plans have been developed in close cooperation with Petro-Canada. The official name of the Project is the Hydro Seismic Survey Program for the Jeanne d'Arc Basin Area, 2008-2016.

## 2.1. Spatial and Temporal Boundaries

The ***spatial boundaries*** of the Project Area encompass ELs 1100 and 1101 and the Terra Nova and White Rose fields and potentially other areas that may become available for seismic exploration and geohazard surveys (see Figure 1.1). The x,y coordinates of the Project Area in NAD 83 Zone 22 coordinates are:

NW Corner: 48° N, 49.5° W
NE Corner: 48° N, 47° W
SW Corner: 46° N, 49.5° W
SE Corner: 46° N, 47° W

At present, the defined Project Area includes space to accommodate a seismic vessel turning radius. The Study Area encompasses the Project Area and includes a 25 km buffer around that area.

The ***temporal boundaries*** of the proposed Project are year-round from 2008-2016. However, seismic surveys will occur between 1 April and 31 October. Geohazard surveys could occur at any time of the year. The duration of a seismic survey is estimated at 40 to >100 days in a given year. In 2008, the seismic survey is anticipated to require at least 57 days. A geohazard survey would typically require 4 to 5 days of data acquisition and could occur over a 9 to 11 day period including transit and weather down time.

[2] A 4-D survey means that sucessive 3-D survey data sets are interpreted to determine the changes that have taken place over time. A typical application of this technique is using a previous 3-D data set and comparing it with a recently aquired 3-D survey to try and detect changes in, and hence, the behaviour of a reservoir in the production phase. Obviously this requires precise survey location control to ensure accurate comparison of the two seismic survey data sets.

## 2.2. Project Overview

The proposed Project is a ship-based seismic program commencing with a 3-D and potentially 4-D survey in 2008 and other surveys (2-D, 3-D, or 4-D) conducted as needed in subsequent years through 2016. In addition, geohazard surveys will be conducted over potential drilling targets on current SHC exploration licenses and in future, yet-to-be-determined, locations as required during the program.

In 2008, SHC is proposing to acquire approximately 840 $km^2$ of seismic survey data within and near ELs 1100 and 1101 (3-D survey: 500 $km^2$) and across the Terra Nova license area (4-D survey: 340 $km^2$). Additional seismic surveys may be conducted within the Project Area in 2009-2016. The seismic survey ship will tow a sound source (airgun array) and streamer(s) composed of receiving hydrophones. The survey in 2008 will likely have survey lines running east-west and spaced 400 m apart. If a 4-D seismic survey is conducted across the Terra Nova license area, an additional seismic source vessel may be used to acquire data coverage directly below the FPSO. In this situation, the airgun arrays from both vessels would not be operated simultaneously. The geohazard surveys will be conducted over a much shorter time frame using a smaller vessel and a combination of smaller scale seismic equipment, sonars, and a boomer.

At the time of this EA writing, the seismic contractor for the proposed 2008 seismic program had not been selected. There is potential that at least one geohazard survey may occur in 2008. Any seismic vessel operated in 2008-2016 will be approved for operation in Canadian waters and be typical of the worldwide seismic fleet. A description of a representative seismic vessel and seismic equipment is provided below.

Proposed mitigation procedures will follow those recommended by the C-NLOPB in Appendix 2 of *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (CNOPB 2004), including ramp-up (i.e., soft start) of the airgun arrays, the use of dedicated Marine Mammal Observer(s) (MMOs) to monitor marine mammals and turtles and implement shut downs of the surveys when appropriate, and the use of a fisheries liaison officer (FLO) and communication procedures to avoid conflicts with fisheries. The need for dedicated MMOs and FLOs for the more limited temporal and geographically scoped geohazard surveys in areas of limited fishing activity will be evaluated and addressed in the following environmental assessment.

### 2.2.1. Objectives and Rationale

The objectives of the Project are to determine the presence and likely locations of geological structures that might contain hydrocarbon deposits. The 3-D data are needed to provide higher resolution and quality images than are available from 2-D surveys which use more widely spaced seismic lines and only one streamer. In general, 2-D surveys are used to determine areas where precise and detailed 3-D surveys should be done. Results of 3-D surveys are then used to find potential locations for exploration drilling. In addition, 4-D surveys may be conducted to assess the changes in a geological structure that have taken place over time. These 4-D data are particularly useful for determining the behaviour of a reservoir in the production phase.

Once a potential drilling site is located it is standard offshore industry procedure, and a requirement of the C-NLOPB, that a well site/geohazard survey be conducted. The purpose of a geohazard survey is to identify, and thus avoid, any potential shallow drilling hazards such as steep and/or unstable substrates or pockets of "shallow gas". Also, a geohazard survey will check for seabed obstructions (manmade or natural), including boulders, shallow hydrates and assess general seabed conditions.

### 2.2.2. Alternatives to the Project, Alternatives within the Project

The existing 2-D seismic data on EL 1100 and 1101 indicate structures that may contain significant volumes of producible hydrocarbons. These existing seismic data, while useful, are insufficient to determine exact structural size and internal complexity. Acquisition of new 3-D seismic data is required to determine if exploration drilling is warranted. Acquisition of 4-D seismic data near the Terra Nova FPSO will help to determine the behaviour of the reservoir in the production phase.

SHC has made commitments to pursue exploration activities on its exploration licenses in the Jeanne d'Arc Basin area. A 3-D (and 2-D) seismic survey is a standard precursor to offshore exploratory drilling. It better defines the target subsurface geological formations believed to contain hydrocarbon resources, lessens the chances of expending resources "drilling dry holes" and increases the overall safety of the drilling activity. Accordingly, there is no alternative to the proposed 3-D survey program other than to incur the financial penalties attendant on not fulfilling SHC's exploration commitments and to explore for oil and gas elsewhere.

As the geohazard surveys are a regulatory requirement of the Board and a safety requirement for drilling operations, there is no alternative to them *per se*. Another alternative would be to not drill the well and thus forgo the energy and economic benefits that would accrue to SHC and partners, the province, and Canada.

Viable alternatives within the seismic and geohazard programs are essentially the choices between different contractor's ships and survey equipment which will be evaluated though the bid evaluation process. In addition, there is potential that SHC may conduct electromagnetic surveys in the Project Area similar to those recently conducted in the Orphan Basin (Buchanan et al. 2006). If electromagnetic surveys are planned, an amendment to this EA will be prepared.

### 2.2.3. Project Scheduling

In 2008, it is anticipated that the seismic survey will be at least 57 days in duration and is expected to start on or about 1 May. Of these 57 days, it is estimated that 35 days will be required to obtain 3-D data in EL1100/1101 and 22 days to acquire 4-D data near the Terra Nova FPSO. In 2009-2016, seismic surveys may occur between 1 April and 31 October and program duration is estimated at 40 to >100 days. There is potential that at least one geohazard survey may occur in 2008. As many as three geohazards surveys per year may occur in 2009-2016, with a total survey duration of 9 to 11 days (4 to 5 days of data acquisition).

### 2.2.4. Site Plans

The area (840 $km^2$) where full-fold seismic data are proposed to be acquired in 2008 is shown in Figure 1.1 (Potential 3D Seismic Area for 2008). Water depth in the survey area ranges from approximately 82 to 117 m. Survey lines are oriented approximately east-west in 2008 and are spaced 400 m apart.

Geohazard surveys will be conducted at exploratory drill sites which will be identified in future years. For potential jack-up drill rig sites, geohazard data will be acquired along transects spaced 50 m apart. Transects will be spaced 250 m apart with tie lines at 500 m at potential semi-submersible drill rig sites. Survey grids (estimated at 5 km x 5 km) will be centered at potential drill sites.

### 2.2.5. Personnel

A seismic vessel can accommodate approximately 50-100 personnel. Personnel on seismic vessels typically include individuals from the Proponent (i.e., SHC), the vessel owner/operator (ship's officers and marine crew), and technical and scientific personnel from the main seismic contractor. The seismic vessel will have a FLO and a MMO(s) on board, as well as a SHC representative(s) that serves as Client Quality Control and Processing Quality Control. All project personnel will have all of the required certifications as specified by relevant Canadian legislation and the C-NLOPB.

Total crew on board a geohazard vessel will likely be 12 (ship's crew), and 12 (technical), and one environmental observer (EO)[3] for a total of 24 to 26 individuals.

### 2.2.6. Seismic Vessel

The seismic vessel to be used will most likely be mobilized from the Gulf of Mexico or North Sea. Vessel specifics will be provided once the contractors are selected. Most, if not all, likely survey vessels have diesel-electric propulsion systems (main and thrusters) and operate on marine diesel or marine gas-oil. A typical example of a seismic vessel is the M/V *Western Patriot* which is 78 m long and 17 m wide with a mean draft of 5.9 m. Its maximum speed is 13 knots and it transits at a speed of 11.5 knots. It has a helicopter deck rating for a Superpuma (single rotor). The *Western Patriot* operates a main engine (two Rolls Royce Bergen/BRM 6: 5300 kW) and has a bow thruster (590 kW). It operates a Simrad EA500 echosounder that operates at 18 kHz and 200 kHz as well as a Furuno FE 680/50. The ship will deploy a workboat to repair streamers when necessary. As previously mentioned, two seismic vessels may be required to obtain seismic data coverage underneath the Terra Nova FPSO.

### 2.2.7. Seismic Energy Source Parameters

The seismic energy source will be comprised of individual airguns arranged in an array. The airgun array for the *Western Patriot* is described here to provide an example of a typical seismic source used in

[3] If space availability aboard the geohazard vessel is limited, one of the ship's crew trained in marine mammal and seabird identification and data collection protocols will perform the duties of an EO.

the Study Area. [The seismic array size (number of airguns, total volume) and configuration will vary depending on the contractor.] Two 5085 $in^3$ arrays of 24 Bolt airguns per array are used by the *Western Patriot*. The largest airgun used will be 290 $in^3$ and the smallest 105 $in^3$. Each array will consist of three eight gun 1695 $in^3$ sub-arrays. The overall dimensions of the array are 15 m long by 16 m wide and the arrays will be separated by 50 m. The two 5085 $in^3$ airgun arrays will fire alternately (flip-flop arrangement) along the survey lines with a shotpoint interval of 25 m (a shotpoint interval of 18.75 m may be used in 2008). The airgun arrays are typically operated at a depth of 5 to 6 m below the water surface and are towed up to 400 m behind the seismic vessel. Survey speed is around 4.5 knots (8.3 km/h). Airguns will be operated at 2000 psi and the estimated source level[4] of the array is 109.9 bar-m (~255 dB re 1 μPa (0-p)). The airguns in the array are strategically arranged to direct most of the energy vertically rather than sideways (see Appendix C *in* LGL (2007a)) for a review of airgun sound characteristics).

## 2.2.8. Seismic Streamers

Typically 8 to 10 streamers (strings of hydrophone sound receivers), each 5 to 6 km in length, will be towed behind the seismic vessel to record the airgun pulses. Once again, the *Western Patriot* is used as a representative example for the purposes of this EA. The *Western Patriot* tows eight 5 km streamers and the streamers are Sentry and Guardian Solid Streamers (Thompson Marconi). The streamers are separated by 100 m for a total spread of 700 m and are typically deployed at a depth of 6 to 7 m. Depending on the seismic contractor, streamers may be separated by 75 m.

Potential seismic operations in 2008-2016, will likely require eight or 10 towed streamers, typically 5000 to 6000 m in length that will be towed behind the seismic vessel at depths of 6 to 8 m. The maximum width of the towed streamers would be 900 m. It is possible that in 2008-2016 streamers may be fluid-filled. These types of streamers control buoyancy with a fluid called Isopar-M. Isopar-M predominantly consists of isoparaffinic hydrocarbons (C12-C15). In a typical Isopar filled streamer, each 100 m hydrophone section contains 11.7 L of Isopar divided amongst 78 hydrophone pockets. Each hydrophone pocket contains 150 mL of Isopar and is isolated and completely sealed from other pockets. This isolation of pockets greatly reduces the chances of releasing large amounts of fluid even in the event of a major streamer accident.

## 2.2.9. Geohazard Vessel and Equipment

The survey will be conducted from a vessel similar to the MV *Anticosti* or *Maersk Placentia*. The *Anticosti* is a 54 m long offshore research vessel/tug owned by Cape Harrison Marine of St. John's. The survey vessel will typically employ the equipment equivalent to that utilized by Fugro-Jacques Geosciences (FJG) within eastern Canada over the past few years, and for recent Petro-Canada (2004), Hibernia (2005), and Husky (2005) geohazard programs. Vessels presently approved and operating on the East Coast on other offshore programs will be utilized. Vessel specifics will be provided once the

[4] Includes frequencies up to 128 Hz.

contractors are selected. Most, if not all likely survey vessels have diesel-electric propulsion systems (main and thrusters) and operate on marine diesel.

The wellsite geohazard program will acquire high resolution seismic, side-scan sonar, sub-bottom profiler and bathymetric data over the proposed area. Survey speed will be on the order of four to five knots. The geohazard equipment is anticipated to be identical to that used in recent years for site survey work offshore Newfoundland for various operators. From an operational perspective, the following text summarizes the typical acoustic sources to be used during surveying.

#### 2.2.9.1. Geohazard Seismic Data

High-resolution multi-channel seismic data will be acquired with an airgun array with a total volume of 160 $in^3$, a 96-channel streamer (6.25 m group and shot interval, 600 m active length), and a TTS 2+ digital recording system. Data will be acquired to two seconds depth, sampled at one millisecond.

The seismic source will be comprised of four airguns, each of 40 $in^3$ capacity. They will be deployed within a ladder array, approximately 30 m off the stern of the vessel, and at a depth of 3 m. The compressed air is provided by a diesel-powered compressor on deck. The maximum output from this array has a peak to peak value of 17.0 Bar metres. This equates to a source level (at 1 m) of 244.6 dB re 1µPa (peak to peak), or 238 dB re 1µPa (zero to peak).

The streamer will be towed from the port quarter of the vessel. A tail buoy will be used, equipped with a radar reflector and strobe light. Total streamer length will be approximately 650 m.

#### 2.2.9.2. Surficial Data

***Huntec Deep Tow System***.—A Huntec Deep Tow System (DTS) will be deployed from the stern of the survey vessel, through an “A” Frame. This system has been proven to be the most effective at providing high resolution sub-bottom profiles from the Grand Banks. The system is towed within the water column, at a distance of between 20 and 40 m off the seabed. The system will be approximately 150 m behind the survey vessel (dependent on cable deployed, water depth and vessel speed).

The Huntec DTS uses a “broadband” boomer acoustic source, with frequency bandwidth from 500 Hz to 6 kHz. Power output is typically 500 Joules, but may be increased to 1 kJ if necessary. Rise time of the pulse is less than 0.1 millisecond. The boomer derived pulse is primarily restricted to a 60º cone. Maximum peak to peak amplitude is 221 dB re 1 µPa at 1 m.

***Side-scan Sonar.—***Seabed imagery, for the clearance survey, will be acquired with a digital, dual frequency (105 kHz and 390 kHz) side-scan sonar system. The sonar source level for 390 kHz is 216 dB re 1 µPa at 1 m (zero to peak) and for 105 kHz is 221 dB re 1 µPa at 1 m (zero to peak). The activation rate of the side-scan sonar is 3.3 times per second at 200 m range. The beamwidth is: horizontal, 1.2º and 0.5º for the 105 kHz and 390 kHz frequencies, respectively. A 50º arc is swept perpendicular to the survey transect. Data will be logged to tape and printed in hard copy for on-board assessment. Geo-referenced data will be utilized to create a digital side scan sonar mosaic for inclusion in survey reports.

***Echo Sounders***.—A Reson 8101 multi-beam echo sounder will be operated to acquire bathymetric data. Power output levels are similar to a typical echo sounder commonly used on the Grand Banks. The system operates at a frequency of 240 kHz and the source level is 207 dB re 1 uPa at 1 m (zero to peak) and its sounding rate may be ~4 to 6 times per second. The multibeam echo sounder covers 1.5º per beam and 101 beams cover a 150º arc perpendicular to the survey transect.

A single-beam echosounder will be operated to provide quality control of the data acquired from the multi-beam echosounder. The single-beam echosounder operates at 24 kHz and 200 kHz (dual frequency capable) and the source levels are 213 dB re 1 uPa at 1 m (zero to peak) and 209 dB re 1 uPa at 1 m (zero to peak) for 24 kHz and 200 kHz frequencies, respectively. The sounding rate of this source will be typically two times per second. The single-beam echosounder derived pulse is primarily restricted to a 9º (200 Hz) and a 24º (24 kHz) conical beam.

***Magnetometer.***—In the event that potential debris is identified by the side scan or multi-beam systems, a proton magnetometer will be utilized. This system is towed behind the vessel, 5 to 10 m above the seabed, and emits a low power electromagnetic field.

***Camera and Sediment Sampler.***—A camera system and sediment sampler will be deployed at a number of locations across the site, for the purposes of groundtruthing the geophysical data. Surficial sediment samples (of approximately 0.7 L in size) will be described on board by a geologist, and stored in sample bags for subsequent processing. The camera will be lowered to an elevation of 1 m or more above the seabed as the vessel drifts across the intended sites. A deployment arm will be mounted on the side of the vessel, as far forward (on the back deck) as possible.

## 2.2.10. Logistics and Support

Offshore seismic operations will be supported by a picket and supply vessel and potentially a helicopter. No new shorebase facilities will be required for the Project.

### 2.2.10.1. Picket Vessel

The seismic ship will be accompanied by a picket vessel with responsibilities for communications with other vessels (primarily fishing vessels) that may be operating in the area and for scouting ahead looking for hazards. The geohazard vessel will not be accompanied by a picket vessel.

### 2.2.10.2. Supply Vessel

Heavy re-supply (including water, food, parts and fuel) to the seismic vessel will be conducted by offshore supply vessel throughout the duration of the program. Given the short duration of a typical geohazard survey, re-supply is not anticipated. Supply vessels will be typical of those that regularly service Hibernia, Terra Nova and White Rose. A typical supply vessel on the Grand Banks is crewed by about 6 to 12 marine qualified personnel.

#### 2.2.10.3. Helicopter

If required, helicopter support will be provided by twin-engine Sikorsky S-92 or equivalent, based in St. John's. Helicopters may be used to ferry personnel and lightweight supplies to the seismic vessels.

### 2.2.11. Waste Management

Wastes produced from the seismic, geohazard, supply and picket vessels, including grey and black water, bilge water, deck drainage, discharges from machinery spaces and hazardous and non-hazardous waste material will be managed in accordance with MARPOL and with SHC's waste management plan. The contracted vessels policies and procedures will be reviewed against the SHC Plan. SHC's waste management plan will be filed with the C-NLOPB. A licensed waste contractor will be used for any waste returned to shore.

### 2.2.12. Air Emissions

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

### 2.2.13. Accidental Events

In the unlikely event of the accidental release of hydrocarbons during the Project, SHC and its seismic and geohazard survey contractor will implement the measures outlined in its oil spill response plan which will be filed with the C-NLOPB. In addition, SHC has emergency response plans in place which will be bridged with the seismic (and geohazard) contractor's response plans prior to commencement of the seismic program.

## 2.3. Mitigation

Mitigation measures are detailed throughout the EA. The measures are reviewed and summarized in Section 5.8.

# 3.0 Physical Environment

The physical environment of the Jeanne d'Arc Basin, which includes the Study Area, was described in the Hibernia EIS (Mobil 1985), Terra Nova EIS (Petro-Canada 1996a,b), the White Rose Comprehensive Study and Supplemental Report (Husky 2000, 2001), and the Husky new drill centre construction and operations program EA and addendum (LGL 2006a, 2007c). Updates are provided below where appropriate and outlined in the Scoping document.

## 3.1. Bathymetry

Water depths in the Project Area range from <100 m on the shelf to ~1500 m (average depth is 233 m) on the continental slope in the eastern portion of the Project Area. The larger Study Area has water depths from <100 m to ~2000 m (average depth is 355 m).

## 3.2. Geology

Geology of the area has been described in the Hibernia EIS (Section 3.1.4), the Terra Nova EIS (Section 3.4), the White Rose Comprehensive Study (Section 2.6) and Supplemental Report (Section 5) and thus is not repeated here.

## 3.3. Climatology

This section provides an overview of the climatology of the Project and Study areas. A detailed report prepared for the EA is provided in Appendix A. The Grand Banks of Newfoundland experience weather conditions typical of a maritime environment with the surrounding waters having a moderating effect on temperature. In general, maritime climates experience cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Furthermore, a maritime climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and significant amounts of precipitation.

### 3.3.1. Wind Climatology

See Section 2.2 in Appendix A for more details on wind climatology. During the winter months, an upper level trough tends to lie over Central Canada and an upper ridge exists over the North Atlantic resulting in three main storm tracks affecting the Grand Banks: one from the Great Lakes Basin, one from Cape Hatteras, North Carolina and one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area.

Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season. Wind and wave climate statistics for EL 1101 and EL 1100 were extracted from the MSC50 data set produced by Oceanweather Inc. under contract to Environment

Canada. The locations of the grid points for which data are examined are shown in Figure 3.1 relative to the Project Area and proposed site for the 2008 seismic program; the conditions at these points are representative of the climate in the Project Area. Mean wind speeds at both grid points in the MSC50 data set as well as in the ICOADS data set, peak during the month of January (Table 3.1). Grid Point 10255 and 10439 had January mean wind speeds of 10.8 m/s and 10.9 m/s respectively, while the ICOADS dataset recorded the highest mean wind speed of 14.1 m/s during January. However, the winds from the ICOADS data set are not directly comparable to the MSC50 data set because the winds in the ICOADS data set were either estimated or measured by anemometers at various heights above sea level. The wind speed is dependent on height since the wind speed increases at increasing heights above sea level. Also, winds speeds from each of the data sources have different averaging-periods. The MSC50 winds are 1-hour averages while the ICOADS winds are 10-minute average winds. The adjustment factor to convert from 1-hour mean values to 10-minute mean values is usually taken as 1.06 (U.S. Geological Survey 1979).

Wind roses of the annual wind speed and histograms of the wind speed frequency from grid points 10255 and 10439 are presented in Figures 3.2 to 3.5. There is a marked increase in the occurrence of winds from the west to northwest in the winter months as opposed to the summer months.

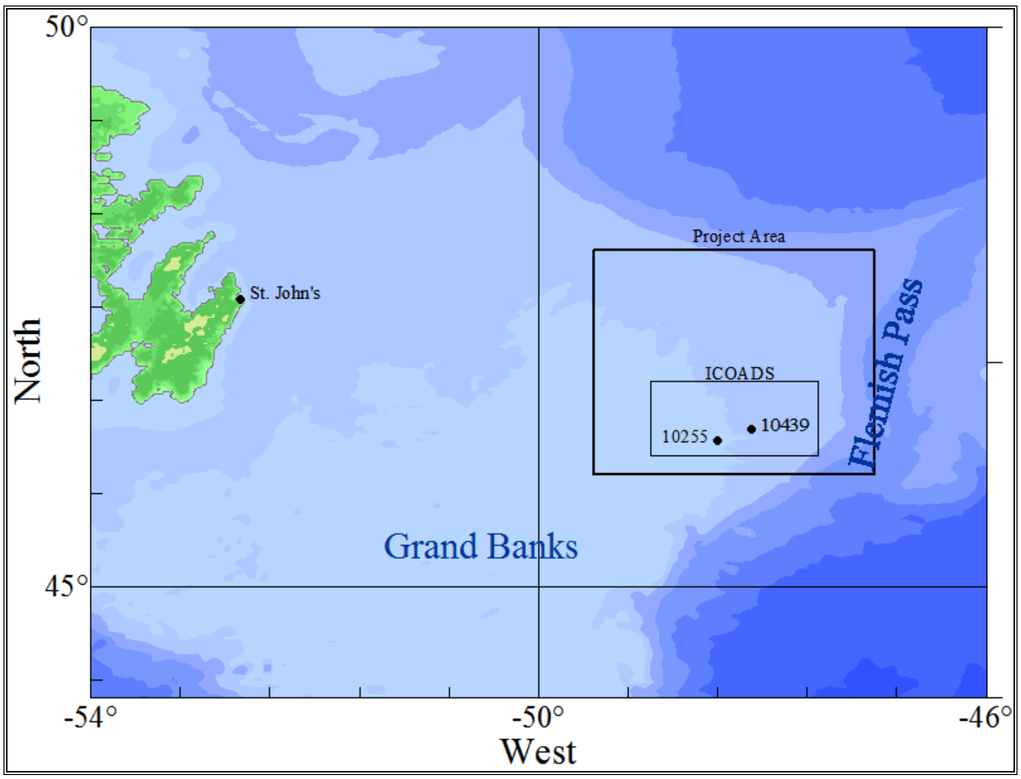



**Figure 3.1. Locations of the climate data sources (grid points) relative to the Project Area and Potential 3D Seismic Area for 2008.**

**Table 3.1. Mean wind speed (m/s) statistics for MSC50 and ICOADS data.**

| Month | MSC50 | | ICOADS |
|---|---|---|---|
| | Grid Point 10255 | Grid Point 10439 | |
| January | 10.8 | 10.9 | 14.1 |
| February | 10.8 | 10.8 | 13.6 |
| March | 9.8 | 9.8 | 12.7 |
| April | 8.3 | 8.3 | 11.8 |
| May | 6.9 | 6.9 | 10.4 |
| June | 6.5 | 6.5 | 10.3 |
| July | 6.0 | 6.0 | 10.0 |
| August | 6.3 | 6.3 | 9.1 |
| September | 7.4 | 7.4 | 10.2 |
| October | 8.7 | 8.7 | 11.8 |
| November | 9.4 | 9.5 | 12.2 |
| December | 10.5 | 10.5 | 14.0 |

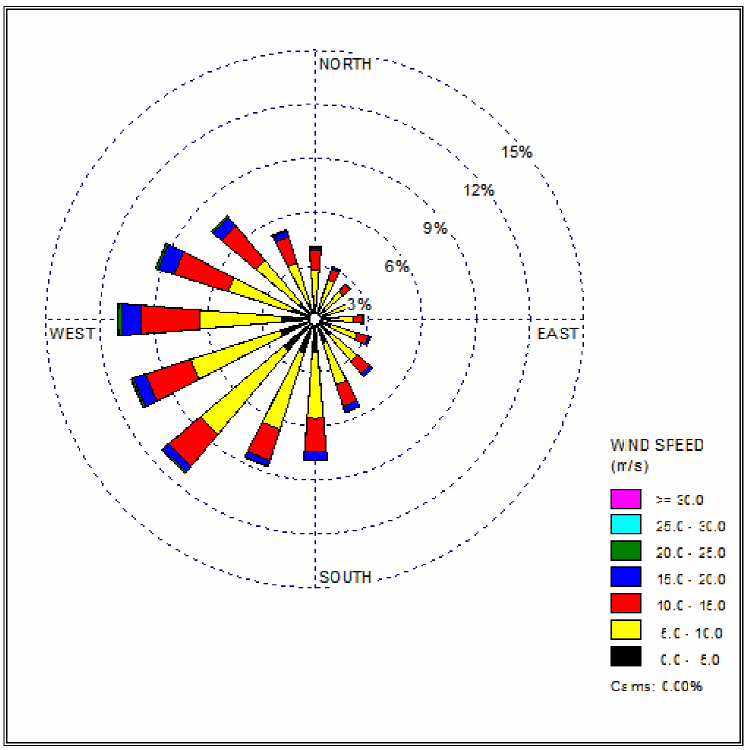



**Figure 3.2. Mean annual wind rose for MSC50 Grid Point 10255 located near 46.3°N, 48.4°W during 1954 – 2005.**

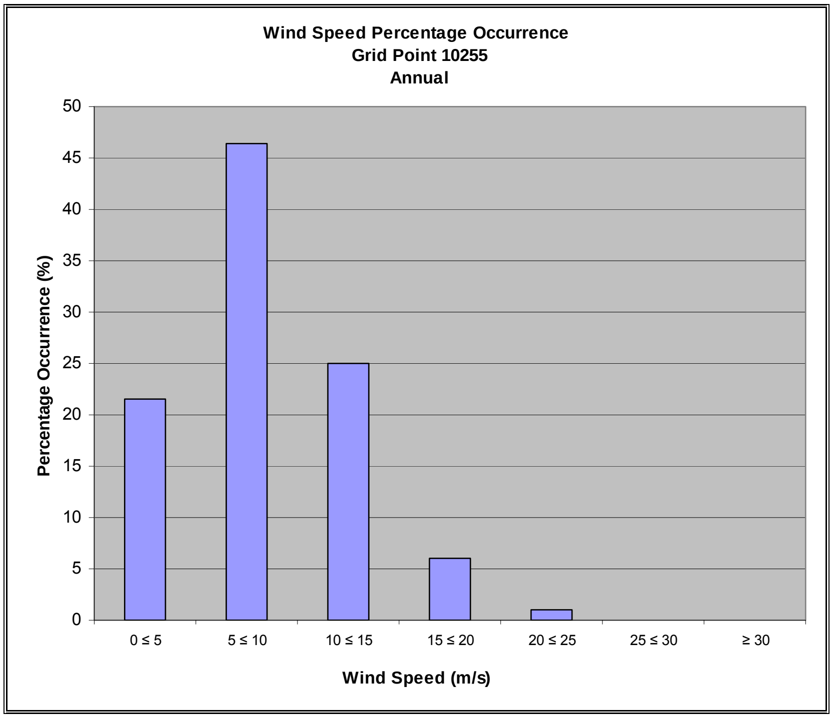



**Figure 3.3. Annual percentage frequency of wind speeds for MSC50 Grid Point 10255 located near 46.3°N, 48.4°W during 1954 – 2005.**

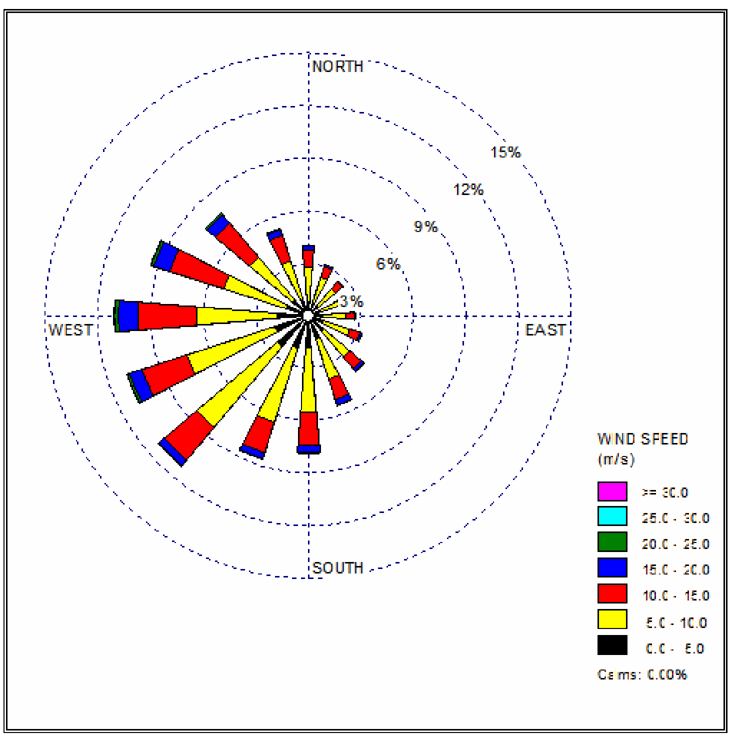



**Figure 3.4. Mean annual wind rose for MSC50 Grid Point 10439 located near 46.4°N, 48.1°W during 1954 – 2005.**

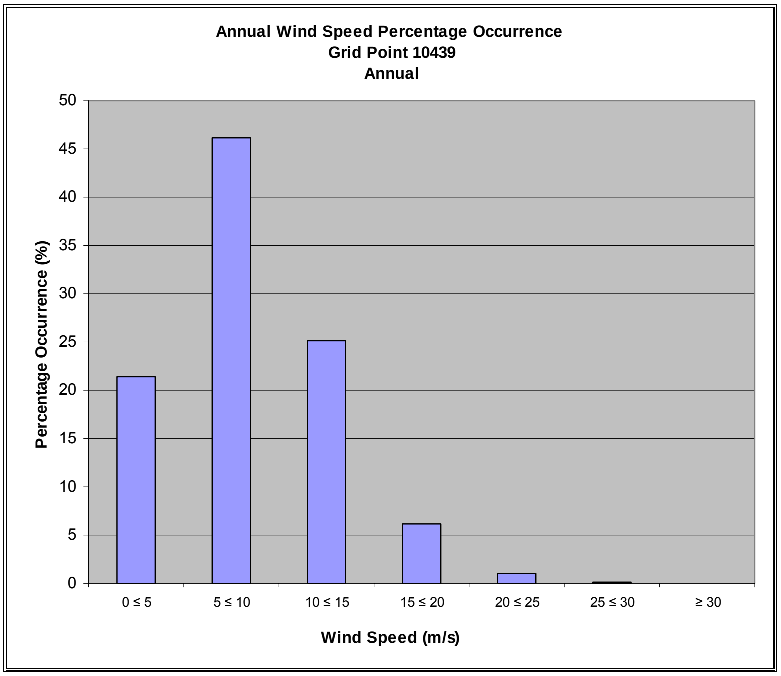



**Figure 3.5. Annual percentage frequency of wind speeds for MSC50 Grid Point 10439 located near 46.42°N, 48.13°W during 1954 – 2005.**

Intense mid-latitude low pressure systems occur frequently from early autumn to late spring. In addition, remnants of tropical systems have passed near Newfoundland between spring and late fall. Therefore, while mean wind speeds tend to peak during the winter months, maximum wind speeds may occur at anytime during the year. A table of monthly maximum wind speeds for each of the data sets is presented in Table 3.2.

**Table 3.2. Maximum wind speeds (m/s) statistics for MSC50 and ICOADS data.**

| Month | MSC50 | | ICOADS |
|---|---|---|---|
| | Grid Point 10255 | Grid Point 10439 | |
| January | 27.4 | 27.0 | 43.7 |
| February | 29.9 | 30.1 | 49.4 |
| March | 27.0 | 27.6 | 38.1 |
| April | 25.0 | 25.2 | 35.0 |
| May | 21.6 | 22.0 | 29.8 |
| June | 22.7 | 23.0 | 28.3 |
| July | 21.1 | 21.0 | 27.3 |
| August | 30.0 | 30.6 | 26.8 |
| September | 23.6 | 23.4 | 32.4 |
| October | 27.7 | 27.8 | 32.4 |
| November | 27.4 | 27.6 | 41.2 |
| December | 29.9 | 30.0 | 43.2 |

Rapidly deepening storm systems known as “weather bombs” frequently move across the Grand Banks. These storm systems typically develop in the warm waters of Cape Hatteras and move northeast across Newfoundland and the Grand Banks. Recently, such a weather bomb occurred on 11 February 2003 and wind speeds at Grid Point 10255 and 10439 peaked at 29.9 m/s and 30.1 m/s, respectively. Wind speeds of 52.5 m/s from the southwest were recorded by the *Henry Goodrich* anemometer (located at a height of 90 m above sea level) as this system passed. During this storm, a low pressure developing off Cape Hatteras on February 10 rapidly deepened to 949 mb as it tracked northeast across the Avalon Peninsula around 18Z on 11 February.

Another intense storm which developed south of the region passed east of the area on 16 December 1961. This storm resulted in wind speeds similar to that produced during the February 11 storm. During this event, grid point 10255 had wind speeds of 29.9 m/s and grid point 10439 had wind speeds peaking at 30.0 m/s. A ship in the ICOADS data set located at 47.8°N, 48.8°W recorded wind speeds of 25.7 m/s on this date.

While mid-latitude low pressure systems account for the majority of the peak wind events on the Grand Banks, storms of tropical origin can also on occasion pass over the region. On 6 August 1971, an unnamed Category 1 Hurricane passed west of the region with maximum sustained wind speeds of 38.6 m/s and a central pressure of 974 mb. During this event, wind speeds recorded in the MSC50 data set peaked at 30.0 m/s from the south-southwest at Grid Point 10255 and 30.6 m/s at Grid Point 10439. Wind speeds of 19 m/s were recorded by a ship located at 47.40°N; 48.00°W as this system passed.

### 3.3.2. Air and Sea Temperature

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

Temperature statistics show that the atmosphere is coldest in February with a mean temperature of -0.4°C, and warmest in August with a mean temperature of 14.5°C. The sea surface temperature (SST) is warmest in August with a mean temperature of 14.1°C and coldest in February and March with a mean temperature of 0.3°C. The mean SST is in the range of 0.1°C to 1.4°C colder than the mean air temperature from March to August, with the greatest difference occurring in the month of June. From September to February, SSTs are in the range of 0.0°C to 0.8°C warmer than the mean air temperature. The colder SSTs from March to August have a cooling effect on the atmosphere, while relatively warmer SSTs from September to February tend to warm the overlying atmosphere.

See Section 2.2 in Appendix A for more details on air and sea temperatures.

### 3.3.3. Visibility

During the winter months, the main obstruction to visibility is snow; however, mist and fog may also reduce visibilities at times. As spring approaches, the reduced visibility is due more to advection fog than to snow. Advection fog forms when warm moist air moves over the cooler waters of the Labrador Current. By March, the sea surface temperature on the Grand Banks is cooler than the surrounding air. As warm moist air moves over the colder sea surface, the air cools and its ability to hold moisture decreases. The air will continue to cool until it becomes saturated and the moisture condenses to form fog. The presence of advection fog increases from April through July. The ICOADS data shows that July month has the highest percentage (65.3%) of obscuration to visibility, most of which is in the form of advection fog, although frontal fog can also contribute to the reduction in visibility (see Figure 2.9 *in* Appendix A). On average, fog reduces visibility below 1 kilometre 50.3% of the time in July. In August, the temperature difference between the air and the sea begins to narrow and by September, the air temperature begins to fall below the SST. As the air temperature drops, the occurrence of fog decreases. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low-pressure systems. Fog is mainly the cause of the reduced visibilities in autumn and snow is the cause of reduced visibilities in the winter. October has the lowest occurrence of reduced visibility (22.1%) since the air temperature has, on average, decreased below the sea surface temperature, and it is not yet cold enough for snow.

See Section 2.4 in Appendix A for more details on visibility conditions.

### 3.3.4. Wave Climate

Wave climatology is described in detail in Section 2.5 in Appendix A. The wave climate of the Grand Banks is dominated by extra-tropical storms, primarily during October through March, however, severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area; however, they are still capable of producing storm force winds and high waves.

The annual wave rose from the MSC50 data for grid points 10255 and 10439 are presented in Figures 3.6 and 3.8, respectively. The corresponding percentage occurrence of wave heights ranges are shown in Figures 3.7 and 3.9. The wave roses show that the majority of wave energy comes from the west-southwest to southwest directions, and accounts for 25.0% of the wave energy at grid point 10255 and 27.4% of the wave energy at grid point 10439. Waves were “iced out” for 0.98% of the time at grid point 10255 and 1.23% of the time at grid point 10439, over the 50-year record; this value may be somewhat high since monthly ice files were used when generating the waves.

During autumn and winter, the dominate direction of the combined significant wave height is from the west. This corresponds with a higher frequency of occurrence of the wind wave during these months, suggesting that during the late fall and winter, the wind wave is the main contributor to the combined

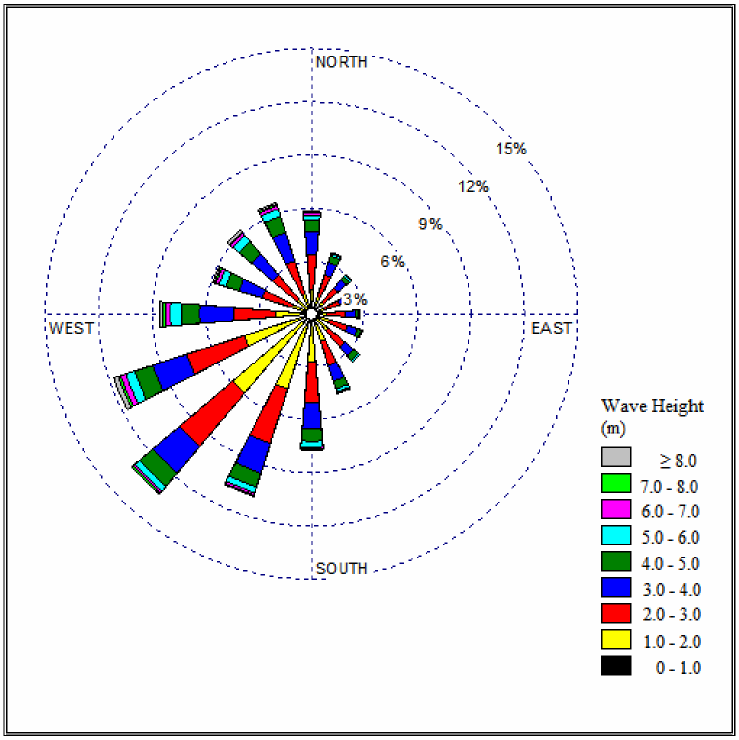



**Figure 3.6. Annual wave rose for MSC50 Grid Point 10255 located near 46.3°N, 48.4°W.**

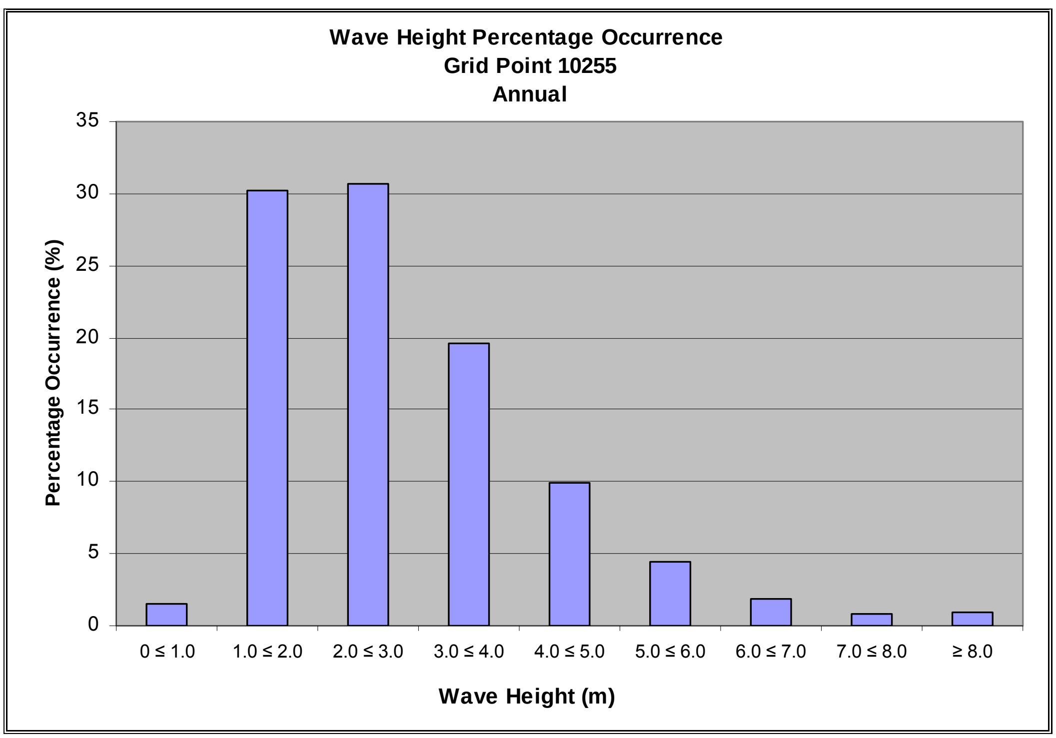



**Figure 3.7. Annual percentage frequency of wave height for MSC50 Grid Point 10255 located near 46.3°N, 48.4°W during 1954 – 2005.**

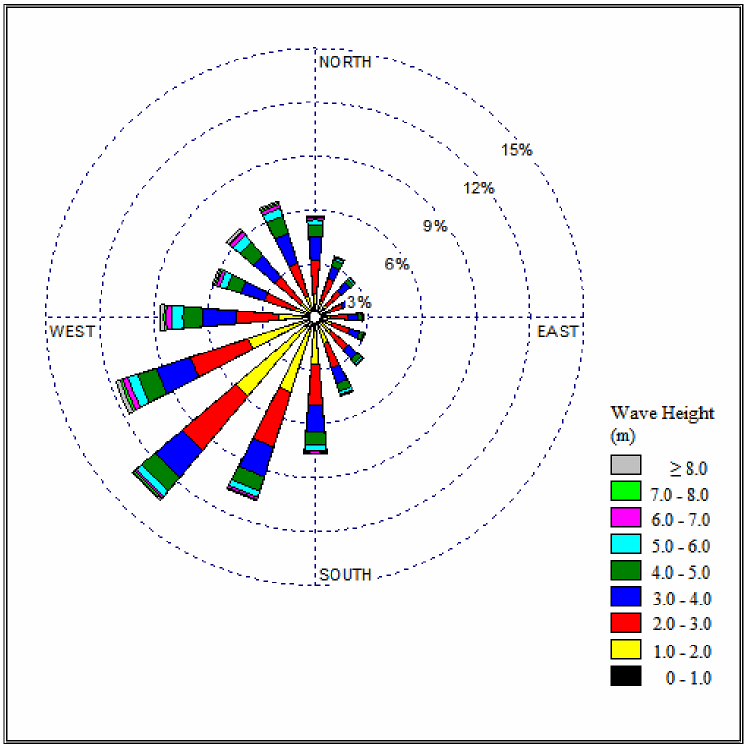



**Figure 3.8. Annual wave rose for MSC50 Grid Point 10439 located near 46.4°N, 48.1°W.**

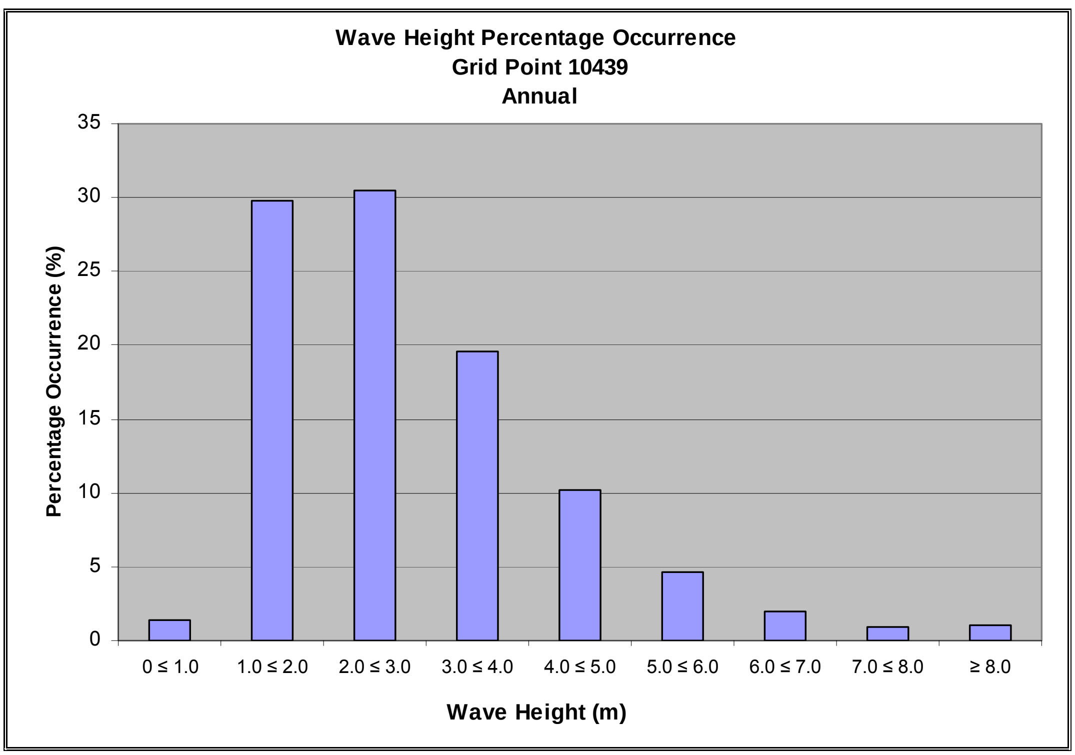



**Figure 3.9. Annual percentage frequency of wave height for MSC50 Grid Point 10439 located near 46.4°N, 48.1°W during 1954 – 2005.**

significant wave height. During the months of March and April, the wind wave remains predominately westerly, while the swell begins to change to southerly, resulting in the vector mean direction of the combined significant wave heights being to southwesterly. A mean southwesterly direction for the combined significant wave heights during the summer months is a result of a mainly southwesterly wind wave and a southwesterly swell. As winter approaches again, during the months of September and October, the wind wave will veer to the west and become the more dominant component of the combined significant wave height. This will result in the frequency of occurrence of the combined significant wave heights being westerly once again.

Significant wave heights on the Grand Banks peak during the winter months with the MSC50 mean monthly significant wave heights of 4.0 metres at both grid points. The lowest significant wave heights occur in the summer with July month having a mean monthly significant wave height of 1.7 m at both grid points (Table 3.3).

**Table 3.3. Mean significant wave height (m) statistics for the MSC50 data sets.**

| Month | Grid Point 10255 | Grid Point 10439 |
|---|---|---|
| January | 4.0 | 4.0 |
| February | 3.7 | 3.8 |
| March | 3.2 | 3.2 |
| April | 2.7 | 2.7 |
| May | 2.2 | 2.2 |
| June | 1.9 | 1.9 |
| July | 1.7 | 1.7 |
| August | 1.8 | 1.8 |
| September | 2.4 | 2.4 |
| October | 2.9 | 3.0 |
| November | 3.3 | 3.4 |
| December | 3.9 | 3.9 |

Significant wave heights of 10.5 metres or more occurred in each month between September and April, with the highest waves occurring during the month of February (Table 3.4). The highest significant wave heights of 13.9 m from the MSC50 Grid Point 10255 and 14.2 m from Grid Point 10439 occurred on 23 February 1967. A low pressure over Nova Scotia on 22 February rapidly deepened as it moved northeast to lie off the northeast coast of Newfoundland on the 23 February resulting in a prolonged period of strong-gale to storm force WSW to W winds over the Grand Banks. While maximum significant wave heights tend to peak during the winter months, a tropical system could pass through the area and produce large wave heights during any month.

**Table 3.4. Maximum significant wave height (m) statistics for the MSC50 data sets.**

| Month | Grid Point 10255 | Grid Point 10439 |
|---|---|---|
| January | 13.3 | 13.6 |
| February | 13.9 | 14.2 |
| March | 11.9 | 11.9 |
| April | 10.8 | 10.7 |
| May | 9.9 | 10.0 |
| June | 9.6 | 9.8 |
| July | 6.2 | 6.2 |
| August | 8.1 | 8.2 |
| September | 10.9 | 11.1 |
| October | 11.8 | 12.0 |
| November | 11.3 | 11.5 |
| December | 13.7 | 13.9 |

### 3.3.5. Tropical Systems

See Section 2.6 in Appendix A for detailed description of tropical storms. The hurricane season in the North Atlantic basin normally extends from June through November, although tropical storm systems occasionally occur outside this period. While the strongest winds typically occur during the winter months and are associated with mid-latitude low pressure systems, storm force winds may occur at any time of the year as a result of tropical systems. Once formed, a tropical storm or hurricane will maintain its energy as long as a sufficient supply of warm, moist air is available. Tropical storms and hurricanes obtain their energy from the latent heat of vapourization that is released during the condensation process. These systems typically move east to west over the warm water of the tropics, however, some of these systems turn northward and make their way towards Newfoundland and the Grand Banks. Since the capacity of the air to hold water vapour is dependent on temperature, as the hurricanes move northward over the colder ocean waters, they begin to lose their tropical characteristics. By the time these weakening cyclones reach Newfoundland, they are usually embedded into a mid-latitude low and their tropical characteristics are usually lost. Since 1950, 41 tropical systems have passed within 278 km of 46°23’N, 48°16’W (see Figure 2.8 and Table 2.10 in Appendix A).

### 3.3.6. Extreme Wind and Wave Conditions

An analysis of extreme wind and waves was performed using the MSC50 data set. The extreme values for wind and waves were calculated using the peak-over-threshold method, for the same two grid points used to obtain the wind and wave statistics. See Section 3.0 in Appendix A for more details on extreme wave and wind conditions.

The extreme value estimates for wind were calculated using Oceanweather’s Osmosis software program for the return periods of 1-year, 10-years, 25-years, 50-years and 100-years. The calculated annual values for 1-hour, 10-minutes and 1-minute are presented in Tables 3.5 and 3.6. The analysis used hourly mean wind values for the reference height of 10-m above sea level. These values were converted to 10-minute and 1-minute wind values using a constant ratio of 1.06 and 1.22, respectively (U.S. Geological Survey, 1979). The annual 100-year extreme 1-hour wind speed was determined to be 31.5 m/s for grid point 10255 and 31.6 m/s at grid point 10439. The 10-minute wind speed had a 100-year return period of 33.4 m/s at both grid points.

The annual and monthly extreme value estimates for significant wave height for return periods of 1-year, 10-years, 25-years, 50-years and 100-years are given in Tables 3.7 and 3.8. The annual 100-year extreme significant wave height ranged from 15.4 m at grid point 10439 to 15.2 m at grid point 10255. The 50-year extreme significant wave heights vary between 14.5 m and 14.7 m

**Table 3.5. Extreme value estimates for wind at MSC50 Grid Point 10255.**

| Return Period (years) | Wind Speed (m/s) 1 hour | Wind Speed (m/s) 10-minute | Wind Speed (m/s) 1-minute |
|---|---|---|---|
| **1** | 24.7 | 26.2 | 30.1 |
| **10** | 28.1 | 29.8 | 34.3 |
| **25** | 29.5 | 31.2 | 36.0 |
| **50** | 30.5 | 32.3 | 37.2 |
| **100** | 31.5 | 33.4 | 38.4 |

**Table 3.6. Extreme value estimates for wind at MSC50 Grid Point 10439.**

| Return Periods (years) | Wind Speed (m/s) 1 hour | Wind Speed (m/s) 10-minute | Wind Speed (m/s) 1-minute |
|---|---|---|---|
| **1** | 24.8 | 26.2 | 30.2 |
| **10** | 28.2 | 29.9 | 34.4 |
| **25** | 29.5 | 31.3 | 36.0 |
| **50** | 30.5 | 32.4 | 37.3 |
| **100** | 31.6 | 33.4 | 38.5 |

**Table 3.7. Extreme value estimates for waves at MSC50 Grid Point 10255.**

| Return Period (years) | Significant Wave Heights (metres) | Maximum Wave Height (metres) | Associated Peak Period (seconds) |
|---|---|---|---|
| **1** | 10.5 | 19.5 | 13.6 |
| **10** | 12.9 | 23.8 | 14.8 |
| **25** | 13.8 | 25.5 | 15.2 |
| **50** | 14.5 | 26.7 | 15.5 |
| **100** | 15.2 | 28.0 | 15.8 |

**Table 3.8. Extreme value estimates for waves at MSC50 Grid Point 10439.**

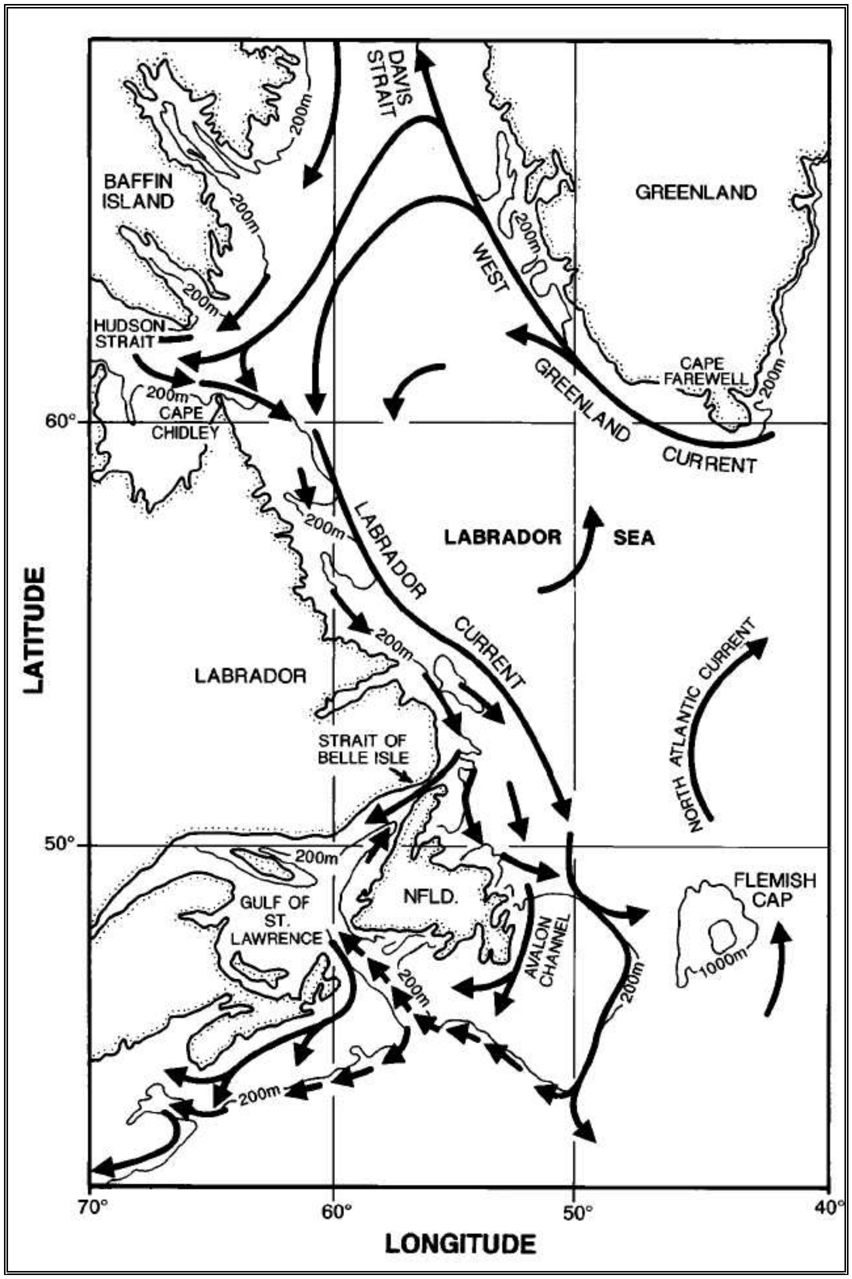
| Return Period (years) | Significant Wave Heights (metres) | Maximum Wave Height (metres) | Associated Peak Period (seconds) |
|---|---|---|---|
| **1** | 10.7 | 19.8 | 13.7 |
| **10** | 13.1 | 24.2 | 14.9 |
| **25** | 14.0 | 25.9 | 15.3 |
| **50** | 14.7 | 27.2 | 15.5 |
| **100** | 15.4 | 28.4 | 15.8 |

## 3.4. Physical Oceanography

The main current system in and near the Study Area is the Labrador Current, which transports sub-polar water to lower latitudes along the Continental Shelf of eastern Canada (Figure 3.10). Over the Grand Banks, a weak current system is observed where the variability often exceeds that of the mean flow (Colbourne 2000).

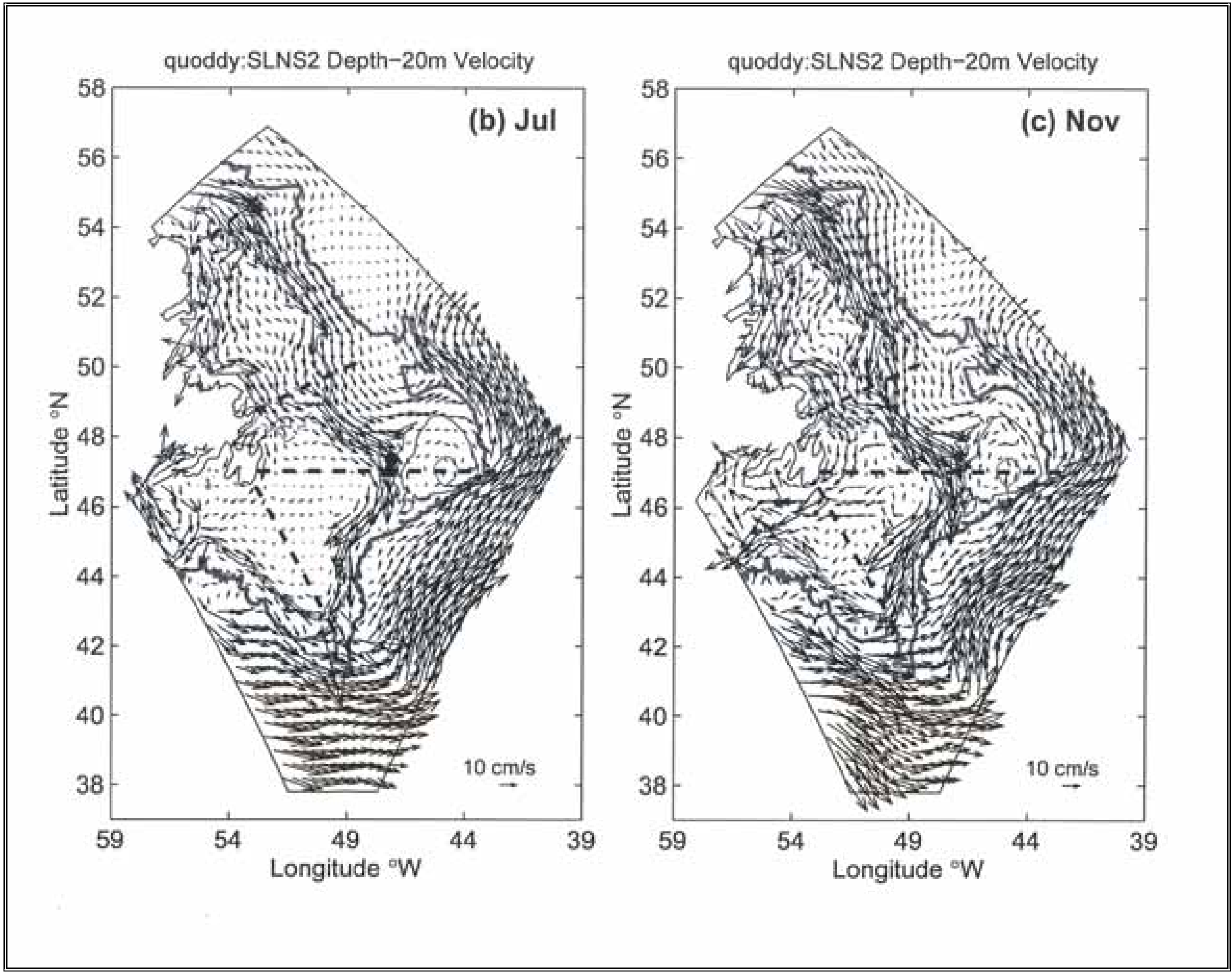
The Labrador Current consists of two major branches. The inshore branch is located on the inner part of the shelf and its core is steered by the local underwater topography through the Avalon Channel. The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope. Lauzier and Wright (1993) found that the offshore branch of the Labrador Current offshore Labrador was located in a 50 km wide band between the 400 m and 1200 m isobaths. This branch of the Labrador Current divides between 48°W and 50°W, resulting in one sub-branch flowing to the east around Flemish Cap and the other flowing south around the eastern edge of the Grand Banks and through Flemish Pass. Characteristic current speeds on the Slope are in the order of 30 cm/sec to 50 cm/sec (Colbourne 2000), while those in the central part of the Grand Banks are generally much lower, averaging between 5-15 cm/s.

Another major current system is situated to the south of the Grand Banks. In the area of the Southeast Newfoundland Rise, the Gulf Stream branches into two streams. The southern branch continues east at approximately 40°N. The northern branch, known as the North Atlantic Current, turns north and flows along the Continental Slope southeast of the Grand Banks and continues northeastward along the east side of Flemish Cap. This circulation pattern is captured in the nonlinear finite element model produced by Han and Wang (2005) and shown in Figure 3.11.




**Source:** Colbourne et al. (2007).

**Figure 3.10. Major ocean circulation features in the Northwest Atlantic.**




**Source:** from Han and Wang (2005).

**Figure 3.11. Model circulation fields at the 20 m depth contour for July and November, representing the summer and fall seasons, respectively.**

## 3.4.1. Currents in the Project Area

In the central region of the Grand Banks, the currents are mainly due to wind stress, tides, and low frequency oscillations related to the passage of storm systems. More details about currents are provided in Section 4.2 of Appendix A.

Wind stress is an important driving force for the currents on the Continental Shelf, with a distinct annual cycle of comparatively strong winds in winter and weaker more variable winds in summer. An analysis of an array of current meter data collected from January to May 1992 by De Tracey et al. (1996) on the northeastern section of the Grand Banks showed that the near-surface currents and local wind are highly coherent in the shallow region of the Grand Banks, suggesting that the currents on the Grand Banks have a strong wind driven component.

Tides play a major role in the currents on the Grand Banks. The major tidal semidiurnal constituents are $M_2$ and $S_2$ and the major diurnal constituents are $O_1$ and $K_1$. The values of the tidal constituents at the Terra Nova site are given in Table 3.9. The contributions by the tidal currents to the overall speed are equivalent to the value of the mean current speeds on the shallow regions of the Grand Banks.

**Table 3.9. Tidal constituents (cm/sec) at the Terra Nova site from current meter records.**

| Water Depth Category | $M_2$ | $S_2$ | $O_1$ | $K_1$ |
|---|---|---|---|---|
| Surface | 6.9 | 2.8 | 3.2 | 3.5 |
| Mid-depth | 5.9 | 2.1 | 2.8 | 3.0 |
| Near bottom | 5.1 | 1.8 | 2.8 | 3.0 |

The semi-diurnal tidal currents rotate through 360° twice per day in a clockwise direction. The diurnal tidal ellipses at Terra Nova are almost circular showing no preferred direction, and the semidiurnal tidal ellipses are slightly elongated in a northwest/southeast direction. Overall, the tidal currents at Terra Nova are responsible for about 30% of the variability near the surface and at mid-depth, and for 20% of the variability near the bottom.

The low frequency components are the most important contributor to the overall flow. The strongest currents have been observed to always occur during the passage of low pressure systems. Some of the flow can be attributed to direct effects of the wind stress upon the sea surface as indicated by an inertial period signal showing up in spectral analysis of the data. Spectral analysis shows that the low frequency components are in the period range of 4 to 7 days. The barotropic component appears to be the largest component of the strong flows.

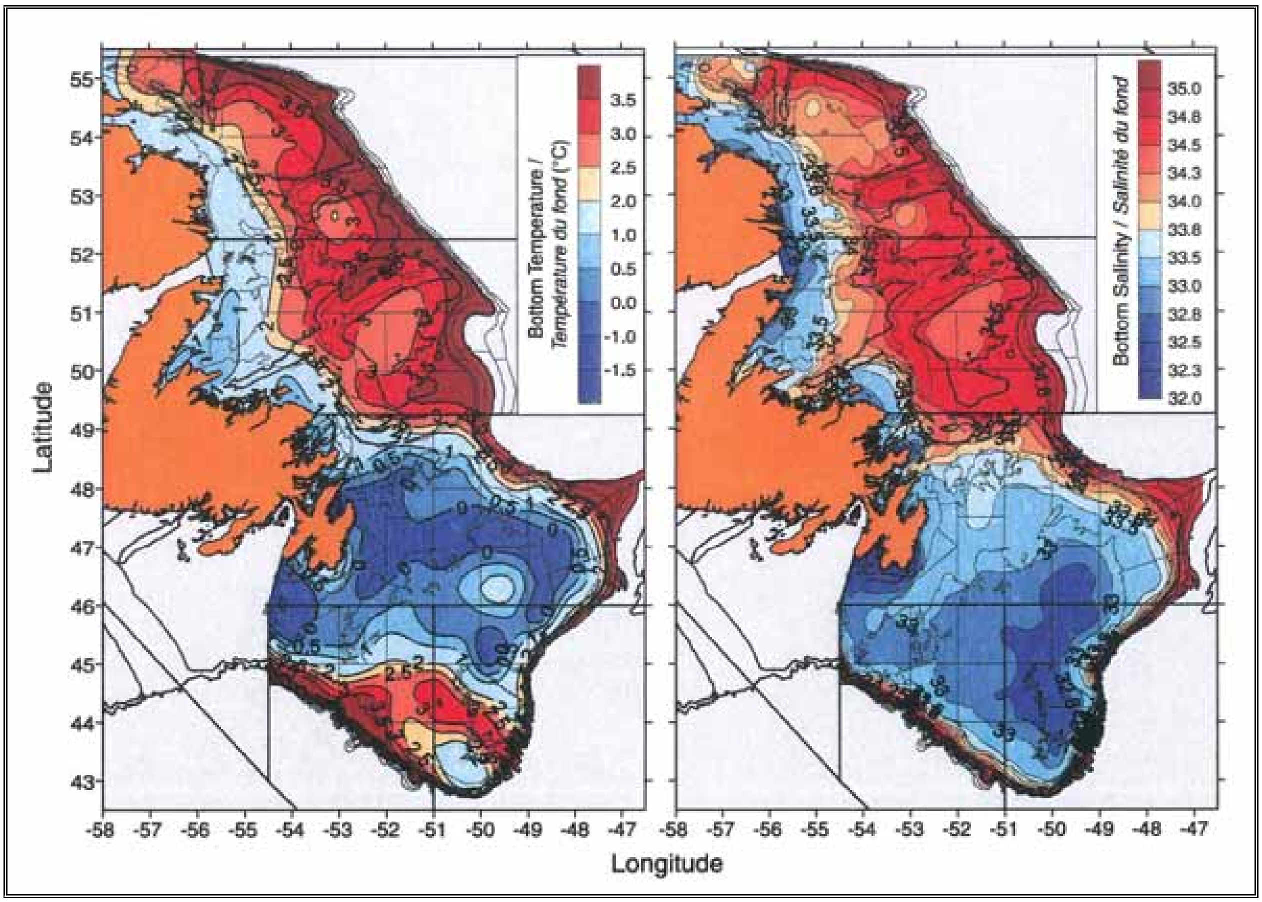
Currents at Terra Nova located near EL 1101 have been measured continuously since 1999. The mean current speeds are in the range of 12 cm/sec to 18 cm/sec at a depth of 20 m below the surface; between 9 cm/sec and 12 cm/sec at mid-depth, and 8 cm/sec to 12 cm/sec at a depth of 10 m above bottom. Maximum current speeds have been measured as 77 cm/sec at 20 m below the surface in 2003, and 42 cm/sec at mid-depth and near bottom in 2001.

### 3.4.2. Water Mass Structure

The water structure on the northeastern section of the Grand Banks of Newfoundland is characterized by the presence of three identifiable features.

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

A second element of the thermohaline structure on the Grand Banks is the Cold Intermediate Layer (Petrie et al. 1988). In areas where the water is deep enough, this layer of cold water is trapped during summer between the seasonally heated upper layer and warmer slope water near the seabed (Colbourne 2002). Its temperatures range from less than -1.5°C to 0°C (Petrie et al. 1988; Colbourne et al. 1996) and salinities vary within 32 and 33 psu. It can reach a maximum vertical extent of over 200 m (Colbourne 2004). The Cold Intermediate Layer is the residual cold layer that occurs from late spring to fall and is composed of cold waters formed during the previous winter season. It becomes isolated from the sea surface by the formation of the warm surface layer during summer, and disappears again during late fall and winter due to the intense mixing processes that take place in the surface layer from strong winds, high waves and atmospheric cooling. In winter, the two layer structure is replaced by a mixed cold body of water which occupies the entire water column. Bottom temperature and salinity maps were produced by Colbourne et al. (2007) by trawl-mounted CTD data from approximately 700 fishing tows during the fall of 2005. These data are presented in Figure 3.12. The Figure shows that the Cold Intermediate Layer is still present in the Project Area.




**Source:** from Colbourne et al. (2007).

**Figure 3.12. Bottom temperature and salinity maps derived for the trawl-mounted CTD data.**

A third element is the sharp density boundary near the Shelf break which separates the water on the shelf from the warmer, more saline water of the Continental Slope. The water over the Slope is the Labrador Sea water which is formed in the Labrador Sea as a result of deep convection processes that take place during severe winters. The temperature and salinity boundary between the water on the Shelf and the Flemish Pass is shown in Figure 3.13 which is based on CTD data collected during April 2007 along the routinely sampled Flemish Cap transect.

### 3.4.3. Water Properties in the Project Area

For the proposed seismic area, temperature and salinity data were obtained from the Bedford Institute of Oceanography and the data are presented in Figure 3.14 which provides the distribution of temperature and salinity by depth on a monthly basis. The contour plots show that the largest temperature and salinity variations occur in the upper 50 m during the summer and fall seasons.

## 3.5. Ice and Icebergs

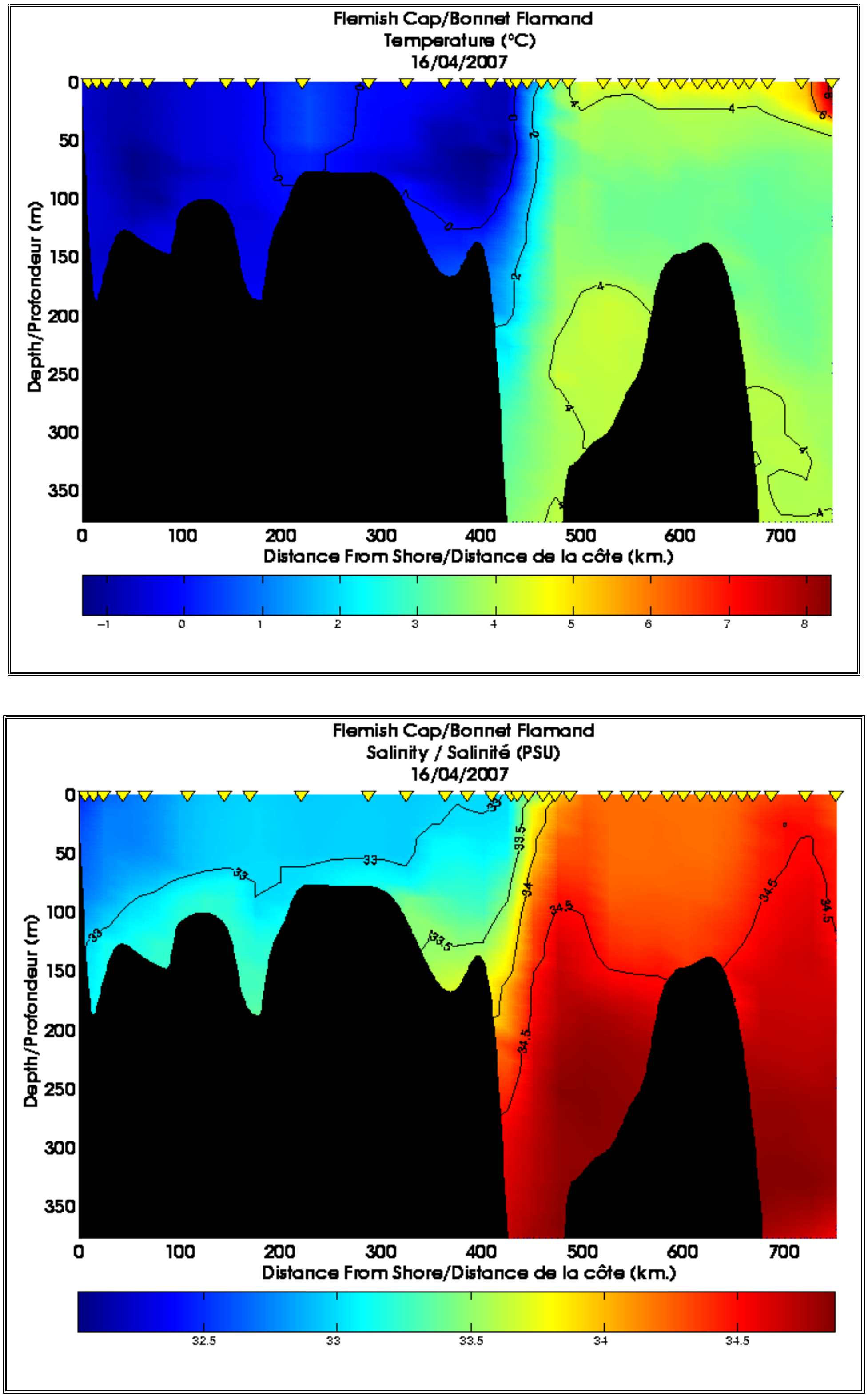
The following is a description of the ice environment on the Grand Banks. This description uses as its base, information and data published in the White Rose Development Environmental Assessment (2000). These data have been updated to include subsequent data and reports from 2001 to 2007. Apart from some small numerical adjustments most data and associated descriptions remain unchanged.

Sea ice and icebergs are two different forms of floating ice present in marine environment. Sea ice is produced when the ocean's surface layer freezes. In the Study Area, when sea ice is present it is usually loosely packed and pressure-free. Floes are small and generally in advanced stages of deterioration.

Icebergs are freshwater ice made from snow compacted in a glacier. When the leading edge of a glacier reaches the sea, slabs of ice fall off it, creating icebergs. The icebergs located on the Grand Banks typically originate from the glaciers of West Greenland. Ice management efforts focus on icebergs because they pose a hazard to offshore drilling and production facilities.

### 3.5.1. Sea Ice

The study site of interest lies close to the extreme southern limit of the regional ice pack. In typical years, the ice edge reaches the Grand Banks in mid-February (Navoc 1986). The pack ice in and near the Project Area generally reaches annual peak coverage in March, just before water temperatures rise above the freezing level.




**Source:** from DFO Marine Environmental Data Service Website.

**Figure 3.13. Hydrographic contours (temperature, salinity) of the Flemish Cap transect during April 2007.**

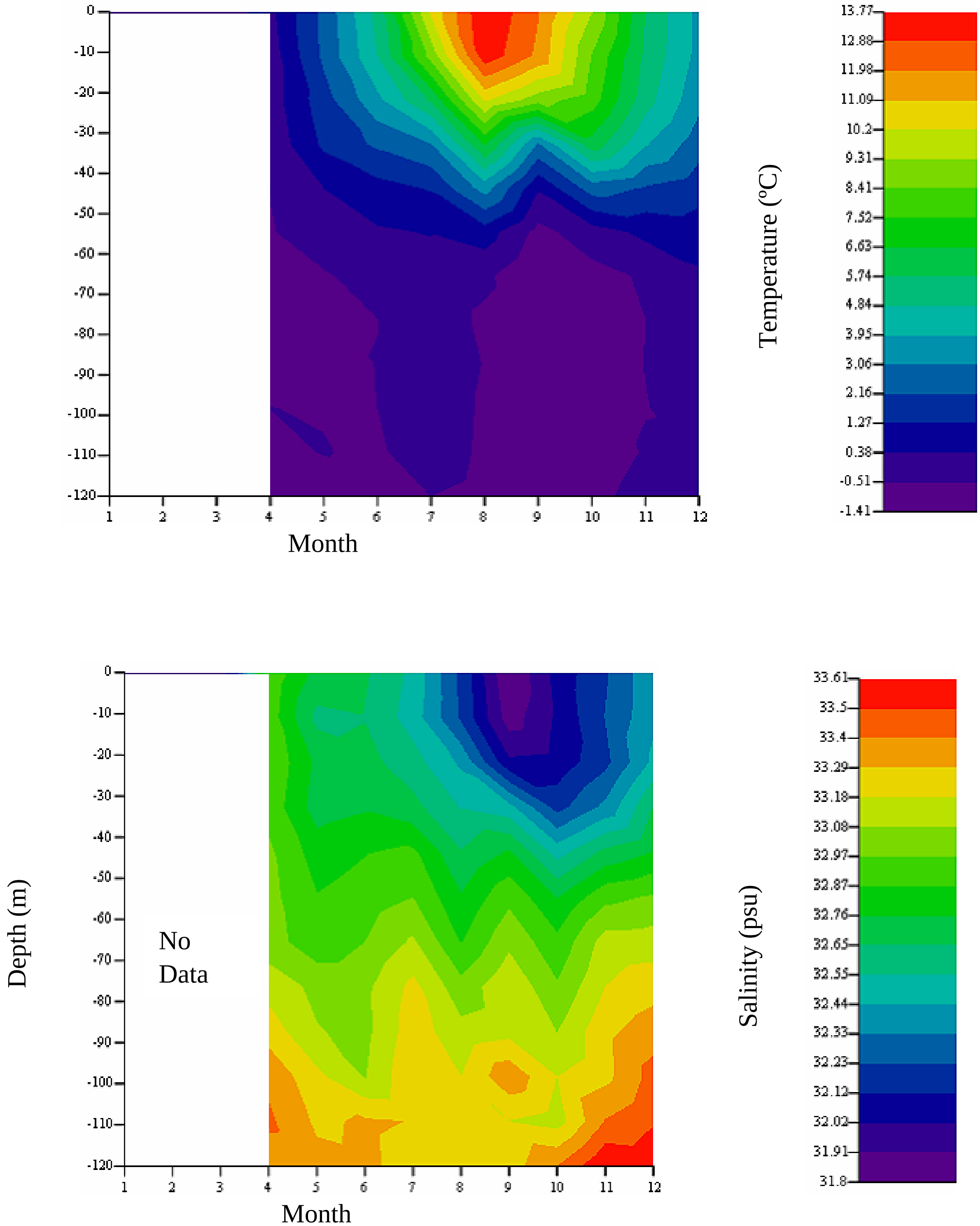
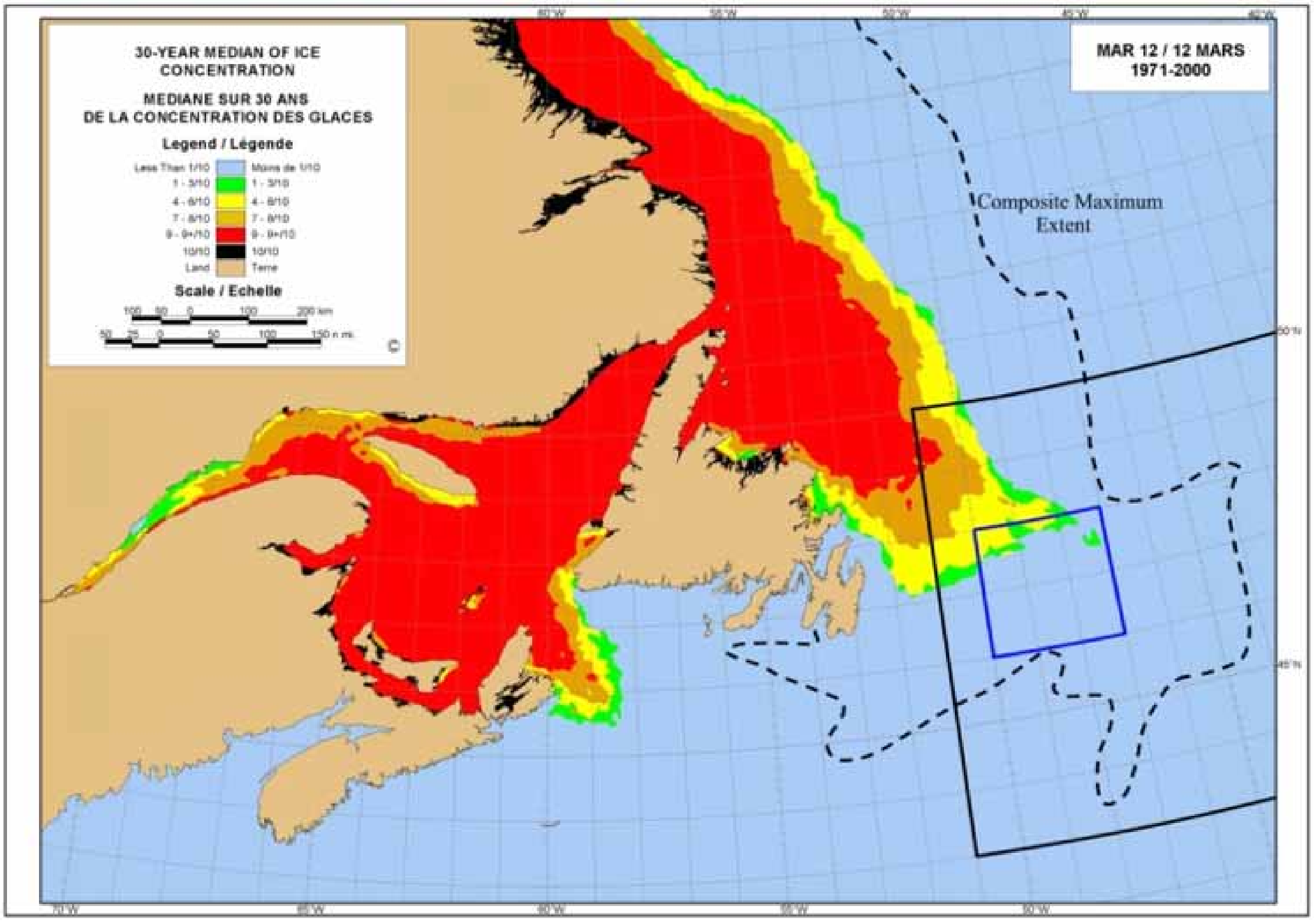



**Figure 3.14. Distribution of temperature and salinity by water depth on a monthly basis.**

### 3.5.1.1. Sea Ice Duration

The median ice edge position shown in Figure 3.15 represents the ice edge for a typical year. About 50% of the time the ice is farther south than the median line and 50% of the time the ice is farther north. The maximum ice positions shown are composites of the most advanced ice-edge positions recorded. Sea ice covers part of the Grand Banks approximately one in every three years. The duration of these incursions varies from a low of one week to a high of five weeks with an average duration of three weeks (Table 3.10).




**Source:** Canadian Ice Services.

**Figure 3.15. Mean and composite maximum sea ice distribution on the Grand Banks.**

**Table 3.10. Duration of sea ice occurrence on the Grand Banks.**

| **Sea Ice Duration (weeks)** | | | |
|---|---|---|---|
| *Mean* | *Maximum* | *Extreme* | *Minimum* |
| 3 | 5 | 5 | 0 |

**Source:** CIS Sea Ice Climatic Atlas (1971-2000).

#### 3.5.1.2. Sea Ice Concentrations

The seasonal movement of the southern pack ice edge can have an effect on the Project Area. Ice concentrations in the southerly edge are usually at the lower end of ice coverage from 2/10ths to 6/10ths. However, in extreme years the Project Area has experienced short periods of 9/10ths or more coverage (Table 3.11).

**Table 3.11. Mean, maximum and extreme sea ice concentrations.**

| **Sea Ice Concentrations (%)** | | |
|---|---|---|
| *Mean* | *Maximum* | *Extreme* |
| 40 | 90 | 100 |

**Source:** CIS Weekly Ice Charts (1970 – 2000).

#### 3.5.1.3. Sea Ice Floe Size

AES composite ice chart data for 1964 to 1998 indicate that, within 50 km of the Project Area, floes larger than 100 m are present only 10 % of the time. Estimates made in an earlier study (Dobrocky Seatech 1985) indicate that mean floe diameters in offshore areas south of 49° N were less than 30 m, with only a few floes with diameters larger than 60 m observed (Table 3.12).

**Table 3.12. Mean, maximum and extreme sea ice floe size.**

| **Sea Ice Floe Size (meters)** | | |
|---|---|---|
| *Mean* | *Maximum* | *Extreme* |
| < 30 | 60 | > 100 |

**Source:** Dobrocky Seatec (1985).

#### 3.5.1.4. Sea Ice Thickness

Ice coverage within 15 km of the Project Area typically ranges from 30 cm to 100 cm in thickness (Table 3.13). This information was derived subjectively from CIS ice chart data for periods of ice coverage during the years 1985 to 2007 that exceeded 4 weeks in duration.

**Table 3.13. Mean, maximum and extreme sea ice thickness (undeformed).**

| **Sea Ice Thickness (undeformed; cm)** | | |
|---|---|---|
| *Mean* | *Maximum* | *Extreme* |
| 70 | 100 | 200 |

**Source:** CIS Weekly Ice Charts (1970 – 2007).

#### 3.5.1.5. Sea Ice Drift Speeds

When present, pack ice at the Project Area is made up of non-continuous, mobile pack. Because of the loose concentrations and the lack of restraint, the pack ice is not subject to pressure.

Pack ice drift rates on the Grand Banks virtually mirror the surface currents. Between 1984 and 1987, Petro-Canada conducted a series of studies using satellite tracked ice drifters. The resulting ice drift patterns and velocities are characteristic of currents on the slope region of the Grand Banks.

Eighty percent of the measured drift speeds were less than 0.6 m/sec with a preferred direction towards the southeast. Mean drift speeds were shown to be 0.25 m/sec with extremes of 0.75 – 1.0 m/sec (Table 3.14). These measurements confirm observations made by mariners who have experience operating in ice on the Grand Banks (P. Rudkin, PAL, pers. comm.).

**Table 3.14. Mean, maximum and extreme sea ice drift speeds.**

| **Sea Ice Drift Speeds (m/sec)** | | |
|---|---|---|
| *Mean* | *Maximum* | *Extreme* |
| 0.25 | 0.6 | 1.0 |

**Source:** Seaconsult Ltd. (1988).

### 3.5.2. Icebergs

As noted previously, glacial ice is formed from the accumulation of snow, which gradually changes form as it is compressed into a solid mass of large granular ice. This process produces a structure quite different from pack ice. The principal origins of the icebergs that reach the Grand Banks and the study site location are the 100 tidewater glaciers of West Greenland, which account for 85% of the icebergs.

#### 3.5.2.1. Iceberg Distribution

According to the International Ice Patrol (IIP), the number of icebergs that reached the Grand Banks each year varied from a low of 0 in 1966 and 2006 to a high of 2,202 in 1984, with the average over the last ten years being 474 icebergs. Of these, only a small proportion would have passed through the Project Area (Table 3.15). Over the last ten years the average annual number of icebergs sighted in an area ($1^{\circ}$ grid - 46-47N, 48-49W) within the Project Area has been 41.

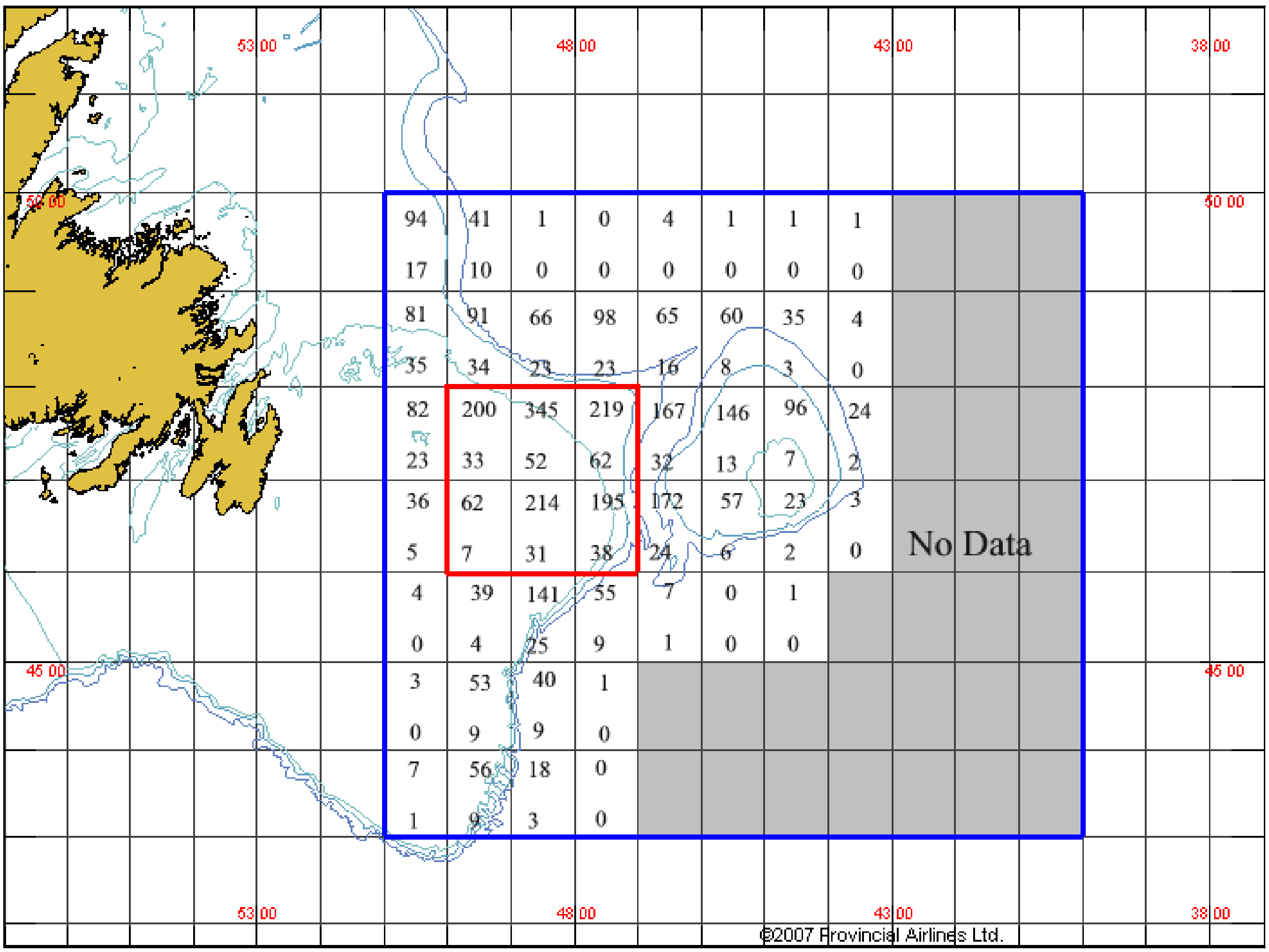
**Table 3.15. Minimum, maximum and mean number of icebergs in a degree block within the Project Area.**

| **Iceberg Distributions (No. of icebergs)** | | | |
|---|---|---|---|
| ***Degree Block Bounded By: 46N – 47N, 48W – 49W*** | | | |
| *Source* | *Maximum* | *Minimum* | *Mean* |
| PAL | 214 | 0 | 31 |

**Source:** Provincial Aerospace (2007).

The long-term average of icebergs drifting south of 48°N peaks in July. High levels are also observed from March through to September based on the data compiled by PAL from 1989 to 2007. On the Grand Banks, the long-term average number of icebergs peak in April with a major flux from March to June. Iceberg sightings on the Grand Banks have been made in each month from January through December. In 1993, about 20 % of the icebergs crossed 48°N in February. It should be noted that in the Project Area over the past ten years, three have been completely iceberg-free and over the long-term record iceberg free conditions account for approximately 12% of all seasons.

A plot (Figure 3.16) of annual iceberg distribution for one-degree grids (8232 km$^2$) between 43°N and 50°N using 1989-2007 PAL data shows the regional iceberg distribution. The upper and lower numbers in each rectangle denote, respectively, the maximum and the mean numbers of icebergs observed each year. The maximum numbers provide a worst-case representation of local annual iceberg severities.




**Source:** PAL Iceberg Sighting Database (1990 – 2007).

**Figure 3.16. Maximum and mean annual numbers of icebergs observed in and near the Project Area.**

When looking at a 50 km radius area in the Project Area (which equates roughly to the size of the typical MODU ice management zone) for the same period, the number of icebergs is reduced by between 70 to 80% (Table 3.16).

**Table 3.16. Minimum, maximum, mean and median number of icebergs in a 50 km radius of the Project Area.**

| Iceberg Distributions (No. of icebergs) | | | |
|---|---|---|---|
| ***50 km radius in the Project Area*** | | | |
| *Maximum* | *Minimum* | *Mean* | *Median* |
| 60 | 0 | 8 | 1 |

**Source:** Provincial Aerospace (2007).

### 3.5.2.2. Iceberg Size Distribution

Two PERD studies: A Compilation of Iceberg Shape and Geometry Data for the Grand Banks Region (CANATEC 1999), and Grand Banks Iceberg Database (Fleet Technology 2000) lists dimensions for 872 icebergs measured on the Grand Banks and off the Labrador coast. These databases provide extensive measurement data (both above and below water) on icebergs. From this database measurement sets were extracted for icebergs within a 100 km radius of the Project Area. Additional data obtained over the previous ice seasons were added using the same criteria.

This data shows that in and near the Project Area, 64 % of measured icebergs fall into the small or lower category. While 24 % were medium and 12 % were considered large in size.

### 3.5.2.3. Iceberg Draft

Off the Continental Shelf, icebergs can have drafts larger than 150 m while on-the-shelf areas such as the Project Area, iceberg drafts are in the 20 m to 100 m range. Mean on-shelf draft is 42 m, while the maximum is restricted by the water depth.

### 3.5.2.4. Iceberg Mass

A review of 224 icebergs measured on the Grand Banks from the PERD (CANATEC 1999) database shows similar results. For water depths less than 100 m the mean iceberg mass was 125,000 tonnes (Table 3.17).

**Table 3.17. Iceberg mass distribution on the Grand Banks for water depths less than 100 m.**

| Iceberg Mass Distribution | | |
|---|---|---|
| *Mean* | *Maximum* | *Extreme* |
| 125,000 tonnes | 1.6 million tonnes | 3.9 million tonnes |

**Source:** CANATEC (1999).

### 3.5.2.5. Iceberg Drift Speeds

Iceberg drift speeds in and near the Project Area show a correlation with the sub-surface currents. Iceberg drift speeds measured from various drilling operations on the Grand Banks show speeds ranging from a low of 0 to a high of 1.3 m/sec and the mean at 0.3 m/sec.

A study conducted by Seaconsult in 1988 showed that 65% of measured iceberg drift speeds were less than 0.4 m/sec regardless of water depth. Over the 2000 ice season, 1370 measurements of iceberg drift speeds were recorded. Speeds ranged from 0 to 1.3 m/sec and again the mean drift speed was 0.3 m/sec (Table 3.18). Both of these observations agree with subsequent data sets obtained over recent ice seasons.

Using the extreme sub-surface currents as a base, and assuming the same relationship between iceberg and current speed, it would appear that the extreme iceberg drift speeds could reach as high as 1.8 m/sec.

**Table 3.18. Mean, maximum and extreme drift speeds of icebergs on the Grand Banks.**

| **Iceberg Drift Speeds (m/sec)** | | |
|---|---|---|
| *Mean* | *Maximum* | *Extreme* |
| 0.3 | 1.3 | 1.8 |

**Source:** Seaconsult Ltd. (1988).

### 3.5.2.6. Iceberg Scour

Icebergs whose drafts exceed their water depths scrape along the sea floor, creating continuous or interrupted gouges and pits known as 'iceberg scours'. When this occurs the icebergs often become grounded in the seabed. Recent reports (Croasdale and Associates 2000) have quantified over 3887 individual iceberg scours from the Grand Banks Scour Catalogue produced by Canadian Seabed Research Ltd. Data for the Project Area show the mean scour depth to be 0.7 m in depth and 656 m in length (Table 3.19).

**Table 3.19. Mean and maximum dimensions of iceberg scours on the Grand Banks.**

| **Iceberg Scour Data** | | |
|---|---|---|
| | *Mean* | *Maximum* |
| Depth (m) | 0.7 | 3.0 |
| Width (m) | 26 | 200 |
| Length (m) | 656 | 9366 |

**Source:** Croasdale, K.R. and Associates (2000).

# 4.0 Biological and Socio-economic Environment

The summary description of the biological environment in the Husky new drill centre construction and operations program EA and addendum (LGL 2006a, 2007c) is directly relevant to this Project. Other recent documents that have also described the biological environment of areas that overlap with this EA's Project Area and Study Area include the White Rose Oilfield Comprehensive Study (Husky 2000), the Husky Jeanne d'Arc Basin exploration drilling EAs and update (LGL 2002, 2005a, 2006b), and the Husky Jeanne d'Arc Basin 3-D seismic EA and update (LGL 2005b; Moulton et al. 2006a). In addition to updated information, summaries of relevant information from these documents are presented in the following sections for plankton, benthos, invertebrates/fish and related habitats, seabirds, marine mammals, and sea turtles.

## 4.1. Ecosystem

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

## 4.2. Invertebrates and Fish

Most of the focus in this section is on commercially important invertebrates and fish although particular non-commercial species with well-recognized ecological importance are also discussed.

### 4.2.1. Sensitive Areas

Although there are probably important feeding areas for fish and invertebrates, particularly in localized upwelling areas that may be associated with slopes, there are no designated marine protected areas (MPAs) or other identified sensitive areas in, or immediately adjacent to, the Study Area.

In April 2003, R.G. Thibault, then Minister of Fisheries and Oceans, announced that special conservation measures were required in the Hawke Channel (off southern Labrador) and the Bonavista Corridor to protect spawning and juvenile concentrations of Atlantic cod and their associated habitat. These measures include an area ("cod box") within the Bonavista Corridor that is closed to otter trawling (www.dfo-mpo.gc.ca). This Bonavista cod box is about 80 km northwest of the Study Area and 105 km northwest of the Project Area.

## 4.2.2. Marine Habitats

The Project Area and the Study Area both include shelf and slope habitats. Water depths in both areas range from <100 m to >1000 m (Figure 1.1). Every substrate type common to the Grand Banks region likely occurs in both the Project Area and Study Area. Therefore, marine invertebrates and fish that occur in the two areas occupy a variety of marine habitats. Gross classification of these habitats include benthic, demersal and pelagic, each of which can be divided into finer classifications.

### 4.2.1.1 Demersal and Pelagic Habitats

Pelagic and demersal invertebrate and fish species occur principally in the water column above the bottom substrate. Those species that occur primarily in the lower water column and remain in association with the bottom are referred to as demersal. Others that occur higher in the water column and have little or no association with the benthic habitat are referred to as pelagic species. Both mobile animals and drifting planktonic species occur in the pelagic zone. A short discussion of plankton is included in Husky's new drill centre EA (Section 5.4 *in* LGL 2006a).

Demersal and pelagic invertebrates include many crustaceans (e.g., shrimps, amphipods) and cephalopods (e.g., squids, octopuses). Zooplankton is included in the discussion of plankton in Husky's new drill centre EA (Section 5.4 *in* LGL 2006a). Demersal and pelagic fish include numerous species such as Atlantic cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*), wolffishes (*Anarhichas* spp.), Atlantic halibut (*Hippoglossus hippoglossus*), swordfish (*Xiphias gladius*) and various tunas (*Thunnus* spp.). Many of demersal and pelagic invertebrates and fish have egg and larval stages (ichthyoplankton) that also exist for a time in either or both of these zones. Ichthyoplankton will be discussed later in this section.

### 4.2.1.2 Benthic Habitats

A short discussion of benthic species found in the Project Area, is included in Husky's new drill centre EA (Section 5.5.1.1 *in* LGL 2006a). Typical benthos that occurs within the Project Area includes the following:

- Micro- and macroalgae;
- Infauna such as polychaete worms and bivalve molluscs; and
- Epifauna such as echinoderms (e.g., sea urchins, sand dollars), crustaceans (e.g., crabs, amphipods), bivalve molluscs (e.g., scallops), and corals.

**Deep-water Corals**

A general discussion of deep-water corals that occur in Atlantic Canada is included in Husky's new drill centre EA (Section 5.5.1.1.1 *in* LGL 2006a). It is noteworthy that the comprehensive summary report on deep-water corals and their habitats off Atlantic Canada (Mortensen et al. 2006) was made possible through the financial support of the oil and gas industry through the Environmental Studies Research Fund (ESRF).

The recent analyses of two datasets obtained from DFO Newfoundland Region (i.e., Fisheries Observer Program 2004-2006, and Scientific Survey, 2003-2005) indicated the occurrence of corals along the eastern slope region of the Grand Bank, the slope region proximate to the Bonavista Cod Box, and along the northern slope of the Flemish Cap (Edinger et al. 2007). The slope area proximate to the Bonavista Cod Box lies in the southern part of an identified priority area for coral conservation that extends between Funk Island Spur and Tobin's Point (Edinger et al. 2007). The southern extent of this particular area is located about 100 km northwest of the Project Area.

Wareham and Edinger (*in press*) mapped the distribution and diversity of deep-sea corals off the coasts of Newfoundland, Labrador and southeast Baffin Island using incidental by-catch from scientific surveys (2002-2006) and fisheries observations aboard commercial vessels (2004-2006). While the scientific survey data alone did not identify the Funk Island Spur/Tobin's Point area as a coral species richness "hotspot", fisheries observations did indicate abundant or diverse corals around Tobin's Point and the Flemish Cap.

Using DFO scientific survey data (2003-2005) and shrimp industry scientific survey data (2005), Edinger et al. (*in press*) mapped coral hotspots in Newfoundland and Labrador waters and compared the diversity and abundance of ten groundfish species and two invertebrate species among five coral classes. Preliminary analysis indicated that nearly all fish species included in the study were more abundant in coral classes than in non-coral classes in at least one depth range, and that witch flounder showed greatest abundances in the same coral class at all depth ranges. Although Edinger et al. (*in press*) did not find any dramatic relationships between corals and abundance of groundfish and invertebrates, there was a weak but statistically significant positive correlation between coral species richness and fish species richness. The authors were not able to conclude if the correlation was coincidental. However, based on studies with shallow water coral communities, it is reasonable to suggest that certain habitats that support diverse corals are also likely to support diverse assemblages of fish.

### 4.2.2 Profiles of Commercially-Important Species

Based on recent DFO Maritimes and Newfoundland and Labrador Regions commercial fishery landings data for the Project and Study areas, "important" fish and invertebrate species have been selected and described in the following sections. In 2006, over 90% of the commercial harvest within the Study Area was comprised of northern shrimp (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*); catches. The remainder of the 2006 harvest was also comprised of invertebrate catches, specifically Stimpsons surf clams (*Mactromeris polynyma*) and Greenland cockle (*Serripes groenlandica*). More details concerning these commercial fisheries are discussed in Section 4.3.

The four invertebrate species mentioned above were profiled in the Husky new drill centre construction and operations program EA and addendum (Sections 5.5.2 *in* LGL 2006a, 2007c). Profiles of northern shrimp and snow crab are also included in the Petro-Canada Jeanne d'Arc Basin 3-D Seismic Program EA (LGL 2007a).

Additional information for snow crab that became available after LGL (2006a, 2007c) has been included in the following subsection. No additional information for the other three invertebrate species was available at the time of writing.

#### 4.2.2.1 Snow Crab

While NAFO Division 3L offshore snow crab recruitment and exploitable biomass in 2006 remained low relative to levels of the late 1990s, the inshore recruitment and exploitable biomass on this Division increased in 2006 and recruitment prospects appeared promising. For Division 3O, survey indices for snow crab are unreliable. Recruitment in 3O has been low in recent years and short term prospects are uncertain (DFO 2007a,b). Essentially all of the 2006 commercial snow crab harvesting in the Project Area occurred within 50 km of the 200 m isobath inside the Canadian EEZ (see Section 4.3 on 'Commercial Fisheries').

### 4.2.3 DFO Research Survey Data, 2005-2006

Data collected during 2005 and 2006 spring and fall DFO RV research surveys in areas overlapping with the Study Area were analyzed and catch weight results are presented in this section (Table 4.1). Data collected during the 2007 RV surveys were not yet available at the time this EA was prepared. Figures 4.1 to 4.10 indicate the distributions of catch weight for these species in the Study Area and Project Area. Figure 4.11 indicates the distribution of catch abundance for Greenland shark (*Somniosus microcephalus*) in the Study Area and Project Area.

