4 EXISTING ENVIRONMENT

This Chapter provides a description of the existing biophysical and socioeconomic environments that overlap and may interact with the proposed Project, including relevant components of the physical (geology, climate, oceanography, ice), biological (plankton, benthos, fish, marine birds, marine mammals, sea turtles) and socioeconomic (fisheries, other marine activities) environments.

In the EA, this overview of the existing environment is used as a basis for identifying potential environmental issues and interactions and required mitigation to avoid or reduce potential adverse environmental effects. It should also be noted that the description of the existing environment focuses primarily, but not exclusively, upon the identified VECs, and includes other aspects of the physical, biological and socioeconomic environments which are relevant as background and/or which have been specified in the March 2015 Scoping Document for the EA.

4.1 Physical Environment

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

4.1.1 Geology

The geology of the offshore area off Eastern Newfoundland is complex and dynamic, and the current bedrock and surficial characteristics of the Study Area have been shaped by various natural and human factors and processes over time.

4.1.1.1 Bedrock and Surficial Geology

The Study Area, located on the eastern continental shelf, was formed by extension during the breakup of Pangea and the opening of the Atlantic Ocean during the Late Triassic to mid-Cretaceous and is underlain by pre-rift basement rocks (Fader et al 1989). Rifting, combined with salt tectonics in the area, created a complex series of Mesozoic rift basins that are separated by basement highs along the central to outer shelf. The resulting combination of stratigraphy, structure and timing have been conducive to hydrocarbon generation and entrapment (Bell and Campbell 1990).

The main sedimentary basins in the Study Area include the Orphan, Flemish Pass, Jeanne d'Arc and Carson (Fader et al 1989). The primary reservoirs are located in the shallow marine and fluvial shale and sandstone deposited during the Late Jurassic and Early Cretaceous periods of the Mesozoic Era. The Late Jurassic Egret member of the Rankin Formation is a world-class source rock that is recognized as the primary source of the oil and gas discovered in the Jeanne d'Arc Basin, which is the only basin in the Study Area containing presently developed producing oil fields. This rock type has also proven to be widespread in the Flemish Pass Basin (G&G 2003).

Notable topographic highs in the Study Area are the Central Ridge, Flemish Cap and Orphan Knoll. The Central Ridge is a faulted intrabasinal high separating the Jeanne d'Arc and Flemish Pass basins (Enachescu 2012).The Flemish Cap is a large, isolated submarine knoll located approximately 600 km east of Newfoundland and represents the most easterly extension of North American continental crust (King and Fader 1985). It consists of a central core of Precambrian and an onlapping sequence of Mesozoic to Cenozoic aged sediments (King et al 1986). The Orphan Knoll is located

approximately 550 km northeast of Newfoundland, and is comprised of Jurassic to Cretaceous sediments overlying mounds of Palaeozoic shallow water marine sediments.

All of the Eastern Canadian continental shelf has been strongly influenced by Quaternary glaciation, which in the Project Area resulted in an erosional morphology (Piper 1991). This glaciation produced a variety of glacial deposits, including sands and gravels, which are generally present as a veneer, basinal muds, muddy sands and gravels, glaciomarine sediments and glacial drift sediments. Within the Study Area, these deposits have been identified and classified as the Grand Banks Sand and Gravel, Placentia Clay, Adolphus Sand, Downing Silt and Grand Banks Drift (Piper et al 1988).

The surficial sediments, surficial features and seabed iceberg scouring as well as current features in the Study Area are illustrated in Figure 4.1 (adapted from Cameron and Best 1985). Features include iceberg scouring, sand ridges and waves, shell beds, pockmarks and seabed depressions of unknown origin.

4.1.1.2 Seismicity

Canada's eastern continental margin is tectonically passive and seismicity is relatively rare throughout much of the region. Natural Resources Canada (2015a) estimates that approximately 450 earthquakes occur each year in Eastern Canada. Seismicity generally occurs randomly along the Grand Banks margin. The most recent edition of the Seismic Hazard Map prepared by Natural Resources Canada (2015a) is shown in Figure 4.2, and illustrates the probability of earthquake occurrences across Canada. According to this map, the Study Area has been classified as having a low to moderate seismic hazard.

According to the National Earthquake Database (Natural Resources Canada 2015b) there have been 18 seismic events recorded within the boundaries of the Study Area in the 1985-2015 period. The magnitudes of these events have been fairly low, ranging from 2.7 to 4.5 with an average magnitude of 3.5 and a median magnitude of 3.4. The majority of these recorded events have epicentres in the west and northwest portions of the Study Area, and are likely related to the various tectonic lineaments in the area.

Figure 4.1 Overview of Key Seabed Features

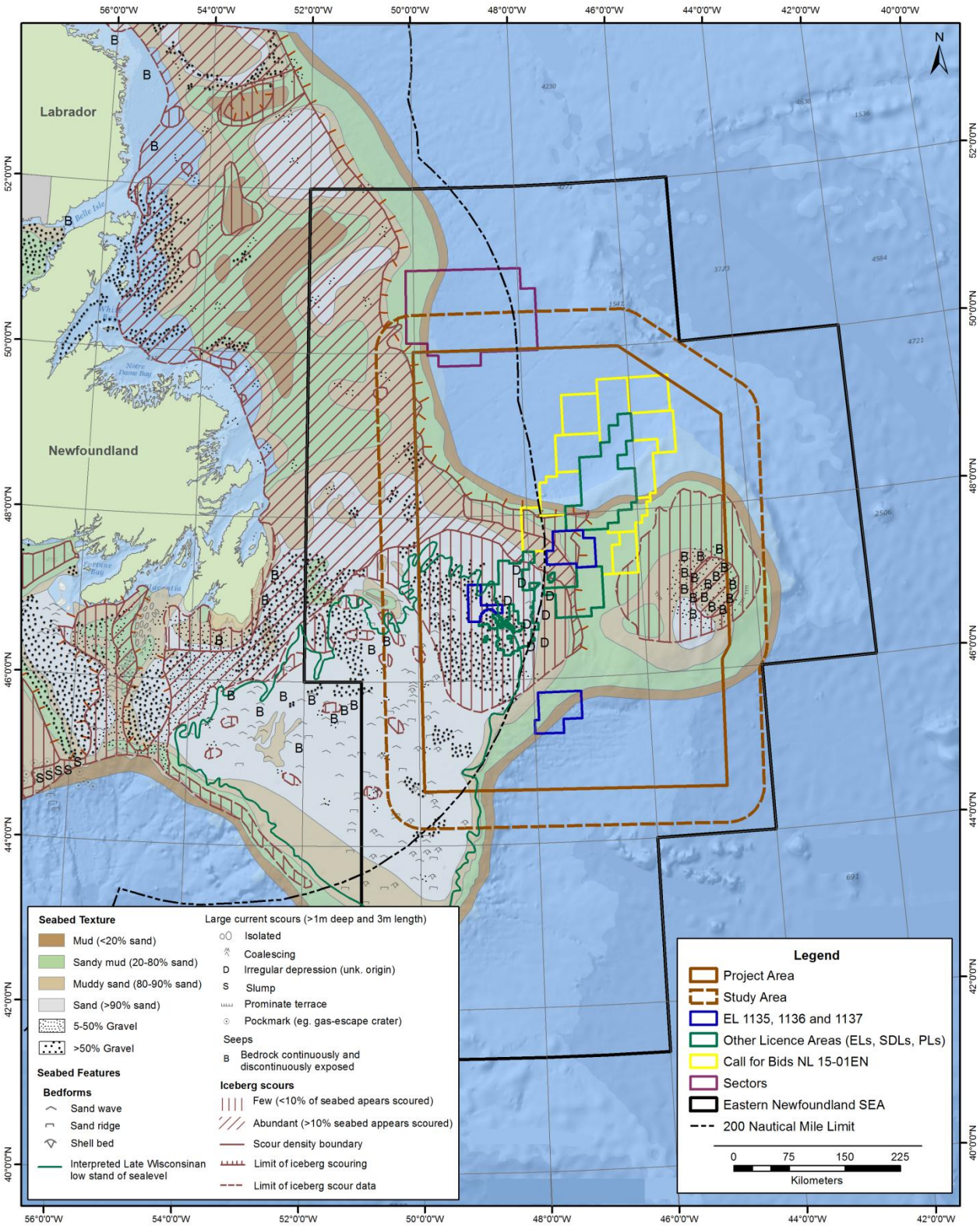
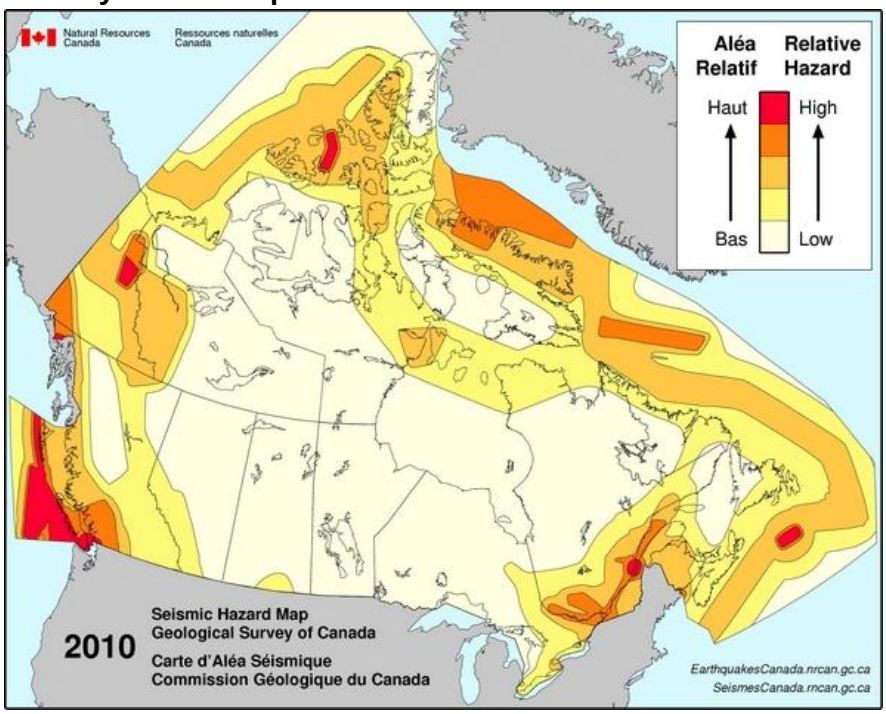