**Table 4.1. Species/Groups with highest catch weights during DFO RV surveys in the Study Area and Project Area, 2005 and 2006.**

| **Project Area** | | **Study Area** | |
|---|---|---|---|
| **2005** | **2006** | **2005** | **2006** |
| **16,161 kg** | **21,921 kg** | **23,051 kg** | **24,092 kg** |
| Shrimp (26.0%) | Shrimp (26.8%) | Shrimp (21.3%) | Shrimp (25.9%) |
| Deepwater redfish (19.2%) | Greenland shark (18.2%) | Sand lance (14.9%) | Greenland shark (16.6%) |
| Sand lance (7.5%) | Deepwater redfish (12.3%) | Deepwater redfish (13.9%) | Deepwater redfish (11.2%) |
| Thorny skate (7.3%) | Roughhead grenadier (5.9%) | Capelin (13.5%) | Roughhead grenadier (5.2%) |
| Brittlestars (7.2%) | Greenland halibut (4.6%) | Thorny skate (5.9%) | American plaice (5.0%) |
| Roughhead grenadier (5.7%) | Thorny skate (4.1%) | Roughhead grenadier (5.4%) | Yellowtail flounder (4.5%) |
| Capelin (4.3%) | American plaice (4.1%) | Brittlestars (5.0%) | Greenland halibut (4.3%) |
| Greenland halibut (4.5%) | Sand lance (3.8%) | Greenland halibut (3.3%) | Sand lance (4.2%) |
| Unspecified invertebrates (3.4%) | Capelin (2.7%) | Unspecified invertebrates (2.6%) | Thorny skate (4.1%) |
| American plaice (2.8%) | Atlantic cod (1.9%) | American plaice (2.5%) | Capelin (2.9%) |

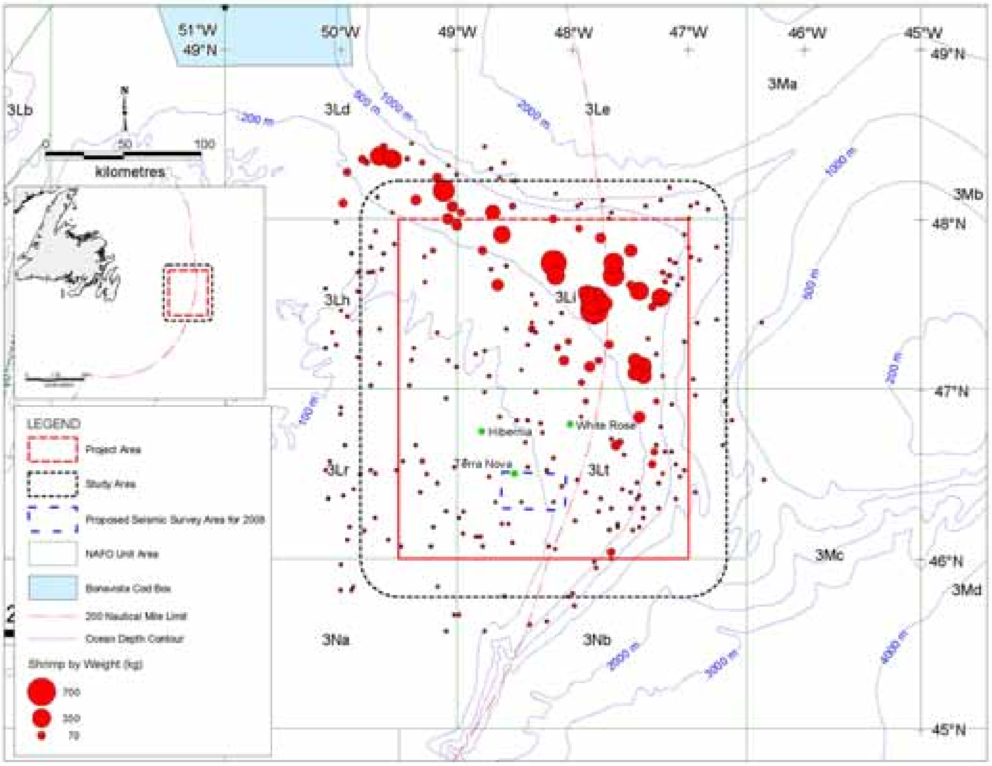



**Figure 4.1. Distribution of shrimp (*Pandalus* sp.) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

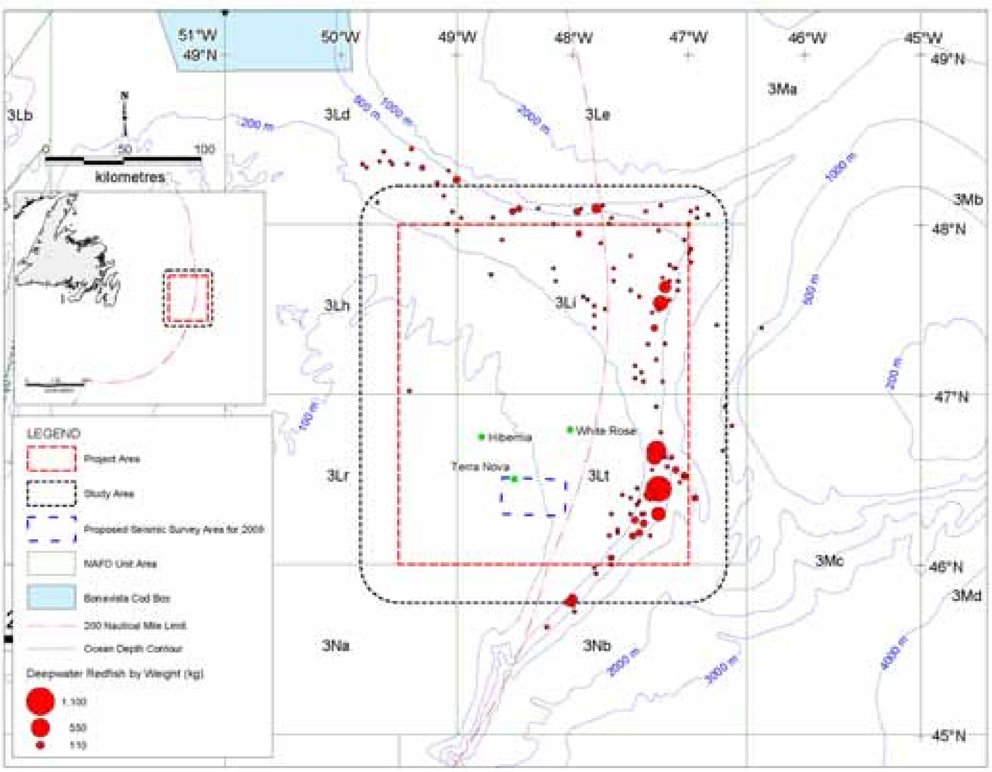



**Figure 4.2. Distribution of deepwater redfish (*Sebastes mentella*) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

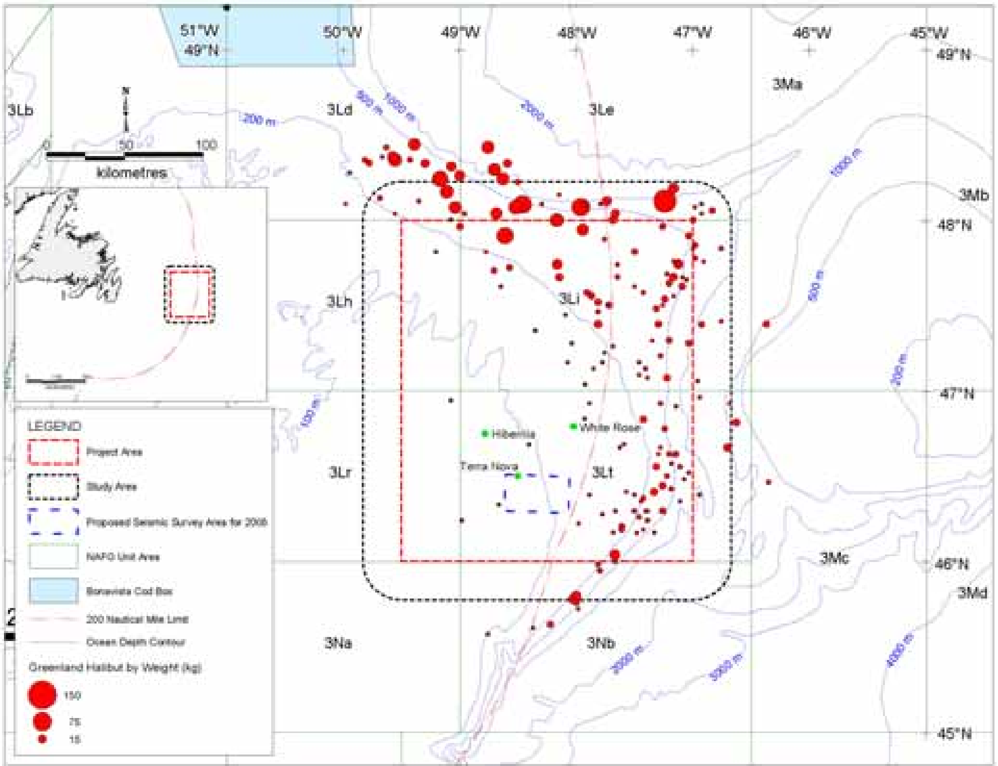



**Figure 4.3. Distribution of Greenland halibut catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

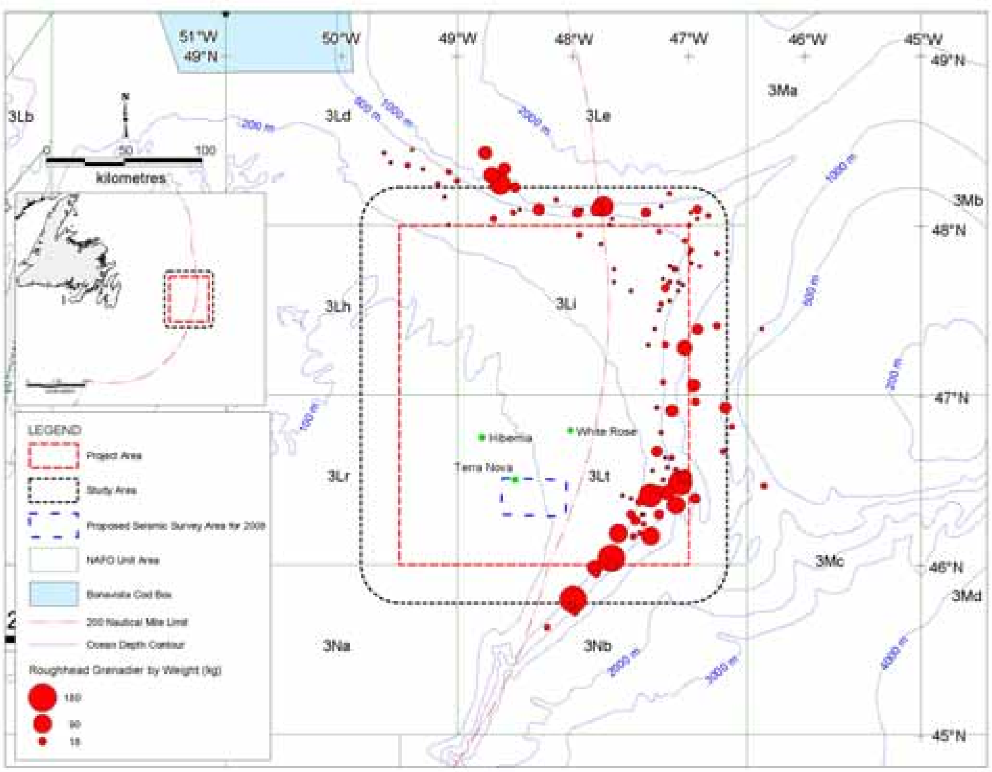



**Figure 4.4. Distribution of roughhead grenadier (*Macrourus berglax*) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

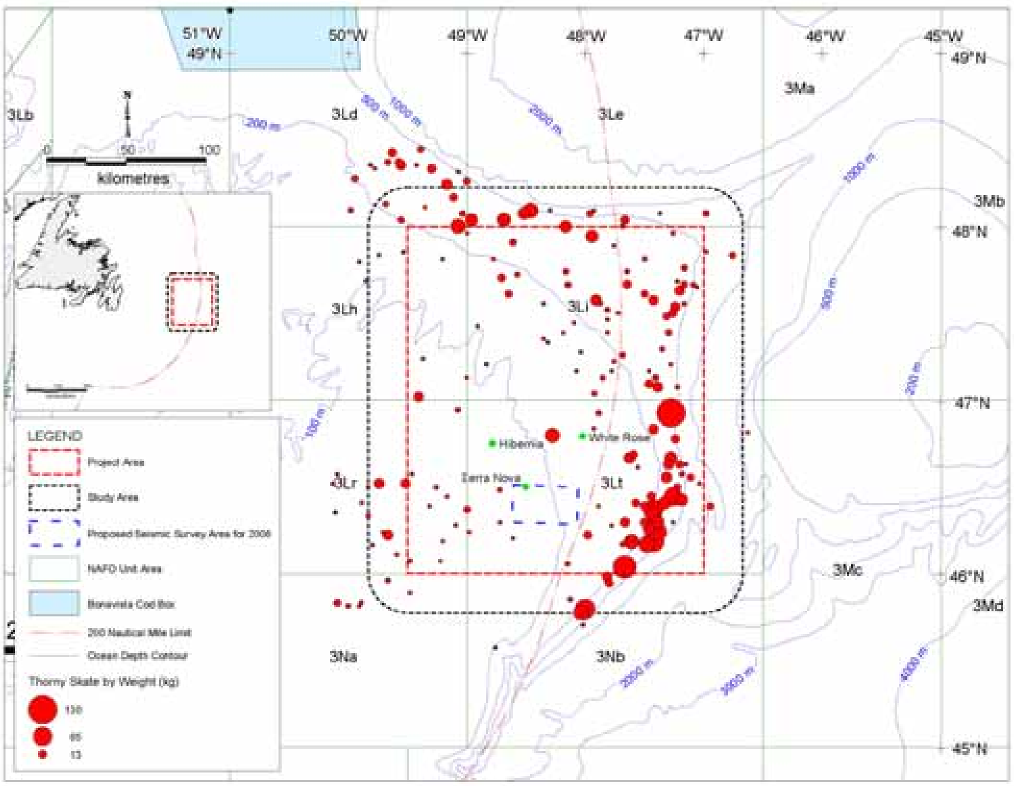



**Figure 4.5. Distribution of thorny skate (*Amblyraja radiata*) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

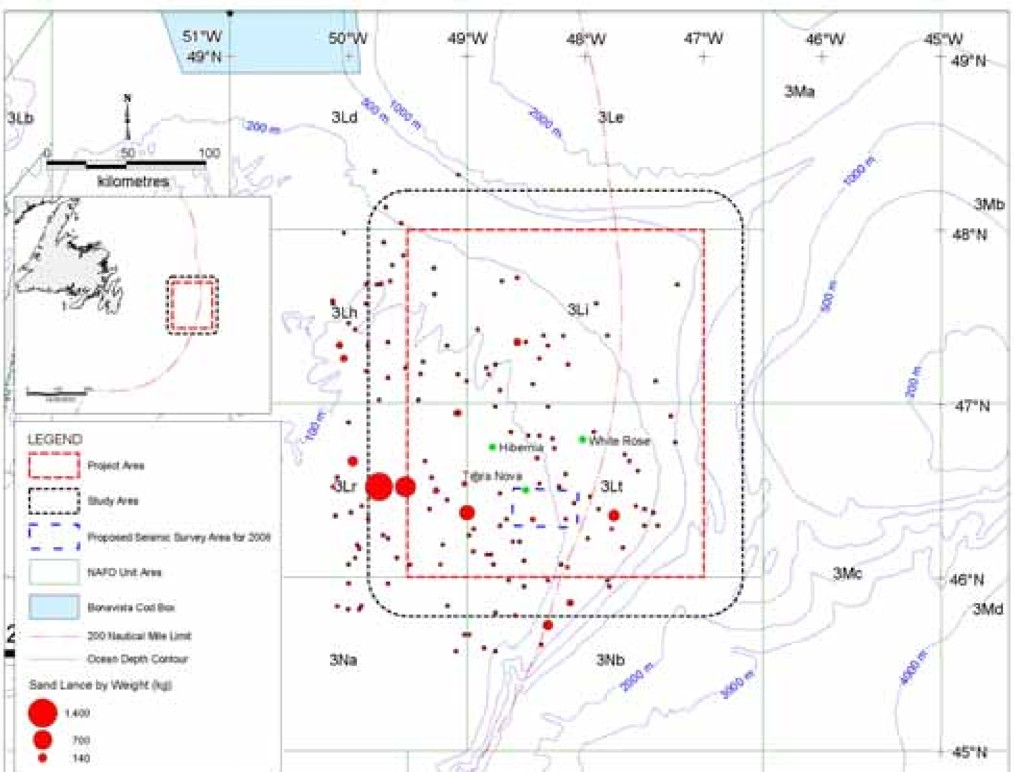



**Figure 4.6. Distribution of sand lance (*Ammodytes* spp.) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

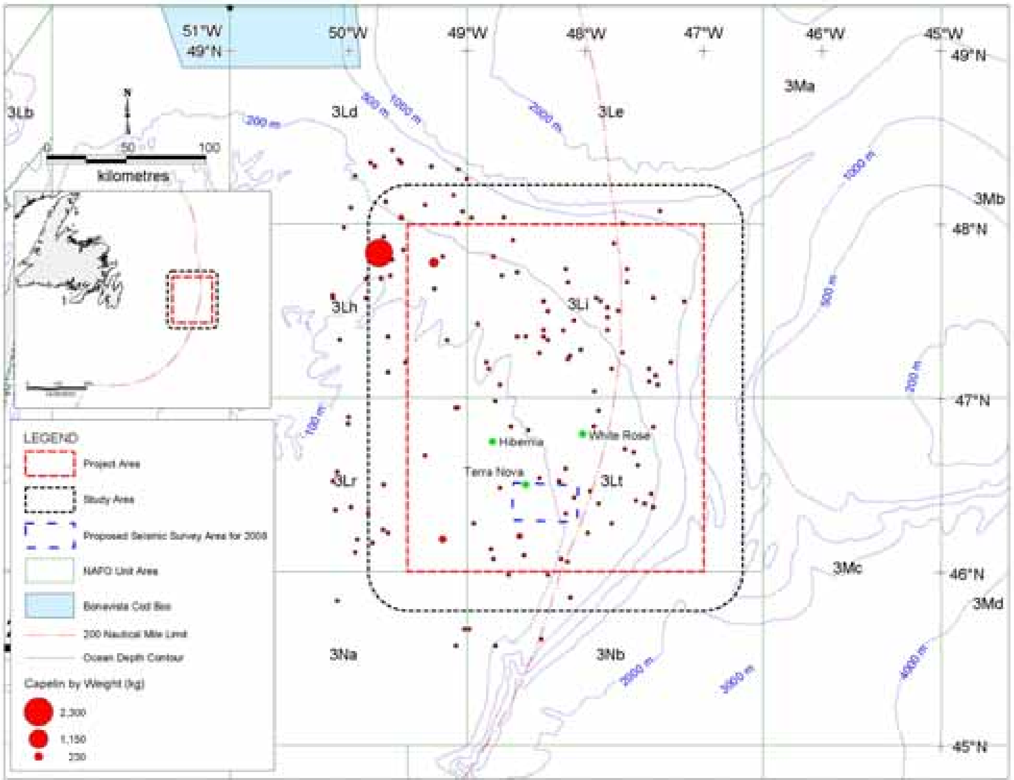



**Figure 4.7. Distribution of capelin (*Mallotus villosus*) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

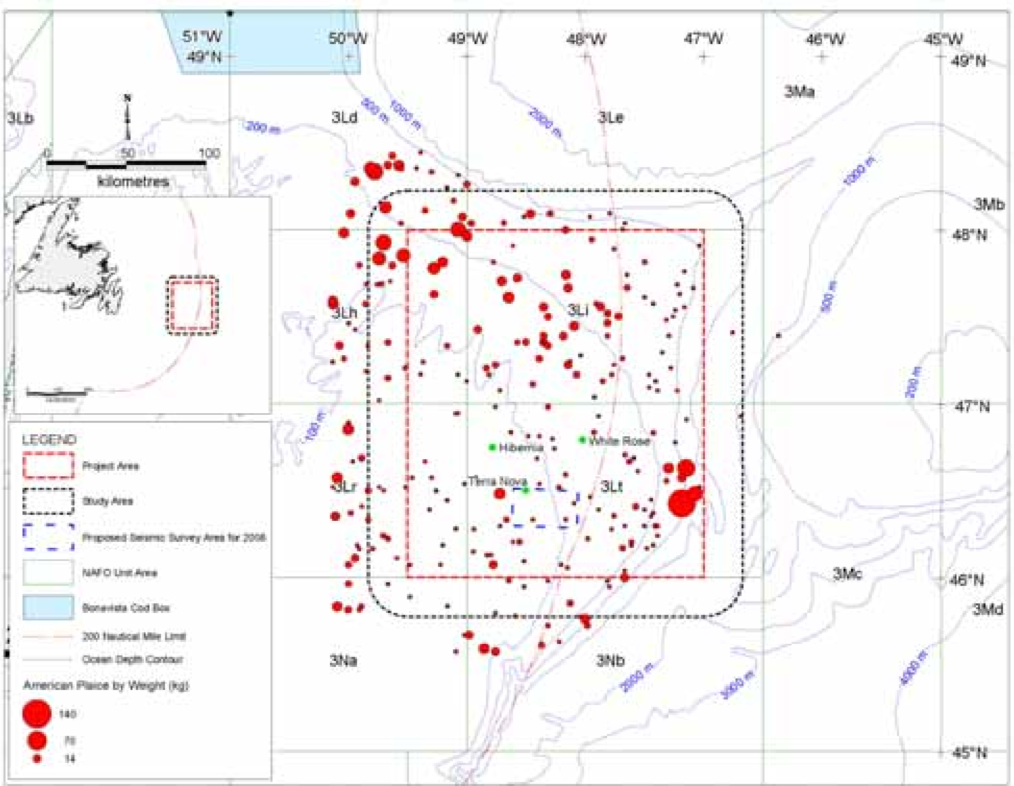



**Figure 4.8. Distribution of American plaice (*Hippoglossoides platessoides*) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

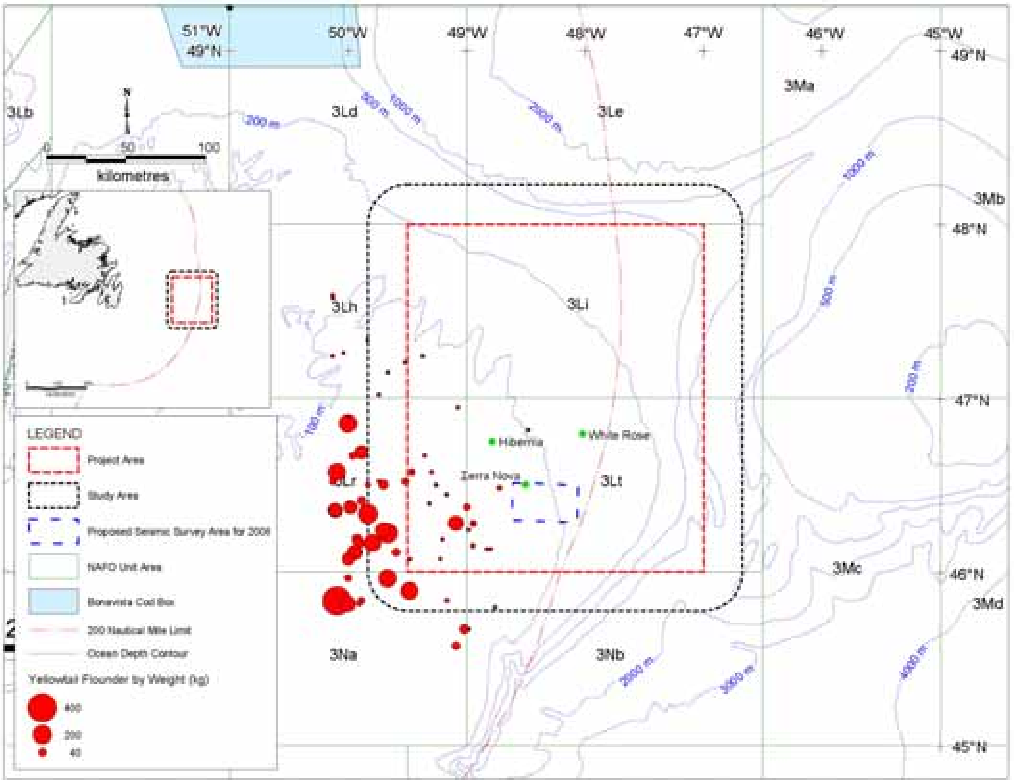



**Figure 4.9. Distribution of yellowtail flounder (*Limanda ferruginea*) catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

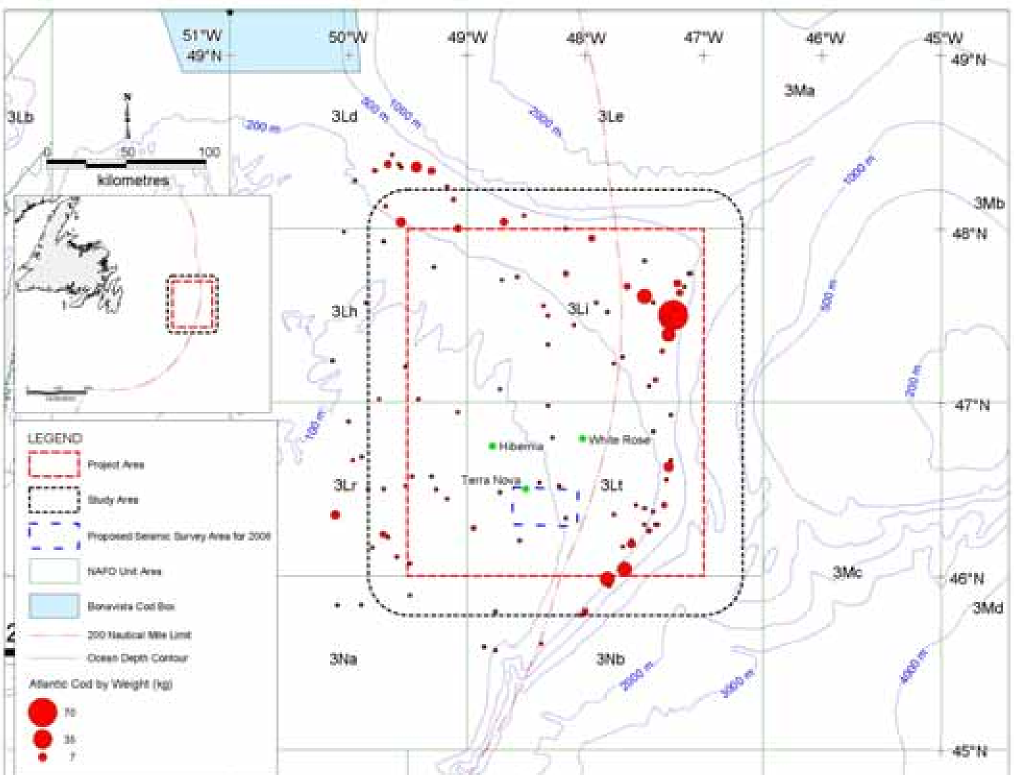



**Figure 4.10. Distribution of Atlantic cod catch weights, DFO RV Surveys, 2005 and 2006 (combined).**

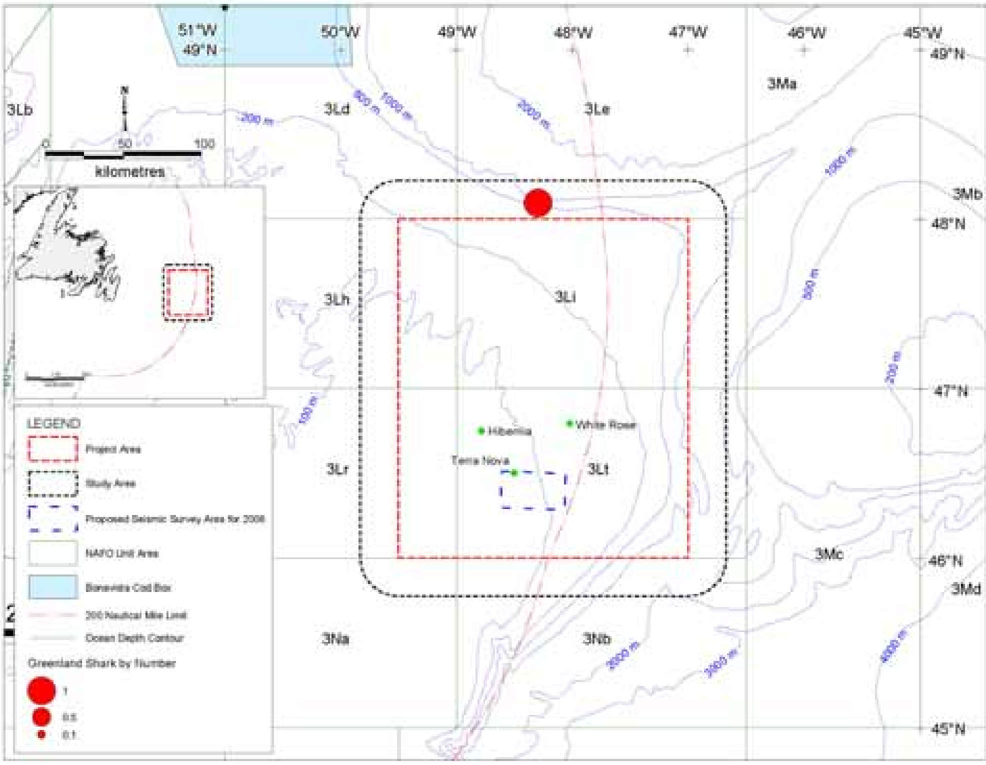



**Figure 4.11. Distribution of Greenland shark (*Somniosus microcephalus*) catch abundance, DFO RV Surveys, 2005 and 2006 (combined).**

Atlantic cod accounted for less than 1% of the total catch weight in the Study Area during the 2005 and 2006 RV surveys. All three species of wolffish listed on Schedule 1 of the *Species at Risk Act* (*SARA*) were captured during both years of RV surveys in the Project Area. In terms of abundance, more Atlantic wolffish (721) was caught than either of the other species (northern wolffish [63] and spotted wolffish [91]). See Figures 4.12 to 4.14 for distribution of wolffish catch abundance in Study Area and Project Area.

Based on the data collected within the Study Area in 2005 and 2006, species whose overall catch weights were largest in June included deepwater redfish, capelin, American plaice, yellowtail flounder, Atlantic cod, Atlantic wolffish, and spotted wolffish. The species with overall catch weights that were largest during the October to December period included shrimp and sand lance. The two-year catch weights of thorny skate, roughhead grenadier and northern wolfish were somewhat evenly distributed between the spring and fall survey times.

The depths at which the various species/species groups were caught during the 2005 and 2006 RV surveys in the Study Area varied considerably. Table 4.2 presents the average mean depth of capture and minimum and maximum depths of capture for species with highest catch weight during the two years of surveying. The three wolffish species are also included because of their *SARA* Schedule 1 listings. Species with catch distributions over much of the Study Area include shrimp, thorny skate, capelin, American plaice, and Atlantic cod although catch size was not evenly distributed. Species with catch distributions primarily in parts of the Study Area where water depths exceed 200 m include deepwater redfish, Greenland halibut, roughhead grenadier and the three wolffishes. Sand lance and yellowtail flounder catches occurred primarily in areas where water depths were <200 m and <100 m, respectively.

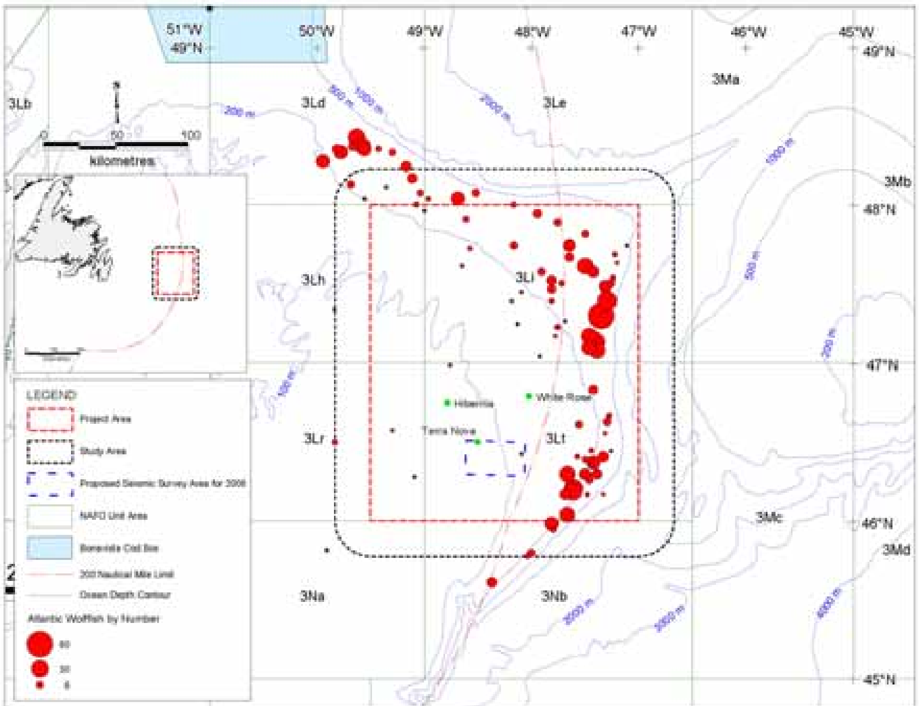



**Figure 4.12. Distribution of Atlantic wolffish (*Anarhichas lupus*) catch abundance, DFO RV Surveys, 2005 and 2006 (combined).**

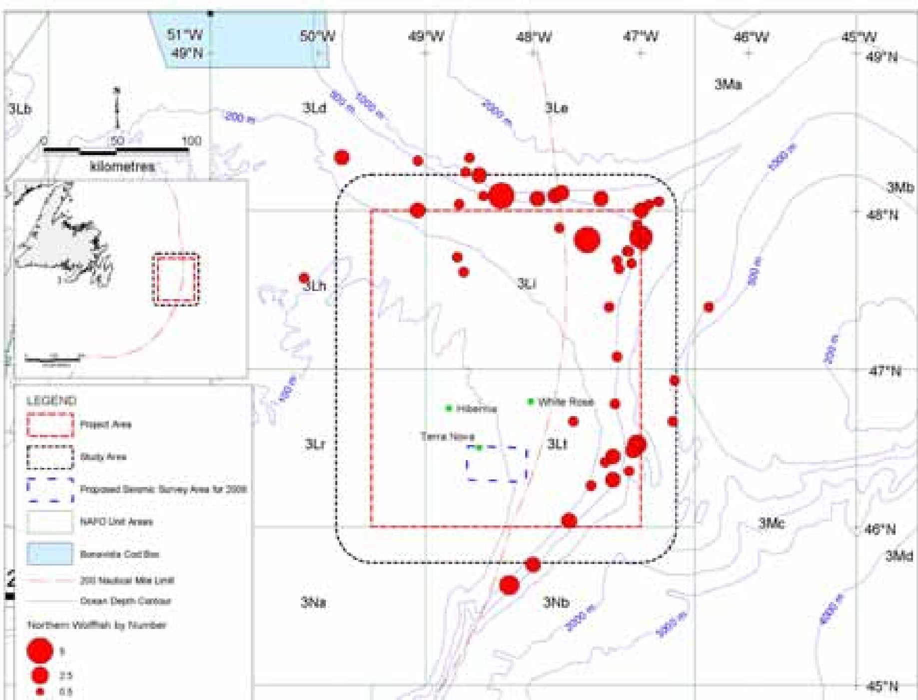



**Figure 4.13. Distribution of Northern wolffish (*Anarhichas denticulatus*) catch abundance, DFO RV Surveys, 2005 and 2006 (combined).**

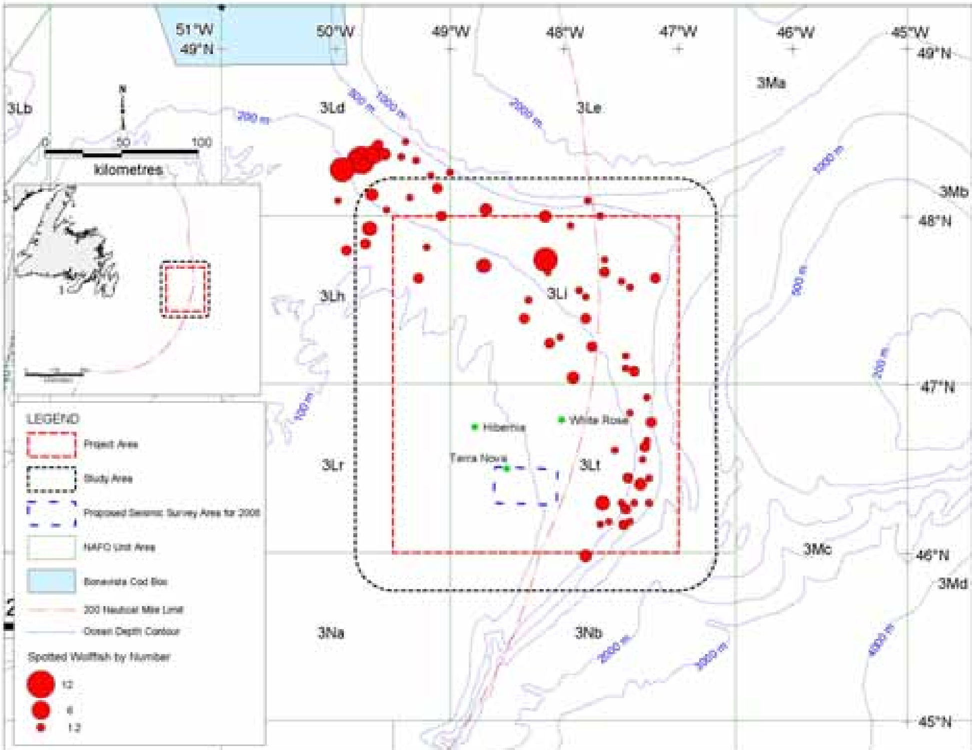



**Figure 4.14. Distribution of spotted wolffish (*Anarhichas minor*) catch abundance, DFO RV Surveys, 2005 and 2006 (combined).**

**Table 4.2. Average 'mean catch depth', and minimum and maximum catch depths during RV Surveys in the Study Area, 2005 and 2006 (combined).**

| Species/Group | Catch Depth (m) | | |
|---|---|---|---|
| | Average 'Mean Catch Depth' | Minimum | Maximum |
| Shrimp | 299 | 59 | 1,299 |
| Deepwater redfish | 399 | 73 | 1,160 |
| Capelin | 175 | 60 | 613 |
| Sand lance | 124 | 59 | 479 |
| Roughhead grenadier | 542 | 166 | 1,299 |
| American plaice | 213 | 58 | 1,160 |
| Thorny skate | 266 | 58 | 879 |
| Yellowtail flounder | 67 | 58 | 99 |
| Greenland halibut | 416 | 59 | 1,299 |
| Greenland shark | 610 | 610 | 610 |
| Atlantic cod | 211 | 58 | 483 |
| Atlantic wolffish | 254 | 63 | 672 |
| Northern wolffish | 528 | 155 | 1,172 |
| Spotted wolffish | 268 | 143 | 557 |

#### 4.2.3.1 Profiles of Some Species Identified in Analysis of RV Survey Data

Many of the species identified with respect to the 2005-2006 DFO RV surveys have been profiled in recent EAs (LGL 2006a, 2007c) of oil and gas industry activities in the same general area as the Study Area of this EA. The following profiles describe fish species not discussed in either of the recent EAs indicated above.

**Redfishes**

Three species of redfish occur in the Flemish Cap area of the Study Area. They include the Atlantic golden redfish (*Sebastes marinus*), the deepwater beaked redfish (*Sebastes mentella*), and the Acadian beaked redfish (*Sebastes fasciatus*). Redfish are ovoviviparous, meaning the eggs are fertilized internally and spawning is characterized by the direct extrusion of larvae in the water column. Redfish mating typically occurs in late fall/early winter, followed by larval extrusion during the following spring/summer (St. Pierre and de Lafontaine 1995).

Redfish typically feed on various zooplankton (e.g., euphausiids and other planktonic crustaceans, jellyfish, and hydroids). The golden and deepwater redfish also prey on various nektonic species (e.g., herring, capelin, cod, and grenadier) and the Acadian redfish prey includes various zoobenthic species (e.g., benthic crustaceans, amphipods, etc.) (Fishbase website, http://www.fishbase.org).

During bottom trawl surveys on the Flemish Cap in June and July 2006, the distribution of redfish varied by species. *Sebastes marinus* catches were highest in areas of the Flemish Cap where water depths ranged from 180 to 250 m. *Sebastes mentella* catches were highest in areas of the Flemish Cap where water depths ranged from 250 to 365 m, particularly on the southern and southwestern parts of the Cap. *Sebastes fasciatus* catches were highest in areas of the Flemish Cap where water depths ranged from 181 to 365 m. Catches of the latter two species were more widespread on the Flemish Cap than for *S. marinus* (Casas and Troncoso 2007).

**Sand Lance**

The sand lance is one of the major unexploited fish resources on the northwest Atlantic. This fish is typically found in shallow water areas (<100 m) where substrate is predominantly comprised of sand and light gravel. The sand lance has a habit of burrowing into the substrate between feeding periods, possibly to avoid strong tidal currents (Underwater World, Fisheries and Oceans Canada website, http://www.dfo-mpo.gc.ca/zone/underwater_sous-marin/SandLance).

Spawning by sand lance typically occurs on sandy substrate in shallow water (<100 m) during the winter. The fertilized eggs adhere to the substrate and remain there during embryonic development. Hatched larvae rise to the surface waters where they remain for a few weeks before descending to the bottom (Underwater World, Fisheries and Oceans Canada website, http://www.dfo-mpo.gc.ca/zone/underwater_sous-marin/SandLance).

During feeding, sand lance move out of the substrate and up into the water column, often at night. Some believe that this fish sometimes moves to surface in order to feed. Copepods often are the prey of choice. The sand lance is a major food item for Atlantic cod, Atlantic salmon and numerous other marine fishes (Underwater World, Fisheries and Oceans Canada website, http://www.dfo-mpo.gc.ca/zone/underwater_sous-marin/SandLance).

**Roughhead Grenadier**

The benthopelagic roughhead grenadier typically inhabits depths ranging from 200 to 600 m. It is thought that spawning by this dioecious deepwater species occurs in winter/early spring. Fertilization by roughhead grenadier is external. Prey species of the roughhead grenadier typically include amphipods, polychaetes and various small crustaceans (Fishbase website, http://www.fishbase.org; Scott and Scott 1988).

Based on results of bottom trawl surveys on the Flemish Cap from 1991 to 2005, the highest estimated biomass of roughed grenadier occurred in areas where water depth exceeded 540 m. The surveys were conducted in areas with water depths ranging from 200 to 720 m (Murua and Gónzalez 2007).

**Thorny Skate**

In the western Atlantic, the thorny skate is widely distributed with the centre of its distribution on the Grand Banks. Presently, the greatest thorny skate density on the Grand Banks occurs on the shallow southwestern bank and shelf break, and into the Laurentian Channel in late fall and winter, and along the outer reaches of the banks in spring and summer. During recent years, thorny skate abundance has been seen to decline most in the northern extent of its range (Kulka et al. 2004). .

This skate is considered sedentary, rarely moving more than 100 km during their lifetime. Mating is by internal fertilization and appears to occur throughout the year. Thorny skate egg cases are released by the female and hatching occurs approximately six months later. Young skates emerge from the egg case as free-swimming fish. They are known to feed on polychaetes, crabs, whelks, sculpins, redfish, sand lance and haddock, with fish being more important prey items for larger skate (Scott and Scott 1988).

**Capelin**

Capelin is a small, pelagic, schooling species that spends most of its life history in the offshore waters. Since 1990, the distribution of capelin has expanded from being centred in Newfoundland to including the Flemish cap and Scotian Shelf. Spawning typically occurs on inshore beaches in late July and August except for the NAFO Divisions 3NO capelin stock which spawns offshore. A capelin is a planktivore, feeding primarily on copepods, euphausiids and amphipods. Some of the main predators of this small pelagic fish include seals, Atlantic cod, Greenland halibut and American plaice (Carscadden et al. 2001).

**American Plaice**

The American plaice typically inhabits depths ranging from 70 to 275 m, although it also occurs in shallower and deeper areas. Generally, this flatfish lives on soft substrate. Spawning by this dioecious species occurs in the spring, often in early April on the Flemish Cap. Fertilization is external and the developing eggs are buoyant and occur near the water's surface. Time to larval hatch is temperature dependent but typically occurs within two weeks of fertilization. The larvae are planktonic during development until settlement to bottom occurs. The American plaice typically feeds on polychaetes, echinoderms, molluscs, crustaceans and fish, and is preyed upon by various fish species and marine mammals (Fishbase website, http://www.fishbase.org; Scott and Scott 1988).

During bottom trawl surveys on the Flemish Cap in June and July 2006, the densest American plaice distribution was found at the shallowest portion of the Flemish Cap where water depth was less than 150 m. American plaice were also caught in areas where depth ranged up to 1000 m. Catches were made in a relatively restricted area in the south-southeastern part of the Flemish Cap (Casas and Troncoso 2007).

### 4.2.4 Invertebrate and Fish Spawning

Spawning by the forementioned invertebrates and numerous fish species was also discussed in the recent Husky new drill centre EA (Section 5.5.4 *in* LGL 2006a).

Table 4.3 provides information on typical spawning times and vertical distribution of eggs and larvae for species likely to spawn within the Study Area. The species include the four primary commercial invertebrate species discussed above, fishes caught during DFO RV surveys in 2005 and 2006, and wolffishes and Atlantic cod which have some status under the *SARA*.

**Table 4.3. Spawning specifics of notable invertebrate and fish species likely to spawn within the Study Area.**

| Species | Occurrence of Planktonic Eggs/Larvae | Timing of Eggs and Larvae | Depth Distribution of Eggs/Larvae |
|---|---|---|---|
| Snow crab | Eggs: No<br>Larvae: Yes | Larval hatch generally occurs in late spring/summer.<br>Larvae remain planktonic for 3 to 4 months. | Developing fertilized eggs carried by female at bottom.<br>Larvae occur in upper water column. |
| Northern shrimp | Eggs: Yes (attached to female)<br>Larvae: Yes | Spawning typically occurs in late June/early July.<br>Eggs remain attached to females from late summer/fall until larval hatch the following spring/summer.<br>Larvae remain planktonic in upper water column for a few months. | Egg depth distribution depends on location of females in the water column.<br>Larvae are in upper water column. |

**Table 4.3 (Continued).**

| Species | Occurrence of Planktonic Eggs/Larvae | Timing of Eggs and Larvae | Depth Distribution of Eggs/Larvae |
|---|---|---|---|
| Stimpson's surf clam | Eggs: Yes<br>Larvae: Yes | Late summer/fall spawning | Eggs occur somewhere in water column<br><br>Larvae occur in the upper water column. |
| Greenland cockle | Poorly understood | Poorly understood | Poorly understood |
| Redfishes | Eggs: No<br>Larvae: Yes | Larval extrusion typically occurs in late spring/summer months. | Larvae are pelagic. |
| Thorny skate | Eggs: No<br>Larvae: No | Some speculation that egg cases are extruded throughout the year. | Females release egg capsules, each containing a single embryo. Upon hatching, young skates are fully developed. Embryo development occurs at ocean bottom. |
| Roughhead grenadier | Poorly understood | Likely winter/early spring spawning | Poorly understood |
| American plaice | Eggs: Yes<br>Larvae: Yes | Eggs and larvae planktonic during spring/summer. | Eggs and larvae occur in upper water column. |
| Yellowtail flounder | Eggs: Yes<br>Larvae: Yes | Spawning typically between May and September, peaking in June | Both eggs and larvae occur in the upper water column |
| Atlantic cod | Eggs: Yes<br>Larvae: Yes | Spawning primarily between April and June. | Fertilized eggs and larvae may occur anywhere within the upper 100 m of the water column, eggs generally most concentrated in the upper 10 m. |
| Wolffishes | Eggs: No<br>Larvae: Yes | Spawning from early fall to early winter. | Eggs are typically benthic/demersal while the larvae are semipelagic, sometimes occurring in near surface waters. |

# 4.3. Commercial Fisheries

This section describes the domestic commercial fisheries in the Project Area and Study Area for SHC's Seismic Survey Program for the Jeanne d'Arc Basin Area, 2008-2016. It also provides additional historical context for the area's foreign and domestic commercial fisheries.

Section 4.2.2 of this assessment describes the biological characteristics and status of the main commercial and other marine species.

## 4.3.1. Data and Information Sources

The Study and Project areas are primarily within NAFO management Division 3L. [A relatively small part of the Study Area overlaps Division 3N in the south.] Most of the Project and Survey areas are within Canada's 200-mile EEZ, as is the potential 2008 survey area (see Figure 4.18). The data used to characterize the fisheries in this assessment report are quantities of harvest rather than harvest values. Quantities are directly comparable from year to year, while values (for the same quantity of harvest) may vary annually with negotiated prices, changes in exchange rates and fluctuating market conditions. Although some species vary greatly in landed value (e.g., snow crab vs. pollock), in terms of potential interference with fisheries, it is the level of fishing effort and gear utilized (better represented by quantities of harvest) that is more important. Value is important, and is carefully evaluated, in case of a compensation incident, as described in the mitigations sections of this assessment.

*DFO Datasets*. The commercial fisheries analysis that follows is based primarily on data derived from the DFO Newfoundland and Labrador and Maritimes Region catch and effort datasets (DFO 1987-2006). The Maritimes Region data are used since some Nova Scotia landed harvest by Nova Scotia-based vessels also occurs in Division 3L and 3N, and is mainly northern shrimp. (NS-landed shrimp make up about 10% of the Study and Project areas' harvest.) This fishery is conducted in the same areas as the NL fishing. Foreign catches landed outside the regions are not included in the DFO data sets. These, too, are primarily shrimp. The data used in the report represent all catch landed within Newfoundland and Labrador region.

DFO Datasets for 1987 to 2006 are used for the historical overview, focusing on NAFO Unit Areas 3Lt and 3Li (the majority of the Project Area), while the detailed analysis of fishing activity specifically in the Study and Project Area employs DFO data for the most recent available years (2004 – 2006), since fishing activities in the area have changed significantly in the last decade or so. [5]

The DFO catch data in the Study and Project areas are georeferenced (typically >95% of the harvest, by quantity), so that past harvesting locations can be plotted. These locations are shown on the fisheries maps in this section. The positions given in the datasets are those recorded in the vessel's fishing log, and are reported in the database by degree and minute of latitude and longitude; thus the positions should be accurate within approximately 0.5 nautical mile (0.9 km) of the reported co-ordinates. For some gear, such as mobile gear towed over an extensive area, or for extended gear, such as longlines, the reference point does not represent the full distribution of the gear or activity on the water. However, over many data entries, the reported locations create a fairly accurate indication of where such fishing activities occur and these kinds of database locations have been groundtruthed by Canning & Pitt Inc. with fishers in Atlantic Canada over many years.

*NAFO Datasets.* For the regional historic overview, datasets from the Northwest Atlantic Fisheries Organization (NAFO) are used to quantify 3L harvesting (STATLANT 21A dataset for 1985-2004). This captures both domestic and foreign fishers (beyond the 200 nmi Exclusive Economic Zone), though not all fisheries are reflected in these data. For instance, shrimp is included, while snow crab is not since in this region it is managed wholly by Canada.

[5] The data for all three years are still classified by DFO as preliminary, though the species data used in this report are not likely to change to any significant extent when the data are finalized. The most recent DFO data were accessed in March 2007 for 2006.

*Consultations.* The fisheries consultations and contacts for this assessment included representatives of Fisheries and Oceans Canada (DFO), Environment Canada, the Natural History Society, One Ocean, the Fish, Food and Allied Workers Union (FFAW), the Association of Seafood Producers, Fishery Products International, the Groundfish Enterprise Allocation Council (Ottawa), Clearwater Seafoods (NS) and Icewater Seafoods. The consultations were undertaken to inform stakeholders about the proposed SHC survey, to gather information about fishing activities, and to determine any issues or concerns. Those consulted are listed in Appendix B. Fisheries-related information provided is reported under the discussions of the commercial fisheries below, and the issues raised during the consultations are discussed in Section 4.3.4.

*Other Sources*. Other sources consulted for this section include fisheries management plans, quota reports and other DFO documents.

## 4.3.2. Regional Historical Overview

The fisheries in the eastern areas of NAFO 3L and 3N, the location of the proposed Study and Project areas, were dominated until the early 1990s by groundfish harvesting by stern otter trawls, primarily for Atlantic cod, American plaice and a few other species. In 1992, with the acknowledgement of the collapse of several groundfish stocks, a harvesting moratorium was declared and directed fisheries for cod virtually vanished in this area. In May 2003, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed the Atlantic cod (Newfoundland and Labrador population) as an *Endangered* species. Since the collapse of these fisheries in the area, formerly underutilized species – mainly northern shrimp (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*) – have come to replace them as the principal harvest in eastern 3L, as they have in many other areas. Figure 4.15 indicates these changes in harvesting in NAFO Unit Areas (UAs) 3Lt and 3Li (which include most of the Project and Study areas) over the last twenty years.

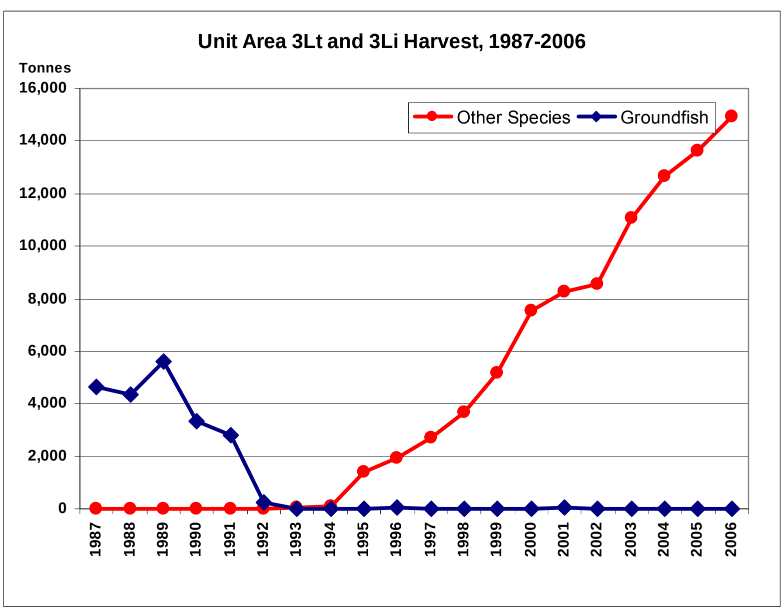



**Figure 4.15. Domestic groundfish and other species harvesting in 3Lt and 3Li, 1987 – 2006.**

The non-groundfish harvest in 3Lt and 3Li is divided almost evenly between snow crab (mainly in the south) and shrimp (to the north). Snow crab is now almost the only species harvested in 3Lt (>99% by quantity from 2000 - 2006), and in 3Li the harvest was 67% northern shrimp and 33% snow crab during the same period.

The foreign and domestic harvest of shrimp for 1984-2004 is shown below, based on NAFO data (Figure 4.16). Figure 4.17 shows the harvest recorded in the NAFO datasets for all NAFO species for this period.

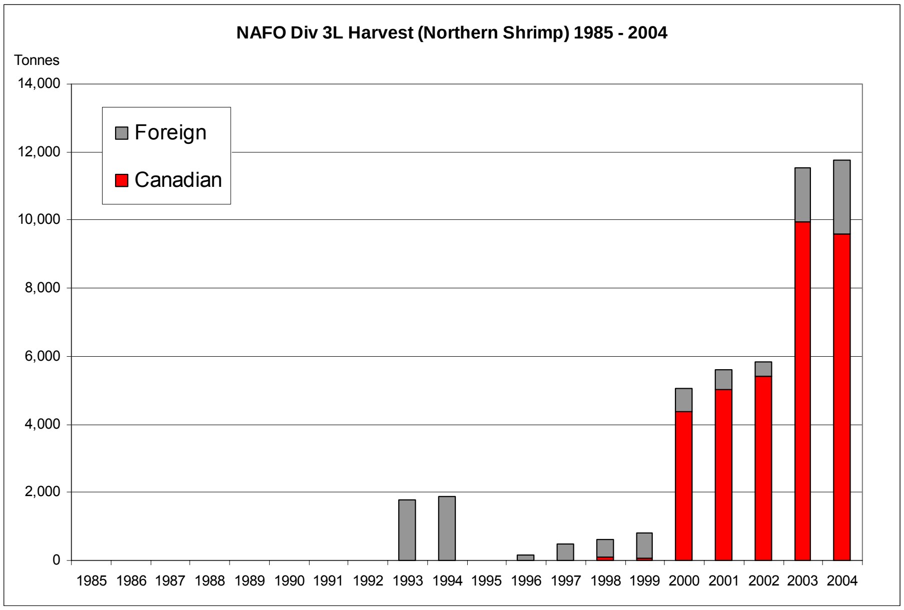



**Figure 4.16. 3L shrimp harvest, 1985-2004, foreign and domestic (NAFO Dataset).**

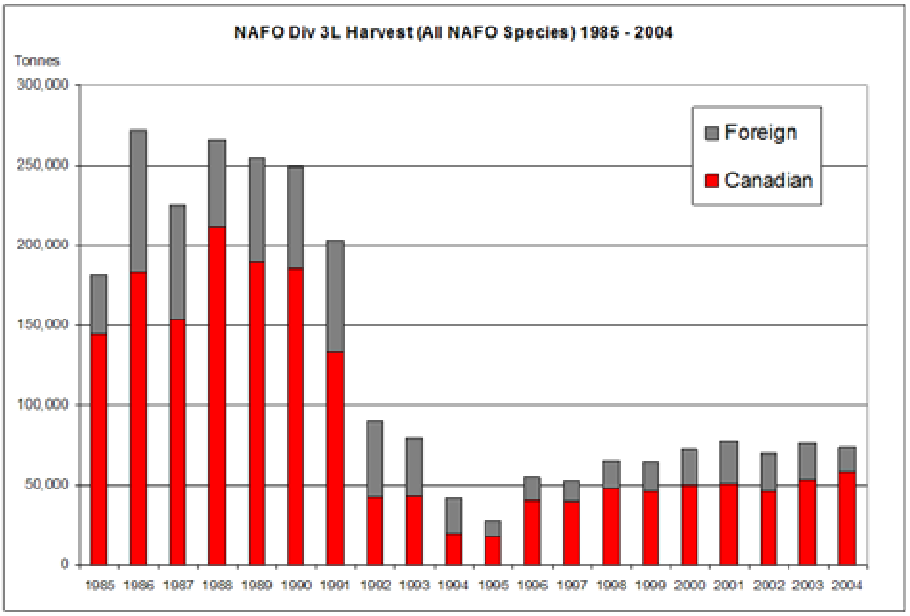



**Figure 4.17. 3L harvest, all species 1985-2004, foreign and domestic (NAFO Dataset).**

### 4.3.3. Fisheries in the Study and Project Areas

Tables 4.4 and 4.5 show the recorded harvest by species from 2004 to 2006 in the Study and Project areas, based on the DFO domestic datasets. For these years, there was no recorded harvesting within the potential 2008 survey area.

The snow crab and northern shrimp fisheries dominated the domestic harvest in both the Study and Project areas during this period.

**Table 4.4. Study Area harvest, 2004 – 2006.**

| Species | Tonnes | % of Total |
|---|---:|---:|
| **2004** | | |
| Turbot (Greenland halibut) | 94.5 | 0.5% |
| Grenadier | 15.1 | 0.1% |
| Other groundfish | 4.0 | 0.0% |
| Swordfish | 1.5 | 0.0% |
| Tuna (sp) | 0.6 | 0.0% |
| Northern shrimp | 9,087.3 | 51.9% |
| Snow crab | 8,299.2 | 47.4% |
| Total | 17,502.1 | 100.0% |
| **2005** | | |
| Northern shrimp | 10,230.5 | 56.3% |
| Snow crab | 7,931.3 | 43.7% |
| Total | 18,161.9 | 100.0% |
| **2006** | | |
| Turbot (Greenland halibut) | 22.7 | 0.1% |
| Grenadier | 4.7 | 0.0% |
| Surf clams | 485.5 | 2.4% |
| Cockles | 67.3 | 0.3% |
| Northern shrimp | 11,610.3 | 57.7% |
| Snow crab | 7,947.2 | 39.5% |
| Total | 20,137.6 | 100.0% |

**Note:** The Study Area data include the harvest from the Project Area.

**Table 4.5. Project Area harvest, 2004 - 2006.**

| Species | Tonnes | % of Total |
|---|---:|---:|
| **2004** | | |
| Northern shrimp | 7,228.3 | 50.4% |
| Snow crab | 7,099.6 | 49.6% |
| Total | 14,327.9 | 100.0% |

**Table 4.5 (Continued).**

| | | |
|---|---|---|
| **2005** | | |
| Northern shrimp | 8,394.5 | 55.3% |
| Snow crab | 6,795.7 | 44.7% |
| Total | 15,190.2 | 100.0% |
| **2006** | | |
| Surf clams | 457.9 | 2.7% |
| Cockles | 73.0 | 0.4% |
| Northern shrimp | 9,406.3 | 55.9% |
| Snow crab | 6,904.8 | 41.0% |
| Total | 16,842.0 | 100.0% |

#### 4.3.3.1. Harvesting Locations

The following maps show the domestic fishing locations on and near the eastern Grand Banks in relation to the SHC seismic survey Study and Project areas and the potential 2008 survey area. The locations shown are for all species harvested from January to December (aggregated) for 2004 (Figure 4.18), 2005 (Figure 4.19) and 2006 (Figure 4.20).

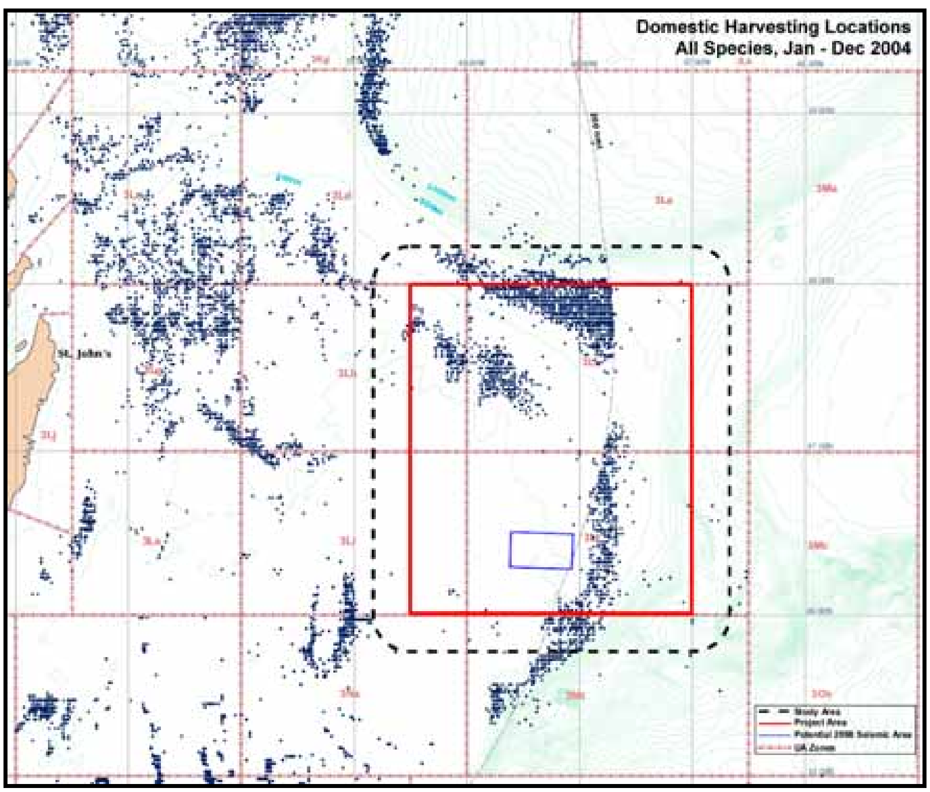



**Figure 4.18. All species harvesting locations, 2004.**

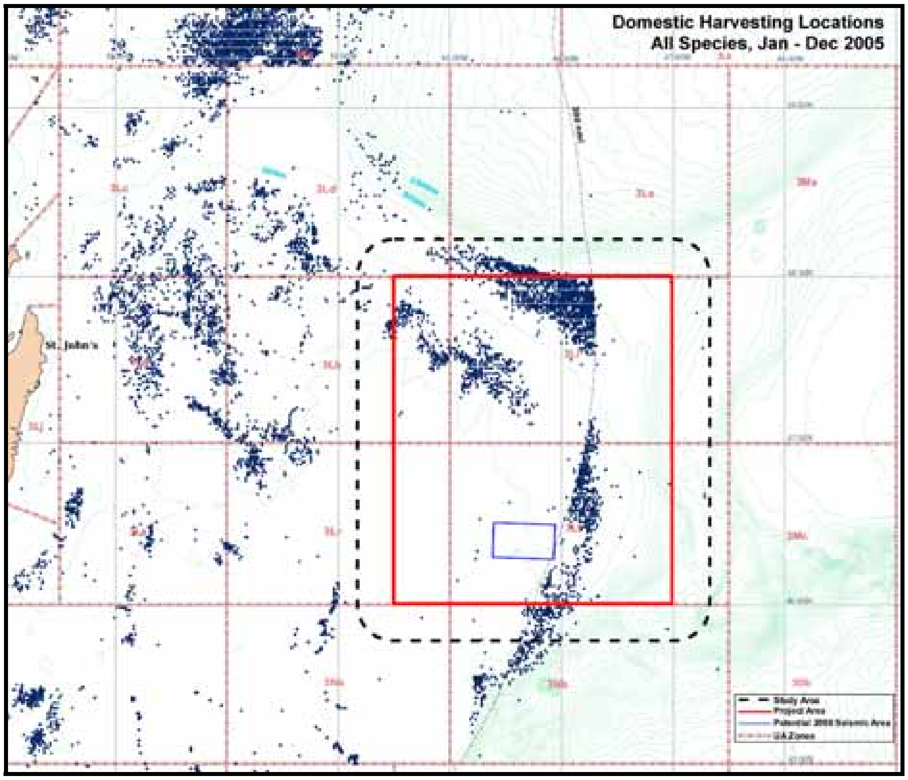



Figure 4.19. All species harvesting locations, 2005.

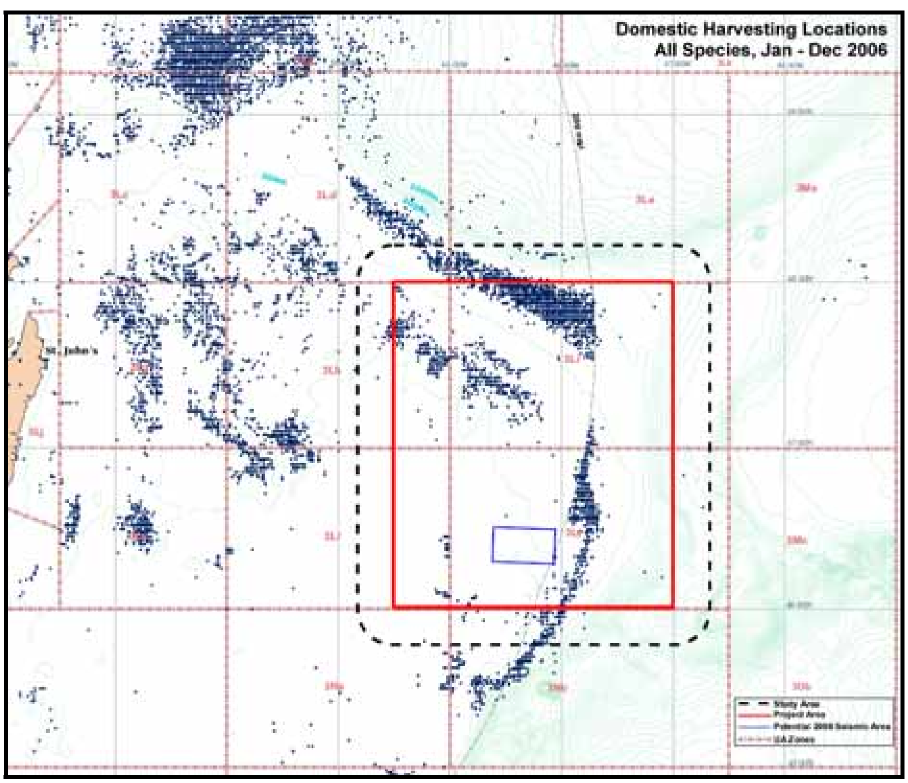



Figure 4.20. All species harvesting locations, 2006.

As the maps illustrate, most of the domestic fish harvesting in the general area is concentrated between the 100 m and 200 m contours of the eastern Grand Bank, both inside and outside the 200-mile EEZ (almost exclusively snow crab), and to the north in depths between 200 m and 1000 m (northern shrimp). The maps also illustrate that the harvesting locations tend to be very consistent from year to year, and this has been the case for most of the last decade.

#### 4.3.3.2. Harvest Timeframe

The times that commercial species are harvested may change, depending on seasons and regulations set by DFO, the harvesting strategies of fishing enterprises, or on the availability of the resource. The following graph shows the 2004 - 2006 catch by month (averaged) from the Study Area (Figure 4.21) and the Project Area (Figure 4.22). As the graph indicates, May, June and July were the most productive months during this period, in both areas, accounting for about 75% of the annual harvest.

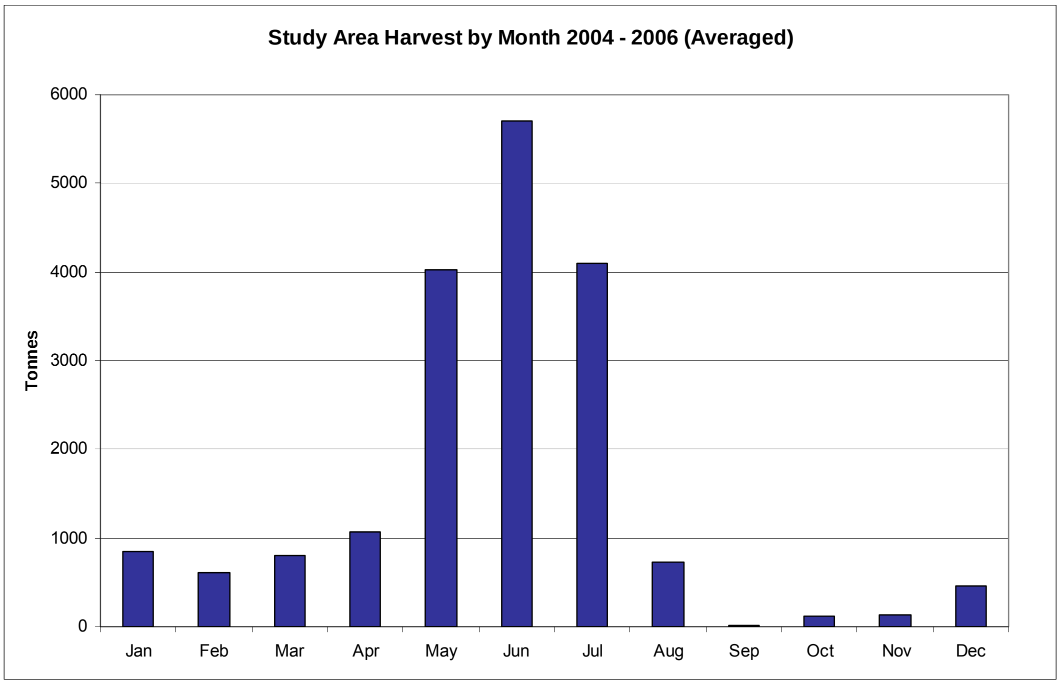



**Figure 4.21. Study Area domestic harvest by month, all species, 2004 to 2006.**

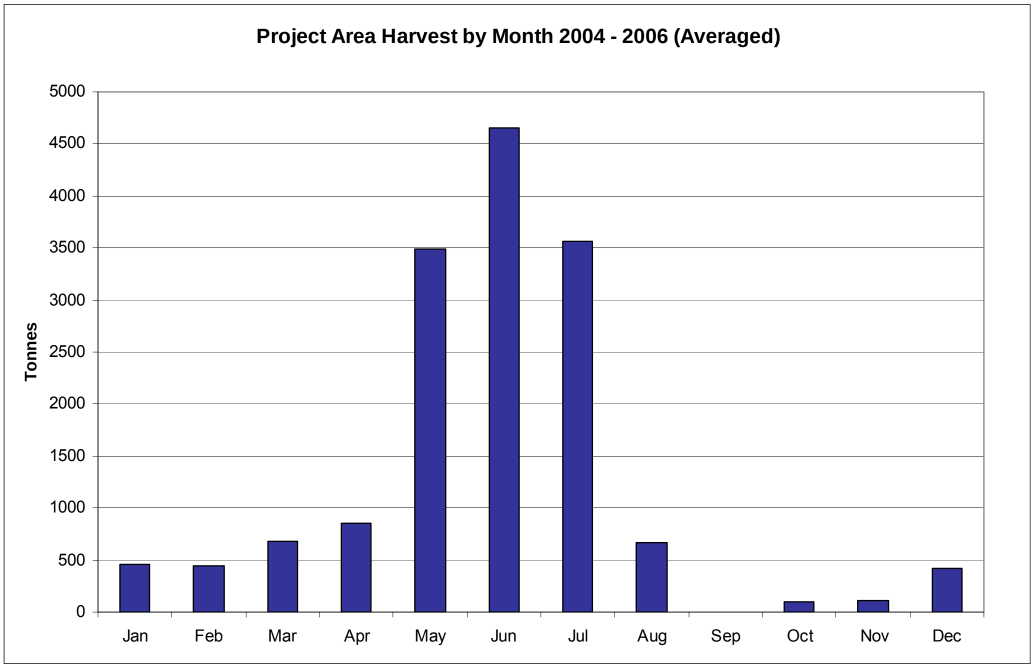



**Figure 4.22. Project Area domestic harvest by month, all species, 2004 to 2006.**

The following maps (Figures 4.23 to 4.34) show the reported domestic harvesting locations for all species by month for January to December 2006.

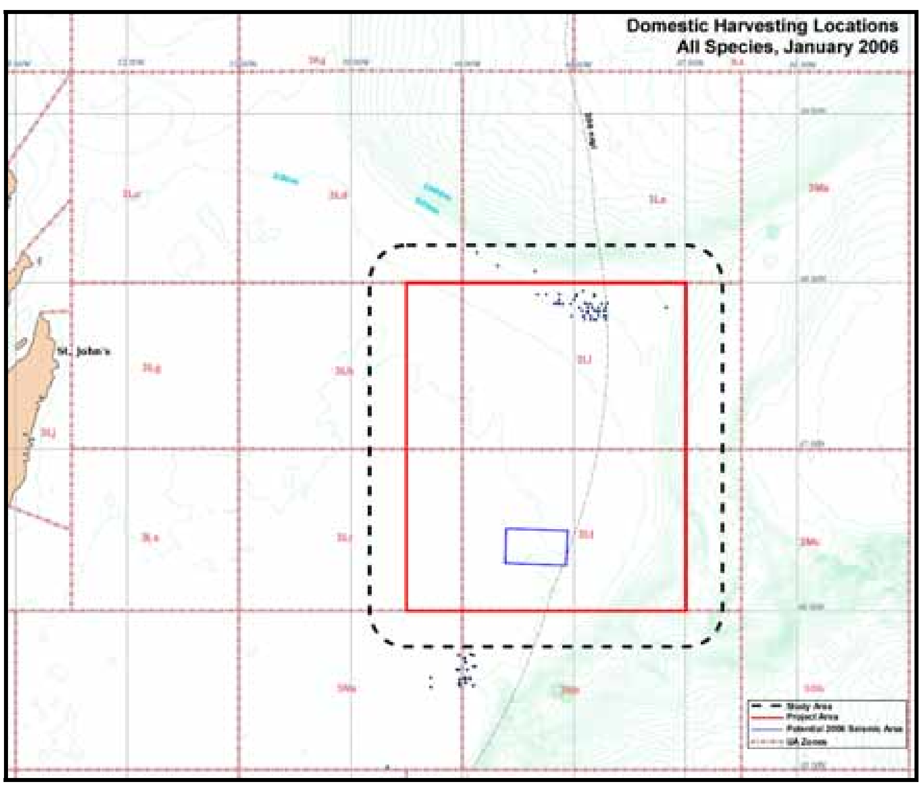



**Figure 4.23. Harvesting locations, all species, January 2006.**

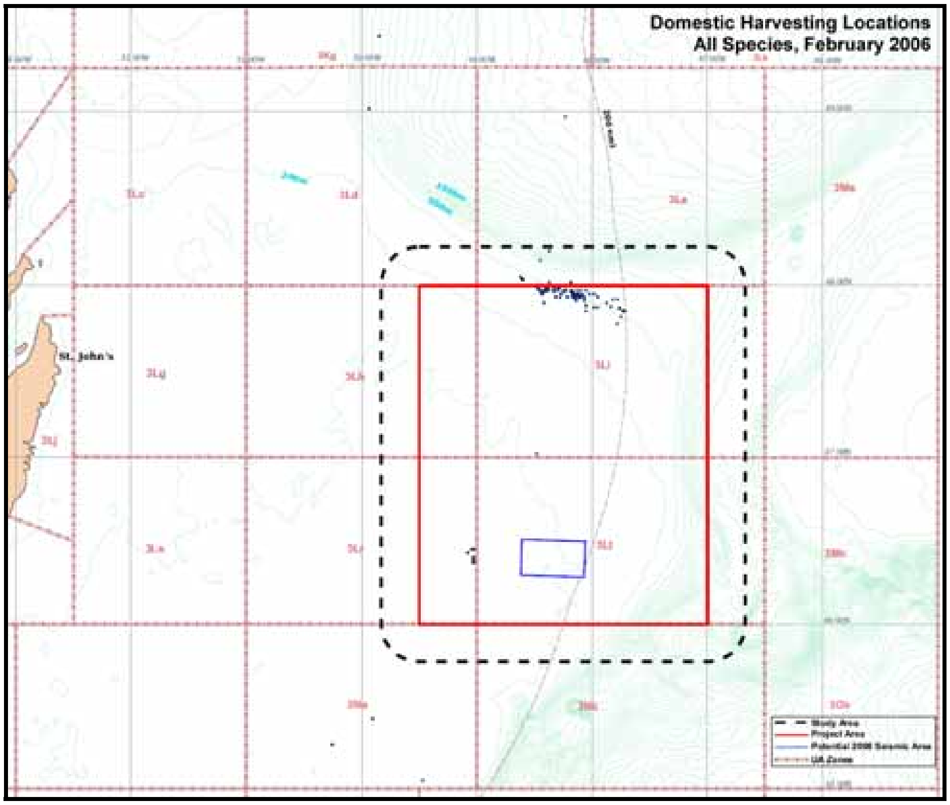



**Figure 4.24. Harvesting locations, all species, February 2006.**

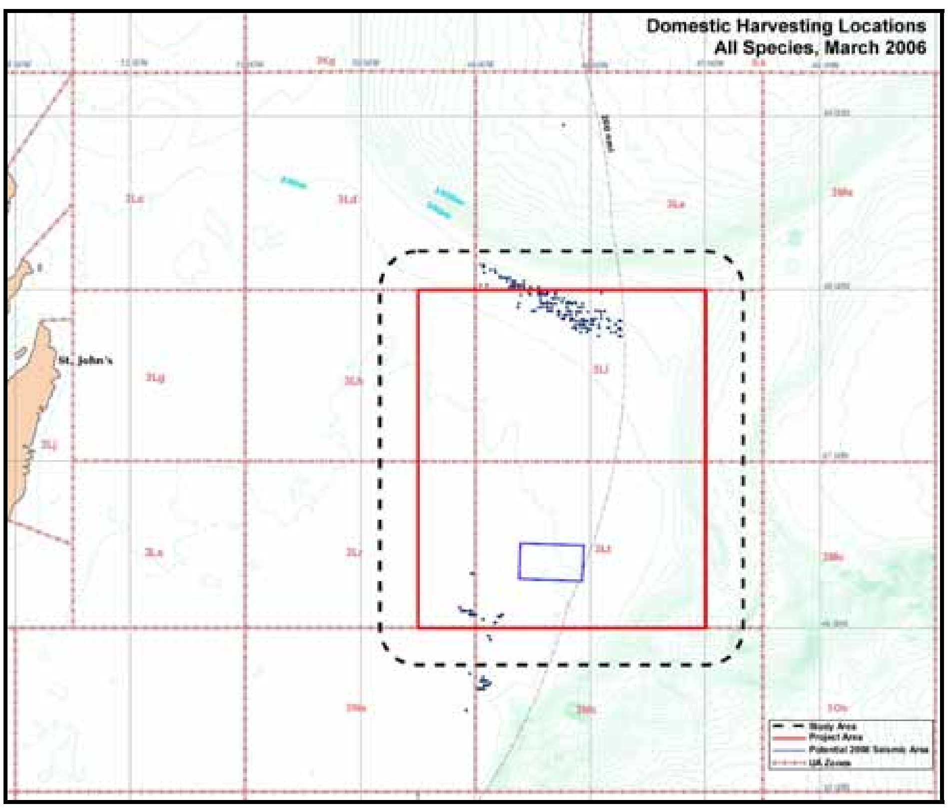



**Figure 4.25. Harvesting locations, all species, March 2006.**

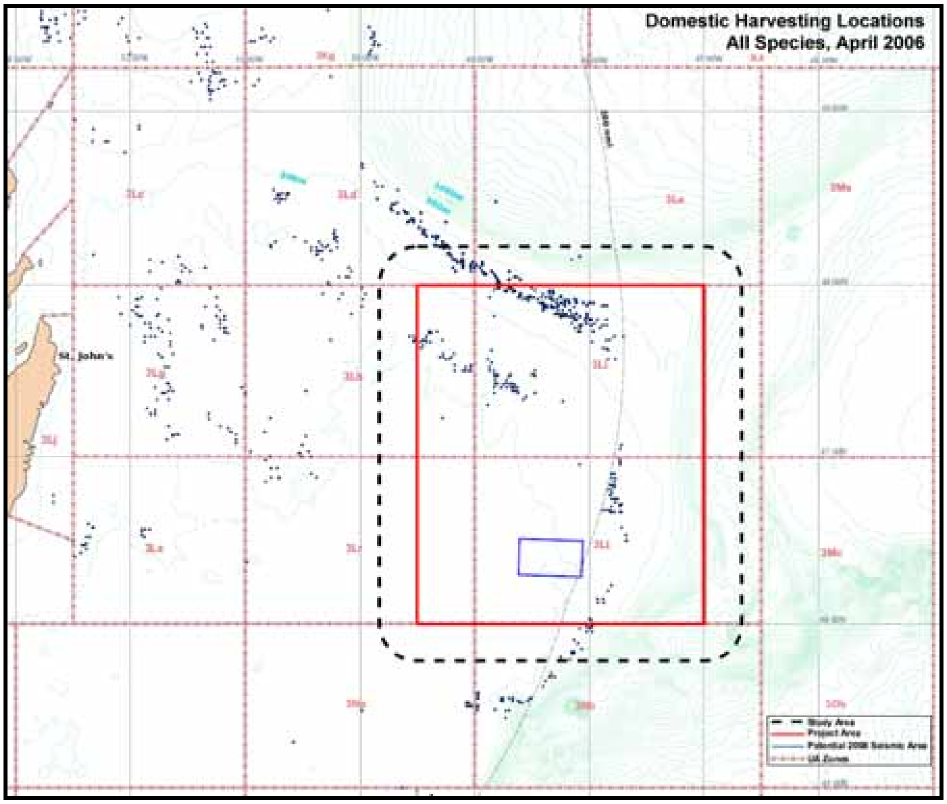



**Figure 4.26. Harvesting locations, all species, April 2006.**

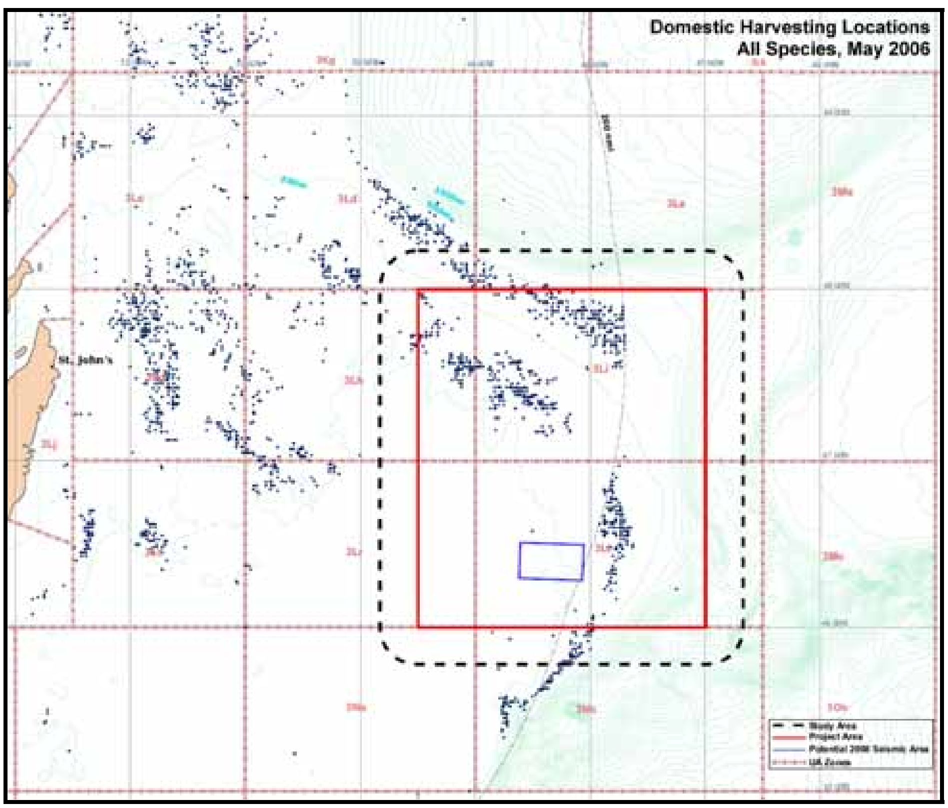



**Figure 4.27. Harvesting locations, all species, May 2006.**

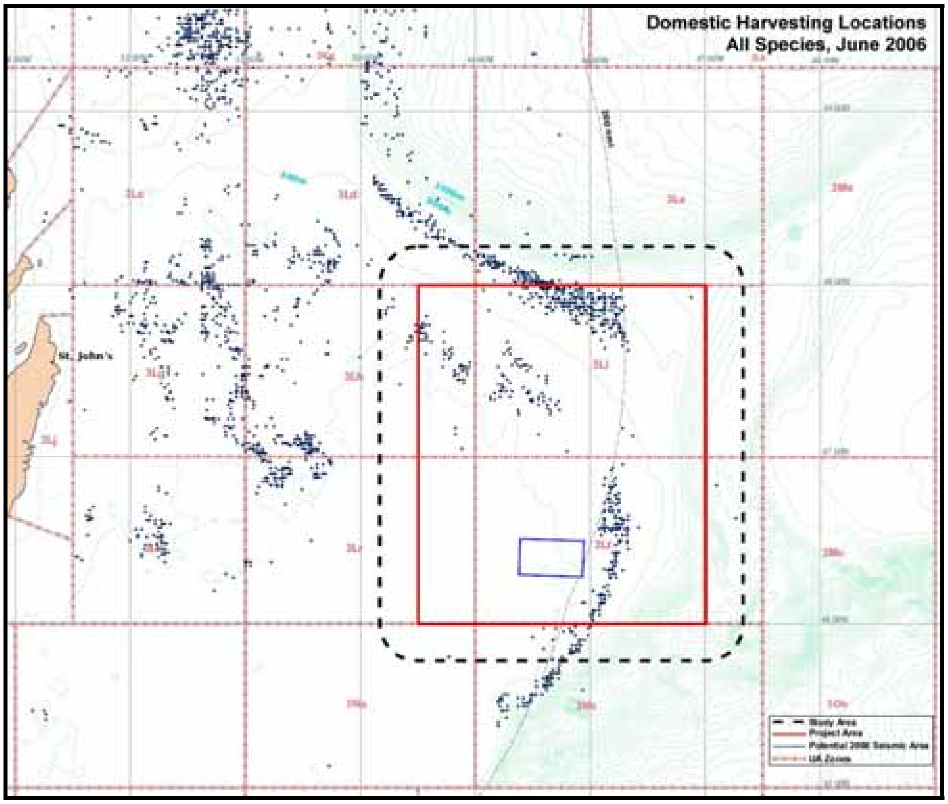



Figure 4.28. **Harvesting locations, all species, June 2006.**

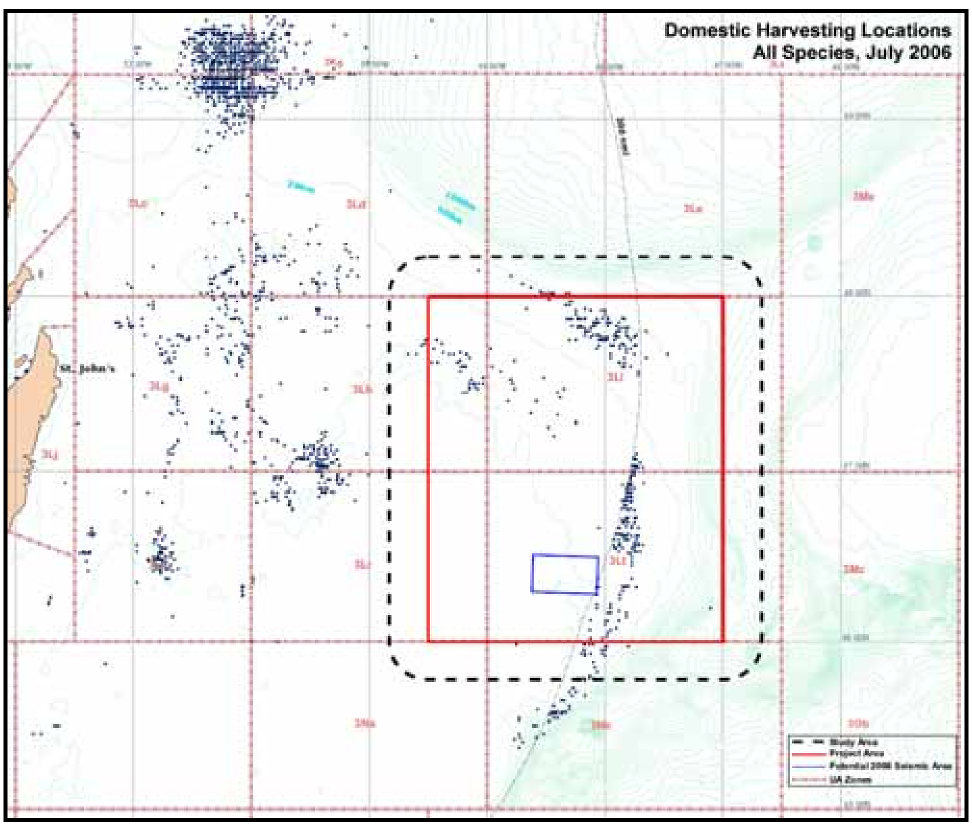



Figure 4.29. **Harvesting locations, all species, July 2006.**

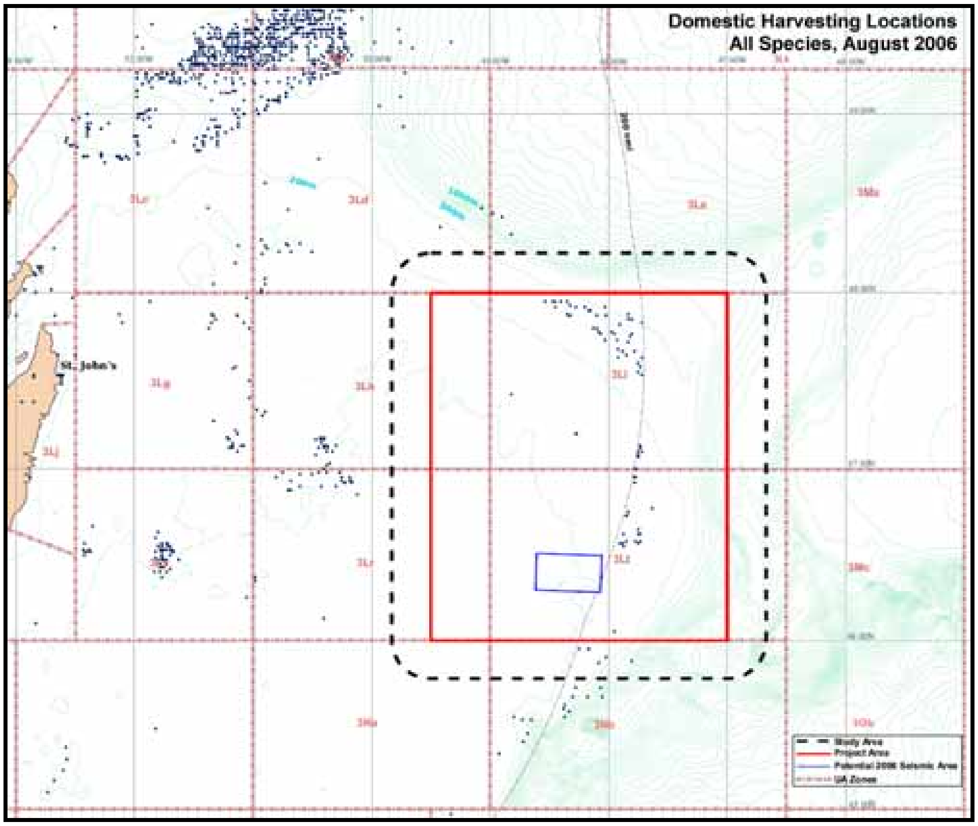



**Figure 4.30. Harvesting locations, all species, August 2006.**

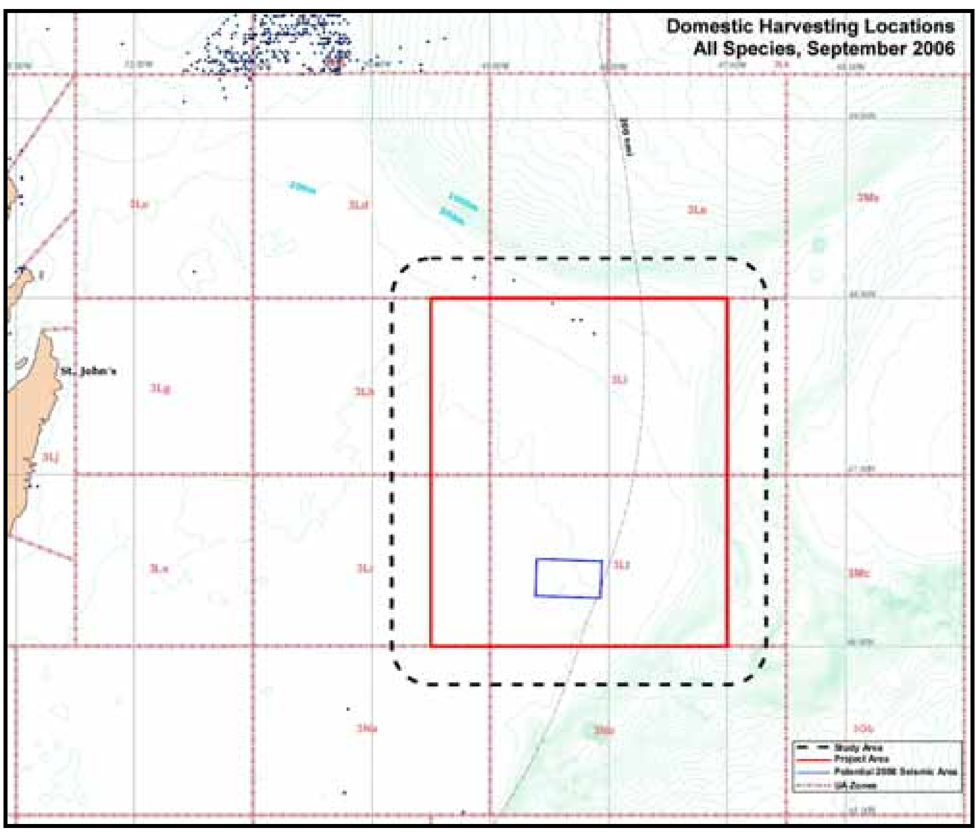



**Figure 4.31. Harvesting locations, all species, September 2006.**

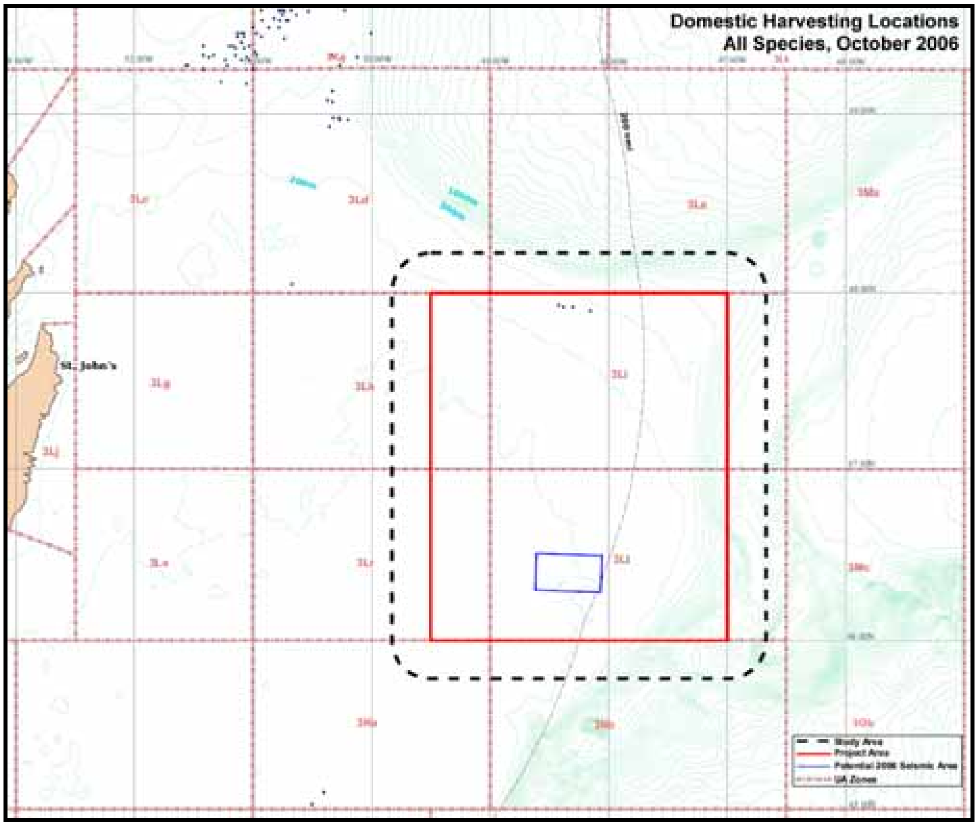



**Figure 4.32. Harvesting locations, all species, October 2006.**

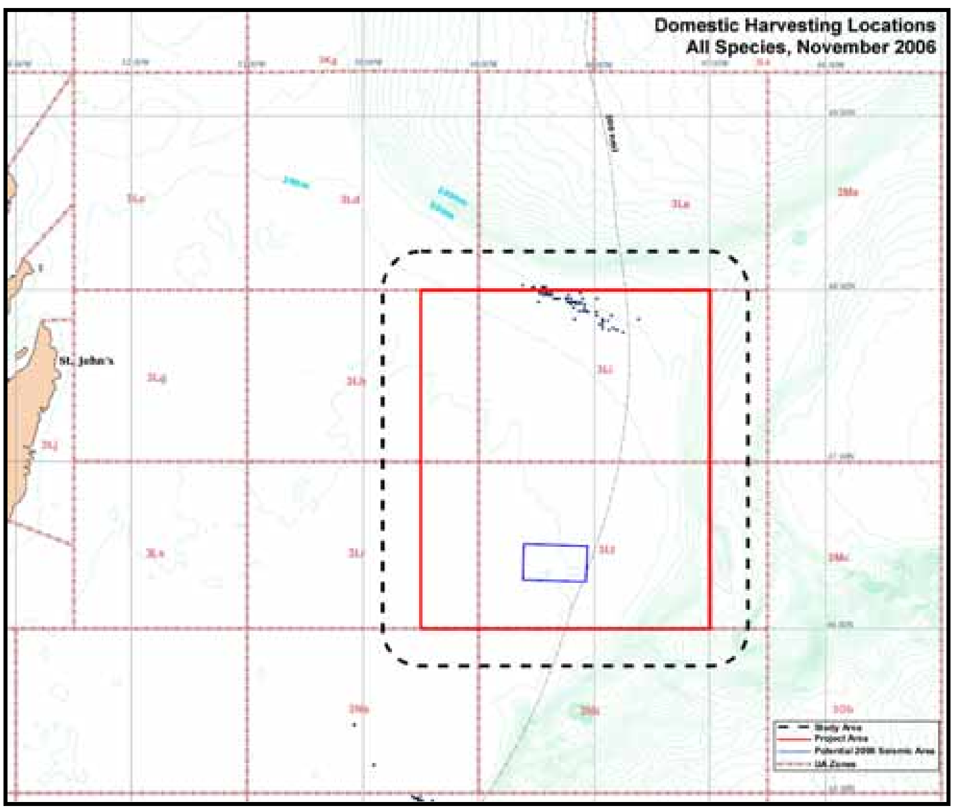



**Figure 4.33. Harvesting locations, all species, November 2006.**

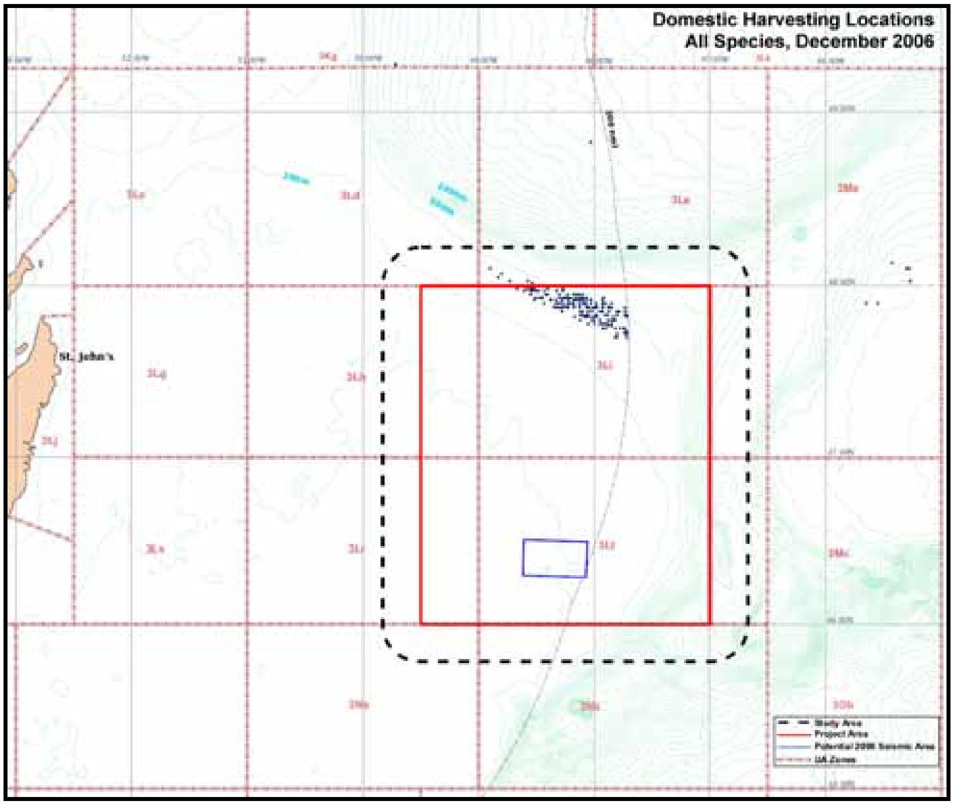



**Figure 4.34. Harvesting locations, all species, December 2006.**

## 4.3.4. Principal Species Fisheries

As the preceding tables indicate, the domestic harvest within the Study and Project areas is largely composed of snow crab and northern shrimp. This section describes these two fisheries in more detail.

In general, fisheries participants and DFO managers consulted confirm that they expect the main 2007 fisheries in the general area will be similar to those of the past year or so, and do not expect any major changes in fishing patterns or new fisheries in the area (FFAW meeting, and other industry consultations, October 2007).

### 4.3.4.1. Snow Crab

The regulatory fishing areas for snow crab are shown in Figure 4.35. Most of the Study and Project areas is within Crab Fishing Areas (CFA) MS/ex, 3L/ex (from 170 miles to 200 miles from shore), and 3L200 (beyond 200 nautical miles).

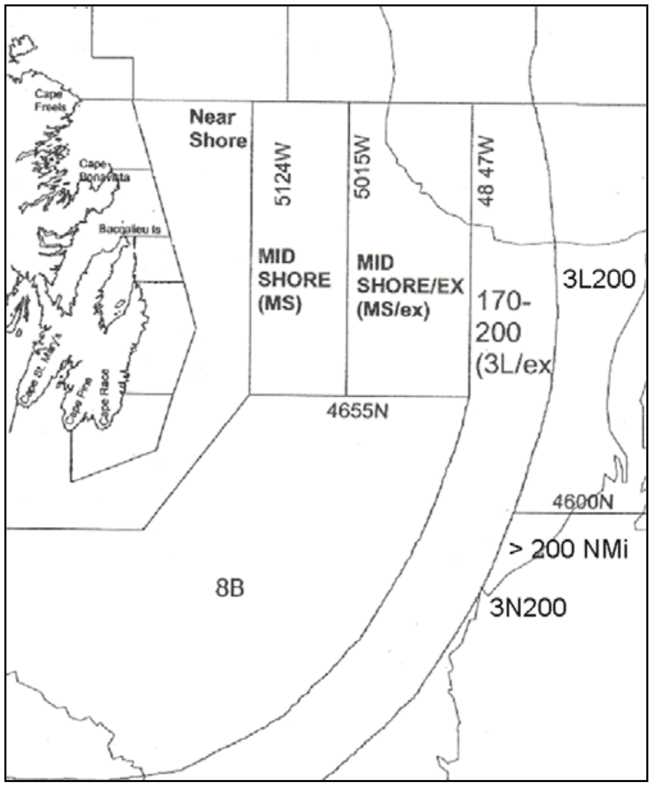



**Figure 4.35. Newfoundland eastern Grand Banks snow crab fishing areas.**

During the past few years, the Newfoundland and Labrador snow crab fishery has declined in quantity and value. Recent DFO snow crab status reports note that the 2J,3KLNOP,4R snow crab landings increased steadily from about 10,000 t annually during the late 1980s to 69,000 t in 1999 largely because of the expansion of the fishery in offshore areas. In 2000, landings decreased by 20% to 55,400 t, increased slightly to 59,400 t in 2002 and 2003 and declined to 55,700 t in 2004 with changes in TACs. In 2005, the harvest decreased by 21% to 43,900 t, primarily as the result of a decline in Division 3K landings where the TAC was not taken that year. Landings increased to 47,100 t in 2006, achieving the reduced TAC, due primarily to increases in Divisions 3KL. Historically, most of the snow crab landings have been from Divisions 3KL (DFO 2006a; 2007). DFO also reports that in Divisions 2J3KLNOP4R the fishery is prosecuted by several fleet sectors under multiple quota-controlled management areas, with more than 3,300 licence holders under enterprise allocation in 2007. Stock status is assessed at the NAFO Division scale, and a vessel monitoring system (VMS) was fully implemented in the offshore fleets in 2004 (DFO 2007).

The Fisheries Resource Conservation Council's (FRCC) 2005 *Strategic Conservation Framework for Atlantic Snow Crab* (FRCC 2005) describes the general conduct of the offshore sector: "Vessels fishing up to and beyond 200 miles from the coast conduct voyages up to four and five days and greater depending on the vessel's holding system. Typically these vessels leave the traps for shorter periods, sometimes only a few hours, prior to retrieving the catch. Given that snow crab must be live at the time of landing and processing, the duration of fishing trips is limited, although some vessels are now able to keep crab live on board in tanks permitting them to extend the length of their trips. Upon landing the live catch, it is weighed at dockside and transferred to shore-based processing facilities where the catch is processed into market ready products on a timely basis. All snow crab catches are independently monitored."

Table 4.6 shows the quotas for the 2007 snow crab fishery in relevant portions of 3L.

**Table 4.6. 2007 snow crab quotas and harvest-to-date.**

| Licence Category / Quota Definition | Quota (Tonnes) | Taken (Tonnes) | % Taken | Date Closed |
|---|---|---|---|---|
| Full-Time | | | | |
| Midshore Extended 3L (MSX) | 1,540 | 1,582 | 103 | 11 Aug 2007 |
| Outside 170 and Inside 200NMi (3LX) | 1,110 | 1,150 | 104 | 11 Aug 2007 |
| Outside 200NMi (3L200) | 950 | 861 | 91 | 11 Aug 2007 |
| Outside 200NMi (3N200) | 600 | 537 | 90 | 11 Aug 2007 |
| SL-Supplementary Large | | | | |
| Midshore Extended (MSX) | 1,585 | 1,650 | 100 | 11 Aug 2007 |
| Outside 170 and Inside 200NMi (3LX) | 1,585 | 1,586 | 104 | 11 Aug 2007 |
| Outside 200 NMi (3L200) | 1,990 | 1,904 | 96 | 11 Aug 2007 |
| Outside 200 NMi (3N200) | 1,215 | 1,140 | 94 | 11 Aug 2007 |

*As of December 2007. See http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Crab_2007.htm

Figures 4.36-4.38 show the 2004 – 2006 harvesting locations for snow crab.

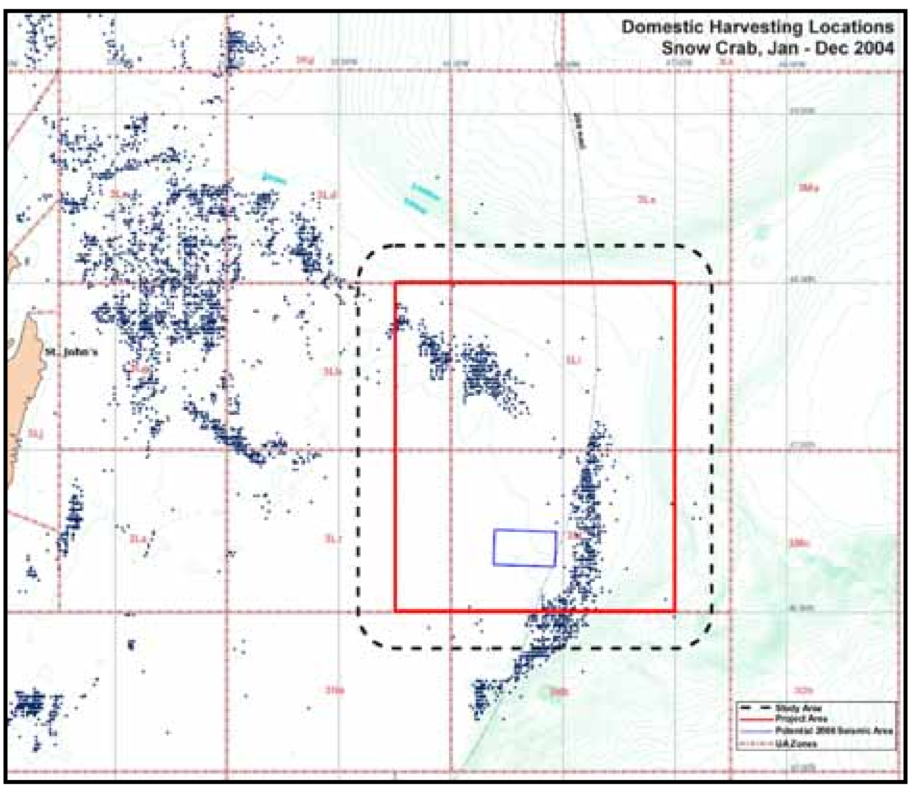



**Figure 4.36. Snow crab harvesting locations, January – December 2004.**

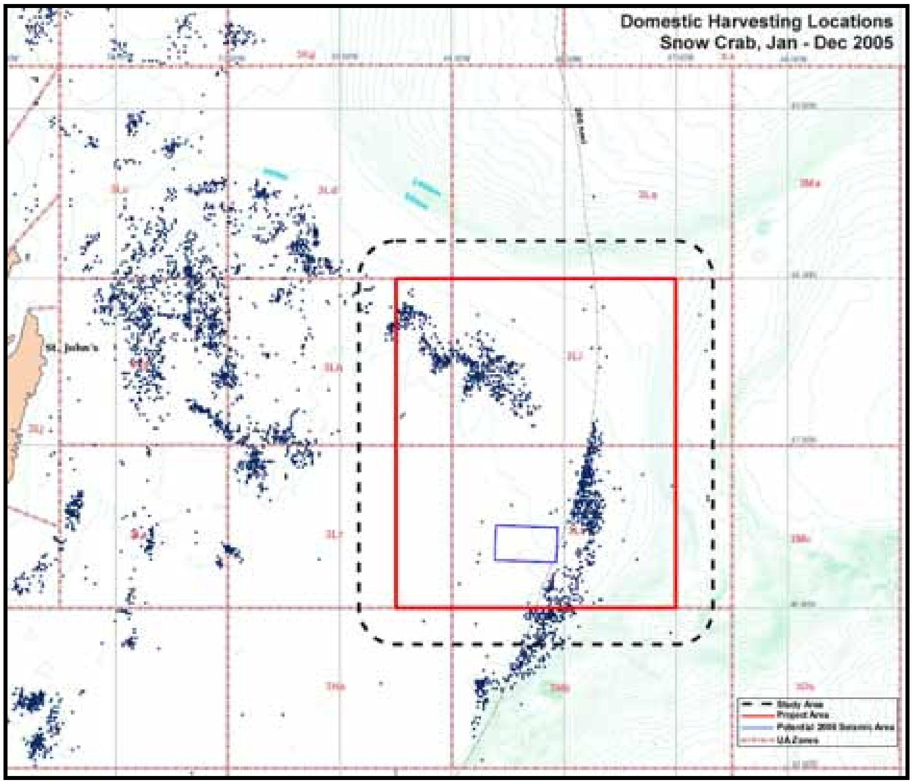



Figure 4.37. Snow crab harvesting locations, January – December 2005.

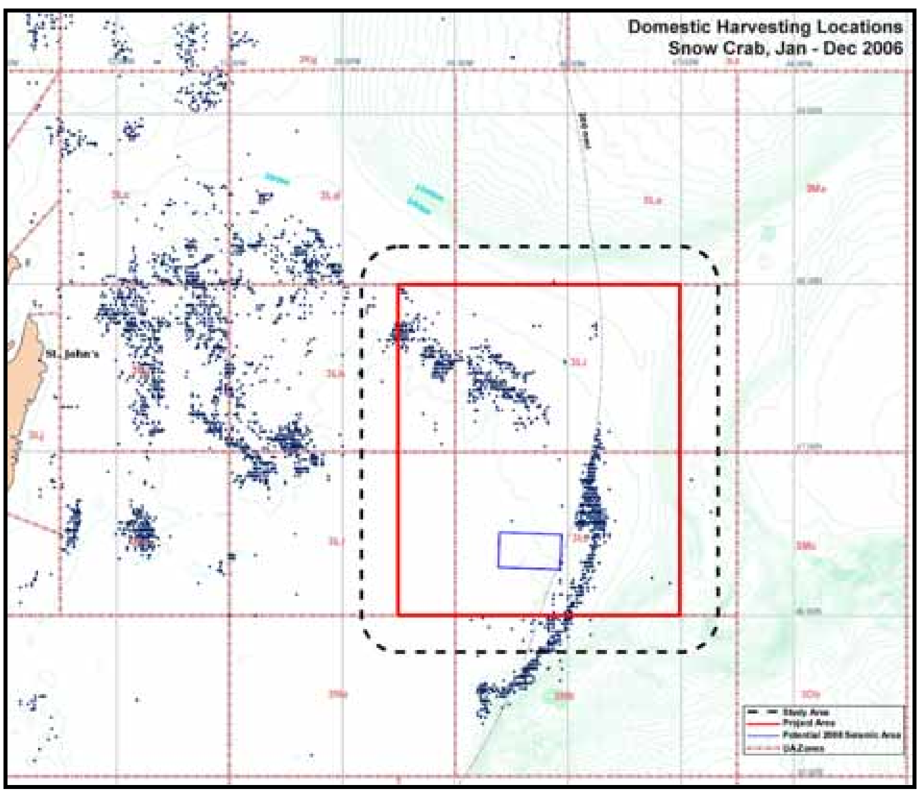



Figure 4.38. Snow crab harvesting locations, January – December 2006.

Figure 4.39 shows the snow crab harvest by month (averaged) within the Project Area from 2004 to 2006.

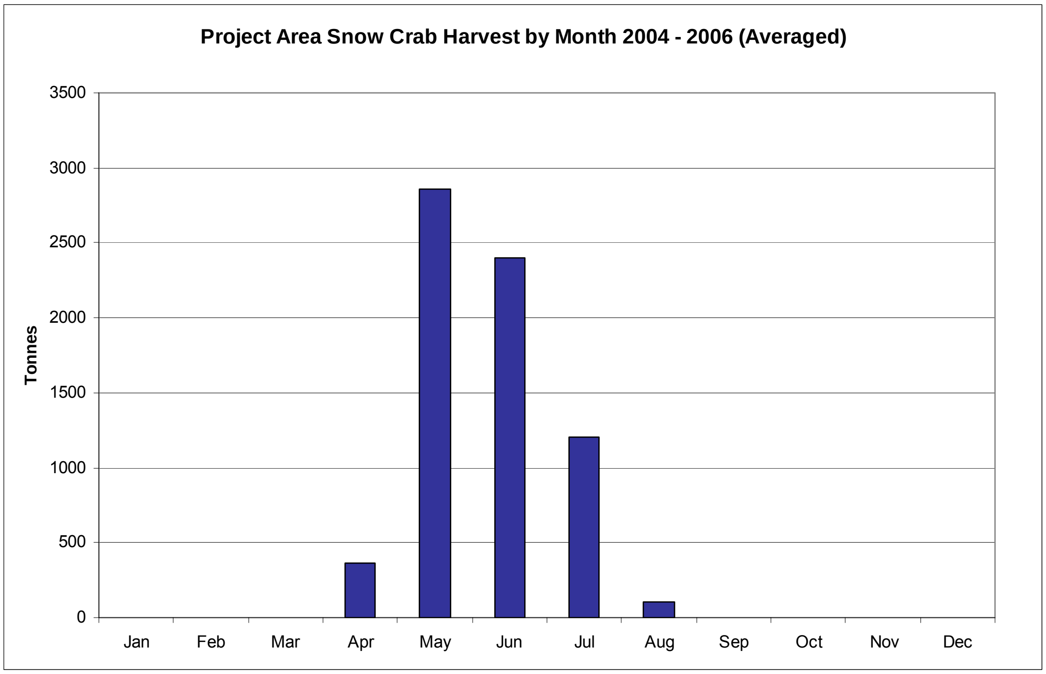



**Figure 4.39. Snow crab harvesting by month, 2004 – 2006.**

***Consultations.—*** Consultations with FFAW and One Ocean representatives did not indicate any major concerns or issues with respect to potential interactions between proposed survey activities and planned crab fishing activities in 2008. However, in previous consultations (One Ocean/FFAW meeting, February 2007) it was noted that one of the recommendations of the Seismic Workshop (held in the fall of 2006) was the need for more direct communications with fishers about any proposed survey operations. Considering this recommendation, One Ocean had suggested that a proponent should provide the FFAW with further information about any proposed surveys as early as possible in a particular survey year. This information could then be published in the spring (May/June) issue of the Union Forum so that all relevant fishers would be better informed of offshore survey activities.

During consultations for the present report, One Ocean and FFAW representatives had several general comments on the "multi-year" approach being proposed for this EA, more specifically about the appropriate process, and information requirements, for reviewing the proponent's survey activities on an annual basis, as well as the procedures for ongoing monitoring of these activities during the proposed 2008-2016 program timeframe. It was suggested that the EA report should specify clearly what an annual review of a "multi-year" document would entail and also identify what factors and conditions might be expected to trigger the requirement for a substantial update of the original EA.

In addition, with respect to monitoring the proponent's ongoing activities and up-coming plans for any one year, One Oceans' representative suggested that the annual review, or update report, would need to identify the proposed location and timing of any seismic activities planned for the coming project year. It should also discuss any significant changes, which may have occurred in the fisheries, e.g., harvesting of a new commercial species, or other environmental changes relevant to these harvesting activities. It was further suggested that, if major changes had occurred, the proponent might be required to undertake new, or additional, stakeholder consultations (One Ocean/FFAW meeting, October 2007).

#### 4.3.4.2. Northern Shrimp

Northern shrimp is a significant species harvested in both the Study and Project areas in terms of quantity and value of harvest. The two areas are within Shrimp Fishing Area (SFA) 7 (see Figure 4.40).

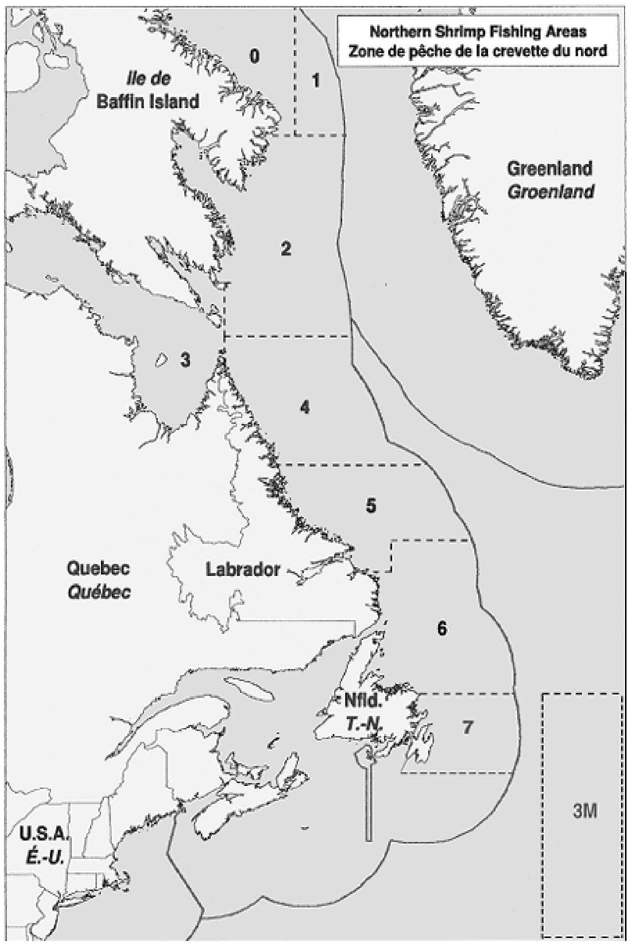



**Figure 4.40. Northern shrimp fishing areas.**

Figures 4.41 to 4.43 show domestic harvesting locations for 2004 to 2006, January to December aggregated. This fishery is confined to a well-defined zone in the northern part of the Study and Project areas and proposed 2008 seismic area.

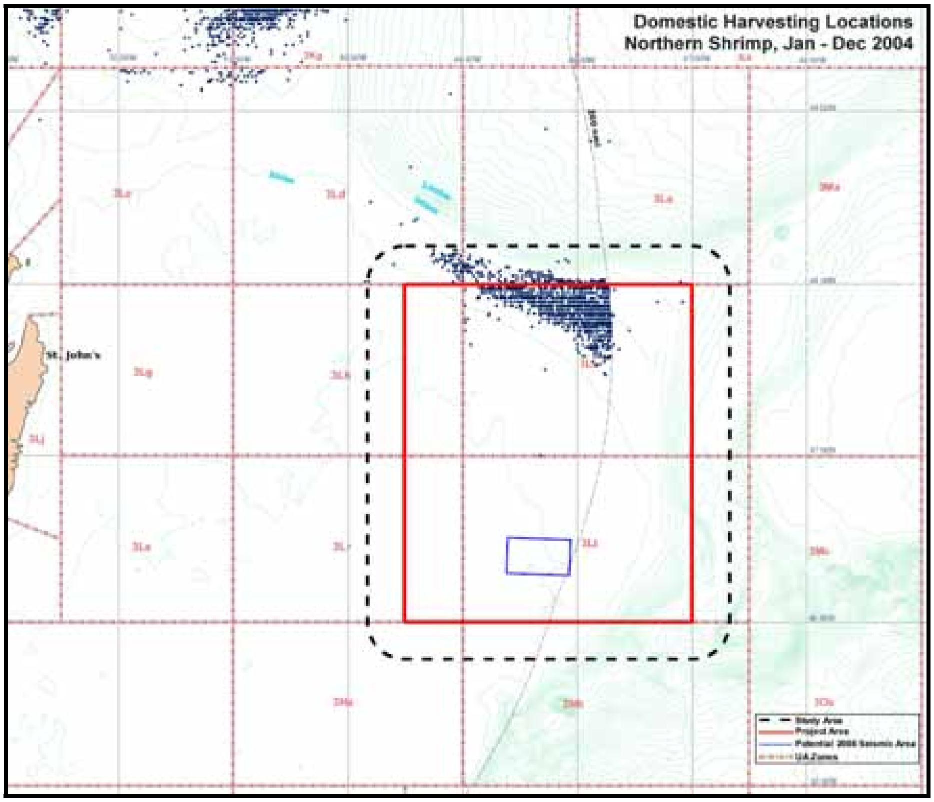



Figure 4.41. Northern shrimp harvesting locations, January – December 2004.

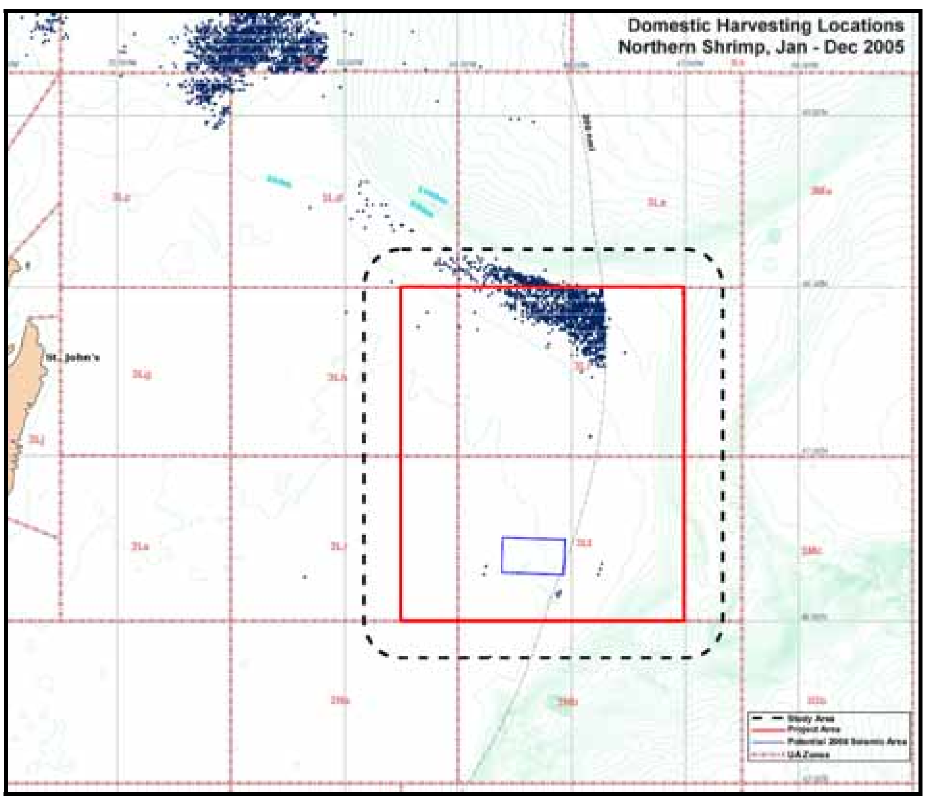



Figure 4.42. Northern shrimp harvesting locations, January – December 2005.

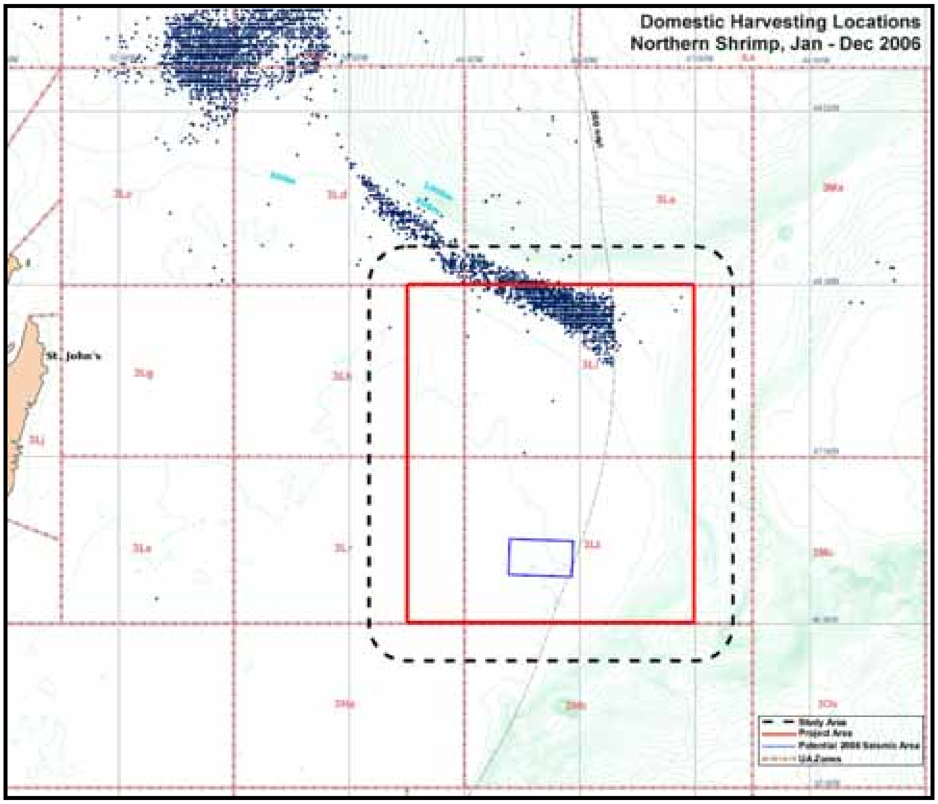



**Figure 4.43. Project Area northern shrimp harvesting locations, January – December 2006.**

Figure 4.44 shows the northern shrimp harvest by month (averaged) from the Project Area, for the period 2004 to 2006.