Figure 4.2 Seismicity Hazard Map



4.1.2 Bathymetry

The Study Area covers a large expanse of the Northwest Atlantic Ocean, extending approximately 700 km north to south and 500 km west to east. The Study Area boundary furthest to the east-southeast is about 770 km east of St. John's, while the western boundary is about 160 km east of St. John's. Some of the key physiographic features of the Study Area and surrounding region and its general bathymetry are shown in Figures 4.3 and 4.4.

The western portion of the Study Area contains the Grand Banks, a region with average depths of about 75 m which extend to about 350 km east of St. John's to the 200 m depth contour and then a farther 50 km to the 1,000 m depth contour. The Flemish Pass has depths of almost 1,300 m. On the eastern side, water depths rise again to the Flemish Cap, a large bathymetric feature of about 50,000 km^2 with depths rising back up about 130 m.

To the south, the Southeast Shoal, has water depths of about 40 to 50 m. This area lies about 75 to 125 km north of the Tail of the Banks. Numerous canyons run down off the continental slope into the Newfoundland Basin and deep ocean where depths range from 2,000 to 4,000 m. The Carson Canyon, about 10 km wide, lies at the 110 m isobath at the shelf break.

The Sackville Spur extends the nose of the Grand Banks at depths of up to 1,000 m. This area lies about 450 km east-northeast from the western boundary of the Study Area. The Grand Banks extend north to the Northeast Newfoundland Shelf, with depths generally of 200 to 300 m.

To the northeast of the shelf, and comprising the northern one third of the study area, lies the Orphan Basin, with water depths ranging from about 1,200 m at the edge of the continental shelf to as deep as 3,500 m. The Labrador Basin and deep ocean lie farther offshore to the north and east of the Orphan Basin and Flemish Cap, with depths of 3,000 to greater than 4,000 m.