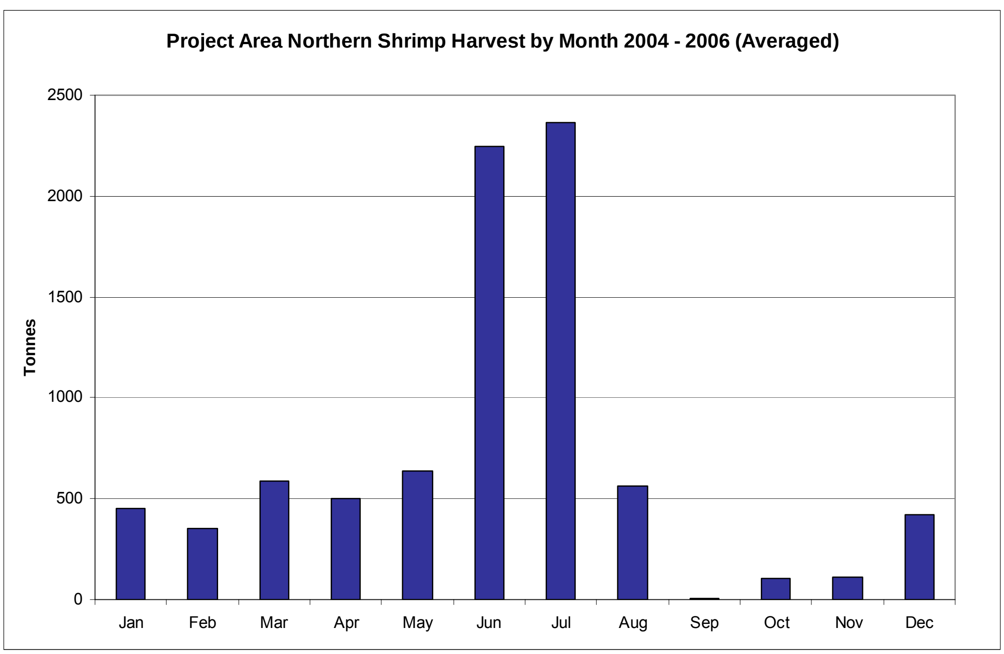



**Figure 4.44. Project Area northern shrimp harvesting by month, 2004 – 2006.**

Table 4.7 indicates the 2007 shrimp quotas and harvest-to-date for SFA 7.

**Table 4.7. SFA 7 2007 northern shrimp quotas and harvest-to-date.**

| Licence Category / Quota Definition | Quota (Tonnes) | Taken (Tonnes) | % Taken | Date Closed |
|---|---|---|---|---|
| Area 7 - Offshore > 100' and Special Allocations | 6,028 | 2,507 | 42 | -- |
| Area 7 - 2J Fishers | 395 | 175 | 44 | -- |
| Area 7 - 3K Fishers North of 50'30 | 395 | 395 | 100 | 16 Nov 2007 |
| Area 7 - 3K Fishers South of 50'30 | 2,886 | 3,102 | 107 | 10 Aug 2007 |
| Area 7 - 3L Fishers | 8,621 | 8,834 | 102 | 15 Aug 2007 |

*As of December 2007. See http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Shrimp_2007.htm.

As DFO (2006b) reports, "all northern shrimp fisheries in eastern Canada are subject to the *Atlantic Fisheries Regulations* regarding territorial waters, bycatches, discarding, vessel logs, etc. The regulations for shrimp refer to the minimum mesh size of 40 mm and that no fishing is permitted in any defined area, after it has been closed. Also, to minimize bycatch of non-target species, large and small vessels must use sorting grates with a maximum bar spacing of 28 mm and 22 mm, respectively. Observers are required on all trips by the large vessel fleet and a target of 10% coverage has been established for the small vessel fleet."

## 4.3.5. Fishing Gear

The commercial fisheries within the Study and Project areas are conducted using both fixed gear (crab pots) and mobile gear (shrimp trawls), reflecting the two dominant fisheries. In general, fixed gear poses a much greater potential for conflicts with towed seismic and geohazard gear since it is often hard to detect when there is no fishing vessel near by, and it may be set out over long distances in the water. In particular, crab pots pose a significant potential for conflict if a seismic survey vessel encounters them. The amount of gear fishers are permitted to use varies by licence category, and also by the area in which a licence holder may be fishing. Crab pots are set on the seabed in strings buoyed at the surface. Crab gear generally has a highflyer (radar reflector) at one end and a large buoy at the other. Some fishers use highflyers at both ends. Depending on weather, they may be left unattended several days at a time.

Fishers typically try to leave about 20 fathoms (37 m) on the seabed between each pot. Thus, allowing slack for the anchor ropes on either end of the string to extend upwards at an angle, the distance between the typical highflyer and end-buoy of, for example, a 50 to 60 pot string of crab gear would be 6,000 feet to 7500 feet, or approximately 1.8 km to 2.3 km.

Shrimp harvesting uses mobile shrimp trawls. These are modified stern otter trawls, for both inshore and offshore vessels, although some use beam trawls. Over the past several years offshore Newfoundland and Labrador, shrimp vessels and survey ships, with good communications, typically avoid each other without interference to either industry.

***Consultations.***—Industry stakeholders (e.g., ASP, FPI, Clearwater and GEAC (Groundfish Enterprise Allocation Council)) with an interest in this fishery did not provide any specific comments on potential interactions between proposed survey operations and established shrimp harvesting activities. However, the industry representative for GEAC (and for the Canadian Association of Prawn Producers) noted that its member firms harvest shrimp (as well as turbot) at various locations within the Study Area (B. Chapman, pers. comm., December 2007).

### 4.3.6. Industry and DFO Science Surveys

Fisheries research surveys conducted by DFO, and sometimes by the fishing industry, are important to the commercial fisheries to determine stock status, as well as for scientific investigation. In any year, there will likely be overlap between the Study and/or Project areas and DFO research surveys in NAFO 3L and/or 3N. Typically, DFO conducts a spring survey in sections of 3LNOPs (April-July), and a fall survey of 2HJ3KLMNO (September/October to December). The fall survey may employ two vessels (in 2007 the R/V *Wilfred Templeman* and the R/V *Teleost*).

The *Wilfred Templeman* usually conducts the spring survey within Division 3L in June. (In 2007, however, this was done by the *Teleost*). The deeper waters of 3L (slope areas) are typically surveyed in October, and the shallower areas in November or December (B. Brodie, pers. comm.; October 2007).

Because locations and exact times vary somewhat each year, the proponent will maintain contact with DFO throughout each work season.

The FFAWU and fishers have been involved in an industry survey for crab in various offshore harvesting locations over the past few years. The FFAW crab survey will be taking place again in 2008, likely in September (though the FFAW would prefer that it take place a bit earlier) and will last 24 to 48 hours. Set locations change from year to year, and the 2008 locations have not yet been finalized. When they are, the FFAW will provide the research locations (i.e., 2008 map) to the survey. [Past locations are shown on Figure 4.45.] The FFAW also noted that it co-ordinated an additional crab survey within an area outside 200 nmi limit during 2007 and would provide a map of the locations surveyed when it is available. Surveys outside the 200 nmi limit are not planned for 2008 (J. Coady, pers. comm., March, October and December 2007).

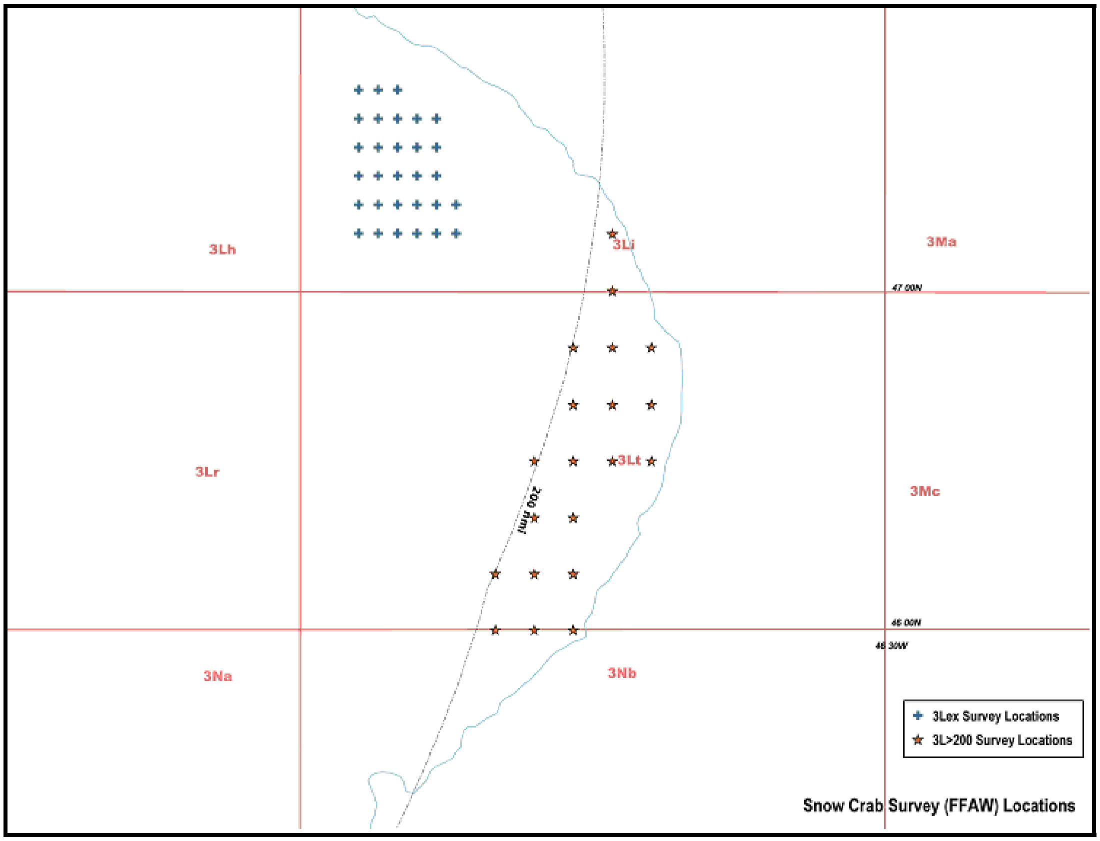



**Figure 4.45. Snow crab survey locations.**

## 4.4. Seabirds

The highly productive Grand Banks support large numbers of seabirds during all seasons (Lock et al. 1994). The Project Area is located on the edge of the Grand Banks where it begins to slope into the deep waters beyond the continental shelf. A branch of the Labrador Current flows south along the shelf edge off eastern Newfoundland including the Grand Banks. The combination of shelf edge and Labrador Current are prime conditions for productivity of zooplankton, the basis of marine food chains, including those involving seabirds. However, there are no sensitive areas identified for seabirds within the Study Area.

The biological background of seabirds in the Jeanne d'Arc Basin area was recently reviewed in LGL (2007a). This section summarizes that information and provides updates based on seabird surveys conducted during a seismic program for Husky during 9 July to 17 August 2006 (Abgrall et al. *in prep*. a) The Grand Banks have been identified as areas rich in abundance and diversity of seabirds (Brown 1986; Lock et al. 1994). Seabird observations from this area are sparse (Lock et al. 1994). Original baseline information has been collected by the Canadian Wildlife Service through PIROP (Programme intégré de recherches sur les oiseaux pélagiques). These data have been published for 1969-1983 (Brown 1986) and up to the early 1990s (Lock et al. 1994). Additional seabird observations have been collected on the northeast Grand Banks by the offshore oil and gas industry. These data have been analyzed for the period 1999-2002 (Baillie et al. 2005; Burke et al. 2005). Husky Energy Inc. conducted seismic exploration on Jeanne d'Arc Basin in 2005 and 2006. LGL biologists experienced in seabird identification conducted seabirds surveys on the MV *Western Neptune* during the period 1 October to 8 November 2005 (Lang et al. 2006) and on the MV *Western Regent* during the period 9 July to 17 August 2006 (Abgrall et al. *in prep*. a). Information from all the above sources was used to predict abundances by month of seabirds occurring in the Study Area (Table 4.8). This report contains a summary of background information on seabirds of the northern Grand Banks presented in detail in the environmental assessment of Petro-Canada's Jeanne d'Arc Basin 3-D Seismic Program (LGL 2007a) with relevant new information from Abgrall et al. (*in prep.* a) and Lang (2007).

The enormous numbers of nesting seabirds on the Avalon Peninsula illustrates the richness of the Grand Banks for seabirds. The seabird breeding colonies on Baccalieu Island, the Witless Bay Islands and Cape St. Mary's are among the largest in Atlantic Canada. More than 4.6 million pairs nest at these three locations alone (Figure 4.46 and Table 4.9). This includes the largest Atlantic Canada colonies of Leach's Storm-Petrel (3,336,000 pairs on Baccalieu Island), Black-legged Kittiwake (23,606 pairs on Witless Bay Islands), Thick-billed Murre (1,000 pairs at Cape St. Mary's) and Atlantic Puffin (216,000 pairs on Witless Bay Islands). All these birds feed on the Grand Banks during the nesting season from May to September. In addition, Funk Island, 150 km northwest of the Grand Banks supports the largest colony of Common Murre in Atlantic Canada. Many of these birds could reach the northern Grand Banks during the breeding season.

There are nine significant seabird nesting sites on the southeast coast of Newfoundland from Cape Freels to the Burin Peninsula. Each meets the criteria for an Important Bird Area (IBA) (Figure 4.46, Table 4.9). An IBA is a site that provides essential habitat for one or more species of breeding or non-breeding birds. These sites may contain threatened species, endemic species, species representative of a biome, or highly exceptional concentrations of birds (www.ibacanada.com).

In addition to local breeding birds, there are many non-breeding seabirds on the Grand Banks during the summer months. Most of the world's population of Greater Shearwater is thought to migrate to the Grand Banks and eastern Newfoundland to moult and feed during the summer months after completion of nesting in the Southern Hemisphere. Depending on the species, seabirds require more that one to four years to become sexually mature. Many non-breeding sub-adult seabirds, especially Northern Fulmar and Black-legged Kittiwake, are present on the Grand Banks year-round.

Other seabirds (jaegers, terns and phalaropes) migrate north in spring and south in autumn over the Grand Banks between breeding sites in the low Arctic to wintering areas in the more southern latitudes. Large numbers of Arctic breeding Thick-billed Murre, Dovekie, Northern Fulmar and Black-legged Kittiwake migrate to eastern Newfoundland, including the Grand Banks, for the winter.

Ivory Gull was listed as an *Endangered* species by COSEWIC in April 2006 and is currently under consideration for legal listing as *Endangered* under *SARA* Schedule 1. Ivory Gull is likely of less than annual occurrence in the Project Area. See Section 4.6.1.6 for more detail.

## Table 4.8. Predicted monthly abundances of seabird species occurring in the Study Area.

| Common Name | Scientific Name | Monthly Abundance | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| ***Procellariidae*** | | | | | | | | | | | | | |
| Northern Fulmar | *Fulmarus glacialis* | C | C | C | C | C | C | U-C | U-C | C | C | C | C |
| Greater Shearwater | *Puffinus gravis* | | | | | U | C | C | C | C | C | S | |
| Sooty Shearwater | *Puffinus griseus* | | | | | S | S-U | S-U | S-U | S-U | S-U | S | |
| Manx Shearwater | *Puffinus puffinus* | | | | | S | S | S | S | S | S | | |
| ***Hydrobatidae*** | | | | | | | | | | | | | |
| Leach's Storm-Petrel | *Oceanodroma leucorhoa* | | | | U-C | U-C | U-C | U-C | U-C | U-C | U-C | S | |
| Wilson's Storm-Petrel | *Oceanites oceanicus* | | | | | | S | S | S | S | | | |
| ***Sulidae*** | | | | | | | | | | | | | |
| Northern Gannet | *Morus bassanus* | | | | S | S | S | S | S | S | S | | |
| ***Phalaropodinae*** | | | | | | | | | | | | | |
| Red Phalarope | *Phalaropus fulicarius* | | | | | S | S | S | S | S | S | | |
| Red-necked Phalarope | *Phalaropus lobatus* | | | | | S | S | S | S | S | | | |
| ***Laridae*** | | | | | | | | | | | | | |
| Great Skua | *Stercorarius skua* | | | | | S | S | S | S | S | S | | |
| South Polar Skua | *Stercorarius maccormicki* | | | | | S | S | S | S | S | S | | |
| Pomarine Jaeger | *Stercorarius pomarinus* | | | | | S | S | S | S | S | S | | |
| Parasitic Jaeger | *Stercorarius parasiticus* | | | | | S | S | S | S | S | S | | |
| Long-tailed Jaeger | *Stercorarius longicaudus* | | | | | S | S | S | S | S | | | |
| Herring Gull | *Larus argentatus* | S | S | VS | VS | VS | VS | VS | VS | S | S | S | S |
| Iceland Gull | *Larus glaucoides* | S | S | S | S | | | | | | | S | S |
| Lesser Blk-backed Gull | *Larus fuscus* | | | | | VS | VS | VS | VS | VS | VS | VS | VS |
| Glaucous Gull | *Larus hyperboreus* | S | S | S | S | | | | | | S | S | S |
| Great Black-backed Gull | *Larus marinus* | U | U | VS | VS | VS | VS | VS | U | U | U | U | U |
| Ivory Gull | *Pagophila eburnea* | VS? | VS? | VS? | VS? | | | | | | | | |
| Black-legged Kittiwake | *Rissa tridactyla* | C | C | C | C | C | S | S | S | U | C | C | C |
| Arctic Tern | *Sterna paradisaea* | | | | | S | S | S | S | S | | | |
| ***Alcidae*** | | | | | | | | | | | | | |
| Dovekie | *Alle alle* | U-C | U-C | U-C | U-C | S | VS | VS | VS | S | C | C | U-C |
| Common Murre | *Uria aalge* | S-U | S-U | S-U | S-U | S-U | S | S | S | S | S-U | S-U | S-U |
| Thick-billed Murre | *Uria lomvia* | U-C | U-C | U-C | U-C | VS-S | VS-S | VS-S | VS-S | VS-S | U-C | U-C | U-C |
| Razorbill | *Alca torda* | | | | S | S | S | S | S | S | S | S | |
| Atlantic Puffin | *Fratercula arctica* | | | | S-U | S-U | S-U | S-U | S-U | S-U | U | U | |

**Source:** Brown (1986); Lock et al. (1994); Baillie et al. (2005); Lang et al. (2006), Abgrall et al (*in prep*. a) and Lang (2007).

**Notes:** C = *Common*, occurring daily in moderate to high numbers, U = *Uncommon*, occurring regularly in small numbers, S = *Scarce*, a few individuals occurring and VS = *Very Scarce*, very few individuals. Blank cells indicate that the species is not expected to occur.

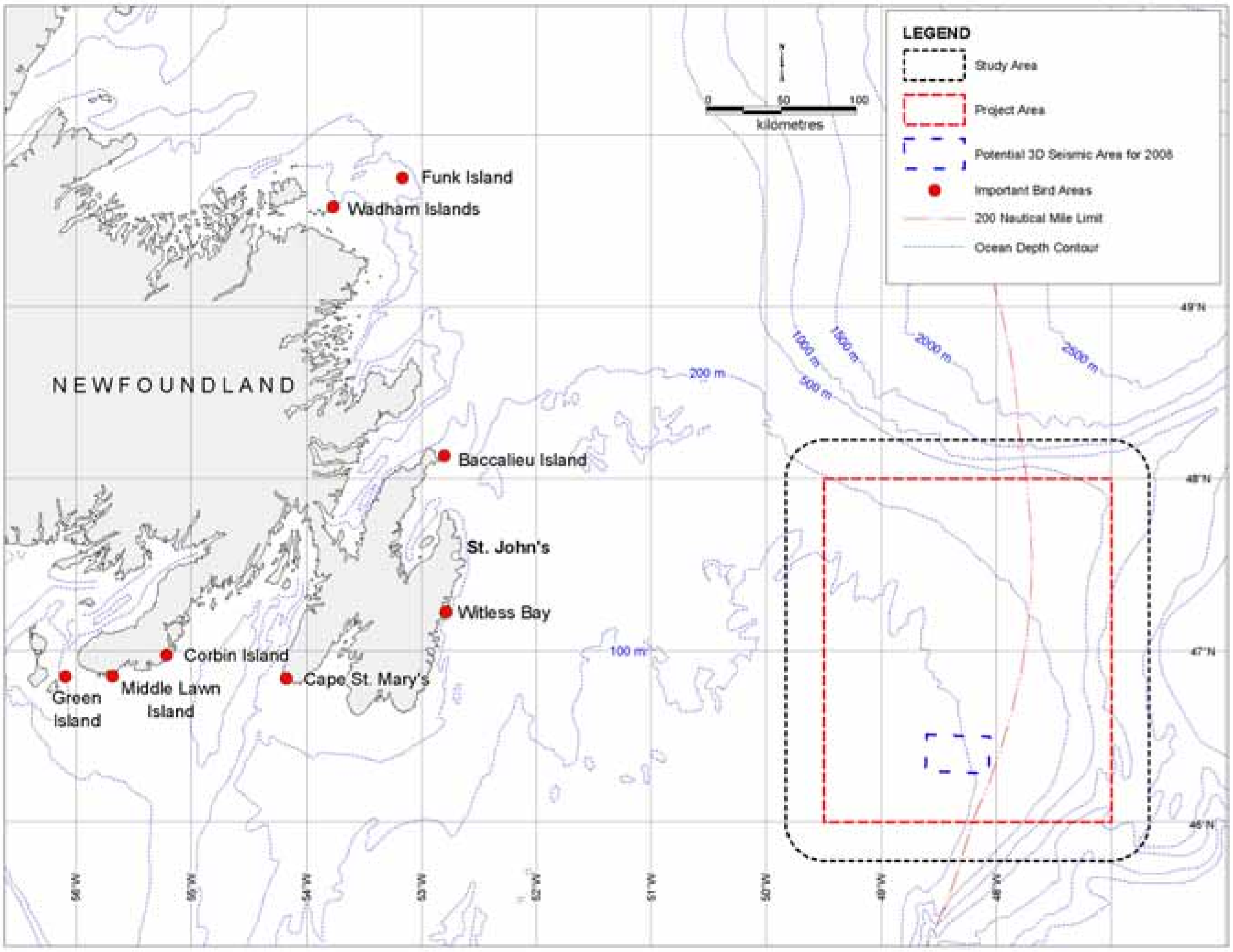



**Figure 4.46. Locations of seabird nesting colonies at Important Bird Areas (IBAs) relative to the Study Area.**

**Table 4.9. Numbers of pairs of seabirds nesting at Important Bird Sites (IBA) in eastern Newfoundland.**

| Species | Wadham Islands | Funk Island | Cape Freels and Cabot Island | Baccalieu Island | Witless Bay Islands | Cape St. Mary's | Middle Lawn Island | Corbin Island | Green Island |
|---|---|---|---|---|---|---|---|---|---|
| ***Procellariidae*** | | | | | | | | | |
| Northern Fulmar | - | 46[a] | - | 12[a] | 22[a,f] | Present[a] | - | - | - |
| Manx Shearwater | - | - | - | - | - | - | 13[k] | - | - |
| ***Hydrobatidae*** | | | | | | | | | |
| Leach's Storm-Petrel | 1,038[d] | - | 250[j] | 3,336,000[j] | 667,086[,h,i,j] | - | 13,879[h] | 100,000[j] | 72,000[j] |
| ***Sulidae*** | | | | | | | | | |
| Northern Gannet | | 9,837[b] | | 1,712[b] | - | 12,156[b] | - | - | - |
| ***Laridae*** | | | | | | | | | |
| Herring Gull | - | 500[j] | - | Present[a] | 4,638[e,j] | Present[j] | 20[j] | 5,000[j] | - |
| Great Black-backed Gull | Present[d] | 100[j] | - | Present[1] | 166[e,j] | Present[j] | 6[j] | 25[j] | - |
| Black-legged Kittiwake | - | 810[j] | - | 12,975[j] | 23,606[f,j] | 10,000[j] | - | 50[j] | - |
| Arctic and Common Terns | 376[j] | - | 250[j] | - | - | - | - | - | - |
| ***Alcidae*** | | | | | | | | | |
| Common Murre | - | 412,524[c] | 2,600[j] | 4,000[j] | 83,001[f,j] | 10,000[j] | - | - | - |
| Thick-billed Murre | | 250[j] | - | 181[j] | 600[j] | 1,000[j] | - | - | - |
| Razorbill | 273[d] | 200[j] | 25[j] | 100[j] | 676[f,j] | 100[j] | - | - | - |
| Black Guillemot | 25[j] | 1[j] | - | 100[j] | 20+[j] | Present[j] | - | - | - |
| Atlantic Puffin | 6,190[d] | 2,000[j] | 20[j] | 30,000[j] | 272,729[f,g,j] | - | - | - | - |
| **TOTALS** | **7,902** | **426,268** | **3,145** | **3,385,080** | **1,052,546** | **32,256** | **13,918** | **105,075** | **72,000** |

**Sources:**

[a] Stenhouse and Montevecchi 1999;
[b] Chardine (2000);
[c] Chardine et al. (2003);
[d] Robertson and Elliot (2002);
[e] Robertson et al. (2001) *in* Robertson et al (2004);
[f] Robertson et al. (2004);
[g] Rodway et al. (2003) *in* Robertson et al. (2004);
[h] Robertson et al. (2002);
[i] Stenhouse et al (2000);
[j] Cairns et al. (1989);
[k] Robertson (2002).

### 4.4.1. Seasonal Occurrence and Abundance of Seabirds

The world range and seasonal occurrence and abundance of seabirds occurring regularly in the Project Area are described below. Table 4.8 summarizes the predicted abundance status for each species monthly. The table uses four categories to define a relative abundance of seabirds species observed:

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

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

#### 4.4.1.1. Procellariidae (fulmars and shearwaters)

Northern Fulmar is present year round in ice free waters off Newfoundland including the northern Grand Banks. It is one the most ubiquitous and numerous species in the Study Area with lowest numbers in mid summer, July and August (Table 4.8). Greater Shearwater migrate north from breeding islands in the South Atlantic and arrive in the Northern Hemisphere during summer. Greater Shearwater is among the most numerous species on the Grand Banks during its May to early November presence. During the monitoring of Husky's seismic program 9 July to 16 August 2006 Greater Shearwater was the most common bird. The mean density during the period was 5.06 birds per $km^2$ (Abgrall et al. *in prep.* a). Sooty Shearwater follows movements similar to Greater Shearwater but is scarce to uncommon during May to early November on the Study Area. Manx Shearwater breeds in the North Atlantic in relatively small world wide numbers compared to Greater Shearwater. It is expected to be scarce in the Study Area during May to October.

#### 4.4.1.2. Hydropbatidae (storm-petrels)

Leach's Storm-Petrel is one the most numerous seabirds breeding in Newfoundland with more than one million pairs (Table 4.9). It was the second most abundant species after Greater Shearwater observed during the 9 July to 16 August 2006 Husky seismic program (Abgrall et al. *in prep.* a). It is expected to be present in the Study Area from April to early November. Like the Greater Shearwater, the Wilson's Storm-Petrel migrates north from breeding islands in the South Atlantic to the North Atlantic in the summer months. Newfoundland is at the northern edge of its range. It is expected to be scarce in the Study Area from June to September.

#### 4.4.1.3. Sulidae (gannets)

More than 23,000 pairs of Northern Gannets nest on three colonies in eastern Newfoundland (Table 4.9). Gannets are common near shore and scarce beyond 100 km from shore. The Study Area is beyond the range of most Northern Gannets. It is expected to be scarce from April to October within the Study Area.

#### 4.4.1.4. Phalaropodinae (phalaropes)

The Red Phalarope and Red-necked Phalarope both breed in the Arctic to sub-Arctic regions of North America and Eurasia. They winter at sea mostly in the Southern Hemisphere. They migrate and feed offshore, including Newfoundland waters during their spring and autumn migrations. Phalaropes seek out areas of upwelling and convergence where rich sources of zooplankton are found. No concentrations of phalaropes have been reported within the Study Area. Small numbers of migrant Red Phalaropes have been observed in the Study Area during spring and fall migration. None were observed during the 9 July to 16 August 2006 Husky's seismic monitoring program (Abgrall et al. *in prep.* a). Phalaropes are expected to be scarce in the Study Area during May to October.

#### 4.4.1.5. Laridae (skuas, jaegers, gulls and terns)

Both species of skua (Great and South Polar) and the three species of jaeger (Pomarine, Parasitic and Long-tailed Jaeger) generally occur in low densities throughout their ranges. All five species occur regularly in low densities in the Study Area generally during spring, summer and fall (May to October or November).

Of the large gull species only the Great Black-backed Gull occurs offshore, including the Study Area, regularly in significant numbers. They are uncommon within the Study Area from August to February and scarce to absent at other times. Herring, Glaucous and Iceland Gulls are scarce or absent in the Study Area. Black-legged Kittiwake is a pelagic gull that goes to land only during the nesting season. Non-breeding sub-adults remain at sea for the first year of life. Black-legged Kittiwake is expected to be present within the Study Area year round, being most numerous during the non-breeding season (August to May).

Concerns over reduced numbers of Ivory Gulls at known breeding colonies in the Canadian Arctic have resulted in COSEWIC listing it as *Endangered*; this species is reviewed in Section 4.6.1.6.

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

#### 4.4.1.6. Alcidae (Dovekie, murres, Black Guillemot, Razorbill and Atlantic Puffin)

Four of the six species of alcidae breeding in the North Atlantic include the Study Area as part of their normal range. Black Guillemot and Razorbill are the exception spending most of the time near shore in Newfoundland waters. Dovekie and Thick-billed Murre are breeding species in Arctic regions of the North Atlantic. Both species winter in significantly large numbers in Newfoundland waters including the Study Area. Dovekie and Thick-billed Murre are present in the Study Area mainly during the non-breeding season from October to May. Common Murre and Atlantic Puffin are both locally abundant breeders in eastern Newfoundland (Table 4.9). Both are expected to be present in low densities within the Study Area during spring migration, summer and fall migration (April to November). During the 9 July to 16 August 2006 monitoring program, at least 50 Common Murres were sighted over 17 dates (Abgrall et al. *in prep.* a). Common Murre is probably present through the winter months as well. During the 2006 monitoring program, at least 17 puffins were seen on eight dates from 13 July to 1 August. Atlantic Puffin is speculated to leave the Study Area during the winter months.

### 4.4.2. Prey and Foraging Habits

Marine birds in the Study Area consume a variety of prey ranging from small fish to zooplankton. Different foraging methods include plunge diving from a height of 30 m into the water, feeding on the surface, and sitting on the water then diving. Table 4.10 summarizes the feeding habits of birds expected to occur in the Study Area.

#### 4.4.2.1. Procellariidae (fulmar and shearwaters)

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

#### 4.4.2.2. Hydrobatidae (storm-petrels)

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

## Table 4.10. Foraging strategy and prey of seabirds in the Study Area.

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

**Sources:** Cramp and Simmons (1983); Nettleship and Birkhead (1985); Lock et al. (1994); Gaston and Jones (1998).

#### 4.4.2.3. Sulidae (Northern Gannet)

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

#### 4.4.2.4. Phalaropodinae (phalaropes)

Red-necked and Red Phalaropes eat zooplankton at the surface of the water. They secure food by swimming and rapidly picking at the surface of the water. The head probably rarely goes beneath surface.

#### 4.4.2.5. Laridae (skuas, jaegers, gulls, terns)

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

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

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

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

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

#### 4.4.2.6. Alcidae (Dovekie, murres, Razorbill and Atlantic Puffin)

This group of birds is different than the other seabirds of the Study Area. They spend considerable time resting on the water and dive deep into the water column for food. Dovekie feeds on zooplankton including larval fish. They can dive down to 30 m and remain under water up to 41 seconds, but average dives are somewhat shallower and shorter in duration (Gaston and Jones 1998). Common Murre and Thick-billed Murre have been recorded diving to 100 m but 20-60 m is thought to be average.

Dives have been timed up to 202 seconds but 60 seconds is closer to average (Gaston and Jones 1998). Razorbill has been recorded diving to 120 m but 25 m is thought to be more typical with time under water about 35 seconds (Gaston and Jones 1998). Black Guillemot usually feeds in water <30 m in depth but in deep water has been recording diving to 50 m with a maximum 147 seconds under water. Average depth and duration of dives is expected to be less (Gaston and Jones 1998). Atlantic Puffin will dive to 60 m but 10 to 45 m is thought to be typical. Maximum length of time recorded under water is 115 seconds but a more typical dive would be about 30 seconds.

# 4.5. Marine Mammals and Sea Turtles

## 4.5.1. Marine Mammals

At least 21 species of marine mammal are known or expected to occur in and near the Study Area including 18 species of cetaceans (whales and dolphins) and three species of phocids (seals; Table 4.11). Additional marine mammal species may occur rarely. Most marine mammals are seasonal inhabitants, the waters of the Grand Banks and surrounding areas being important feeding grounds for many of them. There are no identified sensitive areas for marine mammals in the Study Area.

**Table 4.11. Marine mammals that may or likely occur in the Study Area and their COSEWIC and *SARA* status.**

| Common Name | Scientific Name | COSEWIC Status[a] (*SARA* listing/status) |
|---|---|---|
| **Baleen Whales** | **Mysticetes** | |
| Blue Whale | *Balaenoptera musculus* | *Endangered* (Schedule 1) |
| Fin Whale | *Balaenoptera physalus* | *Special Concern* (Schedule 1) |
| Sei Whale | *Balaenoptera borealis* | *Data Deficient* (No status) |
| Humpback Whale | *Megaptera novaeangliae* | Not At Risk (No status) |
| Minke Whale | *Balaenoptera acutorostrata* | Not At Risk (No status) |
| North Atlantic Right Whale | *Eubalaena glacialis* | *Endangered* (Schedule 1) |
| **Toothed Whales** | **Odontocetes** | |
| Sperm Whale | *Physeter macrocephalus* | Candidate Species—low priority (No status) |
| Northern Bottlenose Whale | *Hyperoodon ampullatus* | *Endangered*—Scotian Shelf Population (Schedule 1); Not At Risk—Davis Strait Population (No status) |
| Sowerby's Beaked Whale | *Mesoplodon bidens* | *Special Concern* (Schedule 3) |
| Killer Whale | *Orcinus orca* | *Data Deficient* (No status) |
| Long-finned Pilot Whale | *Globicephala melas* | Not assessed (No status) |
| Atlantic White-sided Dolphin | *Lagenorhynchus acutus* | Not assessed (No status) |
| Short-beaked Common Dolphin | *Delphinus delphis* | Not assessed (No status) |
| White-beaked Dolphin | *Lagenorhynchus albirostris* | Not assessed (No status) |
| Bottlenose Dolphin | *Tursiops truncatus* | Not assessed (No status) |
| Striped Dolphin | *Stenella coeruleoalba* | Not assessed (No status) |
| Risso's Dolphin | *Grampus griseus* | Not At Risk (No status) |
| Harbour Porpoise | *Phocoena phocoena* | *Special Concern* (No schedule or status; referred back to COSEWIC) |
| **True Seals** | **Phocids** | |
| Harp Seal | *Phoca groenlandica* | Candidate Species—low priority (No status) |
| Hooded Seal | *Cystophora cristata* | Candidate Species—low priority (No status) |
| Grey Seal | *Halichoerus grypus* | Not assessed (No status) |

[a] Based on COSEWIC (2007).

Recent monitoring programs (2004 – 2007) of seismic and CSEM surveys conducted in Jeanne d'Arc Basin and areas adjacent to the Grand Banks provide new information on marine mammal spatial and temporal distribution. These programs include:

- Petro-Canada's seismic program in Jeanne d'Arc Basin during June – July 2007 (Lang and Moulton *in prep*.)
- Husky's seismic program in the Jeanne d'Arc Basin during October – November 2005 (Lang et al. 2006) and July – August 2006 (Abgrall et al. *in prep.* a)
- ExxonMobil's CSEM program in Orphan Basin during July – August 2006 and August - September 2007 (Abgrall et al. *in prep.* b)
- Chevron and Co-venturers seismic program in Orphan Basin during July – September 2004 (Moulton et al. 2005) and May – October 2005 (Moulton et al. 2006b)

Prior to these programs, marine mammal surveys conducted over 25 years ago in support of the Hibernia EIS (Parsons and Brownlie 1981) were the primary source of information on distribution and abundance of marine mammals in the Jeanne d'Arc Basin area. The results from these surveys were described in the Hibernia EIS in 1985 (Mobil 1985), updated in 1995 for the Terra Nova EIS (Petro-Canada 1996a,b), and updated again in 2000 for the White Rose EIS (Husky 2000). The detailed information from these surveys and other biological information presented in the EISs are not repeated in this report. As requested in the Scoping Document, summary descriptions of marine mammal spatial and temporal distributions as well as relevant life history details are provided. Figure 4.47 shows the locations of seismic and CSEM survey areas in recent years, along with marine mammal sightings observed during these surveys, relative to the Study, Project and Seismic Area (proposed for 2008) for SHC's proposed 2008 – 2016 seismic program. [It should be noted that marine mammal densities or relative abundance *cannot* be implied from Figure 4.47 because the number of observations is highly related to survey effort which was highly variable from area to area.] Results of these monitoring reports are summarized here and detailed in LGL (2007a). Table 4.12 summarizes the monitoring program sightings.

Population estimates and feeding information of many of the marine mammal species that occur within the Project Area are provided in Tables 4.13 and 4.14, respectively. For most species of marine mammals there are no reliable population estimates for Atlantic Canada; most estimates provided in Table 4.13 are based on data collected in northeastern U.S. waters (Waring et al. 2007).

#### 4.5.1.1. DFO Cetacean Sighting Database

The Department of Fisheries and Oceans in St. John's (J. Lawson, DFO Marine Mammal Research Scientist, 2007, pers. comm.) is compiling a database of cetacean sightings in waters around Newfoundland and Labrador. These data provide some indication of what species can be expected to occur in the area but they cannot, at this point in the development of the database, provide any fine-scale quantitative information as the database typically does not include observation effort. Table 4.15 contains the coarse summary data pertaining to sightings within the Study Area; caveats associated with the DFO data are also presented.

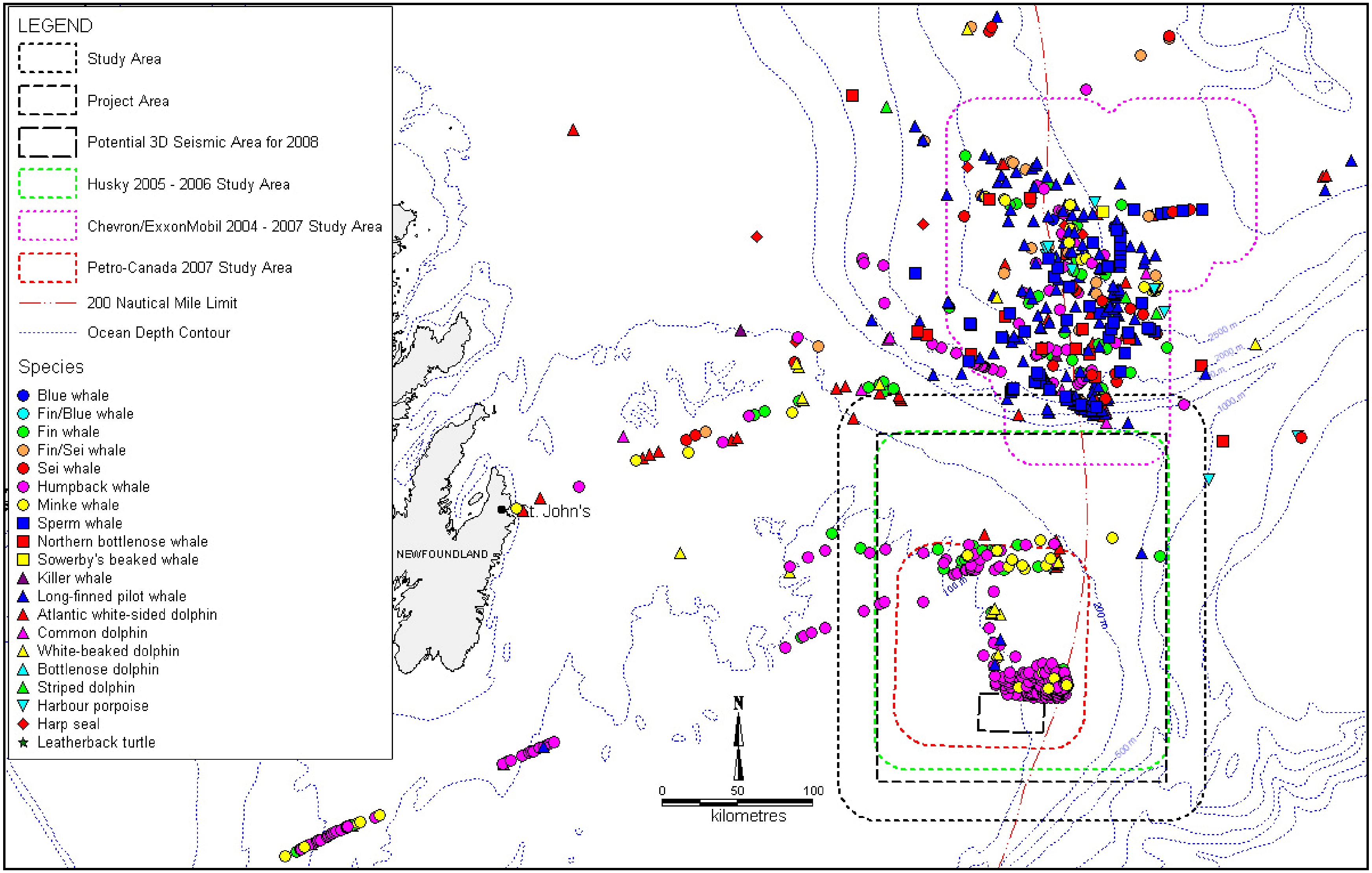



**Figure 4.47.** **Locations of seismic and CSEM survey areas (2004 – 2007), along with marine mammal and sea turtle sightings observed during these surveys, relative to the Study, Project and Seismic Area (proposed for 2008) for SHC's 2008 -2016 seismic program. [Animal densities or relative abundance *cannot* be implied from this map because the number of observations survey effort was highly variable from area to area.]**

**Table 4.12. Marine mammals known to occur within the Jeanne d'Arc Basin area and the number of marine mammal sightings (and individuals) made during monitoring of seismic and CSEM surveys (2004 – 2007) in and near the proposed Study Area.**

| Species | No. of Sightings (individuals) during Chevron Monitoring 2004[a] | No. of Sightings (individuals) during Chevron Monitoring 2005[b] | No. of Sightings (individuals) during Husky Monitoring 2005[c] | No. of Sightings (individuals) during Husky Monitoring 2006[d] | No. of Sightings (individuals) during ExxonMobil Monitoring 2006[e] | No. of Sightings (individuals) during ExxonMobil Monitoring 2007[e] | No. of Sightings (individuals) during Petro-Canada Monitoring 2007[f] |
|---|---|---|---|---|---|---|---|
| **Baleen Whales (Mysticetes)** | | | | | | | |
| Blue Whale | 0 | 0 | 0 | 0 | 0 | 2 (2) | 0 |
| Fin Whale | 9 (16) | 16(24) | 16 (22) | 16 (24) | 7 (8) | 13 (30) | 1 (1) |
| Sei Whale | 6 (9) | 15(24) | 0 | 0 | 2 (3) | 0 | 0 |
| Fin/Blue Whale | 0 | 0 | 0 | 1 (2) | 0 | 0 | 0 |
| Fin/Sei Whale | 12 (18) | 7(8) | 0 | 0 | 2 (2) | 0 | 0 |
| Humpback Whale | 13 (30) | 36 (111) | 59 (79) | 181 (218) | 1 (1) | 9 (14) | 5 (6) |
| Minke Whale | 6 (6) | 8(8) | 9 (9) | 12 (12) | 2 (2) | 2 (2) | 1 (1) |
| North Atlantic Right Whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Toothed Whales (Odontocetes)** | | | | | | | |
| Sperm Whale | 5 (5) | 32(47) | 0 | 0 | 5 (8) | 16 (26) | 0 |
| Northern Bottlenose Whale | 3 (9) | 7(21) | 0 | 0 | 2 (5) | 4 (10) | 0 |
| Sowerby's Beaked Whale | 0 | 1(4) | 0 | 0 | 0 | 0 | 0 |
| Killer Whale | 0 | 0 | 1 (6) | 0 | 0 | 1 (1) | 0 |
| Long-finned Pilot Whale | 43 (597) | 101 (1713) | 2 (16) | 2 (24) | 14 (326) | 9 (165) | 1 (15) |
| Atlantic White-sided Dolphin | 4 (70) | 18 (304) | 6 (128) | 8 (145) | 6 (197) | 10 (195) | 0 |
| Common Dolphin | 0 | 9 (88) | 4 (61) | 7 (106) | 1 (5) | 1 (7) | 0 |
| White-beaked Dolphin | 1 (5) | 6 (52) | 2 (23) | 1 (4) | 0 | 1 (12) | 5 (38) |
| Bottlenose Dolphin | 0 | 1 (15) | 0 | 0 | 0 | 0 | 0 |
| Striped Dolphin | 1(4) | 2 (15) | 0 | 0 | 0 | 0 | 0 |
| Risso's Dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Harbour Porpoise | 1 (2) | 9(24) | 1 (2) | 0 | 0 | 0 | 0 |
| **True Seals (Phocids)** | | | | | | | |
| Harp Seal | 2 (2) | 5(603) | 0 | 0 | 0 | 0 | 0 |
| Hooded Seal | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grey Seal | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Sources:** Moulton et al. 2005[a], 2006b[b]; Lang et al. 2006[c]; Abgrall et al. *in prep.* a[d], b[e], Lang and Moulton *in prep.*[f].

## Table 4.13. Population estimates of marine mammals that occur in the Study Area.

| Species | Northwest Atlantic (NW) Population Size | Population Occurring in the Study Area | | |
|---|---|---|---|---|
| | Estimated Number | Stock | Estimated Number | Source of Updated Information |
| **Baleen Whales** | | | | |
| Blue Whale | 308 [a] (600-1500 in North Atlantic) | NW Atlantic | Unknown | Sears and Calambokidis (2002) |
| Fin Whale | 2,814 [b] (CV=0.21) | Can. E. Coast | Unknown | Waring et al. (2007) |
| Sei Whale | Unknown | Nova Scotia | Unknown | COSEWIC (2003a); Waring et al. (2007) |
| Humpback Whale | 5,505 (11,570 in North Atlantic; CV=0.068) | NF/Labrador | 1,700-3,200 | Whitehead (1982); Katona and Beard (1990); Baird (2003); Stevick et al. 2003 |
| Minke Whale | 2,998 [c] (CV=0.19) | Can. E. Coast | Unknown | Waring et al. (2007) |
| **Toothed Whales** | | | | |
| Sperm Whale | 4,804 [d] (CV=0.38) | North Atlantic | Unknown | Reeves and Whitehead (1997); Waring et al. (2007) |
| Northern Bottlenose Whale | Tens of thousands? | North Atlantic | Unknown | Reeves et al. (1993); Waring et al. (2007) |
| Sowerby's Beaked Whale | Unknown | | | Katona et al. (1993) |
| Killer Whale | Unavailable | | Unknown | Lien et al. (1988); Waring et al. (2007) |
| Long-finned Pilot Whale | 31,139 [e] (CV=0.27) | NW Atlantic | Abundant | Nelson and Lien (1996); Waring et al. (2007) |
| Atlantic White-sided Dolphin | 51,640 [f] (CV=0.38) | NW Atlantic | Unknown | Palka et al. (1997); Waring et al. (2007) |
| Short-beaked Common Dolphin | 120,743 [g] (CV=0.23) | NW Atlantic | Unknown | Katona et al. (1993); Waring et al. (2007) |
| White-beaked Dolphin | Unknown | NW Atlantic | Unknown | Waring et al. (2007) |
| Bottlenose Dolphin (offshore stock) | 81,588 [h] (CV=0.17) | NW Atlantic | Unknown | Waring et al. (2007) |
| Striped Dolphin | 94,462 [i] (CV= 0.40) | NW Atlantic | Unknown | Waring et al. (2007) |
| Risso's Dolphin | 20,479 [j] (CV=0.59) | US East Coast | Unknown | Waring et al. (2007) |
| Harbour Porpoise | Unknown | Newfoundland | Unknown | Wang et al. (1996); COSEWIC (2006); Waring et al. (2007) |
| **True Seals** | | | | |
| Harp Seal | 5.9 million (CV=0.13) | NW Atlantic | Unknown | ICES (2005) |
| Hooded Seal | 592,100 (±187,700) | NW Atlantic | Unknown | ICES (2006) |
| Grey Seal | 154,000 | E. Canada | Unknown | Mohn and Bowen (1996) |

[a] Based on surveys from the Gulf of St. Lawrence. This estimate deemed unsuitable for abundance estimation.
[b] Based on surveys from George's Bank to the mouth of the Gulf of St. Lawrence.
[c] Based on surveys from George's Bank to the mouth of the Gulf of St. Lawrence plus a survey in the Gulf of St. Lawrence.
[d] Based on surveys from Florida to the Gulf of St. Lawrence.
[e] Based on surveys from Gulf of St. Lawrence to Florida. Considers both long- and short-finned pilot whales.
[f] Gulf of Maine Stock.
[g, i, j] Based on surveys from Florida to Bay of Fundy
[h] Based on surveys from Florida to Georges Bank. Numbers in Atlantic Canada unknown.

## Table 4.14. Prey of marine mammals that occur in the Study Area.

| Species | Prey | Source of Updated Information |
|---|---|---|
| **Baleen Whales** | | |
| Blue Whale | Euphausiids | |
| Fin Whale | Fish (predominantly capelin), euphausiids | Piatt et al. (1989) |
| Sei Whale | Copepods, euphausiids, some fish | |
| Humpback Whale | Fish (predominantly capelin), euphausiids | Piatt et al. (1989) |
| Minke Whale | Fish (predominantly capelin), squid, euphausiids | Piatt et al. (1989) |
| **Toothed Whales** | | |
| Sperm Whale | Cephalopods, fish | Reeves and Whitehead (1997) |
| Northern Bottlenose Whale | Primarily squid, also fish | |
| Sowerby's Beaked Whale | Squid, some fish | Pitman (2002) |
| Killer Whale | Herring, squid, seals, dolphins, other whales | Lien et al. (1988) |
| Long-finned Pilot Whale | Short-finned squid, northern cod, amphipods | Nelson and Lien (1996) |
| Atlantic White-sided Dolphin | Schooling fish (sand lance, herring), hake, squid | Palka et al. (1997) |
| Short-beaked Common Dolphin | Squid, fish | Katona et al. (1993) |
| White-beaked Dolphin | Fish (cod, capelin, herring), squid | Hai et al. (1996) |
| Bottlenose Dolphin | Squid, fish (mackerel, butterfish) | Gaskin (1992a) |
| Striped Dolphin | Cephalopods, shoaling fish | Reeves et al. (2002) |
| Risso's Dolphin | Squid | Reeves et al. (2002) |
| Harbour Porpoise | Schooling fish (capelin, cod, herring, mackerel) | |
| **True Seals** | | |
| Harp Seal | Fish (capelin, cod, halibut, sand lance), crustaceans | Lawson and Stenson (1995); Lawson et al. (1998); Wallace and Lawson (1997); Hammill and Stenson (2000). |
| Hooded Seal | Fish (Greenland halibut, redfish, Arctic and Atlantic cod, herring), squid, shrimp, molluscs | Ross (1993) |
| Grey Seal | Fish (herring, cod, hake, pollock), squid, shrimp | Benoit and Bowen (1990); Hammill et al. (1995) |

**Source:** Mobil (1985) with updates where indicated.

**Table 4.15. Cetacean sightings (from the DFO database) within the Study Area, 1945-2007.**

| Species | No. of Sightings | No. of Individuals | Month(s) Sighted |
|---|---|---|---|
| Fin Whale | 26 | 1 | May-July, Sept-Oct |
| Sei Whale | 7 | 312 | Aug-Sept |
| Humpback Whale | 188 | 46 | Jan-Dec |
| Minke Whale | 26 | 2418 | Jan, April-Dec |
| Right Whale | 1 | 365 | June |
| Sperm Whale | 45 | 2 | Jan-August, Oct-Dec |
| Northern Bottlenose Whale | 2 | 240 | June |
| Killer Whale | 10 | 47 | June, Aug, Oct-Nov |
| Long-finned Pilot Whale | 29 | 161 | Feb-March, May-Oct, Dec |
| Atlantic White-sided Dolphin | 3 | 2217 | Feb, July, Sept |
| Common Dolphin | 3 | 216 | March, Aug |
| Harbour Porpoise | 3 | 1402 | May-June, Sept |

**Source***:* DFO (2007).
*Note the following caveats associated with the tabulated data:
(1) The sighting data have not yet been completely error-checked.
(2) The quality of some of the sighting data is unknown.
(3) Most data have been gathered from platforms of opportunity that were vessel-based. The inherent problems with negative or positive reactions by cetaceans to the approach of such vessels have not yet been factored into the data.
(4) Sighting effort has not been quantified (i.e., the numbers cannot be used to estimate true species density or real abundance).
(5) Both older and some more recent survey data have yet to be entered into this database. These other data will represent only a very small portion of the total data.
(6) Numbers sighted have not been verified (especially in light of the significant differences in detectability among species).
(7) For completeness, these data represent an amalgamation of sightings from a variety of years (e.g., since 1945) and seasons. Hence, they may obscure temporal or real patterns in distribution (e.g., the number of pilot whales sighted in nearshore Newfoundland appears to have declined since the 1980s but the total number sighted in the database included here suggest they are relatively common).

Humpback whales accounted for most sightings in the Study Area followed by sperm whales, long-finned pilot whales, fin whales, and minke whales (Figure 4.48). Most sightings of humpbacks in the DFO database were recorded from oil development sites within the Study Area (Figure 4.48). There are relatively few sightings of dolphins and harbour porpoise recorded in the Study Area.

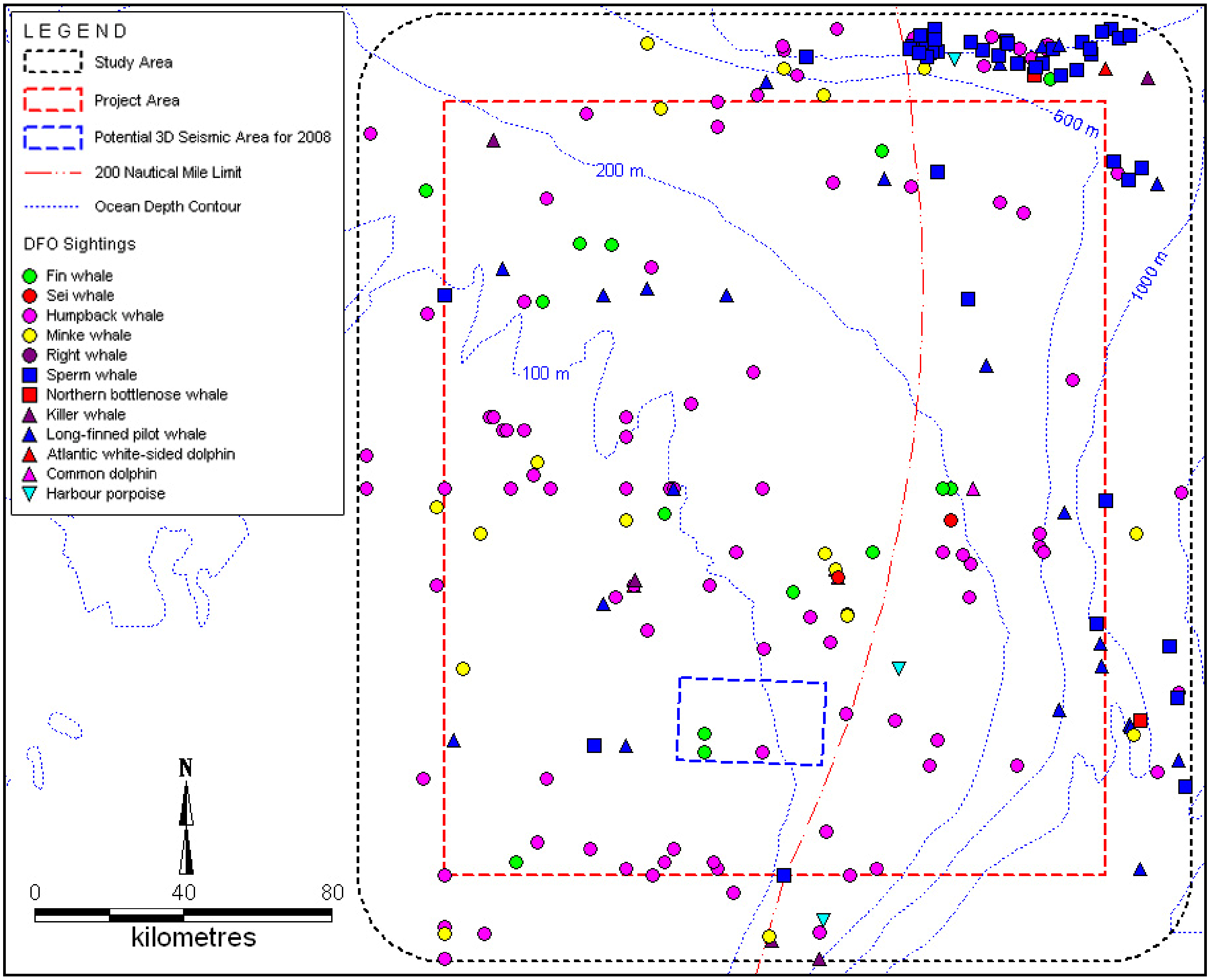



**Figure 4.48. Sightings of cetaceans within the Study Area from the DFO Cetacean Sighting Database (1945-2007).**

### 4.5.1.2. Species Profiles

***Baleen Whales (Mysticetes).***—The five species of baleen whales that may occur in the Project Area include the blue, fin, sei, humpback and minke whale (Table 4.12). It is possible, but highly unlikely, that a North Atlantic right whale may occur in the Project Area. Although nearly all of the baleen whales experienced depletion due to whaling, it is likely that many are experiencing some recovery (Best 1993). Detailed species profiles for baleen whales are provided in Husky's Northern Jeanne d'Arc Basin seismic program EA (LGL et al. 2005b, Section 5.7.1.2) and Petro-Canada's Jeanne d'Arc Basin seismic EA (LGL 2007a, Section 4.7.1.2).

*Blue Whale:* This species is considered *Endangered* by COSEWIC and is listed as such on Schedule 1 of *SARA*. More information is found in Section 4.6.1.1 of this report.

*Humpback Whale:* Humpback whales are relatively common within and near the Study Area (Table 4.15; Figure 4.48); especially during summer and early fall. Humpback whales were the most commonly sighted whales during the 2005 and 2006 Husky seismic monitoring programs with 240 sightings accounting for 81.6% of all confirmed baleen whale sightings (Lang et al. 2006; Abgrall et al. *in prep*. a; Table 4.12). Humpback whales were also the most commonly sighted whales during the 2007 Petro-Canada seismic monitoring program (five of the seven baleen whale sightings; Lang and Moulton *in prep*.; Table 4.12). Two sightings (one and three individuals) of humpback whales were made in late May 2006, within 10 nautical miles of the Terra Nova FPSO (T. Lang, LGL Ltd, pers. comm.). Humpback whales were also the most commonly sighted baleen whale species in the Orphan Basin during seismic monitoring programs in 2004 and 2005 (Moulton et al. 2005, 2006b), and the second most commonly sighted baleen whale species in the Orphan Basin during ExxonMobil CSEM monitoring programs in 2006 and 2007 (Abgrall et al. *in prep.* b). In terms of the number of sighting events recorded in the DFO database (DFO 2007), humpback whales ranked first in the Study Area, with 188 sightings recorded (Table 4.15).

*Fin Whale:* This species is listed as *Special Concern* on Schedule 1 of *SARA* and is described in Section 4.6.1.5.

*Sei Whale:* Available information suggests that sei whales are uncommon visitors to the Project Area compared to other cetacean species. No sei whales were sighted during the 2005 and 2006 Husky, and during the 2007 Petro-Canada seismic monitoring programs in Jeanne d'Arc Basin (Lang et al. 2006; Abgrall et al. *in prep.* a; Lang and Moulton *in prep.*; Table 4.12). Sei whales were, however, commonly sighted in the Orphan Basin during the Chevron seismic monitoring programs in 2004 and 2005 (6 and 15 sightings, respectively; Moulton et al. 2005, 2006b; Table 4.12). In addition, sei whales were observed twice on the Orphan Basin during the ExxonMobil CSEM monitoring program in 2006, but not in 2007 (Abgrall et al. *in prep.* b; Table 4.12). Based on the DFO cetacean sightings database (DFO 2007), seven sei whale sightings have been reported in the Study Area (Table 4.15). The Atlantic population of the sei whale is considered by COSEWIC as *Data Deficient* (COSEWIC 2007).

*Minke Whale:* Minke whales commonly occur within and near the Study Area (Figure 4.48). Minke whales were sighted 21 times (7.1% of all confirmed baleen whale sightings) during the 2005 and 2006 Husky seismic monitoring programs, and once during the 2007 Petro-Canada seismic monitoring program (Lang et al. 2006; Abgrall et al. *in prep.* a, Lang and Moulton *in prep.*; Table 4.12). Several minke whales were also sighted during the Orphan Basin seismic monitoring programs in July of 2004 and 2005 (Moulton et al. 2005, 2006b) and two minke whales were sighted during the Orphan Basin ExxonMobil CSEM monitoring programs in each of 2006 and 2007 (Abgrall et al. *in prep*. b; Table 4.12). Within the Study Area, minke whales were the fourth most commonly recorded mysticete in the DFO sightings database (DFO 2007), with sightings predominantly recorded during summer months (Table 4.15).

*North Atlantic Right Whale*: This species is listed as *Endangered* on Schedule 1 of *SARA* and is described in Section 4.6.1.2.

***Toothed Whales (Odontocetes).—*** Twelve species of toothed whales may occur in the Study Area (Table 4.12). Most of these marine mammals are thought to occur seasonally in and near the Project Area and little is known regarding their distribution and population size in these waters. Detailed species profiles for toothed whales are provided in Section 5.7.1.2 of LGL (2005b) and in Section 4.7.1.2 of LGL (2007a).

*Sperm Whale:* This species is listed as a low priority *candidate* species by COSEWIC and is described in Section 4.6.1.20.

*Northern Bottlenose Whale:* The Study Area is within the known range of the northern bottlenose whale and two sightings have been recorded there in the DFO cetacean sightings database (DFO 2007; Table 4.15). This whale's life history is poorly known and most records from Newfoundland are based on carcasses washed ashore. There have been several sightings of this species in deep waters north and south of the Project Area (Wimmer and Whitehead 2004; Moulton et al. 2005, 2006b; Abgrall et al. *in prep.* b). Since most of the Project Area has water depths <500 m, the possibility of northern bottlenose whale occurrence should be considered low. None were sighted during the 2005 and 2006 Husky seismic monitoring programs (Abgrall et al. *in prep.* a) or during the 2007 Petro-Canada program in Jeanne d'Arc Basin (Lang and Moulton *in prep*.; Table 4.12).

The northern bottlenose whale that inhabits the Scotian Shelf is considered *Endangered* whereas the Davis Strait population is considered *not at risk* (COSEWIC 2007). It is uncertain to which population individuals sighted off eastern Newfoundland would belong, but available information suggests that it is unlikely that (potential) sightings of northern bottlenose whales in or near the Jeanne d'Arc Basin area would be from the Scotian Shelf population. However, there has been recent debate about this topic (J. Lawson, DFO, pers. comm., March 2007). Whales from the Scotian Shelf population are known to spend most of their time in the Gully, Haldimand and Shortland canyons on the Scotian Slope and their home ranges are thought to be a few hundred kilometres or less (COSEWIC 2002; Wimmer and Whitehead 2004).

*Sowerby's Beaked Whale:* This species is listed as *Special Concern* on Schedule 3 of *SARA* and is described in Section 4.6.1.12.

*Killer Whale:* The killer whale is a year-round resident that is thought to occur in relatively small numbers in the Study Area (Lien et al. 1988). Three killer whales were sighted within 20 km of the White Rose area on 24 August 1999 (Wiese and Montevecchi 1999). A pod of eight killer whales was sighted south of the Study Area on 26 May 2006 (T. Lang, LGL Ltd, pers. comm.). There was a single sighting of six killer whales during the Husky seismic monitoring program in 2005 (Lang et al. 2006) and a single sighting of an individual killer whale in the Orphan Basin during the 2006 ExxonMobil CSEM monitoring program (Abgrall et al. *in prep.* b). In addition, 10 killer whale sightings in the Study

Area have been recorded in the DFO sightings database (DFO 2007; Table 4.15). This species is considered '*Data Deficient*' by COSEWIC (2007).

*Long-finned Pilot Whale:* Long-finned pilot whales were regularly sighted in deeper waters (Orphan Basin) north of Jeanne d'Arc Basin during the summers of 2004, 2005, 2006 and 2007 (Moulton et al. 2005, 2006b; Abgrall et al. *in prep.* b). There were two confirmed sightings of long-finned pilot whales during each of the 2005 and 2006 Husky seismic monitoring program (Lang et al. 2006; Abgrall et al. *in prep.* a) and one sighting during the 2007 Petro-Canada seismic monitoring program in Jeanne d'Arc Basin (Lang and Moulton *in prep.*; Figure 4.47). There have been 29 sightings within the Study Area recorded in the DFO database (DFO 2007; Table 4.15).

*Atlantic White-sided Dolphin:* The number of white-sided dolphins in the Study Area is unknown. There were seven sightings of 250 individuals on the Grand Banks in August to September 1999, including several sightings within approximately 30 km of the White Rose site, during an offshore supply vessel surveys (Wiese and Montevecchi 1999). There were 14 sightings of Atlantic white-sided dolphins during the Jeanne d'Arc Basin 2005 and 2006 Husky seismic monitoring programs (Lang et al. 2006; Abgrall et al. *in prep.* a), but none during the 2007 Petro-Canada monitoring program (Lang and Moulton *in prep.*; Table 4.12). This species was also commonly sighted in and near Orphan Basin in 2004, 2005, 2006 and 2007 (Moulton et al. 2005, 2006b; Abgrall et al. *in prep.* b; Table 4.12). Three sightings of this dolphin within the Study Area are recorded in the DFO cetacean sightings database (DFO 2007; Table 4.15). The most easterly recorded sighting for individuals from the northwest Atlantic population occurred on the Flemish Cap (Gaskin 1992b).

*Common (Short-beaked) Dolphin:* Considering the water depth ranges in areas where this cetacean has been sighted in U.S. waters, common dolphins could potentially occur throughout most of the Study Area. There were 11 confirmed sighting of common dolphins in the Jeanne d'Arc Basin during the 2005 and 2006 Husky seismic monitoring programs, but none during the 2007 Petro-Canada seismic monitoring program (Lang et al. 2006; Abgrall et al. *in prep.* a; Lang and Moulton *in prep.*; Table 4.12). Nine other sightings of this species were recorded in the Orphan Basin, north of the Project Area, during late summer 2005 (Moulton et al. 2006b) and single sightings of common dolphins were recorded in each of the two ExxonMobil CSEM monitoring surveys in 2006 and 2007 (Abgrall et al. *in prep.* b; Table 4.12). There were three sightings of this species recorded in the Study Area in the DFO database (DFO 2007; Table 4.15).

*White-beaked Dolphin:* White-beaked dolphin occurrence in the Study Area is not well documented. There were two and one sightings of white-beaked dolphins during the Jeanne d'Arc Basin 2005 and 2006 Husky seismic monitoring program, respectively (Lang et al. 2006; Abgrall et al. *in prep.* a; Table 4.12). Another five sightings of white-beaked dolphins were made during the Jeanne d'Arc Basin Petro-Canada seismic monitoring program in 2007 (Lang and Moulton *in prep.*). White-beaked dolphins were also sighted north of the Jeanne d'Arc Basin during the Orphan Basin seismic and CSEM monitoring programs in 2004, 2005 and 2007, but not in 2006 (Moulton et al. 2005, 2006b; Abgrall et al. *in prep.* b; Table 4.12). There are no sightings of white-beaked dolphins in the Study Area in the DFO cetacean sightings database (DFO 2007; Table 4.15).

*Bottlenose Dolphin:* There was only one sighting of bottlenose dolphins (15 individuals) during recent marine mammal monitoring programs. It was made in 2005 during the Chevron seismic monitoring program in the Orphan Basin, north of the proposed Project Area (Moulton et al. 2006b). There are no sightings of bottlenose dolphins in the Study Area in the DFO cetacean sightings database (DFO 2007; Table 4.15).

*Striped Dolphin:* This species' preferred habitat seems to be deep water along the edge and seaward of the continental shelf, particularly in areas with warm currents (Baird et al. 1993). Offshore waters of Newfoundland are thought to be at the northern limit of its range. There were only three sightings of this species in Orphan Basin during Chevron seismic monitoring programs in 2004 and 2005 (Moulton et al. 2005, 2006b) and none were sighted during ExxonMobil CSEM monitoring programs in 2006 and 2007 (Abgrall et al. *in prep.* b; Table 4.12). None were sighted in the Jeanne d'Arc Basin during the 2005 and 2006 Husky seismic monitoring programs (Lang et al. 2006; Abgrall et al. *in prep.* a) or during the 2007 Petro-Canada seismic monitoring program (Lang and Moulton *in prep.*). There are no sightings of striped dolphins recorded in the DFO sightings database, within the Study Area (DFO 2007; Table 4.15).

*Risso's Dolphin:* Risso's dolphins are abundant worldwide but are probably rare in the Study Area (Reeves et al. 2002). None were observed during recent marine mammal monitoring programs in Jeanne d'Arc Basin and Orphan Basin (Table 4.12) and no sightings are recorded in the Study Area in the DFO cetacean sightings database (DFO 2007; Table 4.15).

*Harbour Porpoise:* The harbour porpoise is considered of *Special Concern* by COSEWIC and is under consideration for addition to Schedule 1 of *SARA*. This species is described in Section 4.6.1.13.

***True Seals (Phocids).—*** Three species of seals are known or suspected to occur in the Study Area including harp, hooded, and grey seals (Table 4.13). Other seal species (ringed, harbour, and bearded) may occur rarely. Hooded and harp seals are listed as candidate species by COSEWIC and are described in Sections 4.6.1.21 and 4.6.1.22, respectively. Grey seals may occur in the Study Area but the number that occurs there is believed to be low.

## 4.5.2. Sea Turtles

Sea turtles are probably not common in the Study Area but are important to consider because of their *Threatened* or *Endangered* status, both nationally and internationally.

Three species of sea turtles may occur in the Study Area: (1) the leatherback (*Dermochelys coriacea*), (2) the loggerhead (*Caretta caretta*), and (3) the Kemp's ridley sea turtle (*Lepidochelys kempi*) (Ernst et al. 1994). However, little can be said to qualify, much less quantify, the degrees of occurrence of these three sea turtle species within the Study Area due to lack of information. The leatherback turtle is listed as *Endangered* under Schedule 1 of *SARA* and by the United States National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS) (Plotkin 1995). The Kemp's ridley is also listed as

*Endangered* and the loggerhead turtle is listed as *Threatened* by NMFS and FWS (Plotkin 1995). Detailed species profiles for sea turtles, other than for leatherbacks, are provided in Section 5.7 of LGL (2005b) and Section 4.7.2 of LGL (2007a). There are no identified sensitive areas for sea turtles in the Study Area. Leatherback turtles are reviewed in Section 4.6.1.3 of this EA.

## 4.6. Species at Risk

Species considered at risk in Canada are listed under *SARA* on Schedules 1 to 3 with only those listed as *endangered* or *Threatened* on Schedule I having immediate legal implications. Nonetheless, attention must be paid to all of the *SARA*-listed species because of their sensitivities to perturbation and the potential for status upgrades. Schedule 1 is the official list of wildlife Species at Risk in Canada. Once a species/population is listed, the measures to protect and recover it are implemented. The two cetacean species/populations, one sea turtle species, and two fish species/populations that are legally protected under *SARA* and have potential to occur in the Study Area are listed in Table 4.16. Atlantic wolffish, fin whale, and Ivory Gull are listed as *Special Concern* on Schedule 1 (Table 4.16). Schedules 2 and 3 of *SARA* identify species that were designated "at risk" by COSEWIC prior to October 1999 and must be reassessed using revised criteria before they can be considered for addition to Schedule 1. Species that potentially occur in the Study Area and are considered at risk but which have not received specific legal protection (i.e., proscribed penalties and legal requirement for recovery strategies and plans) under *SARA* are also listed in Table 4.16 as *Endangered*, *Threatened* or species of *Special Concern* under COSEWIC. Other non-*SARA* listed marine species which potentially occur in the Study Area and are listed by COSEWIC as *candidate* species are also included in Table 4.16.

Under *SARA*, a 'recovery strategy' and corresponding 'action plan' must be prepared for *Endangered*, *Threatened*, and *Extirpated* species. A management plan must be prepared for species listed as *Special Concern*. Currently, there is only one final recovery strategy and no action plans, or final management plans in place for species listed under Schedule 1 and which are known to occur in the Study Area. There is a proposed recovery strategy for northern and spotted wolffish and a proposed management plan for Atlantic wolffish. SHC will monitor *SARA* issues through the Canadian Association of Petroleum Producers (CAPP), the law gazettes, the Internet and communication with DFO and Environment Canada, and will adaptively manage any issues that may arise in the future. The company will comply with relevant regulations pertaining to *SARA* Recovery Strategies and Action Plans. The Proponent acknowledges the rarity of the Species at Risk and will continue to exercise due caution to minimize impacts during all of its operations. SHC also acknowledges the possibility of other marine species being listed as *Endangered* or *Threatened* on Schedule 1 during the course of the Project. Due caution will also be extended to any other species added to Schedule 1 during the life of this Project.

Species profiles, related special or sensitive habitat, and any effects or mitigations that relate to *SARA* species are discussed in the following sections.

**Table 4.16. *SARA* Schedule 1 and COSEWIC-listed marine species that potentially occur in the Study Area.**

| Species | | *SARA* Schedule 1 | | | COSEWIC | | | |
|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | ***Endangered*** | ***Threatened*** | ***Special Concern*** | ***Endangered*** | ***Threatened*** | ***Special Concern*** | ***Candidate*** |
| Blue whale | *Balaenoptera musculus* | X | | | X | | | |
| North Atlantic right whale | *Eubalaena glacialis* | X | | | X | | | |
| Leatherback sea turtle | *Dermochelys coriacea* | X | | | X | | | |
| Northern wolffish | *Anarhichas denticulatus* | | X | | | X | | |
| Spotted wolffish | *Anarhichas minor* | | X | | | X | | |
| Atlantic wolffish | *Anarhichas lupus* | | | X | | | X | |
| Fin whale (Atlantic population) | *Balaenoptera physalus* | | | X | | | X | |
| Ivory Gull | *Pagophila eburnean* | | | X | X | | | |
| Atlantic cod (NL[c] population) | *Gadus morhua* | | | | X | | | |
| Porbeagle shark | *Lamna nasus* | | | | X | | | |
| White shark | *Carcharodon carcharias* | | | | X | | | |
| Cusk | *Brosme brosme* | | | | | X | | |
| Shortfin mako shark | *Isurus oxyrinchus* | | | | | X | | |
| Sowerby's beaked whale | *Mesoplodon bidens* | | | | | | X | |
| Harbour porpoise | *Phocoena phocoena* | | | | | | X | |
| Blue shark | *Prionace glauca* | | | | | | X | |
| Atlantic halibut | *Hippoglossus hippoglossus* | | | | | | | High priority |
| Spiny eel | *Notacanthus chemnitzi* | | | | | | | High priority |
| Pollock | *Pollachius virens* | | | | | | | High priority |
| Atlantic salmon | *Salmo salar* | | | | | | | High priority |
| Ocean pout | *Zoarces americanus* | | | | | | | High priority |
| Sperm whale | *Physeter macrocephalus* | | | | | | | Low priority |
| Hooded seal | *Cystophora cristata* | | | | | | | Low priority |
| Harp seal | *Phoca groenlandica* | | | | | | | Low priority |

**Sources:** [a] *SARA* website (http://www.sararegistry.gc.ca/default_e.cfm) (as of 31 December 2007)
[b] COSEWIC website (http://www.cosepac.gc.ca/index.htm) (as of 31 December 2007)
[c] Newfoundland and Labrador

## 4.6.1. Profiles of *SARA* Schedule 1 - and COSEWIC-Listed Species

### 4.6.1.1. Blue Whale

The blue whale is currently listed as *Endangered* on Schedule 1 of *SARA* and by COSEWIC (Table 4.16). There is currently no confirmed blue whale sighting in the Study Area based upon available data provided by DFO (DFO 2007; Figure 4.49). One possible blue whale (recorded as a fin/blue whale) was sighted in the Jeanne d'Arc Basin during the 2006 Husky seismic monitoring program (Abgrall et al. *in prep*. a; Figure 4.49). Based upon the DFO sightings database, most sightings of blue whales in Newfoundland have occurred near the coast, which may, in part, be related to the lack of dedicated marine mammal surveys in offshore waters. Blue whales were regularly sighted in offshore waters (~100 to 3,000 m deep) of the Laurentian sub-basin area during a seismic monitoring program in June to September 2005. In fact, blue whales were the most frequently sighted baleen whale species. The sighting rate of blue whales was highest in water depths ranging from 2000 to 2500 m (Moulton et al. 2006c). There have been two sightings of blues whales in the Orphan Basin, both occurred in August 2007 and in water depths of 2366 m and 2551 m (Abgrall et al. *in prep*. b; Figure 4.49). No blue whales were sighted during a seismic monitoring program in the Jeanne d'Arc Basin in October and November 2005 (Lang et al. 2006) or in June and July 2007 (Lang and Moulton *in prep.*; Table 4.12); baleen whales are typically less abundant on the Grand Banks in late fall vs. summer. It is possible that blue whales may occur in the Jeanne d'Arc Basin but numbers are expected to be low. A detailed profile of the blue whale is included in Husky's drill centre construction and operations program EA and addendum (Sections 5.7.3 *in* LGL 2006a, 2007c) and in Section 4.8.3 of LGL (2007a).

### 4.6.1.2. North Atlantic Right Whale

The North Atlantic right whale is currently listed as *Endangered* on Schedule 1 of *SARA* and by COSEWIC (Table 4.16). It is a slow-moving whale prone to collisions with ships. It feeds on krill and other crustaceans. The right whale is among the most *Endangered* whales and today it is distributed only in the northwest Atlantic and numbers about 300 individuals (COSEWIC 2003b). Off Atlantic Canada, right whales typically concentrate in the Bay of Fundy and off southwestern Nova Scotia. However, some right whales are known to occur off Iceland and it is possible (although highly unlikely) that it may occur in the Project Area. Right whales were only recorded once in the Study Area; on 27 June 2003, north of the Project Area (DFO 2007; Figure 4.49).

### 4.6.1.3. Leatherback Sea Turtle

The leatherback sea turtle is currently listed as *Endangered* on Schedule 1 of *SARA* and by COSEWIC (Table 4.16). Critical habitat has not been identified in the Recovery Strategy but studies are underway to do so (ALTRT 2006). Leatherbacks equipped with satellite tags did not occur in the Project Area but some did migrate through the Grand Banks south of Newfoundland (James et al. 2005). A tagged leatherback was also tracked approximately 50 miles east of St. John's, NL, in 2005. Two leatherbacks were sighted in mid-August 2006 in the Study Area during Husky's seismic program (Figure 4.49; Abgrall et al. *in prep*. a); these are the first documented sightings in the Jeanne d'Arc Basin. To date, no sea turtles have been reported in or near the Terra Nova Development by observers on various platforms (G. Janes, Petro-Canada, January 2008, pers. comm.). Also, no leatherbacks were sighted during monitoring programs in the Orphan Basin in 2004 – 2007 (Moulton et al. 2005, 2006b; Abgrall et al. *in prep*. b) and during other seismic monitoring program in Jeanne d'Arc Basin in fall 2005 and June – July 2007 (Lang et al. 2006; Lang and Moulton *in prep.*). It is possible that leatherbacks may occur in the Study Area during SHC's proposed seismic and geohazard program but the frequency of sightings is expected to be low. A detailed profile of the leatherback turtle is included in Husky's drill centre construction and operations program EA and addendum (Sections 5.7.3 *in* LGL 2006a, 2007c) and in Section 4.8.4 of LGL (2007a).

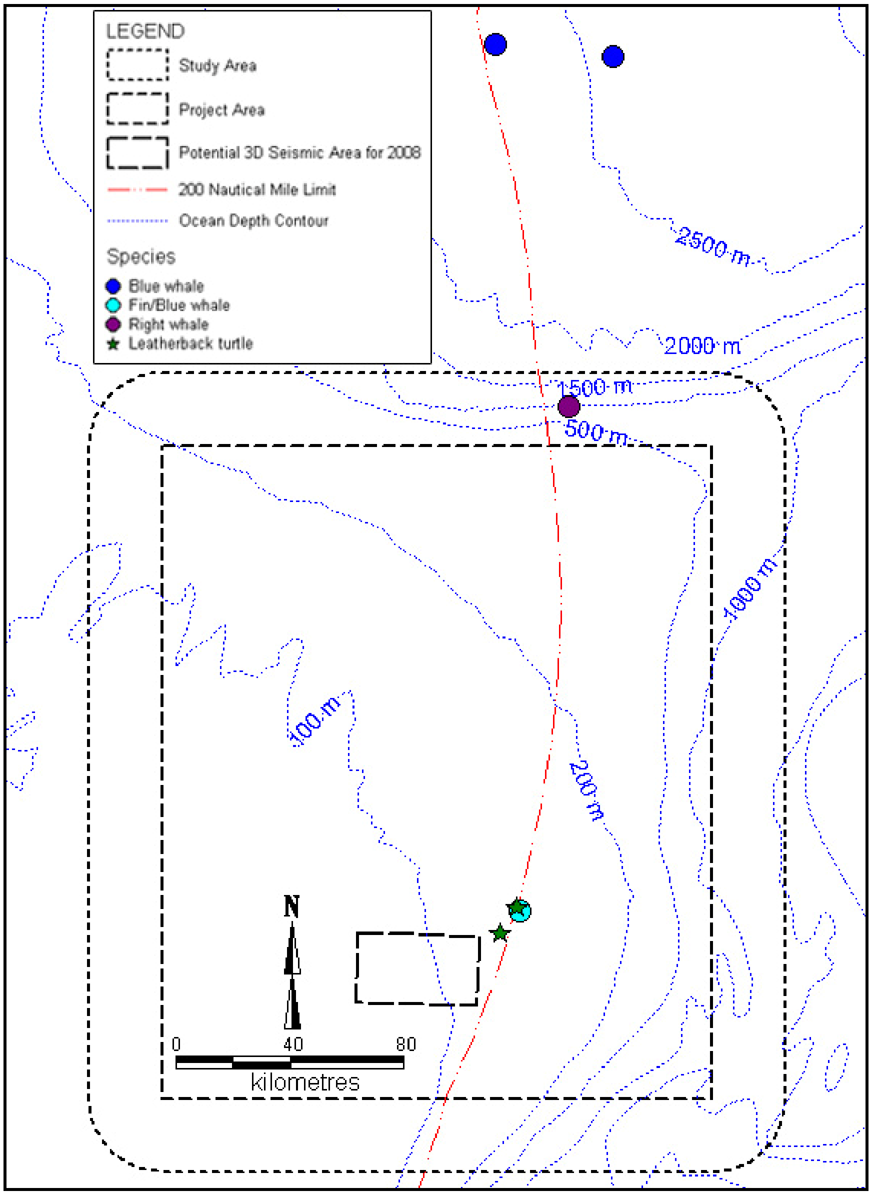



**Figure 4.49. Sightings of *Endangered* marine mammals and sea turtles within the Study Area from the DFO cetacean sighting database (1945-2007) and recent seismic and CSEM marine mammal monitoring programs (2004-2007).**

#### 4.6.1.4. Wolffishes

Two species, the northern wolffish and the spotted wolffish, are currently listed as *Threatened* on both Schedule 1 of the *SARA*, and by COSEWIC (Table 4.16). A third species, the Atlantic or striped wolffish, is currently listed as a species of *Special Concern* on both Schedule 1 of the *SARA* and by COSEWIC (Table 4.16). A proposed Recovery Strategy for northern and spotted wolffishes and a Management Plan for Atlantic wolffish were recently published (Kulka et al. 2007).

Profiles of the three wolffish species are included in Husky's drill centre construction and operations program EA and addendum (Sections 5.5.3.1 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.5. Fin Whale

The Atlantic population of the fin whale is currently listed as *Special Concern* on Schedule 1 of *SARA* and by COSEWIC (Table 4.16). Twenty-six fin whale sightings have been recorded within the Study Area based upon the DFO sightings database (DFO 2007; Figure 4.48). In 2004 – 2007, fin whales were commonly sighted in the deep waters (typically >2000 m) of Orphan Basin, during summer months, most commonly in July and August (Moulton et al. 2005, 2006b, Abgrall et al. *in prep*. b; Figure 4.47). Fin whales were commonly sighted in the Study Area during Husky's seismic monitoring programs in 2005 and 2006 (Abgrall et al. *in prep*. a; Table 4.12). They were the second most abundant mysticete (humpback whales were most common) observed. There was also a single sighting of a fin whale during the Petro-Canada seismic monitoring program in 2007 (Lang and Moulton *in prep*.; Table 4.12) It is likely that fin whales commonly occur in the Study Area at least during late spring to fall. A detailed profile of the fin whale is included in Husky's drill centre construction and operations program EA and addendum (Sections 5.7.3 *in* LGL 2006a, 2007c) and in Section 4.8.3 of LGL (2007a).

#### 4.6.1.6. Ivory Gull

The Ivory Gull is currently listed as *Endangered* by COSEWIC (Table 4.16). There have been no sightings of this species in or near the Study Area during recent seismic and CSEM monitoring programs. A profile of the Ivory Gull is included in Husky's drill centre construction and operations program EA and addendum (Sections 5.7.3 *in* LGL 2006a, 2007c) and in Section 4.8.2 of LGL (2007a). The predicted status of the Ivory Gull in the Study Area is very scarce, less than annual, and individuals are most likely to occur from January to April.

#### 4.6.1.7. Atlantic Cod (NL Population)

The Newfoundland and Labrador population of Atlantic cod is currently listed as *Endangered* by COSEWIC (Table 4.16). A profile of the Atlantic cod is included in the Husky drill centre construction and operations program EA and addendum (Sections 5.5.3.2 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.8. Porbeagle Shark

The porbeagle shark is currently listed as *Endangered* by COSEWIC (Table 4.16). It is now under consideration for addition to Schedule 1 of *SARA*. A profile of the porbeagle shark is included in the Husky drill centre construction and operations program EA and addendum (Sections 5.5.3.3 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.9. White Shark

The great white shark is currently designated as *Endangered* by COSEWIC but not listed under *SARA* (Table 4.16). A profile of the white shark is included in the Husky drill centre construction and operations program EA and addendum (Sections 5.5.3.4 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.10. Cusk

In May 2003, the cusk was designated as *Threatened* by COSEWIC but it is not on the official *SARA* list (Schedule 1) of wildlife at risk (Table 4.16). An allowable harm assessment for cusk in Atlantic Canada was recently prepared by DFO (DFO 2004). A profile of the cusk is included in the Husky drill centre construction and operations program EA and addendum (Sections 5.5.3.7 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.11. Shortfin Mako Shark

The shortfin mako shark is currently designated as *Threatened* by COSEWIC (Table 4.16). A profile of the shortfin mako shark is included in the Husky drill centre construction and operations program EA and addendum (Sections 5.5.3.5 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.12. Sowerby's Beaked Whale

The Sowerby's beaked whale is currently listed as *Special Concern* by COSEWIC (Table 4.16). Sowerby's beaked whales are expected to occur more frequently in deeper waters (but in relatively low numbers) than those of the proposed Project Area. During the 2005 seismic monitoring program in Orphan Basin, there was one sighting of four Sowerby's beaked whales in September; it occurred in 2500 m of water (Moulton et al. 2006b; Figure 4.47). Sowerby's beaked whales have not been observed during seismic monitoring on the Jeanne d'Arc Basin (Lang et al. 2006; Abgrall et al. *in prep*. a; Lang and Moulton *in prep*.). No Sowerby's beaked whales were observed during the 2004, 2006 and 2007 monitoring programs in Orphan Basin (Moulton et al. 2005; Abgrall et al. *in prep*. b) No Sowerby's beaked whales occurred in the proposed Study Area in the DFO cetacean sightings database (DFO 2007; Table 4.15). A profile of the Sowerby's beaked whale is included in Husky's drill centre construction and operations program EA and addendum (Sections 5.7.3 *in* LGL 2006a, 2007c) and in Section 4.8.3 of LGL (2007a).

#### 4.6.1.13. Harbour Porpoise

The harbour porpoise is currently listed as *Special Concern* by COSEWIC (Table 4.16). This porpoise is known to occur in the Study Area (Lang et al. 2006; DFO 2007) but overall, distributional data for harbour porpoises in Newfoundland and Labrador waters is limited (COSEWIC 2006). During the fall 2005 seismic monitoring program for Husky in Jeanne d'Arc Basin, there was one sighting of harbour porpoise (two individuals) in an area with a water depth of 165 m (Lang et al. 2006; Table 4.12). No harbour porpoise were recorded in Jeanne d'Arc Basin during seismic monitoring programs in 2006 and 2007 (Abgrall et al. *in prep*. a; Lang and Moulton *in prep.*). Harbour porpoise have also been sighted in deep waters of Orphan Basin. During the 2005 monitoring program, there were nine sightings consisting of 24 individuals in areas where water depth ranged from 787 to 2,633 m (Moulton et al. 2006b). Of these nine sightings, seven occurred in July. An addition sighting of two harbour porpoise was made the previous year during the 2004 Orphan Basin monitoring program at a water depth of 2538 m (Moulton et al. 2005; Table 4.12). None were sighted in Orphan Basin during ExxonMobil CSEM monitoring programs in 2006 and 2007 (Abgrall et al. *in prep*. b). A profile of the harbour porpoise is included in Husky's drill centre construction and operations program EA and addendum (Sections 5.7.3 *in* LGL 2006a, 2007c) and in Section 4.8.3 of LGL (2007a).

#### 4.6.1.14. Blue Shark

The blue shark is currently designated as *Special Concern* by COSEWIC (Table 4.16). A profile of the blue shark is included in the Husky drill centre construction and operations program EA and addendum (Sections 5.5.3.6 *in* LGL 2006a, 2007c) and in Section 4.8.1 of LGL (2007a).

#### 4.6.1.15. Atlantic Halibut

The Atlantic halibut is currently listed as a high priority *candidate* species by COSEWIC (Table 4.16). Atlantic halibut, the largest of the flatfishes, is typically found along the slopes of the continental shelf. Atlantic halibut move seasonally between deep and shallow waters, apparently avoiding temperatures below 2.5ºC (Scott and Scott 1988). The spawning grounds of the Atlantic halibut are not clearly defined. The fertilized eggs are slightly positively buoyant so that they naturally disperse and only gradually float toward the ocean's surface. Once hatched, the developing larvae live off their yolk for the next six to eight weeks while their digestive system develops so they can begin feeding on natural zooplankton. After a few weeks of feeding, they metamorphose from a bilaterally symmetrical larva to an asymmetrical flatfish, and are ready to assume a bottom-living habit. At this point they are approximately 20 mm long. As juveniles, Atlantic halibut feed mainly on invertebrates, including annelid worms, crabs, shrimps, and euphausiids. Young adults (between 30 to 80 cm in length) consume both invertebrates and fish, while mature adults (greater than 80 cm) feed entirely on fishes (Scott and Scott 1988).

#### 4.6.1.16. Spiny Eel

The spiny eel is currently listed as a high priority *candidate* species by COSEWIC (Table 4.16). The spiny eel is a bottom-living fish that typically occurs over a depth range of 250 to 1,000 m, but has been caught in waters as shallow as 125 m on the Grand Bank to more than 3,000 m off the coast of Ireland (Scott and Scott 1988). Data suggests a northward migration of this species as individuals become older and larger. Ripe specimens of the spiny eel have been found near Iceland in September and October yet little is known about the specifics of eggs and young of this species. It is not known where in the water column the fertilized eggs develop or the young hatch from the eggs. Spiny eels appear to be bottom feeders. Identified stomach contents of this species include sea anemones. Predators of spiny eels are not known.

#### 4.6.1.17. Pollock

The pollock is currently listed as a high priority *candidate* species by COSEWIC (Table 4.16). While its range extends off southern Labrador, and off southern Newfoundland, along the Scotian Shelf to about Cape Hatteras, pollock is most abundant on the Scotian Shelf and southern Grand Banks (DFO 2005). Relative to other cod-like fishes, the pollock spends less time on the bottom, moving freely through the water column. Spawning by pollock appears to occur during fall and winter in Canadian waters. Both the eggs and larvae are planktonic, and juvenile pollock appear to develop in coastal waters. Pollock typically display strong schooling behaviour (Scott and Scott 1988).

#### 4.6.1.18. Atlantic Salmon

The Atlantic salmon is currently listed as a high priority *candidate* species by COSEWIC (Table 4.16). Perspectives on the marine ecology of Atlantic salmon in the northwest Atlantic were recently presented at a workshop sponsored by DFO-SARCEP (Species at Risk Committee) (DFO 2006). Atlantic salmon spend time in both freshwater and the sea during its life cycle. As indicated by data storage tags, salmon at sea spend much of their time in surface waters but also dive to deeper areas of the water column probably in search of prey. They tend to be closer to surface at night than during the day. Figures from Reddin (1988) presented in DFO (2006) indicate the likelihood of salmon passage through the eastern Grand Bank during movement to and from the marine waters off Greenland. Salmon moving from the freshwater would likely pass through in the fall while those returning to freshwater would likely pass through in early to mid-summer. A wintering area which overlaps with the eastern Grand Bank and the Flemish Cap is also indicated.

#### 4.6.1.19. Ocean Pout

The ocean pout is currently listed as a high priority *candidate* species by COSEWIC (Table 4.16). The ocean pout is a bottom dweller that uses a wide variety of habitats. This fish typically spawns in protected habitats, such a rock crevices, where it lays eggs in a nest and subsequently guards the eggs as they develop. It has been suggested that ocean pout larvae remain close to the nest site. Juvenile ocean pout are often found in shallow coastal waters around rocks and attached algae (Steimle et al. 1999).

Scott and Scott (1988) reported that adult ocean pout in Canadian waters typically occur at depths ranging from 55 to 110 m. Ocean pout tend to feed on benthic organisms.

#### 4.6.1.20. Sperm Whale

The sperm whale is currently listed as a low priority *candidate* species by COSEWIC (Table 4.16). A detailed profile of the sperm whale is included in Section 4.7.1.2 of LGL (2007a). Sperm whales are known to feed in deep water and it is possible that they occur regularly beyond the continental shelf within the Slope waters near the Study Area. Sperm whales were regularly sighted in deeper waters (Orphan Basin) north of Jeanne d'Arc Basin during the summers of 2004, 2005, 2006 and 2007 (Moulton et al. 2005, 2006b; Abgrall et al. *in prep.* b). No sperm whales were sighted during the 2005, 2006 and 2007 seismic monitoring programs in Jeanne d'Arc Basin (Lang et al. 2006; Abgrall et al. *in prep*. a; Lang and Moulton *in prep.*). There are 45 sightings of a sperm whale reported in the DFO cetacean sightings database (DFO 2007) that occurred in the Study Area (Figure 4.48).

#### 4.6.1.21. Hooded Seal

The hooded seal is currently listed as not at risk and is considered a low priority *candidate* species by COSEWIC (Table 4.16). Hooded seals reproduce on the spring ice in the Gulf of St. Lawrence and along the Labrador coast, and then migrate northwards to subarctic and arctic waters to feed during summer (Lydersen and Kovacs 1999). The most recent estimate of pup production at "the Front" off Labrador, made in 2005, was approximately 107,000 (ICES 2006), suggesting a current total population of hooded seals in the northwest Atlantic of approximately 537,000 (ICES 2006). Data collected from satellite transmitters deployed on hooded seals in the Gulf of St. Lawrence indicate that some females feed near the Flemish Cap after breeding while migrating to Greenland waters (G.B. Stenson, unpubl. data). Tagged males migrating to Greenland in early summer were recorded along the Grand Banks shelf edge near the Flemish Pass. It appears that males spend little time foraging in this area (G.B. Stenson, unpubl. data). Little is known regarding their winter distribution, although it is believed that the majority of seals remain offshore; they have been seen feeding off the Grand Banks in February. Surveys in the early 1990s suggested that the offshore waters on the northern edge of the Grand Banks might be an important over-wintering area for hooded seals (Stenson and Kavanagh 1994). No hooded seals were sighted in Jeanne d'Arc Basin during seismic monitoring programs in 2005, 2006 and 2007 (Abgrall et al. *in prep*. a; Lang and Moulton *in prep.*) or in Orphan Basin during monitoring programs in the summers of 2004 – 2007 (Moulton et al. 2005, 2006b; Abgrall et al. *in prep*. b). Hooded seals consume a variety of prey. In nearshore areas of Newfoundland, prey (in decreasing order of total wet weight) includes: Greenland halibut, redfish, Arctic cod, Atlantic herring and capelin. Relatively small amounts of squid (*Gonatus* spp.) and Atlantic cod were also found (Ross 1993). Data from offshore areas are limited, but suggest that similar prey species are consumed (J.W. Lawson and G.B. Stenson, unpubl. data).

### 4.6.1.22. Harp Seal

The harp seal has not been assessed by COSEWIC and it is currently listed as a low priority *candidate* species by COSEWIC (Table 4.16). Harp seals whelp in the spring each year in the Gulf of St. Lawrence and in an area known as the 'Front' and northeastern Newfoundland (Sergeant 1991). The total population estimate of harp seals in the northwest Atlantic is 5.9 million ± 0.75 millions (ICES 2005). Surveys conducted during the early 1990s suggested that offshore waters on the northern edge of the Grand Banks in NAFO fishing area 3L were an important over-wintering area for these animals during those years (Stenson and Kavanagh 1994). Seven harp seal sightings were observed in Orphan Basin during the summers of 2004 and 2005 (Moulton et al. 2005, 2006b). However, none were observed in Orphan Basin during the summers of 2006 and 2007 (Abgrall et al. *in prep.* b). As well, no harp seals were sighted in Jeanne d'Arc Basin during seismic monitoring programs in 2005, 2006 and 2007 (Abgrall et al. *in prep*. a). Similarly, data from satellite transmitters deployed on harp seals suggest that the Grand Banks is an important wintering area for some seals (Stenson and Sjare 1997). During summer months, harp seals are thought to primarily occur in subarctic and arctic waters off Greenland. The diet of harp seals foraging off Newfoundland and Labrador appears to vary considerably with age, season, year and location. On the Grand Banks and Labrador Shelf, capelin predominates, followed by sand lance, Greenland halibut and other flatfish (Wallace and Lawson 1997; Lawson et al. 1998).

# 5.0 Effects Assessment

Two general types of effects are considered in this document:

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

Methods of effects assessment used here are comparable to those used in recent east coast offshore drilling (e.g., LGL 2006a) and seismic EAs (e.g., LGL 2007a). These documents conform to the *Canadian Environmental Assessment Act* (*CEAA*) and it's associated Responsible Authority's Guide and the CEA Agency Operational Policy Statement (OPS-EPO/5-2000) (CEA Agency 2000). Cumulative effects are incorporated within the procedures in accordance with *CEAA* (CEA Agency 1994) as adapted from Barnes and Davey (1999) and used in the White Rose EA.

## 5.1. Scoping

The C-NLOPB provided a scoping document (dated 1 August 2007) for the Project which outlined the factors to be considered in the assessment. In addition, various stakeholders were contacted for input (see below). Another aspect of scoping for the effects assessment involved reviewing relevant and recent EAs that were conducted in the Jeanne d'Arc Basin area including (but not limited to) the Petro-Canada seismic EA (LGL 2007a) and its addendum (LGL 2007b) which assessed geohazard surveys, the Husky new drill centre construction and operations program EA and addendum (LGL 2006a, 2007c), the White Rose Oilfield Comprehensive Study (Husky 2000), the Husky Jeanne d'Arc Basin exploration drilling EAs and update (LGL 2002, 2005a, 2006b), and the Husky Jeanne d'Arc Basin 3-D seismic EA and update (LGL 2005b; Moulton et al. 2006a). Reviews of present state of knowledge were also conducted.

### 5.1.1. Consultations

In preparing the EA for SHC's proposed 2008-2016 Seismic Survey Program, Canning and Pitt Associates, Inc. consulted with relevant government agencies, representatives of the fishing industry and other interest groups. The purpose of these consultations was to describe the planned program, to identify any issues and concerns and to gather additional information relevant to the EA report.

Copies of the Project Description for the proposed 2008-2016 seismic program, including maps of the Study Area and Project Area, were sent to all agencies and groups in October 2007. The consultants asked each stakeholder to review this information and to provide any comments on these proposed activities.

Consultations were undertaken with the following agencies, stakeholders and interest groups. (A list of all persons consulted is provided in Appendix B.)

- Fisheries and Oceans
- Environment Canada
- Natural History Society
- One Ocean
- Fish, Food and Allied Workers Union (FFAW)
- Association of Seafood Producers
- Fishery Products International
- Groundfish Enterprise Allocation Council (Ottawa)
- Clearwater Seafoods
- Icewater Seafoods

SHC and its consultants met with DFO managers, and with representatives of One Ocean, the FFAW and the Natural History Society in October 2007. Environment Canada managers received relevant project information but did not request a meeting with the consultants.

To date, fisheries industry stakeholders (FPI, Icewater Seafoods, GEAC and Clearwater) contacted for these consultations have not responded. The Association of Seafood Producers (ASP) reports it did not have any specific concerns about the proposed seismic survey program. The Association's Executive Director indicated that he would like to receive a copy of the EA report noting that he was particularly interested in reading the section dealing with the assessment of fish and fish habitat in that document.

Specific comments and concerns raised and discussed with agency managers and industry stakeholders during the consultation meetings are discussed below.

*DFO*.— DFO managers did not have any specific concerns or issues about the proposed seismic survey program, but asked why two separate EA reports (i.e. one for exploration drilling and one for seismic surveys) were being prepared. SHC's consultants explained that a separate EA assessment was required for the proposed seismic program because of the potential environmental effects of noise associated with these operations.

During the meeting, several points were raised and discussed. These included the nature and content of the "multi-year" approach being proposed for the EA, the timing of survey activities, yearly "updates" to the EA document and the need to provide advance notice to DFO managers, for example to the department's annual RV survey operations, before survey operations commenced.

SHC's consultants noted that there would likely be an annual update to the original EA document. Planned survey activities for a particular project year would be reviewed in light of expected changes in the commercial fisheries, or RV surveys, for example. If no major changes in these or other VECs were anticipated, the annual EA update might only comprise a short "letter" report to the Board. If more significant changes within the project area were forecasted, the annual update might require preparation of a revised EA document.

SHC's consultants also noted that, recently, the C-NLOPB has been encouraging proponents to prepare shorter, "summary-type" EA documents, with a substantial portion of data pertaining to the relevant project area being included by way of reference to previous EA (or SEA) documents. It is expected that this approach will make it easier for various agency managers to review and assess the information and discussion contained in the EA report.

In response, DFO mangers suggested that these shorter EA documents should clearly identify which previous documents and sources were being referenced. Further, if a short annual update appeared to be required, it would be very useful if that document was accompanied by a CD (e.g., as an appendix) containing any relevant previous studies, reports, etc., that were being cross-referenced. This information would be quite helpful for any agency reviewer, especially for a new manager who might not be familiar with some or all of the previous reference documents.

SHC's consultants asked DFO managers if they had any further information on the status of the seismic survey "protocols" which the department has been working on during the past year or so. DFO managers noted they have not heard any further discussion of this matter since the Seismic Survey Workshop held last year.

There was a brief discussion concerning SHC's plans to employ a dedicated Marine Mammal Observer (MMO), in addition to an FLO, during its survey operations. DFO managers asked if there is a special training program for FLOs that may also be acting as the on board MMO. It was noted that most, if not all, of the FLO's that have been involved in survey activities have taken the required observer training program available from DFO's marine mammal science group.

*Natural History Society*.— NHS representatives did not have any specific comments on SHC's proposed survey program. Most of the discussion at the meeting dealt with the possibility and benefits of organizing an "all-operators" meeting which would allow NHS members, and other independent scientists, to meet with oil company personnel and to discuss and review a number of multi-year EAs at the same time. It was suggested that this type of meeting would facilitate a more productive and comprehensive exchange of information and commentary between offshore exploration proponents and the scientific community. Such a gathering could take the form of a one-day seminar attended by various offshore firms and other agency personnel, e.g., from the C-NLOPB.

NHS suggested that such an arrangement would probably encourage more scientists to attend and participate in these discussions, and would perhaps be more interesting than the "single proponent" consultation meetings that have been the usual practice thus far.

*One Ocean/FFAW*.— One Ocean's representative had several questions about the "multi-year" approach being proposed for this EA, more specifically about the appropriate process, and information requirements, for reviewing the proponent's activities on an annual basis, as well as the procedures needed for monitoring these activities during the proposed 2008-2016 timeframe for the survey program.

After some discussion, it was generally agreed that the present EA report should include a section specifying clearly what an annual review of a "multi-year" EA document would entail. It should also identify what factors and conditions would trigger the requirement for a substantial update of the original EA document (see Section 1.1.1).

One Oceans' representative stated that, with respect to monitoring a proponent's ongoing activities and up-coming plans for any one year, the annual review, or update report, would need to identify the proposed location and timing of any seismic activities planned for the coming project year, and a discussion of any significant changes which may have occurred in the fisheries, e.g. harvesting of a new commercial species, or other environmental changes relevant to these harvesting activities. One Ocean noted that, when this updated information was available, it could be disseminated to fishers via the *Union Forum*. One Oceans' indicated that if major changes had occurred, the proponent should be required to undertake new, or additional, stakeholder consultations.

## 5.2. Valued Ecosystem Components

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

VECs include the following groups:

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

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

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

- **Commercial fish** (including fish habitat considerations) with emphasis on the three primary species: (1) shrimp, (2) snow crab, and (3) Greenland halibut (turbot), and *SARA* species (e.g., Atlantic cod and wolffish). It is recognized that there are many other fish species, commercial or prey species, that could be considered but it is our professional opinion that this suite of species captures all of the relevant issues concerning the potential effects of seismic surveys on important invertebrate and fish populations of the Project Area.

- **Commercial fisheries** are directly linked to the fish VEC above but all fisheries (trawling, gillnetting, longlines, pots, etc.) are considered where relevant. This includes those listed above plus some potential pelagic fisheries (e.g., tuna) that could occur in the Project Area.

The commercial fishery is a universally acknowledged important element in society, culture, economic and aesthetic environment of Newfoundland and Labrador. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Seabirds** with emphasis on those species most sensitive to seismic activities (e.g., deep divers such as murres) or vessel stranding (e.g., petrels), and *SARA* species (e.g., Ivory Gull). Newfoundland supports some of the largest seabird colonies in the world and the Grand Banks area hosts very large populations during all seasons. They are important socially, culturally, economically, aesthetically, ecologically and scientifically. This VEC is of prime concern from both a public and scientific perspective, at local, national and international scales.

- **Marine Mammals** with emphasis on those species potentially most sensitive to low frequency sound (e.g., baleen whales) or *SARA* species (e.g., blue whale). Whales and seals are key elements in the social and biological environments of Newfoundland and Labrador. The economic and aesthetic importance of whales is evidenced by the large number of tour boats that feature whale watching as part of a growing tourist industry. This VEC is also of prime concern from both a public and scientific perspective, at local, national and international scales.

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

- **Species at Risk** are those listed as *Endangered* or *Threatened* on Schedule I of *SARA*. In addition, species listed as *Special Concern* have been considered here as well. All species at risk in Newfoundland and Labrador offshore waters are captured in the VECs listed above. However, due to their special status, they are also discussed separately.

## 5.3. Boundaries

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

**Temporal—**the temporal boundaries of the Project are 1 May to 31 December in 2008. In subsequent years (2009 to 2016), seismic surveys may occur from 1 April to 31 October and geohazard surveys may be conducted at any time of the year.

**Project Area—**the 'Project Area' is defined as the area where seismic data could be acquired plus an additional area around the outer perimeter of the data acquisition area to accommodate the ships' turning radii (see Figure 1.1). The 'Potential 3D Seismic Area for 2008" is the area where seismic data will be acquired in 2008.

**Affected Area**—the 'Affected Area' varies according to the specific vertical and horizontal distributions and sensitivities of the VECs of interest and is defined as that area within which effects (physical or important behavioural ones) have been reported to occur. It is likely that in the present case most potential effects will be confined within the Project Area.

**Study Area**—an area larger than the Project Area that encompasses any potential effects (including those from accidental events) reported in the literature.

**Regional Area**—the regional boundary is the boundary as defined in previous EAs such as Hibernia, Terra Nova and White Rose and is retained here for consistency.

## 5.4. Effects Assessment Procedures

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

1. preparation of interaction (between Project activities and the environment) matrices;
2. identification and evaluation of potential effects including description of mitigation measures and residual effects, and
3. preparation of residual effects summary tables, including evaluation of cumulative effects.

### 5.4.1. Identification and Evaluation of Effects

Interaction matrices were prepared that identify all possible Project activities that could interact with any of the VECs. The interaction matrices are used only to identify potential interactions; they make no assumptions about the potential effects of the interactions.

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

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

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

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

### 5.4.2. Classifying Anticipated Environmental Effects

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

- negative effects on the health of biota;
- loss of rare or *Endangered* species;
- reductions in biological diversity;
- loss or avoidance of productive habitat;
- fragmentation of habitat or interruption of movement corridors and migration routes;
- transformation of natural landscapes;
- discharge of persistent and/or toxic chemicals;
- toxicity effects on human health;
- loss of, or detrimental change in, current use of lands and resources for traditional purposes;
- foreclosure of future resource use or production; and
- negative effects on human health or well-being.

### 5.4.3. Mitigation

Mitigation measures appropriate for each effect predicted in the matrix were identified and the effects of various Project activities were then evaluated assuming that appropriate mitigation measures are applied. Residual effects predictions were made taking into consideration both standard and project-specific mitigations.

### 5.4.4. Evaluation Criteria for Assessing Environmental Effects

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

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

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

Magnitude was defined as:

| | |
|---|---|
| Negligible | An interaction that may create a measureable effect on individuals but would never approach the 10% value of the 'low' rating. Rating = 0. |
| Low | Affects >0 to 10 percent of individuals in the affected area (e.g., geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 1. |
| Medium | Affects >10 to 25 percent of individuals in the affected area (see geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 2. |
| High | Affects more than 25 percent of individuals in the affected area (e.g., geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance. Rating = 3. |

Definitions of magnitude used in this EA have been used previously in numerous offshore oil-related environmental assessments under CEAA. These include assessments of the Petro-Canada seismic EA (LGL 2007a) and its addendum (LGL 2007b) which assessed geohazard surveys, the Husky new drill centre construction and operations program EA and addendum (LGL 2006a, 2007c), the White Rose Oilfield Comprehensive Study (Husky 2000), the Husky Jeanne d'Arc Basin exploration drilling EAs and update (LGL 2002, 2005a, 2006b), and the Husky Jeanne d'Arc Basin 3-D seismic EA and update (LGL 2005b; Moulton et al. 2006a).

Durations are defined as:

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

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

### 5.4.5. Cumulative Effects

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

- Survey program within-project cumulative impacts. For the most part, and unless otherwise indicated, within-project cumulative effects are fully integrated within this assessment;
- Existing offshore oil developments: Hibernia (GBS platform), Terra Nova FPSO, and White Rose FPSO;
- Other offshore oil exploration activity (particularly seismic surveys and exploratory drilling as outlined on the C-NLOPB website). On the Grand Banks and Orphan Basin for 2008, activity may include seismic programs and exploratory drilling. Three exploratory drilling programs (two on Grand Banks, one on Orphan Basin) may occur in 2008. The amount of seismic activity planned by operators other than SHC in 2008 is not currently available. However, Husky is proposing to conduct a seismic program in the Jeanne d'Arc Basin area after SHC's program concludes (D. Taylor, pers. comm.). The amount and timing of drilling and seismic operations in and near the Study Area in 2009-2016 is also not currently available.
- Commercial fisheries;
- Marine transportation (tankers, cargo ships, supply vessels, naval vessels, fishing vessel transits, etc.); and
- Hunting activities (marine birds and seals).

### 5.4.6. Integrated Residual Environmental Effects

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

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

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

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

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

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

### 5.4.7. Significance Rating

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

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

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

### 5.4.8. Level of Confidence

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

### 5.4.9. Determination of Whether Predicted Environmental Effects are Likely to Occur

As per other EAs (e.g., LGL 2007a), the following criteria for the evaluation of the likelihood of any predicted significant effects are used.

- probability of occurrence; and
- scientific certainty.

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

### 5.4.10. Follow-up Monitoring

Because any effects of the Project on the environment will be relatively short-term and transitory, there is no need to conduct follow-up monitoring. However, there will be some level of monitoring during the course of the Project, and if these observations indicate an accidental release of fuel or flotation fluid (Isopar) or some other unforeseen occurrence, then the need for follow up monitoring will be assessed in consultation with the C-NLOPB.

## 5.5. Effects of the Environment on the Project

The physical environment is described in Section 3 and the reader is referred to this section to assist in determining the effects on the Project. Furthermore, safety issues are assessed in some detail during the permitting and program application processes. Nonetheless, effects on the Project are important to consider, at least on a high level, because they may sometimes cause effects on the environment. For example, accidental spills of streamer fluid may be more likely to occur during rough weather.

Given the Project time frame of April to October (May to October for 2008) for seismic operations and the requirement of a seismic survey to avoid periods and locations of sea ice, sea ice should have no effect on the Project. Icebergs in the spring and early summer may cause some survey delays if tracks have to be altered to avoid them. Most environmental constraints on seismic surveys are those imposed by wind and wave. The Project scheduling avoids the most continuous extreme weather conditions and SHC’s contractors will be thoroughly familiar with east coast operating conditions. As a prediction of the effects of the environment on the Project, SHC will likely use an estimate of 25% weather-related down time for the Project for planning purposes. This cannot be considered a significant effect on the Project otherwise the Project would not be acceptable to the Proponent. Seismic (and geohazard) vessels typically suspend surveys once wind and wave conditions reach certain levels because the ambient noise affects the data. They also do not want to damage towed gear which would cause costly delays.

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

## 5.6. Effects of the Project on the Environment

The main pathway that links the Project and environment is the transmission of sound from the seismic (and geohazard) source to the receivers or various VECs. The basics of sound and its propagation in the marine environment are described in Richardson et al. (1995). Of principal concern during seismic and geohazard programs is the potential effects of sound from airguns on VECs as airguns used during marine seismic operations introduce strong sound impulses into the water (see Appendix C *in* LGL (2007a) for a review of the characteristics of airgun pulses). The seismic pulses produced by the airguns are directed downward toward the seafloor, insofar as possible; however, energy will propagate outward from the source through the water. The following sections review the hearing/detection abilities of VECs and the available information on potential effects of sound (as well as other Project activities) from seismic and geohazard sources on VECs.

## 5.6.1. Invertebrates and Fish

There will likely be *no significant effect* (*negligible* at most) of the Project on fish habitat components that include water quality, phytoplankton, zooplankton and microbenthos. Therefore, they are not discussed directly in this section. Ichthyoplankton and macrobenthos are discussed as part of the invertebrates and fish VEC.

### 5.6.1.1. Sound

Potential effects of exposure to seismic (and geohazard) sound on invertebrates and fish can be categorized as either physical (includes both pathological and physiological) or behavioural. Pathological effects include lethal and sub-lethal damage, physiological effects include temporary primary and secondary stress responses, and behavioural effects are changes in exhibited behaviours. The three types of potential effects should not be considered independently of one another. They are likely interrelated in complex ways. For example, it is possible that certain physiological and behavioural changes could potentially lead to the ultimate pathological effect on individual animals (i.e., mortality).

The following sections provide an overview of available information pertaining to the detection abilities and effects of exposure to seismic (and geohazard) sound on invertebrates and fish. Summaries of the various topics are provided with cross-references to recent relevant EAs for details. Examples of EAs that will be cross-referenced include the Environmental Assessment of Petro-Canada's Jeanne d'Arc Basin 3-D Seismic Program (LGL 2007a) and the Addendum to the Environmental Assessment of Petro-Canada's Jeanne d'Arc Basin 3-D Seismic Program (LGL 2007b).

**Background on Sound Detection**

Rather than being pressure sensitive, invertebrates appear to be most sensitive to particle displacement. However, their sensitivity to particle displacement and hydrodynamic stimulation appears to be less than that of fish. Decapods, for example, have an extensive array of hair-like receptors both within and upon the body surface that could potentially respond to water- or substrate-borne displacements. They are also equipped with an abundance of proprioceptive organs that could serve secondarily to perceive vibrations. Crustaceans appear to be most sensitive to sounds of low frequency (i.e., <1,000 Hz) (Budelmann 1992; Popper et al. 2001). See Section 5.6.2.3 of LGL (2007a) for more details regarding sound detection by marine invertebrates.

Among fishes, at least two major pathways for sound transmission to the ear have been identified. The first and most primitive is the conduction of sound directly from the water to tissue and bone. Acoustic particle motion affects the fish ear area directly, resulting in subsequent hair cell stimulation due to the difference in inertia between the hair cells and their overlying otoliths. The second sound pathway to the ears is indirect. The swim bladder or some other gas bubble proximate to the ears expands and contracts in volume in response to sound pressure fluctuations. This particle motion is then transmitted to the otoliths. The swim bladder occurs in most bony fishes but it is either absent or reduced in many other fish species. Of the fishes with a swim bladder, only particular species appear to be sound pressure-sensitive via this indirect pathway to the ears. These fish are known as 'hearing specialists'. The hearing specialists have some type of connection between the swim bladder and the inner ear. These connections include bony structures known as Weberian ossicles, extensions of the swim bladder, or simply the close proximity of the swim bladder to the inner ear. Typically, hearing specialist fish have relatively high sound pressure sensitivity and their upper frequency range of detection is extended above those species that detect sound by the direct pathway only. Fish species having only the direct pathway are known as 'hearing generalists' (Fay and Popper 1999). Typically, most fish detect sounds of frequencies up to 2 kHz but others can detect much higher frequencies (e.g., 20 kHz). Mann et al. (2007a) studied the hearing of eight species of northern Canadian freshwater fishes and demonstrated the variability in hearing sensitivity. Through the measurement of hearing thresholds, they showed the fish with the most sensitive hearing were the species with connections between the swimbladder and inner ear.