Figure 4.3 Key Bathymetric Features

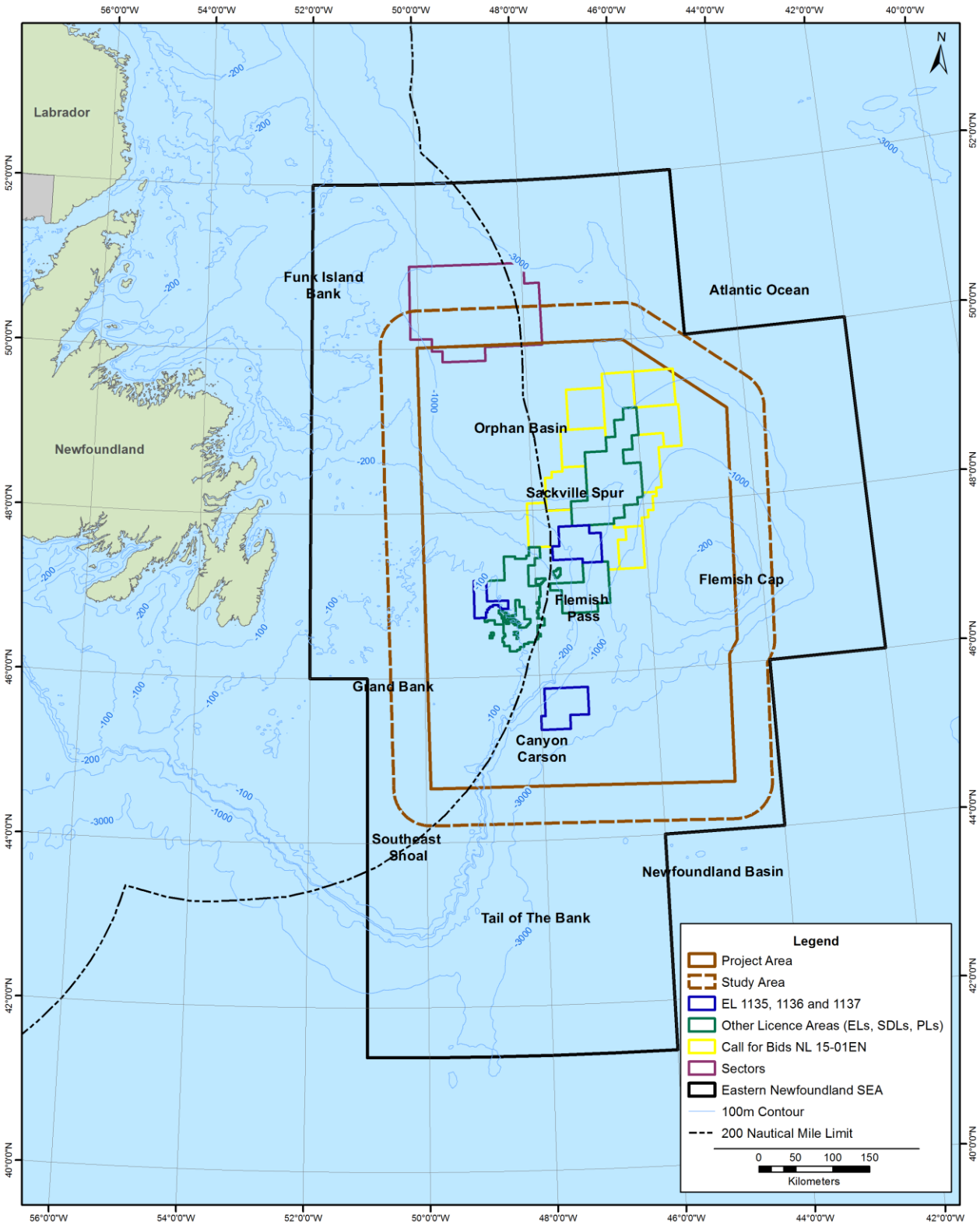
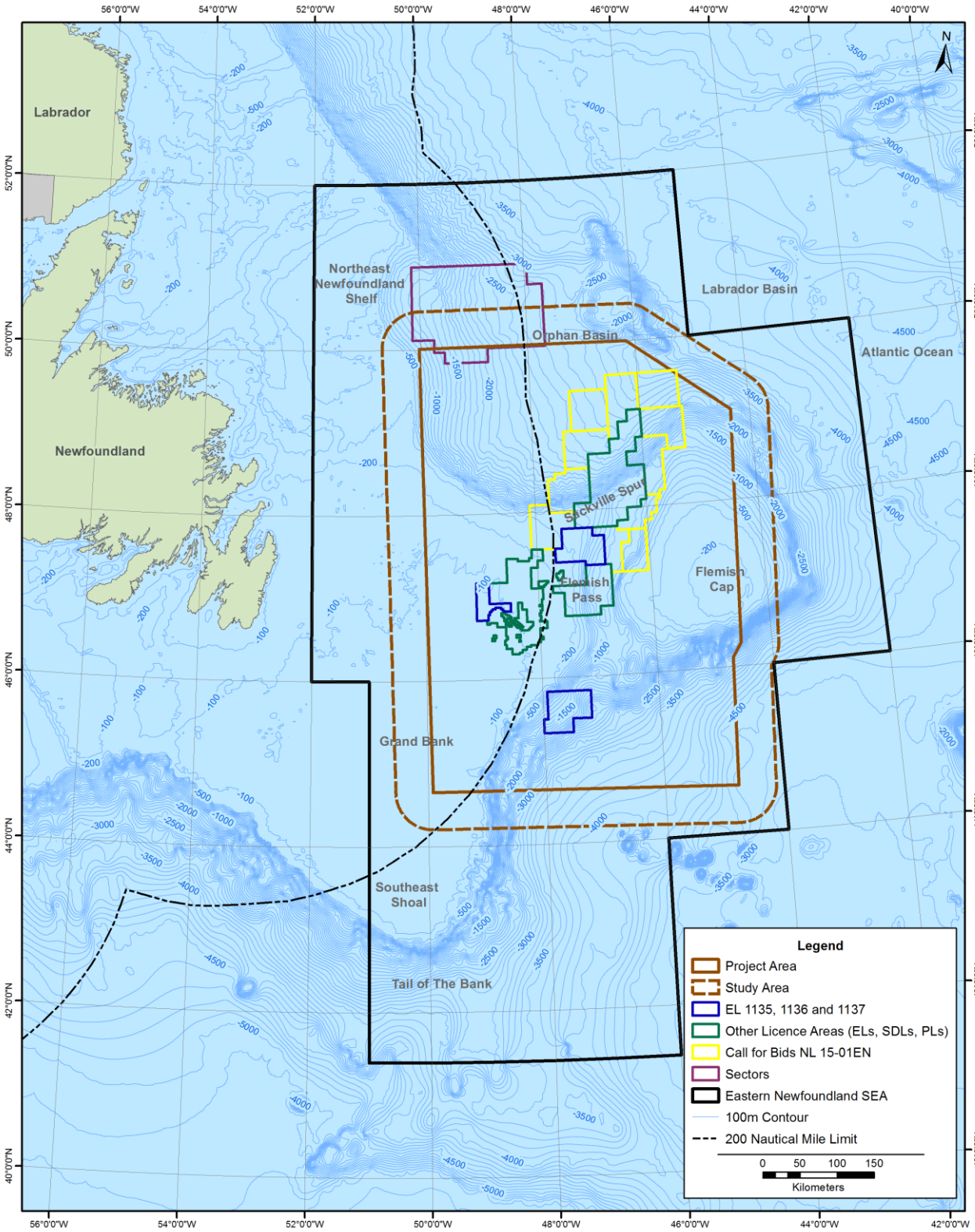


Figure 4.4 General Bathymetry of the Study Area



4.1.3 Climatology

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

As illustrated in Figure 4.5, four regions were defined for the Study Area, and these were used to query the ICOADS for 1960 to 2014 and assemble statistics of meteorological and marine conditions across this region.

4.1.3.1 Wind

The prevailing winds over the Study Area are from the west to northwest in winter and from the southwest in summer. Extreme wind gusts greater than 100 knots (51 m/s) have been measured in winter and in association with tropical and post-tropical weather systems. Many storm systems are still strengthening as they pass through the area; as a result winds over the northeast are on average stronger than those over the southwest (Bowyer 1995).

Figure 4.6 summarizes seasonal monthly mean and maximum wind speeds for the four ICOADS regions that comprise the Study Area (data from NCDC et al 2015). On average, wind speeds are generally the greatest for the Northern Grand Banks Maximum wind speeds from the ICOADS database are as large as a 49.4 m/s (178 km/h) (wind direction from the northwest) observation reported 11 February 2003 at the Hibernia Platform (Northern Grand Banks).

4.1.3.2 Air Temperature

Air temperatures in the Study Area overall are coolest in January or February and warmest from July through September for all regions. Figure 4.7 (data from NCDC et al 2015) presents minimum, mean and maximum monthly air temperatures for the four (ICOADS) regions that comprise the Study Area. Minimum temperatures in May, for all regions range from -6°C to -4°C. Minimum temperatures in August, for all regions range between 1°C and 5°C. Maximum air temperatures over the Study Area range between 17°C and 25°C in February to 23°C and 29°C in August.

Figure 4.5 ICOADS Regions in the Study Area

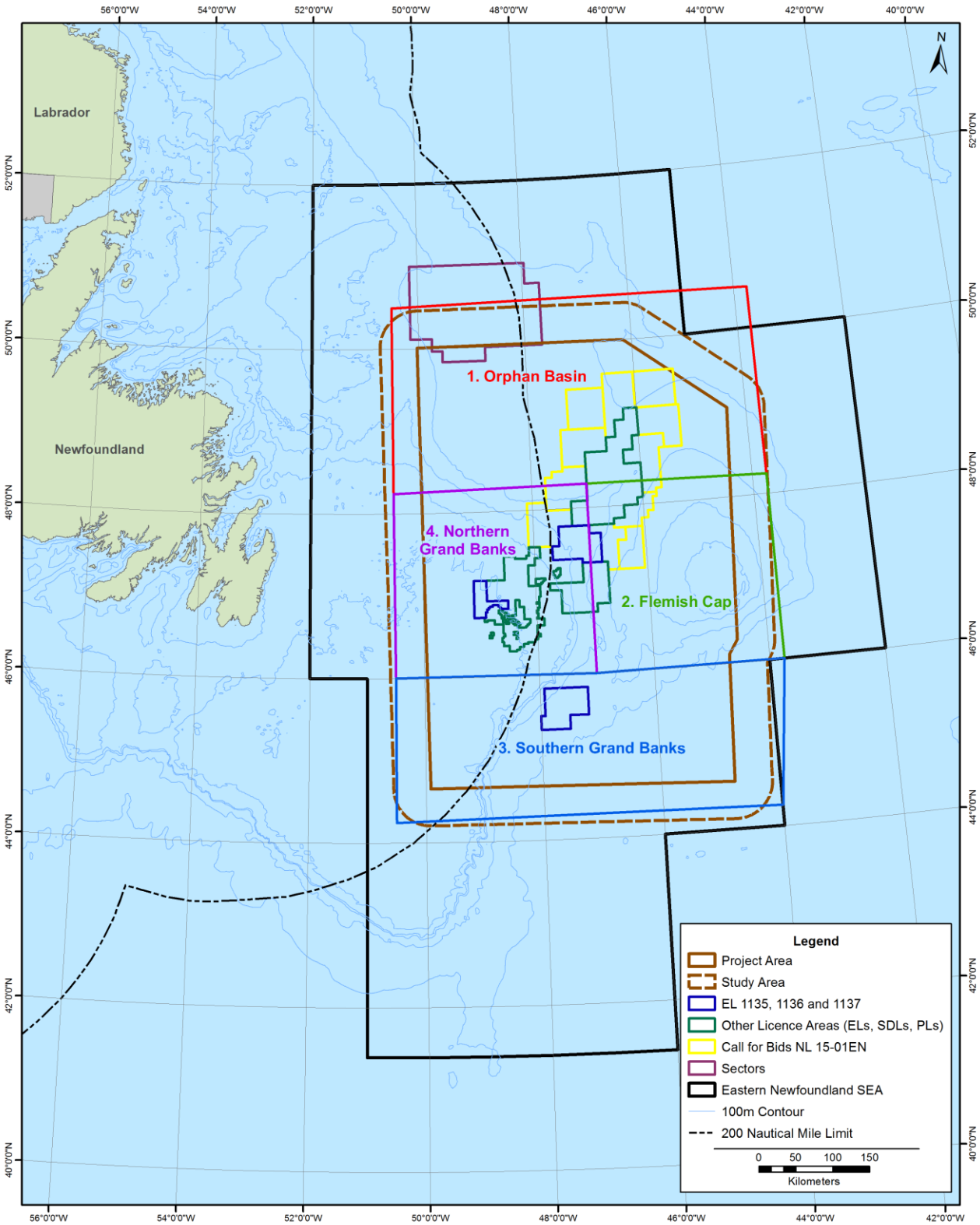


Figure 4.6 Wind Speeds

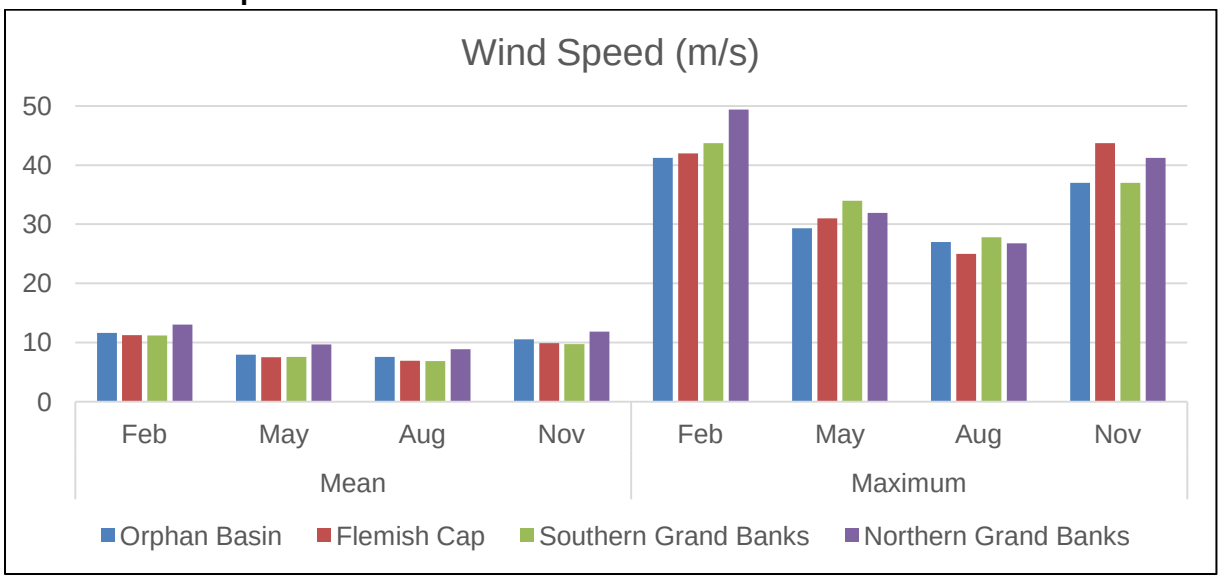
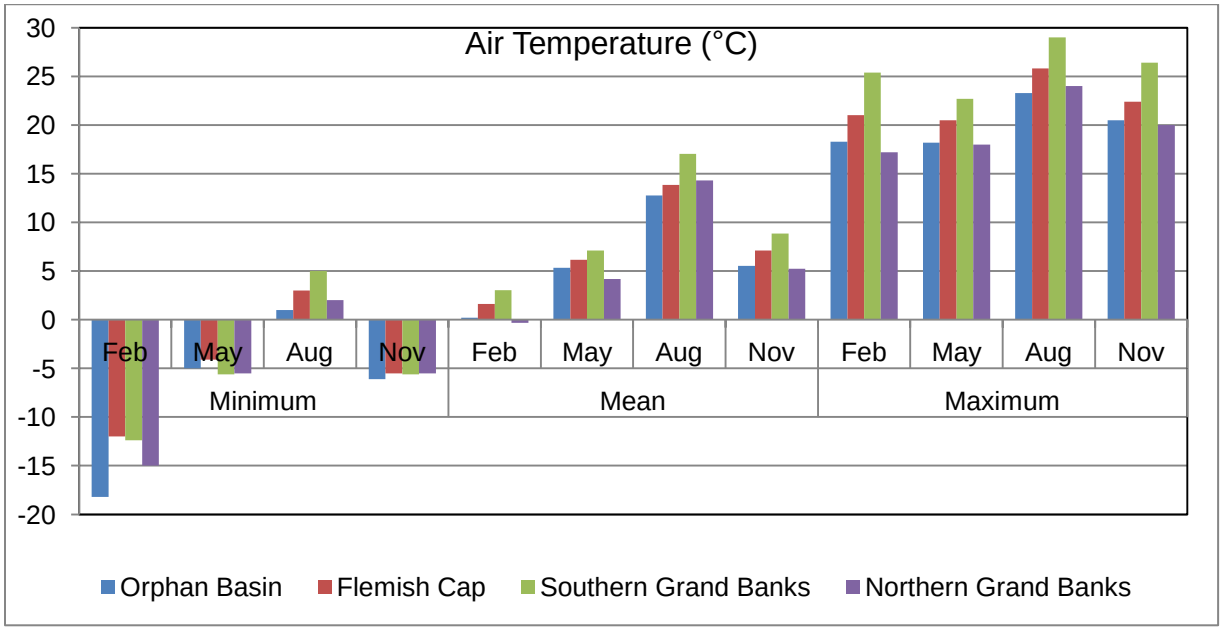