Fish also possess lateral lines that detect water movements. The essential stimulus for the lateral line consists of differential water movement between the body surface and the surrounding water. The lateral line is typically used in concert with other sensory information, including hearing (Sand 1981; Coombs and Montgomery 1999).

Mann et al. (2007b) examined existing hearing data of fishes in relation to ambient sound levels around reefs to estimate the distance over which reef fish might detect reef sounds. They concluded that particle motion is likely the principal stimulus for larval fish in sound detection, and that under prime conditions, larval fish likely cannot detect ambient sound particle motion at distances exceeding one kilometer.

Elasmobranchs, including sharks and skates, lack any known pressure-to-displacement transducers such as swim bladders. Therefore, they presumably must rely on the displacement sensitivity of their mechanoreceptive cells. Unlike acoustic pressure, the kinetic stimulus is inherently directional but its magnitude rapidly decreases relative to the pressure component as it propagates outward from the sound source in the near field. It is believed that elasmobranches are most sensitive to low frequencies (i.e., <1 kHz) (Corwin 1981).

See Section 5.6.2.3 of LGL (2007a) for more details regarding sound detection by fishes.

**Background on Physical Effects of Sound Exposure**

**Pathological**

In water, acute damage to organisms exposed to seismic sound is likely related primarily to two features of the sound: (1) received peak pressure, and (2) time required for the pressure to rise and decay (Hubbs and Rechnitzer 1952 *in* Wardle et al. 2001). Generally, the higher the received pressure and the less time it takes for the pressure to rise and decay, the greater the chance of acute pathological effects. Considering the peak pressure and rise/decay time characteristics of seismic airgun arrays used today, the pathological zone for fish and invertebrates would be expected to be small ( i.e., within a few metres of the seismic source).

To date, there are not any properly documented cases of acute mortality of juvenile or adult fish or invertebrates exposed to seismic sound characteristic of typical field seismic surveys. Sub-lethal injury or damage has been observed but as a result of repeated exposure to very high received levels of sound, a higher cumulative level than would be expected in the field under normal seismic operating conditions. Acute mortality of eggs and larvae have been demonstrated in experimental exposures but only when the eggs and larvae were exposed very close to the seismic sound sources and the received pressure levels were presumably very high. Based on study results to date, there is no evidence to suggest that exposure to seismic causes chronic mortality in juvenile/adult fish and invertebrates.

See Section 5.6.2.1 of LGL (2007a) for more details on the potential pathological effects of exposure to sound on invertebrates and fish, including discussion of the limited number of studies done to date.

**Physiological**

Biochemical responses of marine fish and invertebrates to acoustic stress have also been studied, albeit in a limited way. Studying the variations in the biochemical parameters influenced by acoustic stress may give some indication of the extent of the stress and perhaps provide insight into associated impacts on the animal. For example, stress could potentially affect animal populations by negatively impacting reproductive capacity.

Primary and secondary stress responses of fish after exposure to seismic energy all appear to be temporary in any studies done to date. The times necessary for these biochemical changes to return to normal are variable depending on numerous aspects of the biology of the species and of the sound stimulus.

Sub-lethal physiological effects on lobsters (*Homarus americanus*) exposed to seismic energy were observed by Payne et al. (2007) during preliminary exploratory studies. The observed serum biochemical effects included reduced levels of serum protein, specific serum enzymes, and serum calcium. In some cases, the reduced levels persisted for a period of weeks.

Popper et al. (2007) investigated the effects of exposure to high-intensity, low frequency sonar on rainbow trout (*Oncorhynchus mykiss*). They found that certain groups of trout showed auditory threshold shifts at particular frequencies but that results varied with different groups, suggesting developmental and/or genetic impacts on how the fish are affected.

See Section 5.6.2.2 of LGL (2007a) for more details on the potential physiological effects of exposure to sound on invertebrates and fish, including discussion of the limited number of studies done to date.

**Background on Behavioural Effects of Sound Exposure**

Because of the relative lack of indication of serious pathological and physiological effects of seismic energy on marine fish and invertebrates, most concern now focuses on the possible effects of exposure to seismic on the distribution, migration patterns and catchability of fish (i.e., behavioural effects).

The full determination of behavioural effects of exposure to seismic is difficult. There have been well-documented observations of fish and invertebrates exhibiting behaviours that appeared to be in response to exposure to seismic (i.e., startle response, change in swimming direction and speed, change in vertical distribution), but the ultimate importance of these behaviours is unclear. Some studies indicate that such behavioural changes are very temporary while others imply that marine animals might not resume pre-seismic behaviours/distributions for a number of days. As is the case with pathological and physiological effects of exposure to sound on fish and invertebrates, available information is relatively scant and often contradictory. There is also evidence that certain clupeids show a graded series of responses to exposure to ultrasound. The strongest responses involve rapid movement away from the sound source.

Sub-lethal behavioural effects on lobsters exposed to seismic energy were observed by Payne et al. (2007) during preliminary exploratory studies. Four of the five exposure trials resulted in observed increases in food consumption, and these feeding differences were often apparent several weeks post-exposure.

Bluefin tuna (*Thunnus thynnus*) behaviour in response to exposure to boat noise was recently studied in the Mediterranean Sea (Sarà et al. 2007). The investigation concluded that boat noise produced behavioural deviations in tuna schools that resulted in changes in swimming direction, increased vertical movement both downwards and upwards, and general disruption of the school structure and swimming behaviour. The authors suggested that alteration in schooling behaviour might affect the accuracy of tuna migration to spawning and feeding grounds.

See Section 5.6.2.3 of LGL (2007a) for more details on the potential behavioural effects of exposure to sound on invertebrates and fish, including discussion of the limited number of studies done to date.

**Sound Exposure Effects Assessment**

The best approach when assessing the effects of noise of the proposed seismic program on the invertebrate and fish VEC is to use species that best represent the variability associated with crucial criteria considered during the assessment. It would also be most effective to assess the effects of seismic on species that have been studied after exposure to seismic. Snow crab and Atlantic cod are two species that appropriately serve just that purpose.

The criteria worth consideration in the assessment include (1) distance between the seismic source and animal under normal conditions (post-larval snow crabs remain on bottom, post-larval cod occur in the water column, and larvae of both snow crab and cod are planktonic in upper water column), (2) motility of the animal (post-larval snow crabs much less motile than post-larval cod, and larvae of both are essentially passive drifters), (3) absence or presence of a swim bladder (i.e., auditory sensitivity) (snow crabs without swimbladder and cod with swimbladder), (4) reproductive strategy (snow crabs carry fertilized eggs at the bottom until larval hatch, and cod eggs are planktonic), and (5) residency in the Project Area (i.e., year-round vs. seasonal) (snow crab are essentially permanent residents and cod are more temporary residents).

Potential impacts on other marine invertebrate and fish species must be inferred from the assessment using snow crab and Atlantic cod. Potential interactions between the proposed Project and the invertebrate and fish VEC are shown in Table 5.1.

**Physical Effects (Pathological and Physiological)**

As indicated in Section 5.1.1, there is a relative lack of knowledge of the effects of seismic sound on marine invertebrates and fish. Available experimental data suggest that there may be physical impacts on the fertilized eggs of snow crab and on the egg, larval, juvenile and adult stages of cod at very close range. Considering the typical source levels associated with commercial seismic arrays, close proximity to the source would result in exposure to very high sound pressure levels. While egg and larval stages are not able to actively escape such an exposure scenario, juvenile and adult cod would most likely avoid it. Juvenile and adult snow crab are benthic and generally far enough from the sound source to receive SPLs well below levels that may have had impact. In the case of eggs and larvae, it is likely that the numbers negatively affected by exposure to seismic sound would be similar to those succumbing to natural mortality.

Limited data regarding physiological impacts on fish and invertebrates indicate that these impacts are both short-term and most obvious after exposure at close range. Table 5.2 provides the details of the physical effects assessment.

## Table 5.1. Potential interactions between Project activities and the invertebrate and fish VEC.

| Project Activities | Valued Ecosystem Component: Invertebrates and Fish | | | | | |
|---|---|---|---|---|---|---|
| | Feeding | | Reproduction | | Adult Stage | |
| | Plankton | Benthos | Eggs/Larvae | Juveniles [a] | Pelagic Fish | Groundfish |
| **Vessel Lights** | x | | x | | x | |
| **Sanitary/Domestic Waste** | x | | x | | x | |
| **Air Emissions** | x | | x | | x | |
| **Garbage** [b] | | | | | | |
| **Noise** | | | | | | |
| Seismic Vessel | | | | | x | |
| Seismic Array | x | x | x | x | x | x |
| Supply Vessel | | | | | x | |
| Picket Vessel | | | | | x | |
| Geohazard Vessel | | | | | x | |
| Helicopter [c] | | | | | | |
| Echo Sounder | x | x | x | x | x | x |
| Side Scan Sonar | x | x | x | x | x | x |
| Boomer | x | x | x | x | x | x |
| Towfish | x | x | x | x | x | x |
| **Presence of Vessel** | | | | | | |
| Seismic Vessel | | | | | | |
| Supply Vessel | | | | | | |
| Picket Vessel | | | | | | |
| Geohazard Vessel | | | | | | |
| **Helicopter** [c] | | | | | | |
| **Shore Facilities** [d] | | | | | | |
| **Accidental Spills** | x | | x | | x | |
| **Other Projects and Activities** | | | | | | |
| **Hibernia** | x | x | x | x | x | x |
| **Terra Nova** | x | x | x | x | x | x |
| **White Rose** | x | x | x | x | x | x |
| **Exploration** | x | x | x | x | x | x |
| **Fisheries** | x | x | x | x | x | x |
| **Marine Transportation** | x | | x | | x | x |

[a] Juveniles are young fish that have left the plankton and are often found closely associated with substrates.
[b] Not applicable as garbage will be brought ashore.
[c] A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks.
[d] There will not be any new onshore facilities. Existing infrastructure will be used.

### Table 5.2. Potential interactions between the Project and the Commercial Fisheries VEC.

| Valued Ecosystem Component: Commercial Fisheries | | | |
|---|---|---|---|
| **Project Activities** | **For Finfish and Mobile Invertebrates (using fixed gear or mobile trawls)** | **For Sedentary Benthic Invertebrates (using fixed crab pots)** | **Research Surveys** |
| **Vessel Lights** | | | |
| **Sanitary/Domestic Waste** | | | |
| **Air Emissions** | | | |
| **Garbage** [a] | | | |
| **Noise** | | | |
| 2D, 3D Seismic and Geohazard vessel | | | |
| Seismic Array and Geohazard sound sources | x | x | x |
| Supply Vessel | | | |
| Picket Vessel | | | |
| Helicopter [b] | | | |
| **Presence of Vessels** | | | |
| Seismic and Geohazard Vessel/Streamers and other tows (including transit to site with deployed streamer) | x | x | x |
| Supply Vessel | | | |
| Picket Vessel | | | |
| **Helicopter** [b] | | | |
| **Shore Facilities** [c] | | | |
| **Accidental Spills** | | | |
| **Other Projects and Activities** | | | |
| **Commercial Fisheries** | x | x | x |
| **Exploration** | x | x | x |
| **Marine Transportation** | x | x | x |

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

As per Tables 5.2 *in* LGL (2007a,b), noise produced as a result of the proposed Project is predicted to have *negligible to low* physical effects on the various life stages of the invertebrate and fish VEC over a duration of *<1 month to 1 to 12 months* in an area *<1* $km^2$. Therefore, as per Tables 5.3 *in* LGL (2007a,b), physical effects of Project noise on the invertebrate and fish VEC would be not significant.

## Behavioural Effects

Based on the review of the effects of seismic on fish and invertebrates in a preceding section, there is limited data to support any conclusive statements regarding the behavioural effects of exposure to seismic sound on these animals. Available information indicates that behavioural changes in response to sound are short-term. However, there is no available information on what constitutes critical durations of change to the various behaviours. There appears to be a great deal of inter- and intra-specific variability. In the case of finfish, three general types of behavioural responses have been identified: (1) startle, (2) alarm, and (3) avoidance. The type of behavioural reaction appears to depend on many factors, including the type of normal behaviour being exhibited at time of exposure, proximity of the sound source, and the pressure/energy level of the sound source. The behaviours of most concern would include those associated with reproduction and migration. Behavioural effects on fish and invertebrates appear to occur at greater distances from the seismic sound source than physical effects. As discussed earlier, certain clupeid fish also exhibit avoidance behaviours when exposed to ultrasound of sufficient amplitude and within a specific frequency range. These responses appear to be temporary. Table 5.2 provides the details of the disturbance effects assessment.

As per Tables 5.2 *in* LGL (2007a,b), noise produced as a result of the proposed Project is predicted to have *negligible to low* behavioural effects on the various life stages of the invertebrate and fish VEC over a duration of *<1 month* to *1 to 12 months* in an area *11 to 100* or *101 to 1,000* $km^2$. Therefore, as per Tables 5.3 *in* LGL (2007a,b), behavioural effects of Project noise on the invertebrate and fish VEC would be *not significant*.

#### 5.6.1.2. Other Project Activities Not Related to Sound

**Vessel Lights**

As indicated in Table 5.1, there are potential interactions between vessel lights and certain components of the invertebrate and fish VEC. However, other than the relatively neutral effect of attraction of certain species/life stages to the upper water column at night, there are not any notable effects of vessel lights on this VEC. Therefore, the effects of vessel lights associated with the proposed Project would be *not significant*.

**Sanitary/Domestic Waste**

As indicated in Table 5.1, there are potential interactions between sanitary/domestic waste and certain components of the invertebrate and fish VEC. However, after application of mitigative measures including treatment of the waste, the residual effects of sanitary/domestic waste on the invertebrate and fish VEC would be *negligible* in magnitude, *<1* $km^2$ in geographic extent, and *1 to 12 months* in duration. Therefore, the residual effects of sanitary/domestic waste associated with the proposed Project on the invertebrate and fish VEC would be *not significant*.

**Air Emissions**

As indicated in Table 5.1, there are potential interactions between air emissions and certain components of the invertebrate and fish VEC that occur near surface. However, considering that the amount of air emissions produced during the proposed seismic program will rapidly disperse to undetectable levels, the residual effects of them on the invertebrate and fish VEC would be *negligible* in magnitude, *<1* $km^2$ in geographic extent, and *1 to 12 months* in duration. Therefore, the residual effects of air emissions associated with the proposed Project on the invertebrate and fish VEC would be *not significant*.

**Accidental Events**

As indicated in Table 5.1, there are potential interactions between accidental events and certain components of the invertebrate and fish VEC that occur near surface. The effects of hydrocarbon spills on marine invertebrates and fish, including associated physical habitats, have been discussed and assessed in numerous recent environmental assessments of proposed offshore drilling programs (e.g., LGL 2006a, 2007c). These assessments have concluded that the residual effects of accidental events on the invertebrate and fish VEC would be *not significant*. Considering that the probabilities of hydrocarbon releases during seismic and geohazard surveying are even lower than those associated with drilling, the residual effects of accidental events associated with the proposed seismic program on the invertebrate and fish VEC would be *not significant*.

#### 5.6.1.3. Cumulative Effects

As indicated in Table 5.1, marine exploration, commercial fisheries, marine transportation and existing production activity (e.g., Hibernia, Terra Nova, and White Rose) all have the potential to interact with invertebrates and fish. It is unlikely that routine activities associated with other marine exploration, marine transportation and existing production areas have much direct impact on marine invertebrates and fish. Commercial fisheries obviously impact marine invertebrates and fish but fisheries management is intended to maintain populations at sustainable levels. Given the predicted minimal effects of other projects and activities, and the prediction that the residual effects of the proposed seismic program on the invertebrate and fish VEC would be *not significant*, the cumulative effects on this VEC are also predicted to be *not significant*.

### 5.6.2. Effects on Commercial Fisheries VEC

The types of potential impacts on the commercial fisheries are similar for each of the three distinct survey components, 2-D seismic, 3-D seismic and geohazard surveys over potential drilling targets. (This will also include the routes used to the survey areas; in some cases, the streamers may be deployed enroute, but the sound sources will not be used in transit.) The principal difference among these components, from the perspective of the fisheries, is the size of the marine area involved (2-D largest, geohazard smallest), and any differences in sound source output.

For any of these surveys potential impacts may be related to (1) changes in catch rates resulting from noise-induced behavioural changes (scaring) of fish, (2) interference with fishing activities - particularly fixed gear - owing to direct gear or vessel conflicts, or (3) as a result of effects on stock assessments / DFO research activities, which are used, among other purposes, for setting fishing quotas or exploring new fisheries. Each of these issues has been raised during consultations and issues scoping for oil and gas exploration. (Impacts related to physical effects on fish and invertebrates, including from accidental spills and wastes, are not discussed here as they are assessed above, and considered to be not significant, with appropriate mitigations in place.)

The chief means of mitigating potential impacts on commercial fisheries activities is to avoid active fishing areas, particularly fixed gear zones, when they are occupied by harvesters. Impacts on DFO assessment/research surveys would occur either as a result of behavioural responses or fishing interference (i.e., through the same pathways as impacts on commercial fishing) and avoidance is also an appropriate mitigation for these potential effects. For the commercial fisheries, gear damage compensation provides a means of final mitigation of impacts, in case a conflict does occur with fishing gear (i.e., contact with the survey streamers or the ship).

As described in the Commercial Fisheries section of this assessment (Section 4.3), while the potential 2008 survey area has had no recorded harvesting activity over the past three years, there has been fishing in well-defined parts of the Project Area. This consists of fixed-gear snow crab fishing just beyond the 200 NMi EEZ boundary and in the northwest quadrant of the Project Area, and mobile-gear shrimp harvesting between the 200 m and 500 m contour in the north-central area. The potential for impacts on fish harvesting will therefore depend very much on the location of the surveying activities in relation to these fishing areas in any given season. If the survey work is situated away from these fishing areas, the likelihood of any impacts on commercial harvesting will be greatly reduced. Potential impacts on fisheries research are discussed separately, below.

For the transit routes to the survey area, where the survey streamers may be deployed during the outbound segment, a separate route analysis will be prepared and discussions with fishing interests undertaken before the transits, to avoid fixed gear fishing activities.

Potential interactions between the proposed survey components and the conduct of commercial fisheries activities (including fisheries research) are shown in Table 5.2. The three types of potential survey activities (2-D, 3-D and geohazard) are considered together since the types of effects would be the same, in relation to fish harvesting and research surveys.

The C-NLOPB April 2004 Guidelines (CNOPB 2004) provide guidance aimed at minimizing any impacts of petroleum industry surveys on commercial fish harvesting. These Guidelines were developed based on best practices during previous years' surveys in Atlantic Canada, and on guidelines from other national jurisdictions. The relevant Guidelines state (Appendix 2, Environmental Mitigative Measures):

1. a) The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other’s planned activities. Communication throughout survey operations with fishing interests in the area should be maintained.

1. c) The operator should publish a Canadian Coast Guard "Notice to Mariners" and a "Notice to Fishers" via the CBC Radio program Fisheries Broadcast.

1. d) Operators should implement a gear and/or vessel damage compensation program, to promptly settle claims for loss and/or damage that may be caused by survey operations. The scope of the compensation program should include replacement costs for lost or damaged gear and any additional financial loss that is demonstrated to be associated with the incident. The operator should report on the details of any compensation awarded under such a program.

1. e) Procedures must be in place on the survey vessel(s) to ensure that any incidents of contact with fishing gear are clearly detected and documented (e.g., time, location of contact, loss of contact, and description of any identifying markings observed on affected gear). As per Section 4.2 of these Guidelines, any incident should be reported immediately to the 24-hour answering service at (709) 778-1400 or to the duty officer at (709) 682 4426.

2. b) Surveys should be scheduled, to the extent possible, to reduce potential for impact or interference with Department of Fisheries and Oceans (DFO) science surveys. Spatial and temporal logistics should be determined with DFO to reduce overlap of seismic operations with research survey areas, and to allow an adequate temporal buffer between seismic survey operations and DFO research activities.

c) Seismic activities should be scheduled to avoid heavy fished areas, to the extent possible. The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained. The use of a 'Fisheries Liaison Officer' (FLO) on-board the seismic vessel would be considered an acceptable approach.

d) Where more than one survey operation is active in a region, the operator(s) should arrange for a 'Single Point of Contact' for marine users that may be used to facilitate communication.

The following sections describe how the proposed SHC survey work will meet each of these mitigative guidelines, as well as other measures that will be applied.

#### 5.6.2.1. Impacts on Catch Rates (Fishing Success)

Some fisheries industry representatives have stated concerns that seismic survey sound sources may scare finfish from their fishing locations, or discourage benthic species (such as snow crab) from entering fishing gear. The likelihood that finfish will move away as the array approaches is considered a factor that helps prevent physical impacts on these species.

The discussion of the behavioural effects on fish and invertebrates in Section 5.6.1.1 presents the results of studies on the effects of seismic noise on catch rates. While most - though not all - of these studies report some decrease in catch rates near seismic arrays, there is less agreement on the duration and geographical extent of the effect, ranging from a quick return to several days, and from very localized effects to decreased catch rates as far as 15 km to 20 km away. Snow crab, being relatively sedentary benthic species, are not likely to disperse and catch rates are not as likely to be affected. Shrimp fishing operators report no observed impact on catch rates offshore Newfoundland and Labrador but request that communications be maintained so that seismic streamers and fishing trawls do not overlap in the same area.

If survey work is planned in areas of snow crab fishing, the gear sets will have to be avoided by the seismic ship because of the risk of gear or vessel conflicts, so direct overlap of activities should not occur.

As per Tables 5.5 *in* LGL (2007a,b), the proposed Project is predicted to have *negligible* effects on catch rates of commercial fisheries (i.e., economic impacts) with the mitigations described below in place. Therefore, as per Tables 5.7 *in* LGL (2007a,b), effects of the Project on the commercial fisheries VEC would be *not significant*.

**Mitigations**

**Avoidance.** Potential impacts on fishing (catch success as well as gear conflicts) will be mitigated by avoiding heavily fished areas when these fisheries are active (specifically the snow crab areas) to the greatest extent possible. As described in this report, most of the fishing in the past has been concentrated in well-defined areas within the Project Area. During any survey, the location of current activities will be monitored by the ship and the Fisheries Liaison Officer (see below) and plotted by project vessels, and fishing boats will be contacted by radio. Survey personnel (through the Single Point of Contact, described below) will also continue to be updated about fisheries near the survey. The mapping of activities contained in this EA report will also be an important source of fisheries information for the survey operators.

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

Relevant information about the survey operations will also be publicized using established communications mechanisms, such as the *Notices to Shipping* (Continuous Marine Broadcast and NavTex) and the CBC (Newfoundland) Radio's *Fisheries Broadcast*, and by the FFAW in the FFAW

*Union Forum* (as suggested during previous consultations), as well as direct communications between the survey vessel and fishing vessels via marine radio at sea. This will also include any transit routes.

**Fisheries Liaison Officer (FLO).** As a specific means of facilitating at-sea communications, and informing the survey vessel operators about local fisheries, SHC will have an on-board fisheries industry liaison officer as a "fisheries representative". The FLO will be hired through, and on the advice of, the FFAW. The FLO will remain on the relevant survey vessel for the entire program. This will provide a dedicated marine radio contact for all fishing vessels in the vicinity of operations to discuss interactions and resolve any problems that may arise at sea. This person will assist the vessel's bridge personnel to become informed about any local fishing activities.

Observers have proven effective in the Nova Scotia sector since 1998. Since 2002 FLOs have been utilized in Newfoundland and Labrador waters and have proven highly effective in communicating with fishers at sea and avoiding gear and fishing conflicts in this sector. (Appendix D *in* LGL (2007a) contains a description of the FLO responsibilities and qualifications, as agreed in previous discussions with the FFAW.)

#### 5.6.2.2. Fishing - Conflict with Fishing Gear (Survey Areas and Transit Routes)

In previous surveys, concerns have been raised about the seismic vessel or streamer fouling fishing gear, most specifically fixed gear (crab pots) if it is concurrent and co-locational with survey operations. In the past, such gear conflicts have occurred in areas of the Atlantic Canada offshore on occasion. All such incidents have involved fixed gear (typically crab or lobster pots, gill nets or large pelagic longlines). When these events have occurred, they have been assessed and compensation paid for losses attributable to the survey vessel or other petroleum industry activities.

For the streamer deployment during the transits to and between survey areas, there will be no use of the sound source (array), so the only potential effects relate to the vessel itself and the streamer, if deployed.

As per Tables 5.5 *in* LGL (2007a,b), the proposed Project is predicted to have *negligible* effects on the commercial fisheries (i.e., economic impacts) with precautions and compensation plans in place (described below), and considering the avoidance of fixed gear fishing areas that will be necessary. Therefore, as per Tables 5.7 *in* LGL (2007a,b), effects of the Project on the commercial fisheries VEC would be *not significant*.

**Mitigations**

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

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

In addition to avoidance based on route analysis and selection, the onshore Single Point of Contact (SPOC) and the at-sea FLO will advise the vessel en route, to ensure fishing gear is avoided. In case avoidance fails, a gear damage program will be in place to compensate fishers who lose gear as a result.

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

**Single Point of Contact (SPOC)**. This has become a standard and effective mitigation for all seismic surveys operating in this sector. The survey will use the firm of Canning & Pitt Associates, Inc. as the survey's SPOC with the fisheries industry, as described in the C-NLOPB Guidelines. In addition, as part of their SPOC role, Canning & Pitt Associates, Inc. have provided these services in the Newfoundland and Labrador offshore each year since 1997. They will endeavor to update vessel personnel (e.g., the FLO) about known fishing activities in the area, and will relay relevant information from DFO and fishing companies.

**Fishing Gear Compensation.** In case of accidental damage to fishing gear or vessels, SHC will implement its fisheries damage compensation policy to provide appropriate and timely compensation to any affected fisheries participants. The Notices to Shipping, filed by the vessels for surveys and for transits to the sites, will also inform fishers that they may contact the SPOC (Canning & Pitt Associates, Inc., toll free at 877-884-3474), if they believe that they have sustained survey-related gear damage.

SHC will follow the procedures (which have been employed successfully in the past) outlined in Appendix E of LGL (2007a) for documenting any incidents; Appendix F *in* LGL (2007a) contains an incident reporting form that will be used, and which meets the requirements of the C-NLOPB Guidelines.

SHC is familiar with programs developed jointly by the fisheries industry and offshore petroleum operators (e.g., by the Canadian Association of Petroleum Producers and other Operators) as alternatives to claims through the courts or the C-NLOPB, to address all aspects of compensation for attributable gear and vessel damage. These programs include provisions for paying compensation for lost or damaged gear, and any additional financial loss, which is demonstrated to be associated with the incident. The programs include mechanisms for claim payments and dispute resolution. The operator will implement similar procedures to settle claims promptly for any loss or damage that may be caused by survey operations, including the replacement costs for lost or damaged gear, and any additional financial loss that is demonstrated to be associated with the damage, as specified under the 2004 Guidelines, Appendix 2 (1d).

SHC will provide the C-NLOPB with details of any compensation that is paid in the event of an incident.

#### 5.6.2.3. DFO and Industry Research Surveys

Since these research surveys are conducted by "fishing" for species, the issues related to potential interference with DFO research surveys are essentially the same as for commercial fish harvesting, i.e. potential effects on catch rates, and potential conflicts with the fisheries research operations.

The set locations of the FFAW's industry crab survey described in Section 4.3.6 will be provided by the FFAW when they are established for the current year. These would include crab survey locations both inside and outside 200 miles (J. Coady, FFAW, pers, comm. December 2007). If they are in the same general areas as previous years, they will not overlap with the potential 2008 survey area, but may do so in subsequent years if these research activities continue to be carried out. Timing may be the most effective mitigation if the fisheries research overlaps spatially with the survey work.

As previously noted, there is some potential for overlap with DFO research surveys of 3LN, though the department's RV schedule may be adjusted from year to year. For the last few years, surveys in some parts of 3L occurred in May and June, and September – December.

In any survey year, it will be necessary to obtain more specific information on survey timing and locations as it becomes available. This information will be acquired from DFO and fishing groups by SHC and forwarded to the seismic contractors. It has been accepted during past surveys, that the best way to prevent overlap between the surveys is to exchange detailed locational information and establish a temporal and spatial separation plan, as was implemented with DFO Newfoundland and Labrador in past seasons. This is discussed in more detail in the Mitigations section, below.

**Mitigations**

The mitigations described above to avoid fisheries disturbance and gear conflicts will apply generally to DFO science cruises.

As in past surveys, the survey vessel and DFO will need to exchange detailed locational information. In 2002, when the plan was first implemented in the eastern Newfoundland Region, the exact planned RV survey locations were provided and plotted by the survey ship, and the locations of planned survey lines and daily vessel location reports were provided to DFO. A temporal and spatial separation plan was then agreed with DFO and implemented by the seismic vessel to ensure that its operations did not overlap spatially and temporally, and to ensure an adequate "quiet time" before the RV came to the location.

Specifically, the avoidance protocol to avoid sound overlap with the research work has been 30 km (16 nmi) separation from research set location, seven days in advance of the locations being surveyed by DFO (i.e. seven days of "quiet time").

As discussed above, any research survey taking place in the vicinity of the proposed project surveys will need to be monitored and avoided by the vessel. Given this, the impact of both noise and the seismic streamer on DFO science surveys will be *negligible* (see Tables 5.6 *in* LGL (2007a,b)) and *not significant* (see Tables 5.7 *in* LGL (2007a,b)).

### 5.6.3. Seabirds

There are three main potential types of impacts to seabirds from offshore seismic (and geohazard) programs: (1) underwater sound from airgun arrays, (2) leakage of petroleum product from streamer(s), and (3) attraction to ship lights at night. Potential interactions between the Project and seabirds are shown in Table 5.3 and a review of available information on potential impacts related to these interactions is provided below.

**Table 5.3. Potential interactions between the Project and Seabird VEC.**

| Project Activities | Valued Ecosystem Component: Seabirds |
|---|---|
| **Vessel Lights** | x |
| **Sanitary/Domestic Waste** | x |
| **Air Emissions** | x |
| **Garbage** [a] | x |
| **Noise** | |
| Seismic Vessel | x |
| Seismic Array | x |
| Supply Vessel | x |
| Picket Vessel | x |
| Geohazard Vessel | x |
| Helicopter [b] | x |
| Echo Sounder | x |
| Side Scan Sonar | x |
| Boomer | x |
| Towfish | x |
| **Presence of Vessels** | |
| Seismic Vessel | x |
| Supply Vessel | x |
| Picket Vessel | x |
| Geohazard Vessel | x |
| **Helicopters** [b] | x |
| **Shore Facilities** [c] | |
| **Accidental Spills** | x |

**Table 5.3 (Continued).**

| Project Activities | Valued Ecosystem Component: Seabirds |
|---|---|
| **Other Projects And Activities** | |
| **Hibernia** | x |
| **Terra Nova** | x |
| **White Rose** | x |
| **Exploration** | x |
| **Fisheries** | x |
| **Marine Transportation** | x |

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

### 5.6.3.1. Sound Effects Assessment on Seabirds

The effects of underwater sound on birds have not been well studied. A study on the effects of underwater seismic surveys on moulting Long-tailed Ducks in the Beaufort Sea showed little effect on their movement or diving behaviour (Lacroix et al. 2003). The study did not monitor potential physical effects on the ducks. The authors suggested caution in interpretation of the data because they were limited in their ability to detect subtle disturbance effects and recommended studies on other species to fully understand the effects of seismic testing.

Most species of seabirds that are expected to occur in the Study Area feed at the surface or at less than one metre below the surface of the ocean (Table 4.10). This includes members of *Procellariidae* (Northern Fulmar,), *Hydrobatidae* (Wilson's Storm-Petrel and Leach's Storm-Petrel), *Phalaropodinae* (Red Phalarope and Red-necked Phalarope), and *Laridae* (Great Skua, South Polar Skua, Pomarine Jaeger, Parasitic Jaeger, Long-tailed Jaeger, Herring Gull, Iceland Gull, Glaucous Gull, Great Black-backed Gull, Ivory Gull, Black-legged Kittiwake and Arctic Tern). Northern Gannets plunge dive to a depth of 10 m. They are under the surface for a few seconds during each dive so would have minimal exposure to underwater sound. Greater Shearwater, Sooty Shearwater and Manx Shearwater feed mainly at the surface but also chase prey briefly beneath the surface down to a distance of two to ten metres below the surface (Brown et al. 1978; 1981).

There is only one group of seabirds occurring regularly in the Study Area that require relatively considerable time under water to secure food. They are the *Alcidae* (Dovekie, Common Murre, Thick-billed Murre, Razorbill and Atlantic Puffin). From a resting position on the water they dive under the surface in search of small fish and invertebrates. Alcids use their wings to propel their bodies rapidly through the water. All are capable of reaching considerable depths and spending considerable time under water (Gaston and Jones 1998). An average duration of dive times for the five species of *Alcidae* is 25 to 40 seconds reaching an average depth of 20 to 60 m, but murres are capable of diving to 120 m and have been recorded underwater for up to 202 seconds (Gaston and Jones 1998). The effects of underwater sounds on *Alcidae* are unknown. Foraging Long-tailed Ducks did not alter their diving intensity during seismic operations (Lacroix et al. 2003) but the authors of this study acknowledge that more research is required. Sounds are probably not important to *Alcidae* in securing food. However, all six species are quite vocal (in-air) at breeding sites indicating auditory capabilities are important in that part of their life cycle.

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

As per Tables 5.9 *in* LGL (2007a,b), noise produced as a result of the proposed Project is predicted to have *low* magnitude effects (if it occurs at all) on the seabird VEC over a duration of *<1 month* to *1 to 12 months* in a small area (probably <1 $km^2$). Therefore, as per Tables 5.10 *in* LGL (2007a,b), effects of Project noise on the seabird VEC would be *not significant*.

### 5.6.3.2. Leakage from Streamers

The seismic vessel in 2008 may employ solid streamers which will eliminate the risk of a spill. However, there is potential that the seismic survey in 2008 and in future years (2009-2016) will employ streamers that contain a paraffinic hydrocarbon called Isopar M. The precise effects of Isopar M on birds are not known. However, petroleum products have detrimental effects on the insulating attributes of seabird’s feathers. Isopar M is a kerosene-like product that leaves a relatively thin layered slick on the surface of water. It evaporates readily. Typical fluid-filled streamers are constructed of self-contained units 100 m in length. Therefore, a single leak in a streamer should result in a maximum loss 208 litres of Isopar M.

All seabirds expected to occur in the Study Area, except Arctic Tern, spend considerable time resting on the water. Birds that spend most of their time on water, such as the murres, Atlantic Puffins and Dovekies, would be the most likely species to suffer negative effects from an Isopar M slick. Northern Fulmar, the shearwaters and storm-petrels are attracted to slicks but would not likely confuse it with a natural oceanic slick comprised of zooplankton or offal. However, flocks of seabirds resting on the water would not necessarily get out of the water if they drifted into an Isopar M slick.

An exposure to a surface slick of a kerosene-like substance under calm conditions may harm or kill individual birds. However, because potential spills will likely be small and evaporation and dispersion rapid, the magnitude (low), and geographic extent (<1 $km^2$; see Tables 5.9 *in* LGL (2007a,b)) of any spills is not expected to cause significant effects on seabird populations and therefore, any effects will be *not significant* (see Tables 5.10 *in* LGL (2007a,b)).

#### 5.6.3.3. Attraction to Lights on Ships

Birds that spend most of their lives at sea are often influenced by artificial light (Montevecchi et al. 1999; Montevecchi 2006). Even before the era of electrical lights, humans used fires on shore to attract seabirds for food (Montevecchi 2006). Birds are more strongly attracted to lights at sea during fog and drizzle conditions. Moisture droplets in the air refract light increasing illumination creating a glow around vessels at seas. In Newfoundland waters, the Leach's Storm-Petrel is the species most often found stranded on the decks of offshore vessels after being attracted to lights at night (Moulton et al. 2005, 2006b and 2006c; Abgrall et al. *in prep.* a; *in prep.* b). Occasionally other Newfoundland seabirds e.g., Greater Shearwater, Northern Fulmar, Thick-billed Murre and Dovekie have been found stranded on vessels at sea in Newfoundland waters at night, presumably attracted to lights on ships. Birds may be confused or blinded by the contrast between a vessel's lights and the surrounding darkness. During the confusion a seabird may collide with the vessel's superstructure causing mortality directly or indirectly. Many seabirds have great difficulty becoming airborne from flat surfaces. Once on a hard surface, stranded seabirds tend to crawl into corners or under objects such as machinery to hide. Here they may die from exposure, dehydration or starvation over hours or days. A stranded seabird's plumage is prone to oiling from residual oil that may be present in varying degrees on the various decks of a ship. Even a dime-size spot of oil on a bird's plumage is sufficient to breach the thermal insulation essential for maintaining vital body heat. So that even if rescued and released over the side of the vessel, a bird may later die from hypothermia. The open ended structure of the stern of a typical seismic ship allows entry of seabirds to several decks. These decks are lighted to various degrees, sometimes brightly. This is unavoidable as seismic surveying is conducted around the clock and adequate lighting is required for safe work practices.

Lights may attract fish to the surface at night thus causing birds to feed at night. Lights are used as a method of fishing some species in other parts of the world. Great Black-backed Gulls and Greater Shearwaters have been observed catching sand lance (*Ammodytes* sp.) at night that were brought to the surface by lights around CSEM ships on the Orphan Basin (Abgrall et al. *in prep.* b). These vessels were stationary or moving at <2 knots (<3.7 km/h). It is not known if sand lance would be available for feeding seabirds around a seismic vessel which generally travels at 4 to 5 knots (7.4 to 9.3 km/h). The vessel may be moving too fast to allow the build up of a concentration of sand lance that would attract numbers of feeding seabirds at night. Night time feeding activity of Greater Shearwaters and Great Black-backed Gulls around CSEM vessels had no obvious negative effects on the birds.

Environmental observer(s) aboard the seismic (and geohazard) vessel will conduct daily searches of the ship and any petrels encountered will be handled and released in accordance with a procedure manual developed by Canadian Wildlife Service and Petro Canada (Williams and Chardine, n.d.). The ship's crew will also be notified to contact the EO if a bird is found. Deck lighting will be minimized (if it is safe and practical to do so) to reduce the likelihood of stranding. Mitigation and monitoring for stranded birds will reduce any effects of attraction to lights to a *low* magnitude, over a geographic extent of 1 to 10 $km^2$, and for a duration of <1 month to 1 to 12 months (see Tables 5.9 *in* LGL (2007a,b)). Thus, effects are predicted to be *not significant* (see Tables 5.10 *in* LGL (2007a,b)). SHC will acquire a seabird handling permit from the CWS prior to the start of the proposed seismic program. A report documenting each stranded bird including the date, global position and the general condition of the feathers when found, and if releasable, the condition upon release, will be completed and delivered to the CWS by the end of the calendar year.

## 5.6.4. Marine Mammals and Sea Turtles

The potential effects of seismic programs on marine mammals and sea turtles have recently been reviewed for Petro-Canada's 3-D program in Jeanne d'Arc Basin (LGL 2007a—section 5.6.6) and for Husky's program in northern Jeanne d'Arc Basin (LGL 2005b—section 6.5.12; Moulton et al. 2006a—sections 6.1.2, 6.1.3). Geohazard surveys are less likely to impact marine mammals and sea turtles as reviewed in three EAs for Jeanne d'Arc Basin in 2005 (LGL 2005a,b,c) and an update to one of the EAs in 2007 (LGL 2007b). The following review is based largely on these documents with new and relevant literature included.

### 5.6.4.1. Effects of Seismic and Geohazards Sounds

The potential effects of sound from airgun arrays on marine mammals and sea turtles are the principal concern associated with seismic programs. Sounds from the geohazards equipment are of less concern given their relatively lower source levels, emittence in a narrow beam, short duration of the geohazards program, and that some equipment operates at frequencies outside the range of marine mammal and sea turtle hearing abilities. There is relatively little information available for the responses of marine mammals and sea turtles to sonar sounds that would be produced during a geohazards survey. Sounds from the geohazards equipment are very short pulses, one to four times every second.

The following text provides summaries and updated literature on the hearing abilities of marine mammals and sea turtles, and masking effects, behavioural (disturbance) effects, the possibility of hearing impairment, physical and non-auditory physiological effects from seismic operations.

**(A) Hearing Abilities of Marine Mammals and Sea Turtles**

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many anthropogenic sounds including sounds made during seismic exploration.

***Toothed Whales.—*** The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. There are very few data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales. However, Mann et al. (2005) report that a Gervais' beaked whale showed evoked potentials from 5 to 80 kHz, with the best sensitivity at 80 kHz.

The Huntec boomer operated from the geohazard vessel emits pulsed sounds with frequency bandwidth from 500 Hz to 6 kHz. That frequency is within the hearing range of many odontocetes. The side-scan sonar emits pulsed sounds at dual frequencies of 100 kHz and 398 kHz. The 100 kHz channel can likely be heard by some odontocetes. The multibeam echosounder operates at frequencies of 240 kHz. Thus, sound pulses from the boomer and sidescan sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam. However, the multibeam echosounder operates at frequencies (240 kHz) that are likely too high to be detected by odontocetes.

***Baleen Whales.—*** The hearing abilities of baleen whales have not been measured directly. Behavioural and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small toothed whales that have been studied directly. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales.

Sound pulses from the Huntec boomer operated from the geohazard vessel will likely be readily audible to baleen whales. However, the multibeam echosounder and side-scan sonar operate at frequencies that are likely too high to be detected by baleen whales.

***Pinnipeds.—*** Underwater audiograms have been obtained using behavioural methods for three species of phocid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). Compared to odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, better auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

Sound pulses from the airgun arrays and from the Huntec boomer operated from the geohazard vessel will likely be readily audible to phocids. However, the multibeam echosounder and side-scan sonar operate at frequencies that are likely too high to be detected by phocids.

***Sea Turtles*****.—**The limited available data indicate that the frequency range of best hearing sensitivity by sea turtles extends from roughly 250 to 300 Hz to 500 to 700 Hz (Ridgway et al. 1969; Bartol et al. 1999). Sensitivity deteriorates as one moves away from this range to either lower or higher frequencies. However, there is some sensitivity to frequencies as low as 60 Hz, and probably as low as 30 Hz. Thus, there is substantial overlap in the frequencies that sea turtles detect vs. the frequencies in airgun pulses. It is likely sea turtles can hear sounds from the Huntec boomer but unlikely that they can hear the side-scan sonar and echosounder.

### (B) Masking Effects

As reviewed in LGL (2007a,b), masking (i.e., reduce the effective communication or echolocation distance) is unlikely to be a significant issue for either marine mammals or sea turtles exposed to the pulsed sounds from seismic and geohazard surveys.

### (C) Behavioural Effects (Disturbance)

Disturbance includes a variety of effects, including subtle changes in behaviour, more conspicuous dramatic changes in activities, and displacement. Disturbance is one of the main concerns in this Project.

***Baleen Whales.—*** Baleen whales tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, studies done since the late 1990s of humpback and especially migrating bowhead whales show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased. Studies indicate monitoring over broader areas may be needed to determine the range of potential effects of some larger seismic surveys (Richardson et al. 1999; Bain and Williams 2006; Moore and Angliss 2006).
Some baleen whales show considerable tolerance of seismic pulses (Stone and Tasker 2006). However, when the pulses are strong enough, avoidance or other behavioural changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160 to 170 dB re 1 μPa rms range seem to cause obvious avoidance behaviour in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km from the source. A substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the operating airgun array. In the case of migrating bowhead whales, avoidance extends to larger distances and lower received sound levels. Recent intensive study of western gray whales summering in feeding areas off Sakhalin Island, Russia showed that some whales (5-10 individuals) moved away from waters inshore of seismic operations to a core feeding area farther south (Yazvenko et al. 2007a) and that there was no measureable effect on bottom feeding by gray whales relative to the seismic survey (Yazvenko et al. 2007b).

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Furthermore, effects likely vary between species, location, past exposure to seismic sounds, etc. In general, among mammals, baleen whales are relatively long-lived, mature late, have relatively low reproductive rates, and require high maternal investment in young. This is particularly true for bowhead and right whales. Thus, the female's ability to provide adequate care to her offspring during a prolonged period of dependency is critical to the continued recovery and long-term viability of the population. These natural history traits support the need to avoid certain seasons or locations as addressed in this analysis (Wilson et al. 2006).

Some populations of mysticetes have continued to grow despite increasing anthropogenic activities, including seismic activities. Long-term data on gray whales show that they continue to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas.

***Toothed Whales*.—** Little systematic information is available about reactions of toothed whales to noise pulses. Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bowriding). However, some studies show avoidance (Stone and Tasker 2006). Belugas summering in the Beaufort Sea tended to avoid waters out to 10–20 km from an operating seismic vessel (Miller et al. 2005). In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance due to their documented tendency to avoid vessels in general. There is increasing evidence that some beaked whales may strand after exposure to strong sonar sounds.

In summary, short-term avoidance behaviour is not likely to cause any negative effects on the well-being of odontocetes or other marine mammals. Furthermore, lack of avoidance is not necessarily a positive result if it means that the animals remain in a heavily ensonified area where (if the ship gets close enough) there is a possibility of temporary hearing loss or temporary threshold shift TTS (described later). In general, there seems to be a tendency for most odontocetes to show some limited avoidance of seismic vessels operating large airgun systems.

***Pinnipeds*.—**Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behaviour. These studies indicate that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, limited telemetry work suggests that avoidance and other behavioural reactions may be stronger than evident to date from visual studies.

***Sea Turtles*.—**There have been far fewer studies of the effects of airgun noise (or indeed any type of noise) on sea turtles than on marine mammals and fish. Most studies have been conducted in shallow water, enclosed areas and thus are not directly applicable to the Project Area. The limited available data indicate that sea turtles will hear airgun sounds. Based on available data, it is likely that sea turtles will exhibit behavioural changes and/or avoidance within an area of unknown size near a seismic vessel. Seismic operations in or near areas where turtles concentrate are likely to have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations do occur in important areas at important times of year. The Jeanne d'Arc Basin, including the Project Area, is not a breeding area for sea turtles and it is not known or thought to be an important feeding area, and thus high concentrations of sea turtles are unlikely.

**(D) Hearing Impairment and Physical and Physiological Effects**

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. The minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable Temporary Threshold Shift (TTS). The level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. Current U.S. National Marine Fisheries Service (NMFS) policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in establishing the safety (=power-down) zones for seismic surveys in some parts of Canada. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause TTS in marine mammals. The 180 dB criterion for cetaceans is probably quite conservative (i.e., lower than necessary to avoid auditory injury), at least for delphinids (see Section 5.6.6.1 *in* LGL 2007a). NMFS is presently developing new noise exposure criteria for marine mammals that account for the now available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For preliminary information about this process, and about the structure of the new criteria in marine and terrestrial mammals see Wieting (2004) and Southall et al. (2007).

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds.

***Temporary Threshold Shift (TTS).—***The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995).

*Toothed Whales:* For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Given the available data, the received sound energy level of a single seismic pulse (with no frequency weighting) might need to be ~186 dB re 1 $\mu Pa^2 \cdot s$ (i.e., 186 dB SEL or ~221 to 226 dB pk–pk) in order to produce brief, mild TTS (Southall et al. 2007). Exposure to several strong seismic pulses that each have received levels near 175 to 180 dB SEL might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. For an odontocete closer to the surface, the maximum radius with ≥186 dB SEL or ≥198 dB rms would be smaller. However, additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. At the present state of knowledge, it is necessary to assume that the effect is directly related to total energy even though that energy is received in multiple pulses separated by gaps. However, the exposure levels necessary to cause TTS in toothed whales when the signal is a series of pulsed sounds, separated by silent periods, remains a data gap.

*Baleen Whales:* For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison 2004). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales. Based on available data, TTS is not expected to occur among baleen whales exposed to seismic sound given the strong likelihood that they would avoid an approaching airgun(s) (or vessel) before being exposed to levels high enough for there to be any possibility of TTS (NSF and L-DEO 2006a,b; Wilson et al. 2006). This assumes that mitigation consisting of ramp-up (soft start) procedure is used when commencing airgun operations. It is assumed that this approach provides the opportunity for whales near the seismic vessel to move away before they are exposed to sound levels that might be strong enough to elicit TTS (Wilson et al. 2006). However, the effectiveness of this procedure has not been empirically studied.

*Pinnipeds:* TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) of underwater sound have not been measured. There are some indications that, for corresponding durations of sound, the harbor seal may incur TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999, 2005; Ketten et al. 2001; *cf*. Au et al. 2000). However, TTS onset in the California sea lion and northern elephant seal may occur at a similar sound exposure level as in odontocetes (Kastak et al. 2005).

*Sea Turtles:* There have been few studies that have directly investigated hearing or noise-induced hearing loss in sea turtles. The apparent occurrence of TTS in loggerhead turtles exposed to many pulses from a single airgun ≤65 m away (Moein et al. 1994) suggests that sounds from an airgun array could cause at least temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs. There is also the possibility of permanent hearing damage to turtles close to the airguns. However, there are few data on temporary hearing loss and no data on permanent hearing loss in sea turtles exposed to airgun pulses.

***Permanent Threshold Shift (PTS).*—**When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges.

*Marine Mammals:* There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the likelihood that some mammals close to an airgun array might incur at least mild TTS (see Finneran et al. 2002), there has been speculation about the possibility that some individuals occurring very close to airguns might incur TTS (Richardson et al. 1995, p. 372*ff*). The specific difference between the PTS and TTS thresholds has not been measured for marine mammals exposed to any sound type. When exposure is measured in SEL units Southall et al. (2007) concludes the PTS-onset to TTS-onset offset for marine mammal exposure to impulse sound is at least 15 dB. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is at least 6 dB higher than the TTS threshold on a peak-pressure basis, and probably more than 6 dB.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. Commonly applied monitoring and mitigation measures, including visual monitoring, ramp-ups, and power-downs of the airguns when mammals are seen within the “safety radii”, are expected to minimize the already-low probability of exposure of marine mammals to sounds strong enough to potentially induce PTS.

*Sea Turtles*: The study by Moein et al. (1994) indicates that sea turtles can experience TTS when exposed to moderately strong airgun sounds. However, there are no data to indicate whether or not there are any plausible situations in which exposure to repeated airgun pulses at close range could cause permanent hearing impairment in sea turtles.

**(E) Strandings and Mortality**

Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding.

Of concern for cetaceans, particularly beaked whales, is that tissue damage and live strandings may be induced at received sound levels that are lower than had previously been anticipated and, in particular, at levels lower than those which induce auditory damage (e.g., reviewed in Dolman and Simmonds 2006). While there are no data positively linking seismic sounds with strandings or mortalities of marine mammals, there is growing evidence that mid-frequency sonar is associated with certain strandings and mortality of beaked whales based on available information. Although documented strandings and mortality of beaked whales exposed to sonar sounds may be related to a variety of factors, it is increasingly evident that gas-bubble disease, induced in supersaturated tissue by a behavioural response to acoustic exposure, is a probable pathologic mechanism (Cox et al. 2006).

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals.

#### (F) Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that could theoretically occur in marine mammals exposed to strong underwater sound might include stress, neurological effects, bubble formation, and other types of organ or tissue damage. However, studies examining such effects are limited. If any such effects do occur, they would probably be limited to unusual situations. Those could include cases when animals are exposed at close range for unusually long periods, or when the sound is strongly channeled with less-than-normal propagation loss, or when dispersal of the animals is constrained by shorelines, shallows, etc.

In summary, very little is known about the potential for seismic survey sounds to cause either auditory impairment or other non-auditory physical effects in marine mammals or sea turtles. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioural avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

### 5.6.4.2. Application of Effects Assessment

Based on the above review, marine mammals and sea turtles will likely exhibit certain behavioural reactions, including displacement from an area around a seismic and some geohazard acoustic sources. The size of this displacement area will likely vary amongst species, during different times of the year, and even amongst individuals within a given species. There is also a risk that marine mammals (and perhaps sea turtles) that are very close to a seismic array may incur temporary hearing impairment. The assessment of impacts presented here is based upon the best available information; however, there are data gaps that limit the certainty of these impact predictions. Note that we have discussed potential impacts separately for toothed whales, baleen whales, and seals given their different hearing abilities and sensitivities to sound. Potential interactions between Project activities and marine mammals and sea turtles are shown in Table 5.4.

**Table 5.4. Potential interactions between the Project and the (1) Marine Mammal and (2) Sea Turtle VECs.**

| Valued Ecosystem Components: (1) Marine Mammals (2) Sea Turtles | | | | |
|---|---|---|---|---|
| **Project Activities** | **Toothed Whales** | **Baleen Whales** | **Seals** | **Sea Turtles** |
| **Vessel Lights** | | | | |
| **Sanitary/Domestic Waste** | x | x | x | x |
| **Air Emissions** | x | x | x | x |
| **Garbage** [a] | | | | |
| **Noise** | | | | |
| Seismic Vessel | x | x | x | x |
| Seismic Array | x | x | x | x |
| Supply Vessel | x | x | x | x |
| Picket Vessel | x | x | x | x |
| Geohazard Vessel | x | x | x | x |
| Helicopter [b] | x | x | x | x |
| Echo Sounder | x | x | x | x |
| Side Scan Sonar | x | x | x | x |
| Boomer | x | x | x | x |
| Towfish | x | x | x | x |
| **Presence of Vessels** | | | | |
| Seismic Vessel | x | x | x | x |
| Supply Vessel | x | x | x | x |
| Picket Vessel | x | x | x | x |
| Geohazard Vessel | x | x | x | x |
| **Helicopters** [b] | x | x | x | x |
| **Shore Facilities** [c] | | | | |
| **Accidental Spills** | x | x | x | x |
| **Other Projects and Activities** | | | | |
| **Hibernia** | x | x | x | x |
| **Terra Nova** | x | x | x | x |
| **White Rose** | x | x | x | x |
| **Exploration** | x | x | x | x |
| **Fisheries** | x | x | x | x |
| **Marine Transportation** | x | x | x | x |

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the program is longer than 5-6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

#### 5.6.4.3. Assessment of Effects of Sound on Marine Mammal VEC

Marine mammal effects assessment is summarized in Tables 5.12 and 5.13 of LGL (2007a,b) and discussed in detail below.

***Toothed Whales***.—Despite the relatively poor hearing sensitivity of toothed whales (at least the smaller species that have been studied) at the low frequencies that contribute most of the energy in seismic pulses, sounds are sufficiently strong that they remain above the hearing threshold of odontocetes at tens of kilometers from the source.

*Hearing Impairment and Physical Effects:* Given that whales typically avoid at least the immediate area around seismic (and other strong) noise sources, whales in and near the Project Area will likely not be exposed to levels of sound from the airgun array and geohazard sources that are high enough to cause non-auditory physical effects or hearing impairment. It is highly unlikely that toothed whales will experience mortality or strand as a result of the Proponent's Project activities. The mitigation measure of ramping-up the airgun array (over a 30 min period) will allow any whales close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the airgun array will not be started if a toothed whale is sighted within the 500 m safety zone. There is little potential for toothed whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". As per Tables 5.12 *in* LGL (2007a,b), the Proponent's seismic and geohazard program is predicted to have *negligible to low* physical effects on toothed whales, over a duration of *<1 month* or *1 to 12 months* (approximately 57 days in 2008), in an area *<1* $km^2$. Therefore, auditory and physical effects on toothed whales would be *not significant* (see Tables 5.13 *in* LGL (2007a,b)).

*Disturbance Effects:* Based on the above review, there could be behavioural effects on some species of toothed whales within the Project Area. Known effects may range from changes in swimming behaviour to avoidance of the seismic vessel. Based on available literature, a 160 dB re 1 µPa (*rms*) sound level is used to assess disturbance effects, more specifically potential displacement from the area around the seismic source.

It is uncertain how many toothed whales may occur in the Study Area at various times of the year. The Study Area is not known to be an important feeding or breeding areas for toothed whales. As per Tables 5.12 *in* LGL (2007a,b), disturbance effects from Project activity noise on toothed whales would likely be *low*, over a *<1 month* or *1 to 12 months* (approximately 57 days in 2008), in an area of *11 to 100* or *101 to 1,000* $km^2$. Therefore, potential effects related to disturbance, are judged to be *not significant* for toothed whales (see Tables 5.13 *in* LGL (2007a,b)).

*Prey Species:* It is unlikely that prey species for toothed whales will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature and over a small portion of a whale's foraging range within the Project Area. Potential effects of reduced prey availability on toothed whales are predicted to be *negligible*.

***Baleen Whales*.—**Baleen whales are thought to be sensitive to low frequency sounds such as those that contribute most of the energy in seismic pulses. As with toothed whales, the 180 dB re 1 µPa (*rms*) criteria is used when estimating the area where hearing impairment may occur for all species of baleen whales (although there are no data to support this criterion for baleen whales). For all baleen whale species, it is assumed that disturbance effects (avoidance) may occur at sound levels greater than 160 dB re 1 µPa (*rms*).

*Hearing Impairment and Physical Effects:* Given that baleen whales typically avoid seismic (and other strong) noise, baleen whales will likely not be exposed to levels of sound from the airgun array high enough to cause non-auditory physical effects or hearing damage. The mitigation measure of ramping-up the airgun array will allow any whales close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, the airgun array will not be started if a baleen whale is sighted within the 500 m safety zone. Therefore, there is little potential for baleen whales being close enough to the array to experience hearing impairment. If some whales did experience TTS, the effects would likely be quite "temporary". As per Tables 5.12 *in* LGL (2007a,b), the Proponent's seismic and geohazard program is predicted to have *negligible to low* physical effects on baleen whales, over a duration of *<1 month* or *1 to 12 months* (approximately 57 days in 2008), in an area *<1* $km^2$. Therefore, auditory and physical effects on baleen whales would be *not significant* (see Tables 5.13 *in* LGL (2007a,b)).

*Disturbance Effects:* Based on the above review, there could be behavioural effects on some species of baleen whales within and near the Project Area. Reported effects range from changes in swimming behaviour to avoidance of the seismic vessel. The area where displacement would most likely occur would have a predicted scale of impact at 11 to 100 or 101 to 1,000 $km^2$. It is uncertain how many baleen whales may occur in the Study Area during the period when seismic and geohazard activity is most likely to occur (April to October). The Project Area is not known to be important feeding or breeding areas for baleen whales. As per Tables 5.12 *in* LGL (2007a,b), disturbance effects on species of baleen whales would likely be *low*, over a duration of *<1 month* or *1 to 12 months*, in an area of *11 to 100* or *101 to 1,000-*$km^2$. Therefore, effects related to disturbance, are judged to be *not significant* for baleen whales (see Tables 5.13 *in* LGL (2007a,b)).

*Prey Species:* It is unlikely that prey species for baleen whales, particularly euphausiids, will be impacted by seismic activities to a degree that inhibits their foraging success. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature and over a small portion of a whale's foraging range within the seismic area. Potential effects of reduced prey availability on baleen whales are predicted to be *negligible*.

***Seals.*****—**Seals are not expected to be abundant within the Study Area, particularly in the time period when seismic and geohazard operations will likely occur (summer, early fall).

*Hearing Impairment and Physical Effects:* Given that seals typically avoid the immediate area around a seismic array, seals, primarily harp and hooded seals, will likely not be exposed to levels of sound from the airgun array (and other noise sources) high enough to cause non-auditory physical effects or hearing impairment. The mitigative measure of ramping-up the airgun array will allow any seals close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, a ramp up will not be initiated if a seal is sighted within the 500 m safety zone. Therefore, there is little potential for seals being close enough to an array to experience hearing impairment. If some seals did experience TTS, the effects would likely be quite "temporary". As per Tables 5.12 *in* LGL (2007a,b), the Proponent's seismic and geohazard program is predicted to have *negligible to low* physical effects on seals, over a duration of *<1 month* or *1 to 12 months*, in an area *<1* $km^2$. Therefore, auditory and physical effects on seals would be *not significant* (see Tables 5.13 *in* LGL (2007a,b)).

*Disturbance Effects:* Based on the above review, there could be behavioural effects on seals within and near the Project Area. Known effects include changes in diving behaviour and localized avoidance of the seismic vessel. It is uncertain how many seals may occur in the Project Area during the period when seismic (and geohazard) activities are most likely to occur (summer, early fall). Most harp and hooded seals would be in arctic waters at this time of year. There are no available criteria for assessing the sound level most likely to elicit avoidance reactions in seals. It is noteworthy that seals have been sighted inside the radius thought to cause TTS (190 dB) in other areas. A 160 dB re 1 µPa (*rms*) sound level has been conservatively used to assess disturbance effects, more specifically potential displacement from the area around the seismic source. Therefore, the area where displacement may occur would have a scale of potential effect at *11 to 100 or 101 to 1,000* $km^2$. This estimated area around the seismic and geohazard vessels would be ensonified for a duration of *<1 month* or *1 to 12 months*. As per Tables 5.12 *in* LGL (2007a,b), the Proponent's proposed seismic and geohazard program is predicted to have *low* disturbance impacts on seals. Therefore, impacts related to disturbance, are judged to be *not significant* for seals (see Tables 5.13 *in* LGL (2007a,b)).

*Prey Species:* It is unlikely that prey species for seals will be impacted by seismic and geohazard activities to a degree that inhibits the foraging success of seals. If prey species exhibit avoidance of the seismic ship it will likely be transitory in nature and over a small portion of a seal's foraging range within the seismic area. Potential impacts of reduced prey availability are predicted to be *negligible*.

#### 5.6.4.4. Assessment of Effects of Sound on Sea Turtle VEC

*Hearing Impairment and Physical Effects:* Based on available data, it is likely that sea turtles might exhibit temporary hearing loss if the turtles are close to the airguns (Moulton and Richardson 2000). However, there is not enough information on sea turtle temporary hearing loss and no data on permanent hearing loss to reach any definitive conclusions about received sound levels that trigger TTS. Also, it is likely that sea turtles will exhibit behavioural reactions or avoidance within an area of unknown size around a seismic vessel. The mitigation measure of ramping-up the airgun array over a 30-min period should permit sea turtles close to the airguns to move away before the sounds become sufficiently strong to have any potential for hearing impairment. Also, ramp up will not commence if a sea turtle is sighted within the 500 m safety zone and the airgun array will be shutdown if a leatherback sea turtle is sighted within the safety zone.

It is unlikely that many sea turtles will occur in the Study Area. Therefore, there is likely little potential for sea turtles to be close enough to an array to experience hearing impairment. If some turtles did experience TTS, the effects would likely be quite "temporary". As per Tables 5.14 *in* LGL (2007a,b), the Proponent's seismic program is predicted to have *negligible* to *low* physical effects on sea turtles, over a duration of *<1 month* or *1 to 12 months*, in an area *<1* $km^2$. Therefore, auditory and physical effects on sea turtles would be *not significant* (see Tables 5.15 *in* LGL (2007a,b)).

*Disturbance Effects:* It is possible that sea turtles will occur in the Project Area, although the cooler water temperatures likely preclude some species from occurring there. If sea turtles did occur near the seismic (and geohazard) vessel, it is likely that sea turtles would exhibit avoidance within a localized area. Based on observations of green and loggerhead sea turtles, behavioural avoidance may occur at received sound levels of 166 dB re µPa *rms*. The area where displacement would most likely occur would have a scale of impact at 11 to 100 $km^2$. As per Tables 5.14 *in* LGL (2007a,b), the Proponent's seismic program is predicted to have *low* disturbance effects on sea turtles, over a duration of *<1 month* or *1 to 12 months*, in an area 11 to 100 $km^2$. Therefore, effects related to disturbance, are judged to be *not significant* for sea turtles (see Tables 5.15 *in* LGL (2007a,b)).

*Prey Species:* Leatherback sea turtles are expected to feed primarily on jellyfish. It is unknown how jellyfish react to seismic and geohazard noise sources, if these invertebrates react at all. Leatherbacks are also known to feed on sea urchins, tunicates, squid, crustaceans, fish, blue-green algae, and floating seaweed. It is possible that some prey species may exhibit localized avoidance of the seismic array but this is unlikely to impact sea turtles, which are also likely to avoid the seismic vessel and are known to search for aggregations of prey. Potential effects of reduced prey availability are predicted to be *negligible*.

#### 5.6.4.5. Effects of Helicopter Overflights

A crew change may occur via helicopter if the seismic program is longer than five to six weeks, depending on the contractor. The 2008 seismic program is anticipated to be 57 days in duration so a helicopter crew change may be necessary. Helicopters will maintain a regulated flight altitude above sea level unless it is necessary to fly lower for safety reasons. Helicopters will not be used during geohazard surveys.

***Marine Mammals***.— Available information (see LGL 2007a: Section 5.6.4.2) indicates that single or occasional aircraft overflights will cause no more than brief behavioural responses in baleen whales, toothed whales and seals. As per Table 5.12 *in* LGL (2007a) disturbance impacts are assessed as *negligible to low* impact, over a duration of *<1 month*, in an area 1 to 10 $km^2$ to 11 to 100 $km^2$. Therefore, effects related to disturbance, are judged to be *not significant* for marine mammals (see Table 5.13 *in* LGL (2007a)).

***Sea Turtles.—***To the best of our knowledge, there are no systematic data on sea turtle reactions to helicopter overflights. Given the hearing sensitivities of sea turtles, they can likely hear helicopters, at least when the helicopters are at lower altitudes and the turtles are in relatively shallow waters. It is unknown how sea turtles would respond, but single or occasional overflights by helicopters would likely only elicit a brief behavioural response. As per Table 5.14 *in* LGL (2007a) disturbance impacts are assessed as *negligible*, over a duration of *<1 month*, in an area <1 $km^2$ to 1 to 10 $km^2$. Therefore, impacts related to disturbance, are judged to be *not significant* for sea turtles (see Table 5.15 *in* LGL (2007a)).

### 5.6.4.6. Effects of Presence of Vessels

During the proposed seismic program, there will be one seismic ship at all times and a picket vessel on site during most of the program (57 days in 2008). It is possible that two seismic vessels will be on site during a portion of the 2008 seismic program (but the airguns arrays from both vessels will not operate at the same time). It is anticipated that a supply ship will also be on site occasionally. Geohazard surveys will involve one vessel in the Project Area for short periods of time. There is some risk for collision between marine mammals and vessels, but given the slow surveying speed (4.5 to 5 knots; 8.3 to 9.3 km/h) of the seismic vessel (and its picket vessel) plus the geohazard vessel, this risk is minimal (Laist et al. 2001; Vanderlaan and Taggart 2007). Marine mammal responses to ships are presumably responses to noise, but visual or other cues are also likely involved. Marine mammal response (or lack thereof) to ships and boats (pre-1995 studies) are summarized in Richardson et al. (1995), p. 252-274. More recent studies are described *in* LGL (2007a). Marine mammal response to the presence of vessels is variable. Seals often show considerable tolerance to vessels. Toothed whales sometimes show no avoidance reactions and occasionally approach them; however, some species are displaced by vessels. Baleen whales often interrupt their normal behaviour and swim rapidly away from vessels have strong or rapidly changing noise, especially when a vessel heads directly towards a whale. Stationary vessels or slow-moving, “non-aggressive” vessels typically elicit very little response from baleen whales. To the best of our knowledge, there are no systematic data on sea turtle reactions to ships and boats but it is thought that response would be minimal relative to responses to seismic sound. Effects of the presence of vessels on marine mammals or sea turtles, including the risk of collisions, are predicted to be *negligible to low,* over a duration of *<1 month*, in an area 1 to 10 $km^2$. Therefore, effects related to the presence of vessels, are judged to be *not significant* for marine mammals and sea turtles (Tables 5.12 to 5.15 *in* LGL (2007a,b)).

### 5.6.4.7. Effects of Accidental Spills

All petroleum hydrocarbon handling and reporting procedures on board will be consistent with SHC’s policy, and handling and reporting procedures. If fluid-filled streamers are used in surveys in 2008-2016, it is possible that small amounts of Isopar could be leaked from the streamers; a fuel spill may occur from the seismic ship and/or its support vessels. Any spills would likely be small and quickly dispersed by wind, wave, and ship’s propellor action. The effects of hydrocarbon spills on marine mammals and sea turtles were overviewed in Husky (2000) in Section 5.9.1.3 and 5.9.2.3, respectively and are not repeated here. Based on studies, whales and seals do not exhibit large behavioural or physiological responses to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil (St. Aubin 1990; Williams et al. 1994). Sea turtles are thought to be more susceptible to the effects of oiling than marine mammals but effects are believed to be sublethal (Husky 2000). Effects of an accidental spill on marine mammals or sea turtles would be *low,* over a duration of *<1 month,* in an area *<1* $km^2$ *to 1 to 10* $km^2$ and are judged to be *not significant* (Tables 5.12 to 5.15 *in* LGL (2007a,b)).

#### 5.6.4.8. Effects of Other Project Activities

There is potential for marine mammals and sea turtles to interact with domestic and sanitary wastes, and air emissions from the seismic ship and its support vessels. Any effects from these interactions are predicted to be *negligible* (Tables 5.12 to 5.15 *in* LGL (2007a,b)).

### 5.6.5. Effects of the Project on Species at Risk

A biological overview of all species considered at risk under *SARA* and/or by COSEWIC that are likely or may occur in the Study Area was provided in Section 4.6. No critical habitat has been defined for the Study Area. As discussed in previous sections and presented in Table 4.16, *SARA*/COSEWIC species of relevance to the Study Area include:

- Wolffishes
- Ivory Gull
- Blue whale, fin whale, right whale
- Leatherback sea turtle

Species not currently listed (see Table 4.16) on Schedule 1 of *SARA* but listed on Schedule 2 or 3 or being considered for addition to Schedule 1 (as per their current COSEWIC listing of *Endangered*, *Threatened* or *Special Concern)*, are not included in the SAR VEC here but have been assessed in the appropriate VEC in sections 5.6.1 (Fish) and 5.6.4 (Marine Mammals and Sea Turtles) of this EA. If species not currently listed on Schedule 1 of *SARA* do become listed on this legal list during the life of the Project (2008-2016), the Proponent will re-assess these species considering the prohibitions of *SARA* and any recovery strategies or action plans that may be in place. Possible mitigation measures as they relate to Species at Risk will be reviewed with DFO and Environment Canada. Interactions between Project activities and the Species At Risk VEC are shown in Table 5.5.

As per the effects assessment contained in Section 5.6.1 and Tables 5.17 and 5.18 *in* LGL (2007a,b), physical effects of the Project on the various life stages of wolffish will range from *negligible* to *low* over a duration of <1 month to 1 to 12 months, within an area of <1 $km^2$. Behavioural effects may extend out to a larger area but are still predicted to be *not significant*. The mitigation measure of ramping up the airgun array (over a 30 min period) is expected to minimize the potential for effects on wolffish. The water depths in the Study Area are primarily shallower than the known preferred water depths that wolffish typically inhabit.

As per the effects assessment in Section 5.6.3 and Tables 5.17 and 5.18 *in* LGL (2007a,b), the predicted effect of the Project on Ivory Gulls is *not significant* as this species foraging behaviour would not likely expose it to underwater sound and this species is unlikely to occur in the Study Area, particularly during the summer when seismic surveys are most likely to be conducted. Furthermore, Ivory Gulls are not known to be sensitive to stranding on vessels. The mitigation measure of monitoring the seismic and geohazard vessel and releasing stranded birds (in the unlikely event that an Ivory Gull will strand on the vessel) and ramping up the airgun array will minimize the potential for impacts on this species.

**Table 5.5. Potential interactions between the Project and Species at Risk VEC.**

| | Valued Ecosystem Components: Species at Risk | | | |
|---|---|---|---|---|
| **Project Activities** | **Wolffish** | **Ivory Gull** | **Blue, Fin, Right Whales** | **LeatherbackTurtle** |
| **Vessel Lights** | x | x | | |
| **Sanitary/Domestic Waste** | x | x | x | x |
| **Air Emissions** | x | x | x | x |
| **Garbage** [a] | | | | |
| **Noise** | | | | |
| Seismic Vessel | x | x | x | x |
| Seismic Array | x | x | x | x |
| Supply Vessel | x | x | x | x |
| Picket Vessel | x | x | x | x |
| Geohazard Vessel | | | | |
| Helicopter [b] | x | x | x | x |
| Echo Sounder | x | x | x | x |
| Side Scan Sonar | x | x | x | x |
| Boomer | x | x | x | x |
| Towfish | x | x | x | x |
| **Presence of Vessels** | | | | |
| Seismic Vessel | x | x | x | x |
| Supply Vessel | x | x | x | x |
| Picket Vessel | x | x | x | x |
| Geohazard Vessel | x | x | x | x |
| **Helicopters** [b] | | x | x | x |
| **Shore Facilities** [c] | | | | |
| **Accidental Spills** | x | x | x | x |
| **Other Projects and Activities** | | | | |
| **Hibernia** | x | x | x | x |
| **Terra Nova** | x | x | x | x |
| **White Rose** | x | x | x | x |
| **Exploration** | x | x | x | x |
| **Fisheries** | x | x | x | x |
| **Marine Transportation** | x | x | x | x |

[a] Not applicable as garbage will be brought ashore.
[b] A crew change may occur via helicopter if the seismic program is longer than 5-6 weeks.
[c] There will not be any new onshore facilities. Existing infrastructure will be used.

Based on available information, blue whales and sea turtles are not expected to occur regularly in the Study Area. It is extremely unlikely that a North Atlantic right whale will occur in the Study Area although there was one reported sighting north of the Project Area (but within the Study Area) in 2003. No confirmed sightings of blue whales have been made in the Study Area and there have been two reported sightings of leatherback sea turtles (see Section 4.6). Fin whales, listed as *Special Concern*, are expected to occur regularly in the Study Area, particularly during summer months. There are no available recovery strategies or action plans in place for marine mammals in Atlantic Canada. A recovery strategy for leatherback sea turtles is available (ALTRT 2006). Mitigation and monitoring designed to minimize potential effects of airgun array noise on *SARA*-listed marine mammals and sea turtles will include:

- ramp-up of the airgun array over a 30-min period;
- monitoring by a MMO (with assistance from a FLO) during daylight hours that the airgun array is active;
- shutdown of the airgun array when an *Endangered* or *Threatened* marine mammal or sea turtle is sighted within the 500 m safety zone; and
- delay of ramp up if any marine mammal or sea turtle is sighted within the 500 m safety zone.

With these mitigation measures in place and as per the effects assessment in Section 5.6.4 and Tables 5.17 and 5.18 *in* LGL (2007a,b), the Project is predicted to have *no significant effect* (physical or behavioural) on blue whales, right whales, fin whales, or leatherback sea turtles.

In summary, potential effects of the proposed seismic and geohazard program are not expected to contravene the prohibitions of *SARA* (Sections 32(1), 33, 58(1)).

## 5.7. Cumulative Effects

This EA has assessed cumulative effects within the Project and thus the residual effects described in preceding sections include any potential cumulative effects from the SHC seismic and geohazard survey activities in the Project Area.

It is also necessary to assess cumulative effects from other activities outside the Project that are planned for the area. These activities may include:

- Commercial fishing [Note that there are no recreational or aboriginal fisheries in Jeanne d'Arc Basin.]
- Vessel traffic (e.g., transportation, defense, yachts)
- Hunting (e.g., seabirds, seals)
- Offshore oil and gas industry

Commercial fishing has been discussed and assessed in detail in Section 5.6.2. Commercial fishing activities, by their nature, cause mortality and disturbance to fish populations and may cause incidental mortalities or disturbance to seabirds, marine mammals, and sea turtles. It is predicted that the seismic surveys will not cause any mortality to these VECs (with the potential exception of small numbers of petrels) and thus, there will be no or negligible cumulative effect from mortalities. There is some potential for cumulative effect from disturbance (e.g., fishing vessel noise) but there will be directed attempts by both industries to mitigate effects and to avoid each other's active areas and times. Any gear damage attributable to the Project will be compensated and thus any effects will be *not significant*.

In the summer, the main North Atlantic shipping lanes between Europe and North America lie to the north of the Grand Banks into the Strait of Belle Isle. In the winter, that traffic shifts to the main shipping lanes along the southern Grand Banks into the Gulf of St. Lawrence. Thus, potential for cumulative effects with other shipping is predicted to be *negligible* to *low*.

The vast majority of hunting of seabirds (mostly murres) in Newfoundland and Labrador waters occurs near shore from small boats and thus, there is little or no potential for cumulative effects on this VEC. Similarly, most, if not all, seal hunting would occur inshore of the Project Area.

Offshore oil and gas industry projects listed on the C-NLOPB public registry (www.cnlopb.nl.ca as viewed 3 January 2008) include:

- Exploration, appraisal, and delineation drilling program in Jeanne d'Arc Basin area, 2008-2016 (StatoilHydro)
- 3-D seismic program in Jeanne d'Arc Basin, 2007-2010 (Petro-Canada)
- White Rose new drill centre construction and operations program, 2008-2015 (Husky Energy)
- Exploration and delineation drilling program in Jeanne d'Arc Basin, 2008-2017 (Husky Energy)
- Exploration drilling program in Laurentian Sub-basin, 2009-2012 (ConocoPhillips)
- 2-D seismic program on Labrador Shelf, 2007-2009 (GSI)

In addition, Husky is proposing to conduct a seismic program in the Jeanne d'Arc Basin in 2008 after SHC's program is completed (D. Taylor, pers. comm.). Also, there are three existing offshore production developments (Hibernia, Terra Nova, and White Rose) on the northeastern part of the Grand Banks. While the existing developments are all included within the boundaries of the proposed Project Area, they are within the range of activities that have occurred on the Grand Banks over the last 10 years. Any cumulative effects (i.e., disturbance), if they occur, will be additive (not multiplicative or synergistic) and predicted to be *not significant*.

There is potential for cumulative effects with the Petro-Canada and Husky Jeanne d'Arc Basin 3-D Seismic Program, the White Rose new drill centre, and exploration drilling programs in the Jeanne d'Arc Basin, which have the potential to overlap in time and, potentially in space, if animals in both areas receive sound from more than one program at a time. Nonetheless, the SHC seismic program will have to maintain geographic and perhaps temporal separation from other programs time so as not to compromise the quality of their seismic data. As discussed in LGL (2007a) and reviewed in this EA, significant negative effects on key sensitive VECs such as marine mammals appear unlikely beyond a localized area from the sound source (it is this zone upon which the mitigation measures are based). In addition, all programs will use mitigation measures such as ramp-ups, delayed start ups, and shutdowns of the airgun arrays. Thus, it seems likely that while some animals may receive sound from one or more oil and gas programs, the current scientific prediction is it that *no significant residual effects* will result.

## 5.8. Mitigations and Follow-up

Project mitigations have been detailed in the various individual sections of the preceding EA and are summarized in the text provided below and in Table 5.6. SHC and contractors will adhere to mitigations detailed in Appendix 2 of the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NOPB, April 2004).

**Table 5.6. Summary of mitigations measures.**

| Potential Effects | Primary Mitigations |
|---|---|
| Interference with fishing vessels | • upfront planning to avoid high concentrations of fishing vessels<br>• SPOC<br>• advisories and communications<br>• FLO<br>• picket vessel<br>• planned transit route to and between Survey Areas |
| Fishing gear damage | • upfront planning to avoid high concentrations of fishing gear<br>• SPOC<br>• advisories and communications<br>• FLO<br>• picket vessel<br>• compensation program<br>• planned transit route to and between Survey Areas |
| Interference with shipping | • SPOC<br>• advisories and communications<br>• FLO<br>• picket vessel |
| Interference with DFO/FFAW research vessels | • Communications and scheduling |
| Temporary or permanent hearing damage/disturbance to marine animals | • delay start-up if marine mammals or sea turtles are within 500 m<br>• ramp-up of airguns<br>• shutdown of airgun arrays for *Endangered* or *Threatened* marine mammals and sea turtles<br>• use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations |
| Temporary or permanent hearing damage/ disturbance to Species at Risk or other key habitats | • delay start-up if marine mammals or sea turtles are within 500 m<br>• ramp-up of airguns<br>• shutdown of airgun arrays for *Endangered* or *Threatened* marine mammals and sea turtles<br>• use of qualified MMO(s) to monitor for marine mammals and sea turtles during daylight seismic operations. [No critical habitat has been identified in or near the Study Area.] |
| Injury (mortality) to stranded seabirds | • daily monitoring of vessel<br>• handling and release protocols<br>• minimize lighting if safe |
| Seabird oiling | • adherence to MARPOL<br>• spill contingency plans<br>• use of solid streamer when feasible |

Fishers who may be operating in the area will be notified of the timing and location of planned activities by means of a CCG "Notice to Mariners" and a "Notice to Fishers" on the CBC Radio Fisheries Broadcast. In addition, if necessary, individual fixed gear fishers will be contacted to arrange mutual avoidance. Any contacts with fishing gear, with any identifiable markings, will be reported to the C-NLOPB within 24 h of the contact. Any floating debris resulting from contact with fish gear will be retrieved and retained if it is safe to do so in the opinion of the vessel's master. SHC will advise the C-NLOPB prior to compensating and settling all valid lost gear/income claims promptly and satisfactorily.

Specific mitigations to minimize potential conflicts and any negative effects with other vessels; these include:

- Excellent communications (VHF, HF, Satellite, etc.)
- Utilization of fisheries liaison officers (FLOs) for advice and coordination in regard to avoiding fishing vessels and fishing gear
- Environmental Observers (MMO(s) and FLO) onboard
- Picket vessel to alert other vessels of towed gear in water
- Posting of advisories with the Canadian Coast Guard and the CBC Fisheries Broadcast
- Compensation program in the event any project vessels damage fishing gear
- Single Point of Contact (SPOC)

SHC will also coordinate with Fisheries and Oceans, St. John's, and the FFAW to avoid any potential conflicts with survey vessels that may be operating in the area.

Mitigation measures designed to reduce the likelihood of impacts on marine mammals and sea turtles will include ramp-ups, no initiation of airgun array if a marine mammal or sea turtle is sighted 30 min prior to ramp-up within 500-m safety zone of the energy source, shutdown of the energy source if an *Endangered* (or *Threatened*) whale or sea turtle is observed within the 500-m safety zone. Prior to the onset of the seismic survey, the airgun array will be gradually ramped up. One airgun will be activated first and then the volume of the array will be increased gradually over a recommended 30 min period. An observer aboard the seismic ship will watch for marine mammals and sea turtles 30 min prior to ramp-up. If a marine mammal or sea turtle is sighted within 500 m of the array, then ramp-up will not commence until the animal has moved beyond the 500-m zone or 20 min have elapsed since the last sighting. The observers will watch for marine mammals and sea turtles when the airgun array is active (during daylight periods) and note the location and behaviour of these animals. The seismic array will be shutdown if an *Endangered* (or *Threatened*) marine mammal or sea turtle is sighted within the safety zone. The planned monitoring and mitigation measures, including ramp-ups, visual monitoring, and shut-down of the airguns when *Endangered* or *Threatened* marine mammals or turtles are seen within the "safety radii", will minimize the already-low probability of exposure of marine animals to sounds strong enough to induce hearing impairment. Any dead or distressed marine mammals or sea turtles will be recorded and reported to the C-NLOPB.

Any seabirds (most likely Leach's Storm-Petrel) that become stranded on the vessel will be released using the mitigation methods consistent with *The Leach's Storm-Petrel: General Information and Handling Instructions* by U. Williams (Petro-Canada) and J. Chardine (CWS) (n.d.). It is understood by SHC that a CWS *Migratory Bird Handling Permit* will likely be required. In the unlikely event that marine mammals, turtles or birds are injured or killed by Project equipment or accidental spills of fuel or streamer flotation fluid, a report will immediately be filed with C-NLOPB and the need for follow-up monitoring assessed.

Marine mammal and seabird observations will be made during ramp-ups and during data acquisition periods, and at other times on an opportunistic basis. Protocols will be consistent with those developed by LGL in conjunction with DFO and Environment Canada. A monitoring program will be designed in consultation with DFO and CWS as per the C-NLOPB *Guidelines*. Data will be collected by a qualified environmental observer(s) (MMO) and FLO. A monitoring report will be submitted to the C-NLOPB within one year after completion of the surveys.

## 5.9. Residual Effects of the Project

A summary of the Project's residual effects on the environment, in other words those effects that remain after mitigations have been instituted, are shown in Table 5.7. SHC's seismic program is predicted to have no significant effects on VECs.

## Table 5.7. Significance of potential residual environmental effects of the proposed seismic and geohazard program on VECs in the Study Area.

| Valued Ecosystem Component: Fish, Fisheries, Birds, Sea Turtles, Marine Mammals, Species at Risk | | | | |
|---|---|---|---|---|
| **Project Activity** | **Significance Rating** | **Level of Confidence** | **Likelihood (Significant Effect Only)** | |
| | **Significance of Predicted Residual Environmental Effects** | | **Probability of Occurrence** | **Scientific Certainty** |
| **Vessel Presence/Lights** | NS | 3 | - | - |
| **Sanitary/Domestic Wastes** | NS | 3 | - | - |
| **Air Emissions** | NS | 3 | - | - |
| **Noise** | | | | |
| Array – physical effects | NS | 3 | - | - |
| Array – behavioural effects | NS | 3 | - | - |
| Geohazard sources | NS | 3 | - | - |
| Seismic Vessel | NS | 3 | - | - |
| Supply Vessel | NS | 3 | - | - |
| Picket Vessel | NS | 3 | - | - |
| Geohazard Vessel | NS | 3 | - | - |
| Helicopter | NS | 3 | - | - |
| **Presence of Vessels** | | | | |
| Seismic Vessel and Streamer | NS | 3 | - | - |
| Geohazard Vessel | NS | 3 | - | - |
| Supply Vessel | NS | 3 | - | - |
| Picket Vessel | NS | 3 | - | - |
| **Helicopters** | NS | 3 | - | - |
| **Accidental Spills** | NS | 2-3 | - | - |

Key:

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

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

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

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

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

# 6.0 Literature Cited


Abgrall, P., A.L. Lang, and V.D. Moulton. *In prep*. a. Marine mammal and seabird monitoring of Husky Energy's 3-D seismic program in the Jeanne d'Arc Basin, 2006 and 2005-2006 combined. LGL Rep. SA920. Rep. by LGL Limited, St. John's, NL, for Husky Energy Inc., Calgary, AB. 98 p. + appendices.

Abgrall, P., B.D. Mactavish and V.D. Moulton. *In prep*. b. Marine mammal and seabird monitoring of Orphan Basin controlled source electromagnetic survey program, 2006 – 2007. LGL Rep. SA904/939. Rep. by LGL Limited, St. John's, NL, for ExxonMobil Canada Ltd., St. John's, NL. 95 p. + appendices.

ALTRT. 2006. Recovery strategy for leatherback turtle (Dermochelys coriacea) in Atlantic Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa vi +45 p.

Au, W. W. L., A.N. Popper and R.R. Fay. 2000. Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 458 p.

Baillie, S.M., G.J. Robertson, F.K. Wiese and U.P. Williams. 2005. Seabird data collected by the Grand Banks offshore hydrocarbon industry 1999-2002: results, limitations and suggestions for improvement. Canadian Wildlife Service Technical Report Series No. 434. Atlantic Region. v + 47 p.

Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Paper SC/58/E35 presented to the IWC Scientific Committee, IWC Annual Meeting, 1-13 June, St. Kitts and Nevis.

Baird, R.W. 2003. Update COSEWIC status report on the humpback whale Megaptera novaeangliae in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +25 p.

Baird, R.W., P J. Stacey and H. Whitehead. 1993. Status of the Striped Dolphin, Stenella coeruleoalba, in Canada. Canadian Field-Naturalist 107:455-465. 1993.

Barnes, J.L. and L.H. Davey. 1999. A practical approach to integrated cumulative environmental effects assessment to meet the requirements of the Canadian Environmental Assessment Act.

Bartol, S., J.A. Musick and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (Caretta caretta). Copeia 1999(3):836-840.

Benoit, D. and W.D. Bowen. 1990. Seasonal and geographic variation in the diet of Grey Seals (Halichoerus grypus) in Eastern Canada. p. 215-226. In: W.D. Bowen (ed.), Population biology of sealworm (Pseudoterranova decipiens) in relation to its intermediate and seal hosts. Canadian Bulletin on Fisheries and Aquatic Sciences. 222 p.

Best, P.B. 1993. Increase rates in severely depleted stocks of baleen whales. ICES Journal of Marine Science. 50: 169-186.

Brown, R.G.B, W.R.P. Bourne and T.R. Wahl. 1978. Diving by shearwaters. Condor, 80:123-125.

Brown, R.G.B. 1986. Revised altas of eastern Canadian seabirds. 1. Shipboard surveys. Canadian Wildlife Service, Ottawa. 111 p.

Brown, R.G.B., S.P. Barker, D.E. Gaskin and M.R. Sandeman. 1981. The foods of great and sooty shearwaters Puffinus gravis and P. griseus in eastern Canadian waters. Ibis, 123 (1):19-30.

Buchanan, R.A., J. Christian, V. Moulton and B. Mactavish. 2004. Orphan 3-D Seismic Program, 2004-2006 environmental assessment. LGL Report No. SA799. Prepared for Chevron Canada Resources and ExxonMobil. 209 p. + appendices.

Buchanan, R.A., R. Fechhelm, J. Christian, V.D. Moulton, B. Mactavish, R. Pitt, and S. Canning. 2006. Orphan Basin controlled source electromagnetic survey program environmental assessment. LGL Rep. SA899. Rep. by LGL Limited and Canning & Pitt Associates Inc., St. John's, NL, for ExxonMobil Canada Ltd., St. John's, NL. 128 p. + appendix.

Budelmann, B.U. 1992. Hearing in crustacea. p. 131-139. In: (eds.) D.B. Webster, R.R. Fay and A.N. Popper. The Evolutionary Biology of Hearing.

Burke, C.M., G.K. Davoren, W.A. Montevecchi and F. K. Wiese. 2005. Seasonal and spatial trends of marine birds along offshore support vessel transects and at oil platforms on the Grand Banks. Pages 587-614 in S.L. Armsworthy, P.J. Cranford, and K. Lee (eds.), Offshore oil and gas environmental effects monitoring: approaches and technologies. Battelle Press, Columbus, Ohio.

Cairns, D.K., W.A. Montevecchi and W. Threlfall. 1989. Researcher's guide to Newfoundland seabird colonies. Second edition. Memorial University of Newfoundland Occasional Papers in Biology, No. 14. 43 p.

Canadian Ice Service. 1960-2007. Composite Ice Charts. Ottawa, ON.

Canadian Ice Service. 1971-2000. Sea Ice Climatic Atlas- East Coast of Canada. Ottawa, ON.

Carscadden, J.E., K.T. Frank, and W.C. Leggett. 2001. Ecosystem changes and the effects on capelin (Mallotus villosus), a major forage species. Can. J. Fish. Aquat. Sci. 58: 73-85.

Casas, J.M. and D.G. Troncoso. 2007. Results from bottom trawl survey on Flemish Cap of June-July 2006. NAFO SCR Doc. 07/10.

CEA Agency. 1994. A reference guide for the Canadian Environmental Assessment Act, addressing cumulative environmental effects. Prepared by the Federal Environmental Assessment Review Office, November 1994.

CEA Agency. 2000. Preparing project descriptions under the Canadian Environmental Assessment Act. Canadian Environmental Assessment Agency Operational Policy Statement OPS –EPO/5-2000. 6 p.

Chardine, J.W. 2000. Census of Northern Gannet colonies in the Atlantic Region in 1999. Canadian Wildlife Service Technical Report Series No. 361. Atlantic Region.

Chardine, J.W., G.J. Robertson, P.C. Ryan and B. Turner. 2003. Abundance and distribution of Common Murres breeding at Funk Island, Newfoundland 1972 and 2000. Canadian Wildlife Service Technical Report Series No. 404. Atlantic Region.

Clark, C.W. and W.T. Ellison. 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: Evidence from models and empirical measurements. Pages 564-589 in J.A. Thomas, C.F. Moss and M. Vater, eds. Echolocation in Bats and Dolphins. University of Chicago Press, Chicago, IL.

CNOPB. 2004. Canada Newfoundland Offshore Petroleum Board. Geophysical, Geological, Environmental and Geotechnical Program Guidelines, April 2004.

Colbourne, E. 2000. Interannual variations in the stratification and transport of the Labrador Current on the Newfoundland Shelf. International Council for the Explorations of the Sea. CM 2000/L:2.

Colbourne, E. 2002. Physical oceanographic conditions on the Newfoundland and Labrador shelves during 2001. CSAS Res.Doc. 2002/023.

Colbourne, E., C. Fitzpatrick, D. Senciall, W. Bailey and P. Stead. 2007. Oceanographic observations from trawl-mounted CTD's on multi-species surveys in the Newfoundland and Labrador Region. A ZMP Bulletin PMZA, No.6, p.43-47.

Colbourne, E.B. 2004. Decadal changes in the ocean climate in Newfoundland and Labrador waters from the 1950s to the 1990s. J. Northw. Atl. Fish. Sci. 34: 41–59.

Colbourne, E.B., and D.R. Senciall. 1996. Temperature, salinity and sigma. T. along the standard Flemish Cap transect. Can. Tech. Rep. Hydrog. Ocean Sci. 172: 222 p.

Coombs, S. and J.C. Montgomery. 1999. The enigmatic lateral line system. p. 319-362. In: (eds.) R.R. Fay and A.N. Popper. Comparative Hearing: Fish and Amphibians. Springer Handbook of Auditory Research. Springer-Verlag New York Inc.

COSEWIC. 2002. COSEWIC assessment and update status report on the northern bottlenose whale Hyperoodon ampullatus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 22 p.

COSEWIC. 2003a. COSEWIC assessment and status report on the sei whale *Balaenoptera borealis* in Canada. Ottawa. vii+ 27 p.

COSEWIC. 2003b. COSEWIC assessment and update status report on the North Atlantic right whale *Eubalaena glacialis* in Canada. Ottawa. vii + 28 p.

COSEWIC. 2006. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (Northwest Atlantic population) in Canada. Ottawa. vii+ 32 p.

COSEWIC. 2007. Canadian Species at Risk. Committee on the Status of Endangered Wildlife in Canada, January 2007. 84 p.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'amico, G. D'spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houserp, R. Hullar, P.D. Jepson, D. Ketten, C.D. Macleod, P. Miller,S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Meads, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7:177-187.

Cramp, S. and K.E.L. Simmons (eds.). 1983. The Birds of the Western Palearctic, Volume III: Wader to Gulls. Oxford Univ. Press, Oxford. 913 p.

Croasdale, K.R. and Associates. 2000. Study of Iceberg Scour and Risk on the Grand Banks. PERD/CHC Report 31-26, Panel on Energy Research and Development). Calgary, AB.

DeTracey, B.M., C.L. Tang and P.C. Smith. 1996. Low-frequency currents at the northern shelf edge of the Grand Banks. J. Geophs Res., V.101, C6, p.14,223-14,236.

DFO. 2004. Allowable harm assessment for cusk in Atlantic Canada. Maritimes Region Stock Status Report 2004/044.

DFO. 2005. Stock assessment of Subdivision 3Ps pollock. Newfoundland and Labrador Region Can. Sci. Adv. Sec. Sci. Adv. Rep. 2005/049.

DFO (Department of Fisheries and Oceans). 2007a. Proceedings of the Newfoundland and Labrador regional advisory process for snow crab. Can. Sci. Advis. Sec. Proc. Ser. 2007/004.

DFO (Department of Fisheries and Oceans). 2007b. Assessment of Newfoundland and Labrador snow crab. Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/008.

DFO. 2006a. Assessment of Newfoundland and Labrador snow crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/006.

DFO. 2006b. Stock assessment of northern (2J3KL) cod in 2006. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/015.

DFO. 1987 – 2006. Newfoundland and Labrador Region Catch and Effort Database (digital version). Georeferenced harvest data, 1987 to 2006.

DFO. 2007. Assessment of Newfoundland and Labrador Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/008.

DFO. Newfoundland and Labrador Region Catch and Effort Database (digital version). Georeferenced harvest data, to 2006.

Dobrocky Seatech. 1985. Field Data Report: Sea Ice Documentation in the Vicinity of the Hibernia Drilling Area. Report prepared for Mobil Oil Canada Ltd., Calgary, AB.

Dolman, S.J. and M.P. Simmonds. 2006. An updated note on the vulnerability of cetaceans to acoustic disturbance. Paper SC/58/E22 presented to the IWC Scientific Committee, IWC Annual Meeting, 1-13 June, St. Kitts and Nevis.

Edinger, E., K. Baker, R. Devillers, and V. Wareham. 2007. Coldwater corals off Newfoundland and Labrador: Distribution and fisheries impacts. Report for the World Wildlife Fund. 31 pp. + App.

Edinger, E.N., V.E. Wareham, and R.L. Haedrich. In press. Patterns of groundfish diversity and abundance in relation to deep-sea coral distributions in Newfoundland and Labrador waters. 22 p.

Ernst, C.H., R.W. Barbour and J.E. Lovich (eds.). 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, DC. 578 p.

Fay, R.R. and A.N. Popper. 1999. Hearing in fishes and amphibians: An introduction. p. 1-14. In: (eds.) R.R. Fay and A.N. Popper. Comparative Hearing: Fish and Amphibians. Springer Handbook of Auditory Research. Springer-Verlag New York Inc.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. J. Acoust. Soc. Am. 111(6):2929-2940.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (Tursiops truncatus) exposed to mid-frequency tones. Journal of the Acoustical Society of America 118:2696-2705.

FRCC (Fisheries Resource Conservation Council (FRCC). 2005. Strategic conservation framework for Atlantic snow crab. Report to the Minister of Fisheries and Oceans. FRCC.05.R1.

FRCC (Fisheries Resource Conservation Council) 2005. Strategic Conservation Framework for Atlantic Snow Crab, FRCC.05.R1, June 2005.

Gaskin, D.E. 1992a. Status of the Common Dolphin, Delphinus delphis, in Canada. Canadian Field-Naturalist 106: 55-63.

Gaskin, D.E. 1992b. Status of the Harbour Porpoise, Phocoena phocoena, in Canada. Canadian Field-Naturalist 106: 36-54.

Gaston, A.J. and I.L. Jones. 1998. The Auks. Bird Families of the World. Oxford Univ. Press, NY. 349 p.

Hai, D.J., J. Lien, D. Nelson and K. Curren. 1996. A contribution to the biology of the White-beaked Dolphin, Lagenorhynchus albirostris, in waters off Newfoundland. Canadian Field-Naturalist 110: 278-287.

Hammill, M.O. and G.B. Stenson. 2000. Estimated prey consumption by harp seals (Phoca groenlandica), grey seals (Halichoerus grypus), harbour seals (Phoca vitulina) and hooded seals (Cystophora cristata), and in Atlantic Canada. Journal of Northwest Fisheries Science 26: 1-23.

Hammill, M.O., M.S. Ryg and B. Mohn. 1995. Consumption of cod by the Northwest Atlantic Grey Seal in Eastern Canada. p. 337-349. In: A.S. Blix, L. Walloe and O. Ulltang (eds.), Whales, seals, fish and man. Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic. Developments in Marine Biology 4.

Han, G. and Z. Wang. 2005. Monthly-mean circulation in the Flemish Cap region: A modeling study. In: Malcolm L. Spaulding (Ed.) Estuarine and Coastal Modeling. Proceedings of the Ninth International Conference on Estuarine and Coastal Modeling held in Charleston, South Carolina, Oct 31 - Nov 2, 2005.

Husky Energy. 2000. Development Application – White Rose Development: Environmental Impact Statement, prepared on behalf of the White Rose Proponents.

Husky. 2000. White Rose oilfield comprehensive study. Report for Husky Oil Operations Ltd. St. John's, NF. 1011 p.

Husky. 2001. White Rose oilfield comprehensive study supplemental report responses to comments from Canada-Newfoundland Offshore Petroleum Board, Department of Fisheries and Oceans, Environment Canada, Natural Resources Canada and Canadian Environmental Assessment Agency. Submitted by Husky Oil Operations Limited (Operator). 265 p. + appendices.

ICES. 2005. Report of the ICES/NAFO Working Group on harp and hooded seals (WGHARP), 30 August-3 September 2005, St. John’s, Newfoundland, Canada. ICES CM 2005/ACFM: 06. 54 p.

ICES. 2006. Report of the ICES/NAFO Working Group on harp and hooded seals (WGHARP), 12-16 June 2006, ICES Headquarters. ICES CM 2006/ACFM: 32. 28 p.

James, M.C., C.A. Ottensmeyer and R.A. Myers. 2005. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. Ecology Letters 8:195-201.

Kastak, D. and R.J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise and ecology. J. Acoust. Soc. Am. 103(4): 2216-2228.

Kastak, D. and R.J. Schusterman. 1999. In-air and underwater hearing sensitivity of a northern elephant seal (*Mirounga angustirostris*). Can. J. Zool. 77: 1751-1758.

Kastak, D., B.L. Southall, R.J. Schusterman, and C. Reichmuth Kastak. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. Journal of the Acoustical Society of America 118:3154-3163.

Kastelein, R.A., P. Mosterd, B. van Santen, M. Hagedoorn and D. de Haan. 2002. Underwater audiogram of a Pacific walrus (*Odobenus rosmarus divergens*) measured with narrow-band frequency-moldualted signals. J. Acoust. Soc. Am. 112(5):2173-2182.

Katona, S.K. and J.A. Beard. 1990. Population size, migration and feeding aggregation of the Humpback Whale (*Megaptera novaeangliae*) in the Western North Atlantic Ocean. Report of the International Whaling Commission (Special Issue 12): 295-305.

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. p. 391-407. In: R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.), Sensory systems of aquatic mammals. De Spil Publ., Woerden, Netherlands. 588 p.

Ketten, D.R. 2000. Cetacean ears. p. 43-108. In: W.W.L. Au, A.N. Popper and R.R. Fay (eds.), Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 485 p.

Ketten, D.R., J. Lien and S. Todd. 1993. Blast injury in humpback whale ears: evidence and implications. J.Acoust. Soc. Am. 94(3, Pt. 2):1849-1850.

Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. J. Acoust. Soc. Am. 110(5, Pt. 2):2721.

Kulka, D.C., C. Hood, and J. Huntington. 2007. Recovery Strategy for northern wolffish (*Anarchichas denticulatus*) and spotted wolffish (*Anarchichas minor*), and Management Plan for Atlantic wolffish (*Anarchichas lupus*) in Canada [Proposed]. Fisheries and oceans Canada: Newfoundland and Labrador Region. St. John’s, NL. x + 103 p.

Kulka, D.W., C.M. Miri, M.R. Simpson, and K.A. Sosebee. 2004. Thorny skate (*Amblyraja radiata* Donovan, 1808) on the Grand Banks of Newfoundland. NAFO SCR Doc. 04/35.

Lacroix, D.L., R.B. Lanctot, J.A. Reed and T.L. McDonald. 2003. Effect of underwater surveys on molting male Long-tailed Ducks in the Beaufort Sea, Alaska. Can. J. Zool. 81:1862-1875.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science 17(1):35-75.

Lang, A.L, V.D. Moulton and R.A. Buchanan. 2006. Marine mammal and seabird monitoring of Husky Energy’s 3-D seismic program in the Jeanne d’Arc Basin, 2005. LGL Rep. by LGL Limited, St. John’s, NL for Husky Energy Inc., Calagary, AB. 63 p. + appendices.

Lang, A.L. 2007. Seabird abundance near Terra Nova offshore oil development during late spring 2006. LGL Rep. No. SA919. Report prepared by LGL Limited, St. John’s, NL for Petro-Canada, St. John’s, NL. 11p.

Lang, A.L. and V.D. Moulton. *In prep.* Marine mammal and seabird monitoring of Petro-Canada’s 3-D seismic program in the Jeanne d’Arc Basin, 2007. LGL Rep. SA938. Rep. by LGL Limited, St. John’s, NL, for Petro-Canada, St. John’s, NL. __ p. + appendices.

Lauzier, J.R.N. and D.G. Wright. 1993. Annual velocity variations in the Labrador Current. J. Phys. Oceanogr. 23:.659-678.

Lawson, J.W. and G.B. Stenson. 1995. Historic variation in the diet of Harp Seals (*Phoca groenlandica*) in the Northwest Atlantic. p. 261-269. In: A.S. Blix, L. Walloe and O. Ulltang (eds.), Whales, seals, fish and man. Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic. Developments in Marine Biology 4.

Lawson, J.W., J.T. Anderson, E.L. Dalley and G.B. Stenson. 1998. Selective foraging by Harp Seals *Phoca groenlandica* in nearshore and offshore waters of Newfoundland, 1993 and 1994. Marine Ecology Progress Series 163: 1-10.

LGL. 2002. Husky Jeanne d’Arc Basin exploration drilling program project description and environmental assessment. LGL Rep. SA723. Rep. by LGL Limited, St. John’s, NL, Oceans Limited, St. John’s, NL, PAL Environmental Services, St. John’s, NL, and SL Ross Environmental Research Limited, Ottawa, ON, for Husky Oil Operations Limited, St. John’s, NL. 179 p.

LGL. 2005a. Husky delineation/exploration drilling program for Jeanne d'Arc Basin area environmental assessment. LGL Rep. SA845. Rep. by LGL Limited, Canning and Pitt Associates, Inc., and PAL Environmental Services, St. John's, NL, for Husky Oil Operations Limited, St. John's, NL. 340 p. + App.

LGL. 2005b. Northern Jeanne d'Arc Basin seismic program environmental assessment. LGL Rep. SA836. Rep. by LGL Limited, St. John's, NL for Husky Energy Inc., Calgary, AB. 241 p.

LGL. 2005c. Wellsite geohazard survey, 2005 environmental assessment Terra Nova Development. Rep. by LGL Limited, St. John's, NL for Petro-Canada, St. John's, NL.

LGL. 2006a. Husky White Rose Development Project: New Drill Centre Construction & Operations Program Environmental Assessment. LGL Rep. SA883. Rep. by LGL Limited, St. John's, NL, for Husky Energy Inc., Calgary, AB. 299 p. + App.

LGL. 2006b. Husky Delineation/Exploration Drilling Program for Jeanne d'Arc Basin Area Environmental Assessment Update. LGL Rep. SA886. Rep. by LGL Limited, St. John's, NL, Oceans Limited, St. John's, NL, Canning & Pitt Associates, Inc., St. John's, NL, and PAL Environmental Services, St. John's, NL, for Services, St. John's, NL, for Husky Oil Operations Limited, St. John's, NL. 67 p. + App.

LGL. 2007a. Environmental Assessment of Petro-Canada's Jeanne d'Arc Basin 3-D Seismic Program. LGL Rep. SA882. Rep. by LGL Limited, St. John's, Oceans Limited, St. John's, NL, Canning & Pitt Associates, Inc., St. John's, NL, and PAL Environmental Services, St. John's, NL, for Services, St. John's, NL, for Petro-Canada, St. John's, NL. 264 p. + App.

LGL. 2007b. Addendum to the Environmental Assessment of Petro-Canada's Jeanne d'Arc Basin 3-D Seismic Program. LGL Rep. SA940-2. Rep. by LGL Limited, St. John's for Petro-Canada, St. John's, NL. 42 p. + App.

LGL. 2007c. Husky White Rose Development Project: New Drill Centre Construction & Operations Program Environmental Assessment Addendum. LGL Rep. SA883a. Rep. By LGL Limited, St. John's, NL for Husky Energy Inc., Calgary, AB. 126 p. + App.

Lien, J., G.B. Stenson and P.W. Jones. 1988. Killer Whales (*Orcinus orca*) in waters off Newfoundland and Labrador, 1978-1986. Rit Fiskideildar. 11: 194-201.

Lock, A.R., R.G.B. Brown and S.H. Gerriets. 1994. Gazetteer of marine birds in Atlantic Canada. An atlas of seabird vulnerability to oil pollution. Canadian Wildlife Service, Environmental Conservation Branch, Environment Canada, Atlantic Region. 137 p.

Lydersen, C. and K.M. Kovacs. 1999. Behaviour and energetics of ice-breeding, North Atlantic phocid seals during the lactation period. Marine Ecology Progress Series. 187: 265-281.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218377.

Mann, D.A., P.A. Cott, B.W. Hanna, and A.N. Popper. 2007a. Hearing in eight species of northern Canadian freshwater fishes. J. Fish Biol. 70: 109-120.

Mann, D.A., B.M. Casper, K.S. Boyle, and T.C. Tricas. 2007b. On the attraction of larval fishes to reef sounds. Mar. Ecol. Prog. Ser. 338: 307-310.

Mann, D.A., R.A. Varela, J.D. Goldstein, S.D. McCulloch, G.D. Bossart, J.J. Finneran, D. Houser, and M.L.H. Cook. 2005. Gervais' beaked whale auditory evoked potential hearing measurements. Pages 178-179 in Abstracts of the 16th Biennial Conference on the Biology of Marine Mammals, 12-16 December 2005, San Diego, CA.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001-2002. p. 511-542. In: S.L. Armsworthy, P.J. Cranford and K. Lee (eds.), Offshore oil and gas environmental effects monitoring/Approaches and technologies. Battelle Press, Columbus, OH. 631 p.

Mobil 1985. Hibernia Development Project, Environmental Impact Statement. Volume IIIa: Biophysical Assessment. Mobil Oil Canada, Ltd. (Operator), Gulf Canada Resources Inc., Petro-Canada Inc., Chevron Canada Resources Ltd., and Columbia Gas Development of Canada Ltd. 258 p.

Moein, S.E., J.A. Musick, J.A. Keinath, D.E. Barnard, M. Lenhardt and R. George. 1994. Evaluation of seismic sources for repelling sea turtles from hopper dredges. Rep. from Virginia Inst. Mar. Sci., [Gloucester Point], VA, for U.S. Army Corps of Engineers. 33 p.

Mohn, R. and W.D. Bowen. 1996. Grey seal predation on the Eastern Scotian Shelf: modelling the impact on Atlantic Cod. Can. J. Fish. Aquat. Sci.. 53: 2722-2738.

Montevecchi, W. A. 2006. Influences of artificial light on marine birds. P. 94-114. In Rich, C. and T. Longcore [eds.]. 2006. Ecological consequences of artificial night Lighting. Island Press, Washington, DC. 458 pp.

Montevecchi, W.A., F.K. Wiese, G. Davoren, A.W. Diamond, F. Huettmann and J. Linke. 1999. Seabird attraction to offshore platforms and seabird monitoring from support vessels and other ships: Literature review and monitoring designs. Prepared for Canadian Association of Petroleum Producers by Memorial University of Newfoundland, St. John's, Newfoundland and University of New Brunswick, Saint John. New Brunswick. 35 p.

Moore, S.E. and Angliss, R.P. 2006. Overview of planned seismic surveys offshore northern Alaska, July-October 2006. Paper SC/58/E6 presented to IWC Scientific Committee, IWC Annual Meeting, 1-13 June, St Kitts and Nevis.

Mortensen, P.B., L. Buhl-Mortensen, S.E. Gass, D.C. Gordon Jr., E.L.R. Kenchington, C. Bourbonnais, and K.G. MacIsaac. 2006. Deep-water corals in Atlantic Canada: A summary of ESRF-funded research (2001-2003), March 2006, Environmental Studies Research Funds Report No. 143. Calgary. 83 p.

Moulton, V.D. and W.J. Richardson. 2000. A review of sea turtles and seismic noise. LGL Report TA2525. Report by LGL Limited, King City, ON for British Petroleum, Aberdeen, Scotland. 12 p.

Moulton, V.D., B.D. Mactavish and R.A. Buchanan. 2005. Marine mammal and seabirds monitoring of Chevron Canada Resources' 3-D seismic program on the Orphan Basin, 2004. LGL Rep. SA817. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Resources, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, and Imperial Oil Resources Ventures Ltd., Calgary, AB. 90 p. + appendices.

Moulton, V.D., B.D. Mactavish and R.A. Buchanan. 2006a. Marine mammal and seabirds monitoring of Chevron Canada Limiteds' 3-D seismic program on the Orphan Basin, 2005. LGL Rep. SA843. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, Shell Canada Limited, Calgary, AB, and Imperial Oil Resources Ventures Ltd., Calgary, AB 111 p. + appendices.

Moulton, V.D., B.D. Mactavish and R.A. Buchanan. 2006b. Marine mammal and seabird monitoring of ConocoPhillips' 3-D seismic program in the Laurentian Sub-basin, 2005. LGL Rep. SA849. Rep. by LGL Limited, St. John's, NL, for ConocoPhillips Canada Resources Corporation, Calgary, AB. 97 p + appendices.

Moulton, V.D., J. Christian, R.A. Pitt, B.D. Mactavish and R.A. Buchanan. 2006c. Jeanne d'Arc Basin 3D Seismic Program, Environmental Assessment Update, 2006-2010. LGL Rep. SA884. Rep. by LGL Limited and Canning & Pitt Associates Inc., St. John's, NL, for Husky Energy Inc., Calgary, AB. 56 p. + appendices.

Murua, H. and F. Gónzalez. 2007. A review of roughhead grenadier (*Macrourus berglax*) biology and population structure on Flemish Cap (NAFO Division 3M) 1991-2006 based upon EU Flemish Cap bottom survey data. NAFO SCR Doc. 07/25.

Navoc (Naval Ocean Command). 1986. Sea Ice Climate Atlas, Vol. II, Arctic East. Document NAVAIR 50-1C-541. 147p.

Nelson, D. and J. Lien. 1996. The status of the Long-finned Pilot Whale, *Globicephala melas,* in Canada. Canadian Field-Naturalist. 110: 511-524.

Nettleship, D.N. and T.R. Birkhead. 1985. The Atlantic alcidae. Academic Press, London. 574 p.

NMFS. 2000. Taking and importing marine mammals; Taking marine mammals incidental to Naval activities/Proposed rule. Fed. Regist. 65(239 12 December): 77546-77553.

NSF and L-DEO. 2006a. Draft Environmental Assessment of the Batholiths marine seismic survey, inland waterways and near-offshore, central coast of British Columbia. Prepared by LGL Ltd., environmental research associates, Sidney, BC. LGL Report TA2822-32. 28 March.

NSF and L-DEO. 2006b. Request by Lamont-Doherty Earth Observatory for an Incidental Harrassment Authorization to Allow the Incidental Take of Marine Mammals during Seismic Testing in the Northern Gulf of Mexico, Fall 2006. LGL Report TA4295-1. 31 May.

Palka, D. 1996. Evidence of ship avoidance from harbour porpoises during line transect sighting surveys in the Gulf of Maine. Abstract SC/47/SM27. Rep. Int. Whal. Commn 46:675.

Palka, D., A. Read and C. Potter. 1997. Summary of knowledge of White-sided Dolphins (*Lagenorhynchus acutus*) from US and Canadian Atlantic Waters. Report of the International Whaling Commission 47: 729-734.

Panel on Energy Research & Development (PERD). A Compilation of Iceberg Shape and Geometry Data for the Grand Banks Region. PERD/CHC Report 20-43. Compiled by: (CANATEC Consultants 1999), Available at: http://www.chc.nrc.ca/Cold Regions Technology/Cold Regions.html

Panel on Energy Research & Development (PERD). Grand Banks Iceberg Update, 2005. PERD/CHC Report 20-40. Complied by: (Fleet Technology), Available at: http://www.chc.nrc.ca/Cold Regions Technology/Cold Regions.html

Parsons. J.L. and J.E. Brownlie. 1981. Distribution and abundance of marine mammals of the Grand Banks, 1980-1981. Grand Banks Wildlife Study, Final Report. Chapter 4. Report by MacLaren Plansearch for Mobil Oil Canada Ltd.

Payne, J.F., C.A. Andrews, L.L. Fancey, A.L. Cook, and J.R. Christian. 2007. Pilot study on the effects of seismic air gun noise on lobster (*Homarus americanus*). Can. Tech. Rep. Fish. Aquat. Sci. 2712: v + 46.

Petrie, B., S. Akenhead, J. Lazier, and J. Loder. 1988. The cold intermediate layer on the Labrador and Northeast Newfoundland Shelves, 1978–1986. NAFO Sci. Counc. Stud. 12:.57–69.

Petro-Canada. 1996a. Development Application Terra Nova Development Environmental Impact Statement. Prepared by Petro-Canada on behalf of Terra Nova Proponents: Petro-Canada, Mobil Oil Canada Properties, Husky Oil Operations Limited, Murphy Oil Company Ltd., and Mosbacher Operating Limited.

Petro-Canada. 1996b. Development Application Terra Nova Development Supplement A to the Application. Prepared by Petro-Canada on behalf of Terra Nova Proponents: Petro-Canada, Mobil Oil Canada Properties, Husky Oil Operations Limited, Murphy Oil Company Ltd., and Mosbacher Operating Limited. 82 p.

Piatt, J.F., D.A. Methven, A.E. Burger, R.L. McLagan, V. Mercer and E. Creelman. 1989. Baleen whales and their prey in a coastal environment. Canadian Journal of Zoology 67: 1523-1530.

Pitman, R.L. 2002. Mesoplodont whales (*Mesoplodon spp.*). p. 84-87. *In:* W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego, California.

Plotkin, P.T. (ed.). 1995. National Marine Fisheries Service and U.S. Fish and Wildlife Service status reviews for sea turtles listed under the Endangered Species Act of 1973. National Marine Fisheries Service, Silver Spring, Maryland. 139 p.

Popper, A.N., A. Kane, D.L. Miller, M.E. Smith, J. Song, P. Stein, and L.E. Wysocki. 2007. The effects of high-intensity, low-frequency active sonar on rainbow trout. J. Acoust. Soc. Am. 122(1): 623-635.

Popper, A.N., M. Salmon and K.W. Horch. 2001. Acoustic detection and communication by decapod crustaceans. J. Comp. Physiol. A 187: 83-89.

Reeves, R. and H. Whitehead. 1997. Status of the Sperm Whale, *Physeter macrocephalus*, in Canada. Canadian Field-Naturalist 111: 293-307.

Reeves, R.R., B.S. Stewart, P.J. Clapham and J.A. Powell (eds). 2002. National Audubon Society Guide to Marine Mammals of the World. Alfred A. Knopf, New York. 527 p.

Reeves, R.R., E. Mitchell and H. Whitehead. 1993. Status of the Northern Bottlenose Whale, *Hyperoodon ampullatus*. Canadian Field-Naturalist 107: 491-509.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 576 p.

Richardson, W.J., G.W. Miller and C.R. Greene Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. J. Acoust. Soc. Am. 106(4, Pt. 2):2281.

Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. Arctic 40(2):93-104.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. Proc. Nat. Acad. Sci. U.S. 64:884-890.

Robertson, G.J. 2002. Current status of the Manx Shearwater (*Puffinus puffinus*) colony on Middle Lawn Island, Newfoundland. Northeastern Naturalist. 9:317-324.

Robertson, G.J. and R.D. Elliot. 2002. Changes in seabird populations breeding on Small Island, Wadham Islands, Newfoundland. Canadian Wildlife Service Technical Report Series No.381. Atlantic Region.

Robertson, G.J., S.I. Wilhelm and P.A. Taylor. 2004. Population size and trends of seabirds breeding on Gull and Great Islands, Witless Bay Islands Ecological Reserve, Newfoundland, up to 2003. Canadian Wildlife Service Technical Report Series No. 418. Atlantic Region.

Robertson, G.J., D. Fifield, M. Massaro and J.W. Chardine. 2001. Changes in nesting habitat use of large gulls breeding in Witless Bay, Newfoundland. Can Zool.79:2159-2167.