Figure 4.7 Air Temperature



4.1.3.3 Precipitation

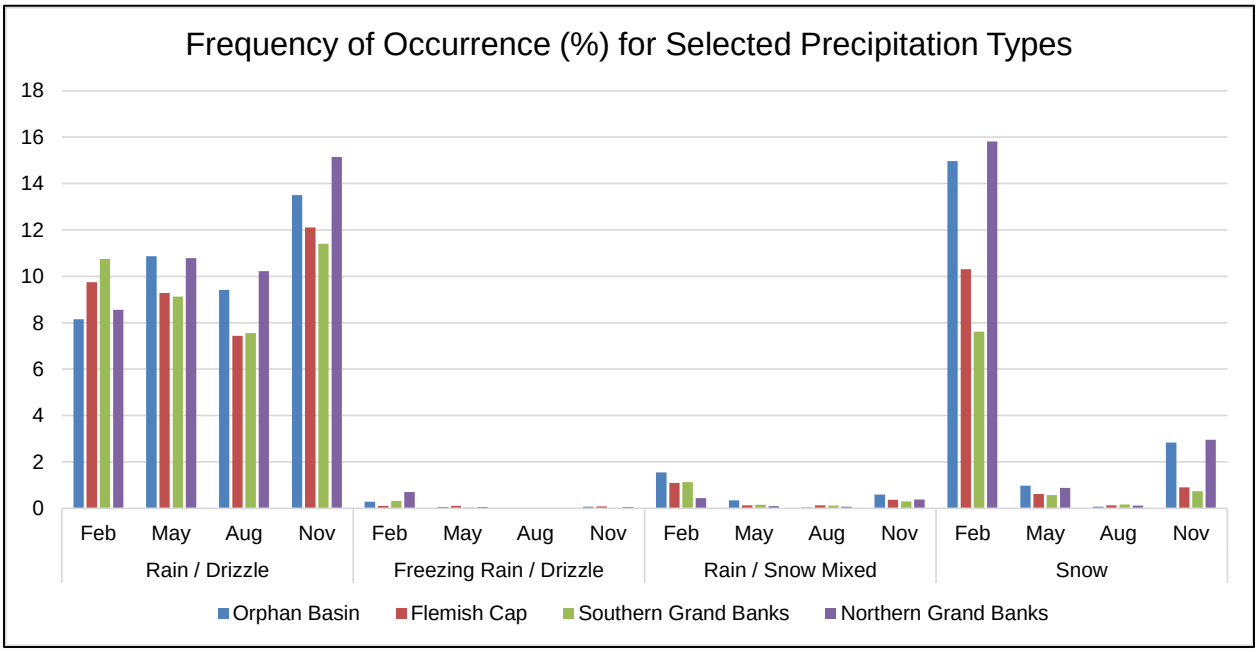
Rain or drizzle can occur at any time of year throughout the Study Area and is most likely to occur with southerly or southwesterly winds. Snow and freezing rain are possible any time from October through May, and snow can accompany winds of any direction. Freezing rain is most common with easterly or north-easterly winds. Freezing drizzle frequently persists for days in the spring along the East Coast of Newfoundland (Bowyer 1995).

Based on the ICOADS data set queried, the total precipitation is the greatest in January and February. Precipitation is lowest in June and is predominantly rain or drizzle. Figure 4.8 (data from NCDC et al 2015) presents the percent occurrence of different precipitation types for each of the four ICOADS regions for select months of the year. The frequency of occurrence can most closely be

characterized as representing unspecified periods of time, for a percentage of all days in the given month.

There is a year-round potential for thunderstorms and hail, with the highest frequency of occurrence of hail occurring in the winter months, and thunderstorms most frequently reported in summer. Annually, the percent occurrence of hail or thunderstorm ranges from about 0.2 percent of the time for the Northern Grand Banks to 0.5 percent for the Southern Grand Banks. The largest percent occurrence of hail is reported at one percent in January for the Orphan Basin, while the largest occurrence of thunderstorms is reported at 0.4 percent in July for the Southern Grand Banks.

Figure 4.8 Precipitation



4.1.3.4 Visibility (Fog)

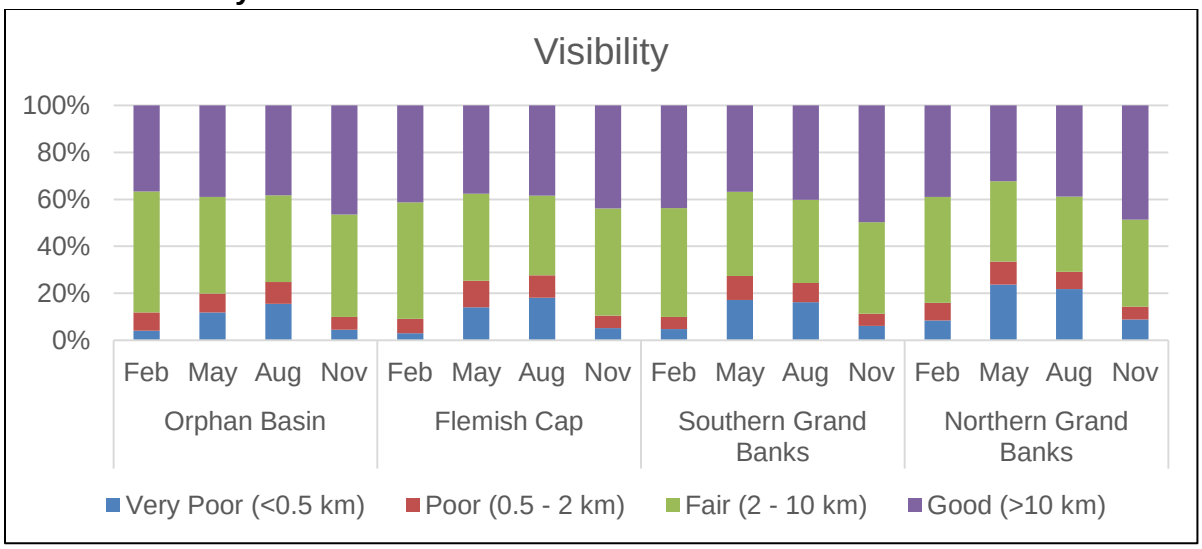
A summary of visibility conditions based on the ICOADS dataset, with classes defined as very poor (less than 0.5 km), poor (0.5 to 2 km), fair (2 to 10 km) and good (greater than 10 km) is shown in Figure 4.9 (data from NCDC et al 2015).

In general, visibility over the Study Area is the most favourable in fall and winter and most frequently restricted in summer and spring. Good visibility (greater than 10 km) conditions occur annually from about 42 percent for the Southern Grand Banks to 39 percent for the other three regions. On a monthly basis, good visibility conditions range from a minimum of 22 percent of the time in July for the Northern Grand Banks to a maximum of 54 percent of the time in October for the Southern Grand Banks. Fair conditions can be expected about 36 percent (Northern Grand Banks) to 43 percent (Orphan Basin) of the time annually.

Visibility is least favourable for the Northern Grand Banks, being very poor (less than 0.5 km) 17 percent of the time annually, compared with 10, 11 and 12 percent for the Orphan Basin, Flemish Pass and Southern Grand Banks regions, respectively. Visibility conditions are the poorest in July for all regions with the conditions being very poor or poor in that month over half the time (54 percent) for

the Northern Grand Banks, 47 percent for the Flemish Cap, 45 percent for the Southern Grand Banks and the least restricted at 40 percent for the Orphan Basin.

Figure 4.9 Visibility



4.1.4 Oceanography

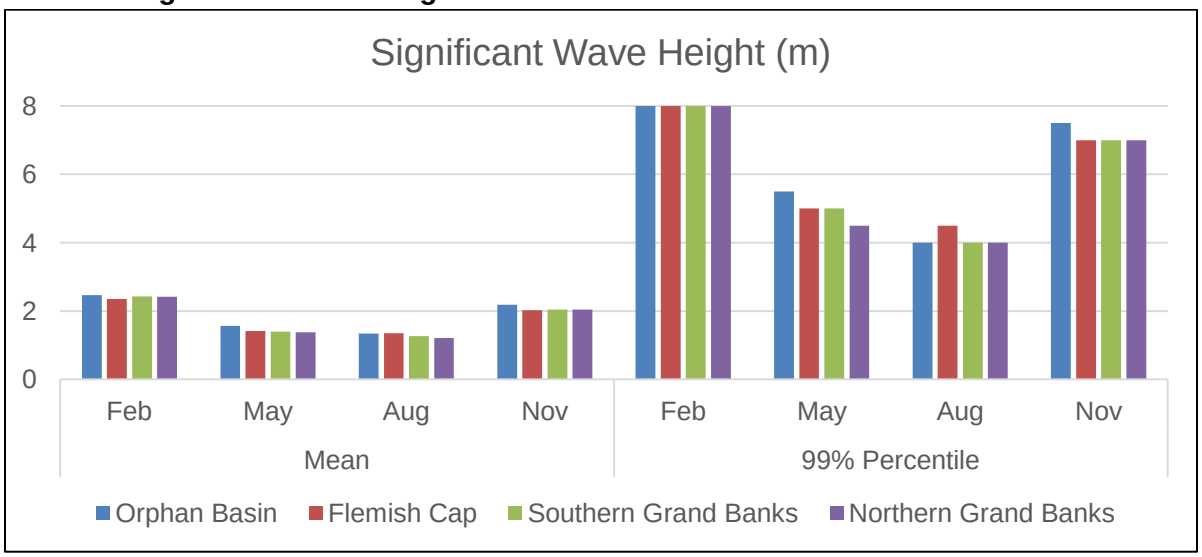
As described above, the ICOADS (1960 to 2014) datasets and other sources were used to provide an overview summary of oceanographic conditions across the Study Area, based on each of the subregions described and illustrated above.