Robertson, G. J., J. Russell and D. Fifield. 2002. Breeding population estimates for three Leach's Storm-petrel colonies in southeastern Newfoundland, 2001. Canadian Wildlife Service Technical Report Series No. 380. Atlantic Region.

Rodway, M.S., H.M. Regehr and J.W. Chardine. 2003. Status of the largest breeding concentration of Atlantic Puffins, *Fraterulca arctica*, in North America. Can. Field Nat. 117:70-75

Rose, G.A. 1993. Cod spawning on a migration highway in the northwest Atlantic. Nature 366: 458-461.

Sand, O. 1981. The lateral line and sound reception. p. 459-478. *In:* W.N. Tavolga, A.N. Popper, and R.R. Fay (eds.) Hearing and Sound Communication in Fishes. Springer-Verlag New York Inc.

Sarà, G., J.M. Dean, D. D'Amato, G. Buscaino, A. Oliveri, S. Genovese, S. Ferro, G. Buffa, M. Lo Martire, and S. Mazzola. 2007. Effect of boat noise on the behaviour of bluefin tuna *Thunnus thynnus* in the Mediterranean Sea. Mar. Ecol. Prog. Ser. 331: 243-253.

Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219. 731 p.

Seaconsult Ltd. 1988. Physical Environmental Data for Production Systems at Terra Nova. Report prepared for Petro-Canada Inc. Calgary, AB.

Sears, R. and J. Calambokidis. 2002. Update COSEWIC status report on the Blue Whale *Balaenoptera musculus* in Canada, in COSEWIC assessment and update status report on the Blue Whale *Balaenoptera musculus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 32 p.

Sergeant, D.E. 1991. Harp Seals, man and ice. Canadian Special Publications of Fisheries and Aquatic Sciences 114: 153 p.

Sodal, A. 1999. Measured underwater acoustic wave propagation from a seismic source. Proceedings of the Airgun Environmental Workshop, 6 July, London, UK.

Sousa-Lima, R.S., M.E. Morete, R.C. Fortes, A.C. Freitas and M.H. Engel. 2002. Impact of boats on the vocal behavior of humpback whales off Brazil. J. Acoust. Soc. Am. Vol. 112(5, Pt. 2):2430.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Acoustical Society of America (submitted).

St. Aubin, D.J. 1990. Physiologic and Toxic Effects on Polar Bears. p. 235-239. *In:* J.R. Geraci and D.J. St. Aubin (eds.), Sea mammals and oil: confronting the risks. Academic Press, San Diego. 282 p.

St. Pierre, J.-F. and Y. de Lafontaine. 1995. Fecundity and reproduction characteristics of beaked redfish (*Sebastes fasciatus* and *S. mentella*) in the Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. No. 2059.

Steele, D. H., and W. A. Montevecchi. 1994. Leach's Storm-Petrels prey on lower mesopelagic (Mysidacea and Decapoda) crustaceans: possible implications for crustacean and avian distributions. Crustaceana 66:212–218.

Steimle, F.W., W.W. Morse, P.L. Berrien, D.L. Johnson, and C.A. Zetlin. 1999. Essential fish habitat source document: Ocean pout, *Macrozoarces americanus*, life history and habitat characteristics. NOAA Tech. Memo NMFS-NE-129.

Stenhouse, I. J and W.A. Montevecchi. 1999. Increasing and expanding populations of breeding northern fulmar in Atlantic Canada. Waterbirds: The International Journal of Waterbird Biology, Vol. 22, No. 3. (1999), pp. 382-391.

Stenhouse, I. J., G. J Robertson and W. A. Montevecchi. 2000. Herring Gull *Larus argentatus* predation on Leach's Storm-Petrels *Oceanodroma leucorhoa* breeding on Great Island, Newfoundland. Atlantic Seabirds 2: 35-44.

Stenson, G.B. and B. Sjare. 1997. Seasonal distribution of Harp Seals, *Phoca groenlandica*, in the Northwest Atlantic. ICES. C.M. 1997/10 p.

Stenson, G.B. and D.J. Kavanagh. 1994. Distribution of Harp and Hooded Seals in offshore waters of Newfoundland. Northwest Atlantic Fisheries Organization, Scientific Council Studies 21: 121-142.

Stevick, P.T., J. Allen, M. Berube, P.J. Clapham, S.K. Katona, F. Larsen, J. Lien, D.K. Mattila, P.J. Palsboll, J. Robbins, J. Sigurjonsson, T.D. Smith, N. Oien and P.S. Hammond. 2003. Segregation of migration by feeding ground origin in North Atlantic humpback whales (*Megaptera novaeangliae*). Journal of Zoology, London 259: 231-237.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. J. Cetacean Res. Manage. 8(3):255-263.

U. S. Geological Survey, Conservation Division. 1979. OCS Platform Verification Program. Reston, Virginia.

U.S. Navy. 2005. Draft Supplemental Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. Chief of Naval Operations, Washington, DC. November.

Vanderlaan, A.S.M. and C.T. Taggart. 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. Mar. Mamm. Sci. 23(1): 144-156.

Wallace, S.D. and J.W. Lawson. 1997. A review of stomach contents of Harp Seals (*Phoca groenlandica*) from the Northwest Atlantic: an update. International Marine Mammal Association 97-01.

Wang, J.Y., D.E. Gaskin and B.N. White. 1996. Mitochondrial DNA analysis of Harbour Porpoise, *Phocoena phocoena*, subpopulations in North American waters. Can. J. Fish. Aquat. Sci. 53: 1632-1645.

Wardle, C.S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson and D. Mackie. 2001. Effects of seismic air guns on marine fish. Cont. Shelf Res. 21(8-10): 1005-1027.

Wareham, V.E. and E.N. Edinger. In press. Distribution of deep-sea corals in the Newfoundland and Labrador region, Northwest Atlantic Ocean. 25 p.

Waring, G.T., E. Josephson, C.P. Fairfield, K. Maze-Foley, editors. 2007. U.S. Atlantic and Gulf of Mexico Marine Mammals Stock Assessments -- 2006. NOAA Tech. Memo NMFS NE 201. 378 p.

Whitehead, H. 1982. Populations of Humpback Whales in the Northwest Atlantic. Report of the International Whaling Commission 32: 345-353.

Wiese, F. K. and W.A. Montevecchi. 1999. Marine bird and mammal surveys on the Newfoundland Grand Bank from offshore supply vessels. Contract Report Prepared for Husky Oil. 23 p. + App.

Wieting, D. 2004. Background on development and intended use of criteria. P. 20 *in* S. Orenstein, L. Langstaff, L. Manning, and R. Maund, eds. Advisory Committee on Acoustic Impacts on Marine Mammals, Final Meeting Summary. Second Meeting, April 28-30, 2004, Arlington, VA. Sponsored by the Marine Mammal Commission. 10 August.

Williams, T.M., G.A. Antonelis and J. Balke. 1994. Health Evaluation, Rehabilitation, and Release of Oiled Harbor Seal Pups. p. 227-242. *In:* T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego. 395 p.

Williams, U. and J. Chardine. n.d. The Leach's Storm-Petrel: General information and handling instructions.

Wilson, J., L. Rotterman, and D. Epperson. 2006. Minerals Management Service overview of seismic survey mitigation and monitoring on the U.S. Outer Continental Shelf. Paper SC/58/E8 presented to IWC Scientific Committee, IWC Annual Meeting, 1-13 June, St. Kitts and Nevis.

Wimmer, T. and H. Whitehead. 2004. Movements and distribution of northern bottlenose whales, *Hyperoodon ampullatus*, on the Scotian Slope and in adjacent waters. Can. J. Zool. 82(11): 1782-1794.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R. Nielson, V.L. Vladimirov and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. Environmental Assessment and Monitoring 34 (1-3):44-73.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton, M.W. Newcomer, R. Nielson and P.W. Wainwright. 2007b. Feeding of western gray whales during a seismic survey near Sakhalin Island, Russia. Environmental Assessment and Monitoring 34 (1-3):93-106.

## Personal Communications:

| | |
|---|---|
| Brodie, B. | DFO |
| Chapman, B. | Groundfish Enterprise Allocation Council |
| Coady, J. | FFAWU |
| Janes, G. | Petro-Canada |
| Lang, T. | LGL Ltd. |
| Lawson, J. | DFO |
| Rudkin, P. | PAL |

## Websites accessed:

Fishbase website, http://www.fishbase.org).

Underwater World, Fisheries and Oceans Canada website, http://www.dfo-mpo.gc.ca/zone/underwater_sous-marin/SandLance).

http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Crab_2007.htm

http://www.nfl.dfo-mpo.gc.ca/publications/reports_rapports/Shrimp_2007.htm.

Important Bird Areas website, www.ibacanada.com).

*SARA* website (http://www.sararegistry.gc.ca/default_e.cfm)

COSEWIC website (http://www.cosepac.gc.ca/index.htm)

C-NLOPB website, www.cnlopb.nl.ca

## Databases accessed:

Canadian Ice Service. 1971-2000. Sea Ice Climatic Atlas- East Coast of Canada. Ottawa, ON.

Canadian Ice Service. 1960-2007. Composite Ice Charts. Ottawa, ON.

DFO. 1987 – 2006. Newfoundland and Labrador Region Catch and Effort Database (digital version). Georeferenced harvest data, 1987 to 2006.

NAFO. Northwest Atlantic Fisheries Organization Annual Fisheries Statistics Databases, Statlant 21A for 1985-2004 (accessed November 2007).

Panel on Energy Research & Development (PERD). Grand Banks Iceberg Update, 2005. PERD/CHC Report 20-40. Complied by: (Fleet Technology), Available at: http://www.chc.nrc.ca/Cold Regions Technology/Cold Regions.html

Panel on Energy Research & Development (PERD). A Compilation of Iceberg Shape and Geometry Data for the Grand Banks Region. PERD/CHC Report 20-43. Compiled by: (CANATEC Consultants 1999), Available at: http://www.chc.nrc.ca/Cold Regions Technology/Cold Regions.html

Provincial Aerospace Limited (PAL). Iceberg Sightings Database, 1985-2007. Available at: http://idns.provair.com/database.asp

# Appendix A: Oceans Report

# Physical Environmental Conditions on the Grand Banks in Support of StatoilHydro's Seismic Program

**Submitted to:**
**LGL Limited**
**Kenmount Road**
**St. John's, NL**

**Submitted by:**
**Oceans Ltd.**
**85 LeMarchant Road**
**St. John's, NL  A1E 2H1**

**November 2007**

# Table of Contents

# 1.0 Introduction

The physical environment of the northeastern Grand Banks is being described in this report to support the Hydro Seismic Survey Program for the Jeanne d'Arc Basin Area, 2008-2016. The study concentrated on EL 1100 and EL 1101 (Figure 1.1) for the planned seismic 3D survey in 2008. The climate data including wave climate presented in the report is representative of the whole project area as outlined in Figure 1.2. The diagrams in Figures 1.1 and 1.2 were extracted fro the Project Description provided by StatoilHydro. Other oceanographic information such as current is more site specific and dependent on local bathymetry. The information presented in the report is representative of currents on the shallow section of the Grand Banks where the water depths is less than 100 m. The majority of the available current meter data has been collected at the Terra Nova site and representative of the expected currents at EL 1101.

Since the speed of sound in seawater is dependent on the temperature and salinity of the water, historical temperature and salinity data for the region encompassing EL 1100, EL 1101 and SDL 1040 are presented in the report for planning purposes. Additional data is also presented for the project area.

The annual wind and wave climate statistics were compiled for the climatology description in the report. Since the wind and wave conditions are extremely variable, depending on season, monthly statistics are presented in the appendices in order to provide climatology information for whichever month the seismic activities are to be carried out. Additional climate information for the project area is also presented.

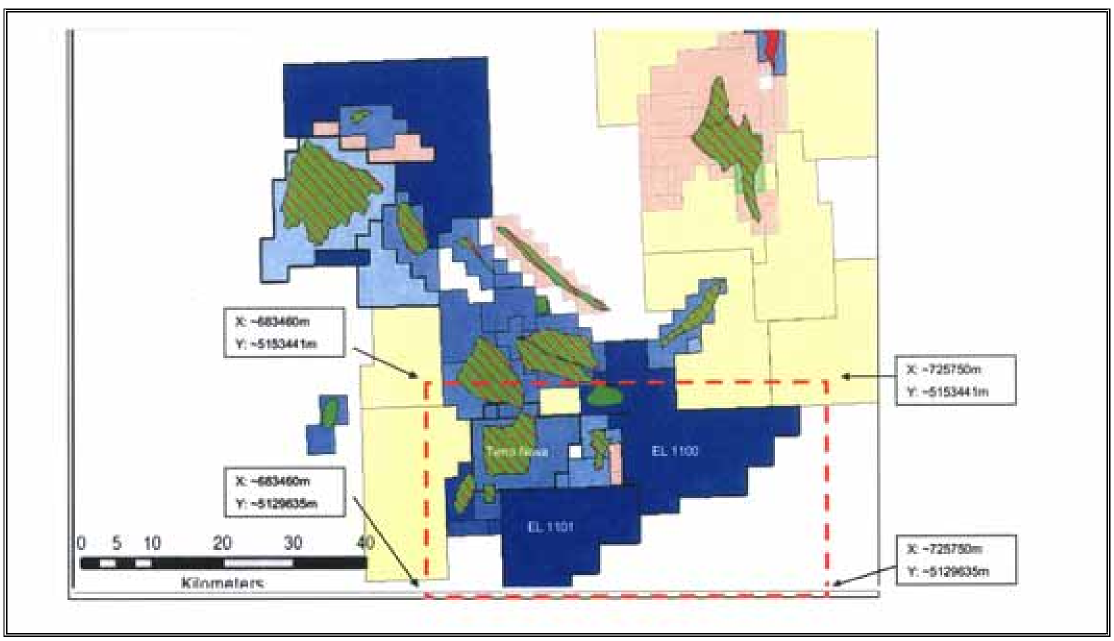


**Figure 1.1 Location of EL 1100 and EL 1101**

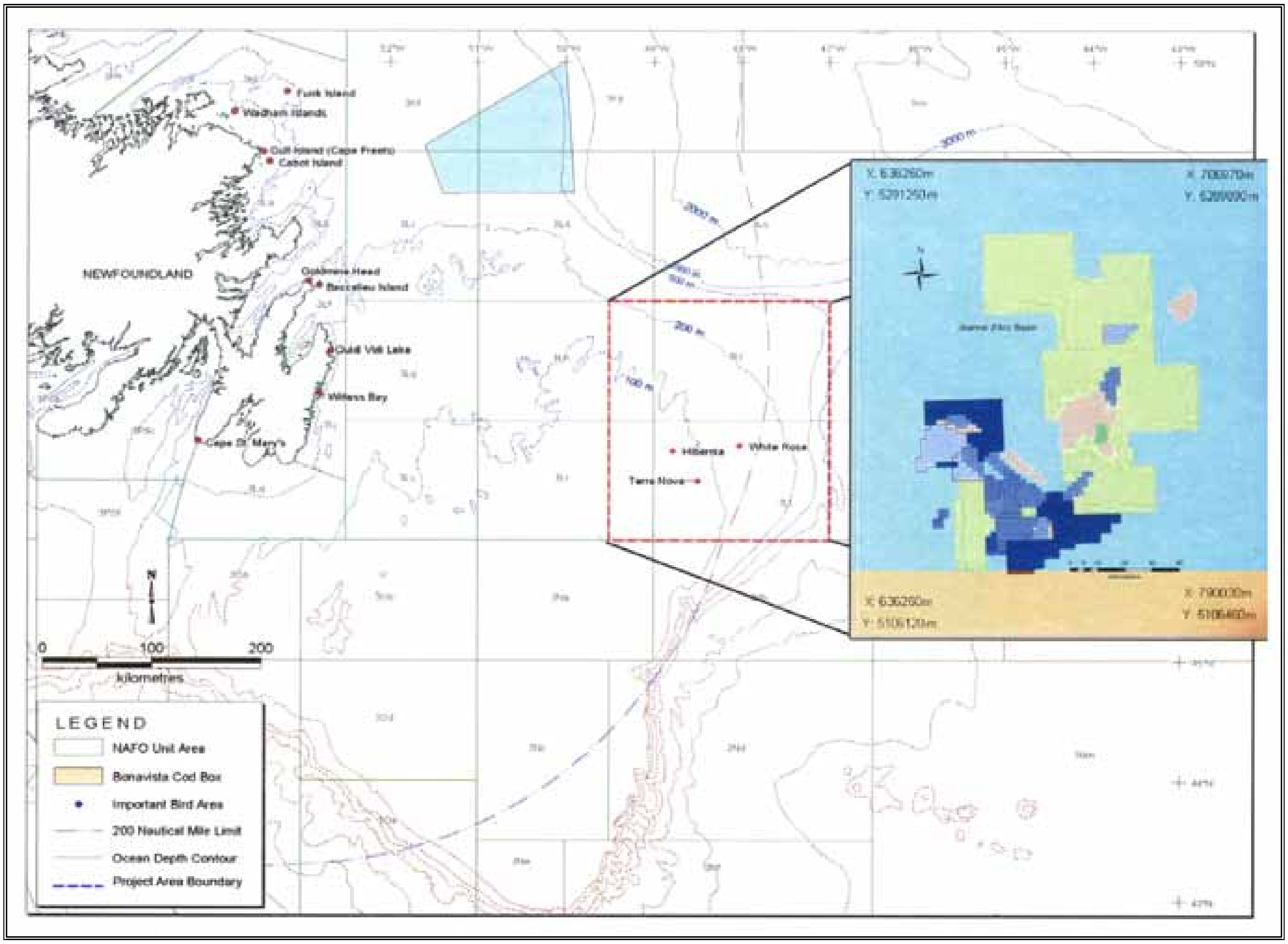



**Figure 1.2 Location of Proposed Project Activity Area**

## 2.0 Climate

The Grand Banks of Newfoundland experiences weather conditions typical of a maritime environment with the surrounding waters having a moderating effect on temperature. In general, maritime climates experience cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Furthermore, a maritime climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and significant amounts of precipitation.

The climate of the Grand Banks is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence is considerably stronger in the winter months than during the summer months, due to an increase in the south to north temperature gradient. [Meteorological convention defines seasons by quarters; e.g., winter is December, January, February, etc.]

At any given time, the upper level flow is a wave-like pattern of large and small amplitude ridges and troughs. These ridges and troughs tend to act as a steering flow for surface features and therefore their positions in the upper atmosphere determine the weather at the earth’s surface. Upper ridges tend to support areas of high pressure at the surface, while upper troughs lend support to low pressure developments. The amplitude of the upper flow pattern tends to be higher in winter than summer, which is conducive to the development of more intense storm systems.

During the winter months, an upper level trough tends to lie over Central Canada and an upper ridge over the North Atlantic resulting in three main storm tracks affecting the Grand Banks: one from the Great Lakes Basin, one from Cape Hatteras, North Carolina and one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area.

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

Rapidly deepening storms are a problem south of Newfoundland in the vicinity of the warm water of the Gulf Stream. Sometimes these explosively deepening oceanic cyclones develop into a “weather bomb”; defined as a storm that undergoes central pressure falls greater than 24 mb over 24 hours. Hurricane force winds near the center, the outbreak of convective clouds to the north and east of the center during the explosive stage, and the presence of a clear area near the center in its mature stage (Rogers and Bosart, 1986) are typical of weather bombs. After development, these systems will either move across Newfoundland or pass near the southeast coast producing gale to storm force winds from the southwest to south over the project area.

There is a general warming of the atmosphere during spring due to increasing heat from the sun. This spring warming results in a decrease in the north-south temperature gradient. Due to this weaker temperature gradient during the summer, storms tend to be weaker and not as frequent. Furthermore, the weaker tropical-to-polar temperature gradient in the summer results in the storm tracks moving further north. With the low pressure systems passing to the north of the region, the prevailing wind direction during the summer months is from the southwest to south. As a result, the incidences of gale or storm force winds are relatively infrequent over Newfoundland during the summer.

## 2.1 Data Sources

Wind and wave climate statistics for the area were extracted from the MSC50 North Atlantic wind and wave climatology data set compiled by Oceanweather Inc. under contract to Environment Canada. The MSC50 data set consists of continuous wind and wave hindcast data in 1-hour time steps from January 1954 to December 2005, on a 0.1° latitude by 0.1° longitude grid. Winds from the MSC50 data set are 1-hour averages of the effective neutral wind at a height of 10 metres (Harris, 2007). In this study, Grid Point 10439 located at 46.4°N; 48.1°W and Grid Point 10255 located at 46.3°N; 48.4°W were deemed to be most representative of conditions within block EL 1100 and block EL 1101, respectively (Figure 2.1).

Air temperature, sea surface temperature, wind speed and direction, visibility, and wave statistics for the area were compiled using data from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). A subset of global marine surface observations from ships, drilling rigs, and buoys covering the period from January 1950 to May 2007 was used in this report. Wind speeds from the ICOADS data set are 10-minute averages. The ICOADS data subset covered an area encompassing EL 1100, EL 1101 and SDL 1040. This area (Figure 2.1) is bounded to the north by 46.83°N, to the south by 46.17°N, to the east by 47.5°W, and to the west by 47.0°W. The ICOADS data set has certain inherent limitations in that the observations are not spatially or temporally consistent. In addition, even though the data used in this report were subjected to standard quality control procedures, the data set is somewhat prone to observation and coding errors, resulting in some erroneous observations within the data set. The errors were minimized by using the standard filtering system using source exclusion flags, composite QC flags and an outlier trimming level of 3.5 standard deviations. The ICOADS data set is also suspected to contain a fair-weather bias, due to the fact that ships tend to avoid severe weather or simply do not transmit weather observations during storm situations.

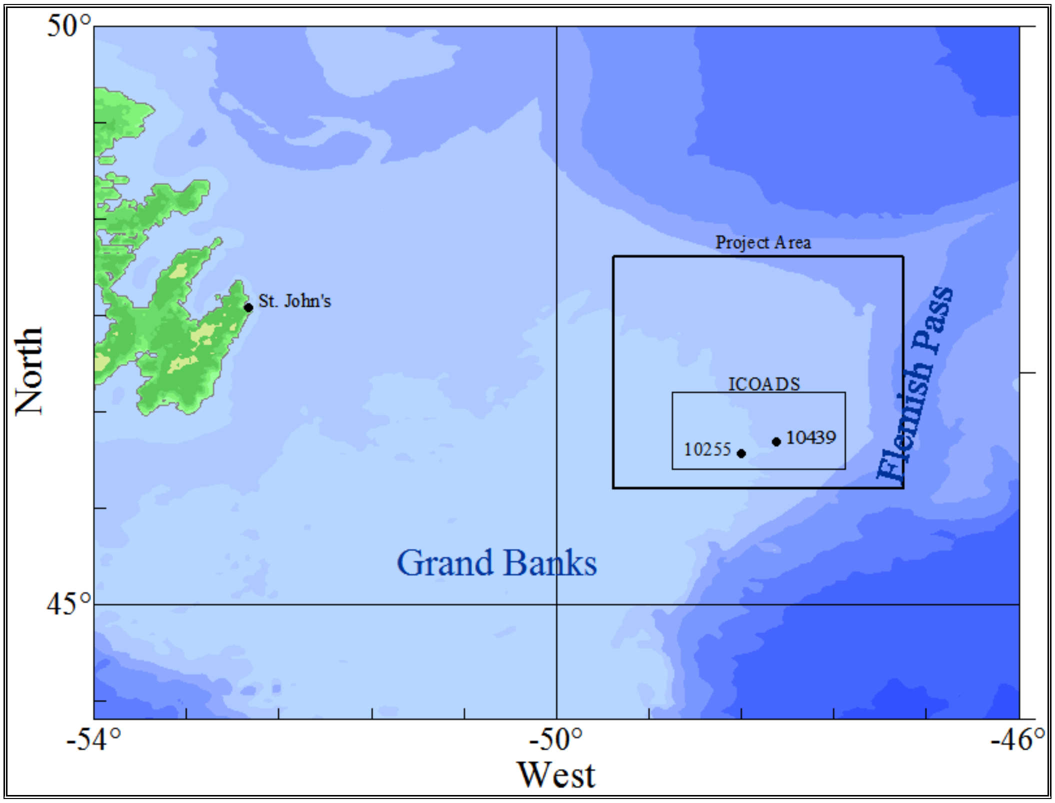



**Figure 2.1 Locations of the Climate Data Sources**

## 2.2 Wind Climatology

The Grand Banks experiences predominately southwest to west flow throughout the year. West to northwest winds which are prevalent during the winter months begin to shift counterclockwise during March and April resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominately westerly again by late fall and into winter.

Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season. Mean wind speeds at both grid points in the MSC50 data set as well as in the ICOADS data set, peak during the month of January (Table 2.1). Grid Point 10255 and 10439 had January mean wind speeds of 10.8 m/s and 10.9 m/s respectively, while the ICOADS dataset recorded the highest mean wind speed of 14.1 m/s during January month. However, the winds from the ICOADS data set are not directly comparable to the MSC50 data set because the winds in the ICOADS data set were either estimated or measured by anemometers at various heights above sea level. The wind speed is dependent on height since the wind speed increases at increasing heights above sea level. Also, winds speeds from each of the data sources have different averaging periods. The MSC50 winds are 1-hour averages while the ICOADS winds are 10-minute average winds. The adjustment factor to convert from 1-hour mean values to 10-minute mean values is usually taken as 1.06 (U.S. Geological Survey, 1979).

**Table 2.1 Mean Wind Speed (m/s) Statistics**

| Month | MSC50 | | ICOADS |
|---|---|---|---|
| | Grid Point 10255 | Grid Point 10439 | |
| January | 10.8 | 10.9 | 14.1 |
| February | 10.8 | 10.8 | 13.6 |
| March | 9.8 | 9.8 | 12.7 |
| April | 8.3 | 8.3 | 11.8 |
| May | 6.9 | 6.9 | 10.4 |
| June | 6.5 | 6.5 | 10.3 |
| July | 6.0 | 6.0 | 10.0 |
| August | 6.3 | 6.3 | 9.1 |
| September | 7.4 | 7.4 | 10.2 |
| October | 8.7 | 8.7 | 11.8 |
| November | 9.4 | 9.5 | 12.2 |
| December | 10.5 | 10.5 | 14.0 |

Wind roses of the annual wind speed and histograms of the wind speed frequency from grid points 10255 and 10439 are presented in Figure 2.2 to Figure 2.5. Monthly wind roses along with histograms of the frequency distributions of wind speeds for Grid Point 10255 can be found in Appendix 1 and for Grid Point 10439 in Appendix 2. There is a marked increase in the occurrence of winds from the west to northwest in the winter months as opposed to the summer months, which is consistent with the wind climatology of the area.

The percentage exceedance of wind speeds at grid points 10255 and 10439 are presented in Figure 2.6 and Figure 2.7, respectively. Plots for individual months are presented in Appendices 3 and 4.

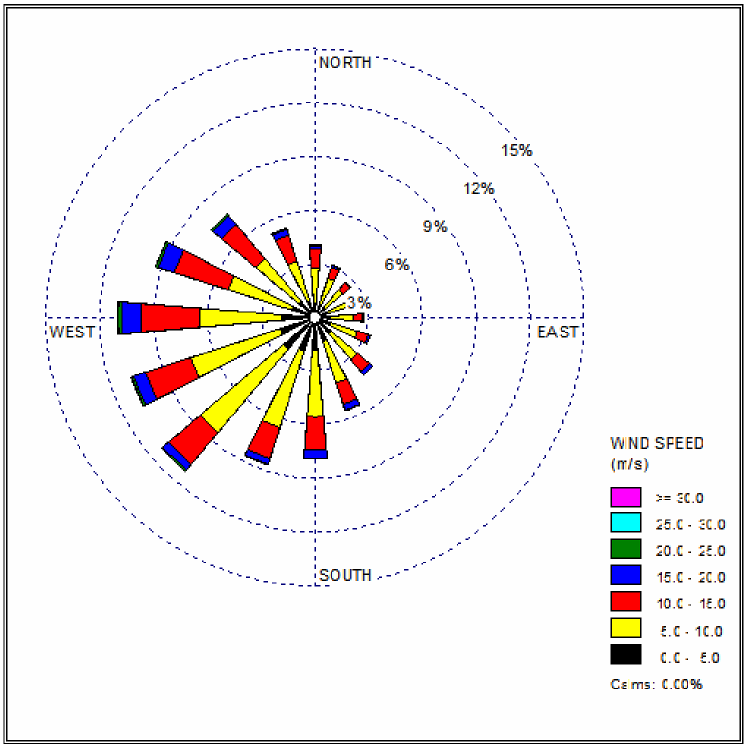



**Figure 2.2 Annual Wind Rose for MSC50 Grid Point 10255 located near 46.3°N; 48.4°W. 1954 – 2005**

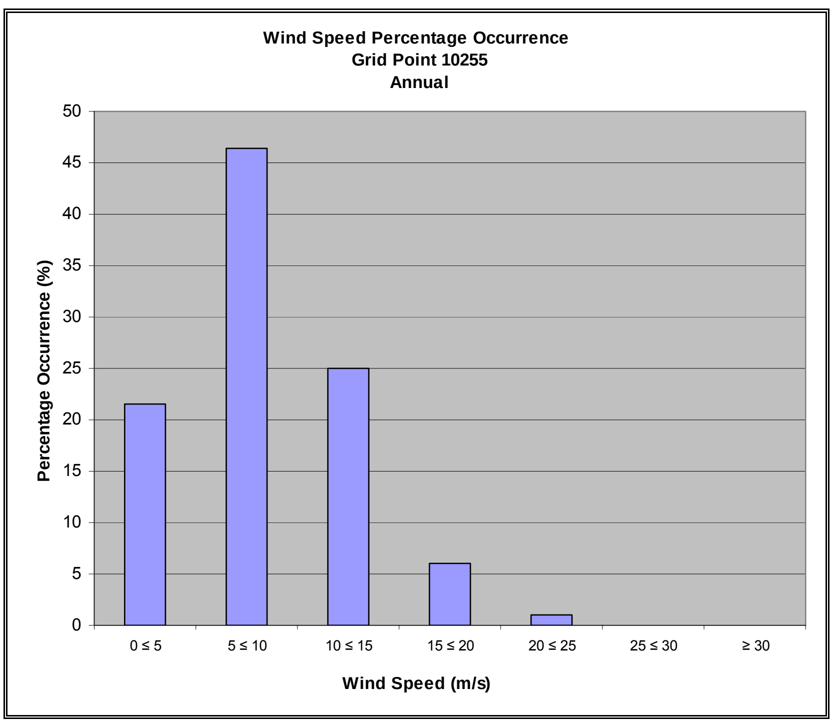



**Figure 2.3 Annual Percentage Frequency of Wind Speeds for MSC50 Grid Point 10255 located near 46.3°N; 48.4°W. 1954 – 2005**

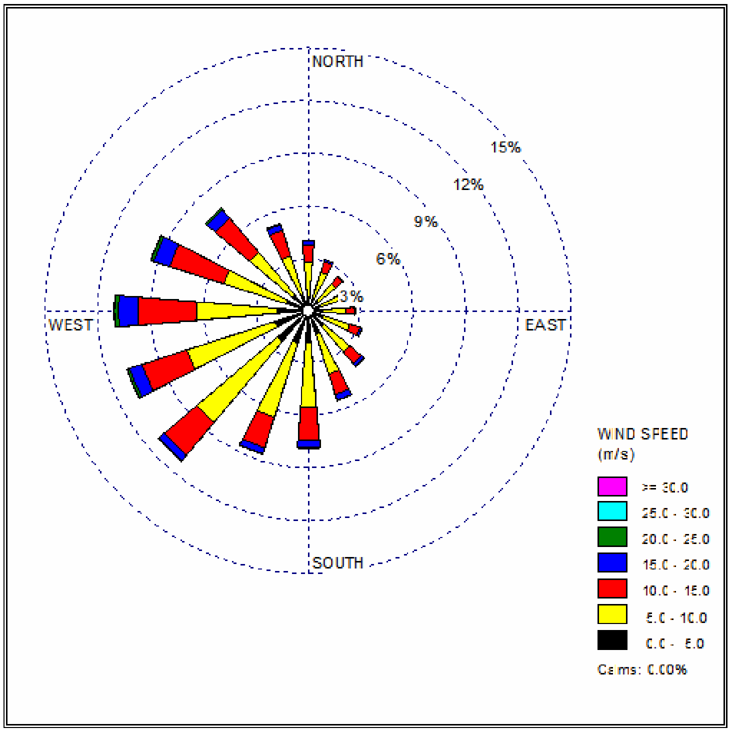



**Figure 2.4 Annual Wind Rose for MSC50 Grid Point 10439 located near 46.4°N; 48.1°W. 1954 – 2005**

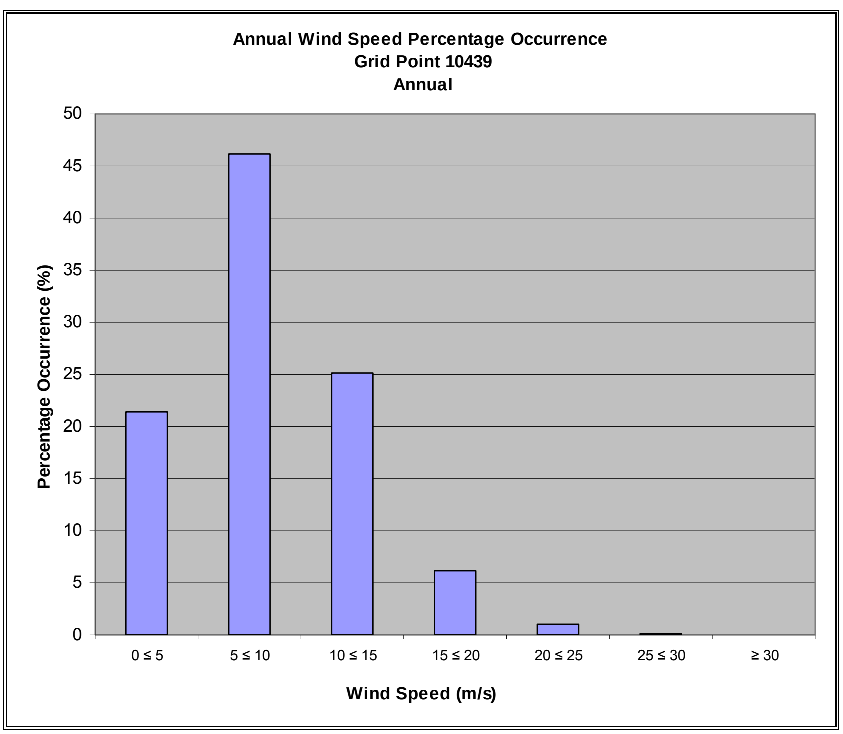



**Figure 2.5 Annual Percentage Frequency of Wind Speeds for MSC50 Grid Point 10439 located near 46.42°N; 48.13°W. 1954 - 2005**

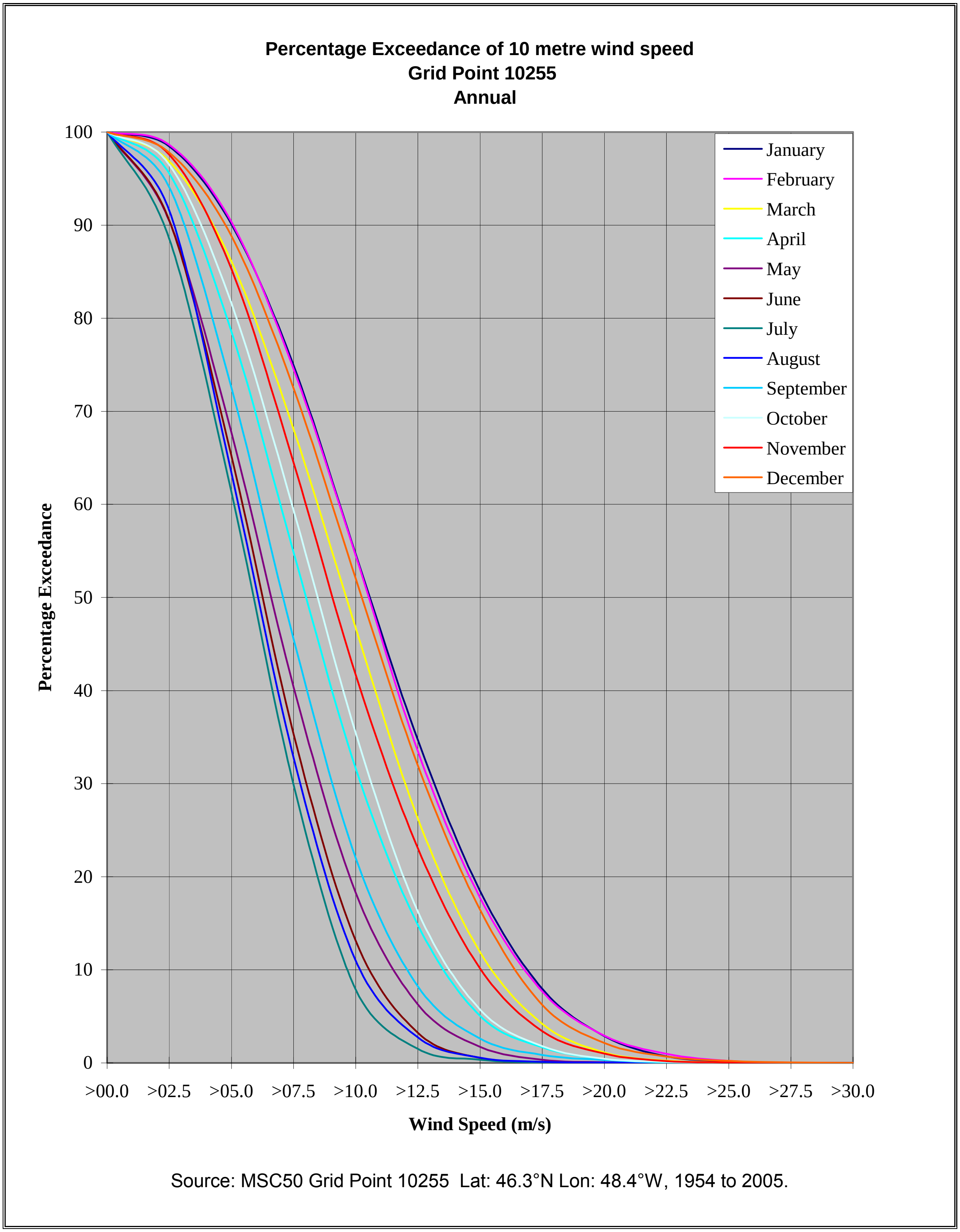



**Figure 2.6 Percentage Exceedance of 10 metre wind speed at Grid Point 10255**

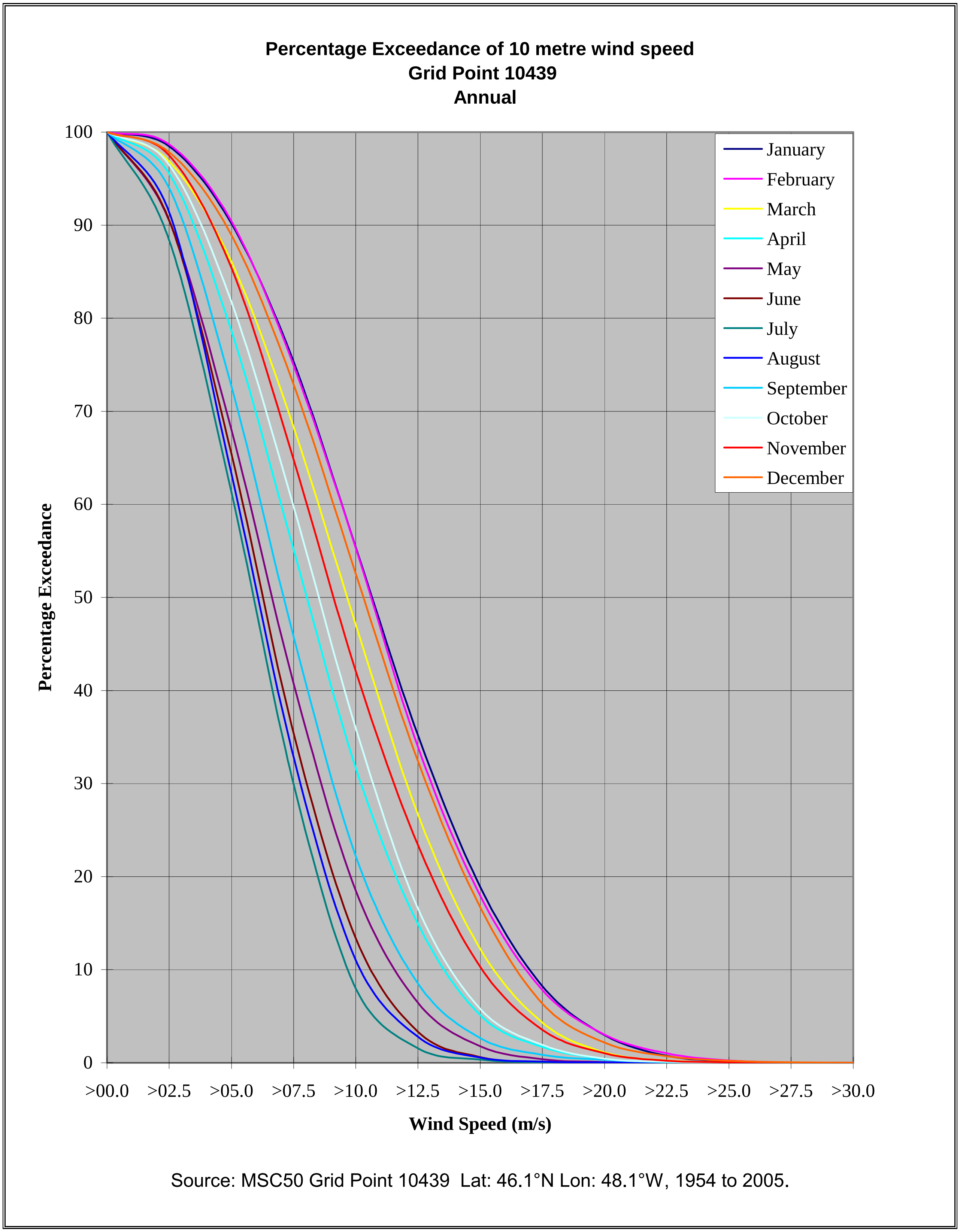



**Figure 2.7 Percentage Exceedance of 10 metre wind speed at Grid Point 10439**

Intense mid-latitude low pressure systems occur frequently from early autumn to late spring. In addition, remnants of tropical systems have passed near Newfoundland between spring and late fall. Therefore, while mean wind speeds tend to peak during the winter months, maximum wind speeds may occur at anytime during the year. A table of monthly maximum wind speeds for each of the data sets is presented in Table 2.2.

Rapidly deepening storm systems known as weather bombs frequently move across the Grand Banks. These storm systems typically develop in the warm waters of Cape Hatteras and move northeast across Newfoundland and the Grand Banks. On February 11, 2003 wind speeds at Grid Point 10255 and 10439 peaked at 29.9 m/s and 30.1 m/s, respectively. Wind speeds of 52.5 m/s from the southwest were recorded by the Henry Goodrich anemometer (located at a height of 90 m above sea level) as this system passed. During this storm, a low pressure developing off Cape Hatteras on February 10 rapidly deepened to 949 mb as it tracked northeast across the Avalon Peninsula around 18Z on February 11.

Another intense storm which developed south of the region passed east of the area on December 16, 1961. This storm resulted in wind speeds similar to that produced during the February 11 storm. During this event, grid point 10255 had wind speeds of 29.9 m/s and grid point 10439 had wind speeds peaking at 30.0 m/s. A ship in the ICOADS data set located at 47.8°N; 48.8°W recorded wind speeds of 25.7 m/s on this date.

While mid-latitude low pressure systems account for the majority of the peak wind events on the Grand Banks, storms of tropical origin can also on occasion pass over the region. On August 06 1971, an unnamed Category 1 Hurricane passed west of the region with maximum sustained wind speeds of 38.6 m/s and a central pressure of 974 mb. During this event, wind speeds in the MSC50 data set peaked at 30.0 m/s from the south-southwest at Grid Point 10255 and 30.6 m/s at Grid Point 10439. Wind speeds of 19 m/s were recorded by a ship located at 47.40°N; 48.00°W as this system passed.

**Table 2.2 Maximum Wind Speeds (m/s) Statistics**

| Month | MSC50 | | ICOADS |
|---|---|---|---|
| | Grid Point 10255 | Grid Point 10439 | |
| January | 27.4 | 27.0 | 43.7 |
| February | 29.9 | 30.1 | 49.4 |
| March | 27.0 | 27.6 | 38.1 |
| April | 25.0 | 25.2 | 35.0 |
| May | 21.6 | 22.0 | 29.8 |
| June | 22.7 | 23.0 | 28.3 |
| July | 21.1 | 21.0 | 27.3 |
| August | 30.0 | 30.6 | 26.8 |
| September | 23.6 | 23.4 | 32.4 |
| October | 27.7 | 27.8 | 32.4 |
| November | 27.4 | 27.6 | 41.2 |
| December | 29.9 | 30.0 | 43.2 |

## 2.3 Air and Sea Temperature

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

Air and sea surface temperatures for the area were extracted from the ICOADS data set. A monthly plot of air temperature versus sea surface temperature is presented in Figure 2.8. Temperature statistics presented in Table 2.3 show that the atmosphere is coldest in February with a mean temperature of –0.4°C, and warmest in August with a mean temperature of 14.5°C. The sea surface temperature is warmest in August with a mean temperature of 14.1°C and coldest in February and March with a mean temperature of 0.3°C. The mean sea surface temperature is in the range of 0.1°C to 1.4 °C colder than the mean air temperature from March to August, with the greatest difference occurring in the month of June. From September to February, sea surface temperatures are in the range of 0.0°C to 0.8 °C warmer than the mean air temperature. The colder sea surface temperatures from March to August have a cooling effect on the atmosphere, while relatively warmer sea surface temperatures from September to February tends to warm the overlying atmosphere.

**Table 2.3 Air and Sea Surface Temperature Statistics**

| | Air Temperature (°C) | | | Sea Surface Temperature (°C) | | |
|---|---|---|---|---|---|---|
| | Mean | Maximum | Minimum | Mean | Maximum | Minimum |
| January | 0.3 | 15.6 | -12.8 | 1.0 | 16.0 | -2.4 |
| February | -0.4 | 17.0 | -13.6 | 0.3 | 11.7 | -2.8 |
| March | 0.4 | 13.1 | -11.0 | 0.3 | 14.4 | -2.8 |
| April | 2.0 | 16.1 | -6.5 | 1.1 | 15.0 | -2.8 |
| May | 4.2 | 17.0 | -4.0 | 3.2 | 16.8 | -1.5 |
| June | 7.5 | 20.2 | -1.0 | 6.2 | 19.0 | -1.0 |
| July | 12.1 | 23.3 | 1.3 | 10.7 | 22.3 | 0.9 |
| August | 14.5 | 23.6 | 4.4 | 14.1 | 22.0 | 2.4 |
| September | 12.8 | 23.5 | 1.0 | 13.0 | 22.1 | 2.0 |
| October | 9.3 | 22.2 | -1.0 | 9.7 | 21.0 | 0.5 |
| November | 5.2 | 19.0 | -4.6 | 5.6 | 18.0 | -0.3 |
| December | 2.2 | 19.0 | -10.2 | 2.8 | 17.0 | -1.8 |
| Winter | 0.7 | 19.0 | -13.6 | 1.4 | 17.0 | -2.8 |
| Spring | 2.2 | 17.0 | -11.0 | 1.5 | 16.8 | -2.8 |
| Summer | 11.4 | 23.6 | -1.0 | 10.3 | 22.3 | -1.0 |
| Autumn | 9.1 | 23.5 | -4.6 | 9.4 | 22.1 | -0.3 |

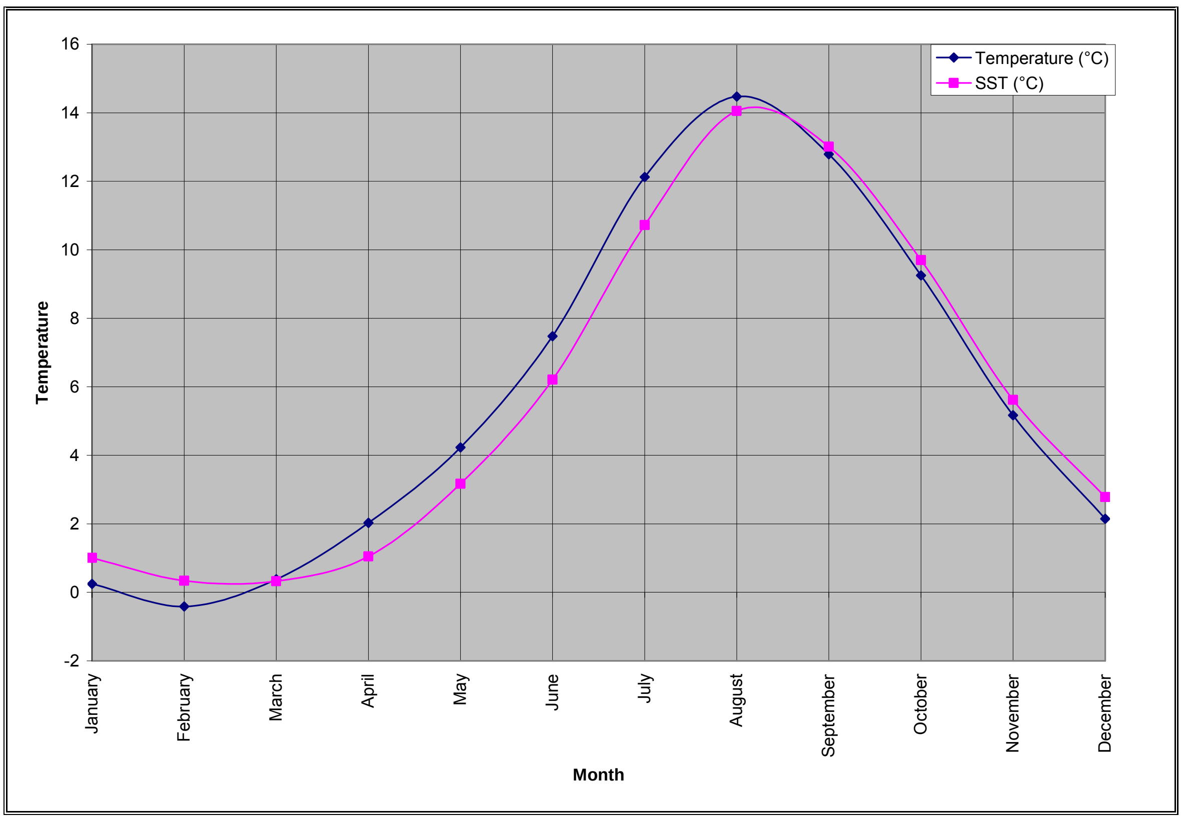


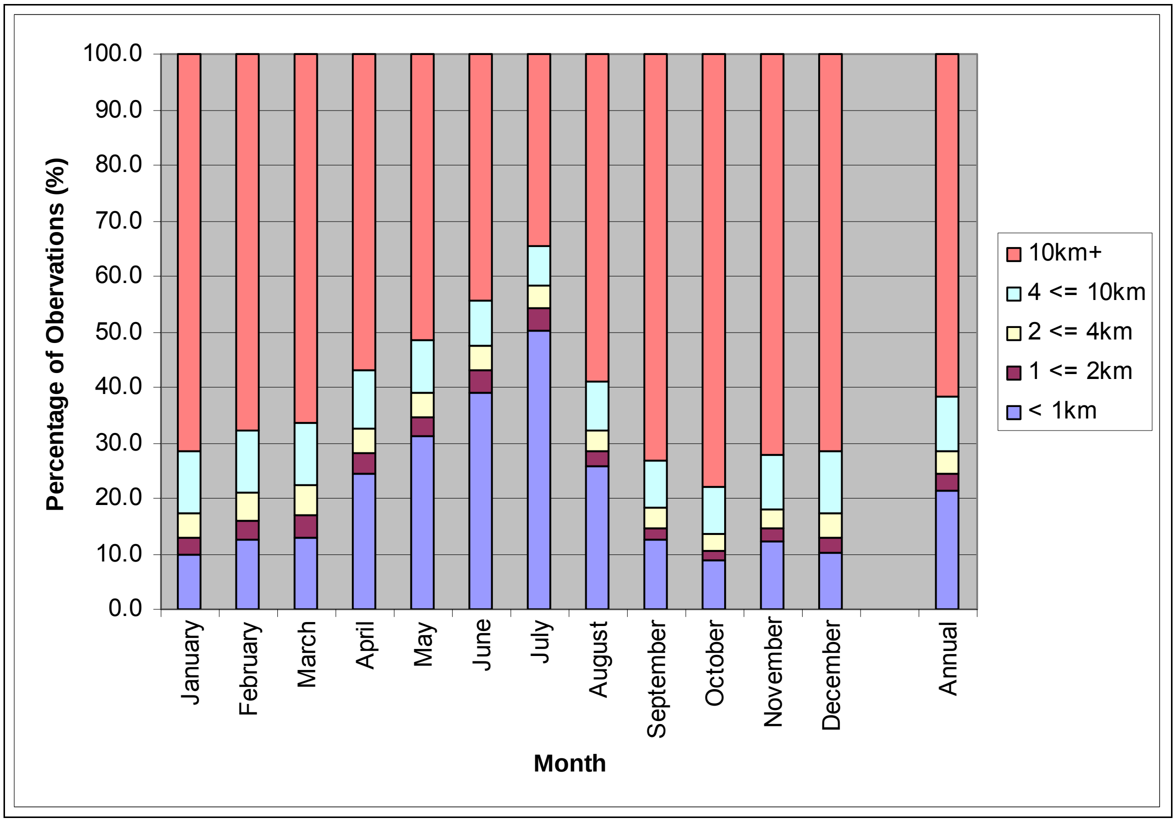

**Figure 2.8 Monthly Mean Air and Sea Surface Temperature**

## 2.4 Visibility

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

- Fog
- Mist
- Haze
- Smoke
- Liquid Precipitation (e.g., Drizzle)
- Freezing Precipitation (e.g., Freezing Rain)
- Frozen Precipitation (e.g., Snow)
- Blowing Snow

A plot of the frequency distribution of visibility from the ICOADS data set is presented in Figure 2.9 which shows that obstructions to vision can occur in any month. Annually, 38.1% of the recorded observations had reduced visibilities. During the winter months, the main obstruction is snow; however, mist and fog may also reduce visibilities at times. As spring approaches, the amount of visibility reduction attributed to snow decreases. As the air temperature increases, so does the occurrence of advection fog. Advection fog forms when warm moist air moves over the cooler waters of the Labrador Current. By March, the sea surface temperature on the Grand Banks is cooler than the surrounding air. As warm moist air moves over the colder sea surface, the air cools and its ability to hold moisture decreases. The air will continue to cool until it becomes saturated and the moisture condenses to form fog. The presence of advection fog increases from April through July. July month has the highest percentage (65.3%) of obscuration to visibility, most of which is in the form of advection fog, although frontal fog can also contribute to the reduction in visibility. On average, fog reduces visibility below 1 kilometer 50.3% of the time in July. In August the temperature difference between the air and the sea begins to narrow and by September, the air temperature begins to fall below the sea surface temperature. As the air temperature drops, the occurrence of fog decreases. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low-pressure systems. Fog is mainly the cause of the reduced visibilities in autumn and snow is the cause of reduced visibilities in the winter. October has the lowest occurrence of reduced visibility (22.1%) since the air temperature has, on average, decreased below the sea surface temperature, and it is not yet cold enough for snow.




*Source:* ICOADS Data set (1950-2006)

**Figure 2.9 Monthly and Annual Percentage Occurrence of Visibility**

## 2.5 Wave Climatology

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

A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell groups. A swell is a wave system not produced by the local wind blowing at the time of observation and may have been generated within the local weather system, or from within distant weather systems. The former situation typically arises when a front, trough, or ridge crosses the point of concern, resulting in a marked shift in wind direction. Swells generated in this manner are usually of low period. Swells generated by distant weather systems may propagate in the direction of the winds that originally formed to the vicinity of the observation area. These swells may travel for thousands of miles before dying away. As the swell advances, its crest becomes rounded and its surface smooth. As a result of the latter process, swell energy may propagate through a point from more than one direction at a particular time.

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

Mean monthly ice statistics were used when calculating the wave heights in the MSC50 data. As a result, if the mean monthly ice coverage for a particular grid point is greater than 50% for a particular month, the whole month (from the $1^{st}$ to the $31^{st}$) gets "iced out"; meaning that no forecast wave data has been generated for that month. This sometimes results in gaps in the wave data.

The annual wave rose from the MSC50 data for both grid points are presented in Figure 2.10 and Figure 2.12, respectively. The wave roses show that the majority of wave energy comes from the west-southwest to southwest, and accounts for 25.0% of the wave energy at grid point 10255 and 27.4% of the wave energy at grid point 10439. Waves were "iced out" for 0.98% of the time at grid point 10255 and 1.23% of the time at grid point 10439, over the 50-year record; this value may be somewhat high since monthly ice files were used when generating the waves.

During autumn and winter, the dominate direction of the combined significant wave height is from the west. This corresponds with a higher frequency of occurrence of the wind wave during these months, suggesting that during the late fall and winter, the wind wave is the main contributor to the combined significant wave height. During the months of March and April, the wind wave remains predominately westerly, while the swell begins to change to southerly, resulting in the vector mean direction of the combined significant wave heights being to southwesterly. A mean southwesterly direction for the combined significant wave heights during the summer months is a result of a mainly southwesterly wind wave and a southwesterly swell. As winter approaches again, during the months of September and October, the wind wave will veer to the west and become the more dominant component of the combined significant wave height. This will result in the frequency of occurrence of the combined significant wave heights being westerly once again.

The annual percentage frequency of significant wave heights is presented in Figure 2.11 and Figure 2.13. These histograms show that the majority of significant wave heights are between 2.0 and 5.0 metres on the Grand Banks. There is a gradual decrease in frequency of wave heights above 4.0 m and only a small percentage of the wave heights exceeding 8.0 m. Monthly wave roses along with histograms of the frequency distributions of wave heights for Grid Point 10255 can be found in Appendix 5, and those for Grid Point 10439 can be found in Appendix 6.

Significant wave heights on the Grand Banks peak during the winter months with the MSC50 mean monthly significant wave heights of 4.0 metres at both grid points. The lowest significant wave heights occur in the summer with July month having a mean monthly significant wave height of only 1.7 m at both grid points (Table 2.4).

**Table 2.4 Mean Significant Wave Height Statistics (m) for the MSC50 data sets**

| | **Grid Point 10255** | **Grid Point 10439** |
|---|---|---|
| January | 4.0 | 4.0 |
| February | 3.7 | 3.8 |
| March | 3.2 | 3.2 |
| April | 2.7 | 2.7 |
| May | 2.2 | 2.2 |
| June | 1.9 | 1.9 |
| July | 1.7 | 1.7 |
| August | 1.8 | 1.8 |
| September | 2.4 | 2.4 |
| October | 2.9 | 3.0 |
| November | 3.3 | 3.4 |
| December | 3.9 | 3.9 |

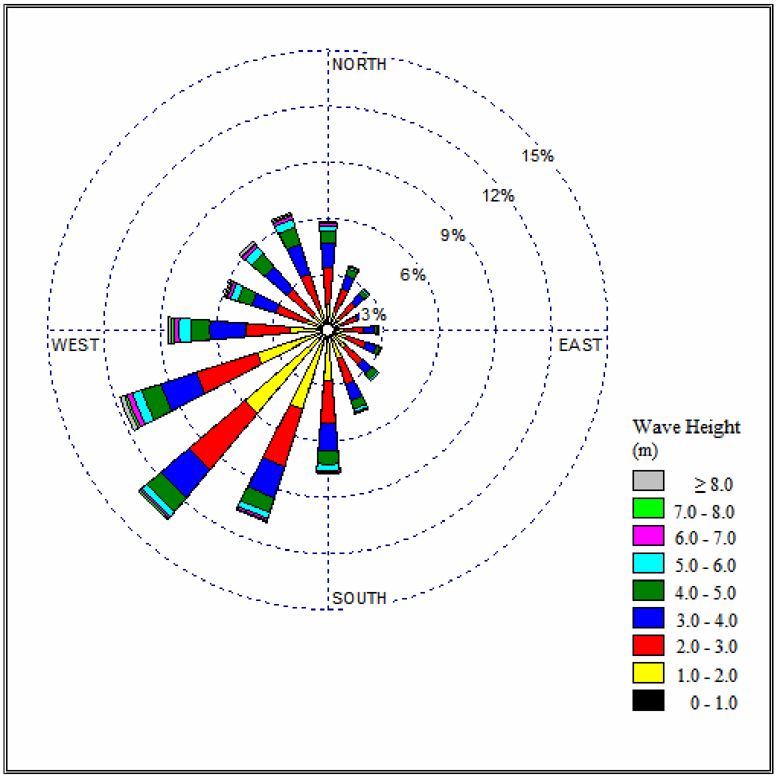



**Figure 2.10 Annual Wave Rose for MSC50 Grid Point 10255 located near 46.3°N; 48.4°W**

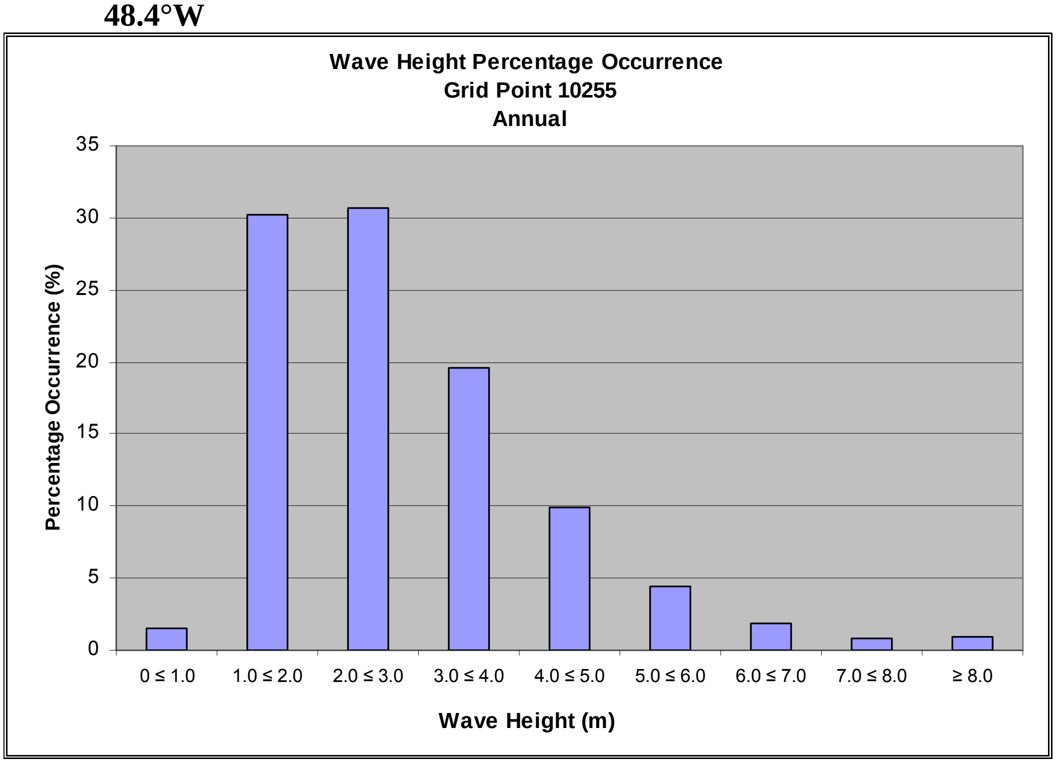



**Figure 2.11 Annual Percentage Frequency of Wave Height for MSC50 Grid Point 10255 located near 46.3°N; 48.4°W. 1954 – 2005**

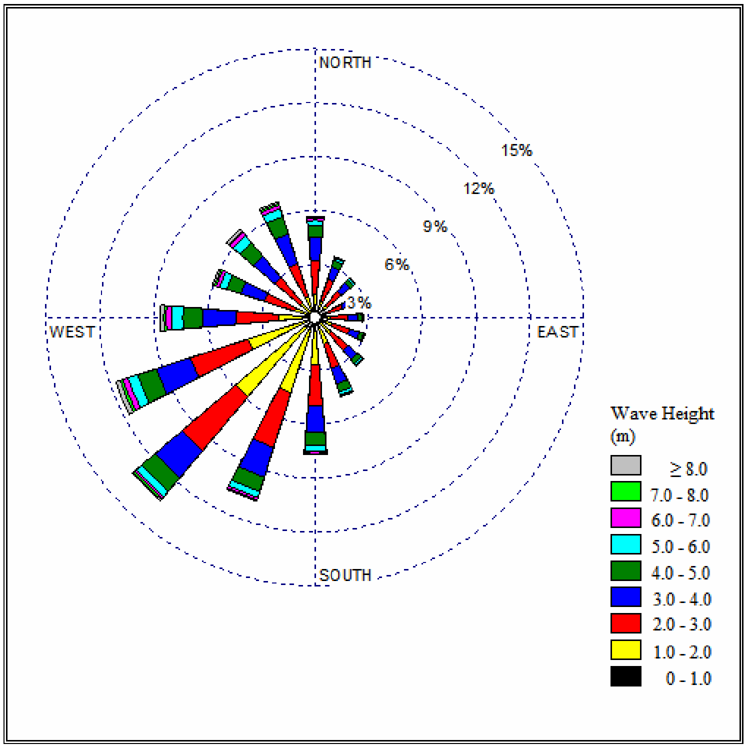



**Figure 2.12 Annual Wave Rose for MSC50 Grid Point 10439 located near 46.4°N; 48.1°W**

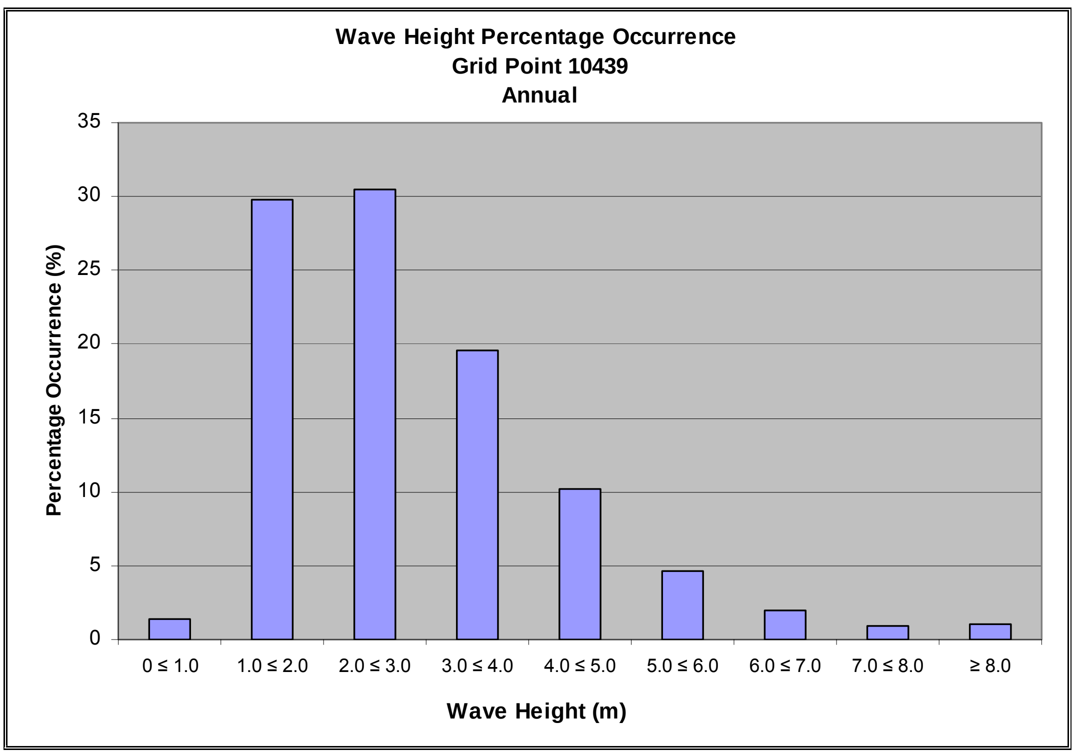



**Figure 2.13 Annual Percentage Frequency of Wave Height for MSC50 Grid Point 10439 located near 46.4°N; 48.1°W. 1954 – 2005**

Significant wave heights of 10.5 metres or more occurred in each month between September and April, with the highest waves occurring during the month of February (Table 2.5). The highest significant wave heights of 13.9 m from the MSC50 Grid Point 10255 and 14.2 m from Grid Point 10439 occurred on February 23, 1967. A low pressure over Nova Scotia on February 22 rapidly deepened as it moved northeast to lie off the northeast coast of Newfoundland on the 23 resulting in a prolonged period of strong-gale to storm force WSW to W winds over the Grand Banks. While maximum significant wave heights tend to peak during the winter months, a tropical system could pass through the area and produce large wave heights during any month.

**Table 2.5 Maximum Significant Wave Height Statistics (m) for the MSC50 data sets**

| | Grid Point 10255 | Grid Point 10439 |
|---|---|---|
| January | 13.3 | 13.6 |
| February | 13.9 | 14.2 |
| March | 11.9 | 11.9 |
| April | 10.8 | 10.7 |
| May | 9.9 | 10.0 |
| June | 9.6 | 9.8 |
| July | 6.2 | 6.2 |
| August | 8.1 | 8.2 |
| September | 10.9 | 11.1 |
| October | 11.8 | 12.0 |
| November | 11.3 | 11.5 |
| December | 13.7 | 13.9 |

Figure 2.14 and Figure 2.15 show percentage exceedance curves of significant wave heights for grid points 10255 and 10439 respectively. Percentage exceedance plots for the months of January through April show that the curves do not reach 100% because of the presence of ice on the Grand Banks during these months. Monthly plots of percentage exceedance of significant wave heights are presented in Appendices 7 and 8.

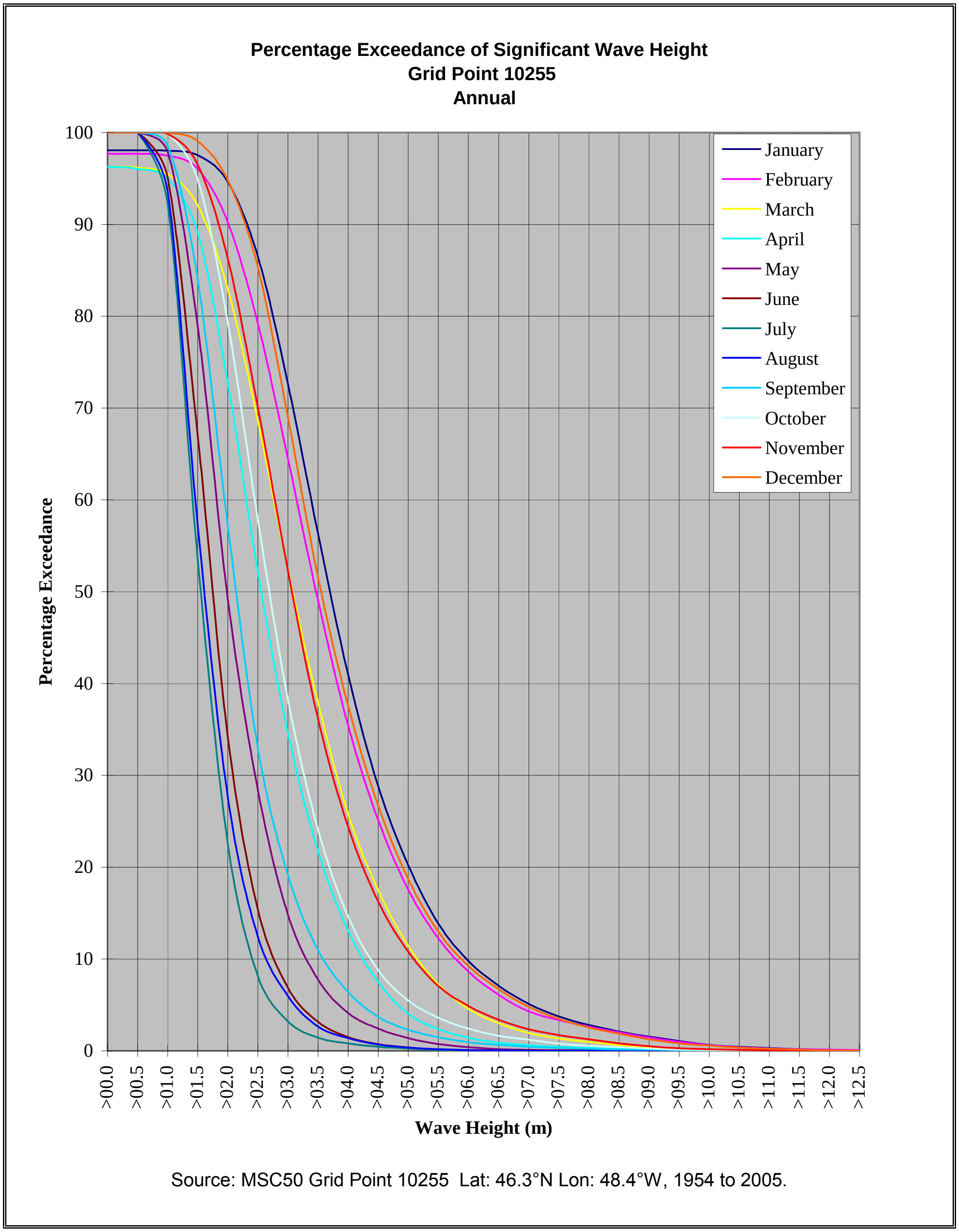



**Figure 2.14 Percentage Exceedance of Significant Wave Height at Grid Point 10255**

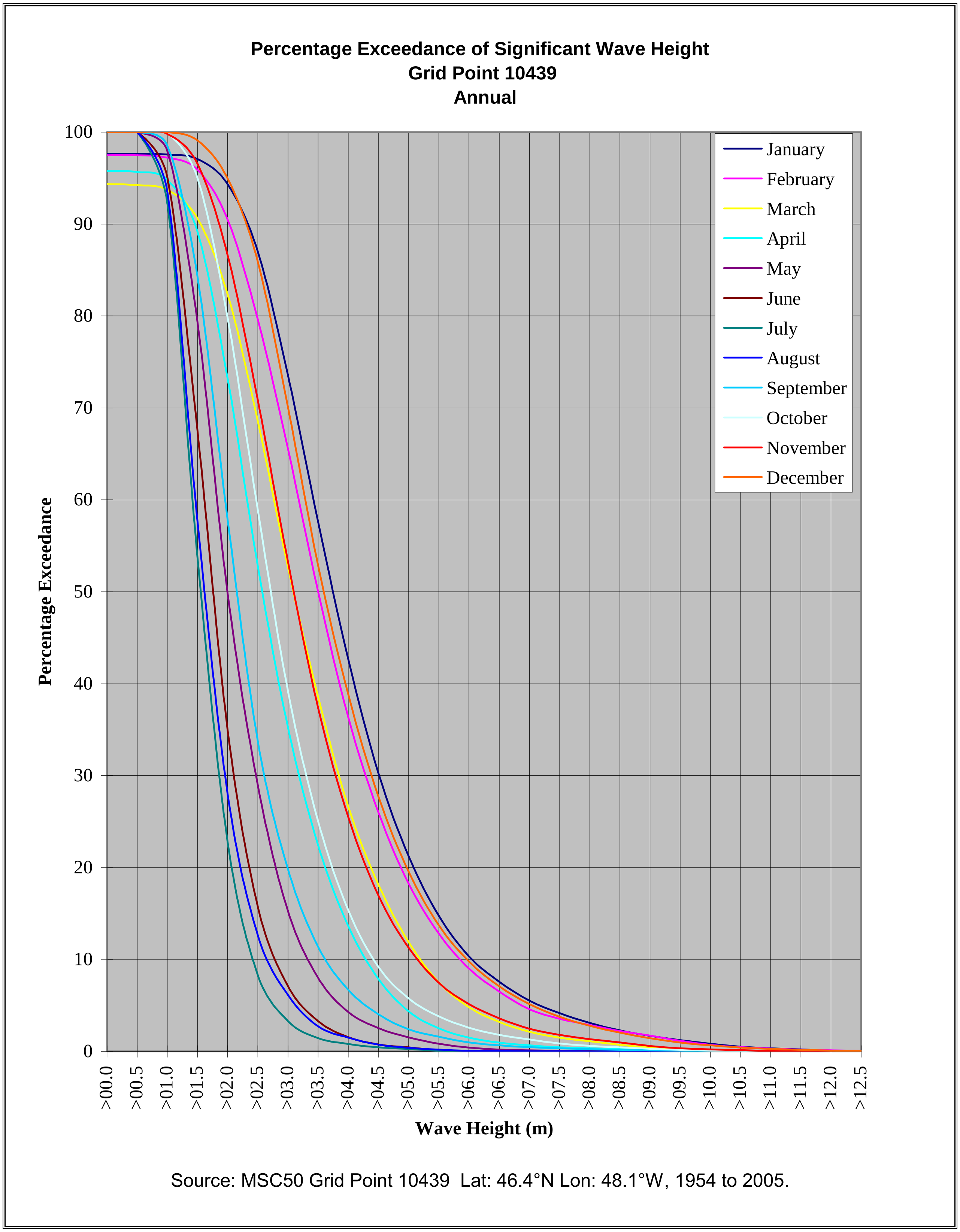



**Figure 2.15 Percentage Exceedance of Significant Wave Height at Grid Point 10439**

The spectral peak period of waves vary with season with the most common period varying from 7 seconds in July and August to 11 seconds in January and February. Annually, the most common peak spectral period is 9 seconds, occurring 19.0% of the time at Grid Point 10255 and 18.6% of the time at Grid Point 10439. Periods above 12 seconds occur more frequently during the winter months; though they may occur during the summer as well. The percentage occurrence of spectral peak period for each month at both grid points is shown in Table 2.6 and Table 2.7, and in Figure 2.16 and Figure 2.17.

A scatter diagram of the significant wave height versus spectral peak period is presented in Table 2.8 and Table 2.9. These tables show that the most common wave is 2 m with a peak spectral period of 9 seconds, and the second most common wave being 2 m and a peak spectral period of 8 seconds. Note that the wave heights in these tables have been rounded to the nearest whole number. Therefore, the 1 metre wave bin would include all waves from 0.51 metres to 1.49 metres.

## Table 2.6 Percentage Occurrence of Peak Spectral Period of the Total Spectrum at Grid Point 10255

| | Peak Spectral Period (seconds) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| January | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.4 | 5.0 | 8.5 | 15.6 | 18.8 | 22.4 | 11.8 | 10.9 | 4.7 | 0.6 | 0.1 |
| February | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 2.5 | 7.1 | 10.1 | 16.5 | 18.3 | 20.2 | 11.7 | 8.0 | 3.8 | 0.6 | 0.2 |
| March | 0.0 | 0.0 | 0.0 | 0.4 | 1.1 | 3.5 | 8.9 | 11.7 | 18.0 | 19.0 | 17.5 | 9.8 | 6.1 | 3.6 | 0.2 | 0.3 |
| April | 0.0 | 0.0 | 0.0 | 0.4 | 1.2 | 4.1 | 8.8 | 15.1 | 24.6 | 19.7 | 14.1 | 7.0 | 3.2 | 1.6 | 0.2 | 0.1 |
| May | 0.0 | 0.0 | 0.0 | 0.1 | 1.7 | 6.8 | 16.3 | 25.7 | 23.4 | 14.0 | 6.2 | 3.8 | 1.5 | 0.4 | 0.0 | 0.0 |
| June | 0.0 | 0.0 | 0.0 | 0.2 | 3.5 | 11.0 | 24.9 | 27.4 | 20.0 | 7.8 | 2.2 | 1.4 | 1.5 | 0.1 | 0.0 | 0.0 |
| July | 0.0 | 0.0 | 0.0 | 0.3 | 4.7 | 14.1 | 30.5 | 27.5 | 13.7 | 5.6 | 1.2 | 0.4 | 1.4 | 0.2 | 0.1 | 0.2 |
| August | 0.0 | 0.0 | 0.0 | 0.4 | 5.2 | 12.9 | 30.0 | 26.1 | 14.1 | 5.0 | 2.5 | 1.9 | 1.4 | 0.4 | 0.0 | 0.0 |
| September | 0.0 | 0.0 | 0.0 | 0.1 | 2.0 | 6.8 | 17.3 | 21.4 | 20.6 | 10.2 | 8.5 | 7.0 | 4.2 | 1.3 | 0.3 | 0.2 |
| October | 0.0 | 0.0 | 0.0 | 0.1 | 0.9 | 3.8 | 11.1 | 17.6 | 23.1 | 16.1 | 12.0 | 8.0 | 4.9 | 1.9 | 0.2 | 0.2 |
| November | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 2.8 | 7.8 | 11.6 | 20.9 | 20.5 | 16.4 | 9.0 | 7.3 | 2.6 | 0.2 | 0.2 |
| December | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 1.3 | 5.1 | 9.0 | 17.0 | 21.7 | 20.5 | 11.5 | 9.5 | 3.4 | 0.5 | 0.2 |
| Winter | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 1.7 | 5.7 | 9.2 | 16.4 | 19.6 | 21.0 | 11.7 | 9.5 | 4.0 | 0.5 | 0.2 |
| Spring | 0.0 | 0.0 | 0.0 | 0.3 | 1.3 | 4.8 | 11.3 | 17.5 | 22.0 | 17.5 | 12.6 | 6.9 | 3.6 | 1.9 | 0.1 | 0.1 |
| Summer | 0.0 | 0.0 | 0.0 | 0.3 | 4.5 | 12.7 | 28.5 | 27.0 | 15.9 | 6.2 | 2.0 | 1.2 | 1.4 | 0.2 | 0.1 | 0.1 |
| Autumn | 0.0 | 0.0 | 0.0 | 0.1 | 1.1 | 4.5 | 12.1 | 16.9 | 21.5 | 15.6 | 12.3 | 8.0 | 5.5 | 2.0 | 0.2 | 0.2 |
| Annual | 0.0 | 0.0 | 0.0 | 0.2 | 1.8 | 5.9 | 14.4 | 17.7 | 19.0 | 14.7 | 12.0 | 6.9 | 5.0 | 2.0 | 0.2 | 0.1 |

*Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.*

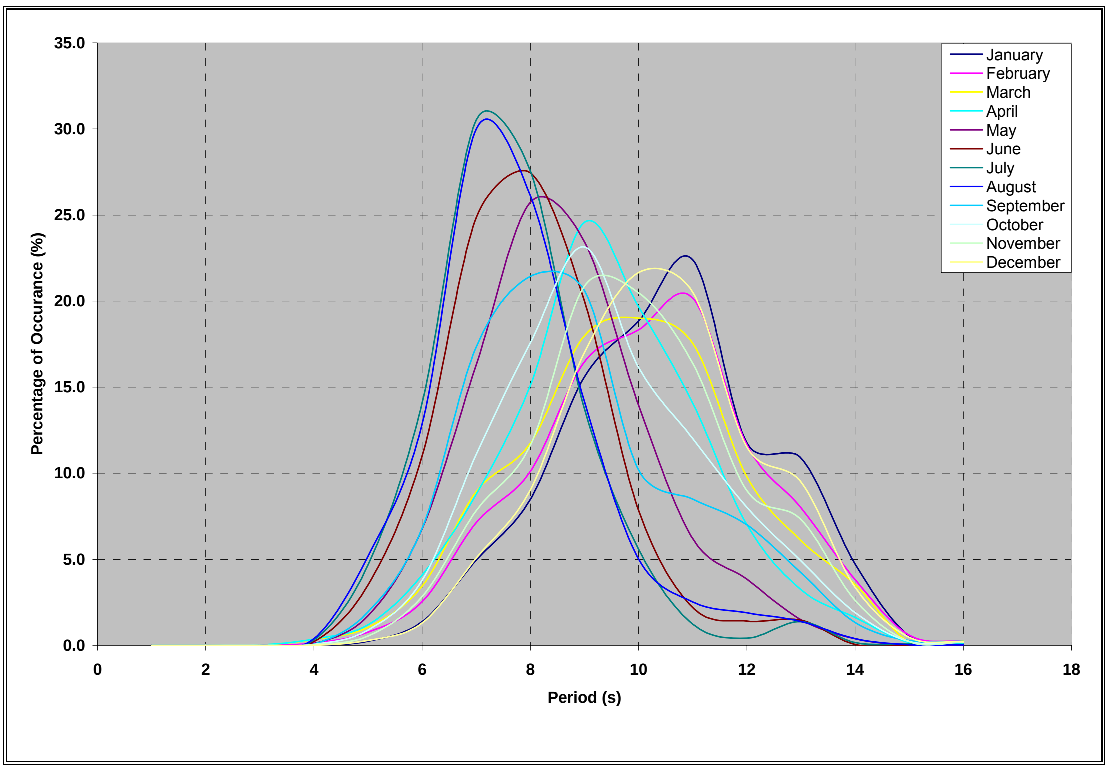



**Figure 2.16 Percentage of Occurrence of Peak Wave Period at Grid Point 10255**

## Table 2.7 Percentage Occurrence of Peak Spectral Period of the Total Spectrum at Grid Point 10439

| | Peak Spectral Period (seconds) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |
| January | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.2 | 4.8 | 8.5 | 14.8 | 18.5 | 22.4 | 12.2 | 11.6 | 4.9 | 0.6 | 0.1 |
| February | 0.0 | 0.0 | 0.0 | 0.1 | 0.7 | 2.4 | 6.7 | 10.2 | 16.0 | 18.2 | 20.2 | 12.1 | 8.4 | 4.1 | 0.6 | 0.2 |
| March | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 | 3.2 | 8.5 | 11.9 | 17.7 | 18.9 | 17.8 | 10.5 | 6.2 | 3.8 | 0.2 | 0.2 |
| April | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 4.0 | 8.6 | 15.2 | 24.1 | 19.8 | 14.3 | 7.3 | 3.4 | 1.8 | 0.2 | 0.1 |
| May | 0.0 | 0.0 | 0.0 | 0.1 | 1.6 | 6.9 | 16.1 | 25.8 | 23.0 | 14.2 | 6.2 | 4.1 | 1.5 | 0.4 | 0.0 | 0.0 |
| June | 0.0 | 0.0 | 0.0 | 0.2 | 3.4 | 10.7 | 24.8 | 27.6 | 20.0 | 7.9 | 2.2 | 1.5 | 1.5 | 0.1 | 0.0 | 0.0 |
| July | 0.0 | 0.0 | 0.0 | 0.3 | 4.5 | 14.2 | 30.4 | 27.6 | 13.7 | 5.7 | 1.2 | 0.5 | 1.5 | 0.2 | 0.1 | 0.2 |
| August | 0.0 | 0.0 | 0.0 | 0.4 | 5.0 | 13.0 | 29.6 | 26.3 | 14.0 | 5.1 | 2.6 | 2.0 | 1.5 | 0.4 | 0.1 | 0.1 |
| September | 0.0 | 0.0 | 0.0 | 0.1 | 1.8 | 6.6 | 17.1 | 21.7 | 20.1 | 10.3 | 8.6 | 7.3 | 4.4 | 1.4 | 0.3 | 0.3 |
| October | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 3.6 | 10.9 | 17.5 | 22.7 | 16.3 | 12.0 | 8.6 | 5.1 | 2.0 | 0.2 | 0.2 |
| November | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 2.6 | 7.7 | 11.7 | 20.2 | 20.2 | 16.6 | 9.3 | 7.8 | 2.8 | 0.2 | 0.2 |
| December | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 1.2 | 4.9 | 9.0 | 16.3 | 21.1 | 20.7 | 12.2 | 10.0 | 3.7 | 0.5 | 0.2 |
| Winter | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 1.6 | 5.5 | 9.2 | 15.7 | 19.3 | **21.1** | 12.2 | 10.0 | 4.2 | 0.6 | 0.2 |
| Spring | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 4.1 | 10.3 | 17.6 | 22.3 | 17.9 | 12.3 | 7.7 | 3.8 | 2.6 | 0.2 | 0.1 |
| Summer | 0.0 | 0.0 | 0.0 | 0.3 | 4.1 | 12.4 | 28.0 | 27.9 | 15.4 | 6.3 | 1.9 | 1.4 | 1.6 | 0.3 | 0.1 | 0.1 |
| Autumn | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 4.0 | 11.5 | 17.5 | 21.0 | 15.6 | 11.9 | 8.9 | 5.2 | 2.9 | 0.4 | 0.2 |
| Annual | 0.0 | 0.0 | 0.0 | 0.1 | 1.6 | 5.5 | 13.7 | 18.0 | 18.6 | 14.7 | 11.6 | 7.8 | 4.9 | 2.8 | 0.4 | 0.2 |

*Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.*

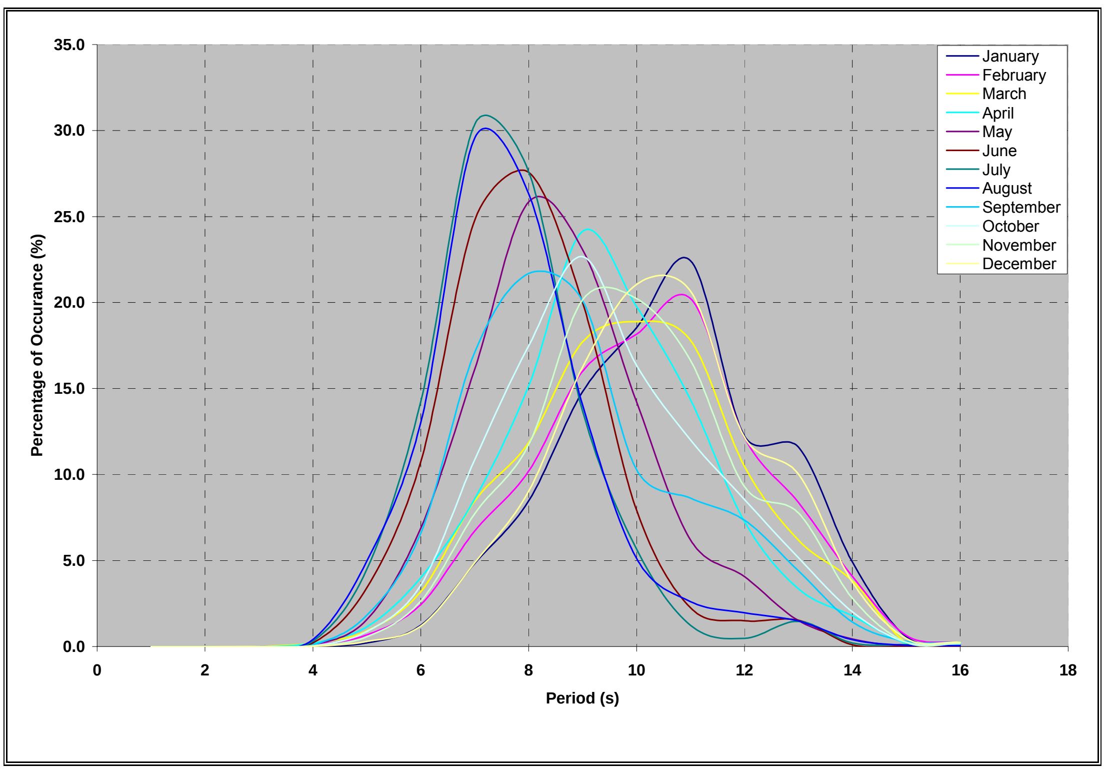



**Figure 2.17 Percentage of Occurrence of Peak Wave Period at Grid Point 10439**

**Table 2.8 Percent Frequency of Occurrence of Significant Combined Wave Height and Peak Spectral Period at Grid Point 10255**

| | | Wave Height (m) | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
| Period (s) | 0 | | | | | | | | | | | | | | | 0.96 |
| | 1 | | | | | | | | | | | | | | | 0.00 |
| | 2 | | | | | | | | | | | | | | | 0.00 |
| | 3 | | | | | | | | | | | | | | | 0.00 |
| | 4 | | 0.14 | 0.03 | | | | | | | | | | | | 0.17 |
| | 5 | | 1.06 | 0.74 | 0.04 | | | | | | | | | | | 1.84 |
| | 6 | | 1.63 | 3.85 | 0.40 | 0.02 | | | | | | | | | | 5.90 |
| | 7 | | 4.81 | 5.86 | 3.43 | 0.28 | 0.01 | | | | | | | | | 14.38 |
| | 8 | 0.01 | 4.66 | 6.47 | 4.34 | 1.97 | 0.14 | | | | | | | | | 17.58 |
| | 9 | | 1.65 | 8.41 | 4.13 | 3.44 | 1.05 | 0.06 | | | | | | | | 18.75 |
| | 10 | 0.01 | 0.58 | 4.37 | 4.35 | 2.41 | 2.16 | 0.59 | 0.04 | | | | | | | 14.52 |
| | 11 | | 0.22 | 2.10 | 4.15 | 2.33 | 1.34 | 1.12 | 0.43 | 0.06 | 0.01 | | | | | 11.76 |
| | 12 | | 0.21 | 1.34 | 1.99 | 1.32 | 0.61 | 0.46 | 0.45 | 0.31 | 0.14 | 0.01 | | | | 6.83 |
| | 13 | | 0.23 | 0.74 | 1.14 | 1.20 | 0.63 | 0.28 | 0.19 | 0.17 | 0.19 | 0.12 | 0.02 | | | 4.91 |
| | 14 | | 0.04 | 0.14 | 0.45 | 0.59 | 0.35 | 0.13 | 0.07 | 0.03 | 0.04 | 0.06 | 0.05 | 0.02 | | 1.96 |
| | 15 | | 0.01 | 0.01 | 0.04 | 0.06 | 0.06 | 0.02 | 0.01 | | | | 0.01 | 0.01 | 0.01 | 0.23 |
| | 16 | | 0.02 | 0.02 | 0.03 | 0.04 | 0.01 | 0.01 | | | | | | | | 0.13 |
| | 17 | | 0.01 | 0.01 | 0.01 | | | | | | | | | | | 0.03 |
| | 18 | | | | | | | | | | | | | | | 0.00 |
| | | 0.02 | 15.25 | 34.12 | 24.48 | 13.64 | 6.37 | 2.67 | 1.19 | 0.58 | 0.38 | 0.19 | 0.08 | 0.03 | 0.01 | 99.95 |

**Table 2.9 Percent Frequency of Occurrence of Significant Combined Wave Height and Peak Spectral Period at Grid Point 10439**

| | | Wave Height (m) | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
| Period (s) | 0 | | | | | | | | | | | | | | | 1.22 |
| | 1 | | | | | | | | | | | | | | | 0.00 |
| | 2 | | | | | | | | | | | | | | | 0.00 |
| | 3 | | | | | | | | | | | | | | | 0.00 |
| | 4 | | 0.11 | 0.03 | | | | | | | | | | | | 0.14 |
| | 5 | | 1.01 | 0.70 | 0.04 | | | | | | | | | | | 1.74 |
| | 6 | | 1.65 | 3.75 | 0.38 | 0.02 | | | | | | | | | | 5.79 |
| | 7 | | 4.65 | 5.84 | 3.35 | 0.27 | 0.01 | | | | | | | | | 14.13 |
| | 8 | | 4.67 | 6.52 | 4.34 | 1.95 | 0.14 | | | | | | | | | 17.62 |
| | 9 | | 1.58 | 8.18 | 4.02 | 3.41 | 1.04 | 0.07 | | | | | | | | 18.29 |
| | 10 | | 0.60 | 4.30 | 4.31 | 2.41 | 2.17 | 0.58 | 0.04 | | | | | | | 14.41 |
| | 11 | | 0.21 | 2.01 | 4.17 | 2.41 | 1.39 | 1.15 | 0.42 | 0.05 | | | | | | 11.80 |
| | 12 | | 0.22 | 1.35 | 2.02 | 1.41 | 0.69 | 0.50 | 0.48 | 0.33 | 0.14 | 0.01 | | | | 7.14 |
| | 13 | | 0.22 | 0.73 | 1.18 | 1.23 | 0.68 | 0.33 | 0.21 | 0.19 | 0.21 | 0.13 | 0.02 | | | 5.13 |
| | 14 | | 0.04 | 0.15 | 0.43 | 0.59 | 0.39 | 0.15 | 0.09 | 0.04 | 0.04 | 0.07 | 0.06 | 0.02 | | 2.09 |
| | 15 | | 0.01 | 0.01 | 0.04 | 0.05 | 0.06 | 0.03 | 0.01 | | | | 0.01 | 0.01 | 0.01 | 0.24 |
| | 16 | | 0.02 | 0.02 | 0.03 | 0.04 | 0.02 | 0.01 | | | | | | | | 0.14 |
| | 17 | | 0.01 | 0.01 | 0.01 | | | | | | | | | | | 0.03 |
| | 18 | | | | | | | | | | | | | | | 0.00 |
| | | | 15.00 | 33.61 | 24.32 | 13.80 | 6.58 | 2.81 | 1.24 | 0.61 | 0.39 | 0.22 | 0.09 | 0.03 | 0.01 | 99.93 |

## 2.6 Tropical Systems

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

Since 1950, 41 tropical systems have passed within 278 km of 46°23'N;48°16'W. The names are given in Table 2.10 and the tracks over the Grand Banks are shown in Figure 2.18. It must be noted that the values in the table are the maximum 1-minute mean winds speeds occurring within the tropical system at the 10-metre reference level as it passed within 65 nm of the location.

On occasion, these systems still maintain their tropical characteristics when they reach Newfoundland. On October 02, 1975, Hurricane Gladys, a Category 4 Hurricane as it passed east of Cape Hatteras tracked northeast towards the Grand Banks. Gladys, still a Category 2 Hurricane with 43.7 m/s winds and a central pressure of 960 mb on October 03 moved northeast across the Grand Banks and maintained Hurricane strength until it moved north of 50° latitude where it weakened to a post-tropical storm. As this system passed over the region, the MSC50 data set has peak winds speeds of 22.5 m/s and wave heights of 7.1 metres at Grid Point 10255, and peak wind speeds of 21.3 m/s and wave heights of 7.2 metres at Grid point 10439. Winds speeds of 19.5 m/s and 9 metre waves were recorded in the ICOADS data set as the system passed.

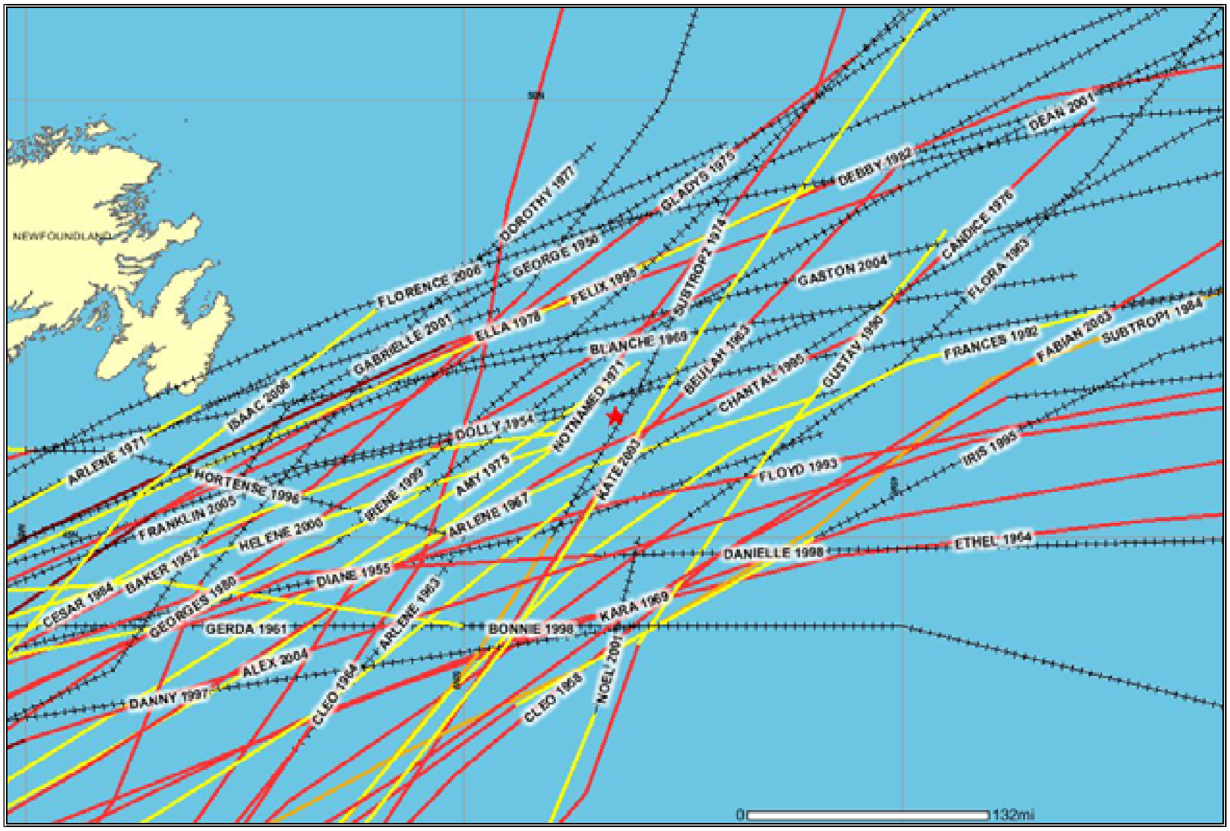



**Figure 2.18 Storm Tracks of Tropical Systems Passing within 278 km of 46°23'N 48°16'W, 1956 to 2006**

**Table 2.10 Tropical Systems Passing within 278 km of 46°23’N 48°16’W, 1950 to 2006**

| Name | Year | Month | Day | Hour(Z) | Wind (m/s) | Pressure (mb) | Category |
|---|---|---|---|---|---|---|---|
| George | 1950 | 10 | 5 | 1200Z | 30.9 | N/A | Post-Tropical |
| Baker | 1952 | 9 | 8 | 1200Z | 30.9 | N/A | Post-Tropical |
| Dolly | 1954 | 9 | 3 | 1200Z | 25.7 | N/A | Post-Tropical |
| Diane | 1955 | 8 | 21 | 1200Z | 18.0 | N/A | Post-Tropical |
| Cleo | 1958 | 8 | 20 | 0000Z | 38.6 | N/A | Category 1 Hurricane |
| Gerda | 1961 | 10 | 22 | 1200Z | 15.4 | N/A | Post-Tropical |
| Beulah | 1963 | 8 | 28 | 0000Z | 36.0 | N/A | Category 1 Hurricane |
| Flora | 1963 | 10 | 12 | 1800Z | 38.6 | N/A | Post-Tropical |
| CLeo | 1964 | 9 | 4 | 1800Z | 36.0 | N/A | Category 1 Hurricane |
| Ethel | 1964 | 9 | 15 | 0600Z | 38.6 | N/A | Category 1 Hurricane |
| Arlene | 1967 | 9 | 4 | 0600Z | 30.9 | N/A | Tropical Storm |
| Blanche | 1969 | 8 | 13 | 0000Z | 25.7 | N/A | Post-Tropical |
| Kara | 1969 | 10 | 18 | 0600Z | 41.2 | 980 | Category 1 Hurricane |
| NotNamed | 1971 | 8 | 6 | 1200Z | 38.6 | 974 | Category 1 Hurricane |
| SubTrop2 | 1974 | 7 | 20 | 0600Z | 20.6 | N/A | Post-Tropical |
| Gladys | 1975 | 10 | 3 | 1200Z | 43.7 | 960 | Category 2 Hurricane |
| Candice | 1976 | 8 | 24 | 0000Z | 41.2 | N/A | Category 1 Hurricane |
| Dorothy | 1977 | 9 | 30 | 0000Z | 25.7 | 995 | Post-Tropical |
| Ella | 1978 | 9 | 5 | 0600Z | 41.2 | 975 | Category 1 Hurricane |
| Georges | 1980 | 9 | 8 | 1200Z | 35.0 | 993 | Category 1 Hurricane |
| Debby | 1982 | 9 | 19 | 0600Z | 38.6 | 979 | Category 1 Hurricane |
| SubTrop1 | 1984 | 8 | 20 | 1800Z | 25.7 | 1002 | Sub-Tropical |
| Cesar | 1984 | 9 | 2 | 1200Z | 25.7 | 994 | Tropical Storm |
| Gustav | 1990 | 9 | 3 | 0000Z | 28.3 | 993 | Tropical Storm |
| Farances | 1992 | 10 | 26 | 1800Z | 28.3 | 988 | Tropical Storm |
| Floyd | 1993 | 9 | 10 | 0600Z | 33.4 | 990 | Category 1 Hurricane |
| Chantal | 1995 | 7 | 20 | 1800Z | 25.7 | 1000 | Post-Tropical |
| Felix | 1995 | 8 | 22 | 1200Z | 25.7 | 985 | Tropical Storm |
| Iris | 1995 | 9 | 4 | 1200Z | 30.9 | 995 | Post-Tropical |
| Danielle | 1998 | 9 | 4 | 0000Z | 33.4 | 975 | Post-Tropical |
| Irene | 1999 | 10 | 19 | 1200Z | 41.2 | 968 | Post-Tropical |
| Dean | 2001 | 8 | 29 | 0000Z | 23.1 | 999 | Post-Tropical |
| Gabrielle | 2001 | 9 | 19 | 1800Z | 30.9 | 986 | Post-Tropical |
| Fabian | 2003 | 9 | 8 | 0000Z | 36.0 | 975 | Category 1 Hurricane |
| Kate | 2003 | 10 | 7 | 1800Z | 30.9 | 980 | Tropical Storm |
| Alex | 2004 | 8 | 6 | 0000Z | 38.6 | 978 | Category 1 Hurricane |
| Gaston | 2004 | 9 | 2 | 0000Z | 23.1 | 997 | Post-Tropical |
| Franklin | 2005 | 7 | 30 | 1800Z | 20.6 | 1006 | Post-Tropical |
| Florence | 2006 | 9 | 14 | 0600Z | 30.9 | 967 | Post-Tropical |
| Isaac | 2006 | 10 | 3 | 0000Z | 28.3 | 996 | Post-Tropical |

# 3.0 Extreme Wind and Waves Conditions

An analysis of extreme wind and waves was performed using the MSC50 data set. This data set was determined to be the most representative of the available data sets, as it provides a continuous 52-year period of hourly data for the study area. The extreme values for wind and waves were calculated using the peak-over-threshold method, and after considering four different distributions, the Gumbel distribution was chosen to be the most representative as it provided the best fit to the data.

Two grid points, deemed to give an accurate depiction of conditions within the region, were used in this analysis: grid point 10255 located at 46.3°N; 48.4°W and grid point 10439 located at 46.4°N; 48.1°W. Since extreme values can vary depending on how well the data fits the distribution, a sensitivity analysis was carried out to determine the number storms to use. The number of storms determined to provide the best fit annually and monthly for each grid point is presented in Table 3.1.

**Table 3.1 Number of Storms Providing Best Fit for Extreme Value Analysis of Winds and Waves**

| | | Annually | Monthly |
|---|---|---|---|
| Grid Point 10255 | Wind | 314 | 71 |
| | Wave | 323 | 73 |
| Grid Point 10439 | Wind | 317 | 72 |
| | Wave | 309 | 70 |

## 3.1 Extreme Value Estimates for Winds from the Gumbel Distribution

The extreme value estimates for wind were calculated using Oceanweather’s Osmosis software program for the return periods of 1-year, 10-years, 25-years, 50-years and 100-years. The calculated annual and monthly values for 1-hour, 10-minutes and 1-minute are presented in Table 3.2 to Table 3.4. The analysis used hourly mean wind values for the reference height of 10-metres above sea level. These values were converted to 10-minute and 1-minute wind values using a constant ration of 1.06 and 1.22, respectively (U.S. Geological Survey, 1979). The annual 100-year extreme 1-hour wind speed was determined to be 31.5 m/s for grid point 10255 and 31.6 m/s at grid point 10439. The 10-minute wind speed had a 100-year return period of 33.4 m/s at both grid points. .

A comparison of these values, with actual values measured by platforms on the Grand Banks was not possible. Logarithmic profiles for adjusting wind speeds from anemometer height to the surface are valid only in neutral or unstable conditions. Observations from platforms on the Grand Banks over the past ten years frequently show stable conditions in which the surface layer wind speed profiles are not valid. Using a logarithmic profile to adjust wind speeds between the 10-metre and anemometer level would therefore introduce an unnecessary source of error in the results.

**Table 3.2 1-hr Extreme Wind Speed Estimates for Return Periods of 1, 10, 25, 50 and 100 Years**

| | GridPoint #10255 | | | | | GridPoint #10439 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | **1** | **10** | **25** | **50** | **100** | **1** | **10** | **25** | **50** | **100** |
| **January** | 22.1 | 25.6 | 26.7 | 27.6 | 28.5 | 22.2 | 25.7 | 26.8 | 27.7 | 28.5 |
| **February** | 21.9 | 26.8 | 28.3 | 29.5 | 30.7 | 22.0 | 26.7 | 28.3 | 29.5 | 30.7 |
| **March** | 20.0 | 24.5 | 25.9 | 27.0 | 28.1 | 20.1 | 24.5 | 25.9 | 27.0 | 28.1 |
| **April** | 18.0 | 22.1 | 23.5 | 24.5 | 25.5 | 18.0 | 22.3 | 23.7 | 24.8 | 25.8 |
| **May** | 15.3 | 19.2 | 20.5 | 21.4 | 22.4 | 15.4 | 19.4 | 20.8 | 21.8 | 22.8 |
| **June** | 14.1 | 17.6 | 18.8 | 19.7 | 20.5 | 14.1 | 17.8 | 19.0 | 19.9 | 20.8 |
| **July** | 13.0 | 17.1 | 18.4 | 19.4 | 20.4 | 13.1 | 17.0 | 18.3 | 19.3 | 20.2 |
| **August** | 13.7 | 20.6 | 22.9 | 24.6 | 26.3 | 13.6 | 20.6 | 22.9 | 24.7 | 26.4 |
| **September** | 16.7 | 22.0 | 23.8 | 25.1 | 26.3 | 16.8 | 21.9 | 23.6 | 24.9 | 26.1 |
| **October** | 17.9 | 23.3 | 25.1 | 26.4 | 27.7 | 18.0 | 23.2 | 24.9 | 26.2 | 27.5 |
| **November** | 19.6 | 24.4 | 26.0 | 27.1 | 28.3 | 19.6 | 24.4 | 26.0 | 27.2 | 28.4 |
| **December** | 21.4 | 26.2 | 27.8 | 29.0 | 30.1 | 21.5 | 26.3 | 27.9 | 29.0 | 30.2 |
| **Annual** | 24.7 | 28.1 | 29.5 | 30.5 | 31.5 | 24.8 | 28.2 | 29.5 | 30.5 | 31.6 |

**Table 3.3 10-min Extreme Wind Speed Estimates for Return Periods of 1, 10, 25, 50 and 100 Years**

| | GridPoint #10255 | | | | | GridPoint #10439 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **10** | **25** | **50** | **100** | **1** | **10** | **25** | **50** | **100** |
| **January** | 23.4 | 27.1 | 28.3 | 29.3 | 30.2 | 23.5 | 27.2 | 28.4 | 29.3 | 30.2 |
| **February** | 23.2 | 28.4 | 30.0 | 31.3 | 32.6 | 23.3 | 28.3 | 30.0 | 31.3 | 32.5 |
| **March** | 21.2 | 25.9 | 27.5 | 28.7 | 29.8 | 21.3 | 25.9 | 27.5 | 28.6 | 29.8 |
| **April** | 19.1 | 23.5 | 24.9 | 26.0 | 27.1 | 19.1 | 23.6 | 25.1 | 26.2 | 27.4 |
| **May** | 16.2 | 20.3 | 21.7 | 22.7 | 23.7 | 16.3 | 20.6 | 22.0 | 23.1 | 24.1 |
| **June** | 14.9 | 18.7 | 19.9 | 20.9 | 21.8 | 14.9 | 18.9 | 20.2 | 21.1 | 22.1 |
| **July** | 13.7 | 18.1 | 19.5 | 20.6 | 21.6 | 13.8 | 18.0 | 19.4 | 20.4 | 21.5 |
| **August** | 14.5 | 21.8 | 24.3 | 26.1 | 27.9 | 14.4 | 21.8 | 24.3 | 26.1 | 28.0 |
| **September** | 17.7 | 23.3 | 25.2 | 26.6 | 27.9 | 17.8 | 23.2 | 25.0 | 26.4 | 27.7 |
| **October** | 18.9 | 24.7 | 26.6 | 28.0 | 29.4 | 19.1 | 24.6 | 26.4 | 27.8 | 29.2 |
| **November** | 20.7 | 25.8 | 27.5 | 28.8 | 30.0 | 20.7 | 25.9 | 27.5 | 28.8 | 30.1 |
| **December** | 22.7 | 27.8 | 29.4 | 30.7 | 31.9 | 22.8 | 27.9 | 29.5 | 30.8 | 32.0 |
| **Annual** | 26.2 | 29.8 | 31.2 | 32.3 | 33.4 | 26.2 | 29.9 | 31.3 | 32.4 | 33.4 |

**Table 3.4 1-min Extreme Wind Speed Estimates for Return Periods of 1, 10, 25, 50 and 100 Years**

| | GridPoint #10255 | | | | | GridPoint #10439 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **10** | **25** | **50** | **100** | **1** | **10** | **25** | **50** | **100** |
| **January** | 26.9 | 31.2 | 32.6 | 33.7 | 34.7 | 27.1 | 31.3 | 32.7 | 33.8 | 34.8 |
| **February** | 26.7 | 32.6 | 34.6 | 36.0 | 37.5 | 26.8 | 32.6 | 34.6 | 36.0 | 37.4 |
| **March** | 24.4 | 29.9 | 31.6 | 33.0 | 34.3 | 24.5 | 29.9 | 31.6 | 32.9 | 34.2 |
| **April** | 22.0 | 27.0 | 28.7 | 29.9 | 31.1 | 22.0 | 27.2 | 28.9 | 30.2 | 31.5 |
| **May** | 18.7 | 23.4 | 25.0 | 26.1 | 27.3 | 18.7 | 23.7 | 25.3 | 26.6 | 27.8 |
| **June** | 17.2 | 21.5 | 22.9 | 24.0 | 25.1 | 17.2 | 21.7 | 23.2 | 24.3 | 25.4 |
| **July** | 15.8 | 20.8 | 22.4 | 23.7 | 24.9 | 15.9 | 20.7 | 22.3 | 23.5 | 24.7 |
| **August** | 16.7 | 25.1 | 27.9 | 30.0 | 32.1 | 16.6 | 25.1 | 28.0 | 30.1 | 32.2 |
| **September** | 20.4 | 26.9 | 29.0 | 30.6 | 32.1 | 20.4 | 26.7 | 28.8 | 30.4 | 31.9 |
| **October** | 21.8 | 28.4 | 30.6 | 32.2 | 33.8 | 21.9 | 28.3 | 30.4 | 32.0 | 33.6 |
| **November** | 23.9 | 29.7 | 31.7 | 33.1 | 34.6 | 23.9 | 29.8 | 31.7 | 33.2 | 34.6 |
| **December** | 26.2 | 32.0 | 33.9 | 35.3 | 36.7 | 26.3 | 32.1 | 34.0 | 35.4 | 36.9 |
| **Annual** | 30.1 | 34.3 | 36.0 | 37.2 | 38.4 | 30.2 | 34.4 | 36.0 | 37.3 | 38.5 |

## 3.2 Extreme Value Estimates for Waves from a Gumbel Distribution

The annual and monthly extreme value estimates for significant wave height for return periods of 1-year, 10-years, 25-years, 50-years and 100-years are given in Table 3.5. The annual 100-year extreme significant wave height ranged from 15.4 metres at grid point 10439 to 15.2 metres at grid point 10255. The 50-year extreme significant wave heights vary between 14.5 m and 14.7 m. These significant wave heights correspond with a significant wave height of 14.66 metres recorded over a 20-minute interval by a waverider buoy in the area on February 11, 2003. A storm with a return period of 50 years means that the calculated significant wave height will occur once every 50 years, averaged over a long period of time. It is entirely possible that this event was a 50-year or longer return period storm. The value recorded on February 11, 2003 was the highest recorded significant wave height in a near continuous waverider data set extending back to early 1999. The previous highest recorded value in this data set was 12.47 metres, which occurred on January 25, 2003. The maximum significant wave heights measured during the "Ocean Ranger" storm of 1982 was approximately 12 m. However, the waves may have been higher during the "Ocean Ranger" storm because immediately before the highest peak was recorded there was a communication gap in the waverider data signifying that the waverider may have been underwater. If more occurrences of an event of this magnitude were observed, the calculated statistics would consequently begin to increase.

**Table 3.5 Extreme Significant Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years**

| | Grid Point #10255 | | | | | Grid Point #10439 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **10** | **25** | **50** | **100** | **1** | **10** | **25** | **50** | **100** |
| **January** | 8.8 | 11.9 | 12.9 | 13.7 | 14.4 | 9.0 | 12.1 | 13.1 | 13.9 | 14.6 |
| **February** | 8.3 | 11.9 | 13.1 | 14.0 | 14.9 | 8.4 | 12.1 | 13.3 | 14.2 | 15.1 |
| **March** | 7.1 | 10.1 | 11.1 | 11.8 | 12.6 | 7.2 | 10.3 | 11.3 | 12.0 | 12.8 |
| **April** | 5.8 | 8.6 | 9.5 | 10.2 | 10.9 | 5.8 | 8.7 | 9.7 | 10.4 | 11.2 |
| **May** | 4.6 | 6.9 | 7.7 | 8.3 | 8.9 | 4.6 | 7.1 | 7.9 | 8.5 | 9.1 |
| **June** | 3.7 | 5.8 | 6.5 | 7.0 | 7.6 | 3.7 | 5.9 | 6.7 | 7.2 | 7.7 |
| **July** | 3.4 | 5.3 | 6.0 | 6.4 | 6.9 | 3.4 | 5.4 | 6.0 | 6.5 | 7.0 |
| **August** | 3.8 | 6.2 | 7.0 | 7.6 | 8.2 | 3.8 | 6.3 | 7.1 | 7.7 | 8.3 |
| **September** | 5.3 | 8.5 | 9.6 | 10.4 | 11.2 | 5.3 | 8.6 | 9.7 | 10.5 | 11.3 |
| **October** | 6.2 | 9.6 | 10.7 | 11.6 | 12.4 | 6.2 | 9.8 | 11.0 | 11.8 | 12.7 |
| **November** | 7.4 | 10.3 | 11.2 | 11.9 | 12.7 | 7.4 | 10.5 | 11.5 | 12.3 | 13.0 |
| **December** | 8.6 | 11.6 | 12.5 | 13.2 | 14.0 | 8.8 | 11.8 | 12.8 | 13.5 | 14.3 |
| **Annual** | 10.5 | 12.9 | 13.8 | 14.5 | 15.2 | 10.7 | 13.1 | 14.0 | 14.7 | 15.4 |

The maximum individual wave heights were calculated within Oceanweather's OSMOSIS software by evaluating the Borgman integral (Borgman 1973), which was derived from a Raleigh distribution function. The variant of this equation used in the software has the following form (Forristall, 1978):

$$\Pr\{H > h\} = \exp\left[-1.08311\left(\frac{h^2}{8M_0}\right)^{1.063}\right]; \quad T = \frac{M_0}{M_1}$$

where h is the significant wave height, T is the wave period, and $M_0$ and $M_1$ are the first and second spectral moments of the total spectrum. The associated peak periods are calculated by plotting the peak periods of the chosen storm peak values versus the corresponding significant wave heights. This plot is fitted to a power function ($y = ax^b$), and the resulting equation is used to calculate the peak periods associated with the extreme values of significant wave height. The maximum individual wave heights and extreme associated peak periods are presented in Table 3.6 and Table 3.7. Maximum individual wave heights and the extreme associated peak periods occur during the month of February.