4.1.4.1 Waves

A summary of regional wave conditions is presented in Figure 4.10 (data from NCDC et al 2015) for the four ICOADS regions that comprise the Study Area. Seasonal monthly mean and maximum significant wave height (Hs), estimated to the nearest 0.5 m are reported.

The largest seas are seen farthest offshore, namely for the Flemish Cap and Southern Grand Banks regions. Mean significant wave heights in spring and summer (May and August) range from 1.2 to 1.6 m, and in fall and winter (November and February) range from 2.0 to 2.4 m. The 99th percentile values of significant wave height in the four regions range from 4.0 to 4.5 m in May to 4.5 to 5.5 m in August. The 99th percentile values are 8 m in February in all regions, and in November the value is 7.5 m for the Orphan Basin and 7 m for the other three regions.

Figure 4.10 Significant Wave Height



4.1.4.2 Ocean Surface Currents

The circulation of the Study Area, which includes the continental shelf waters off Eastern Canada, is dominated by a generally southward flow of the cold Labrador Current and its two streams: 1) an inshore branch that flows along the coast on the continental shelf, and 2) an offshore branch that flows along the outer edge of the Grand Banks. The current's inshore branch tends to flow mainly in the Avalon Channel along the coast of the Avalon Peninsula but may sometimes also spread further on the Grand Banks. The offshore branch of the Labrador Current flows over the upper Continental Slope at depth, and through the Flemish Pass with average speeds of approximately 40 cm/s. Over parts of the Grand Banks with water depths less than 100 m, the mean currents are generally weak (less than 10 cm/s) and flow southward, dominated by wind-induced and tidal current variability. The offshore branch meets with the Gulf Stream south of the Study Area near the Tail of the Grand Banks and flows to the east.

4.1.4.3 Seawater Properties (Temperature, Salinity)

Summaries of winter and summer sea temperature and salinity derived from DFO's Climatology for the Newfoundland Shelf (DFO 2012) are provided in Tables 4.1 and 4.2. (data from ICOADS 1960-2014). Four geographic areas have been selected to characterize the conditions for Study Area, although it is noted that these cover only a portion of the Newfoundland Shelf:

- *Area 34* (Funk Offshore, depth 1,000 m) for Orphan Basin;
- *Area 38* (Flemish Cap, depth 250 m) for Flemish Cap;
- *Area 43* (SW Newfoundland Basin, depth 1,000 m) for Southern Grand Banks; and
- *Area 46* (NE Grand Bank, depth 600 m) for Northern Grand Banks

Average sea surface temperatures generally range from about 0°C to 7°C in February and from about 10°C to 16°C in summer, whereas near-bottom sea temperatures generally range from 8°C to 13°C on average year-round.

Average sea surface salinities range from about 32 psu in the southern portion of the Study Area to almost 34 psu to the north. Near-bottom salinities are typically around 34 psu in both summer and winter.

Table 4.1 Sea Temperature

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

Table 4.2 Salinity

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

4.1.5 Ice Conditions

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

4.1.5.1 Sea Ice

The Sea Ice Climatic Atlas for the East Coast 1981-2010 (CIS 2011) reports how frequently sea ice is present, its concentration when present, and its predominant ice type and hence thickness. In the northwest portion of the Study Area, sea ice can be present as early as the first week of January and in thicknesses of up to 30 cm. By the end of March, most of the ice over the Study Area is thin first year (30-70 cm), with patches of medium (70-120 cm) and thick (greater than 120 cm) first year.

The sea ice begins to retreat over the entire region by mid-April, and by the beginning of May is generally ice free over the Southern Grand Banks and Flemish Cap regions, with ice presence just 1-15 percent of the time in the outermost northwestern portions of the Study Area (Figure 4.11, from CIS 2011). At the beginning of June, small areas of thick first year ice and occasionally old ice (ice which has survived at least one summer's melt) may be found in the northern parts of the Orphan Basin.

As illustrated in the companion Figure 4.12 (CIS 2011), while most of the Study Area is generally ice free by mid-May, small patches of 7/10 or greater ice concentration can persist over much of the Grand Banks. By the end of May, any remaining ice is generally of concentrations 1/10 to 3/10.

Figure 4.11 Frequency of Presence of Sea Ice (%), Week of May 7 (1981-2010)

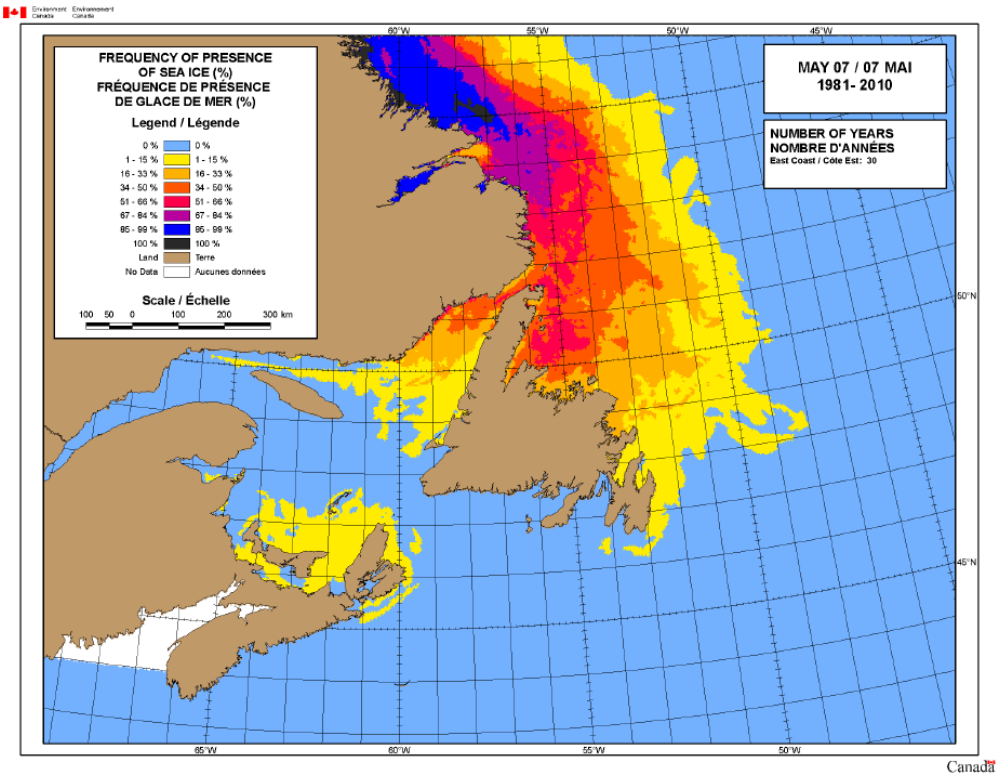
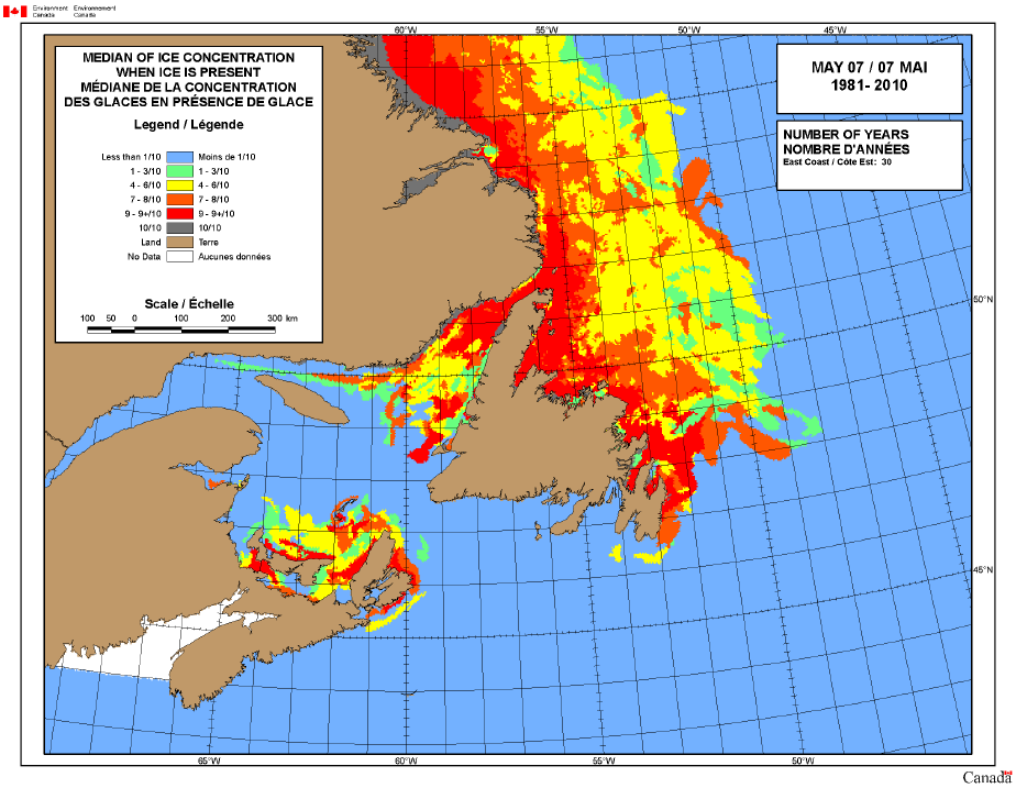


Figure 4.12 Median of Ice Concentration when Ice is Present, Week of May 7 (1981-2010)



4.1.5.2 Icebergs

A summary of iceberg sightings from the comprehensive NRC-PERD Iceberg Sighting Database (NRC 2013) for the years 1983 to 2012 is presented below for the four (ICOADS) regions defined above.

The iceberg sightings are from various sources including industry, aircraft and ship, and include radar, visual and measured observations. Statistics are reported here for first iceberg sightings (excluding any re-sightings of the same iceberg), and include size classes ranging from growlers (less than 1 m in height, less than 5 m in length and mass about 500 t) to very large icebergs (greater than 100 m in height, greater than 200 m in length, and mass over 5 Mtonnes). Icebergs of unknown size are also reported. These criteria yield 19,452 icebergs.

As illustrated in Figure 4.13 (data from NRC 2013), the majority of icebergs are observed in the Northern Grand Banks sub-region: 8,699 over the past 30 years, or 45 percent of the total first observed in all four sub-regions, compared with 4,735 (24 percent) for the Orphan Basin, 3,218 (17 percent) for the Southern Grand Banks, and 2,817 (14 percent) for the Flemish Cap. Of the 11,835 icebergs for which size is known, 19 percent are growlers or bergy bits, 67 percent are small or medium, 13 percent are large, and just over one percent are very large.

Of this subset of icebergs in the Study Area and in the range 1983 to 2012, 1,377 icebergs have draft values, 11 percent of these being measurements, the rest being estimates. Observations from the Northern Grand Banks comprise 95 percent of the data set. The annual mean, maximum and number of observations for each year are shown in Figure 4.14 (NRC 2013). The historical mean draft is 47 m. The maximum draft of 276 m is an estimate for a very large (length=900 m, width=740 m) tabular iceberg reported 23 April 2012 in the Northern Grand Banks. The largest measured draft is 147 m for a large (length=333 m, width=152 m) tabular iceberg in April 2003 also from the Northern Grand Banks.

Figure 4.13 Iceberg Sightings in the Study Area by Size Category (1983-2012)