During a storm event on January 08, 2007 a maximum individual wave height of 22.63 metres was recorded by a waverider in the Terra Nova field. This is greater than the January maximum 10-year return period estimate of 21.8 metres for grid point 10255, which is the closest grid point to the Terra Nova waverider, however less than the 25-year return period estimate of 23.7 metres. The significant wave height during this event was 9.72 metres.

**Table 3.6 Extreme Maximum Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years**

| | Grid Point #10255 | | | | | Grid Point #10439 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **10** | **25** | **50** | **100** | **1** | **10** | **25** | **50** | **100** |
| **January** | 16.4 | 21.8 | 23.7 | 25.0 | 26.4 | 16.6 | 22.2 | 24.0 | 25.4 | 26.8 |
| **February** | 15.5 | 22.1 | 24.3 | 25.9 | 27.5 | 15.9 | 22.4 | 24.6 | 26.2 | 27.8 |
| **March** | 13.5 | 19.3 | 21.2 | 22.6 | 24.0 | 13.6 | 19.3 | 21.1 | 22.5 | 23.9 |
| **April** | 11.0 | 15.9 | 17.5 | 18.7 | 19.9 | 11.1 | 16.3 | 18.0 | 19.3 | 20.5 |
| **May** | 8.6 | 13.9 | 15.7 | 17.0 | 18.3 | 8.8 | 14.3 | 16.1 | 17.5 | 18.8 |
| **June** | 7.1 | 11.0 | 12.3 | 13.3 | 14.3 | 7.1 | 11.2 | 12.5 | 13.5 | 14.5 |
| **July** | 6.4 | 9.9 | 11.1 | 12.0 | 12.8 | 6.4 | 10.0 | 11.2 | 12.1 | 13.0 |
| **August** | 7.2 | 11.6 | 13.0 | 14.1 | 15.2 | 7.1 | 11.2 | 12.6 | 13.6 | 14.6 |
| **September** | 10.3 | 16.0 | 17.9 | 19.4 | 20.8 | 10.1 | 15.9 | 17.8 | 19.2 | 20.7 |
| **October** | 11.7 | 17.8 | 19.8 | 21.3 | 22.8 | 11.9 | 18.3 | 20.4 | 22.0 | 23.5 |
| **November** | 13.9 | 19.1 | 20.7 | 22.0 | 23.3 | 14.0 | 19.5 | 21.3 | 22.6 | 23.9 |
| **December** | 16.4 | 21.7 | 23.5 | 24.8 | 26.1 | 16.4 | 21.9 | 23.7 | 25.0 | 26.3 |
| **Annual** | 19.5 | 23.8 | 25.5 | 26.7 | 28.0 | 19.8 | 24.2 | 25.9 | 27.2 | 28.4 |

**Table 3.7 Extreme Associated Peak Period Estimates for Return Periods of 1, 10, 25, 50 and 100 Years**

| | Grid Point #10255 | | | | | Grid Point #10439 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **1** | **10** | **25** | **50** | **100** | **1** | **10** | **25** | **50** | **100** |
| **January** | 12.6 | 14.3 | 14.8 | 15.1 | 15.4 | 12.6 | 14.5 | 15.0 | 15.4 | 15.8 |
| **February** | 12.2 | 14.4 | 15.0 | 15.5 | 15.9 | 12.3 | 14.4 | 15.0 | 15.5 | 15.9 |
| **March** | 11.4 | 13.3 | 13.8 | 14.2 | 14.6 | 11.9 | 13.3 | 13.7 | 13.9 | 14.2 |
| **April** | 11.1 | 12.5 | 12.9 | 13.2 | 13.5 | 10.7 | 12.3 | 12.8 | 13.1 | 13.4 |
| **May** | 10.0 | 11.4 | 11.8 | 12.0 | 12.3 | 10.2 | 11.8 | 12.2 | 12.5 | 12.8 |
| **June** | 9.4 | 11.0 | 11.4 | 11.8 | 12.1 | 8.8 | 10.7 | 11.2 | 11.5 | 11.9 |
| **July** | 8.5 | 10.2 | 10.7 | 11.1 | 11.4 | 8.4 | 10.6 | 11.3 | 11.7 | 12.2 |
| **August** | 8.9 | 11.5 | 12.2 | 12.8 | 13.3 | 9.3 | 11.4 | 12.0 | 12.4 | 12.8 |
| **September** | 10.6 | 13.1 | 13.8 | 14.3 | 14.8 | 10.9 | 12.9 | 13.4 | 13.8 | 14.2 |
| **October** | 11.4 | 13.6 | 14.2 | 14.6 | 15.0 | 11.4 | 13.4 | 14.0 | 14.4 | 14.7 |
| **November** | 11.9 | 13.4 | 13.8 | 14.1 | 14.4 | 12.1 | 13.5 | 13.9 | 14.2 | 14.4 |
| **December** | 12.8 | 14.0 | 14.4 | 14.6 | 14.9 | 13.0 | 14.1 | 14.4 | 14.7 | 14.9 |
| **Annual** | 13.6 | 14.8 | 15.2 | 15.5 | 15.8 | 13.7 | 14.9 | 15.3 | 15.5 | 15.8 |

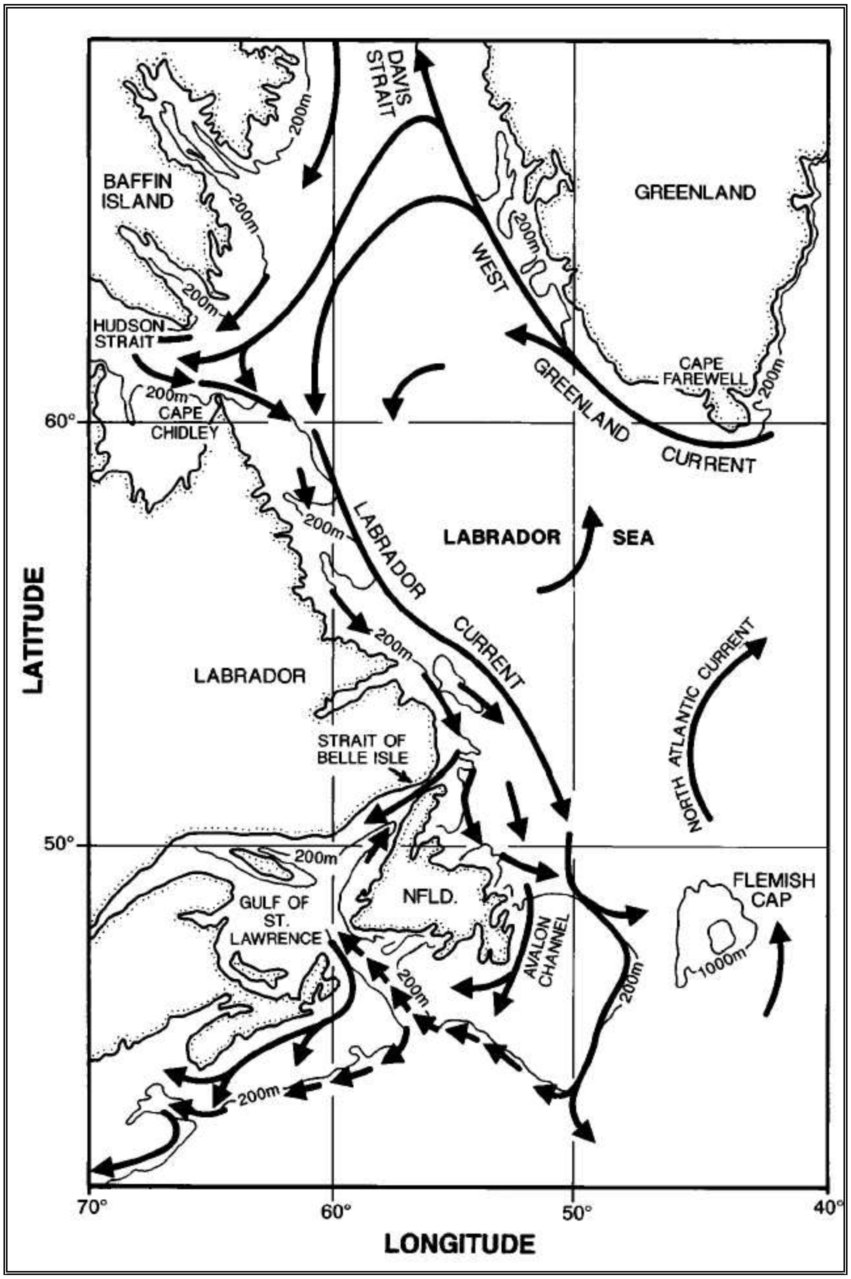
# 4.0 Physical Oceanography

## 4.1 General Description of the Major Currents

The large scale circulation offshore Newfoundland and Labrador is dominated by well established currents that flow along the margins of the Continental Shelf. The main circulatory feature near the study area is the Labrador Current, which transports sub-polar water to lower latitudes along the Continental Shelf of eastern Canada (Figure 4.1). Oceanographic studies show a strong western boundary current following the shelf break with relative low variability compared to the mean flow. Over the Grand Banks a weaker current system is observed where the variability often exceeds that of the mean flow (Colbourne, 2000).

The Labrador Current consists of two major branches. The inshore branch is located on the inner part of the shelf and its core is steered by the local underwater topography through the Avalon Channel. The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope. Lauzier and Wright (1993) found that the offshore branch of the Labrador Current offshore Labrador was located in a 50 km wide band between the 400 m and 1200 m isobaths. This branch of the Labrador Current divides between 48°W and 50°W, resulting in one sub-branch flowing to the east around Flemish Cap and the other flowing south around the eastern edge of the Grand Banks and through Flemish Pass. Characteristic current speeds on the Slope are in the order of 30 cm/sec to 50 cm/sec (Colbourne, 2000), while those in the central part of the Grand Banks are generally much lower, averaging between 5-15 cm/s.

The outer branch of the Labrador Current exhibits a distinct seasonal variation in flow speeds (Lazier and Wright, 1993), in which the mean flows is a maximum in October and a minimum in March and April. This annual cycle is reported to be the result of the large annual variation in the steric height over the continental shelf in relation to the much less variable internal density characteristic of the adjoining deep waters. The additional freshwater in spring and summer is largely confined to the waters over the shelf. In summer, the difference in sea level between the shelf and open ocean is 0.09 m greater than in winter (Lazier and Wright, 1993). This difference produces a greater horizontal surface pressure gradient and hence stronger mean flows.




*Source:* Colbourne et al., 1997

**Figure 4.1 Mayor Ocean Circulation Features in the Northwest Atlantic**

Figure 4.2 shows the trajectories and mean current velocities calculated by Pepin and Helbig (1997) of 41 satellite tracked drifting buoys that were placed the Labrador Current near Hamilton Bank during 1992 and 1994. This figure illustrated the general pattern of the spatial distribution of the surface currents in the northeast sector of the Newfoundland Shelf.

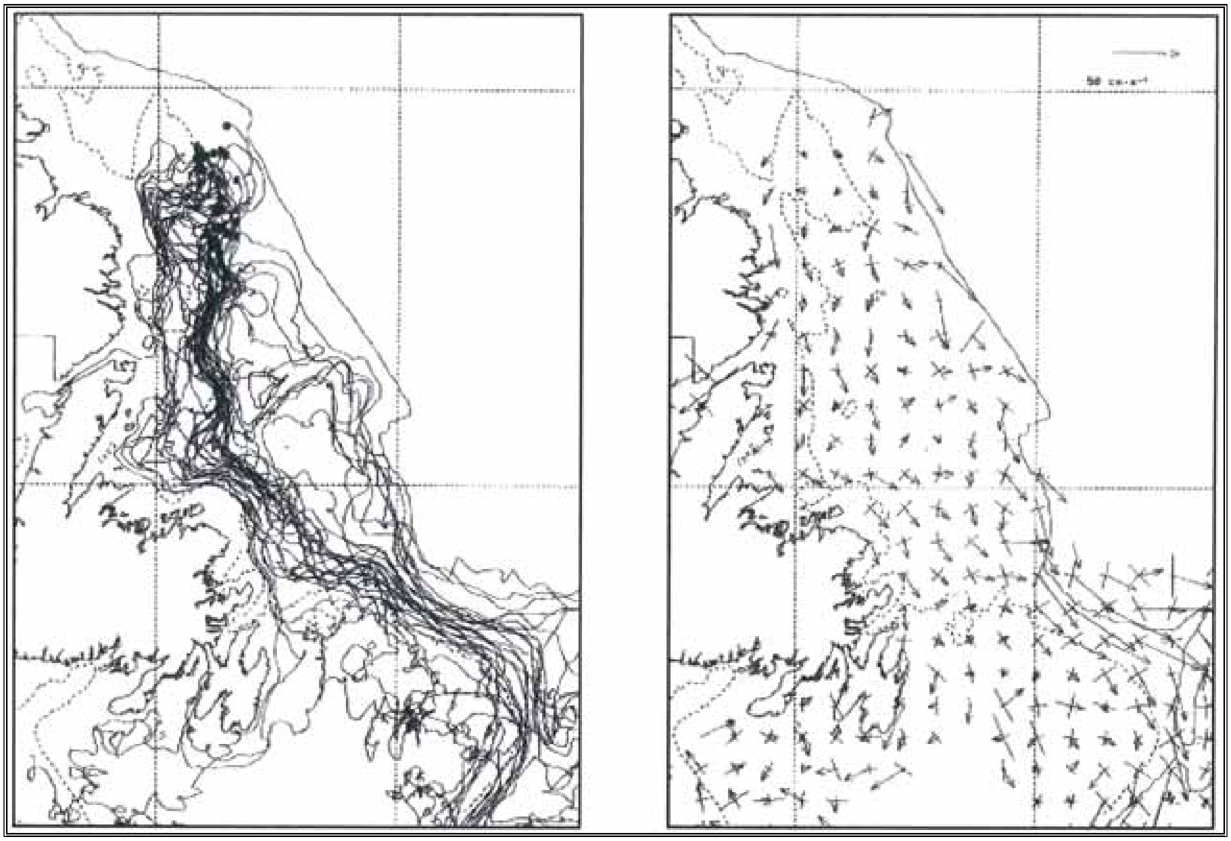


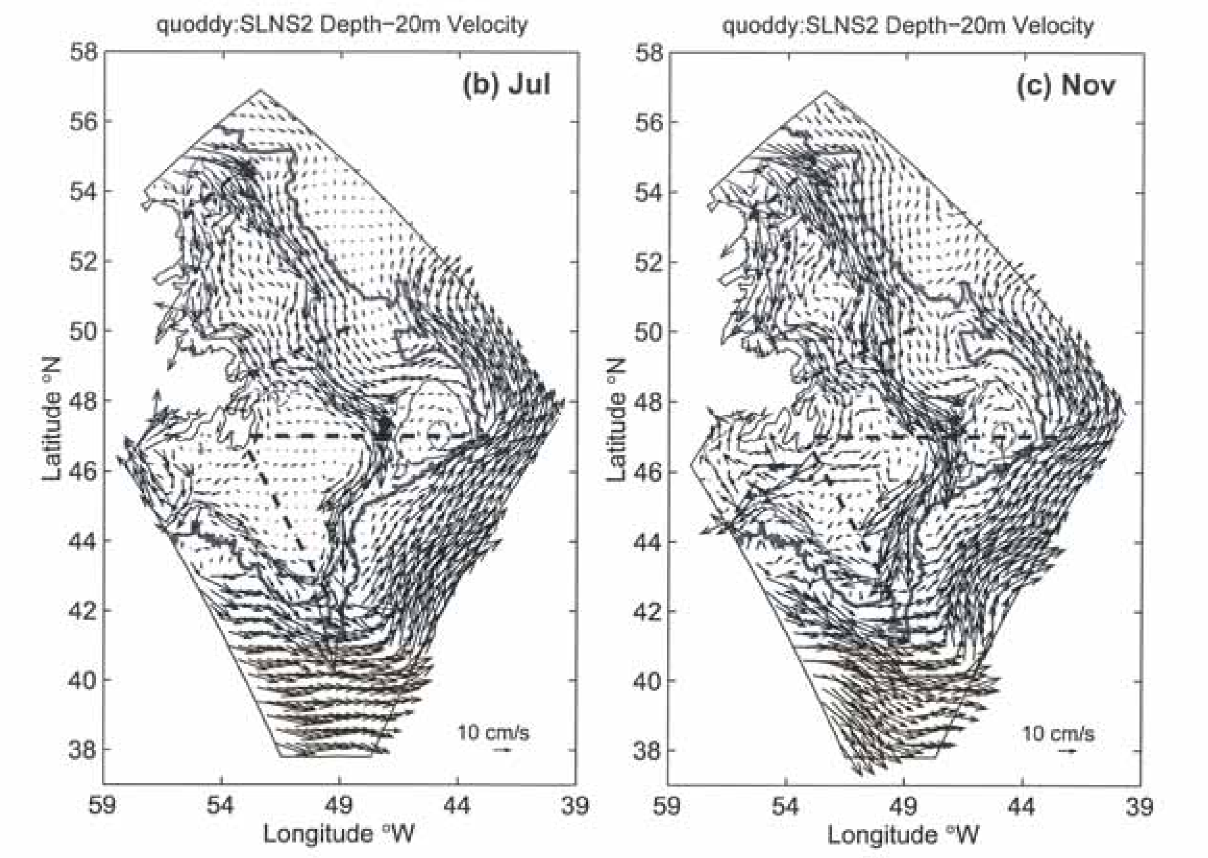
**Figure 4.2 Currents on the northeast Newfoundland Shelf as inferred from 149 drifting buoys by Pepin and Helbig (1997)**

*Left Panel: Low-pass-filtered drifting buoys tracks. Drop locations are indicated by circles and terminal positions by asterisks.*

*Right Panel: Mean surface currents derived from spatial averages of all drifting buoy tracks. The principal axes of variation are indicated by crosses.*

Another major current system is situated to the south of the Grand Banks. In the area of the Southeast Newfoundland Rise, the Gulf Stream branches into two streams. The southern branch continues east at approximately 40°N. The northern branch, known as the North Atlantic Current, turns north and flows along the Continental Slope southeast of the Grand Banks and continues northeastward along the east side of Flemish Cap. This circulation pattern is captured in the nonlinear finite element model produced by Han and Wang (2005) and shown in Figure 4.3.

There is evidence that on occasion a secondary branch of the North Atlantic Current may flow northward in Flemish Pass (Colbourne and Foote, 2000), transporting warmer high salinity water along the southeast slope of the Grand Banks.




*(from* Han and Wang, 2005*)*

**Figure 4.3 Model circulation fields at the 20 m depth for (2a) July and (b) November, representing the summer and fall respectively**

## 4.2 Currents in the Project Area

In the central region of the Grand Banks, the currents are mainly due to wind stress, tides, and low frequency oscillations related to the passage of storm systems.

Wind stress is an important driving force for the currents on the Continental Shelf, with a distinct annual cycle of comparatively strong winds in winter and weaker more variable winds in summer. An analysis of an array of current meter data collected from January to May 1992 by De Tracey et al. (1996) on the northeastern section of the Grand Banks showed that the near-surface currents and local wind are highly coherent in the shallow region of the Grand Banks, suggesting that the currents on the Grand Banks have a strong wind driven component.

Tides play a major role in the currents on the Grand Banks. The major tidal semidiurnal constituents are $M_2$ and $S_2$ and the major diurnal constituents are $O_1$ and $K_1$. The values of the tidal constituents at Terra Nova are given in Table 4.1. The contributions by the tidal currents to the overall speed are equivalent to the value of the mean current speeds on the shallow regions of the Grand Banks.

**Table 4.1 Tidal constituents (cm/sec) at Terra Nova from current meter records**

| | $M_2$ | $S_2$ | $O_1$ | $K_1$ |
|---|---|---|---|---|
| Surface | 6.9 | 2.8 | 3.2 | 3.5 |
| Mid-depth | 5.9 | 2.1 | 2.8 | 3.0 |
| Near bottom | 5.1 | 1.8 | 2.8 | 3.0 |

The semi-diurnal tidal currents rotate through 360° twice per day in a clockwise direction. The diurnal tidal ellipses at Terra Nova are almost circular showing no preferred direction, and the semidiurnal tidal ellipses are slightly elongated in a northwest/southeast direction.

Overall, the tidal currents at Terra Nova are responsible for about 30% of the variability near the surface and at mid-depth, and for 20% of the variability near the bottom.

The low frequency components are the most important contributor to the overall flow. The strongest currents have been observed to always occur during the passage of low pressure systems. Some of the flow can be attributed to direct effects of the wind stress upon the sea surface as indicated by an inertial period signal showing up in spectral analysis of the data. Spectral analysis shows that the low frequency components are in the period range of 4 to 7 days. The barotropic component appears to be the largest component of the strong flows.

Tables 4.2 to 4.4 present current values at Terra Nova measured 20 m below the surface, at mid-depth, and at 10 m above the bottom. Tables 4.2 to 4.4 present typical maximum speeds and directions, mean velocities, and mean speeds for each month. The identifier in the table is only for the maximum speeds and directions to identify the data set from which the values were extracted. The mean speeds and velocities have been averaged from different data sets covering a few years for each month and depth. Since the degree of variability at Terra Nova is high, different data sets will have the maximum currents in different directions and the mean velocities may also be different in both magnitude and direction.

**Table 4.2 Near-surface Currents at Terra Nova**

| Month | Identifier | Max Speed (cm/sec) | Direction | Mean Speed (cm/sec) | Mean Velocity (cm/sec) | Direction (°T) |
|---|---|---|---|---|---|---|
| January | TN9904 | 48 | E | 13 | 5.6 | 183 |
| February | TN0301 | 59 | ENE | 13 | 3.6 | 178 |
| March | TH0201 | 45 | SE, E | 12 | 4.7 | 171 |
| April | TN0101 | 41 | N | 12 | 1.6 | 170 |
| May | TN0302 | 57 | N | 13 | 2.0 | 211 |
| June | TN0102 | 52 | W | 12 | 1.7 | 127 |
| July | TN0102 | 39 | E | 12 | 0.9 | 198 |
| August | TN0003 | 60 | NW | 13 | 0.8 | 265 |
| September | TN0003 | 77 | SSW | 18 | 2.0 | 213 |
| October | TN0203 | 57 | N | 18 | 2.7 | 196 |
| November | TN9904 | 48 | E, S | 14 | 4.3 | 357 |
| December | TN9904 | 59 | S | 13 | 1.4 | 28 |

**Table 4.3 Mid-depth Currents at Terra Nova**

| Month | Identifier | Max Speed (cm/sec) | Direction | Mean Speed (cm/sec) | Mean Velocity (cm/sec) | Direction (°T) |
|---|---|---|---|---|---|---|
| January | TNC09 | 19 | S | 11 | 3.5 | 287 |
| February | TNC09 | 30 | W, SE, E | 11 | 1.1 | 286 |
| March | TN0201 | 42 | SSW | 10 | 3.0 | 183 |
| April | TN0201 | 36 | SSW | 10 | 1.3 | 194 |
| May | TN0002 | 31 | NE | 9 | 0.8 | 174 |
| June | TN0002 | 34 | NE, NW | 10 | 1.7 | 208 |
| July | TN0002 | 30 | E | 9 | 1.8 | 308 |
| August | TN0102 | 25 | E, NW | 10 | 2.4 | 324 |
| September | TN0202 | 25 | SE, SW, W | 11 | 1.2 | 177 |
| October | TN0103 | 29 | SW | 12 | 1.1 | 305 |
| November | TN0004 | 41 | W | 11 | 0.6 | 334 |
| December | TN0004 | 37 | SW | 11 | 0.7 | 232 |

**Table 4.4 Near-bottom current values for Terra Nova**

| Month | Identifier | Max Speed (cm/sec) | Direction | Mean Speed (cm/sec) | Mean Velocity (cm/sec) | Direction (°T) |
|---|---|---|---|---|---|---|
| January | TN0104 | 36 | N | 12 | 4.2 | 193 |
| February | TN03013 | 42 | E, S, E | 12 | 2.6 | 167 |
| March | TN0201 | 32 | SE, S, SW | 11 | 2.5 | 177 |
| April | TN009 | 27 | N | 9 | 3.0 | 205 |
| May | TN0002 | 28 | E | 8 | 1.3 | 159 |
| June | TN0002 | 26 | NE | 8 | 0.7 | 169 |
| July | TN0202 | 20 | NE | 8 | 0.5 | 296 |
| August | TN0202 | 24 | NW | 10 | 2.0 | 310 |
| September | TN0002 | 30 | NE | 10 | 0.2 | 135 |
| October | TN0003 | 41 | E | 10 | 0.41 | 296 |
| November | TN0303 | 29 | NE, SE, SW, N | 11 | 0.6 | 89 |
| December | TN0303 | 32 | NW, N | 11 | 0.4 | 283 |

The current values presented in Tables 4.2 to 4.4 are valid for EL 1101 and SDL 1040. Parcel 1100 is in slightly deeper water and there are no current meter records available for this area. However, the currents would not present any difficulties for seismic work or exploration drilling because there are no sharp density gradients in the water column, irregular bathymetry, or close enough to the shelf break to find major differences in the currents.

## 4.3 Water Mass Structure

The water structure on the northeastern section of the Grand Banks of Newfoundland is characterized by the presence of three identifiable features.

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

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

Figure 4.4 shows average bottom temperature during the decade from 1991 to 2000. The figure shows that positive bottom temperatures are found south of 46°N. The blue area to the north of 46° N in Figure 4.1 corresponds to the average spread of the Cold Intermediate Layer. The variabilities in temperature and salinity in the area have been the subject of systematic research (Colbourne, 2004; Colbourne et al., 1997; Colbourne and Foote, 2000). These studies suggest that the water properties on the Grand Banks experience notable temporal variability. Colbourne (2004) explains that bottom temperatures ranged from near record lows during 1991 to very high values in the late 90’s. The areal coverage of the Cold Intermediate Layer was highest on the Newfoundland Shelf during years 1972, 1984 and 1991 (Colbourne, 2004). Since 1991, the areal coverage of the Cold Intermediate Layer has been decreasing.

Bottom temperature and salinity maps were produced by Colbourne et al. (2007) by trawl-mounted CTD data from approximately 700 fishing tows during the fall of 2005. These maps are presented in Figure 4.5. Both Figures 4.4 and 4.5 shows that the Cold Intermediate Layer is still present near the bottom in the Project Area and in EL 1100, 1101 and SDL 1040.

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

During the last 50 years there have been three warming periods in the Labrador Sea; 1960 to 1971, 1977 to 1983, and 1994 to present. In 1994, the Labrador Sea water filled the entire central part of the Labrador Sea basin within the depth range of 500-2400 m (Yashayaev and Clarke, 2006). The warming trend since 1994 has caused the water to become warmer, saltier, and more stratified; thus making it more difficult for winter renewal of Labrador Sea Water to take place. Unusual warming took place in 2004 believed to have originated from waters transported north and west by the North Atlantic Current and the Irminger Current (Yashayaev and Clarke, 2006).

The temperature and salinity boundary between the water on the Shelf and the water in Flemish Pass is shown in Figure 4.6 from CTD data collected during April 2007 along the routinely sampled Flemish Cap transect.

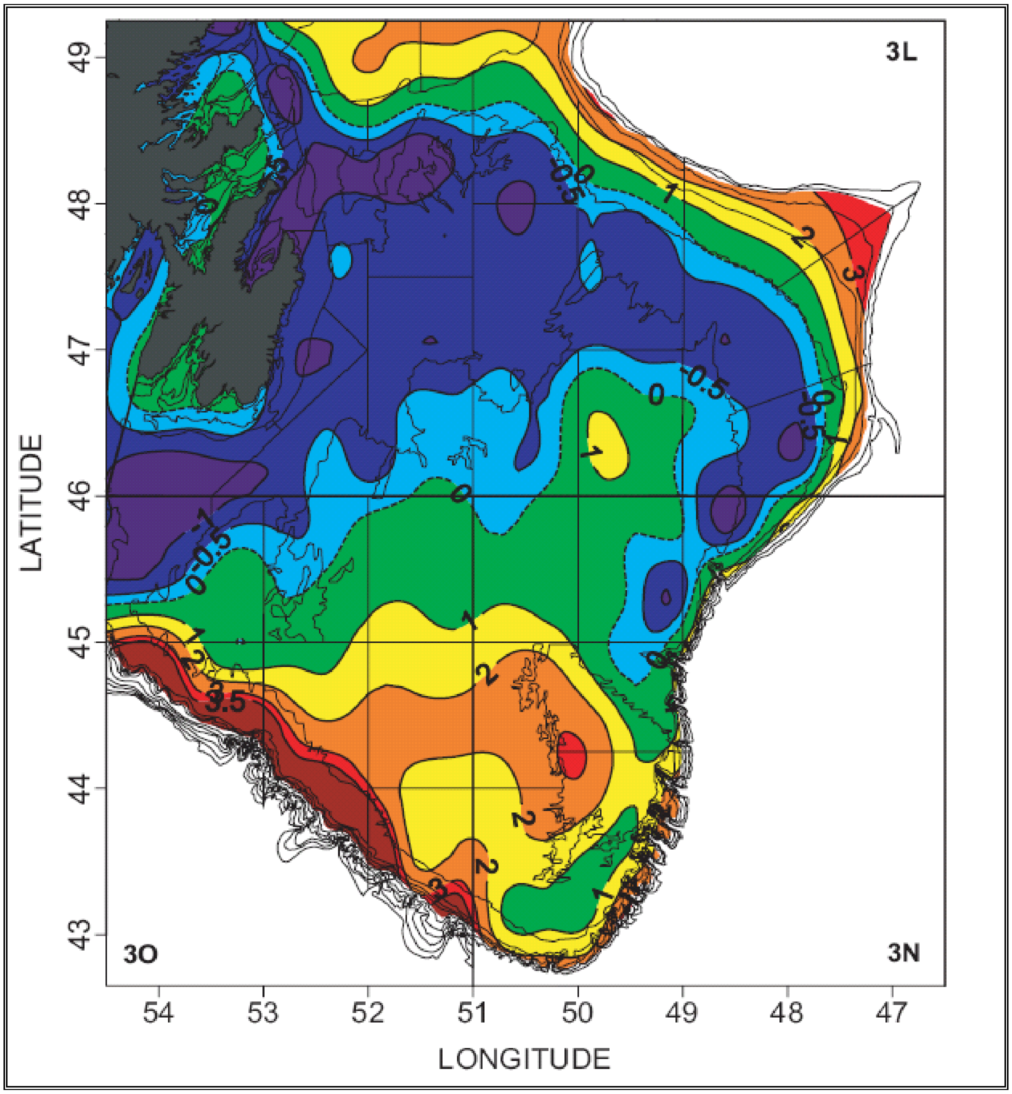
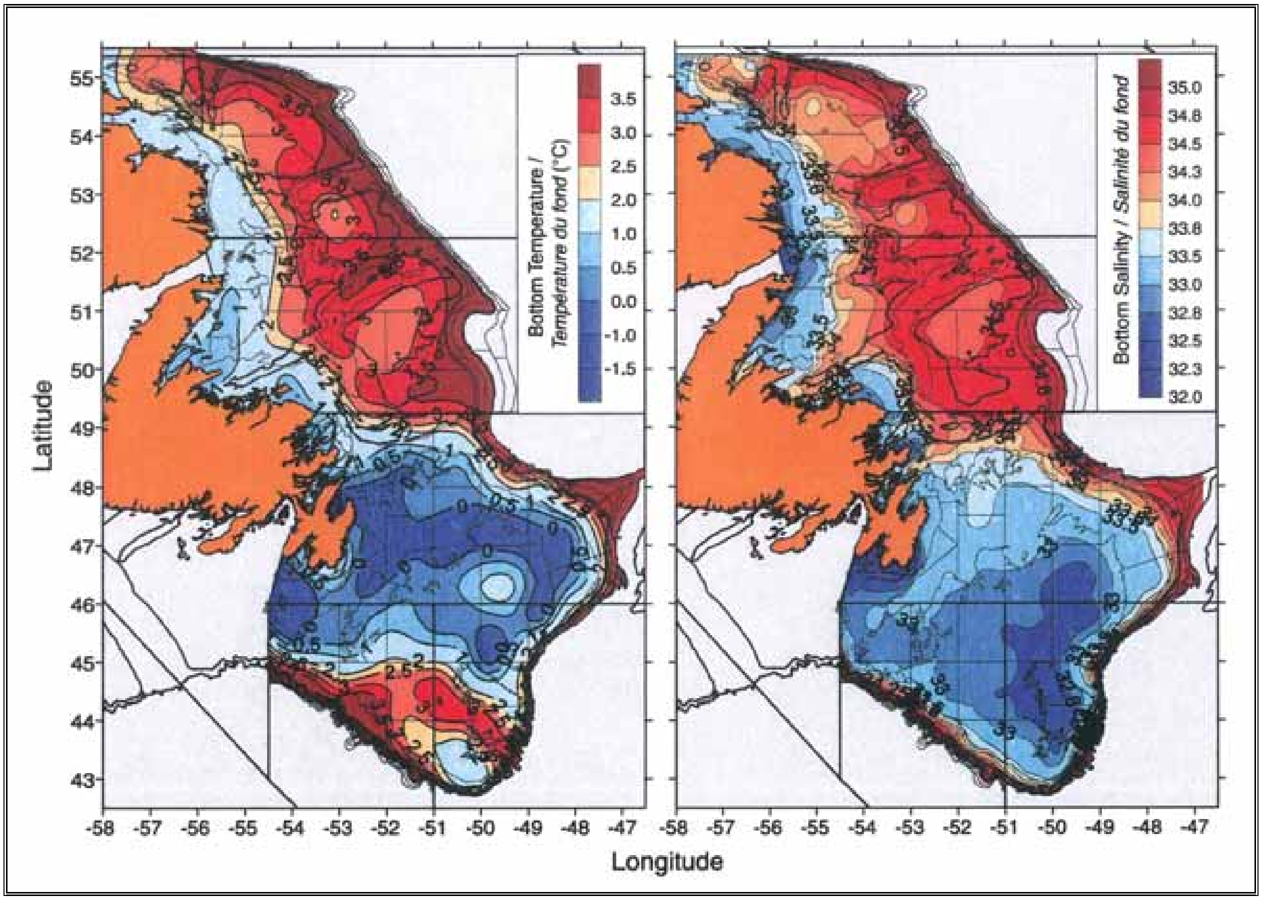
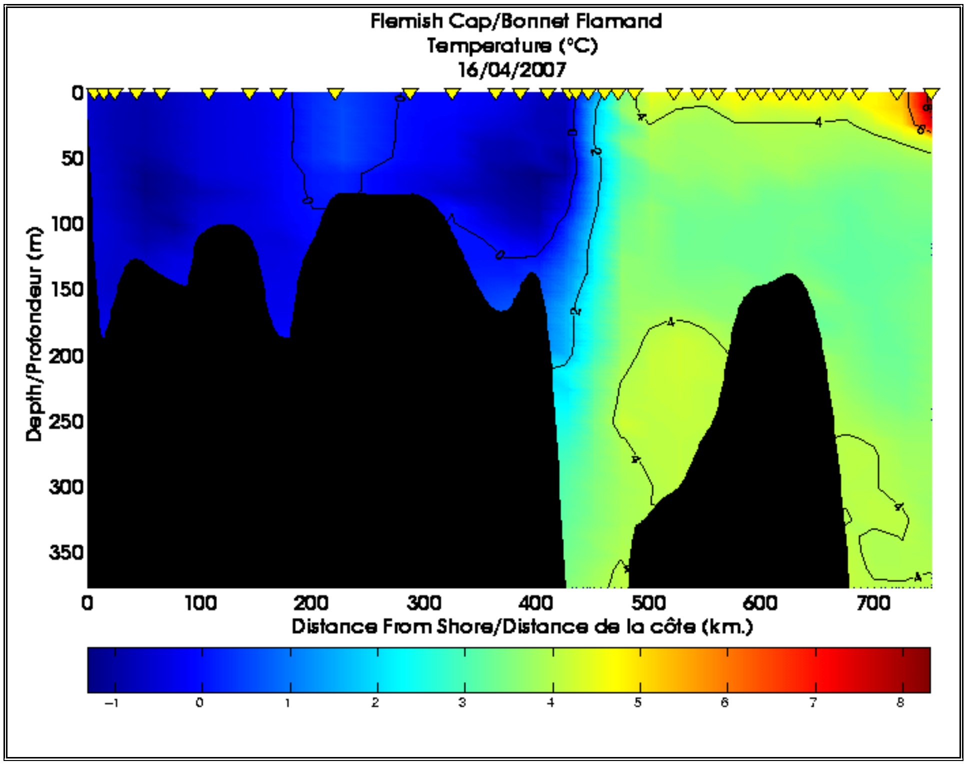


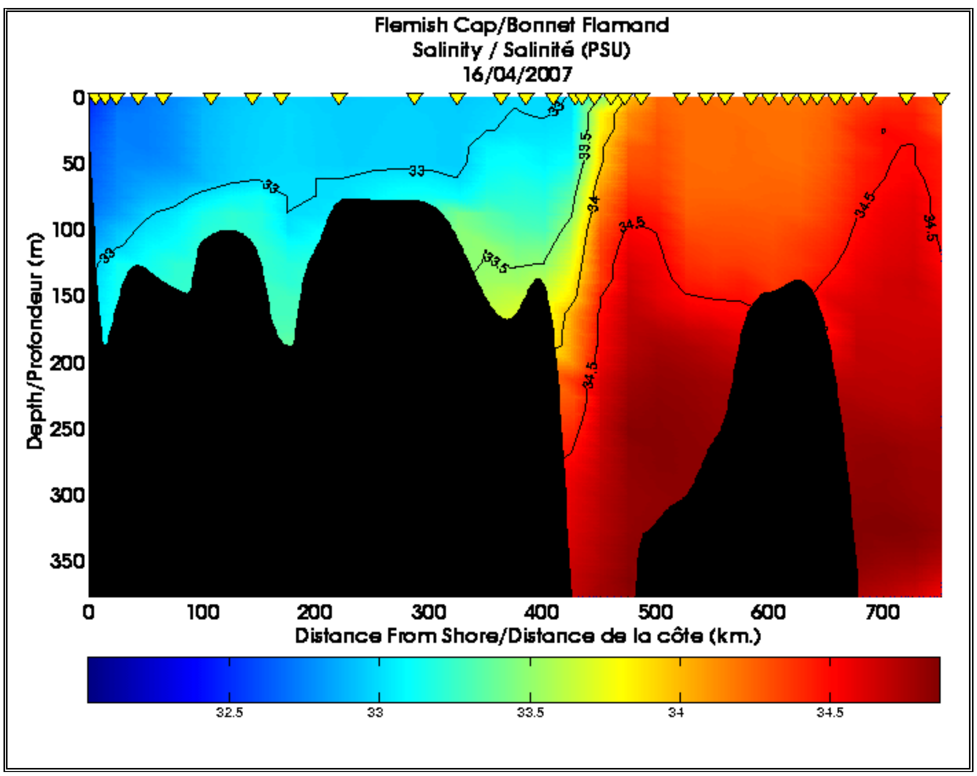

**Figure 4.4 Average near bottom temperature during Spring from all available data for the decade 1991-2000 (adapted from Colbourne, 2004)**




*(from* Colbourne et al. 2007)

**Figure 4.5 Bottom temperature and salinity maps derived for the trawl-mounted CTD data**




*(from* DFO Marine Environmental Data Service Website)

**Figure 4.6 Hydrographic contours of the Flemish Cap transect during April 2007**

## 4.4 Water Properties in the Project Area

For the seismic area, temperature and salinity data were obtained from the Bedford Institute of Oceanography and presented in Tables 4.5 to 4.7. The tables show the mean, minimum, and maximum values plus the standard deviation on a monthly basis for the surface waters, and for depths of 40 m ± 3m, and 80 m ± 3 m. The majority of the data is for the summer months, and there is no data at all for January, February, and March.

The tables show that the warmest mean temperatures are in August near the surface and at a depth of 40 m with mean values of 13.8°C and 5.3°C, respectively. At 80 m, the warmest mean temperatures are in July with a mean value of 0.04°C. The coldest mean temperatures are 0.17°C in April in the surface waters, -0.26°C in April at a depth of 40 m, and -1.03°C in September at a depth of 80 m. The highest mean salinities at the surface and at 40 m are in April with values of 32.9 psu and 33.0 psu, respectively. At 80 m, the highest mean salinity is in December with a value of 33.3 psu. The lowest mean salinities are 31.8 psu in September in the surface waters, 32.4 psu in October at 40 m, and 33.0 in May and June at 80 m.

Figure 4.7 presents the distribution of temperature and salinity by depth on a monthly basis. The contour plots show that the largest temperature and salinity variations occur in the upper 50 m during the summer and fall seasons.

**Table 4.5 Monthly temperature and salinity statistics from the BIO Archive for surface waters**

| Temperature | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | N | Mean | Min | Max | STD | 95% Limits | |
| Jan | 0 | - | - | - | - | - | - |
| Feb | 0 | - | - | - | - | - | - |
| Mar | 0 | - | - | - | - | - | - |
| Apr | 35 | 0.17 | -1.00 | 2.00 | 0.76 | -0.08 | 0.42 |
| May | 39 | 2.17 | 0.52 | 4.77 | 1.13 | 1.82 | 2.53 |
| Jun | 325 | 5.49 | 1.30 | 10.34 | 1.17 | 5.36 | 5.61 |
| Jul | 186 | 10.84 | 7.00 | 14.05 | 1.69 | 10.60 | 11.08 |
| Aug | 1 | 13.77 | 13.77 | 13.77 | - | - | - |
| Sep | 11 | 13.49 | 9.62 | 16.58 | 3.13 | 11.64 | 15.34 |
| Oct | 48 | 8.49 | 5.71 | 10.65 | 1.85 | 7.97 | 9.02 |
| Nov | 72 | 5.72 | 3.32 | 10.62 | 2.17 | 5.22 | 6.22 |
| Dec | 43 | 3.70 | 2.66 | 6.86 | 1.18 | 3.35 | 4.06 |

| Salinity | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | N | Mean | Min | Max | STD | 95% Limits | |
| Jan | 0 | - | - | - | - | - | - |
| Feb | 0 | - | - | - | - | - | - |
| Mar | 0 | - | - | - | - | - | - |
| Apr | 35 | 32.93 | 32.48 | 33.32 | 0.19 | 32.87 | 32.99 |
| May | 39 | 32.69 | 32.41 | 33.08 | 0.17 | 32.64 | 32.75 |
| Jun | 325 | 32.67 | 32.03 | 33.30 | 0.12 | 32.66 | 32.69 |
| Jul | 186 | 32.52 | 32.08 | 32.77 | 0.13 | 32.50 | 32.54 |
| Aug | 1 | 32.20 | 32.20 | 32.20 | - | - | - |
| Sep | 11 | 31.83 | 31.35 | 32.03 | 0.22 | 31.70 | 31.97 |
| Oct | 48 | 32.18 | 31.96 | 32.43 | 0.17 | 32.13 | 32.23 |
| Nov | 72 | 32.22 | 31.76 | 32.91 | 0.22 | 32.17 | 32.28 |
| Dec | 43 | 32.43 | 32.13 | 32.73 | 0.17 | 32.38 | 32.48 |

**Table 4.6 Monthly temperature and salinity statistics from the BIO Archive for a depth of 40 m**

| Temperature | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | N | Mean | Min | Max | STD | 95% Limits | |
| Jan | 0 | - | - | - | - | - | - |
| Feb | 0 | - | - | - | - | - | - |
| Mar | 0 | - | - | - | - | - | - |
| Apr | 7 | -0.26 | -1.15 | 0.40 | 0.48 | -0.62 | 0.09 |
| May | 27 | 0.47 | -0.56 | 3.52 | 0.87 | 0.14 | 0.79 |
| Jun | 291 | 1.75 | -1.66 | 4.90 | 1.07 | 1.62 | 1.87 |
| Jul | 192 | 2.17 | -0.56 | 7.28 | 1.36 | 1.98 | 2.36 |
| Aug | 5 | 5.28 | 4.63 | 5.83 | 0.49 | 4.85 | 5.70 |
| Sep | 12 | 1.48 | 0.37 | 5.64 | 1.47 | 0.65 | 2.31 |
| Oct | 60 | 4.24 | -0.97 | 9.72 | 3.43 | 3.37 | 5.10 |
| Nov | 57 | 2.32 | -1.20 | 8.45 | 2.58 | 1.65 | 2.99 |
| Dec | 48 | 2.11 | -0.99 | 3.52 | 1.23 | 1.76 | 2.45 |

| Salinity | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | N | Mean | Min | Max | STD | 95% Limits | |
| Jan | 0 | - | - | - | - | - | - |
| Feb | 0 | - | - | - | - | - | - |
| Mar | 0 | - | - | - | - | - | - |
| Apr | 7 | 33.01 | 32.68 | 33.33 | 0.23 | 32.84 | 33.19 |
| May | 27 | 32.87 | 32.57 | 33.68 | 0.36 | 32.73 | 33.01 |
| Jun | 291 | 32.82 | 32.49 | 34.64 | 0.26 | 32.79 | 32.85 |
| Jul | 192 | 32.79 | 32.03 | 33.98 | 0.32 | 32.74 | 32.83 |
| Aug | 5 | 32.58 | 32.56 | 32.60 | 0.02 | 32.57 | 32.59 |
| Sep | 12 | 32.72 | 31.86 | 32.92 | 0.30 | 32.55 | 32.90 |
| Oct | 60 | 32.42 | 31.97 | 33.02 | 0.36 | 32.33 | 32.51 |
| Nov | 57 | 32.54 | 31.70 | 33.72 | 0.34 | 32.45 | 32.63 |
| Dec | 48 | 32.73 | 31.68 | 33.19 | 0.31 | 32.64 | 32.82 |

**Table 4.7 Monthly temperature and salinity statistics from the BIO Archive for a depth of 80 m**

| Temperature | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | N | Mean | Min | Max | STD | 95% Limits | |
| Jan | 0 | - | - | - | - | - | - |
| Feb | 0 | - | - | - | - | - | - |
| Mar | 0 | - | - | - | - | - | - |
| Apr | 11 | -0.96 | -1.63 | 0.20 | 0.62 | -1.33 | -0.59 |
| May | 29 | -0.72 | -1.33 | 0.88 | 0.45 | -0.89 | -0.56 |
| Jun | 291 | -0.39 | -1.66 | 0.44 | 0.34 | -0.43 | -0.35 |
| Jul | 184 | 0.04 | -1.11 | 0.59 | 0.40 | -0.02 | 0.10 |
| Aug | 1 | -0.64 | -0.64 | -0.64 | - | - | - |
| Sep | 9 | -1.03 | -1.49 | -0.79 | 0.34 | -1.25 | -0.80 |
| Oct | 44 | -0.99 | -1.32 | -0.67 | 0.20 | -1.05 | -0.93 |
| Nov | 53 | -0.49 | -1.26 | 1.46 | 0.59 | -0.65 | -0.33 |
| Dec | 48 | -0.27 | -1.01 | 0.75 | 0.54 | -0.43 | -0.12 |

| Salinity | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | N | Mean | Min | Max | STD | 95% Limits | |
| Jan | 0 | - | - | - | - | - | - |
| Feb | 0 | - | - | - | - | - | - |
| Mar | 0 | - | - | - | - | - | - |
| Apr | 11 | 33.18 | 32.94 | 33.68 | 0.22 | 33.05 | 33.31 |
| May | 29 | 33.03 | 32.79 | 33.46 | 0.18 | 32.97 | 33.09 |
| Jun | 291 | 33.03 | 32.84 | 33.46 | 0.16 | 33.02 | 33.05 |
| Jul | 184 | 33.23 | 32.98 | 33.47 | 0.12 | 33.21 | 33.25 |
| Aug | 1 | 33.06 | 33.06 | 33.06 | - | - | - |
| Sep | 9 | 33.10 | 33.02 | 33.16 | 0.04 | 33.08 | 33.13 |
| Oct | 44 | 33.11 | 32.87 | 33.38 | 0.13 | 33.07 | 33.15 |
| Nov | 53 | 33.19 | 32.91 | 33.83 | 0.18 | 33.14 | 33.23 |
| Dec | 48 | 33.30 | 33.13 | 33.45 | 0.10 | 33.27 | 33.33 |

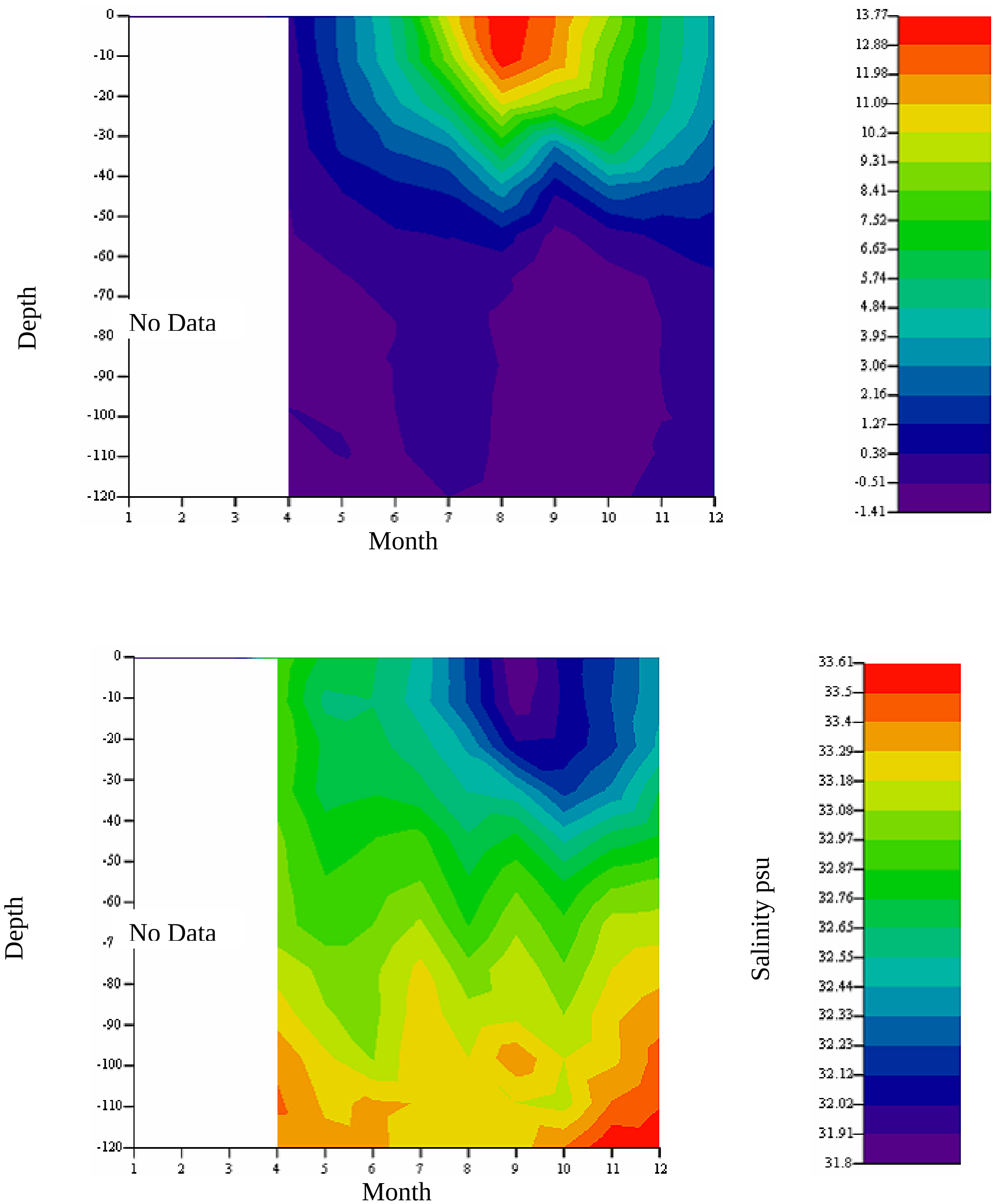



**Figure 4.7 Distribution of Temperature and Salinity by Depth on a Monthly basis**

## References


Borgman, L. E., 1973. Probabilities for the highest wave in a hurricane. J. Waterways, Harbors and Coastal Engineering Div., ASCE, p.185-207.

Colbourne, E., 2000. Interannual variations in the stratification and transport of the Labrador Current on the Newfoundland Shelf. International Council for the Explorations of the Sea. CM 2000/L:2.

Colboure, E., 2002. Physical Oceanographic Conditions on the Newfoundland and Labrador Shelves during 2001. CSAS Res.Doc. 2002/023.

Colbourne, E. B., 2004. Decadal Changes in the Ocean Climate in Newfoundland and Labrador Waters from the 1950s to the 1990s**.** J. Northw. Atl. Fish. Sci., V.34. p.41–59.

Colbourne, E., C. Fitzpatrick, D. Senciall, W. Bailey and P. Stead. Oceanogrpahic Observations from Trawl-Mounted CTD's on Multi-Species Surveys in the Newfoundland and Labrador Region. A ZMP Bulletin PMZA, No.6, p.43-47.

Colbourne, E., B. deYoung, S. Narayanan, and J. Helbig, 1997. Comparison of hydrography and circulation on the Newfoundland Shelf during 1990–1993 with the long-term mean. Can. J. Fish. Aquat. Sci. V.54 (Suppl. 1), p.68-80.

Colbourne, E. B., and D. R. Senciall, 1996. Temperature, Salinity and Sigma. T. along the standard Flemish Cap transect. Can.Tech.Rep. Hydrog.Ocean Sci., V.172, 222p.

Colbourne, E. B., and K. D. Foote, 2000. Variability of the Stratification and Circulation on the Flemish Cap during the Decades of the 1950s-1990s. J. Northw. Atl. Fish. Sci**.,** V.26, p.103–122.

DeTracey, B. M., C. L. Tang; and P.C. Smith, 1996. Low-frequency currents at the northern shelf edge of the Grand Banks. J. Geophs Res., V.101, C6, p.14,223-14,236.

Forristall, G. Z., 1978. On the statistical distribution of wave heights in a storm. J. Geophys. Res., v.83, p.2353-2358.

Han, G. and Z. Wang, 2005. Monthly-mean circulation in the Flemish Cap region: A modeling study. In: Malcolm L. Spaulding (Ed.) Estuarine and Coastal Modeling. Proceedings of the Ninth International Conference on Estuarine and Coastal Modeling held in Charleston, South Carolina, Oct 31 - Nov 2, 2005.

Harris, Erin. Personal Correspondence. Oceanweather, October 15, 2007.

Historical Hurricane Tracks. NOAA Coastal Services Center. National Oceanic & Atmospheric Administration. 01 August 2006. http://hurricane.csc.noaa.gov/hurricanes/index.htm

Lazier, J. R. N., and D. G. Wright, 1993. Annual velocity variations in the Labrador Current, J. Phys. Oceanogr., V.23, p.659-678.

Pepin ,P., and J. A. Helbig, 1997. Distribution and drift of Atlantic cod (Gadus morhua) eggs and larvae on the northeast Newfoundland Shelf. Can. J. Fish. Aquat. Sci. 54. p.670-685.

Petrie, B., S. Akenhead,. J. Lazier, and J. Loder, 1988. The cold intermediate layer on the Labrador and Northeast Newfoundland Shelves, 1978–1986. NAFO Sci. Counc. Stud. V.12, p.57–69.

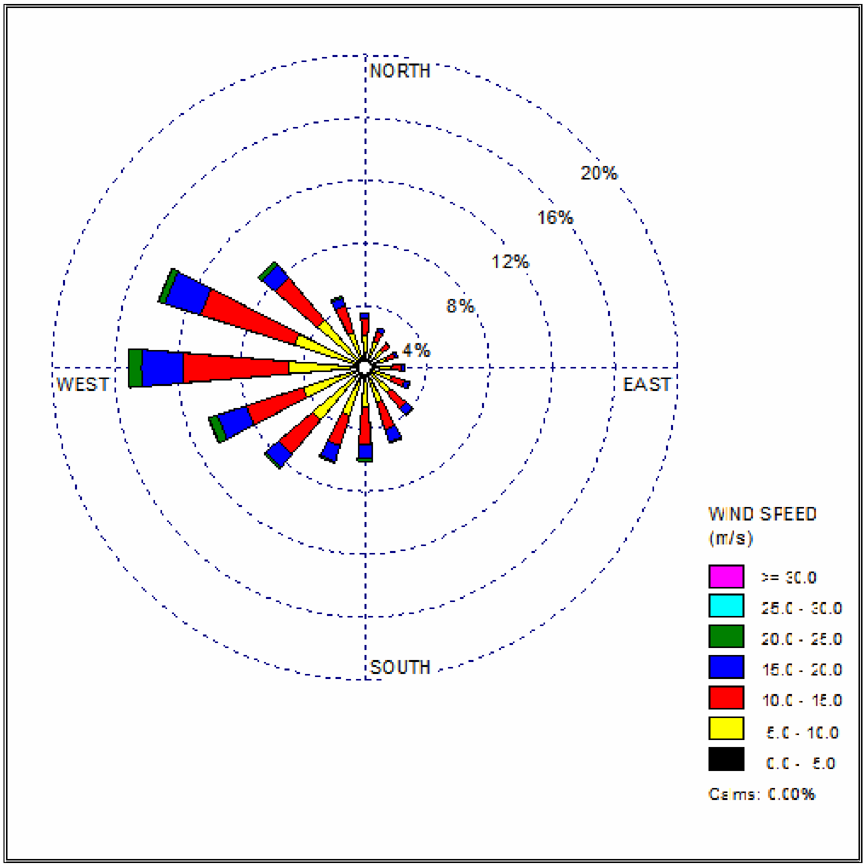
Rogers, E. , and L. F. Bosart. 1986. An Investigation of Explosively Deepening Oceanic Cyclones. Monthly Weather Review, V.114, p.702-718.

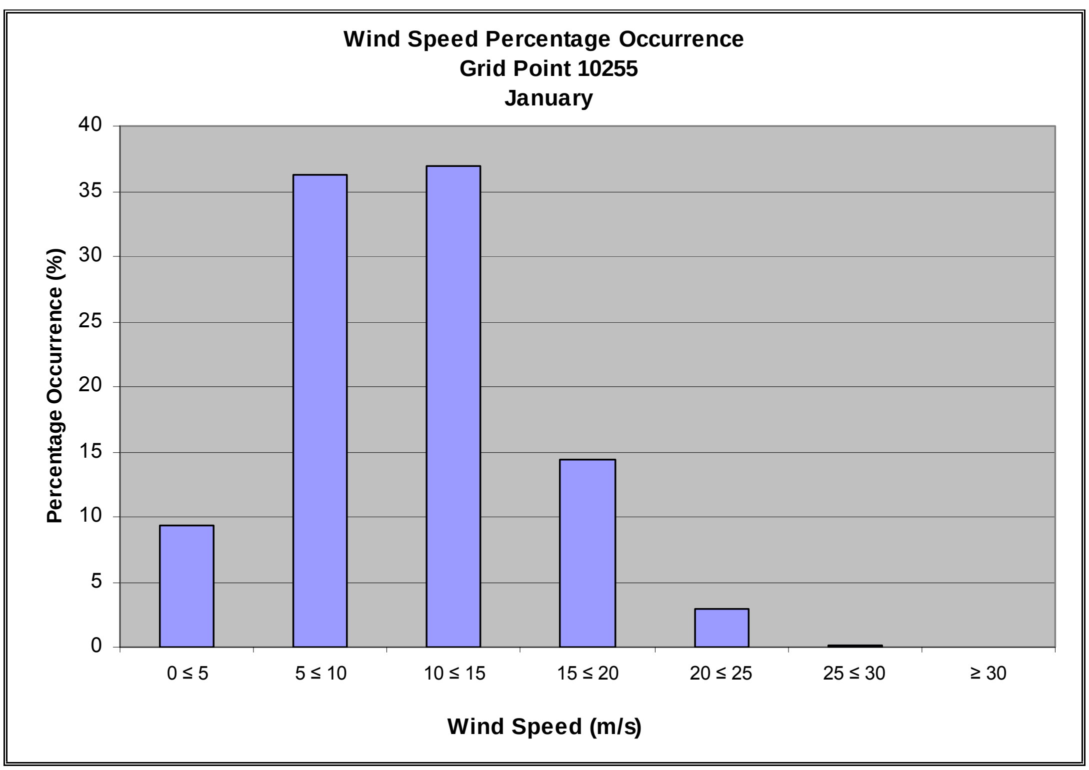
U. S. Geological Survey, Conservation Division, 1979. OCS Platform Verification Program. Reston, Virginia.

Yashayaev, I, and A. Clarke, 2006. Recent warming of the Labrador Sea. DFO AZMP Bulletin, No. 5, 2006.

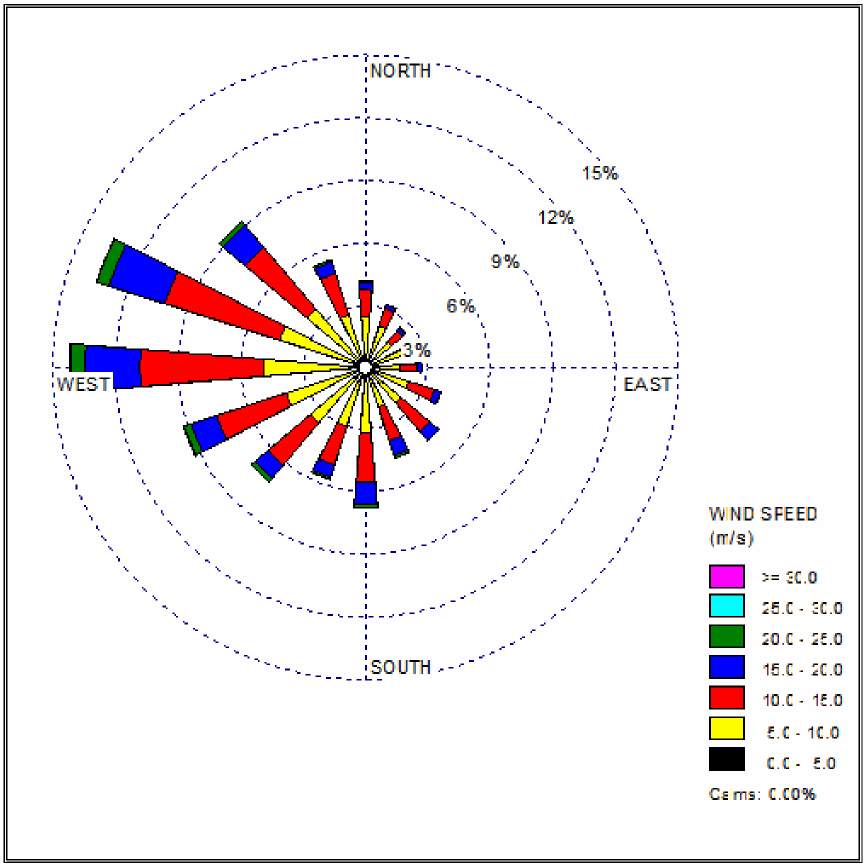
# Appendix 1

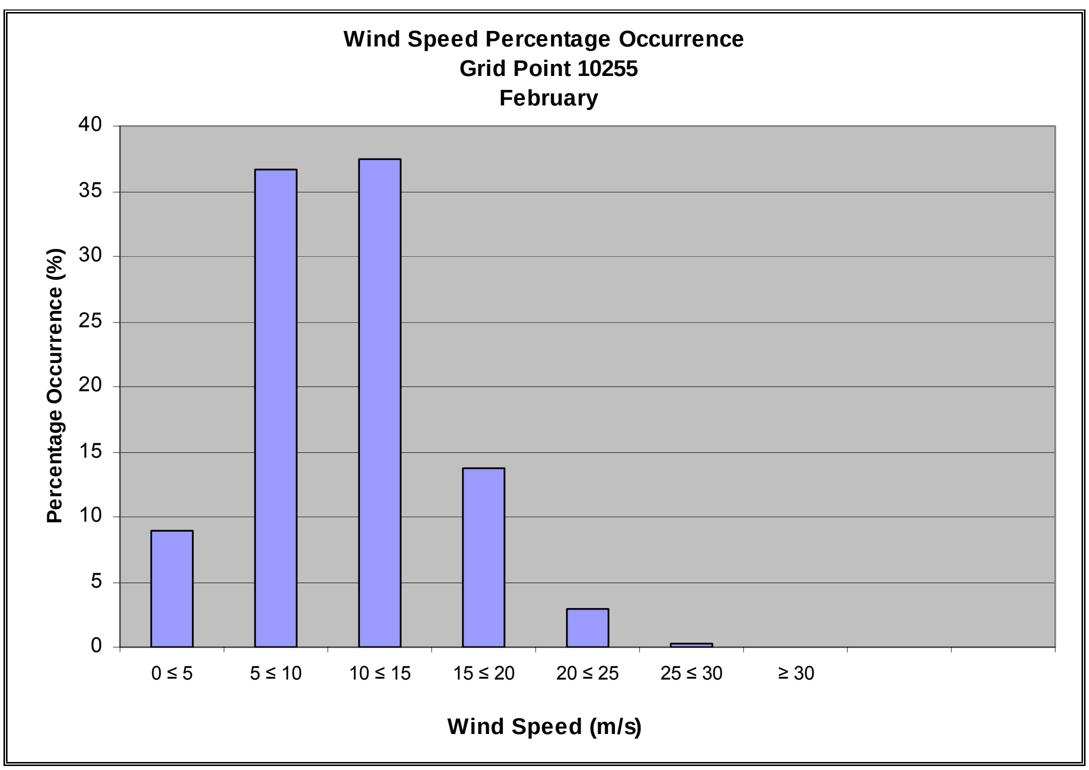
# Wind Rose and Frequency Distributions for MSC50 GridPoint 10255




**January Wind Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**

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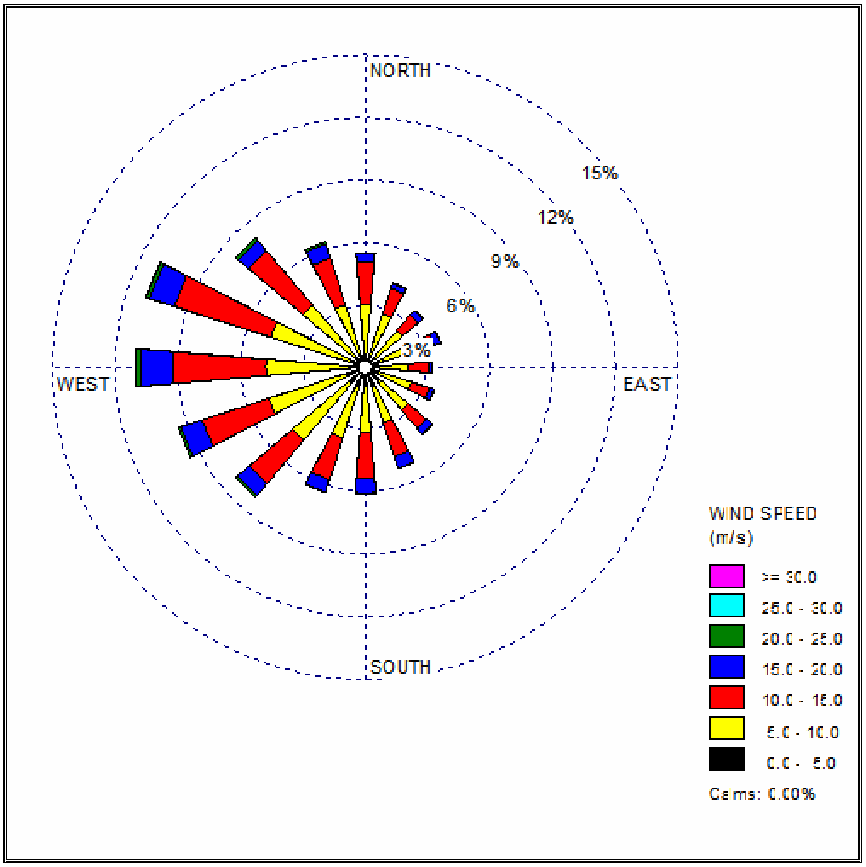


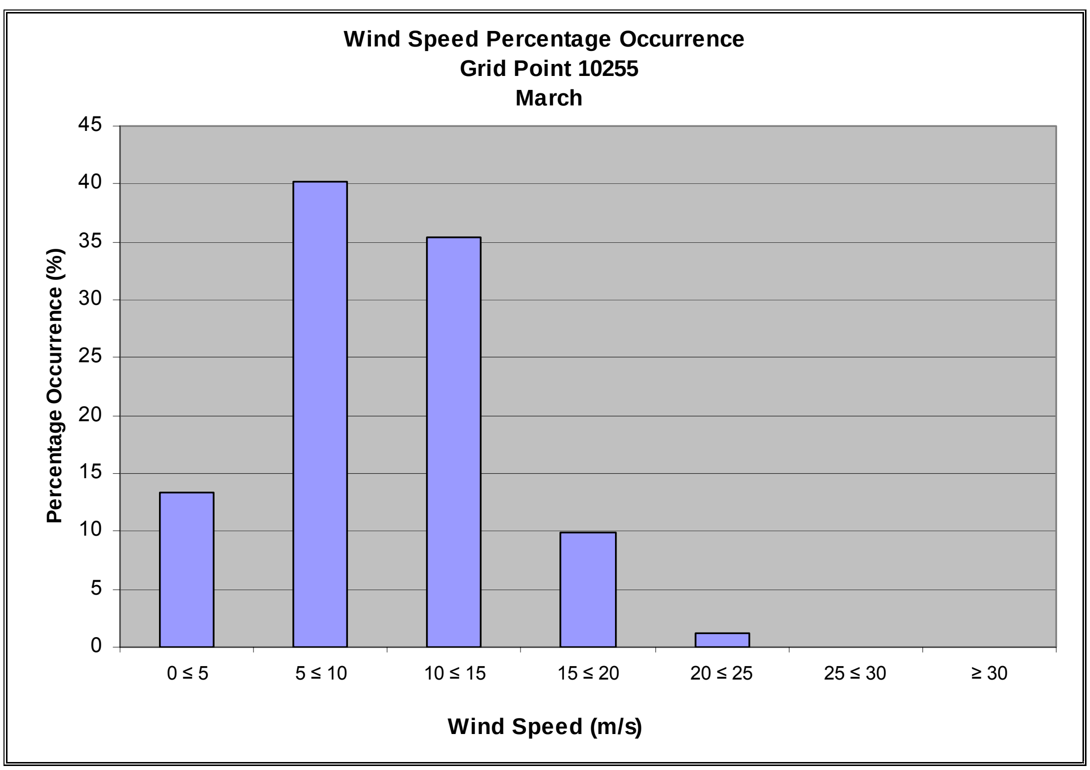


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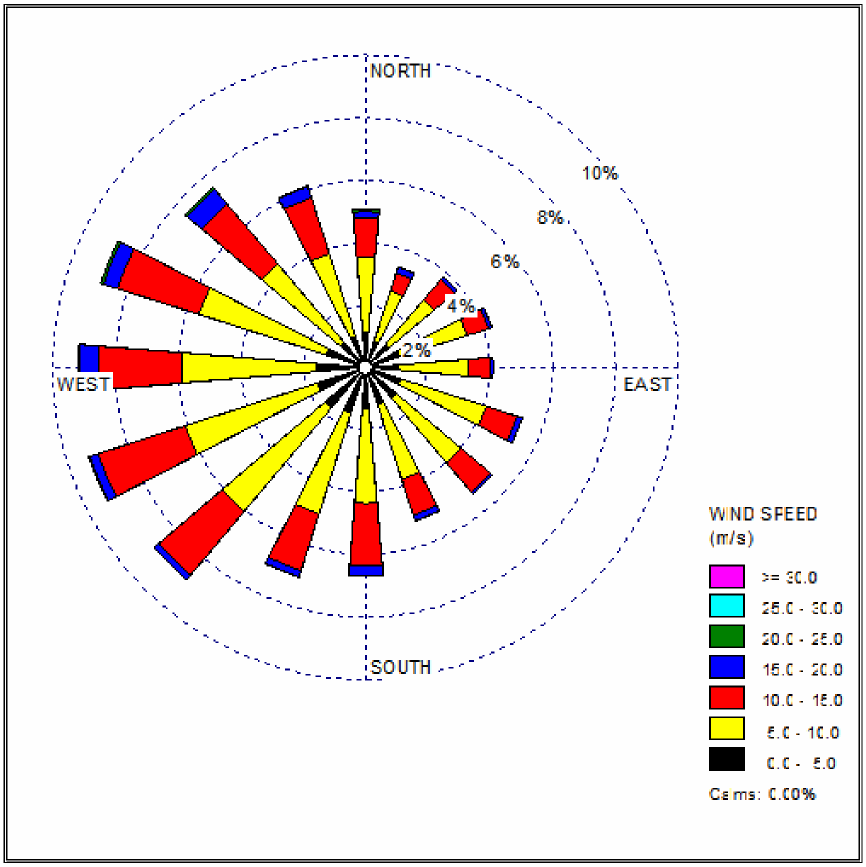


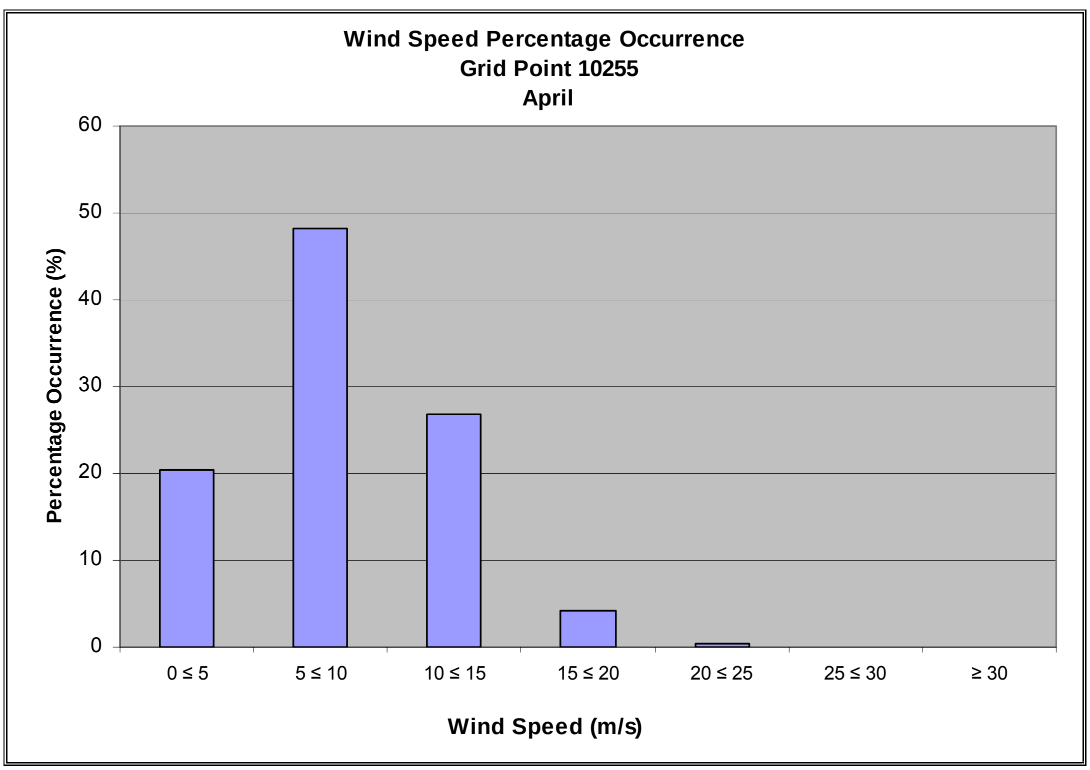


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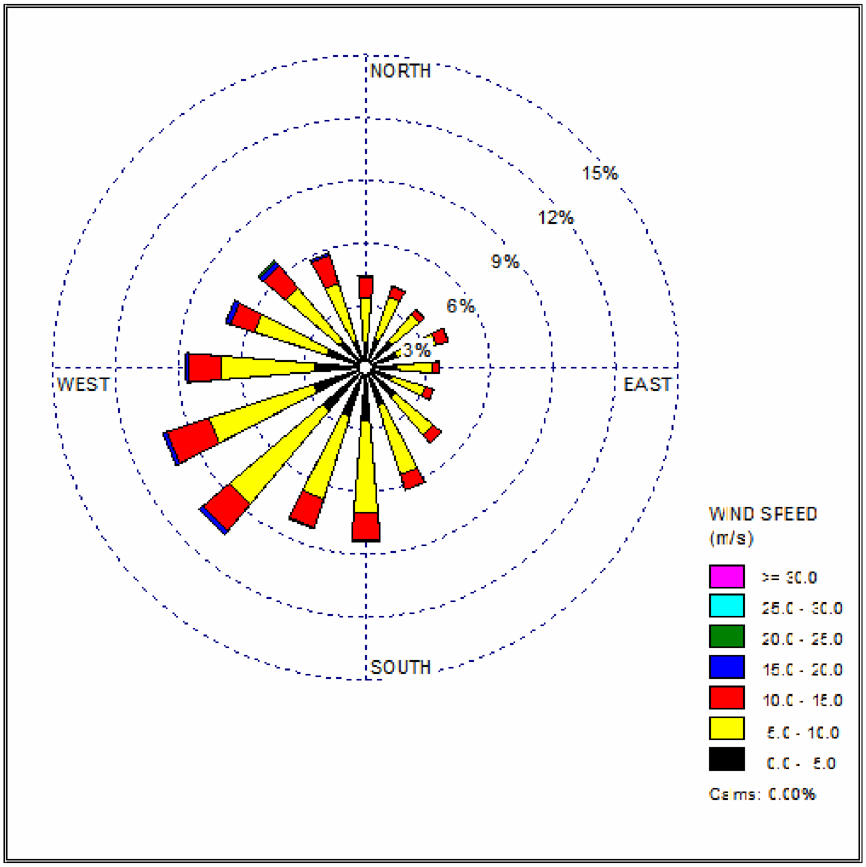


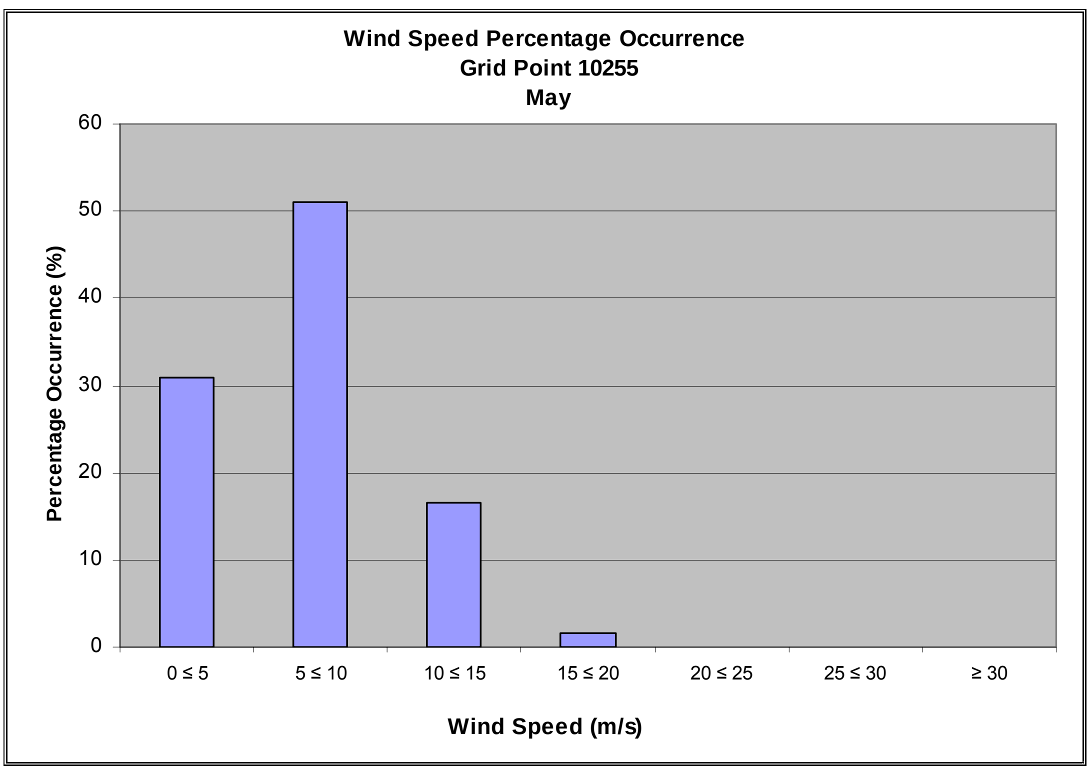


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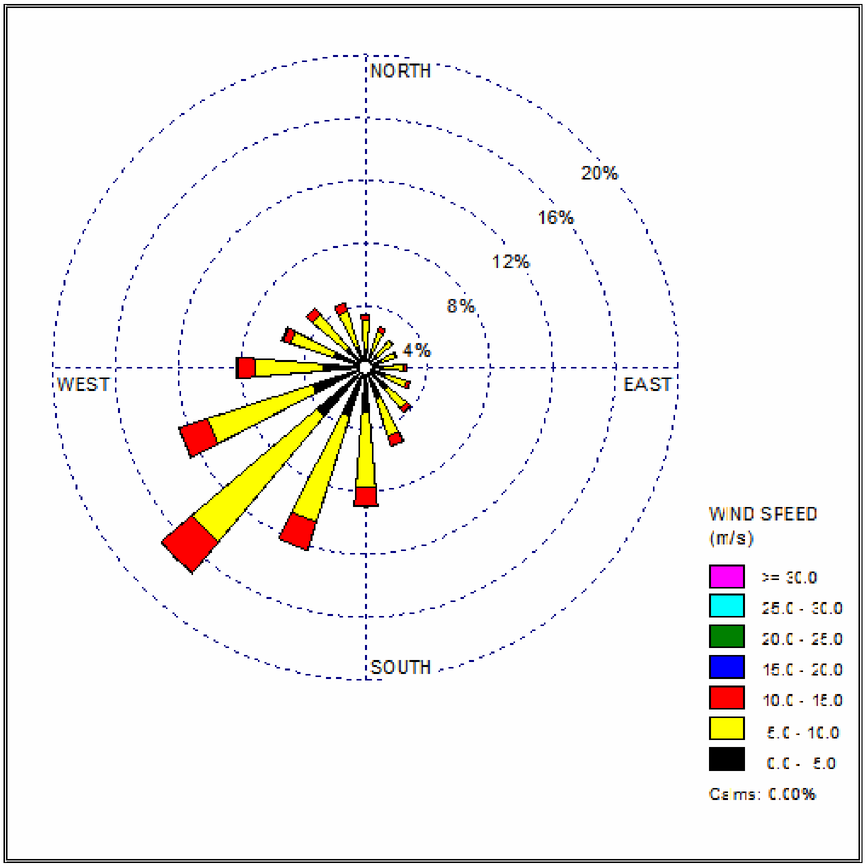


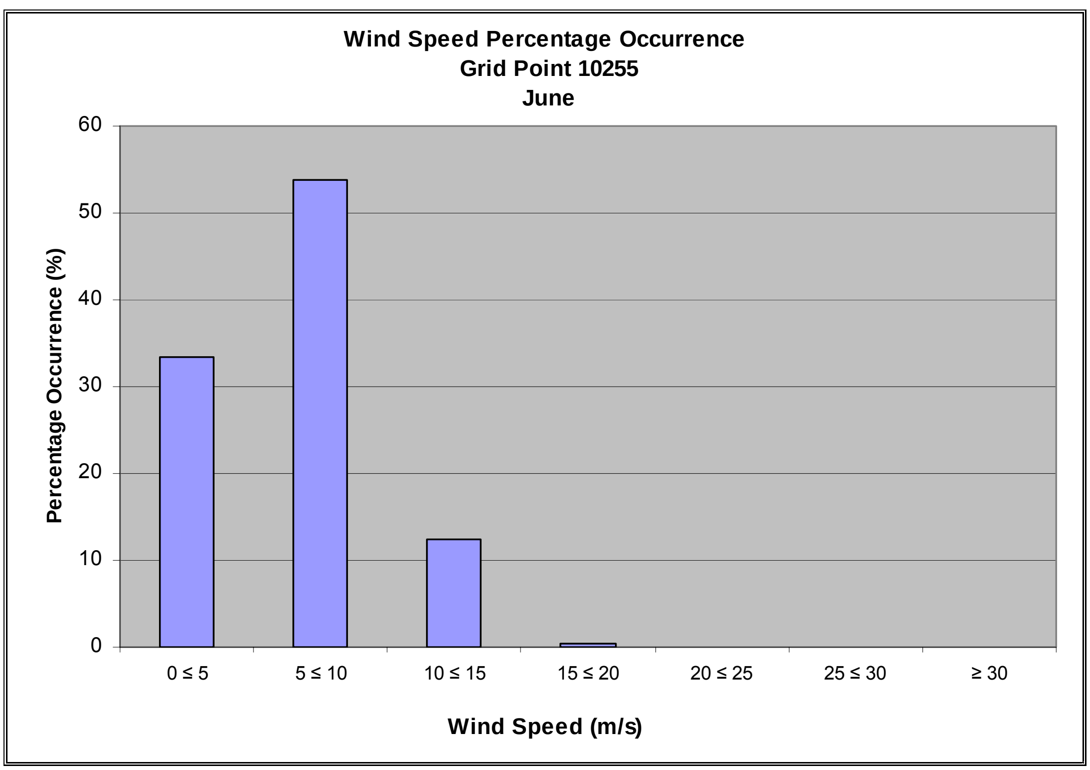


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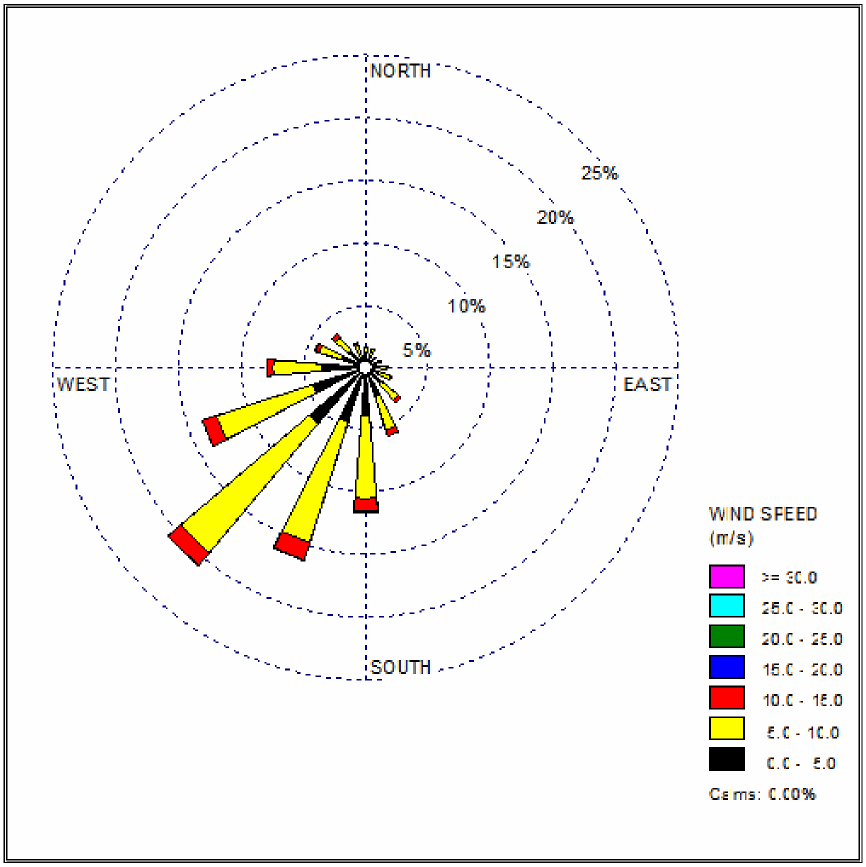


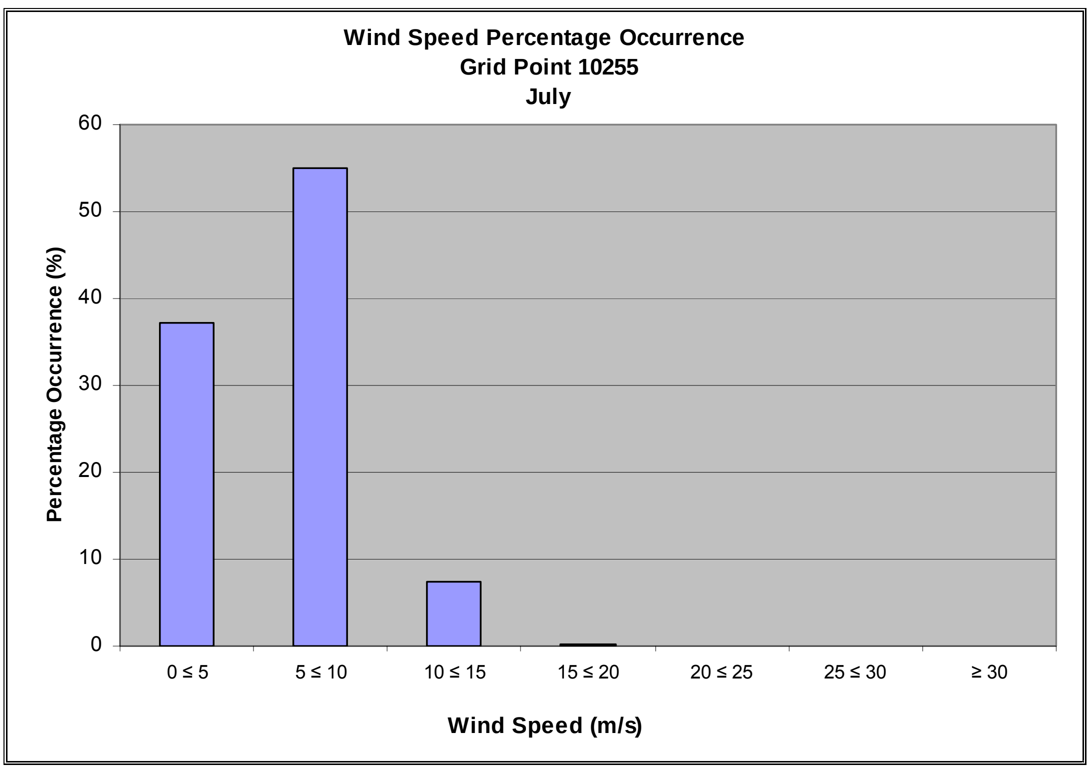


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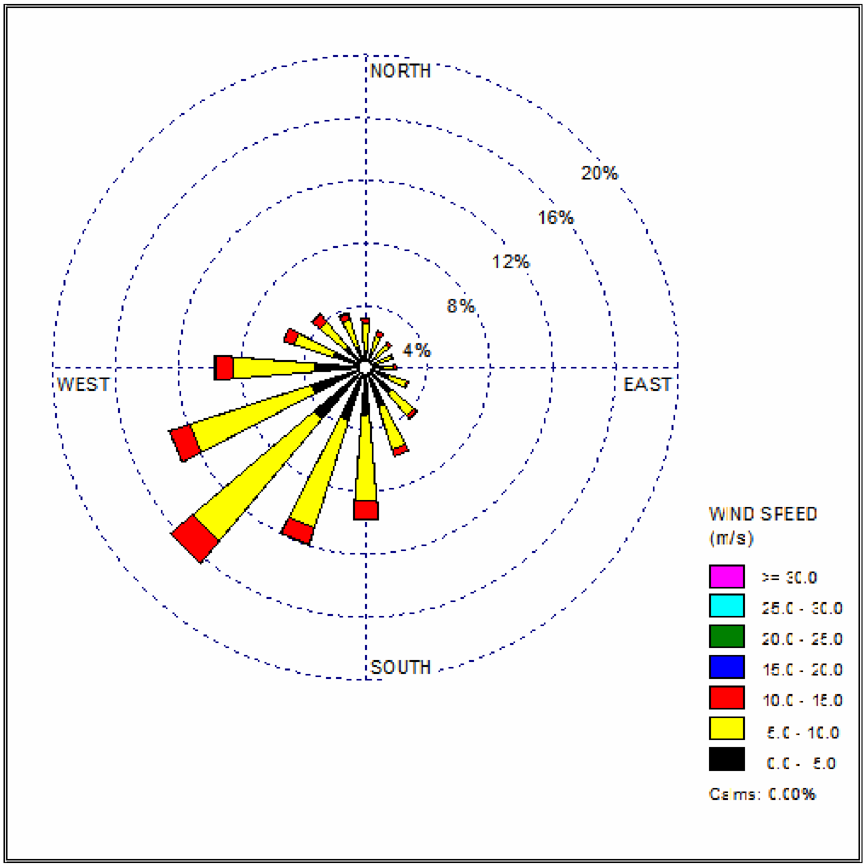
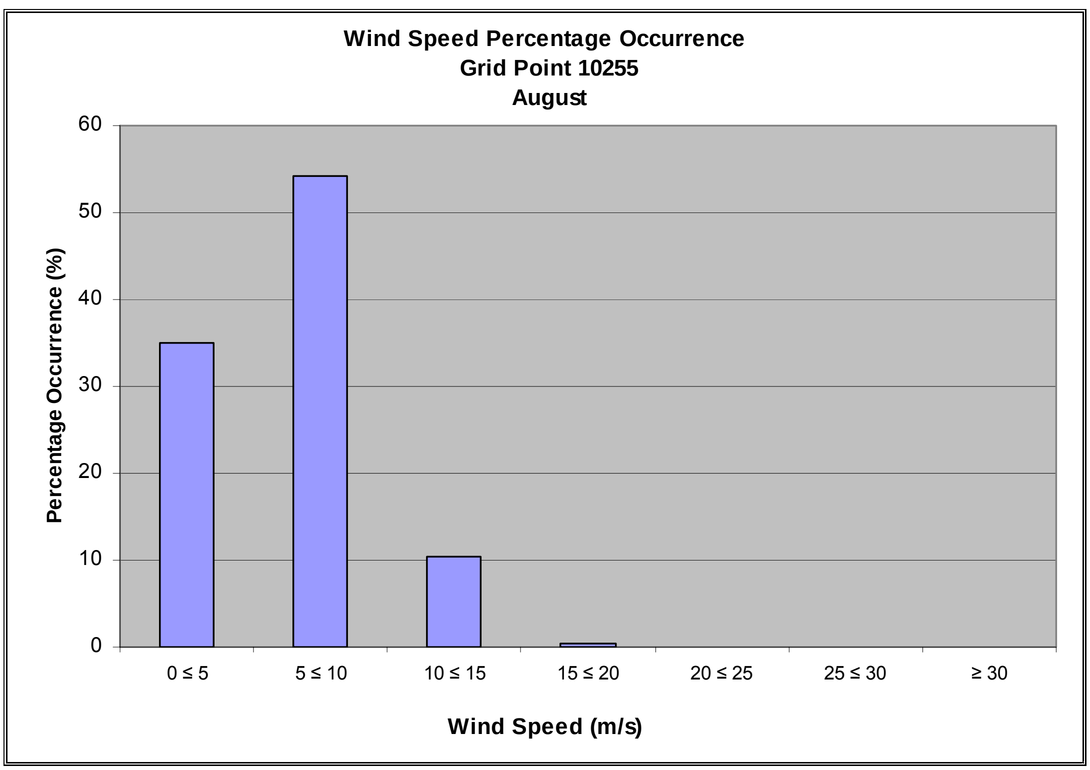
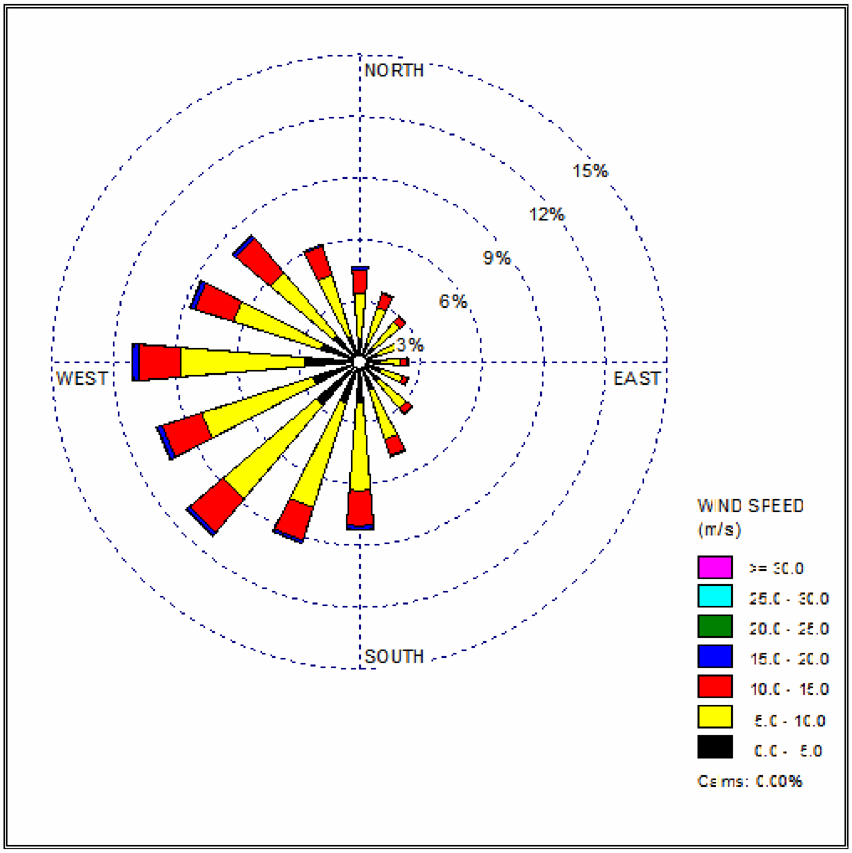
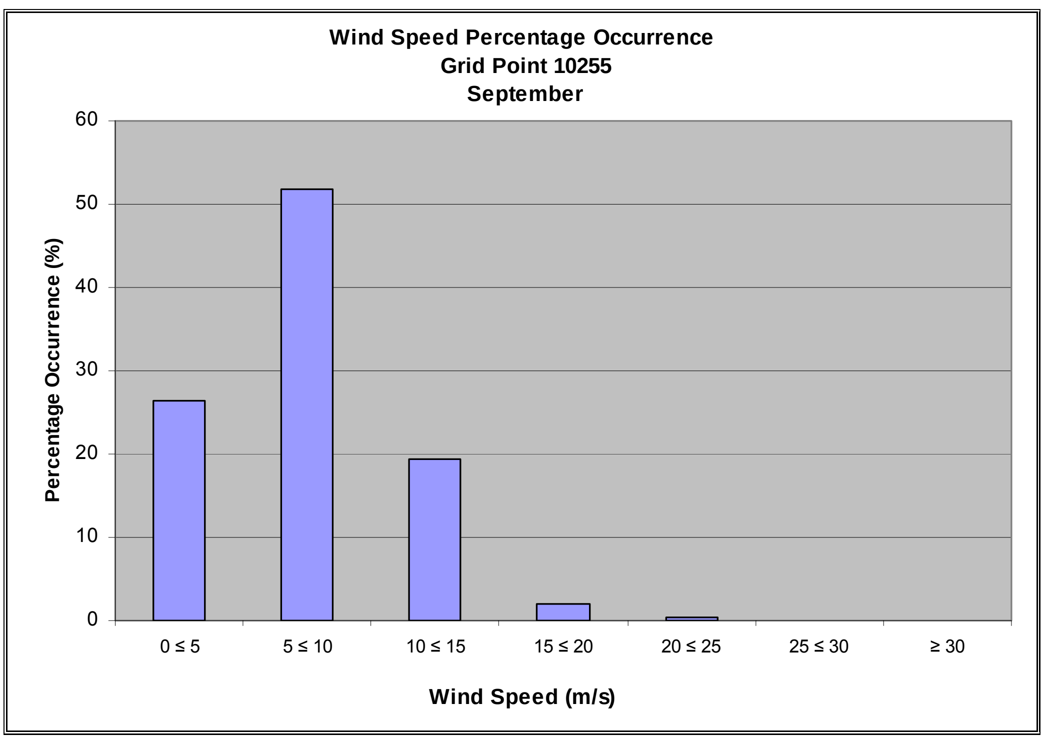



**August Wind Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**

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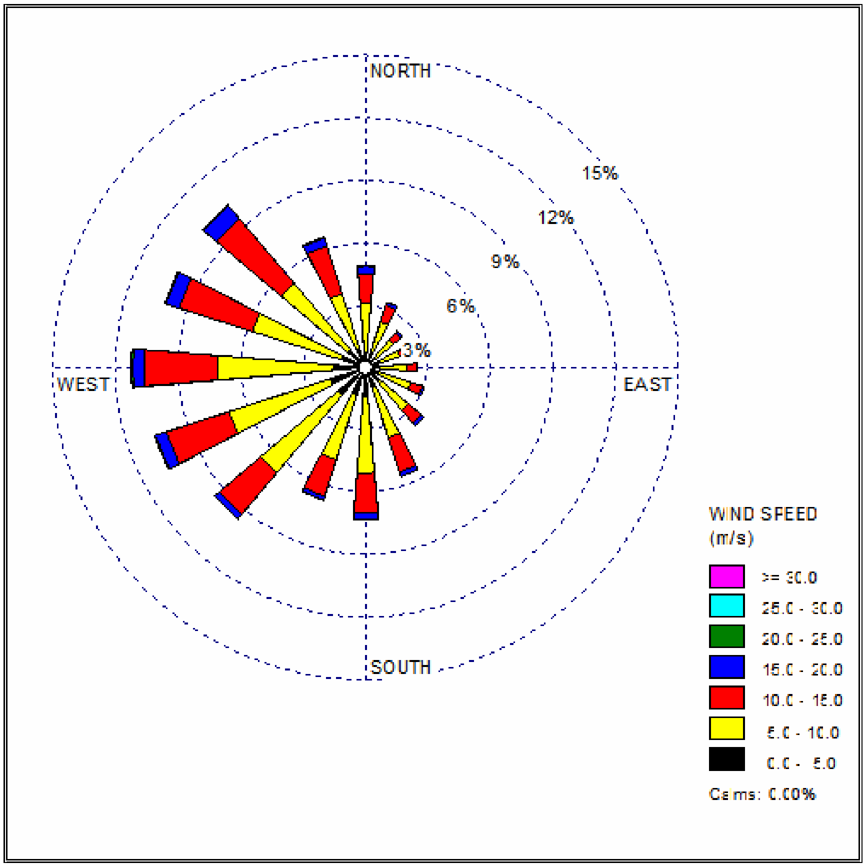


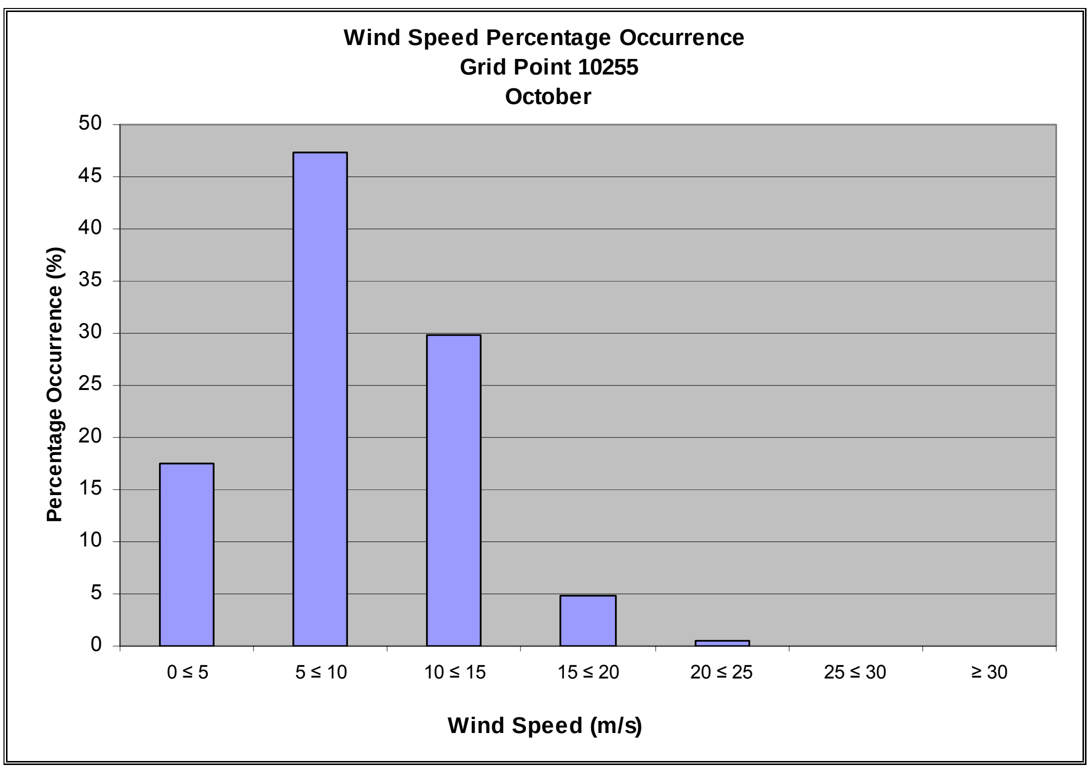


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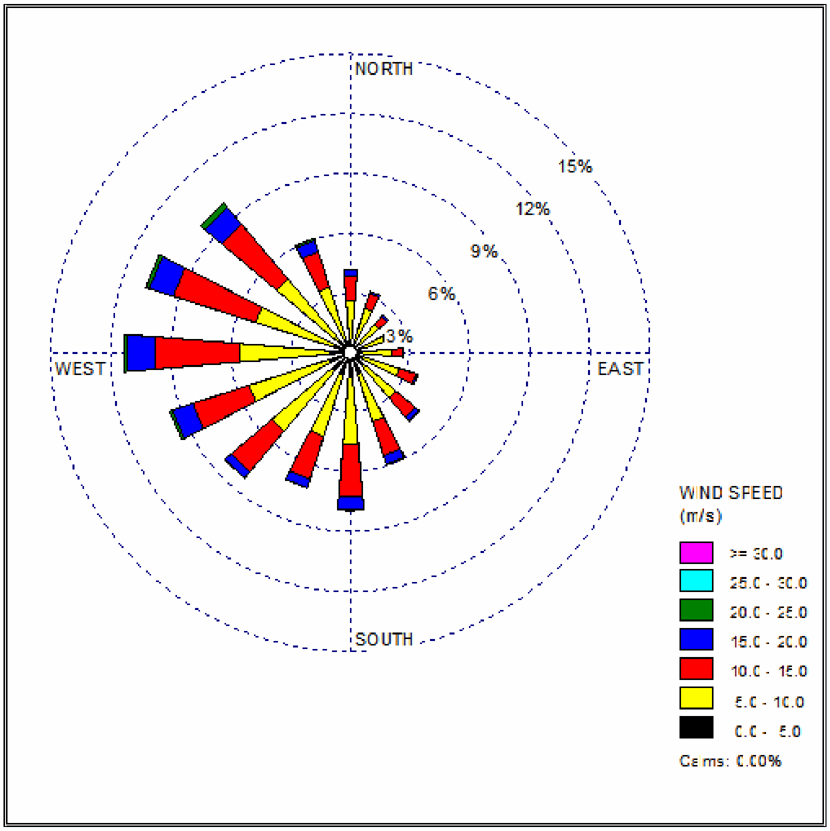


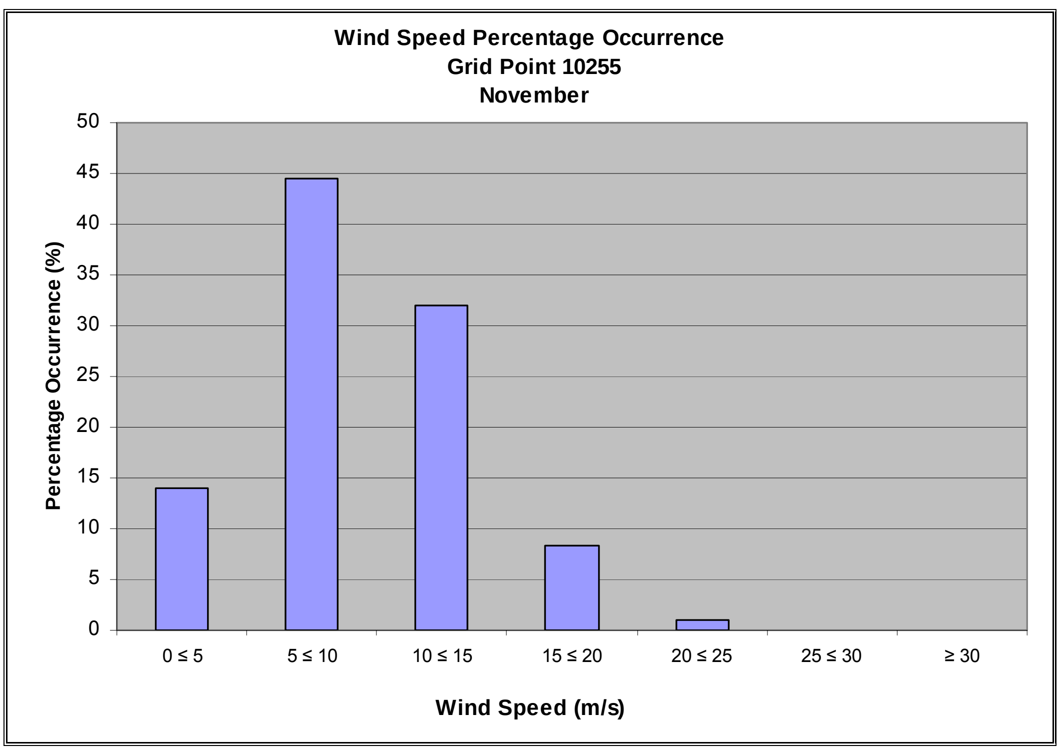


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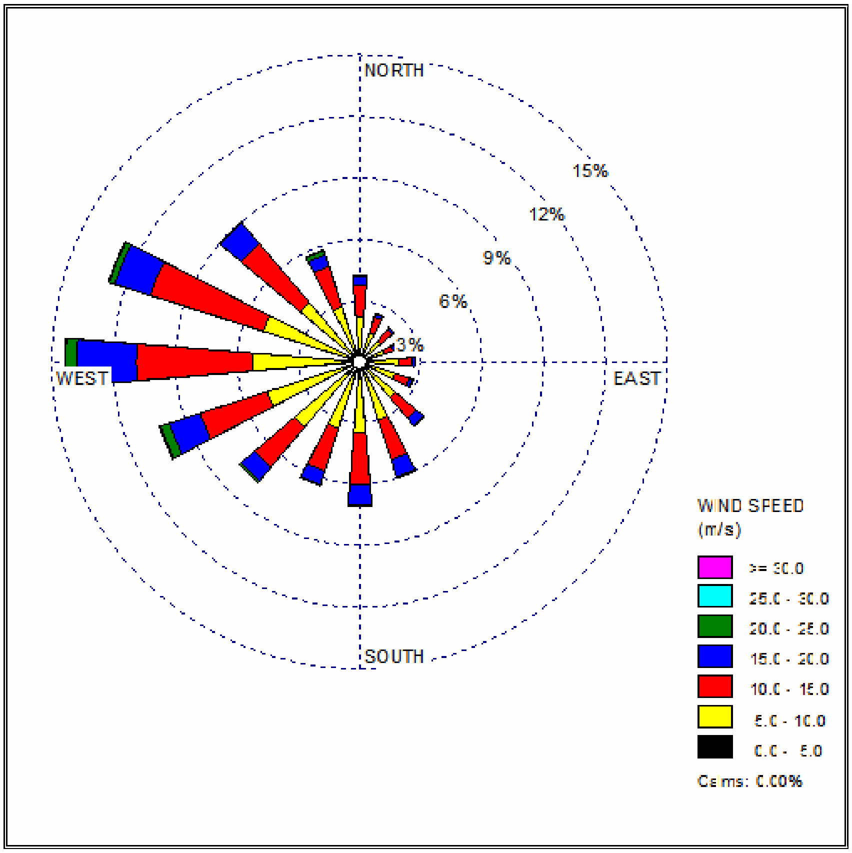
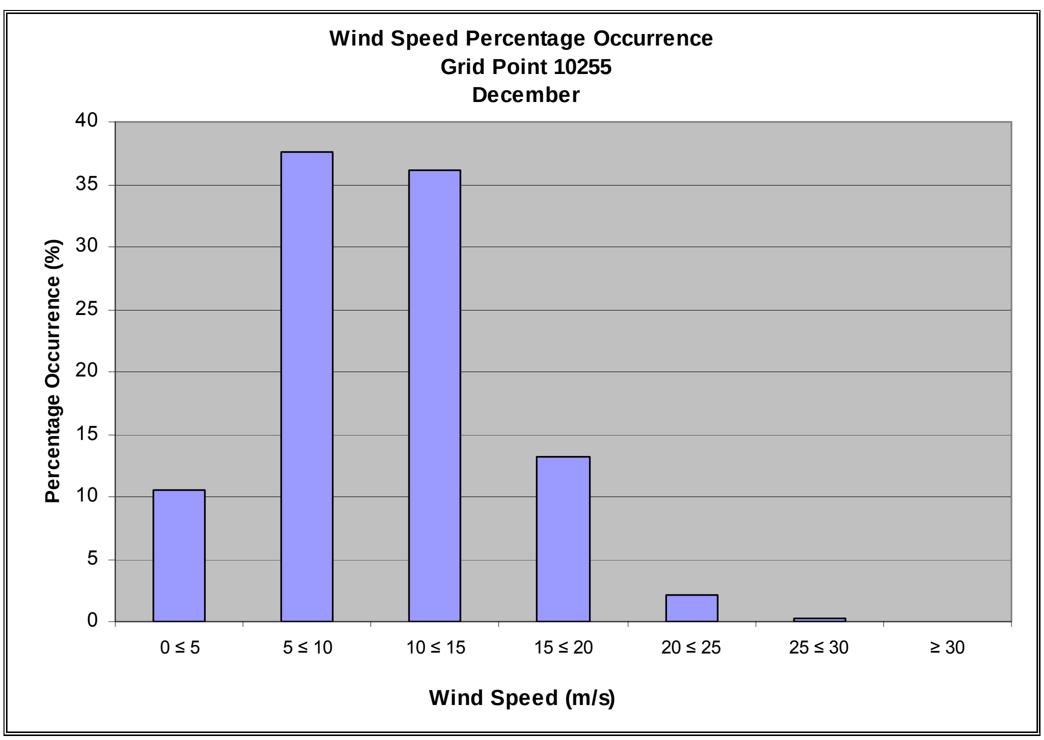
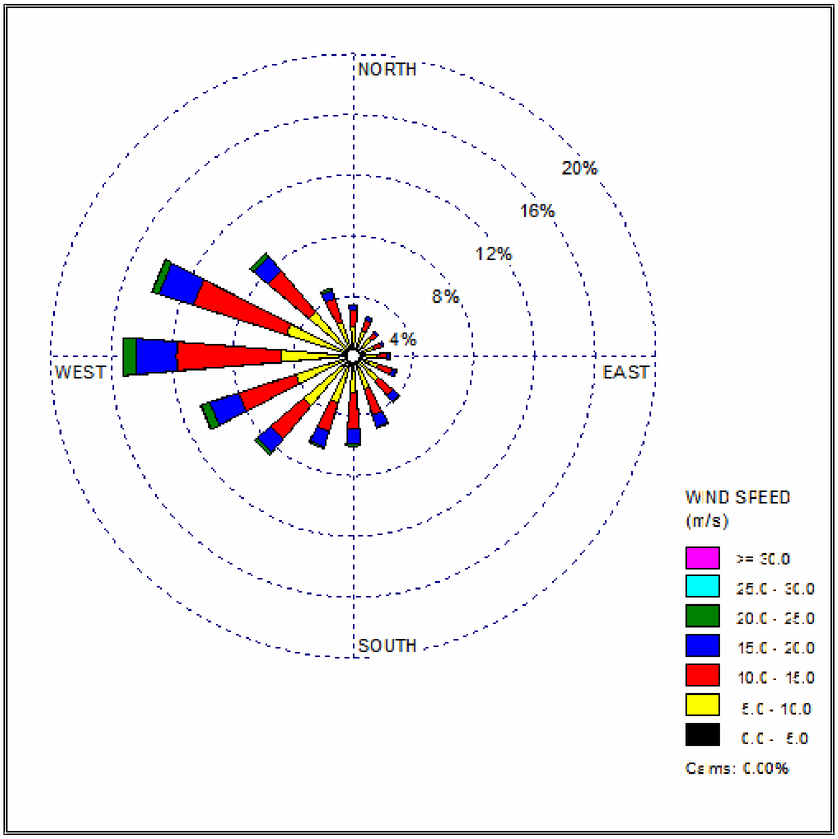


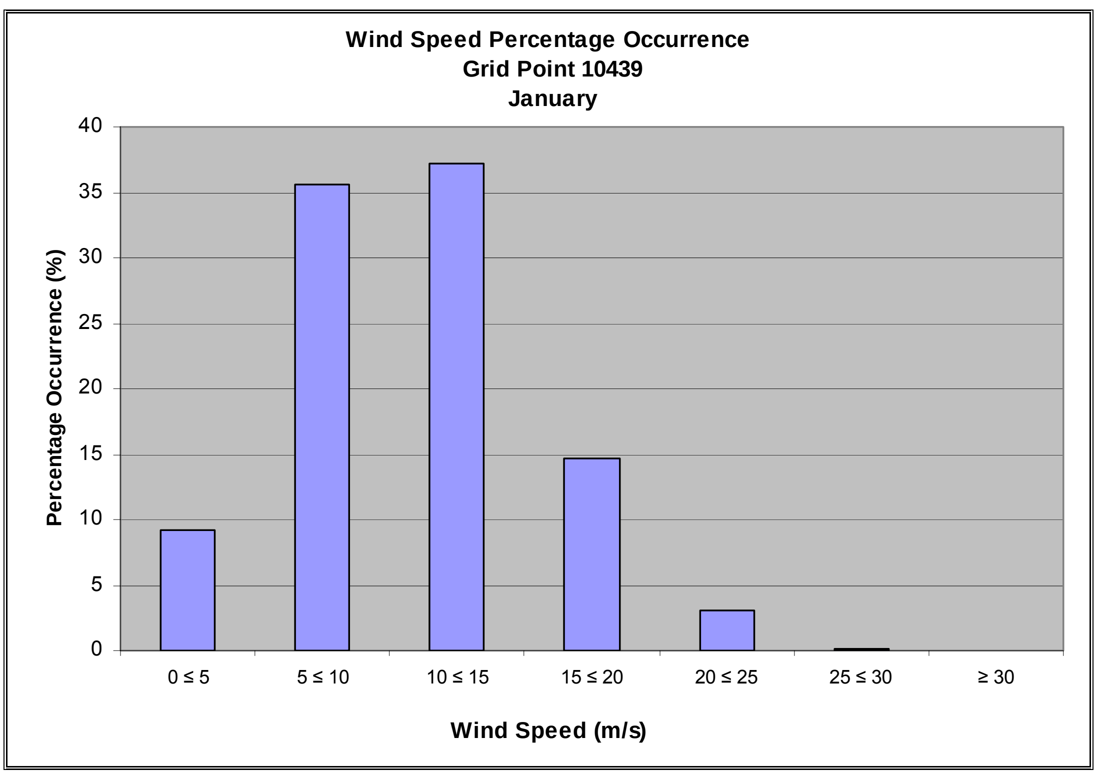




**December Wind Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**

# Appendix 2

# Wind Rose and Frequency Distributions for MSC50 GridPoint 10439

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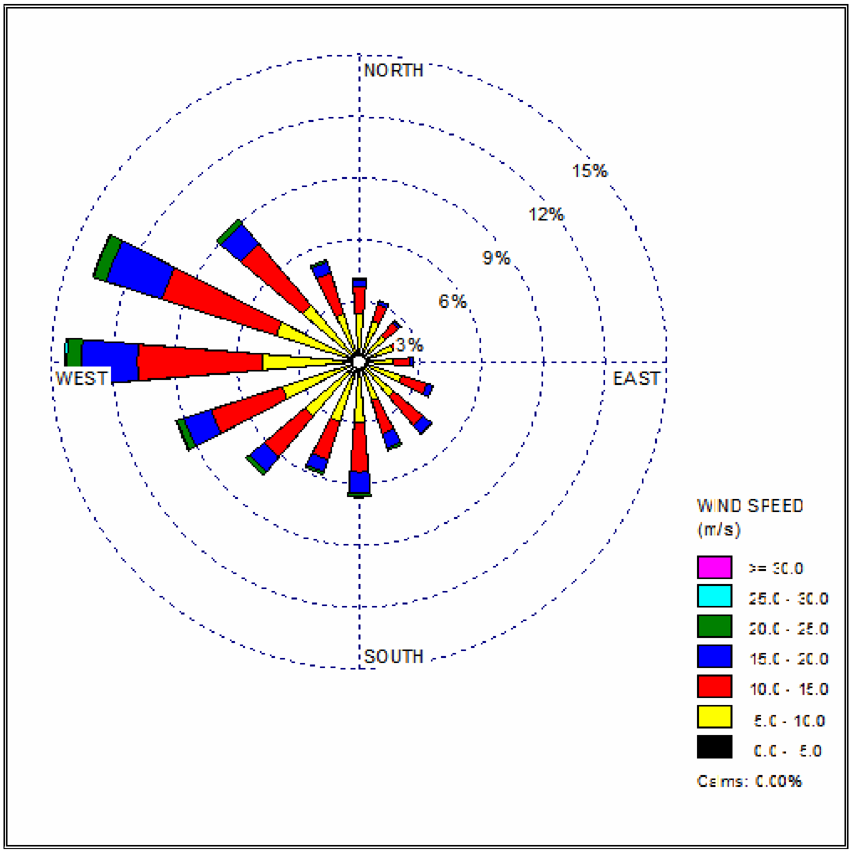


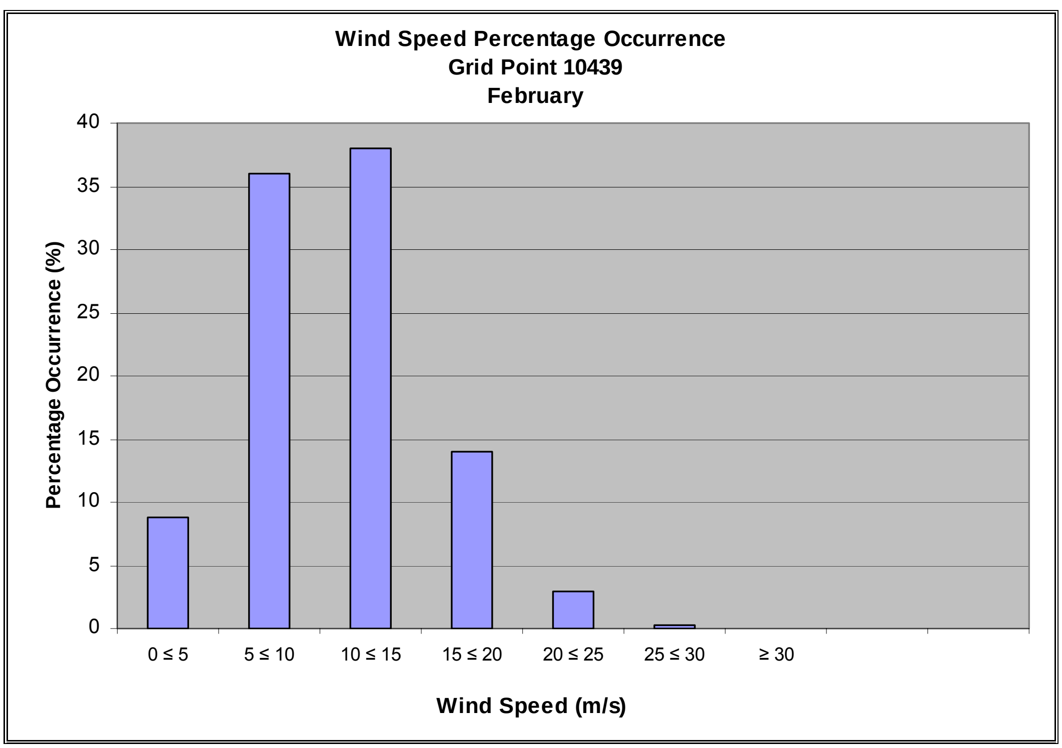


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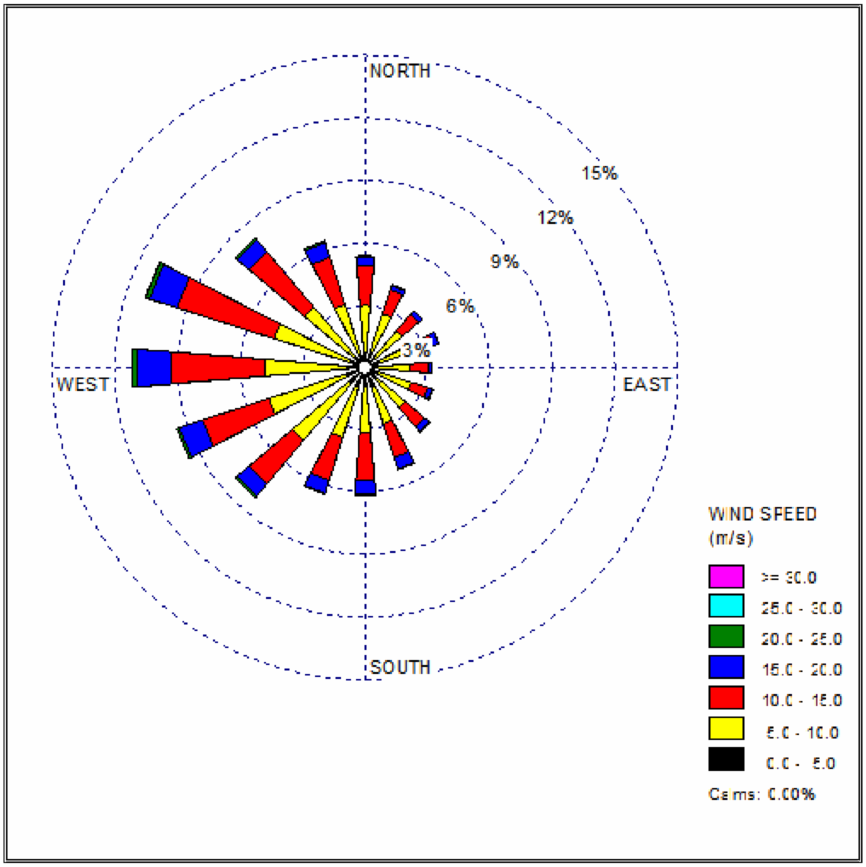


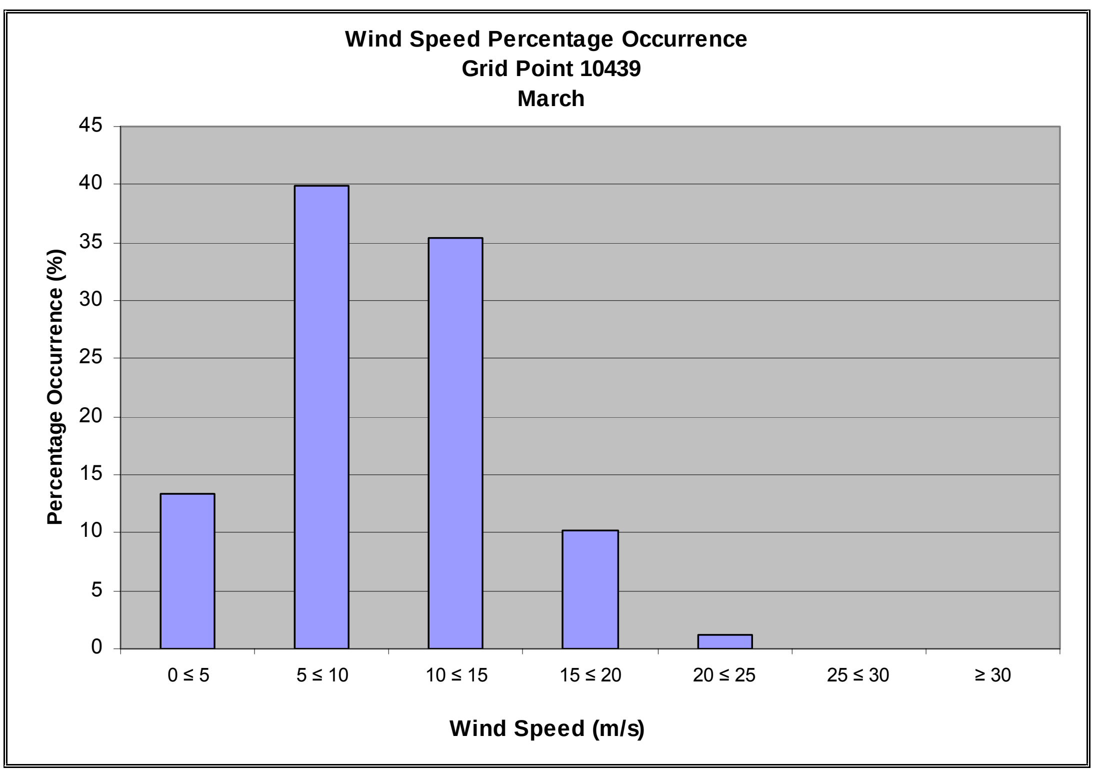


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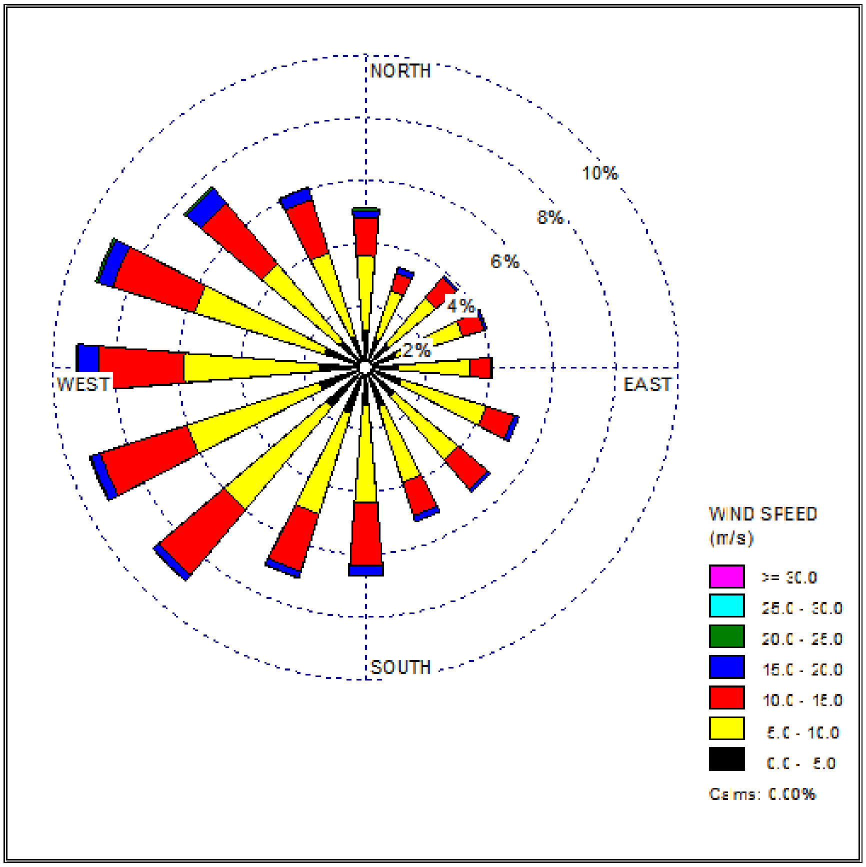


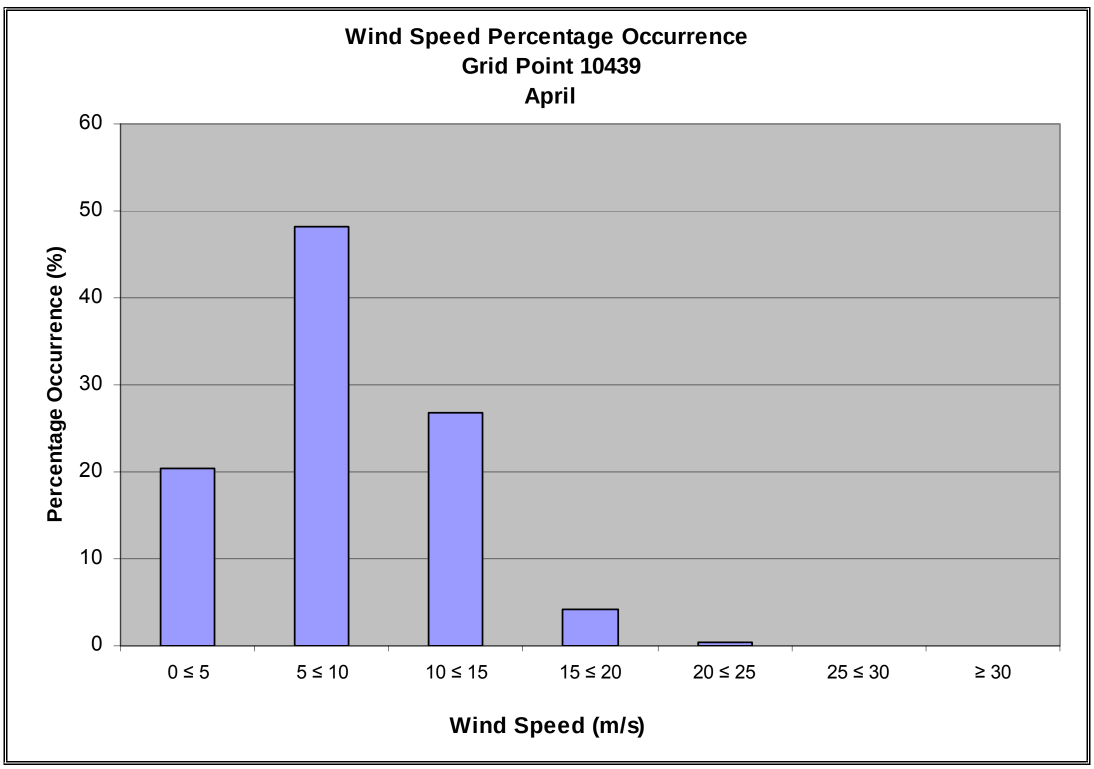


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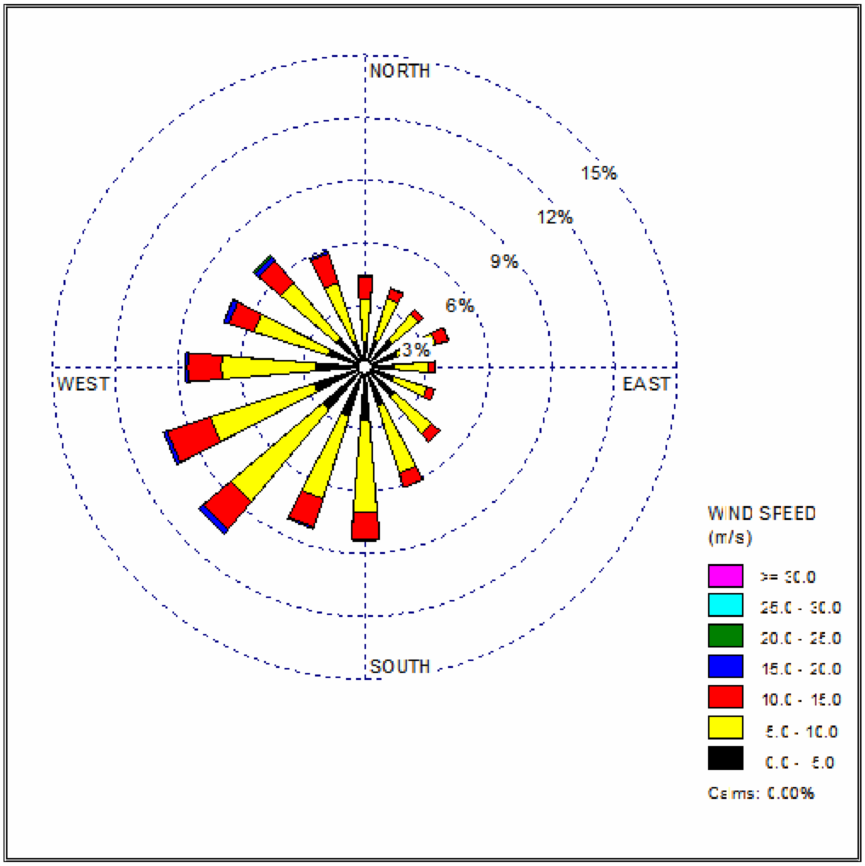


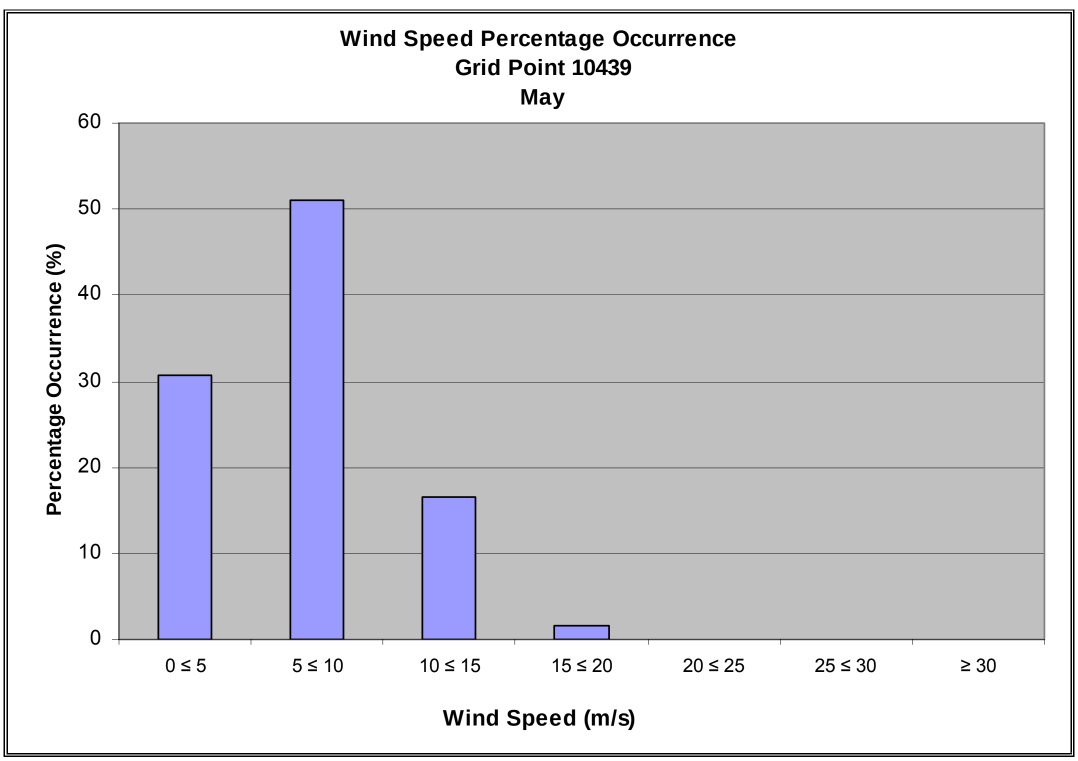


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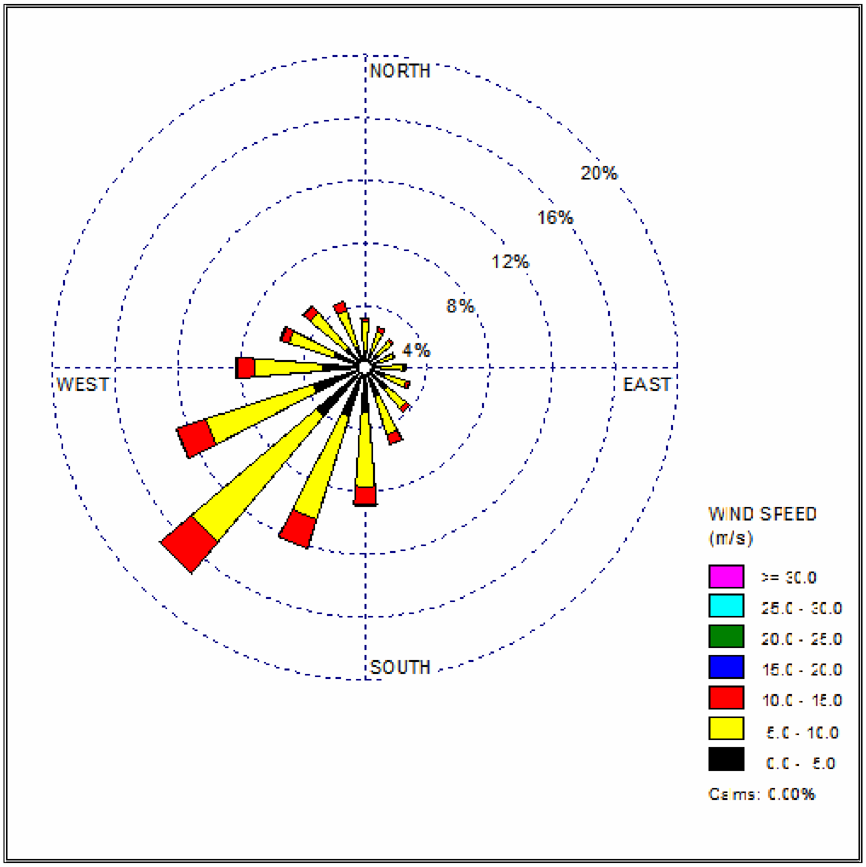


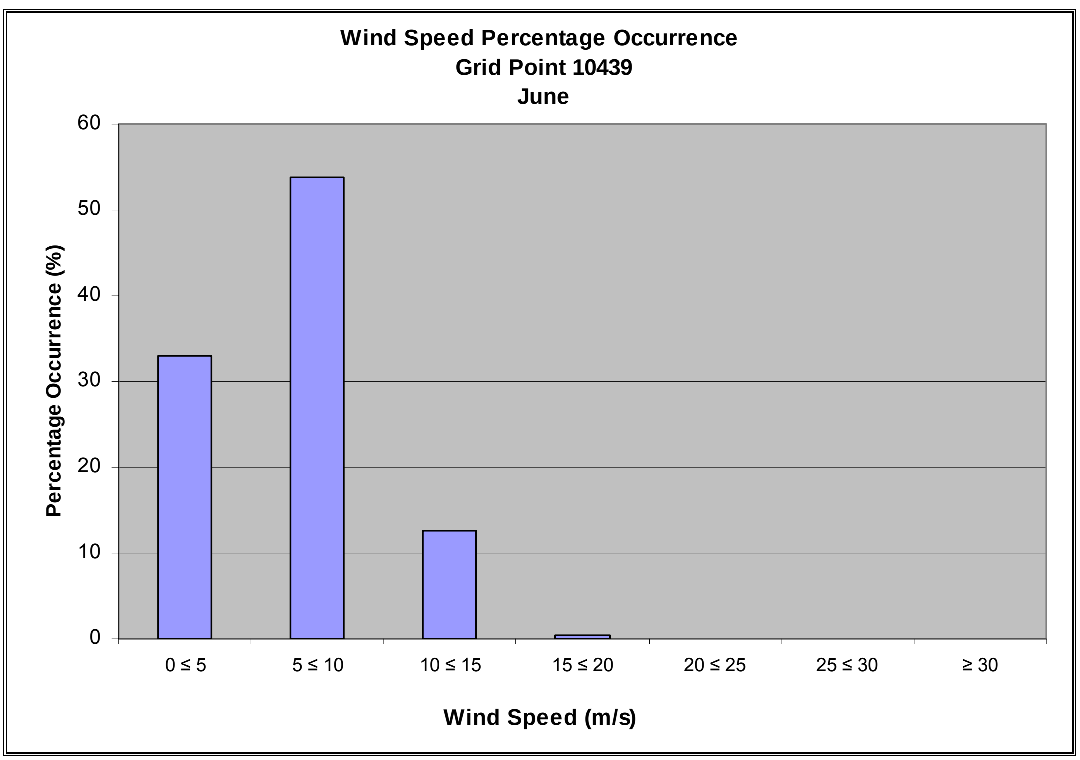


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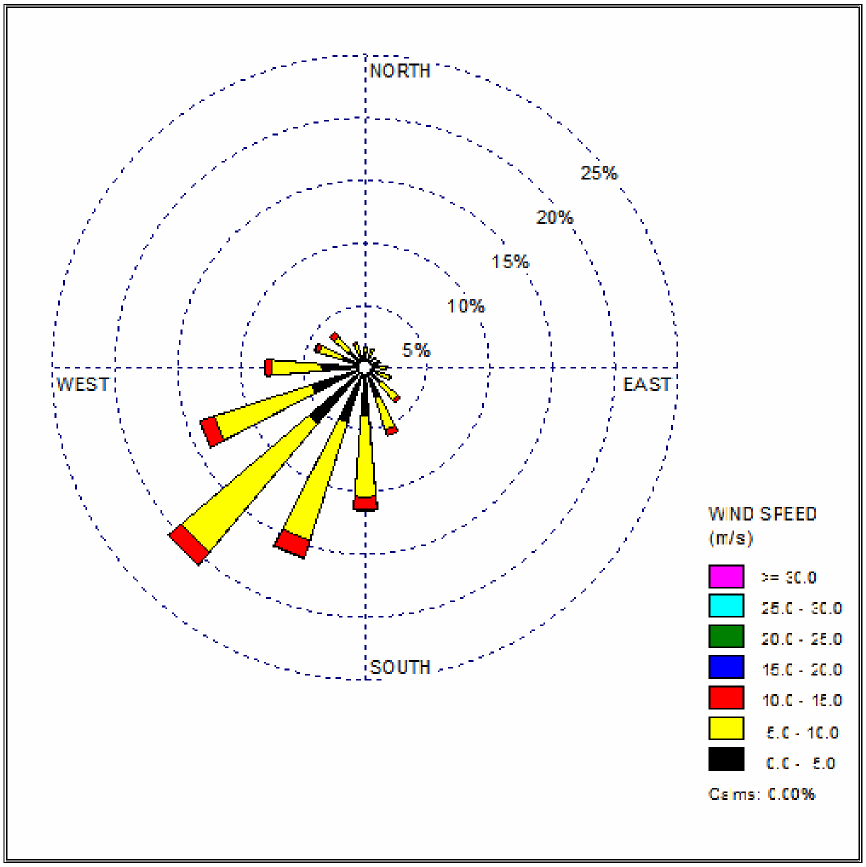


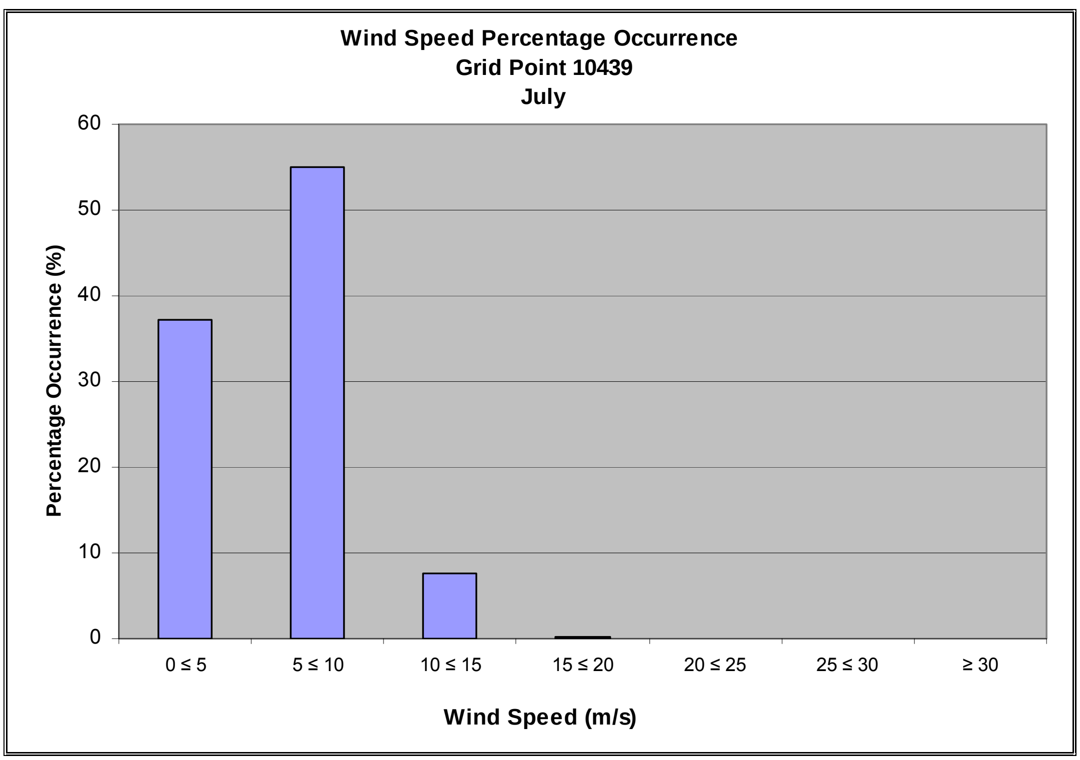


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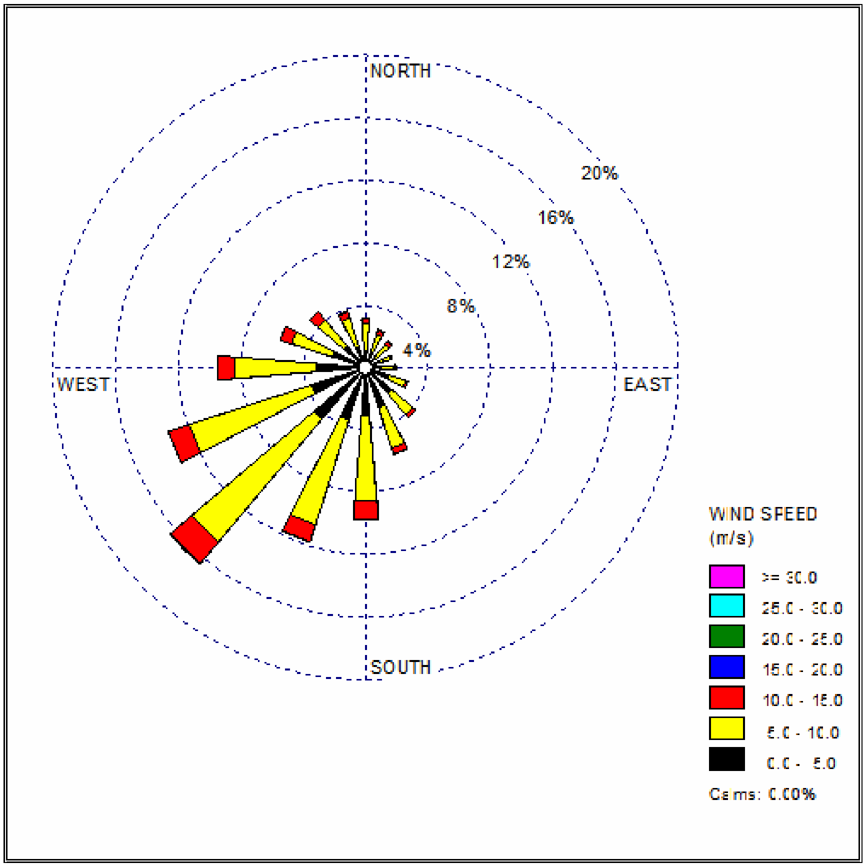


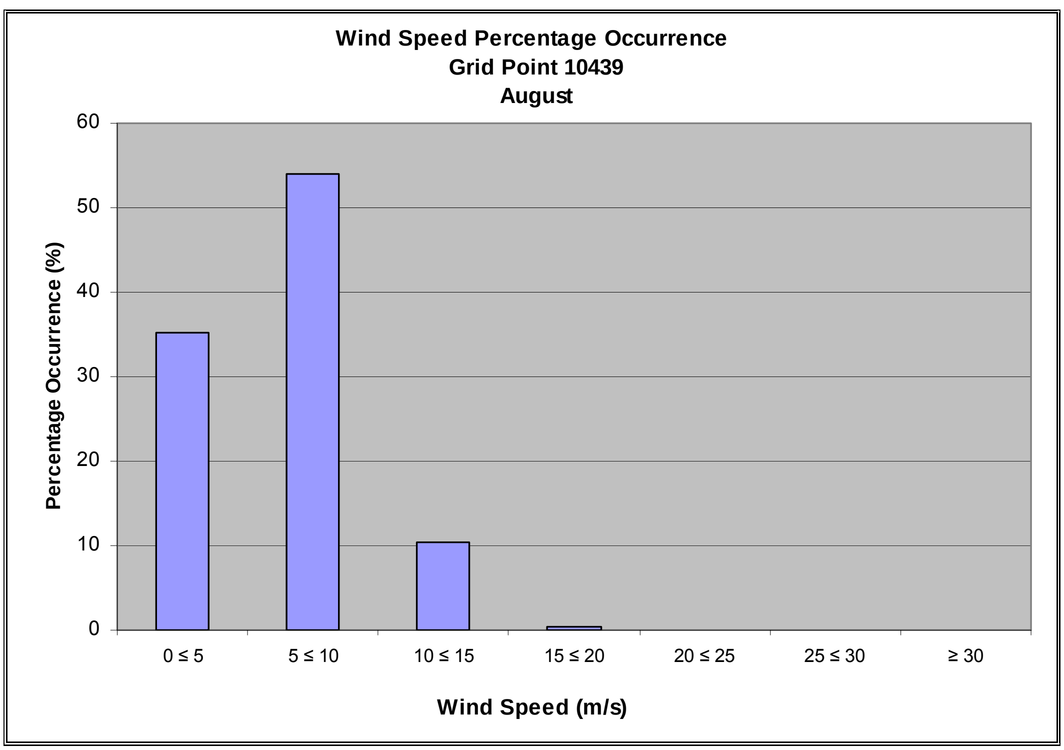


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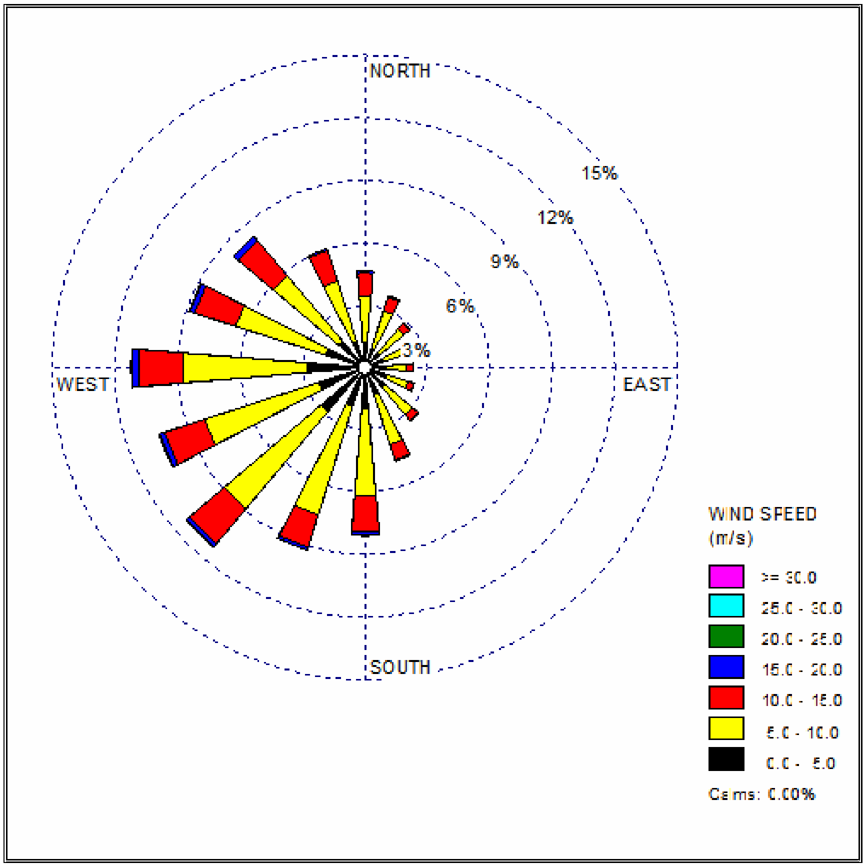


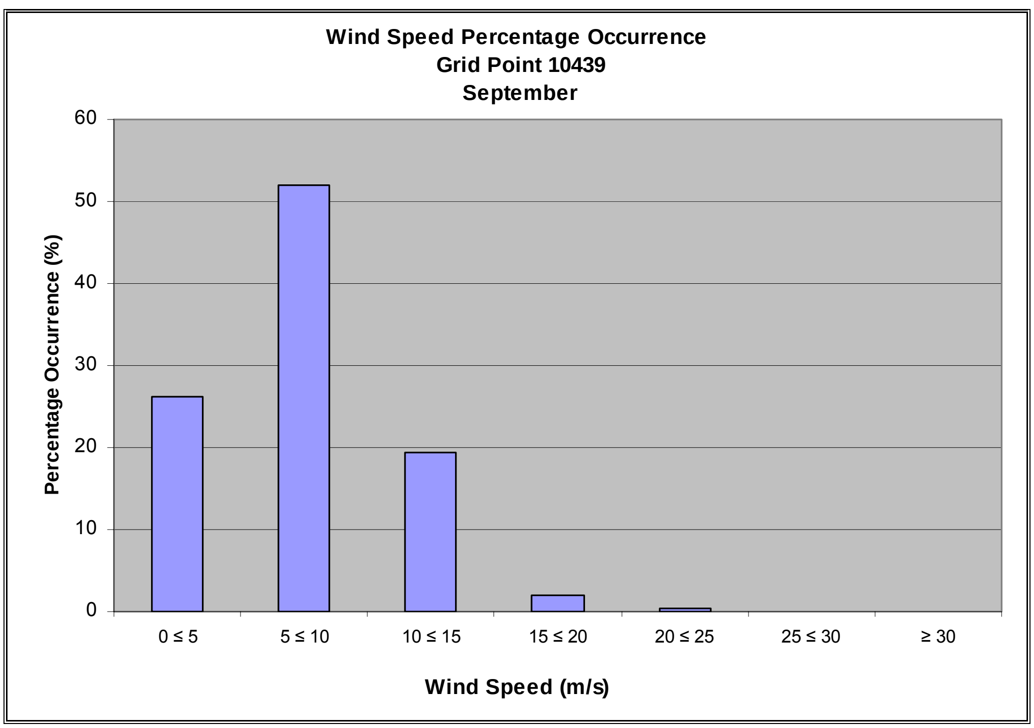


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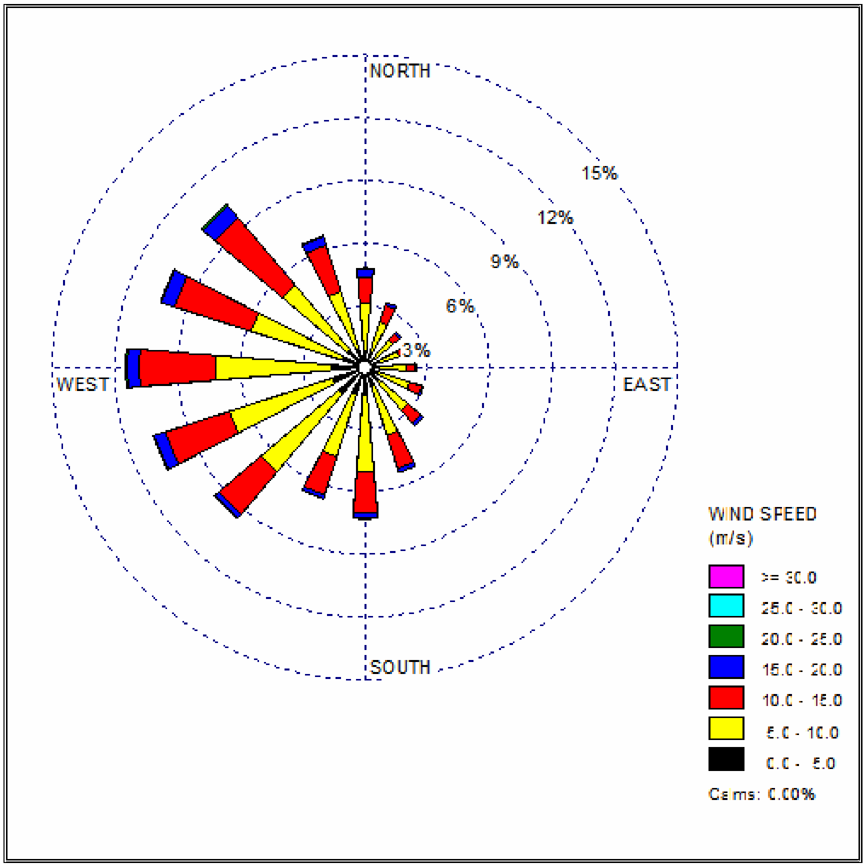


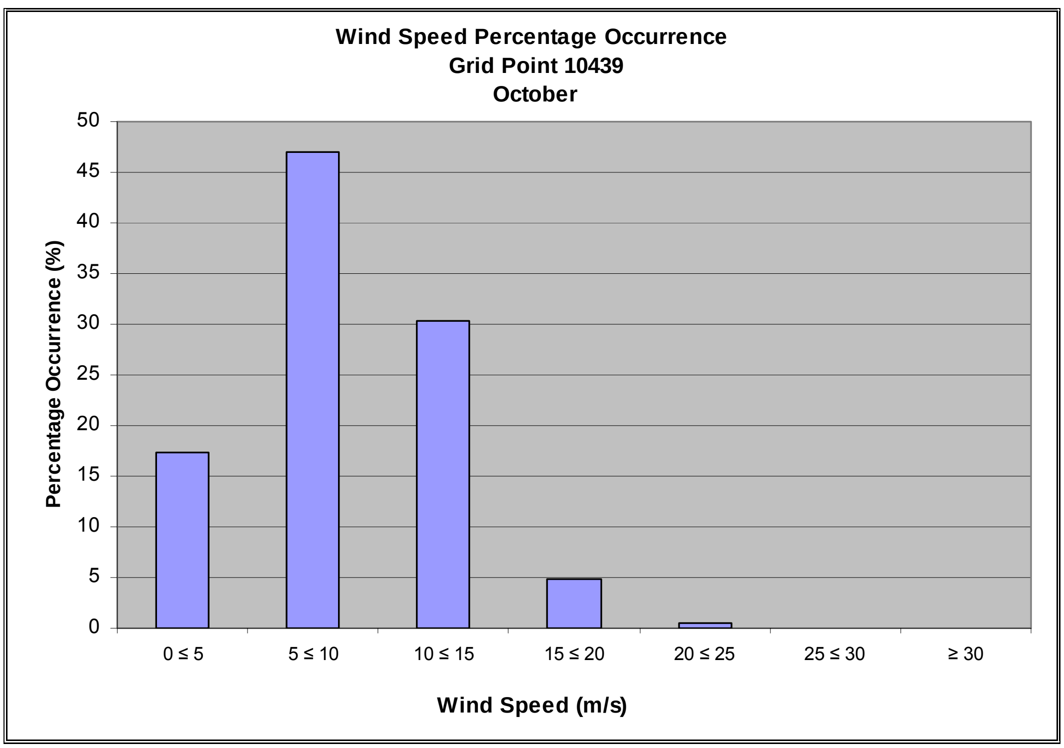


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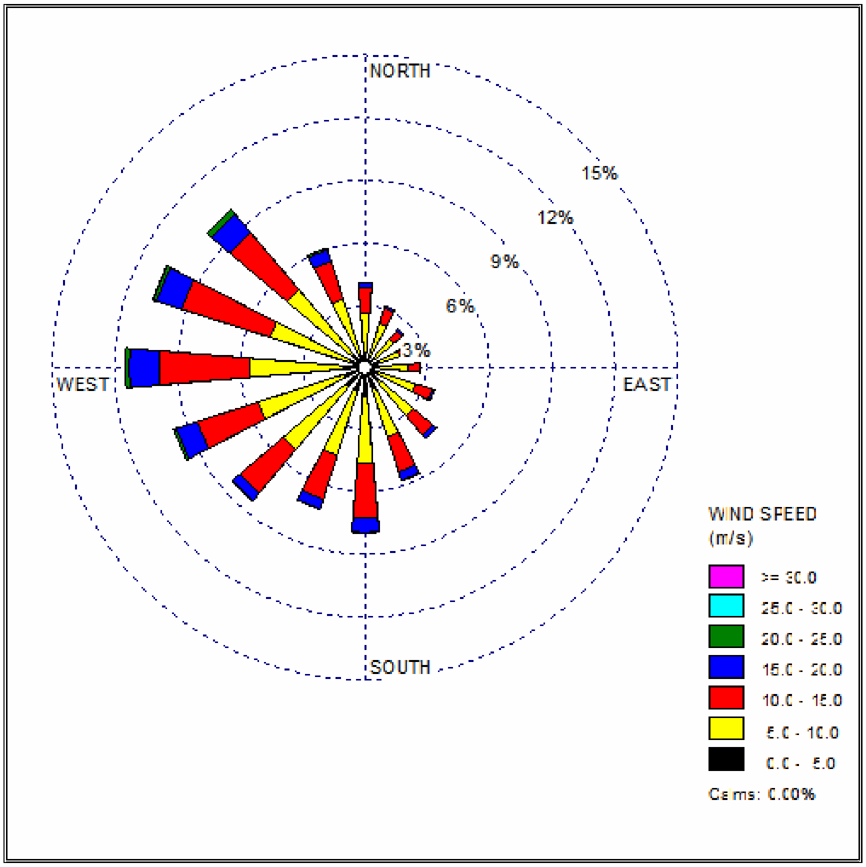


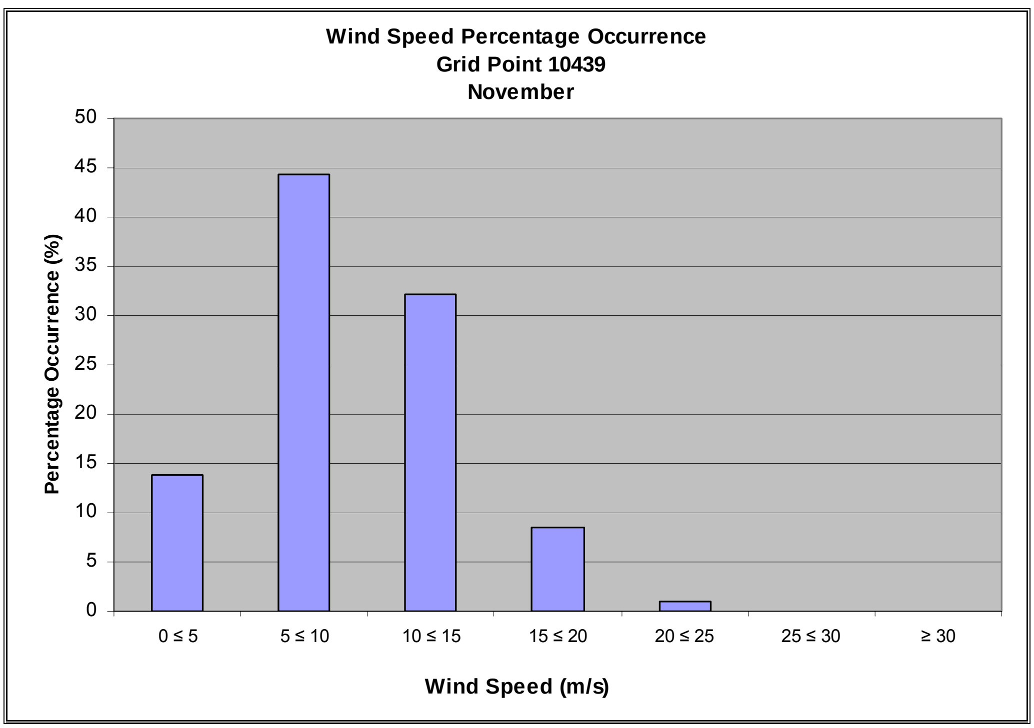


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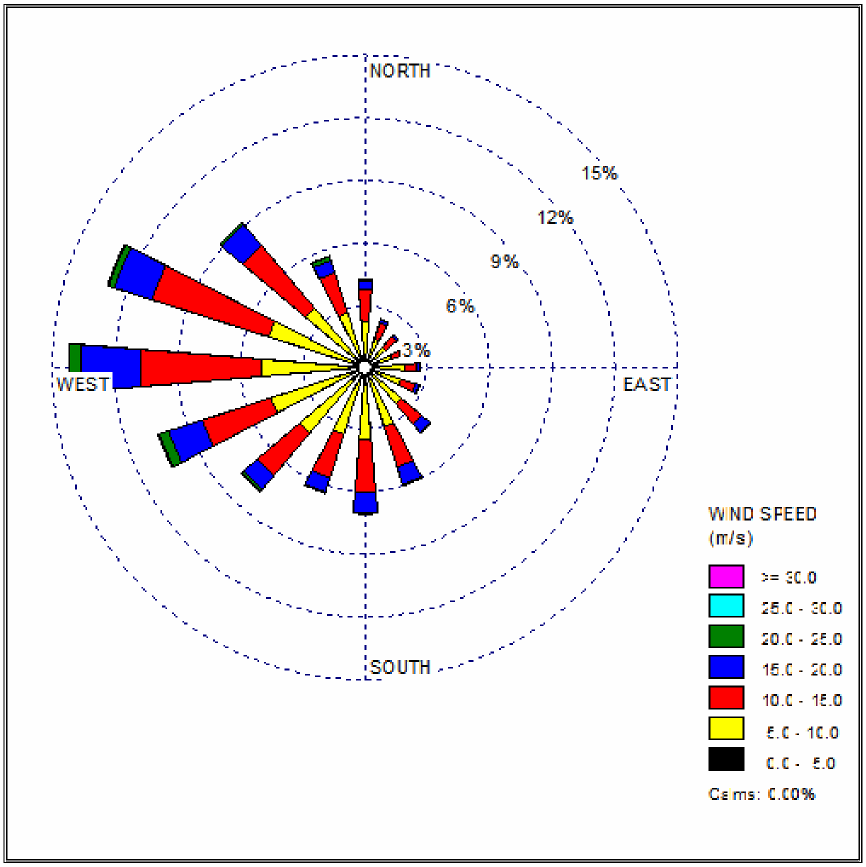
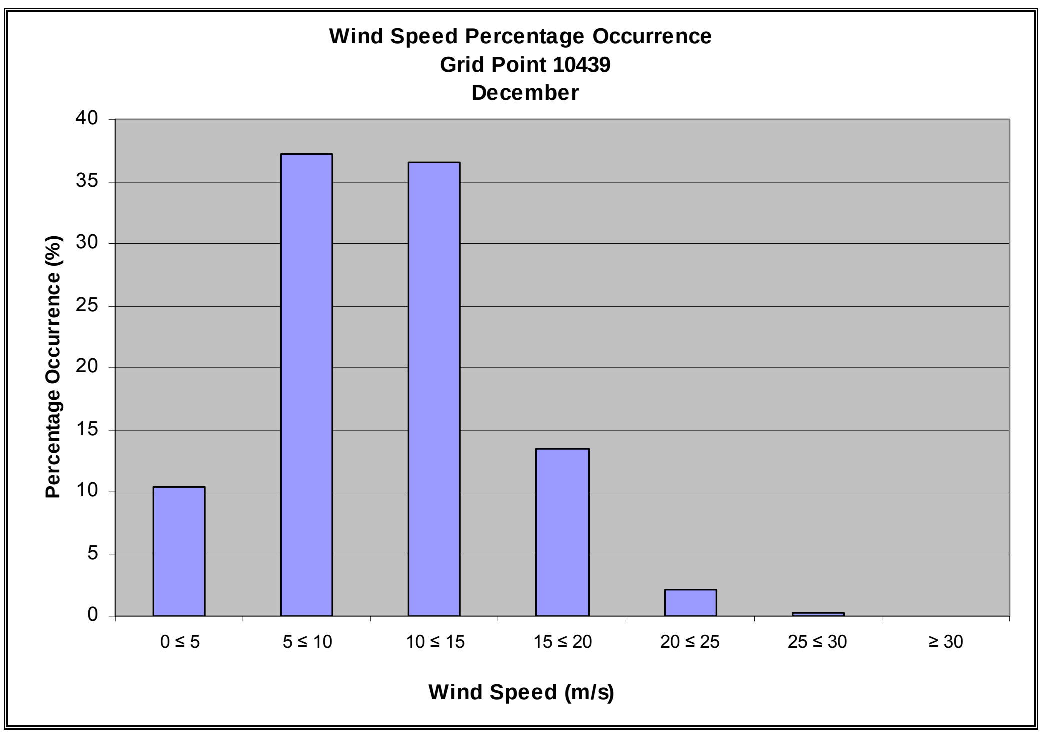
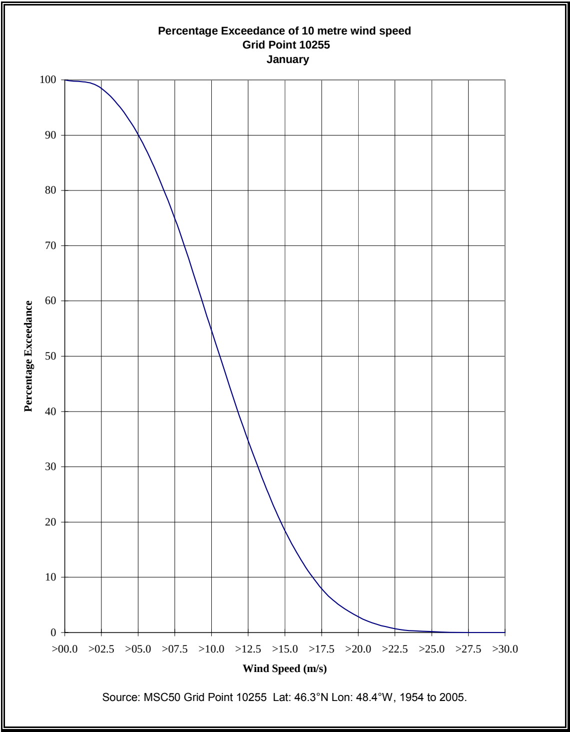


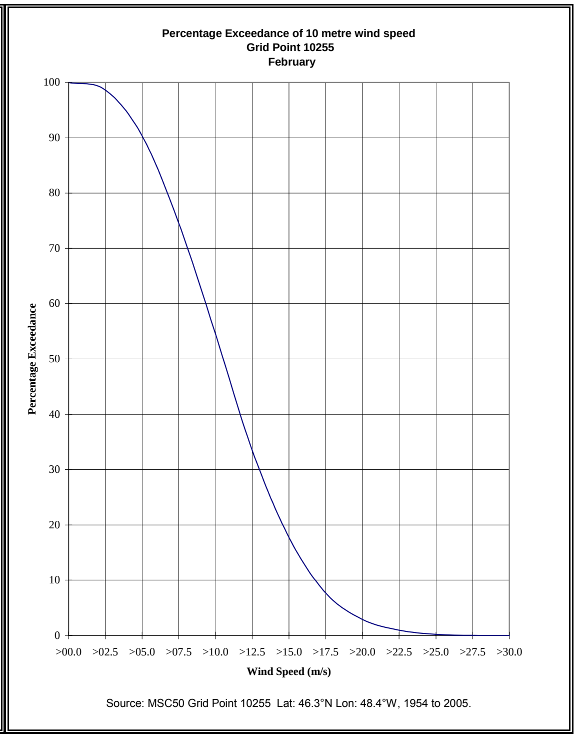



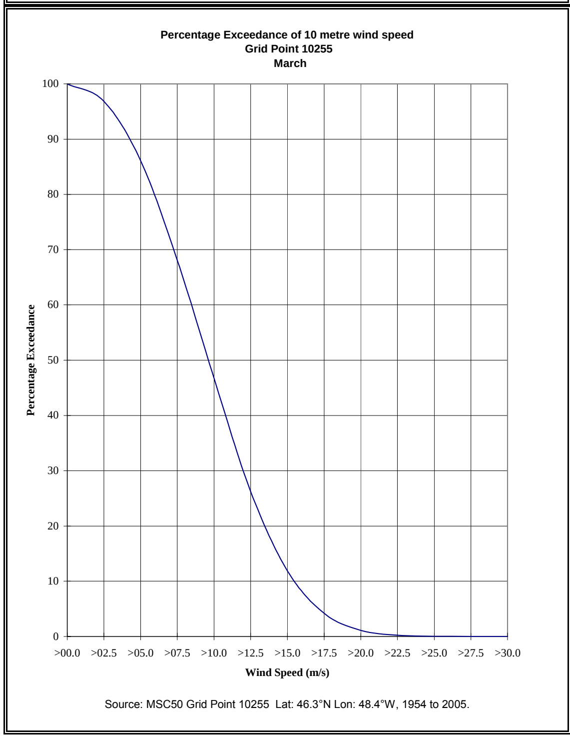

**December Wind Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**

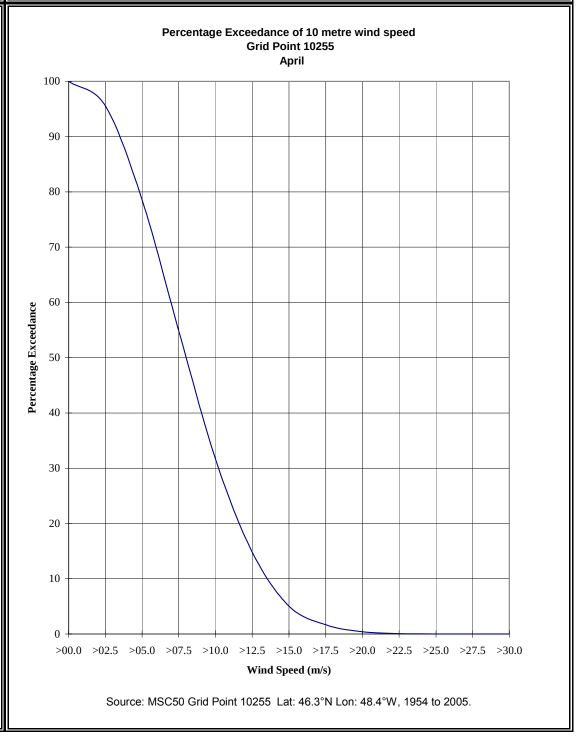
# Appendix 3

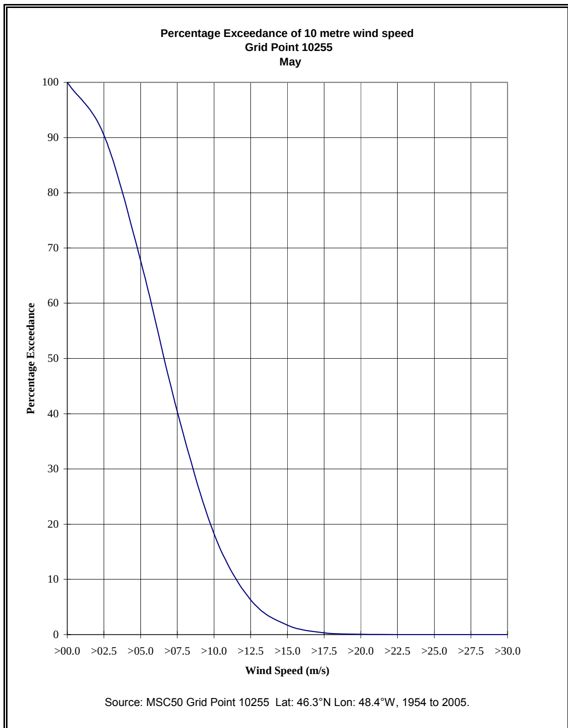
# Percentage Exceedance of 10m Wind Speed at Grid Point 10255


Percentage Exceedance of 10 metre wind speed
Grid Point 10255
January
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
0 10 20 30 40 50 60 70 80 90 100
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

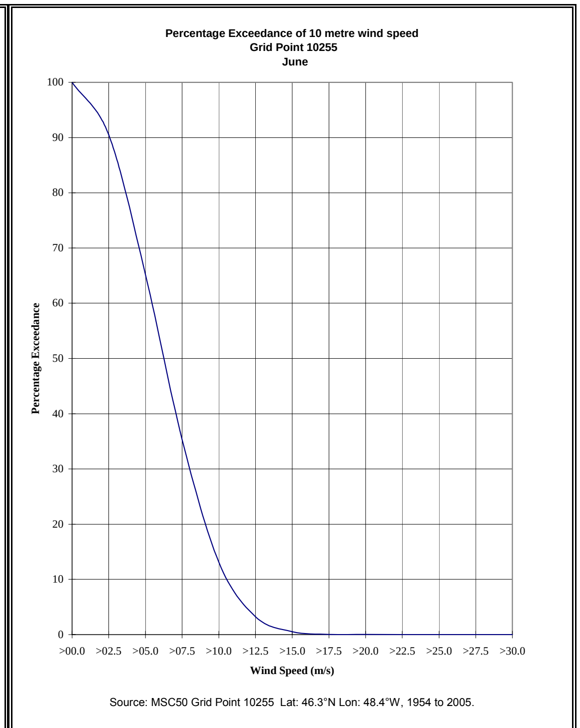

Percentage Exceedance of 10 metre wind speed
Grid Point 10255
February
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
0 10 20 30 40 50 60 70 80 90 100
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10255
March
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
0 10 20 30 40 50 60 70 80 90 100
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

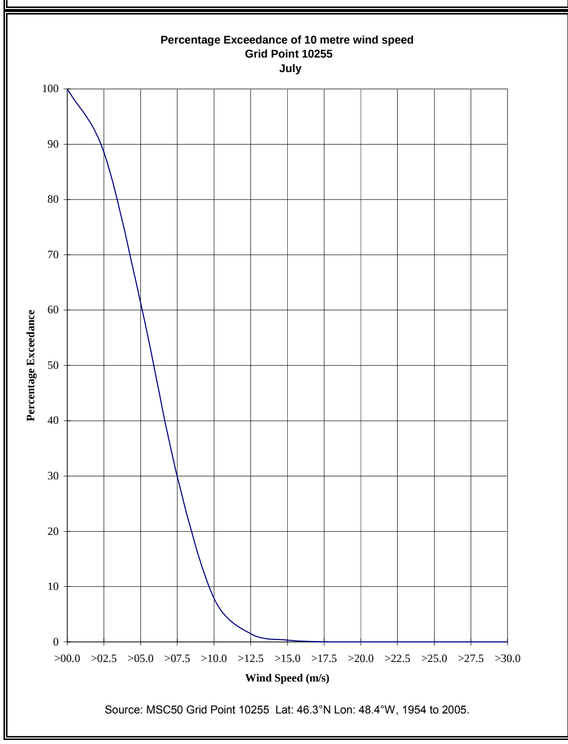

Percentage Exceedance of 10 metre wind speed
Grid Point 10255
April
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
0 10 20 30 40 50 60 70 80 90 100
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.



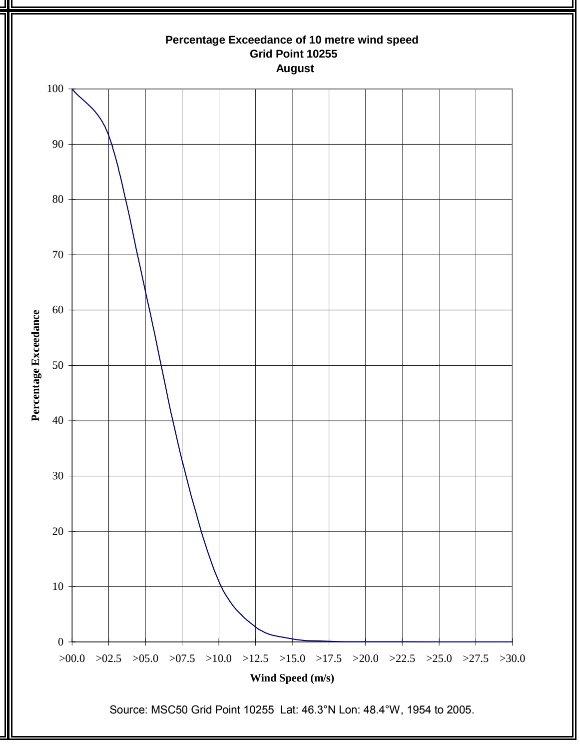
Percentage Exceedance of 10 metre wind speed
Grid Point 10255
May
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

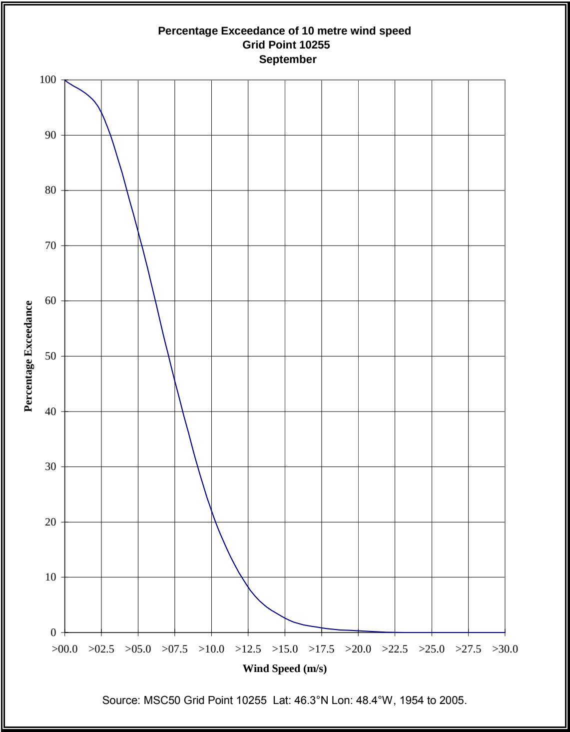
Percentage Exceedance of 10 metre wind speed
Grid Point 10255
June
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

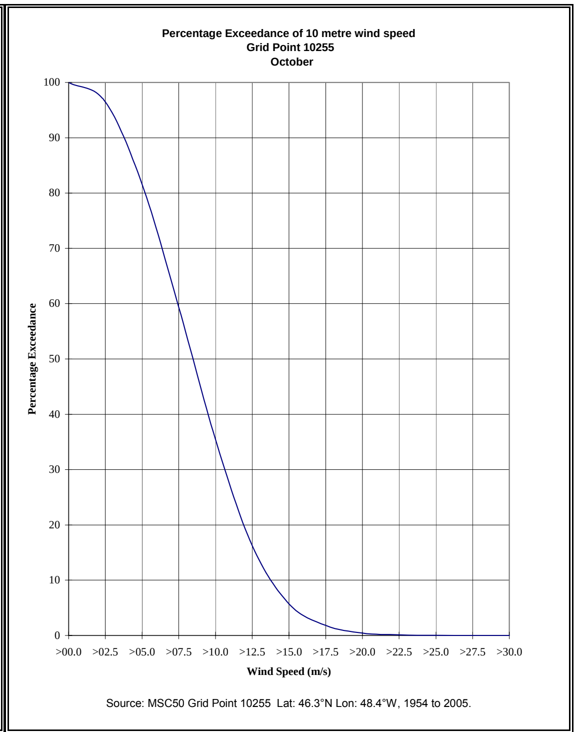



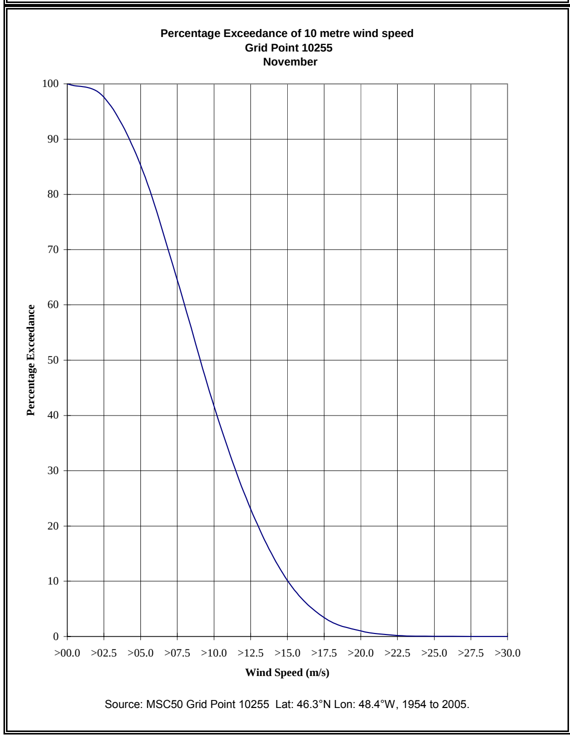
Percentage Exceedance of 10 metre wind speed
Grid Point 10255
July
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

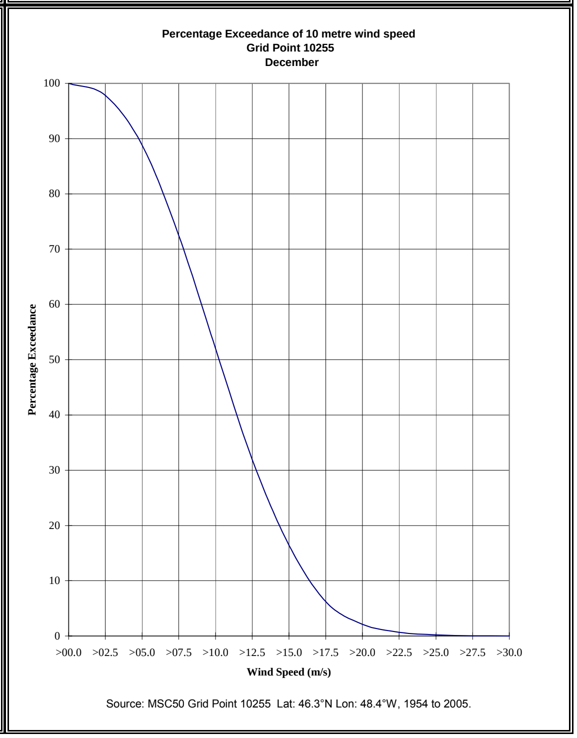



Percentage Exceedance of 10 metre wind speed
Grid Point 10255
August
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10255
September
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10255
October
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

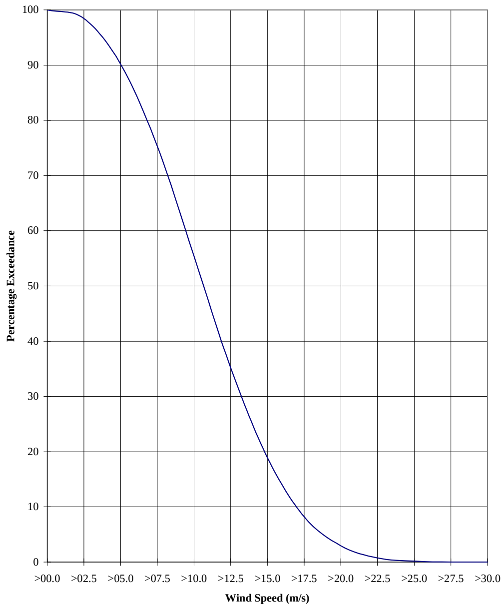

Percentage Exceedance of 10 metre wind speed
Grid Point 10255
November
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10255
December
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

# Appendix 4

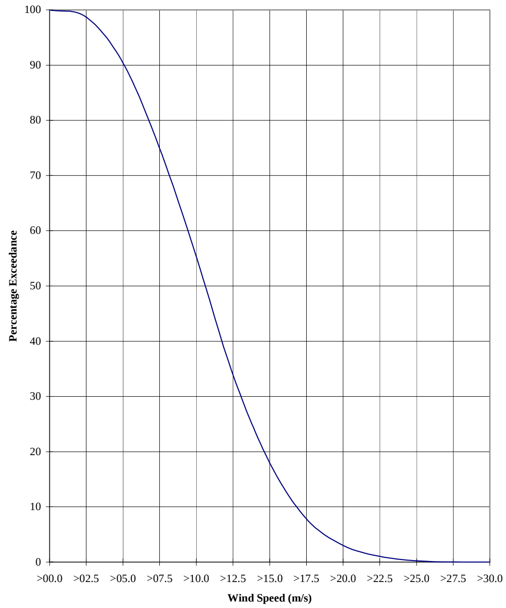
# Monthly Percentage Exceedance of 10m Wind Speed at Grid Point 10439

**Percentage Exceedance of 10 metre wind speed**
**Grid Point 10439**
**January**



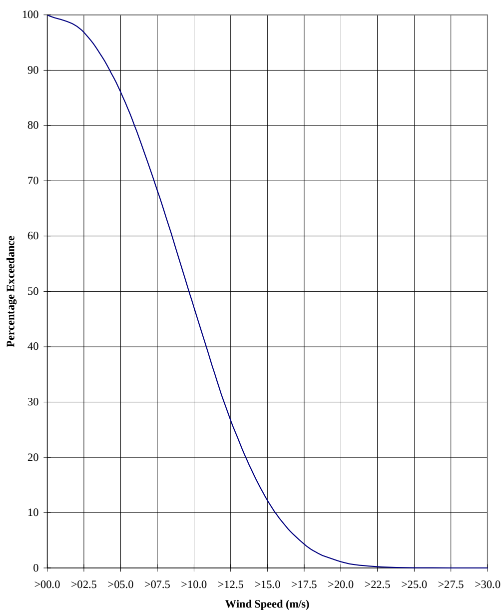

Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

**Percentage Exceedance of 10 metre wind speed**
**Grid Point 10439**
**February**



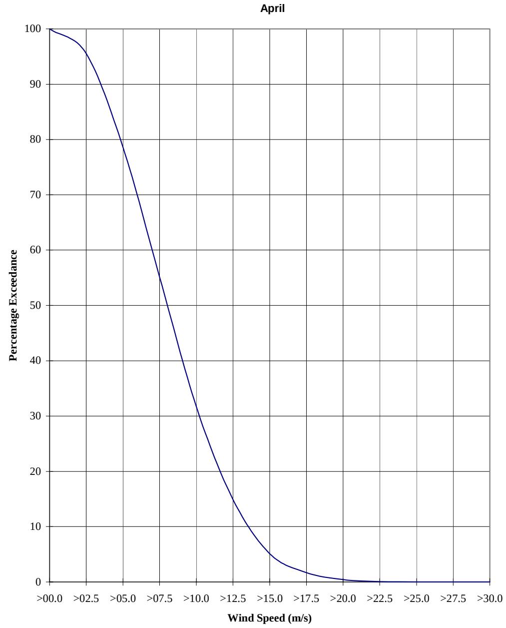

Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

**Percentage Exceedance of 10 metre wind speed**
**Grid Point 10439**
**March**

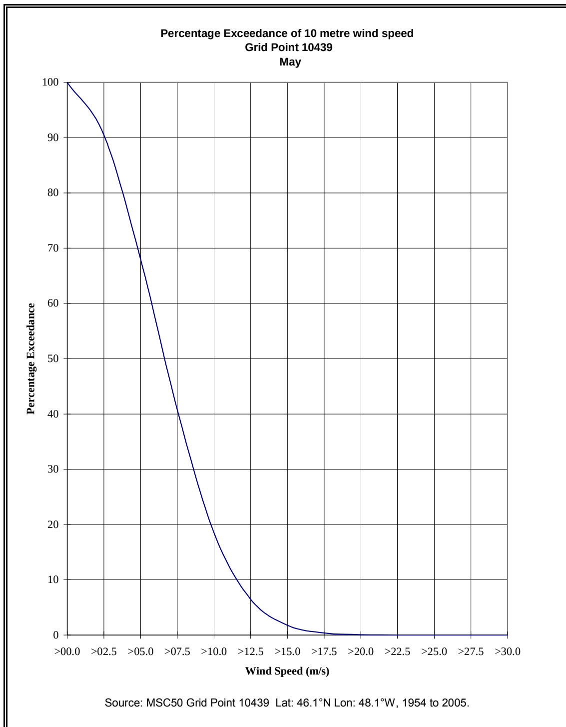


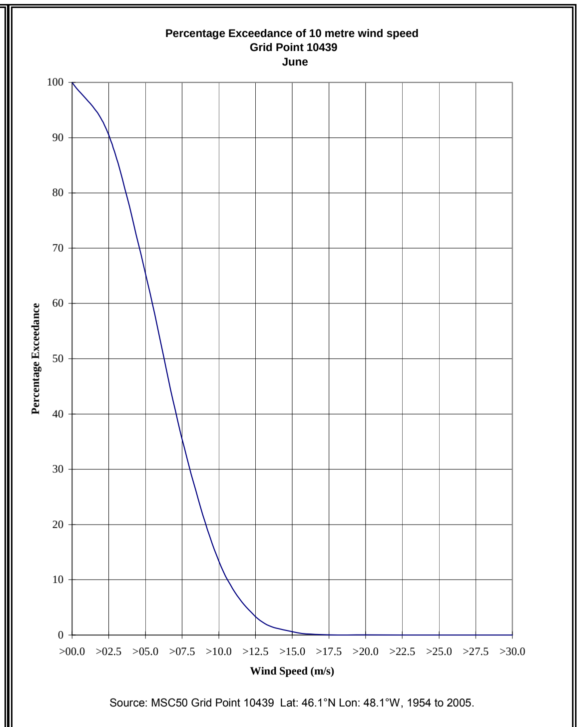

Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

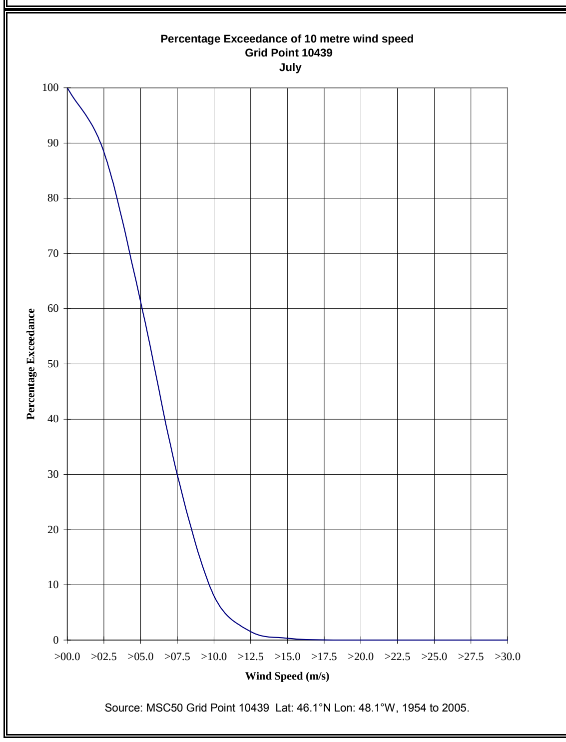
**Percentage Exceedance of 10 metre wind speed**
**Grid Point 10439**
**April**

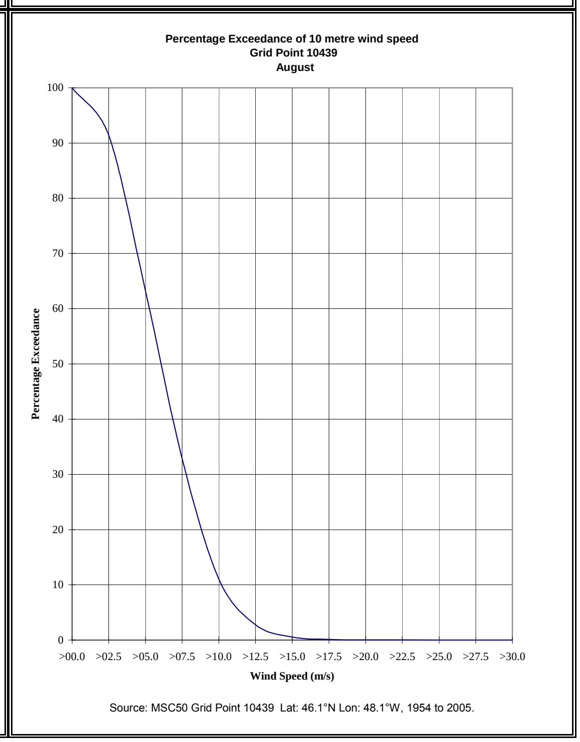


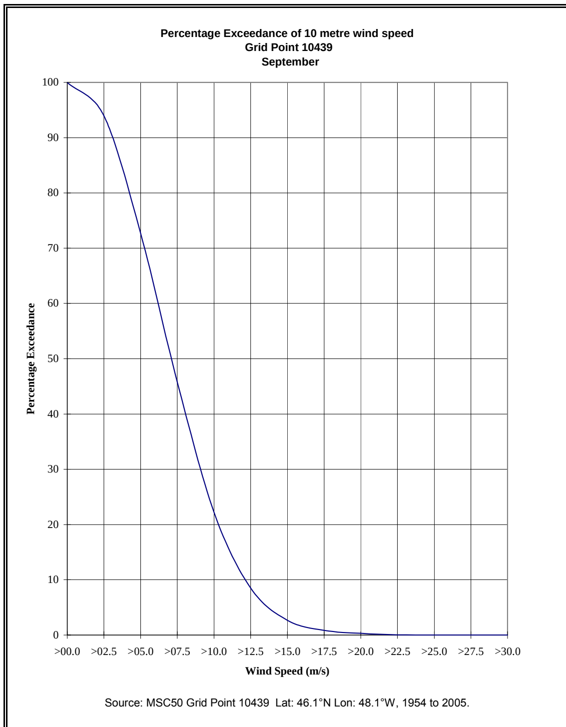

Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

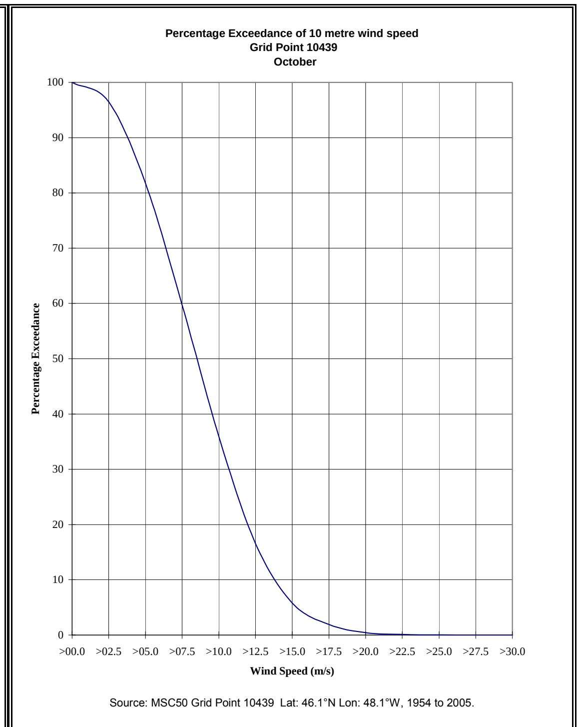

Percentage Exceedance of 10 metre wind speed
Grid Point 10439
May
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

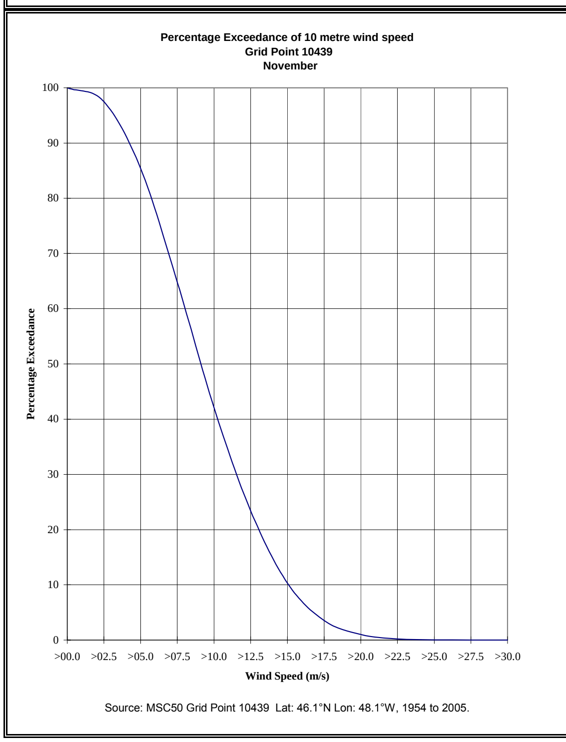

Percentage Exceedance of 10 metre wind speed
Grid Point 10439
June
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

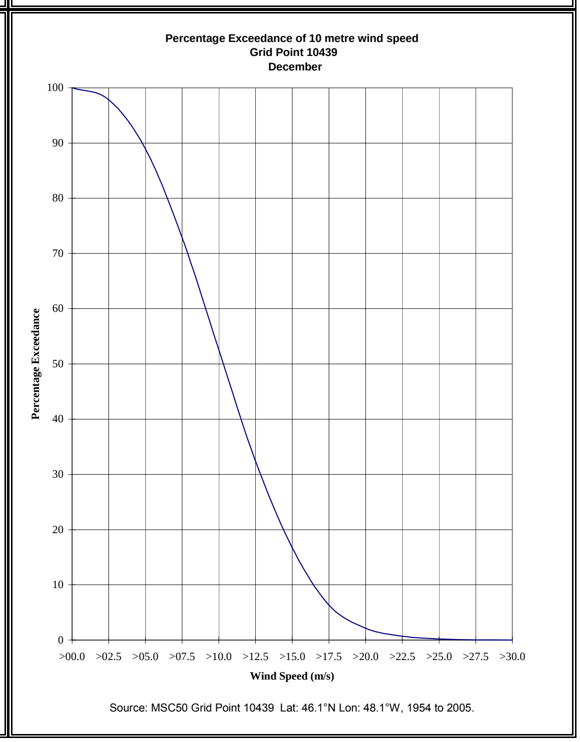

Percentage Exceedance of 10 metre wind speed
Grid Point 10439
July
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10439
August
Percentage Exceedance
Wind Speed (m/s)
>00.0 >02.5 >05.0 >07.5 >10.0 >12.5 >15.0 >17.5 >20.0 >22.5 >25.0 >27.5 >30.0
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10439
September
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

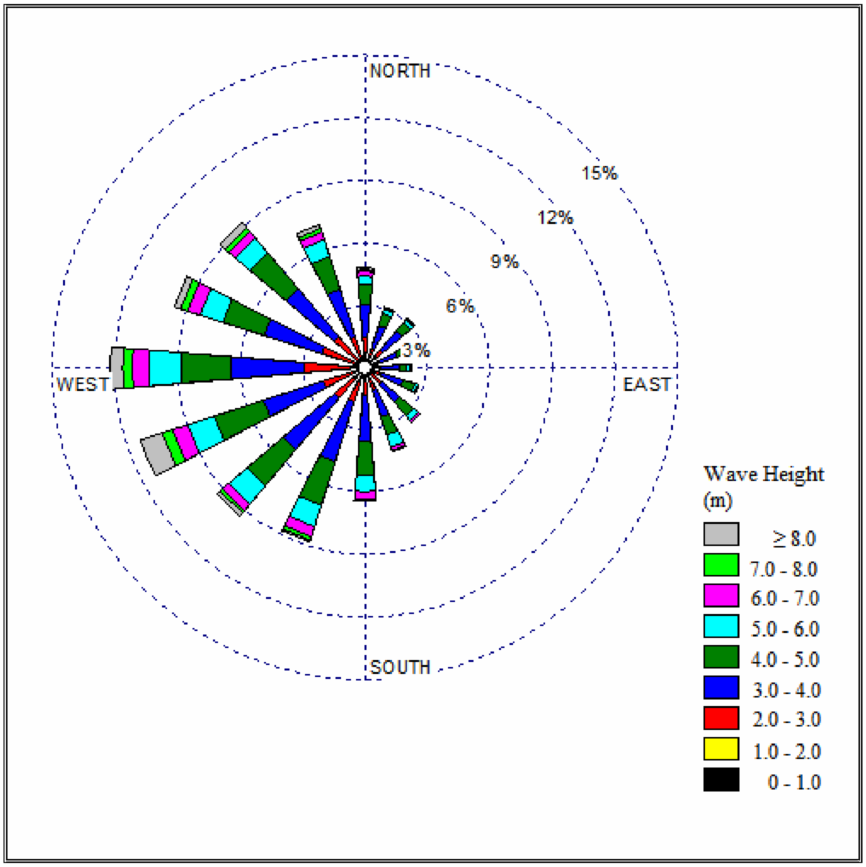

Percentage Exceedance of 10 metre wind speed
Grid Point 10439
October
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

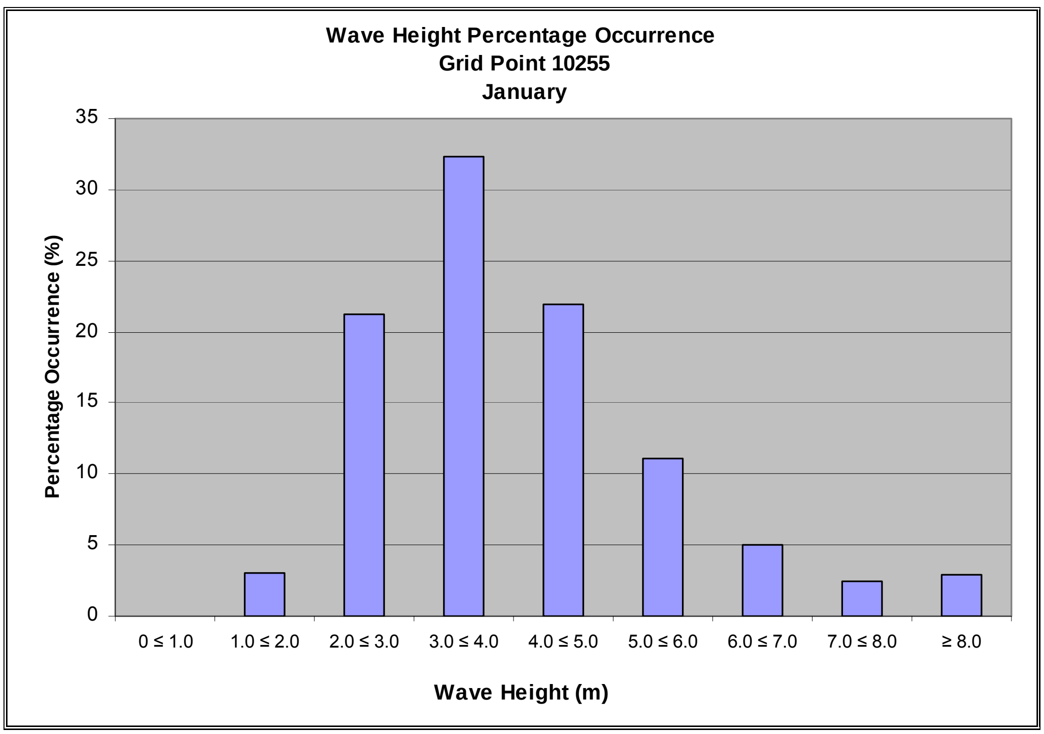

Percentage Exceedance of 10 metre wind speed
Grid Point 10439
November
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of 10 metre wind speed
Grid Point 10439
December
Percentage Exceedance
Wind Speed (m/s)
Source: MSC50 Grid Point 10439 Lat: 46.1°N Lon: 48.1°W, 1954 to 2005.

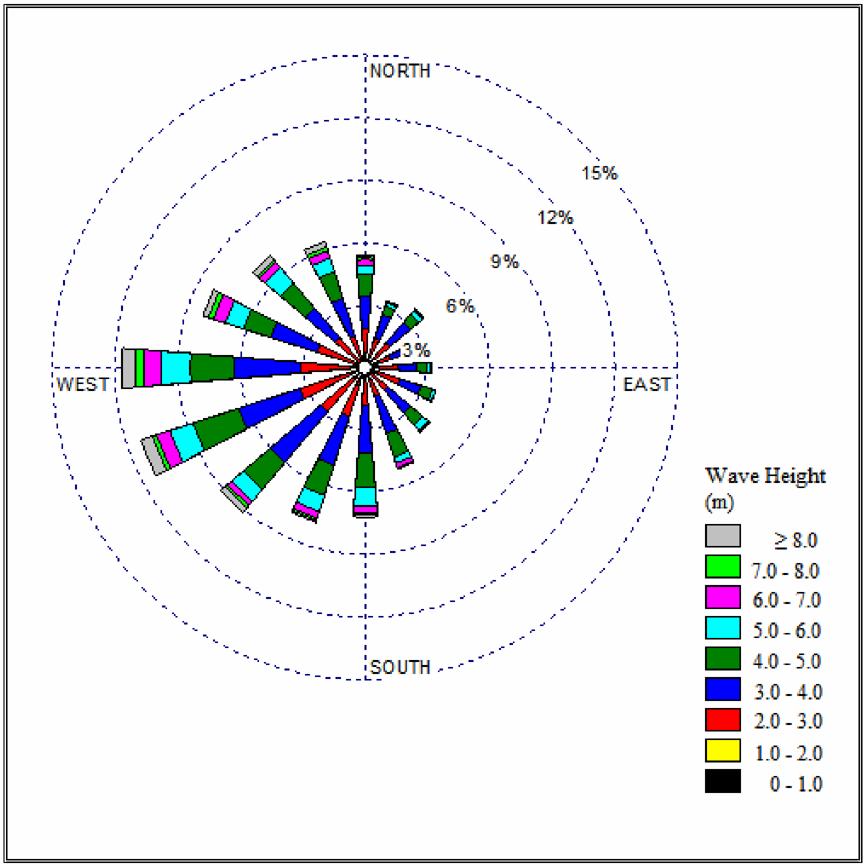
# Appendix 5

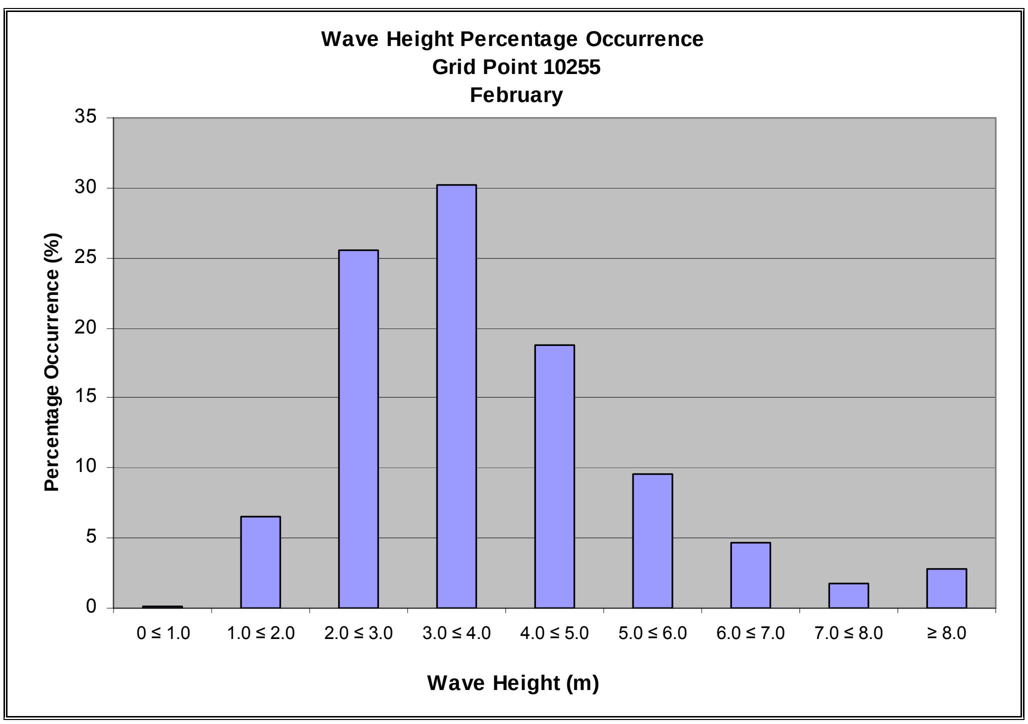
# Wave Rose and Frequency Distributions for MSC50 GridPoint 10255



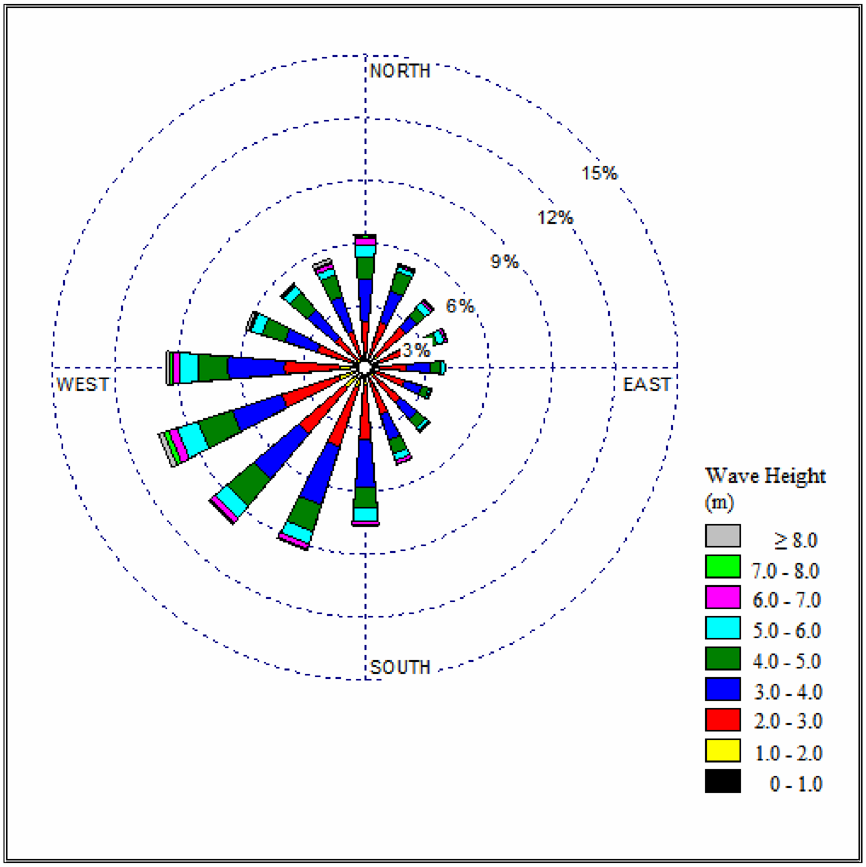



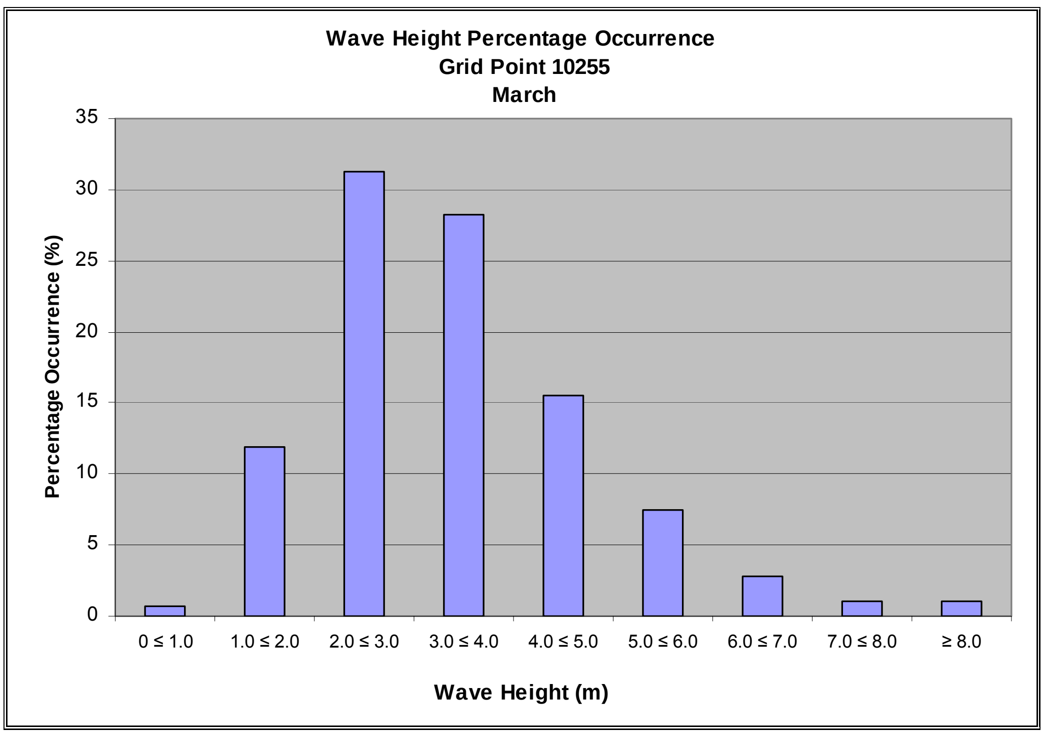

**January Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



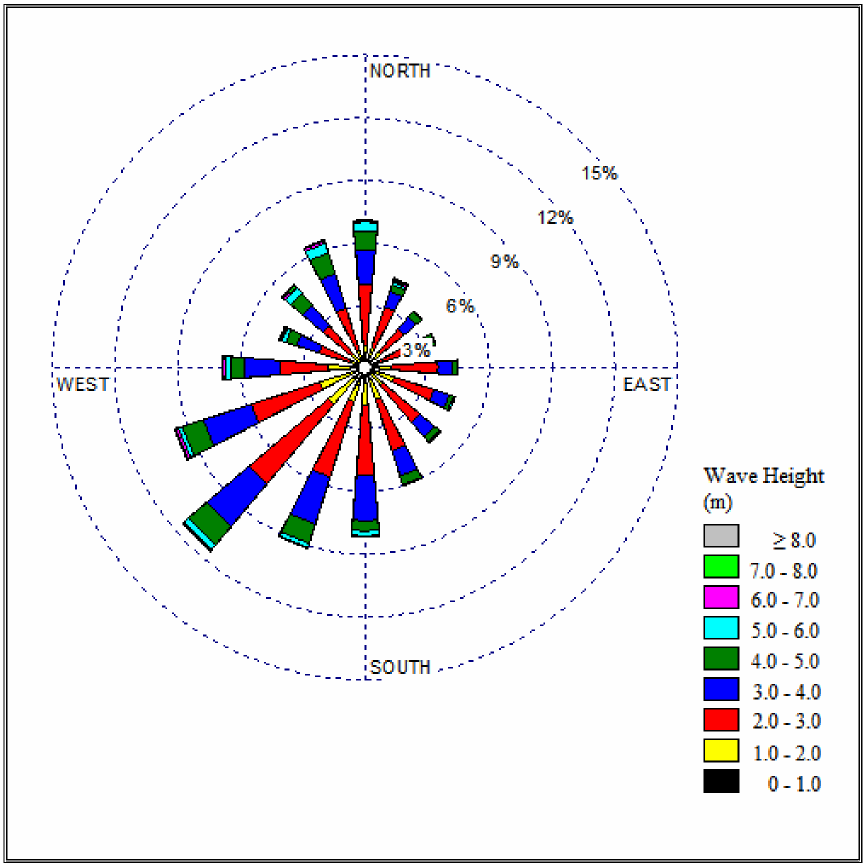



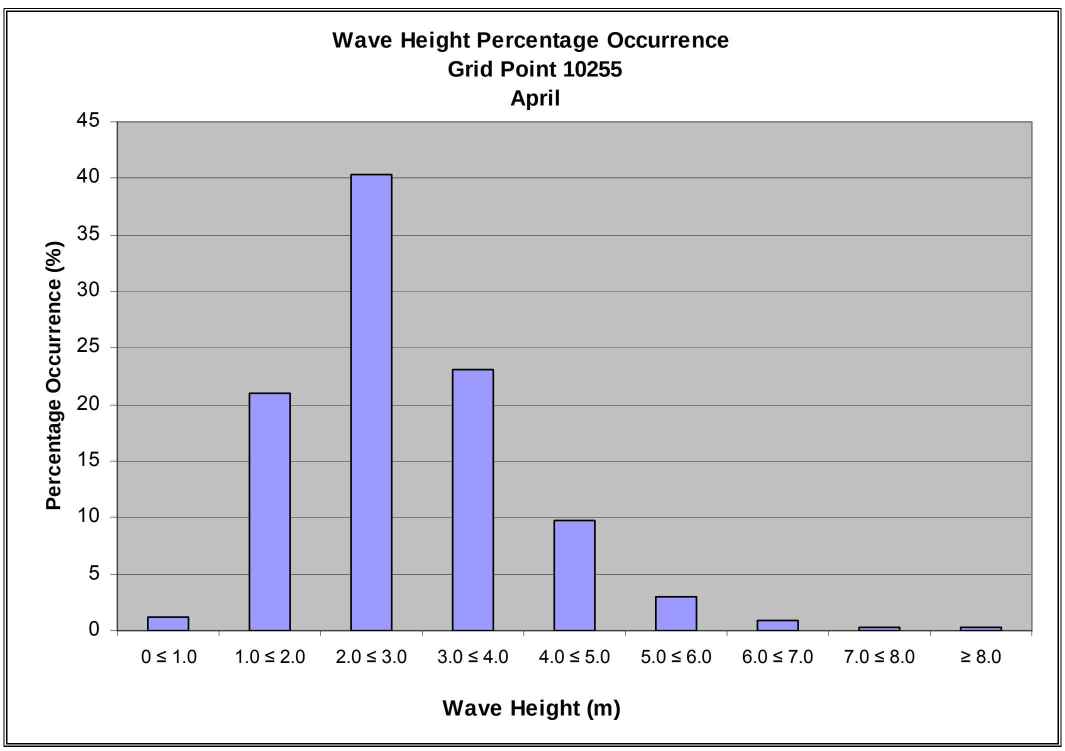

**February Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



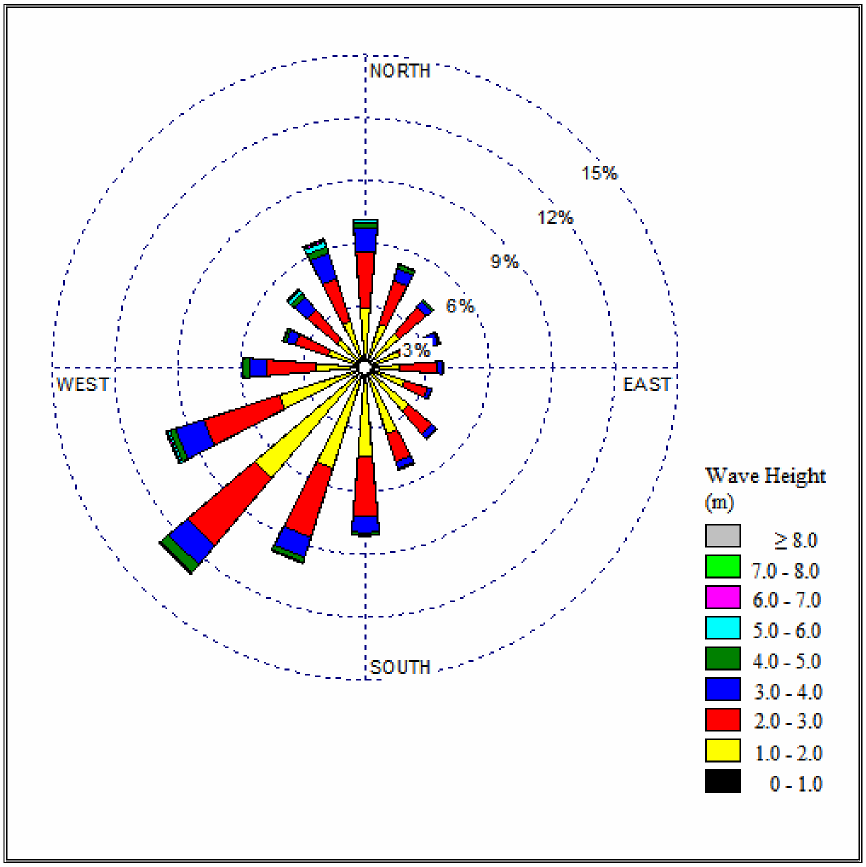



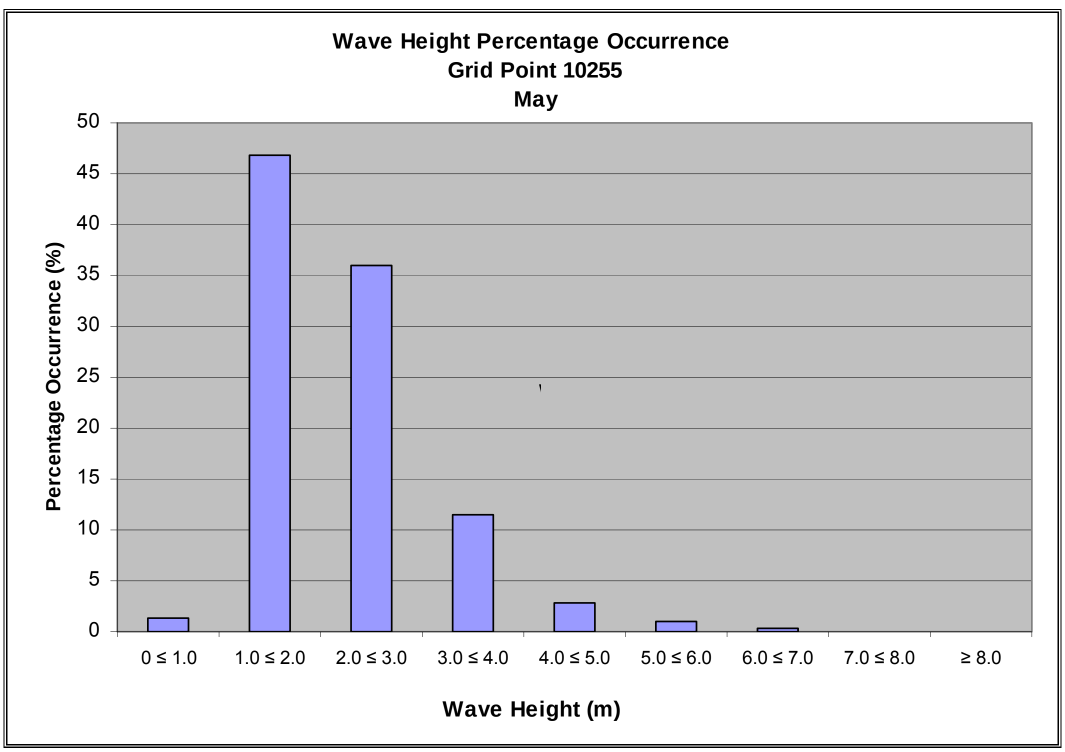

**March Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



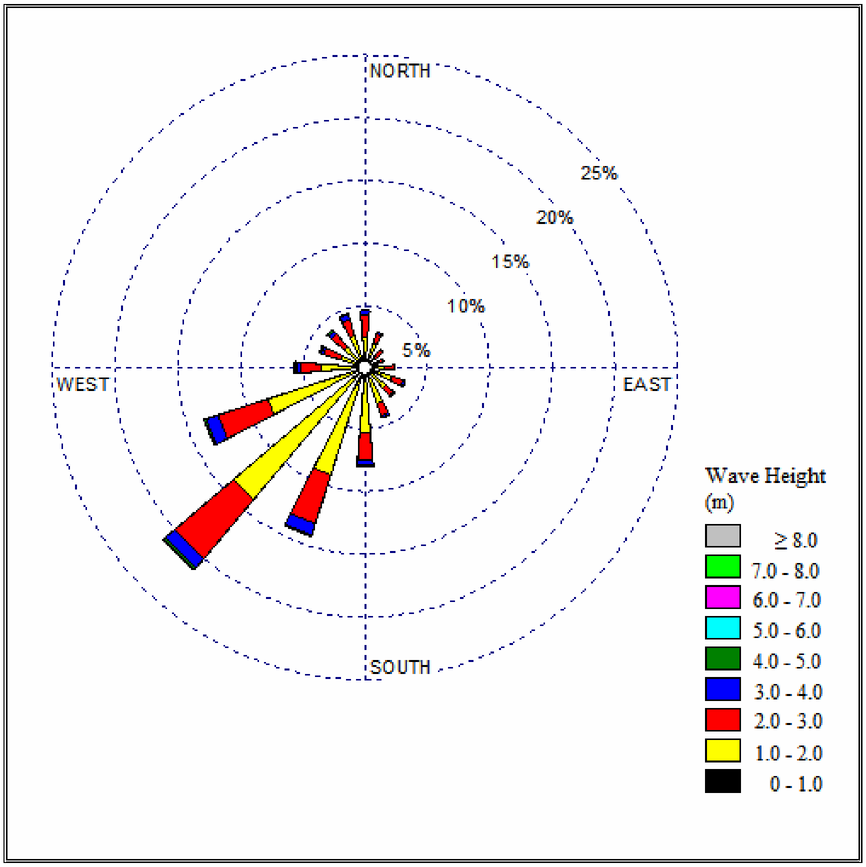



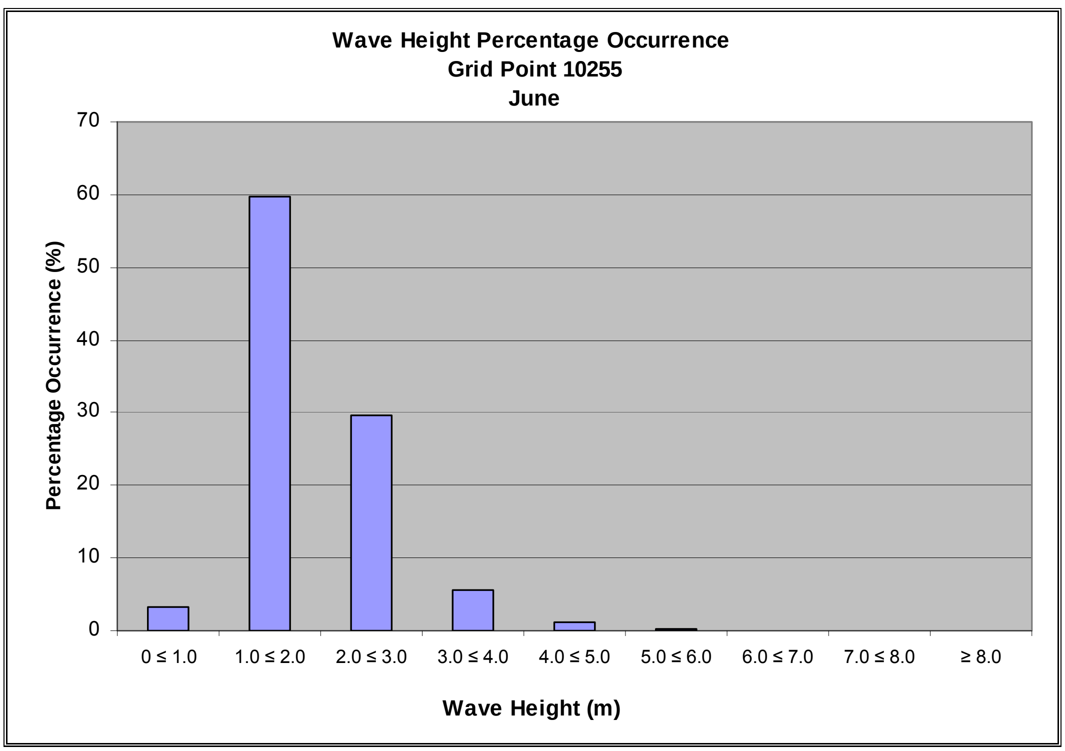

**April Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



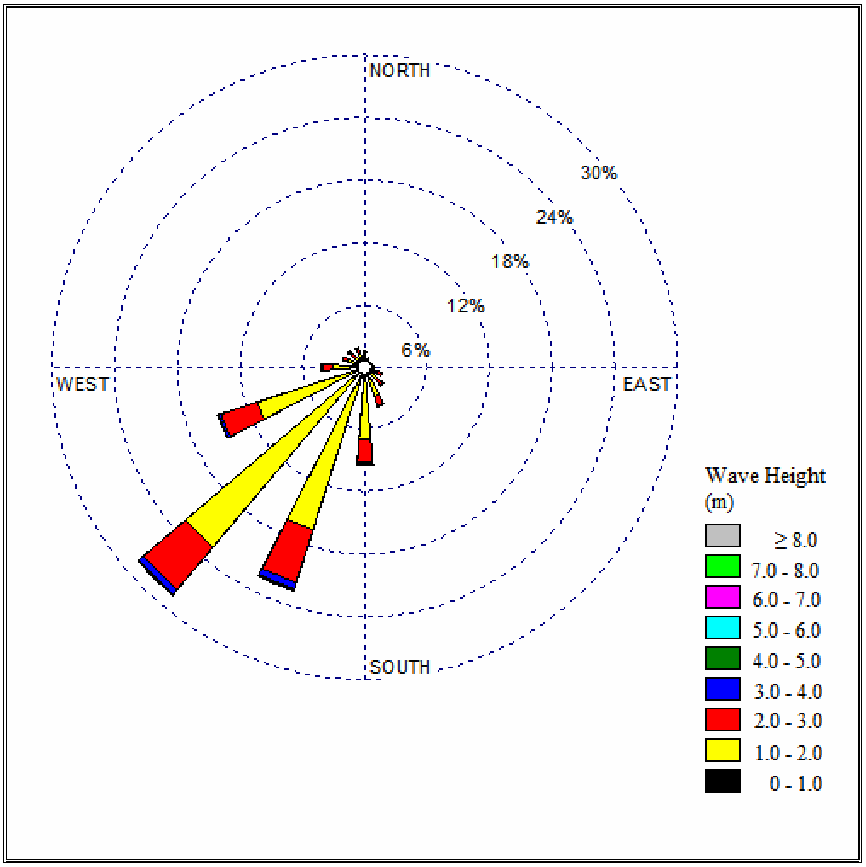



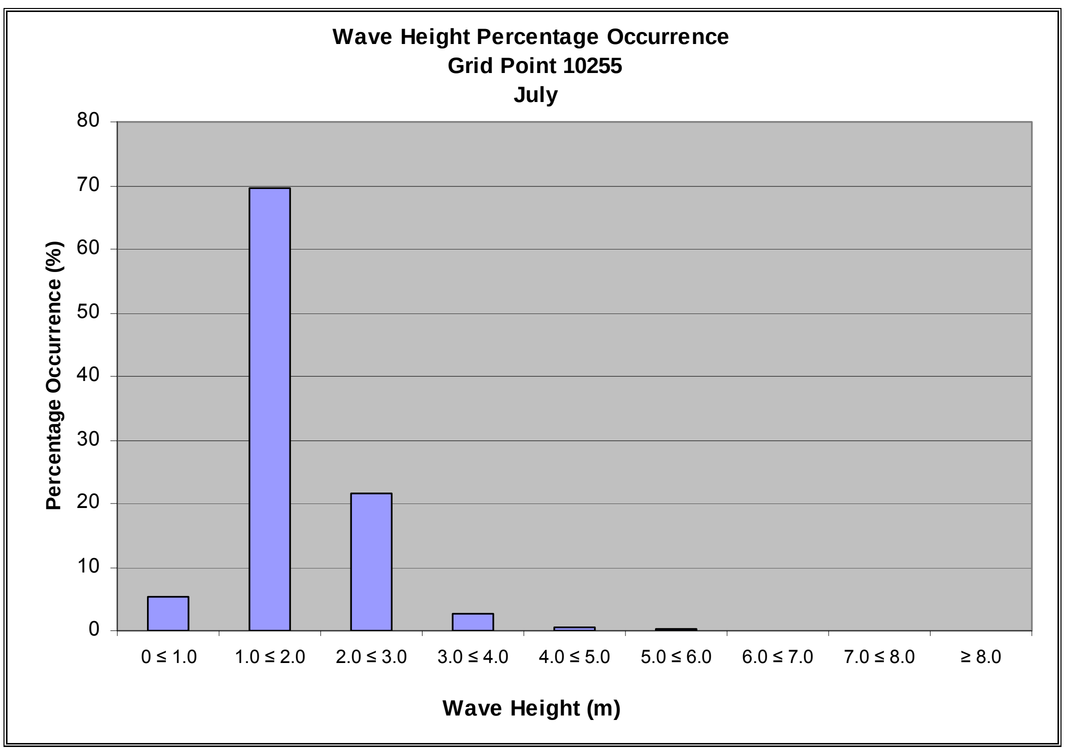

**May Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



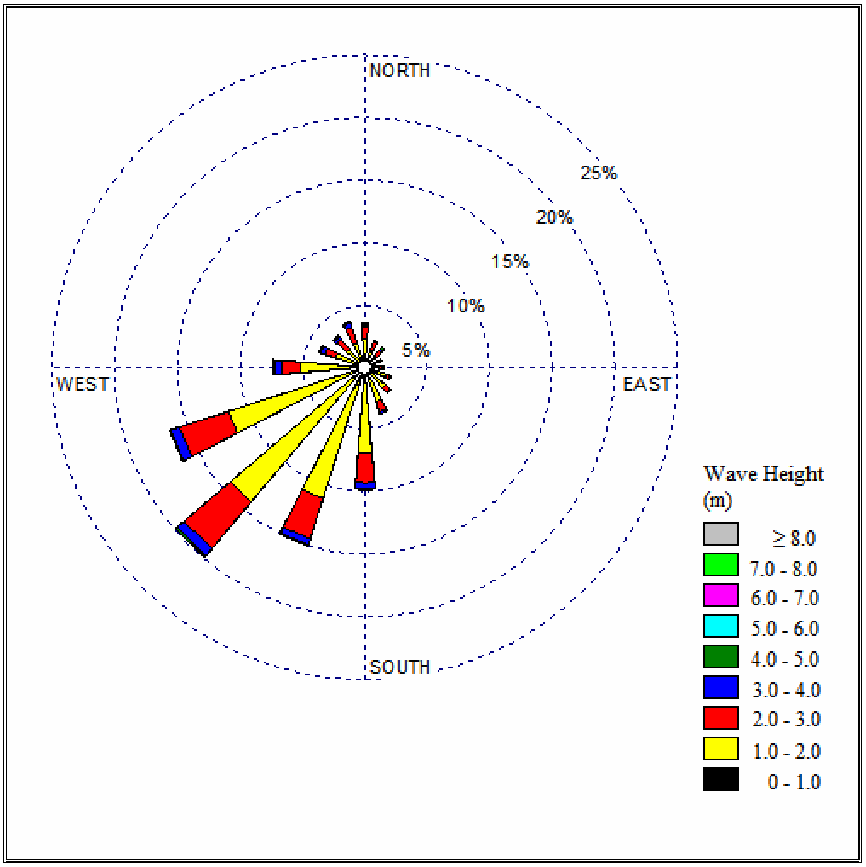



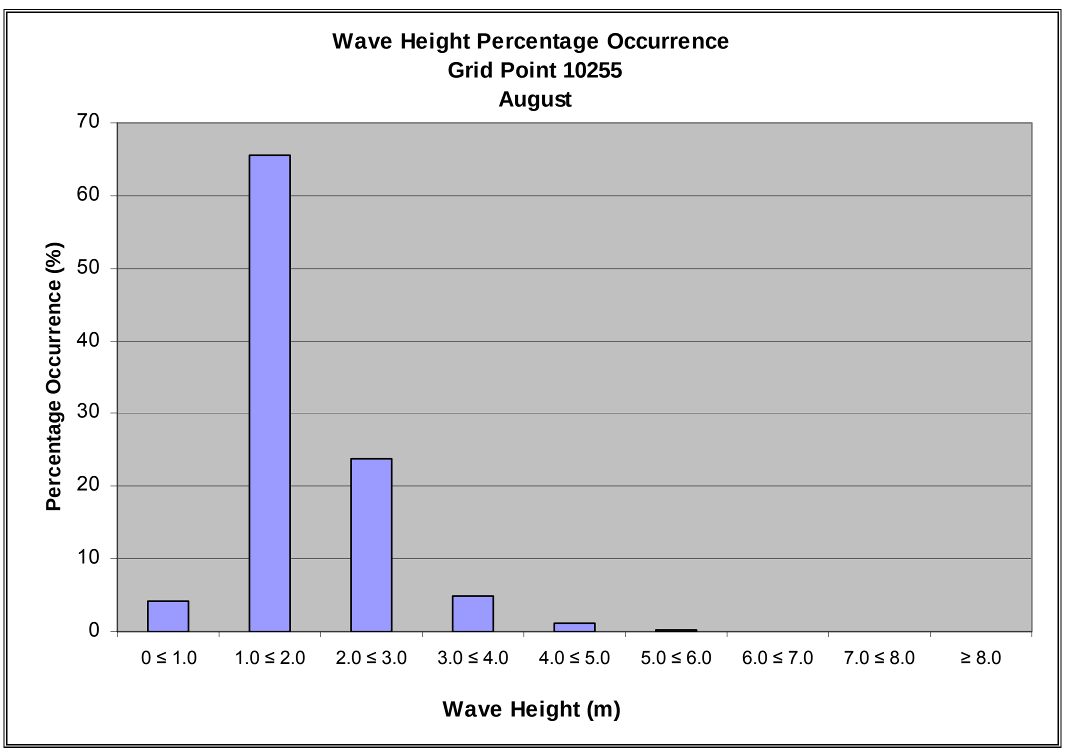

**June Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



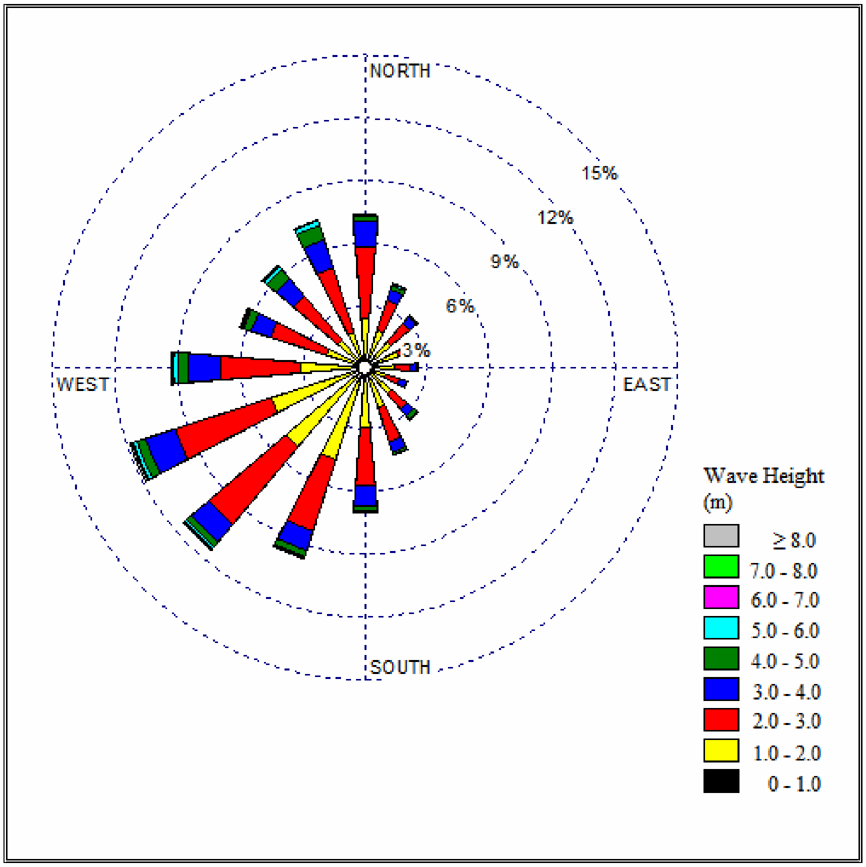



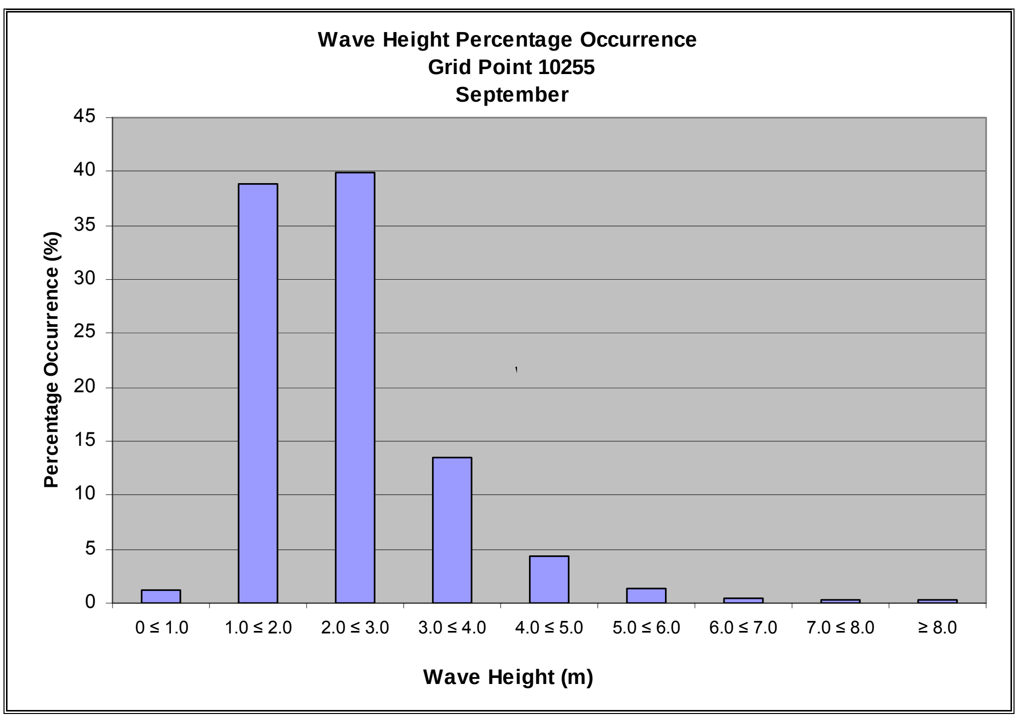

**July Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



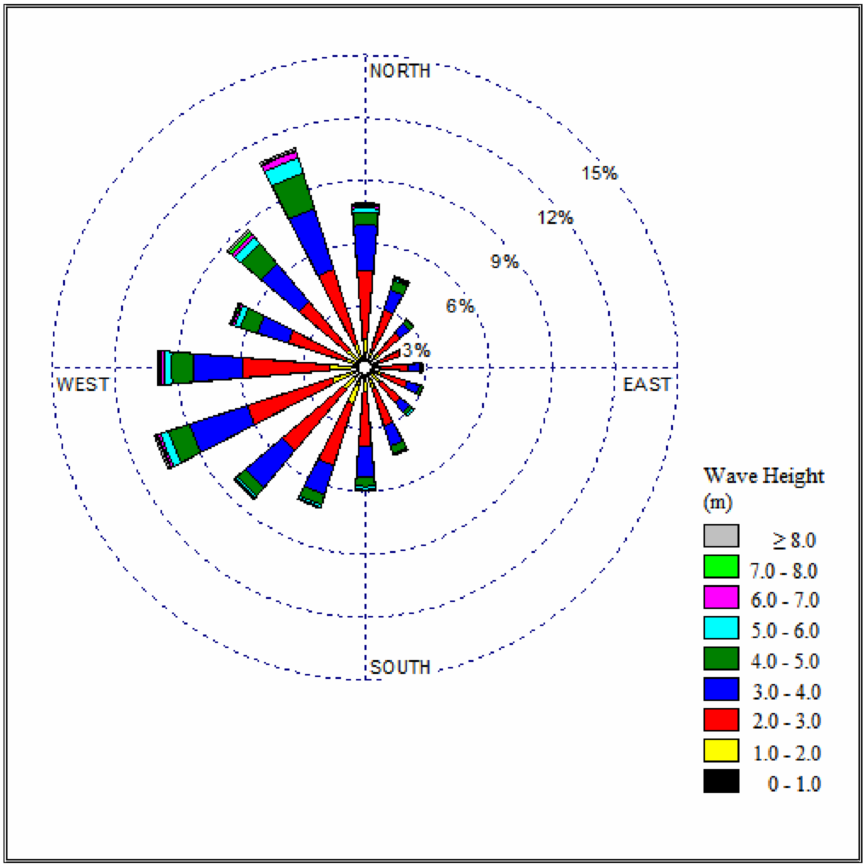



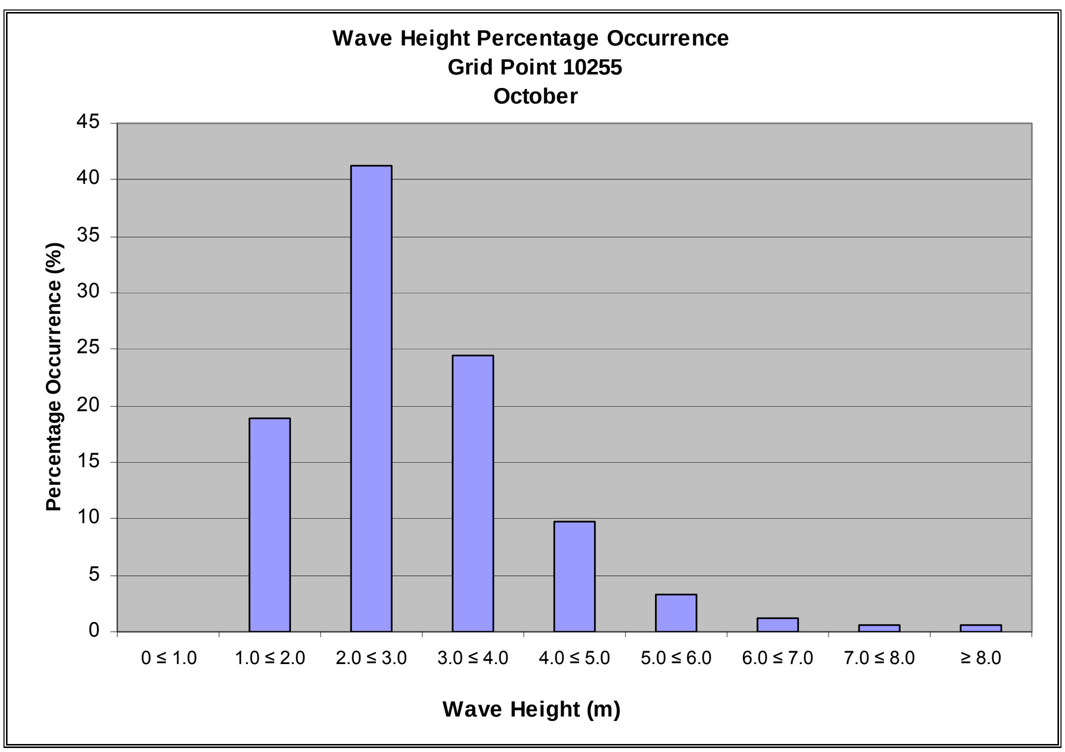

**August Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



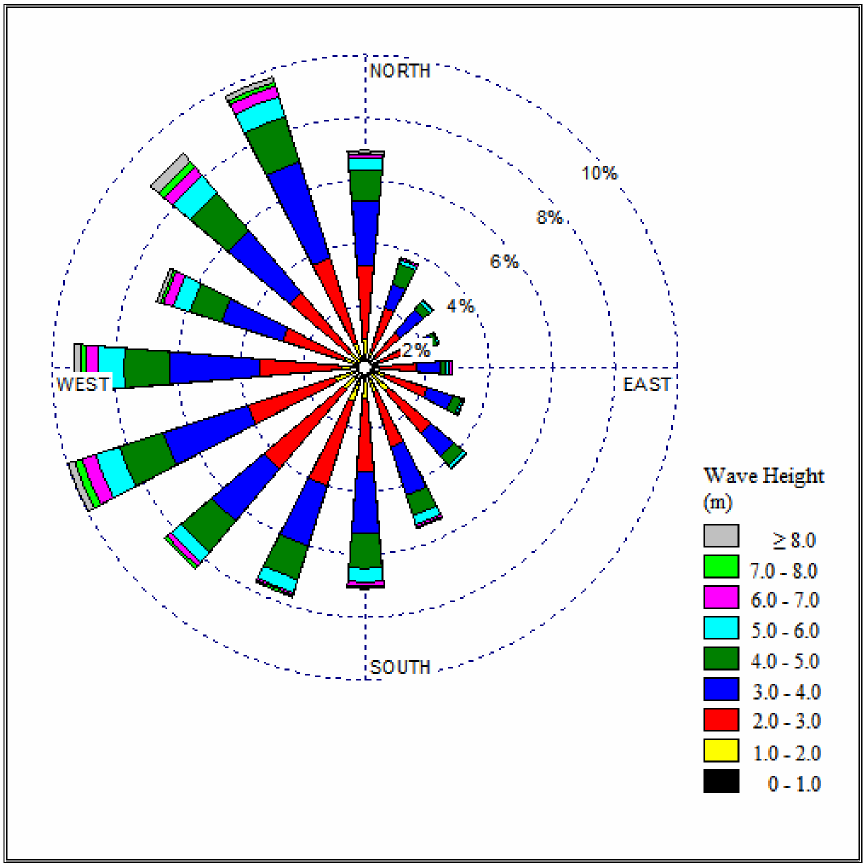



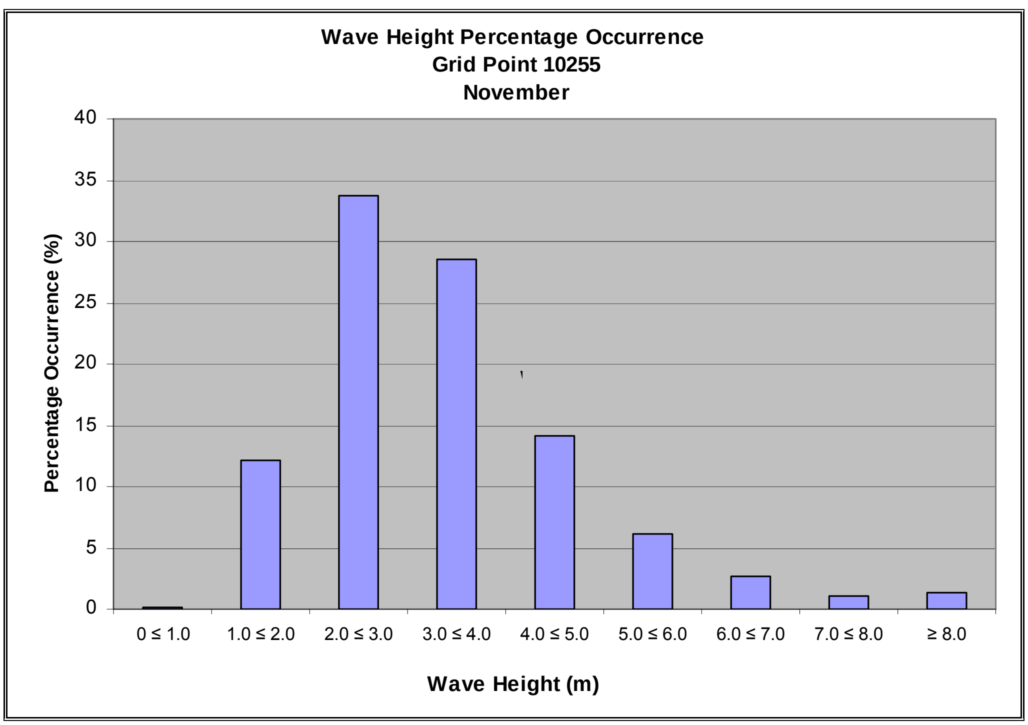

**September Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**



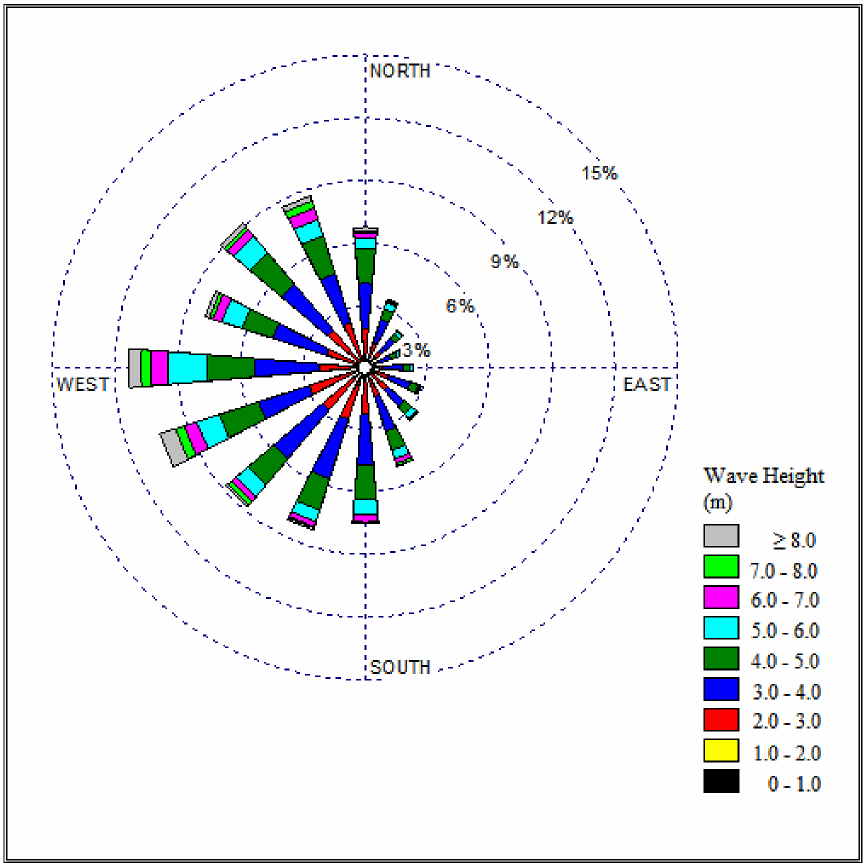



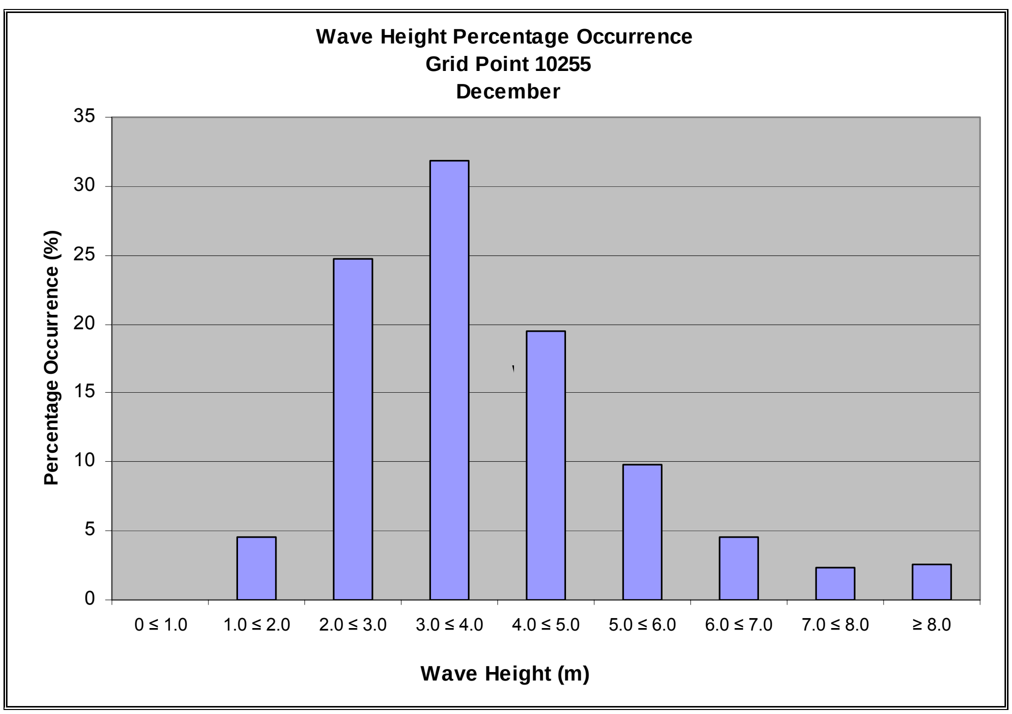

**October Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**




**November Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**

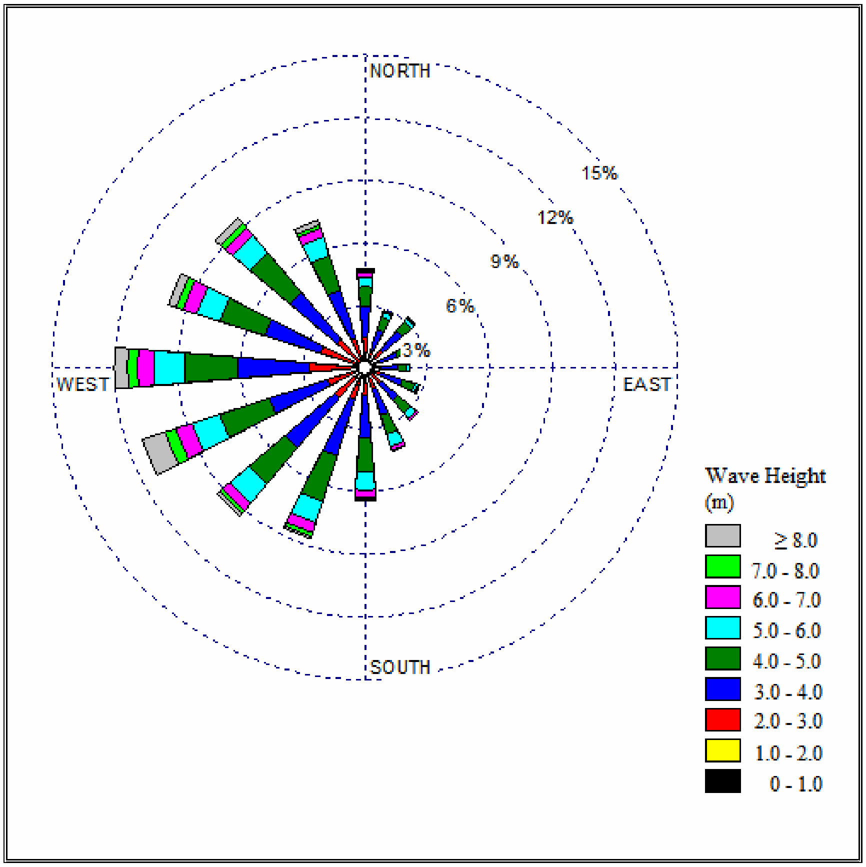


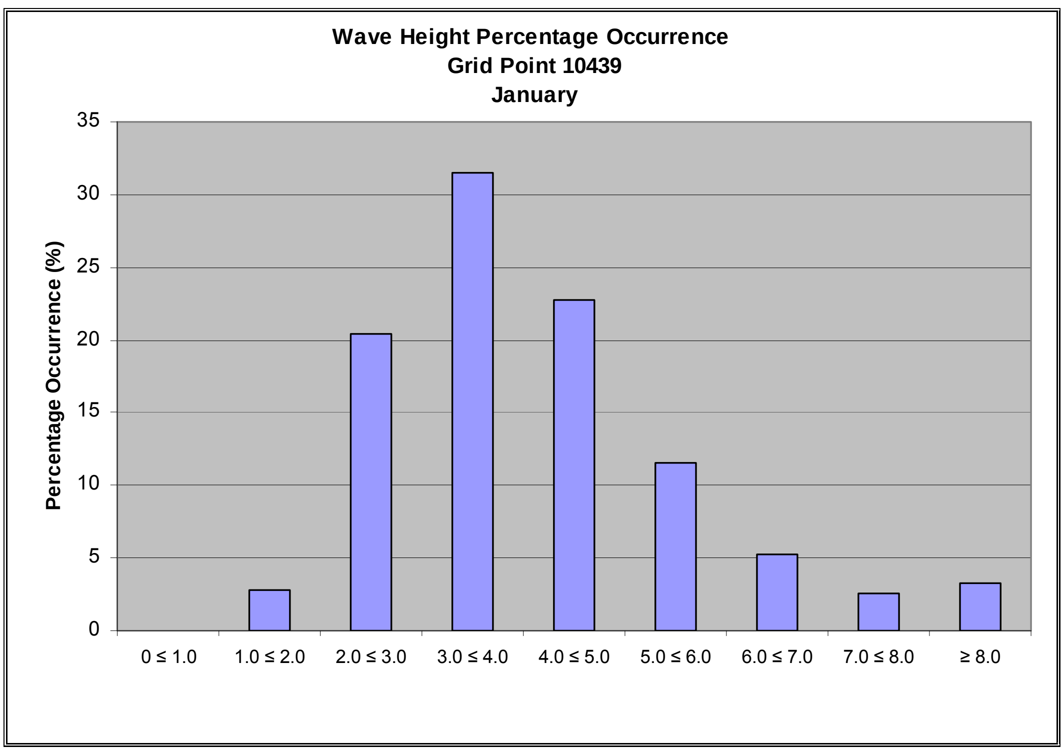




**December Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10255**

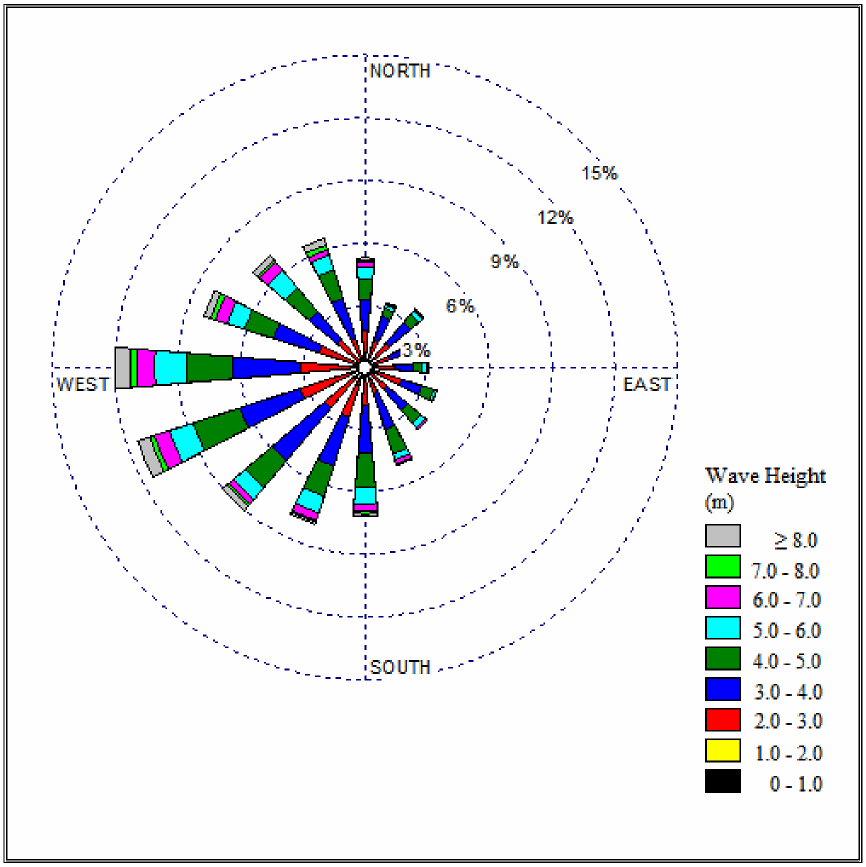
# Appendix 6

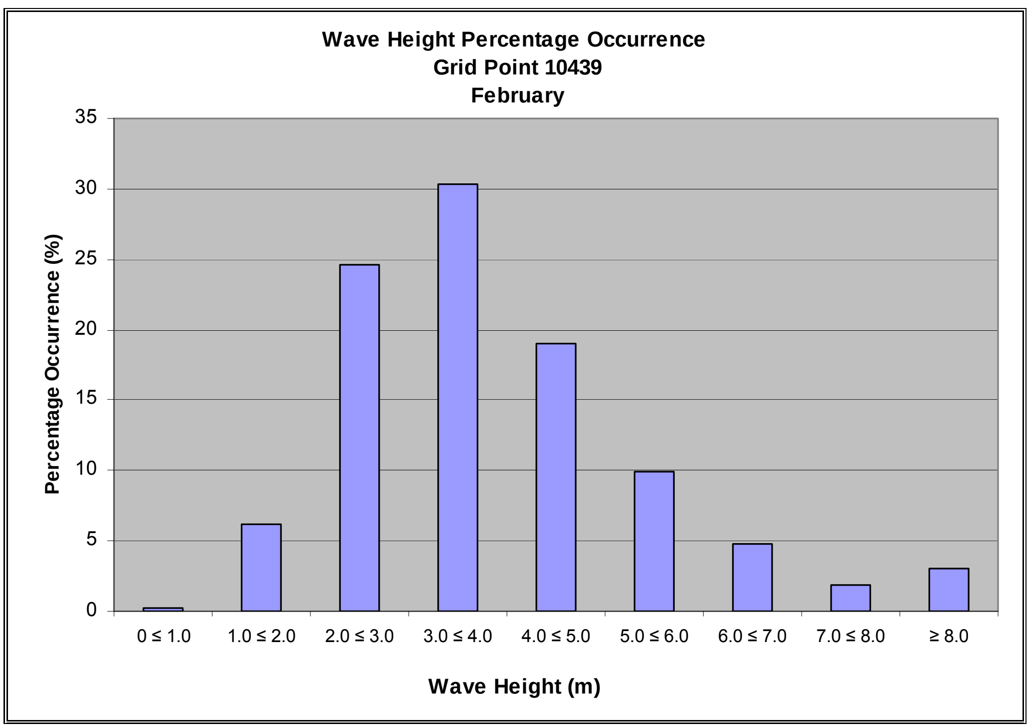
# Wave Rose and Frequency Distributions for MSC50 GridPoint 10439



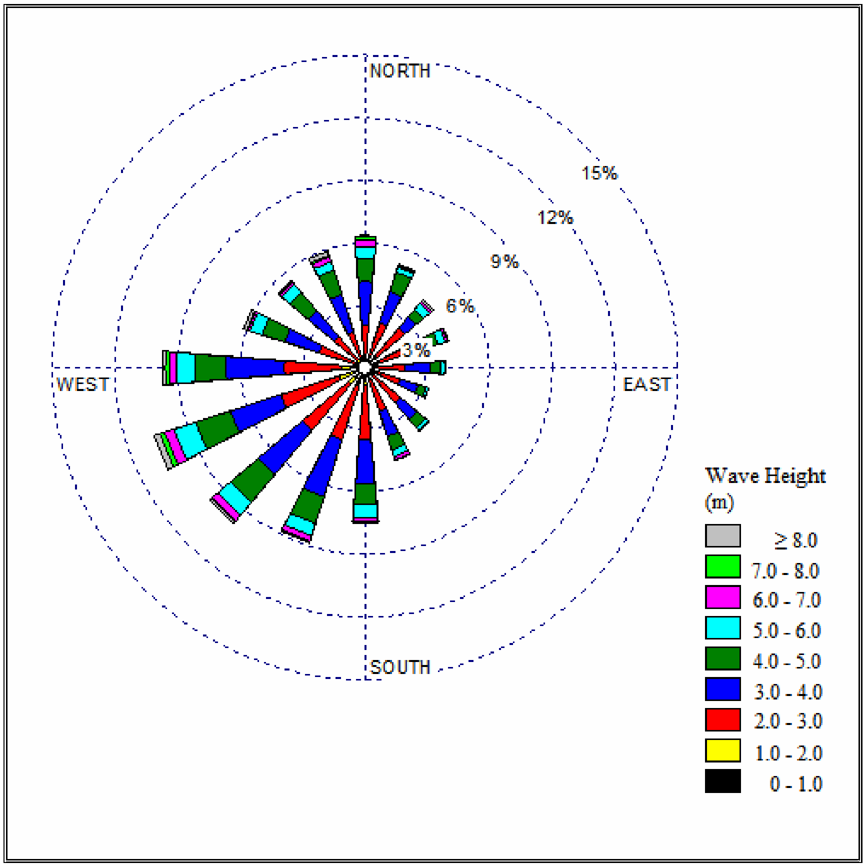



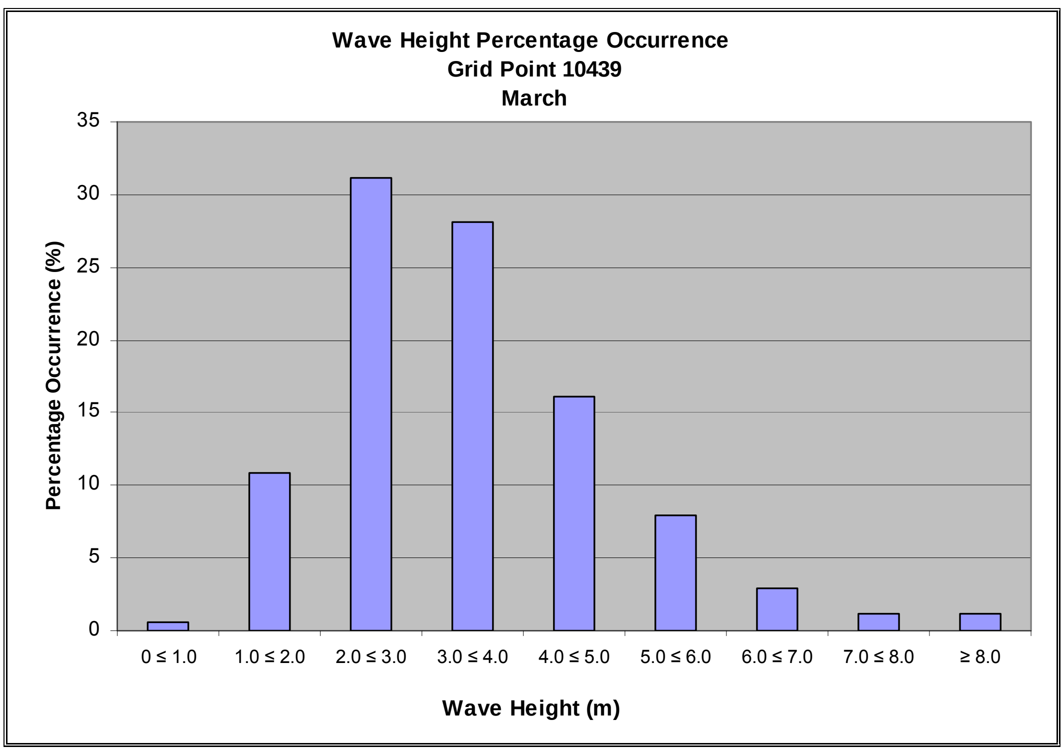

**January Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



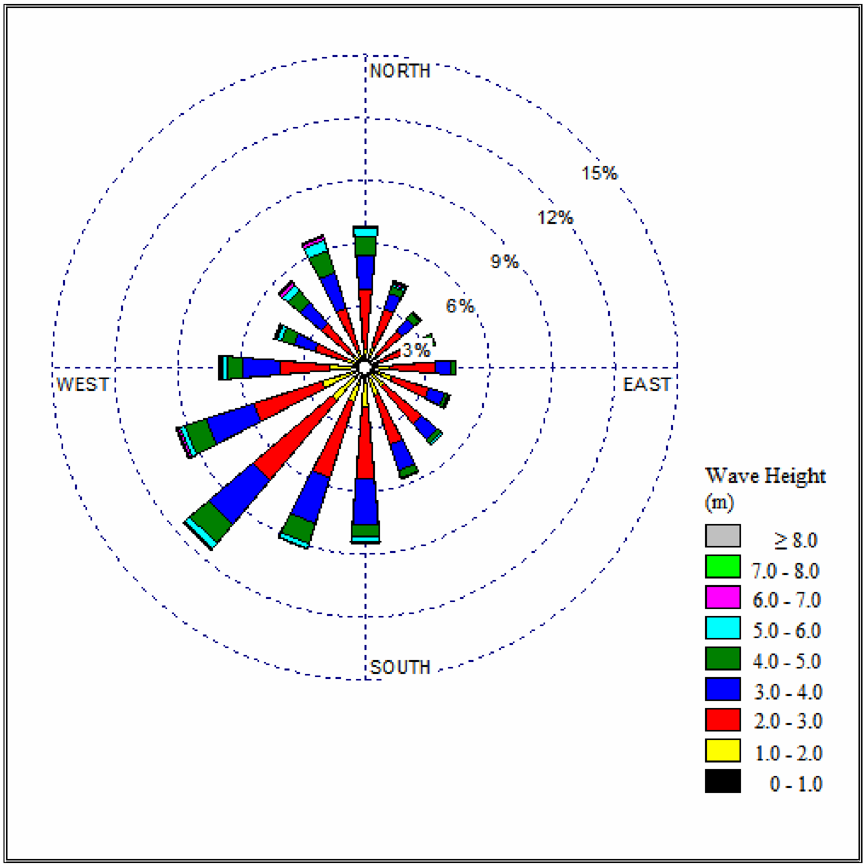



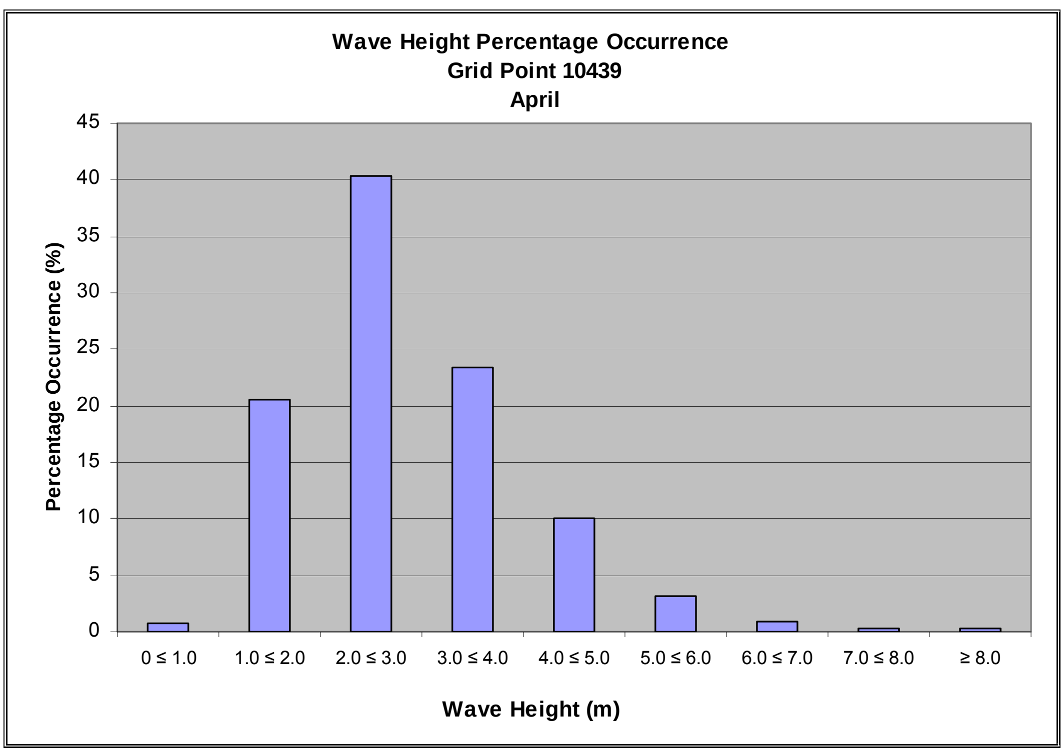

**February Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



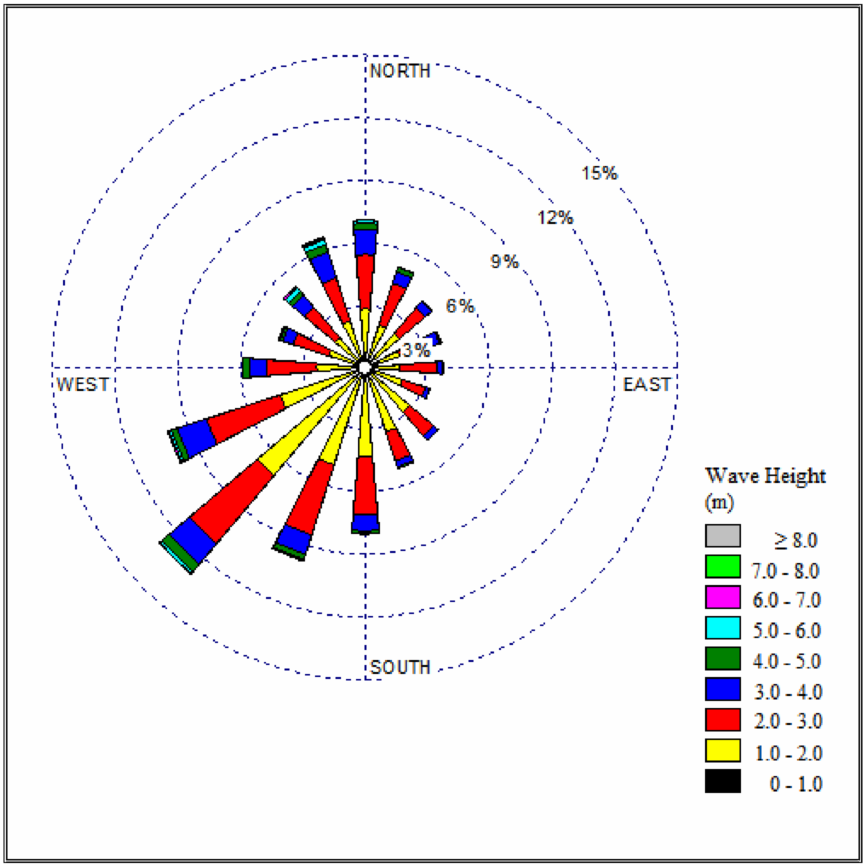



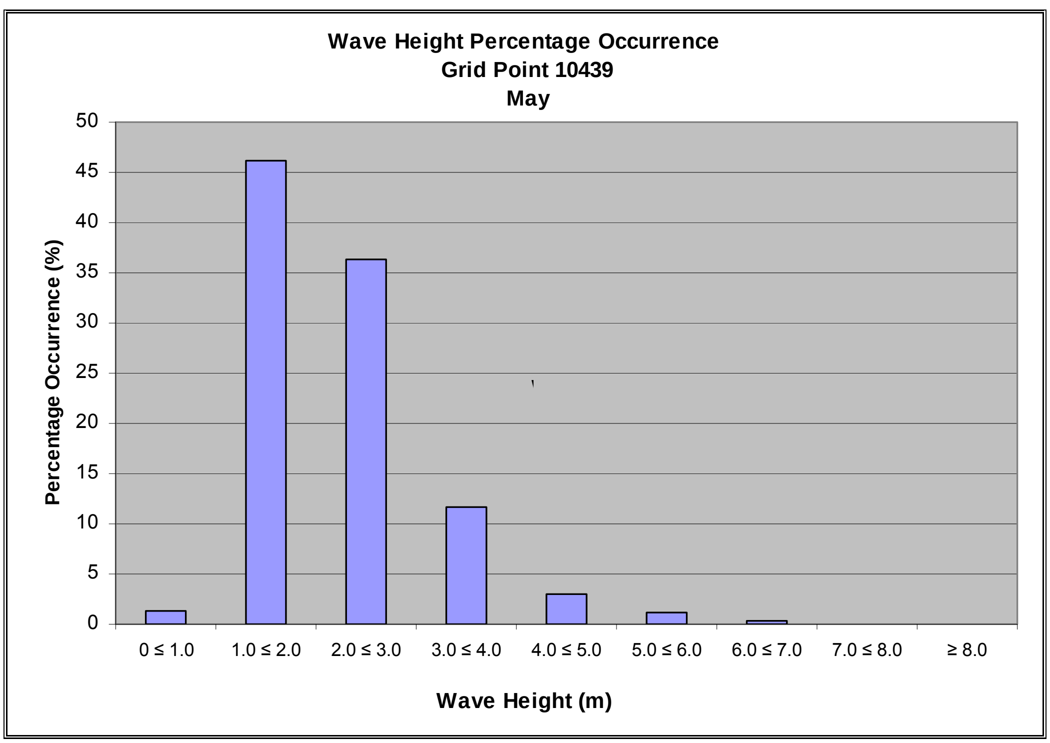

**March Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



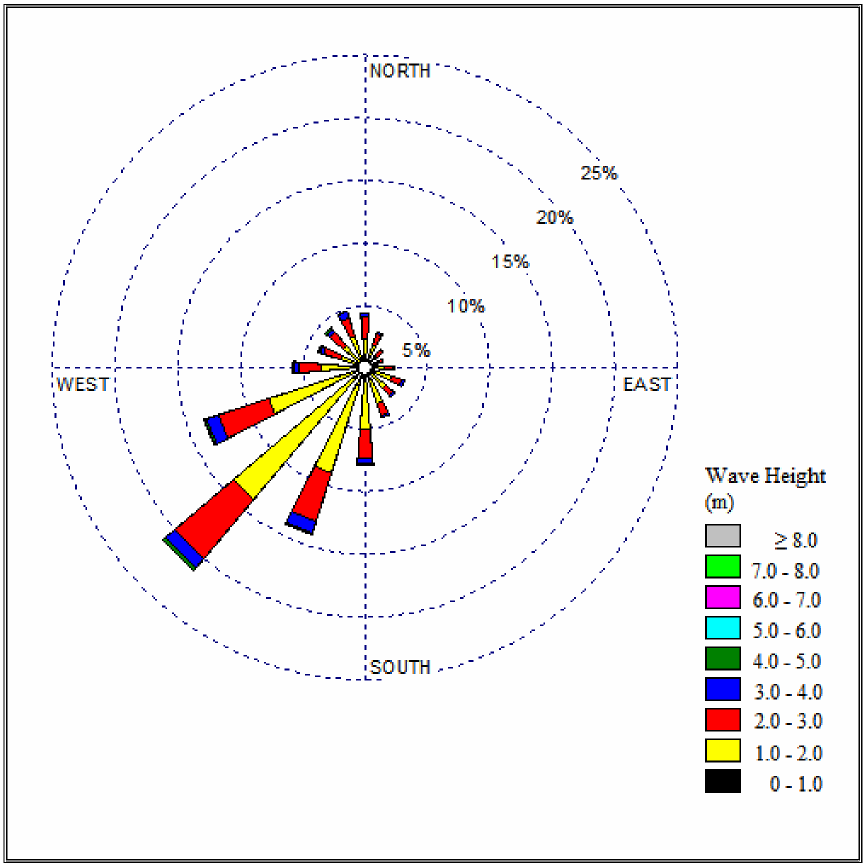



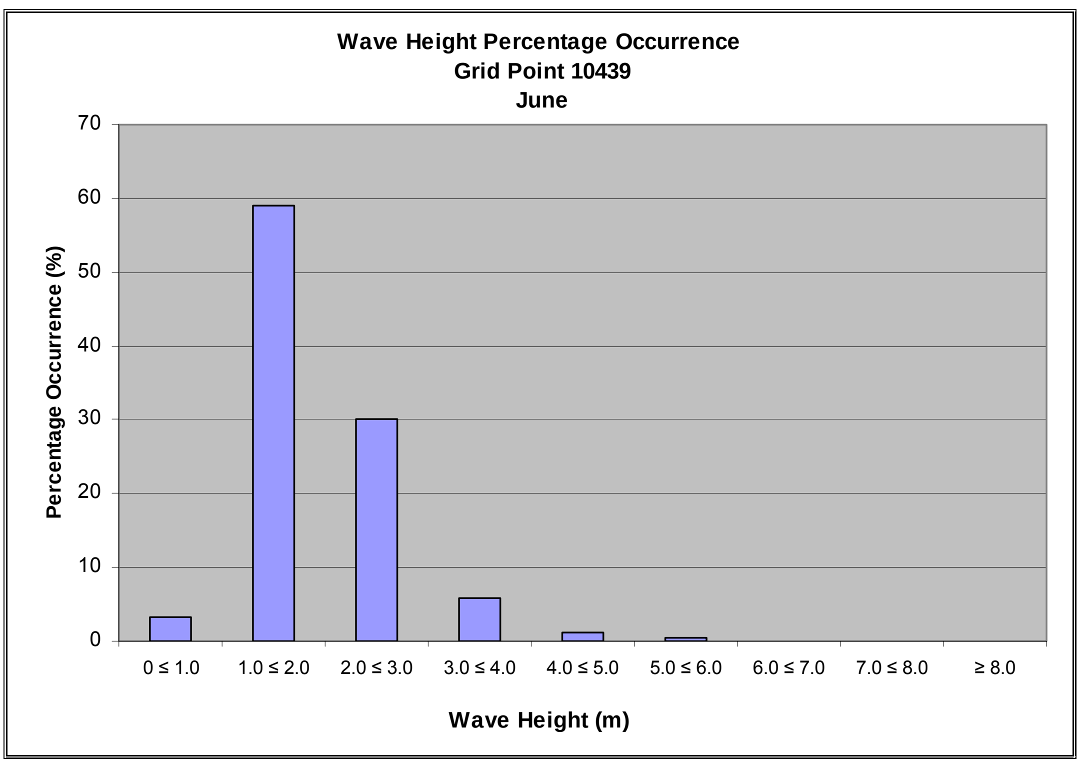

**April Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



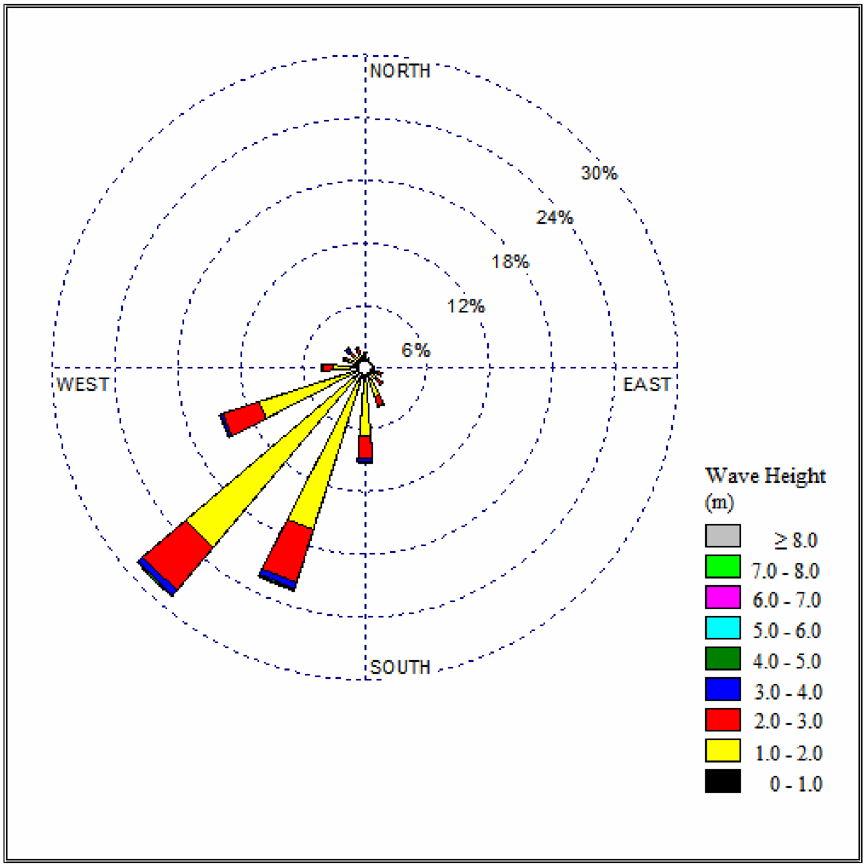



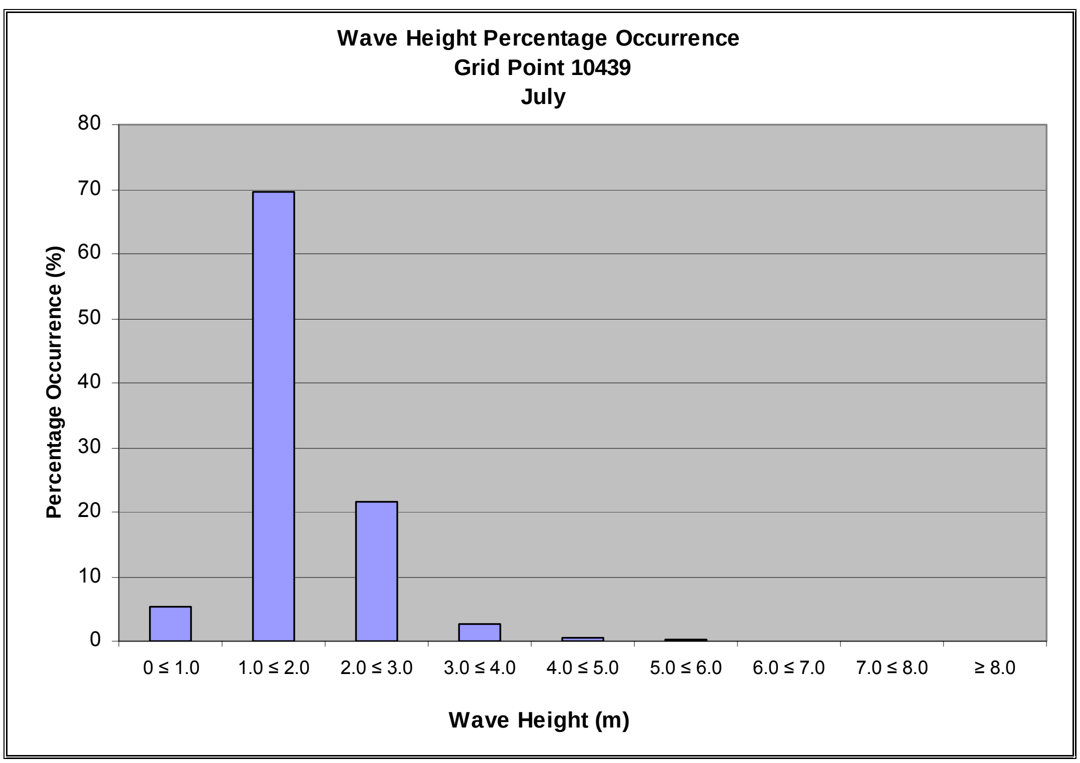

**May Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



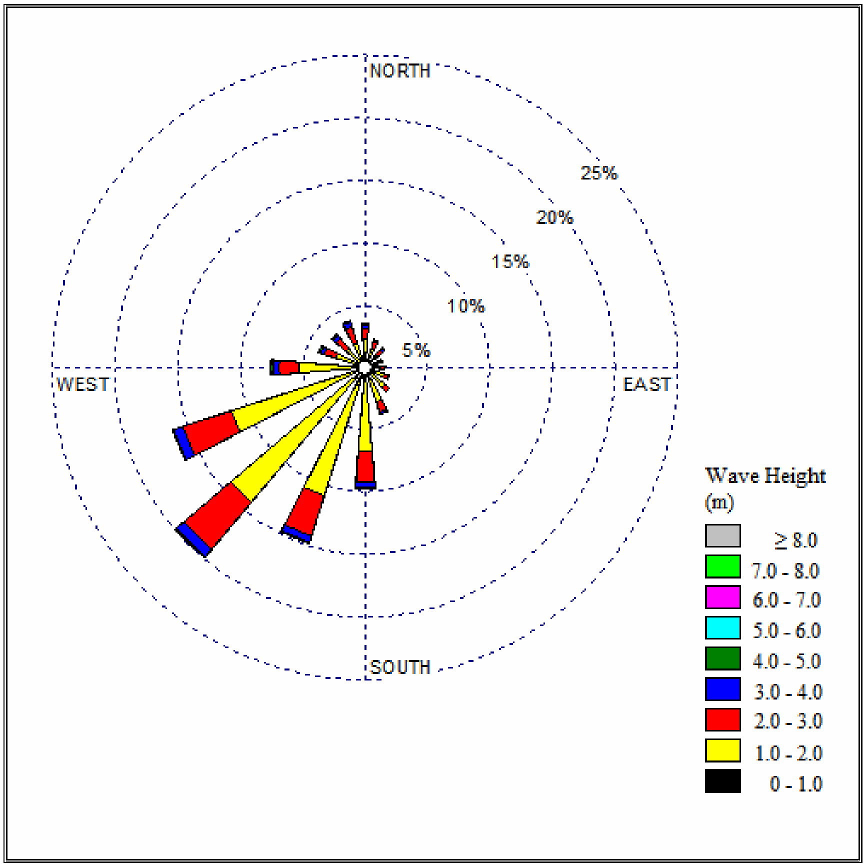



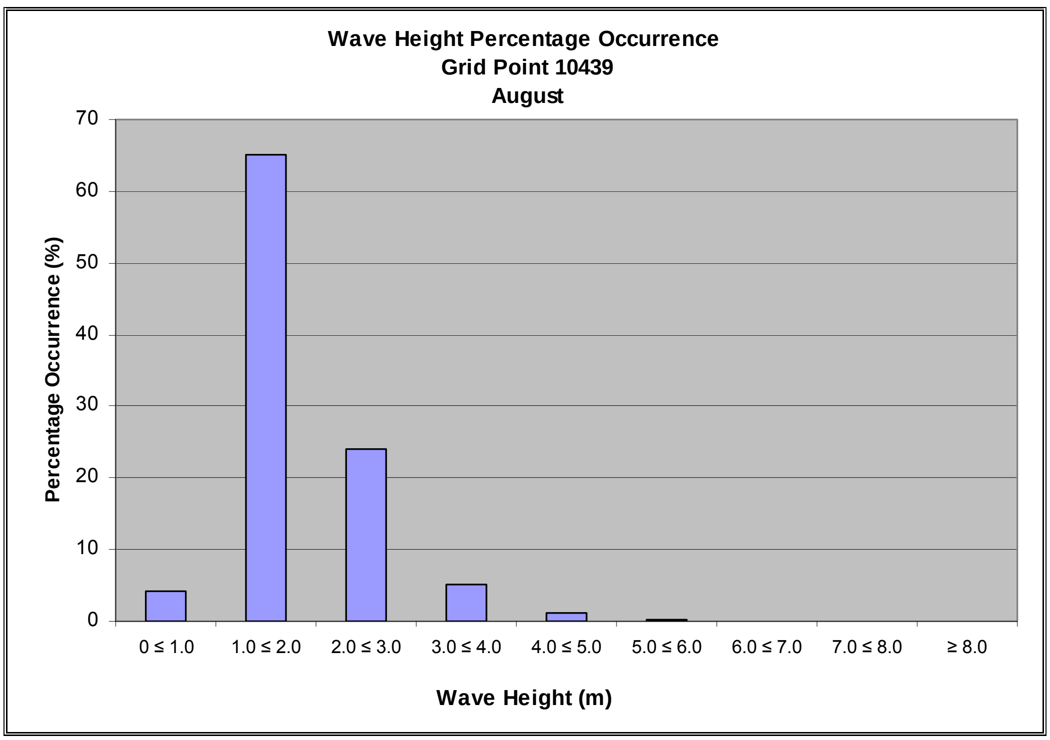

**June Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



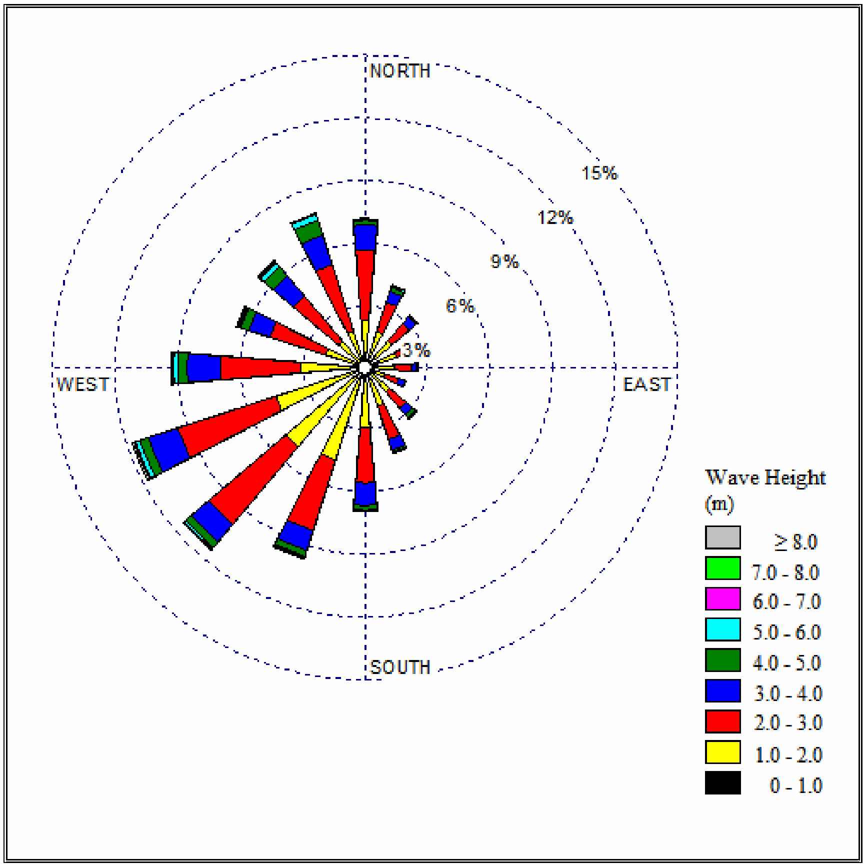



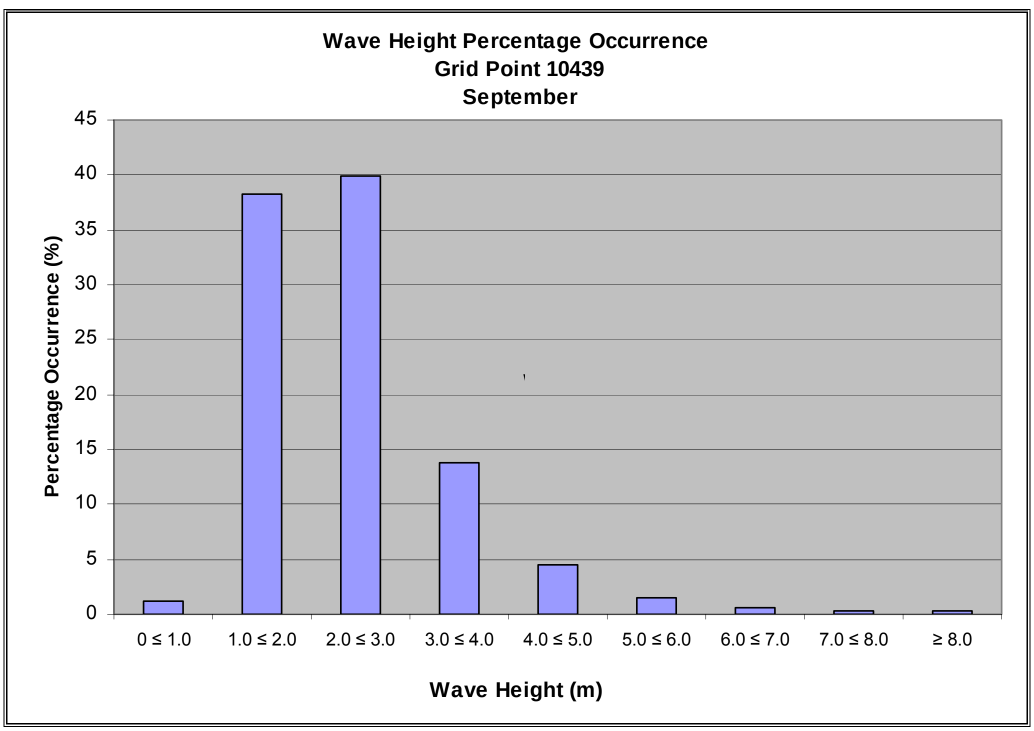

**July Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



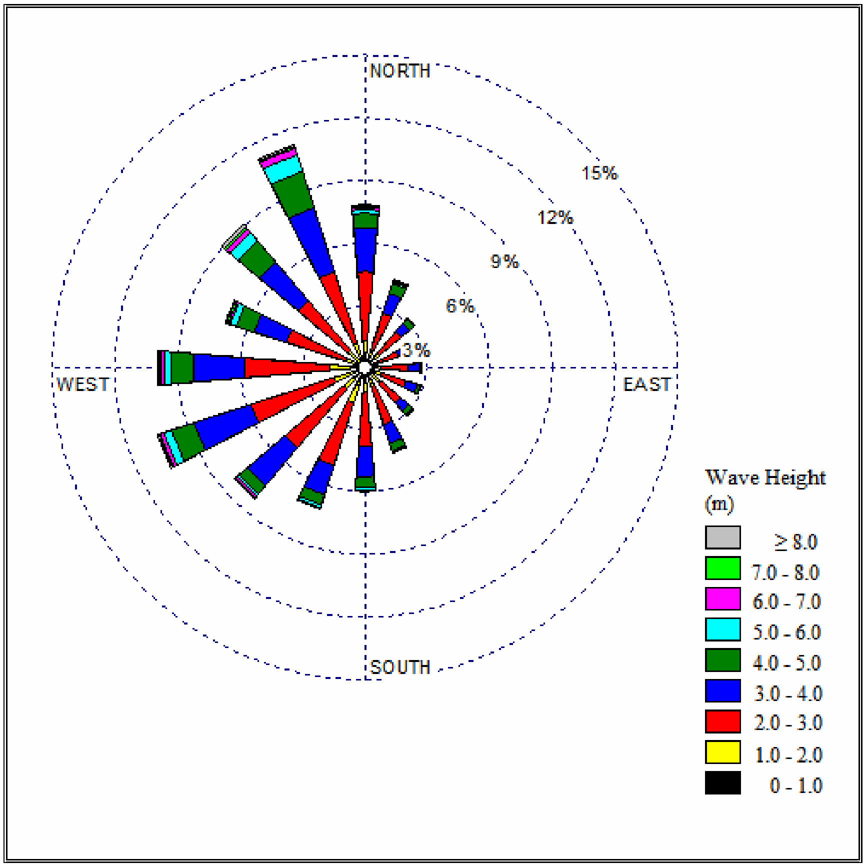



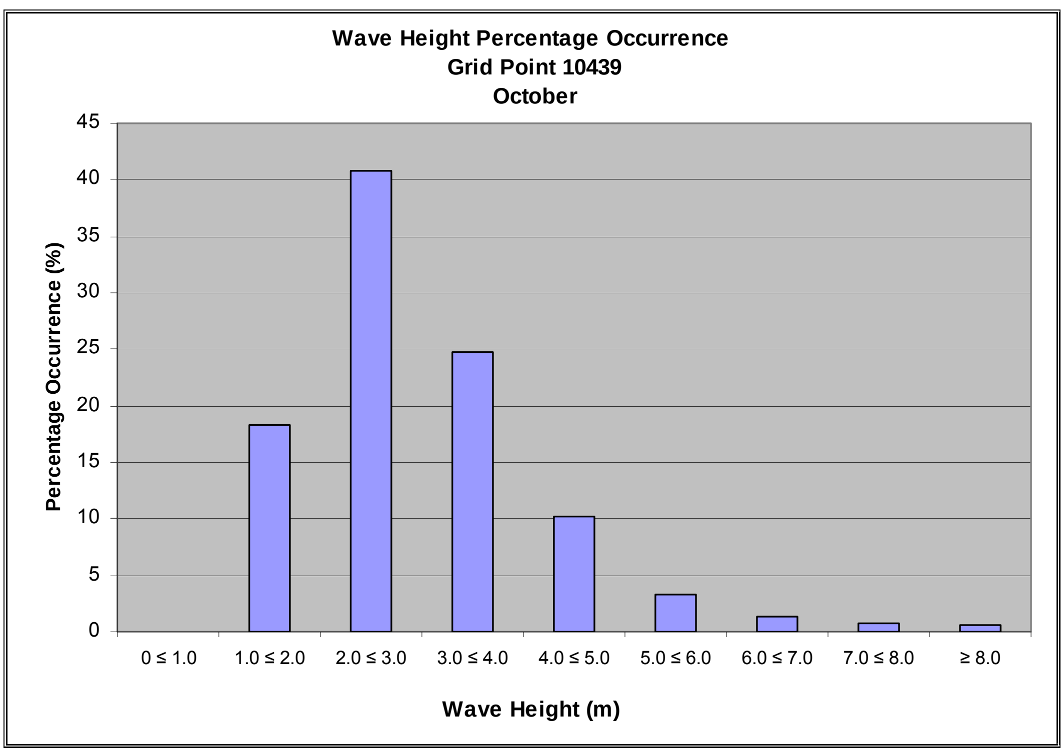

**August Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



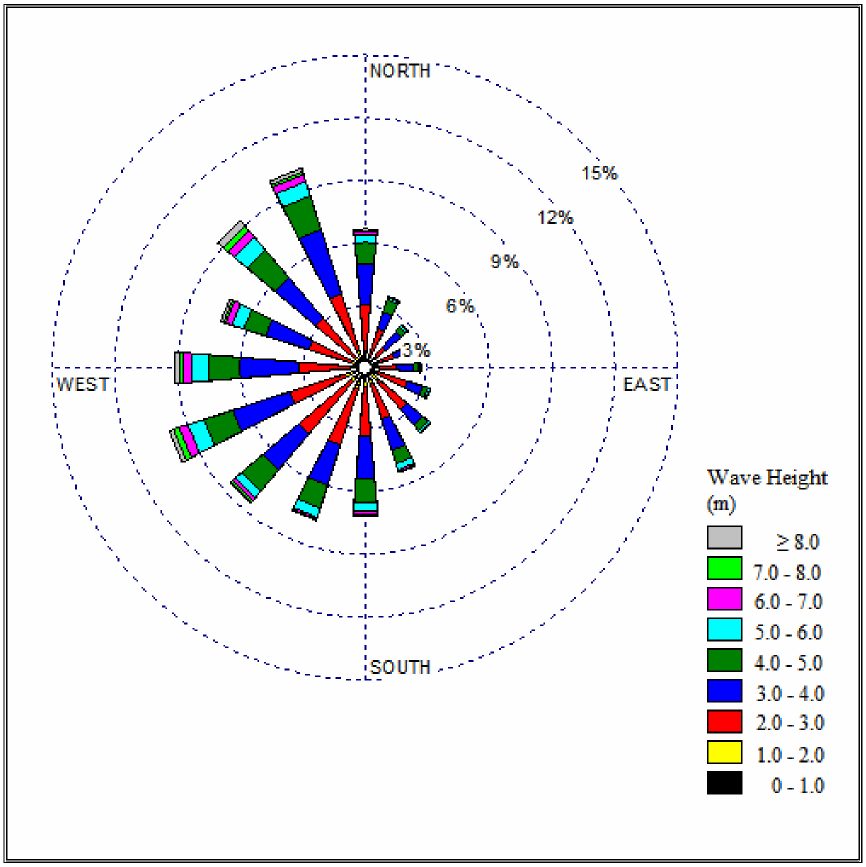



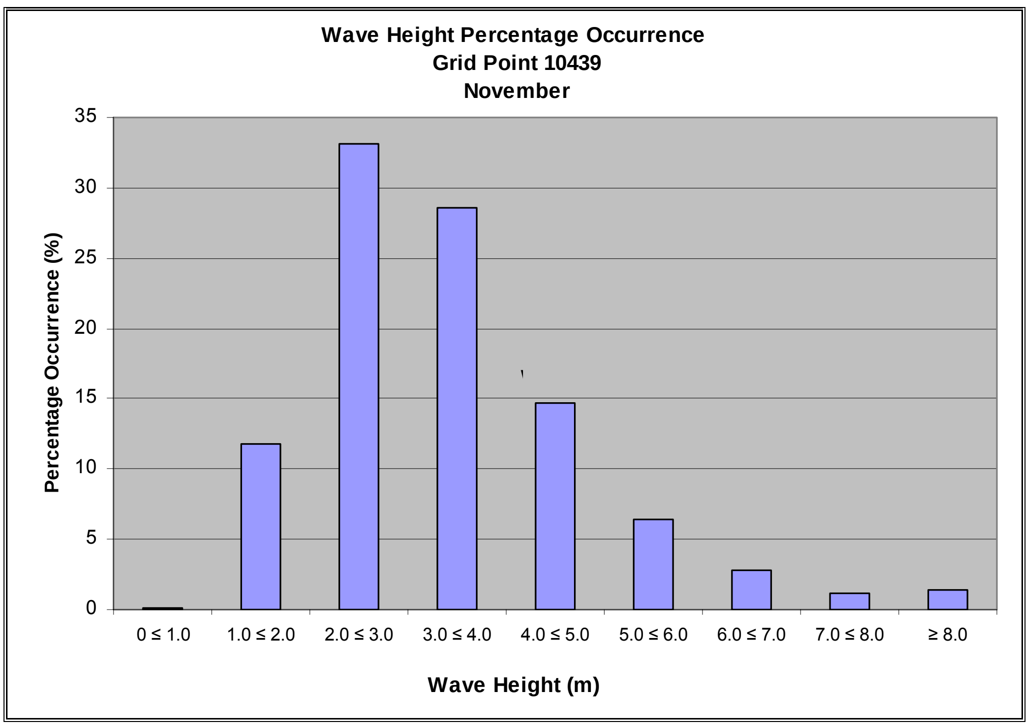

**September Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**



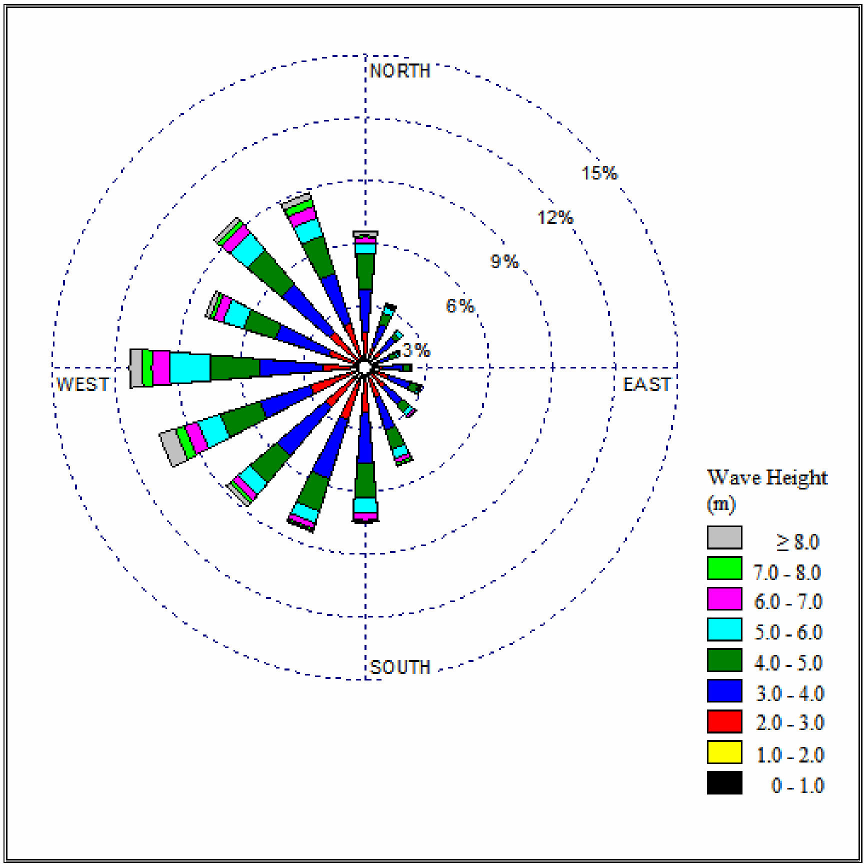



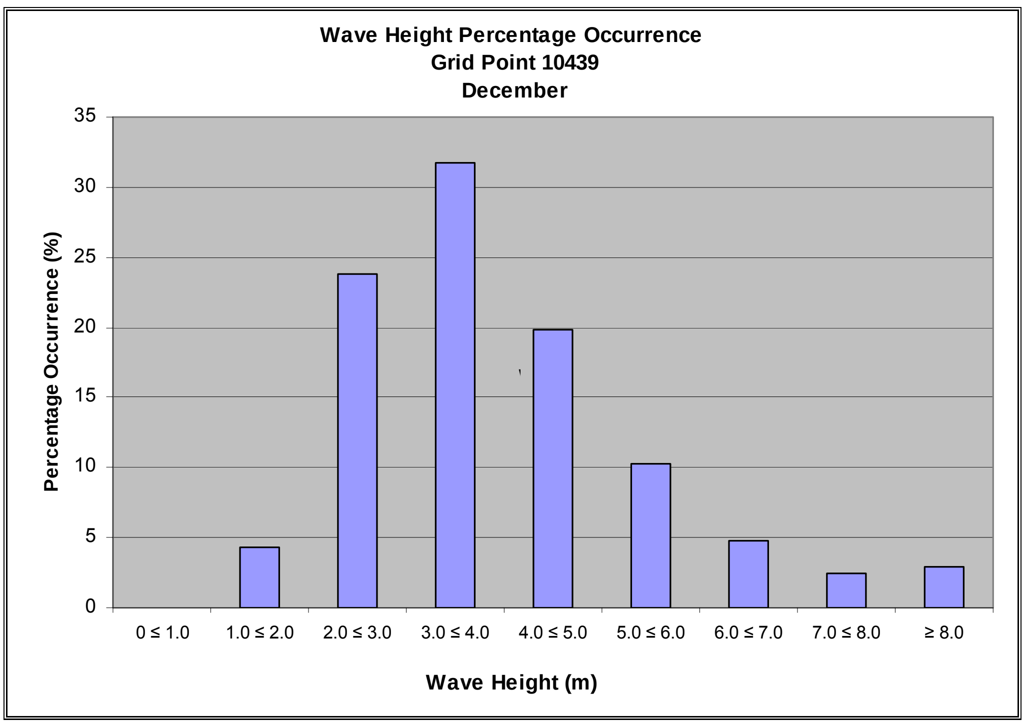

**October Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**




**November Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**

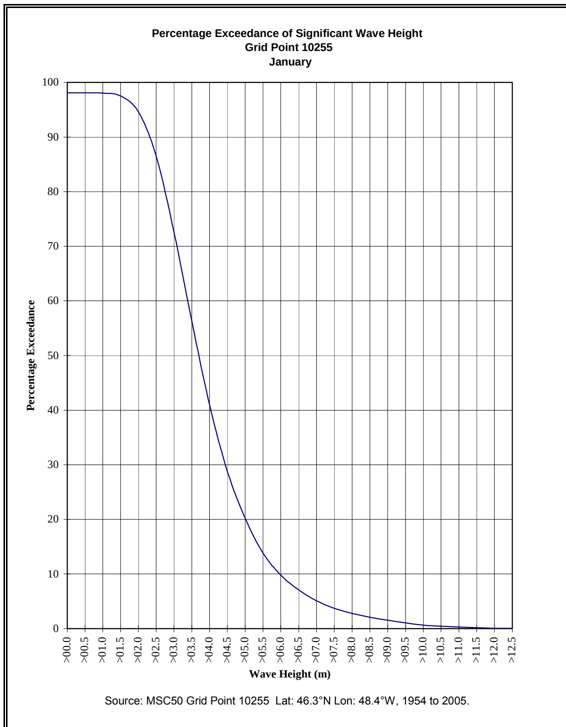


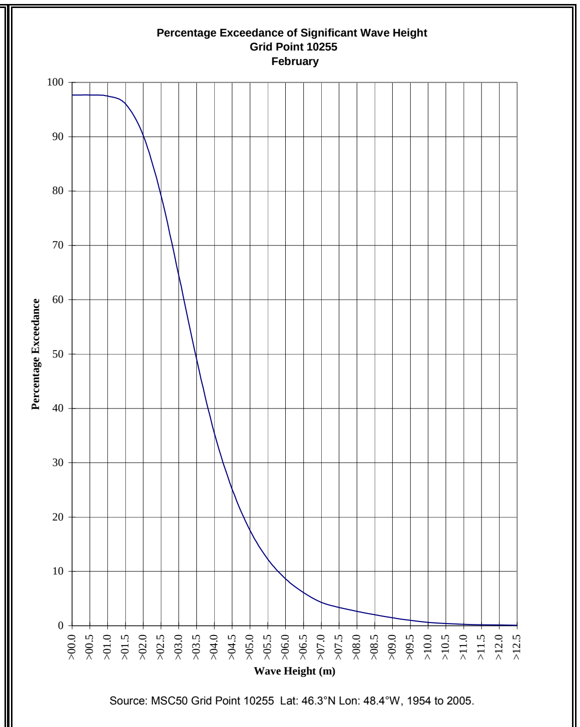



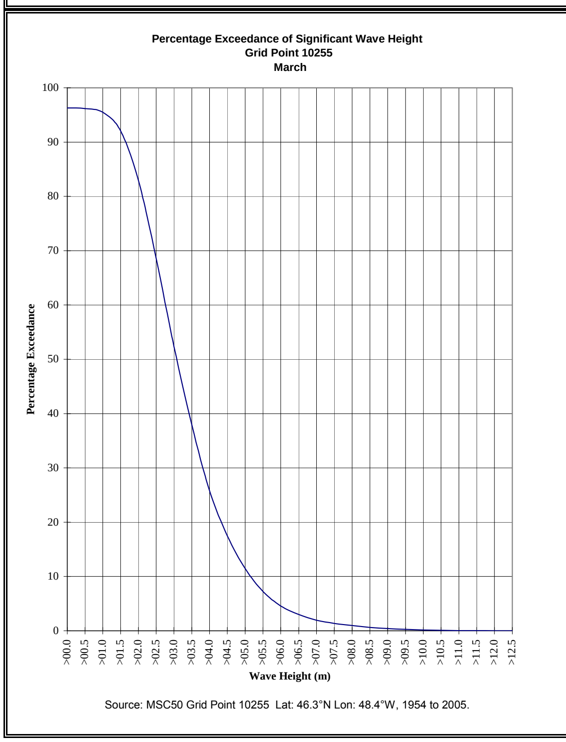

**December Wave Rose and Percentage Occurrence Graphs for MSC50 GridPoint 10439**

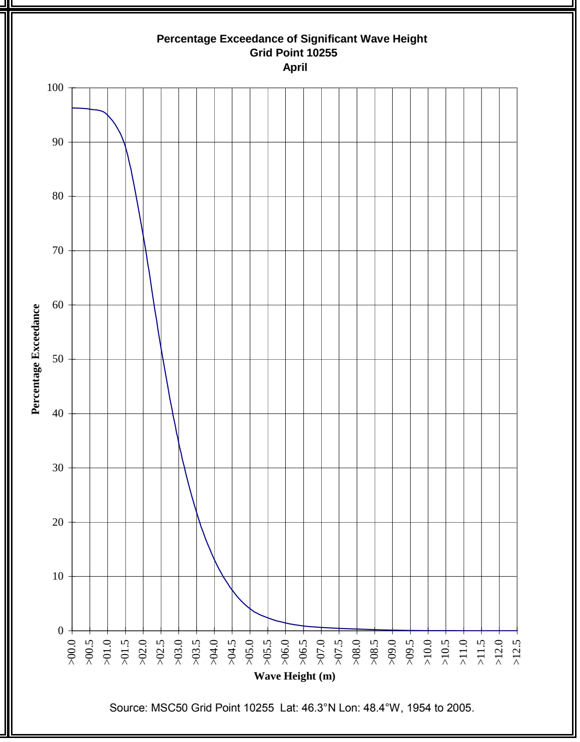
# Appendix 7

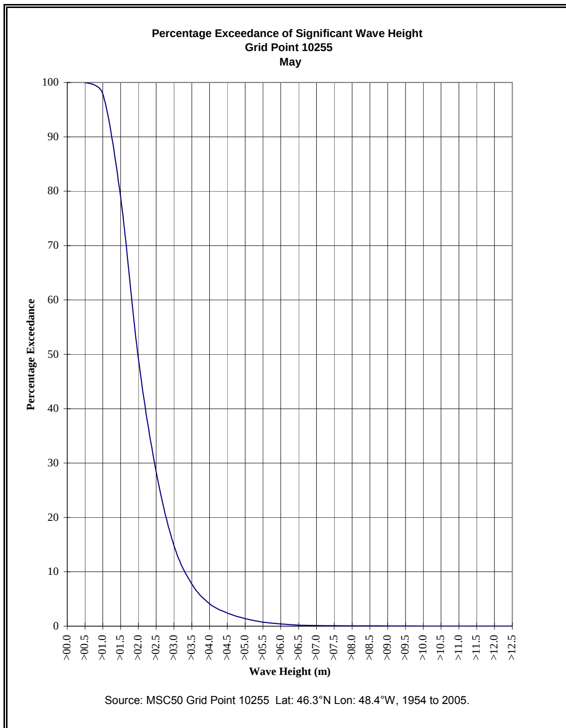
# Monthly Percentage Exceedance of Significant Wave Height at Grid Point 10255

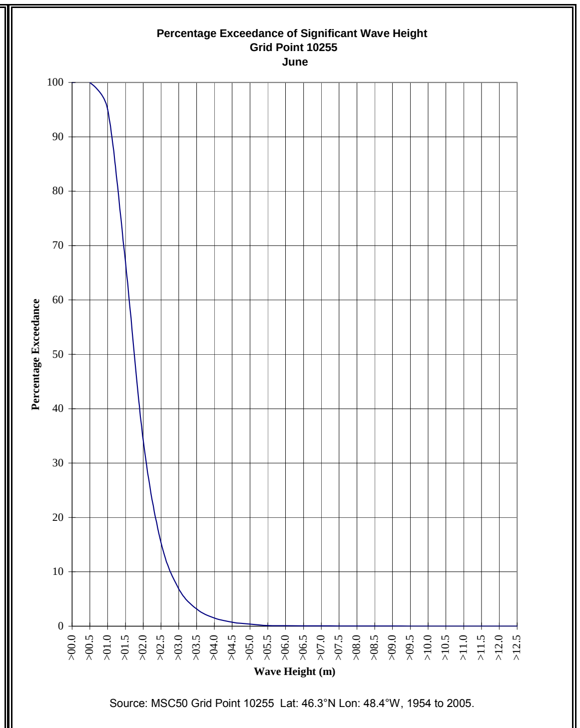

Percentage Exceedance of Significant Wave Height
Grid Point 10255
January
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

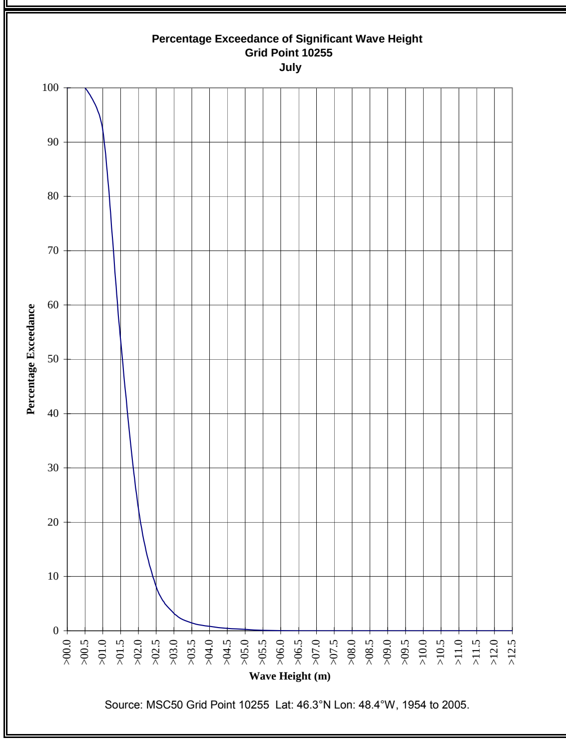

Percentage Exceedance of Significant Wave Height
Grid Point 10255
February
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

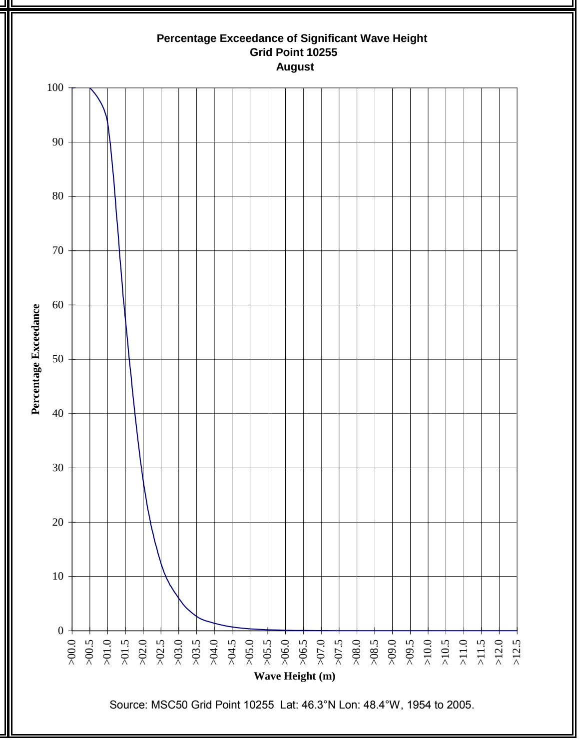

Percentage Exceedance of Significant Wave Height
Grid Point 10255
March
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

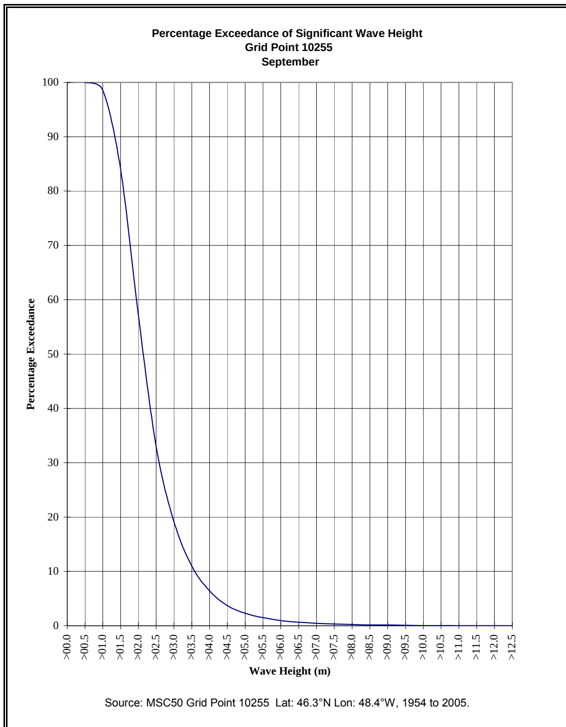

Percentage Exceedance of Significant Wave Height
Grid Point 10255
April
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10255
May
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

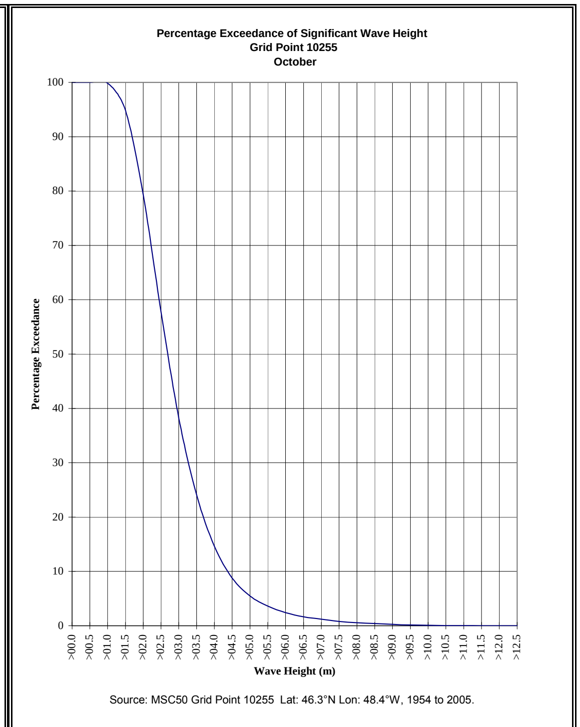

Percentage Exceedance of Significant Wave Height
Grid Point 10255
June
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10255
July
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

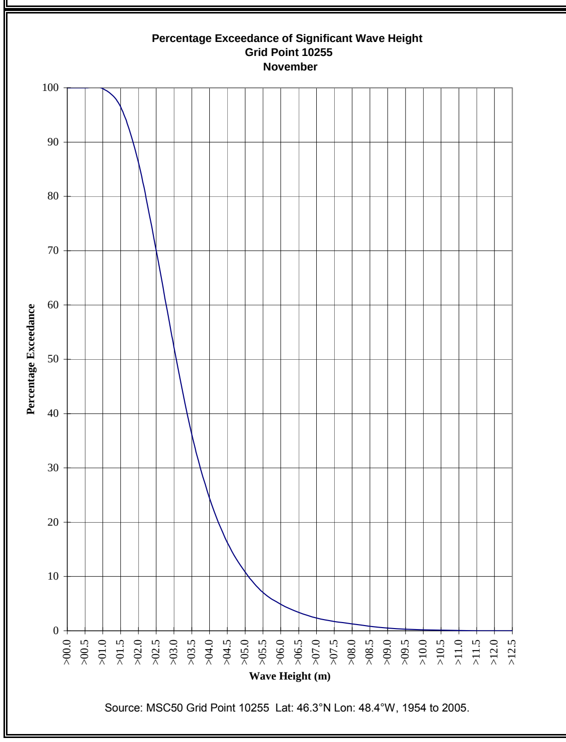

Percentage Exceedance of Significant Wave Height
Grid Point 10255
August
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.



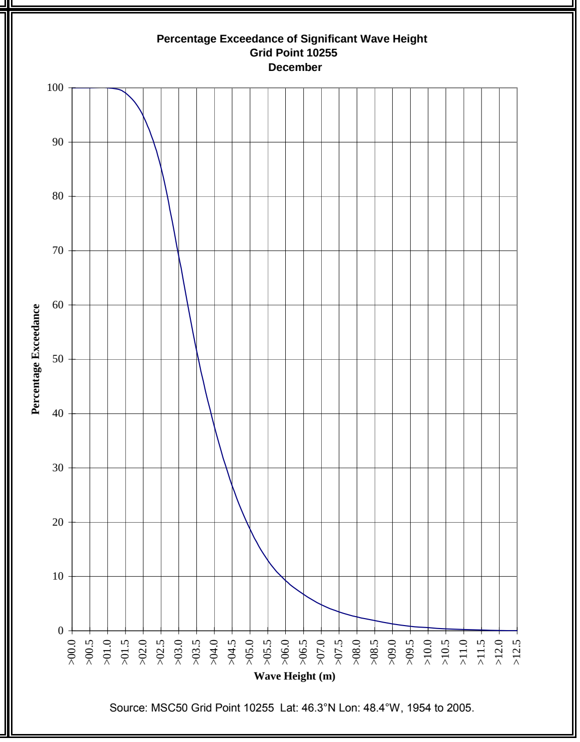
Percentage Exceedance of Significant Wave Height
Grid Point 10255
September
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

Percentage Exceedance of Significant Wave Height
Grid Point 10255
October
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

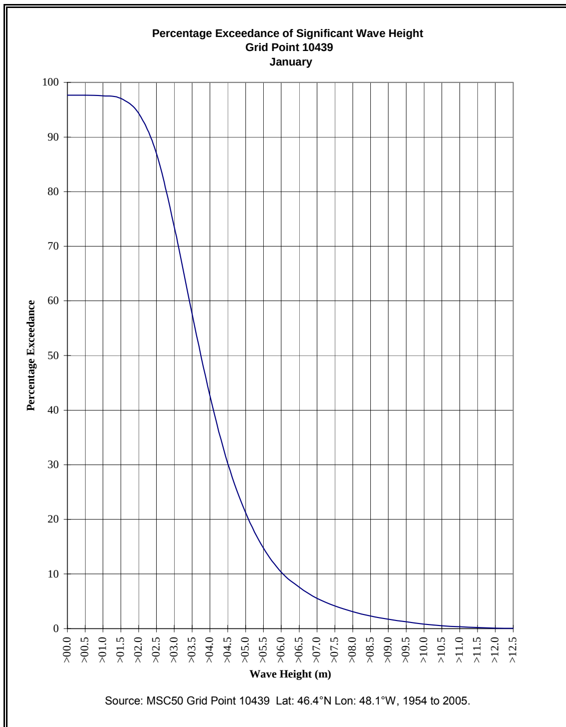
Percentage Exceedance of Significant Wave Height
Grid Point 10255
November
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

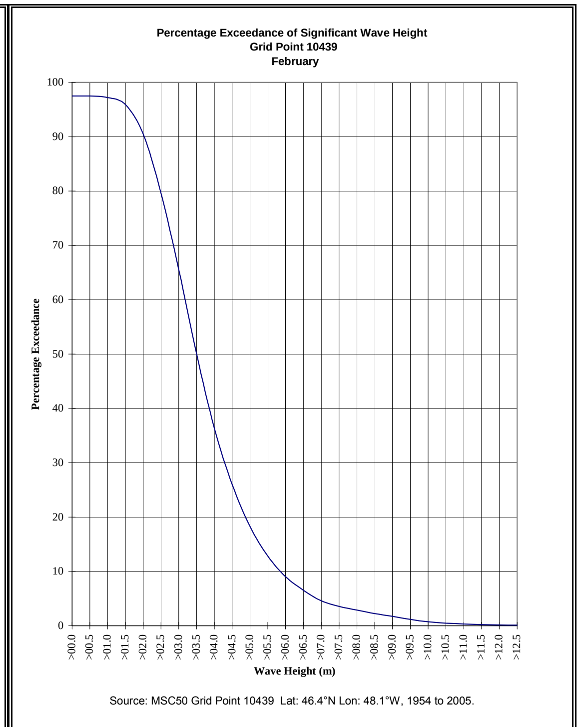



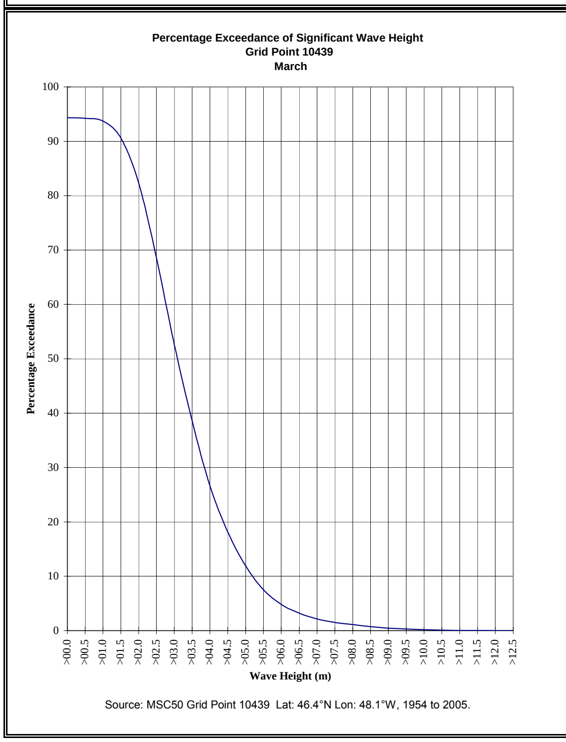
Percentage Exceedance of Significant Wave Height
Grid Point 10255
December
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10255 Lat: 46.3°N Lon: 48.4°W, 1954 to 2005.

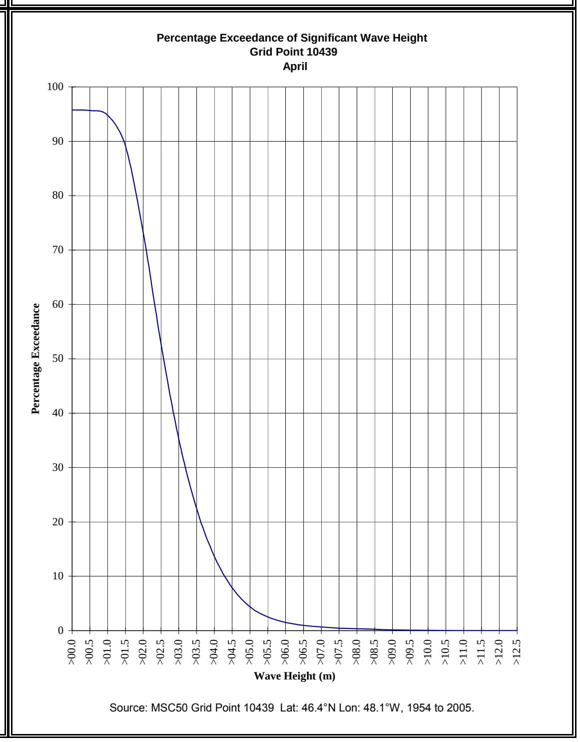
# Appendix 8

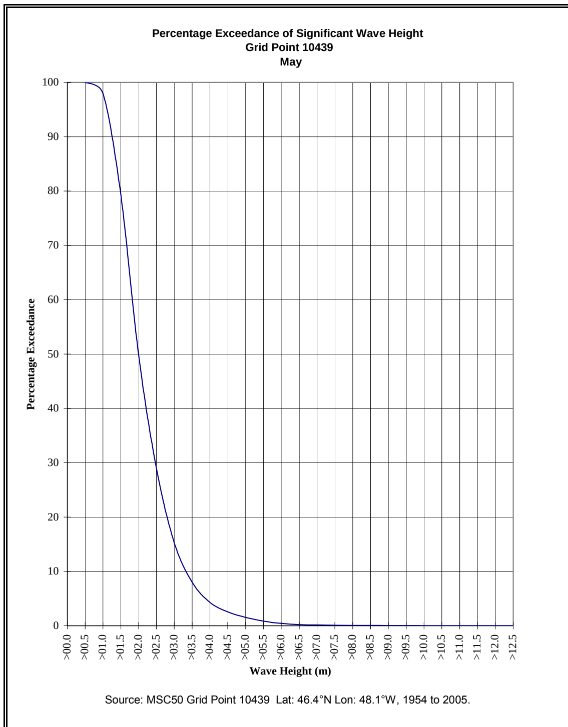
# Percentage Exceedance of Significant Wave Height at Grid Point 10439

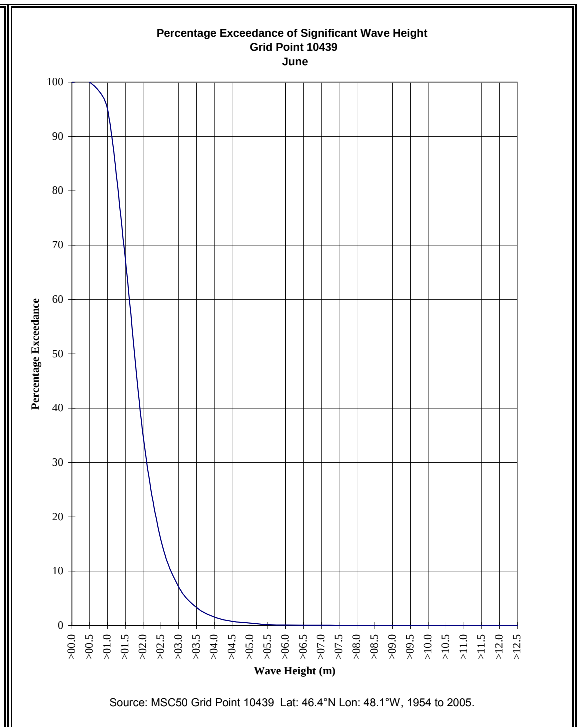

Percentage Exceedance of Significant Wave Height
Grid Point 10439
January
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

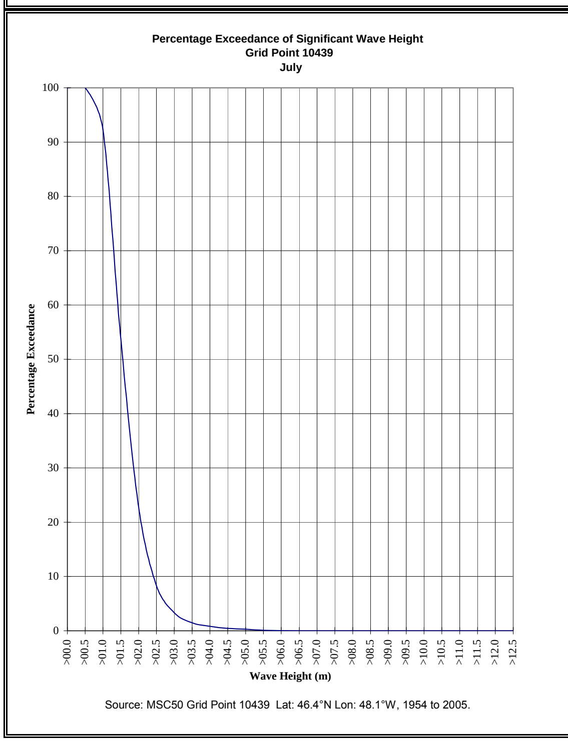

Percentage Exceedance of Significant Wave Height
Grid Point 10439
February
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

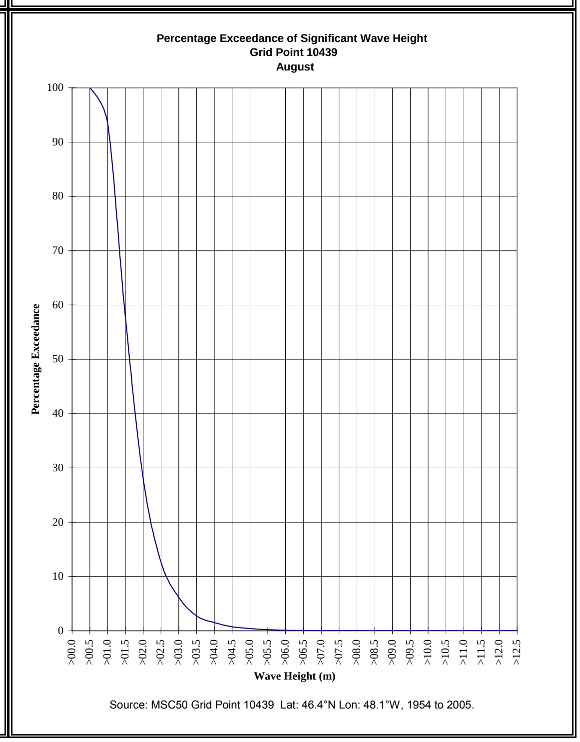

Percentage Exceedance of Significant Wave Height
Grid Point 10439
March
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

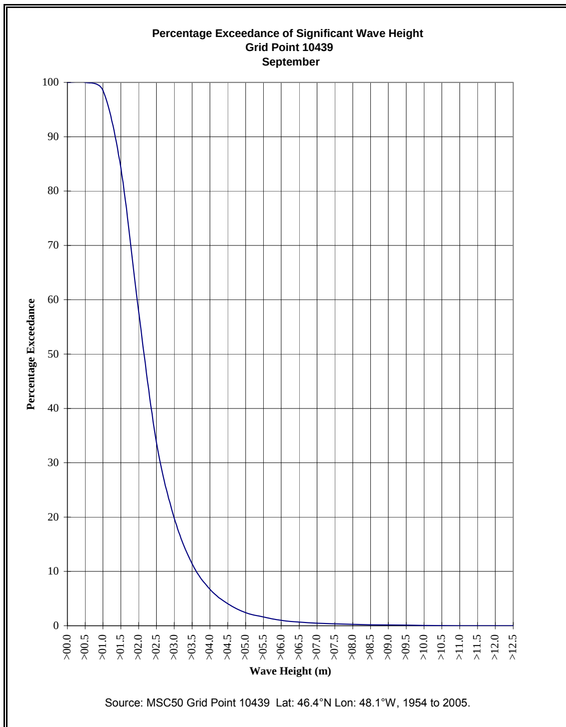

Percentage Exceedance of Significant Wave Height
Grid Point 10439
April
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

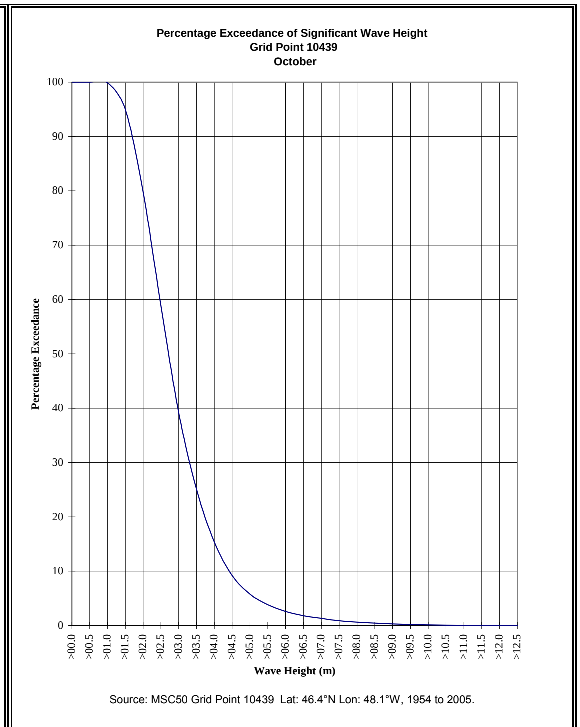

Percentage Exceedance of Significant Wave Height
Grid Point 10439
May
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

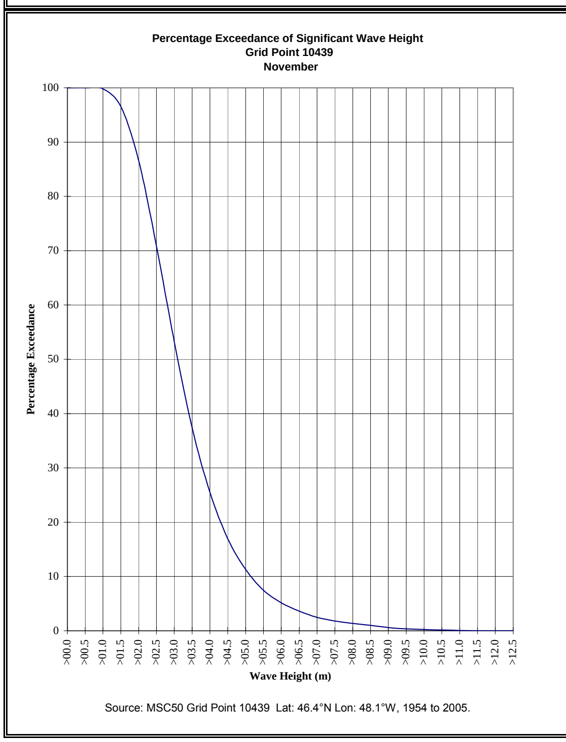

Percentage Exceedance of Significant Wave Height
Grid Point 10439
June
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

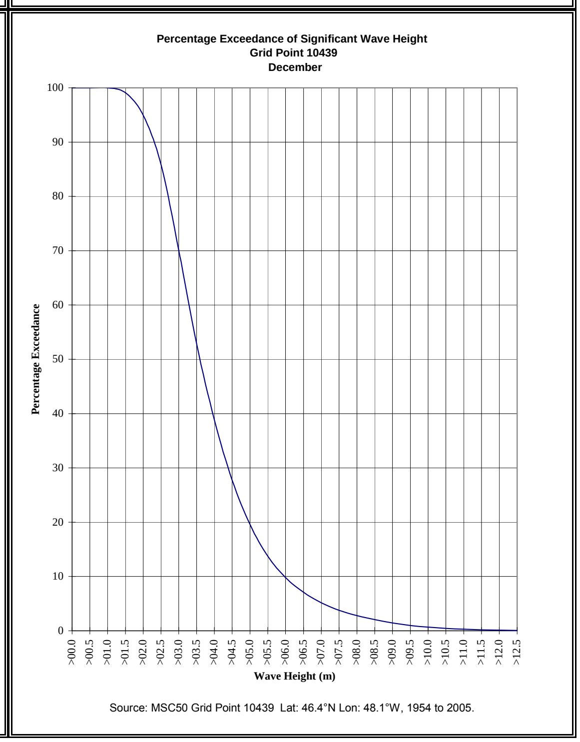

Percentage Exceedance of Significant Wave Height
Grid Point 10439
July
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10439
August
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10439
September
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10439
October
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10439
November
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.


Percentage Exceedance of Significant Wave Height
Grid Point 10439
December
Percentage Exceedance
Wave Height (m)
Source: MSC50 Grid Point 10439 Lat: 46.4°N Lon: 48.1°W, 1954 to 2005.

# Appendix B: Persons Consulted

The following agencies and persons were consulted about SHC's proposed 2008-2016 seismic program.

Environment Canada (Environmental Protection Branch)

- Glenn Troke, EA Co-ordinator

Fisheries and Oceans

- Randy Power, Acting Senior Regional Habitat Biologist
- Sigrid Kuehnemund, Senior Regional Habitat Biologist
- Bill Brodie, Research Scientist, RV Science Surveys

Natural History Society

- Len Zedel, MUN

One Ocean/FFAW

- Maureen Murphy, Director of Operations

Fish, Food and Allied Workers Union (FFAWU)

- Jamie Coady, Fisheries Liaison Co-ordinator

Association of Seafood Producers

- E. Derek Butler, Executive Director

Fishery Products International

- Derek Fudge, Manager, Fleet Administration and Scheduling (via email)

Icewater Seafoods

- Michael O'Connor, Fish Harvesting Consultant
- Tom Osbourne, Plant Manager, Arnold's Cove

Clearwater Seafoods

- Rik Scheffers, Director of Fleet Operations

Groundfish Enterprise Allocation Council

- Bruce Chapman, Executive Director