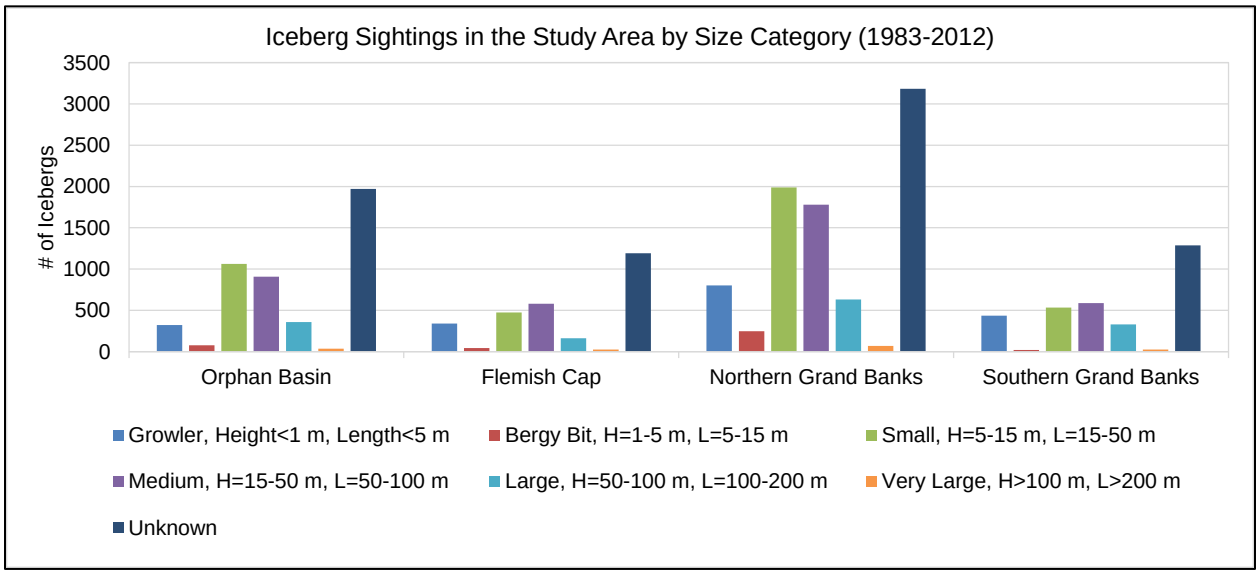
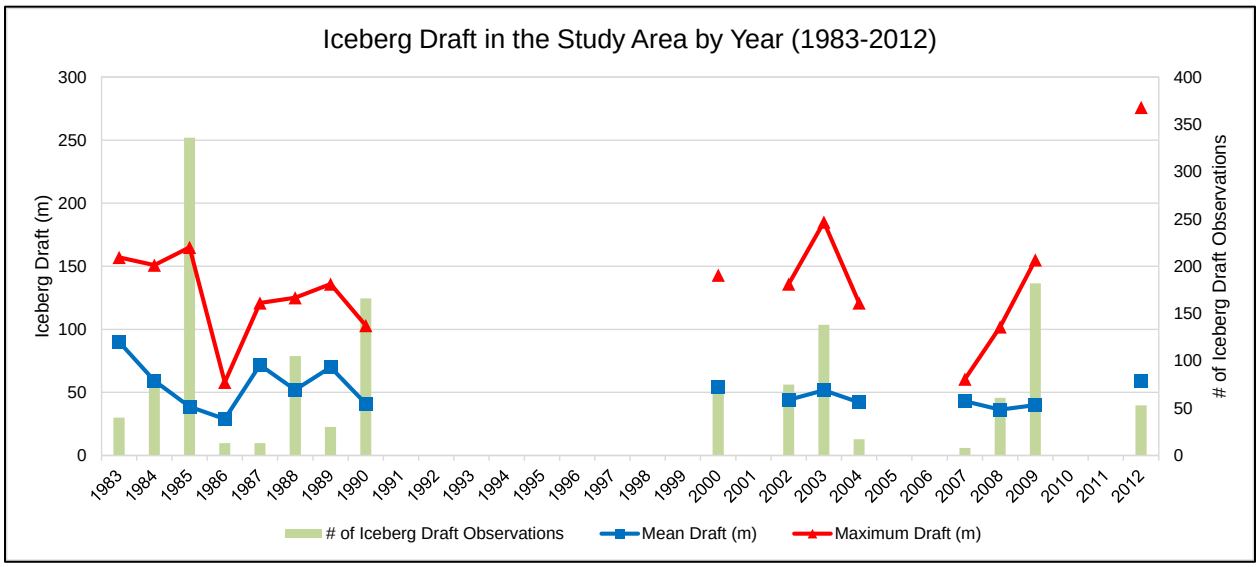
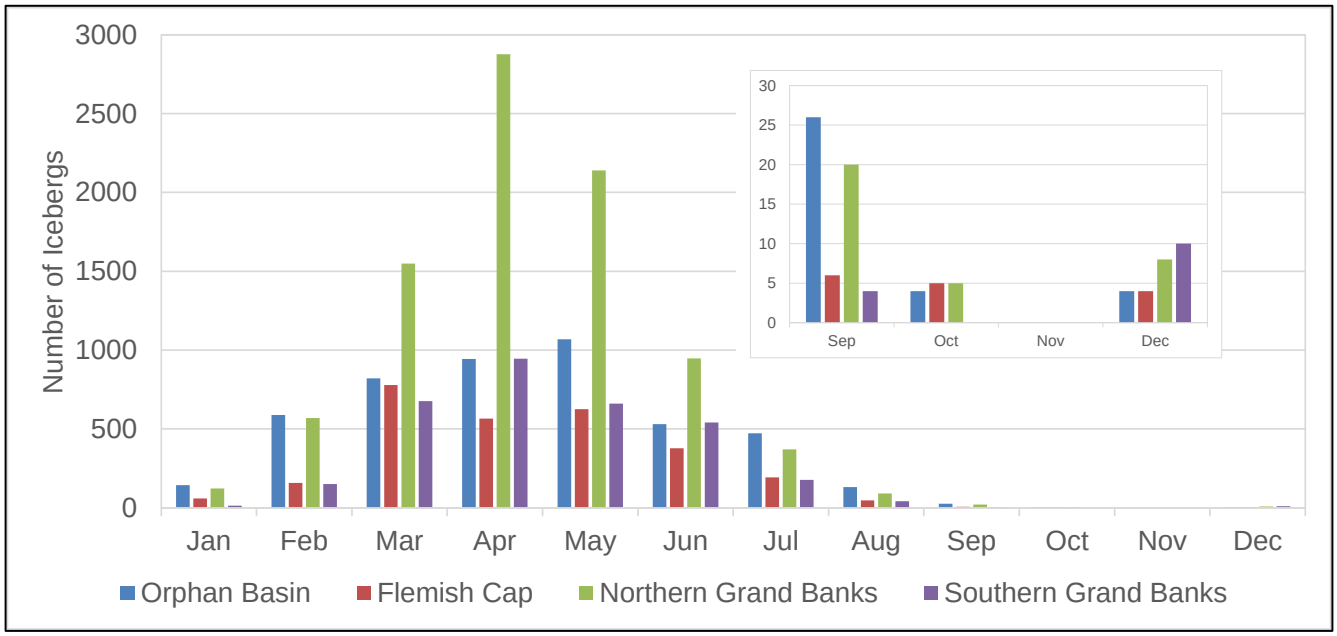


Figure 4.14 Iceberg Draft in the Study Area by Year (1983-2012)



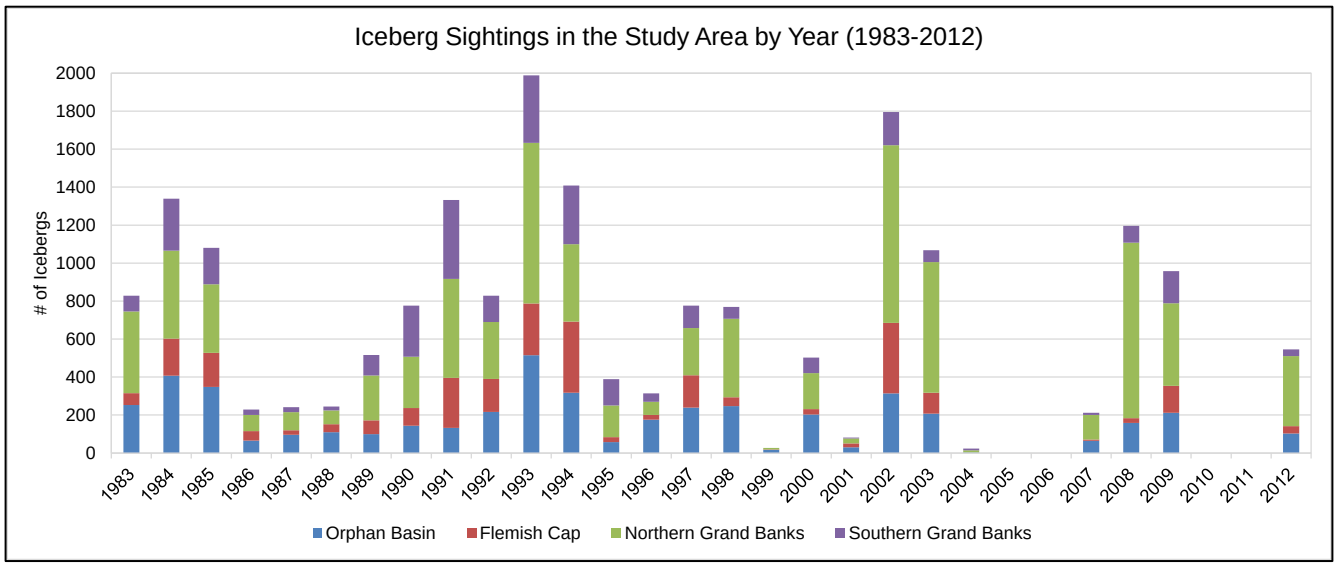
The iceberg season for the Study Area traditionally lasts from January through August, with 82 percent of first sightings during March through June (Figure 4.15, data from NRC 2013). Over the 30 year record, 1983-2012, there have been 14 sightings as late as October in the three northern regions, and 26 sightings as early as December in each of the four regions.

Figure 4.15 Iceberg Sightings in the Study Area by Month (1983-2012)



As illustrated in Figure 4.16 (NRC 2013), each ice season is different: the number of icebergs reported annually for the Study Area ranges from zero in 2005, 2006, 2010 and 2011 to 2,027 in 1998 and averages 563. For the East Coast South, just over 1,000 icebergs were sighted in both 1990 and 1991: the annual average is 281. For the South Newfoundland region, about 15 icebergs might be expected in any given year.

Figure 4.16 Iceberg Sightings in the Study Area by Year (1983-2012)



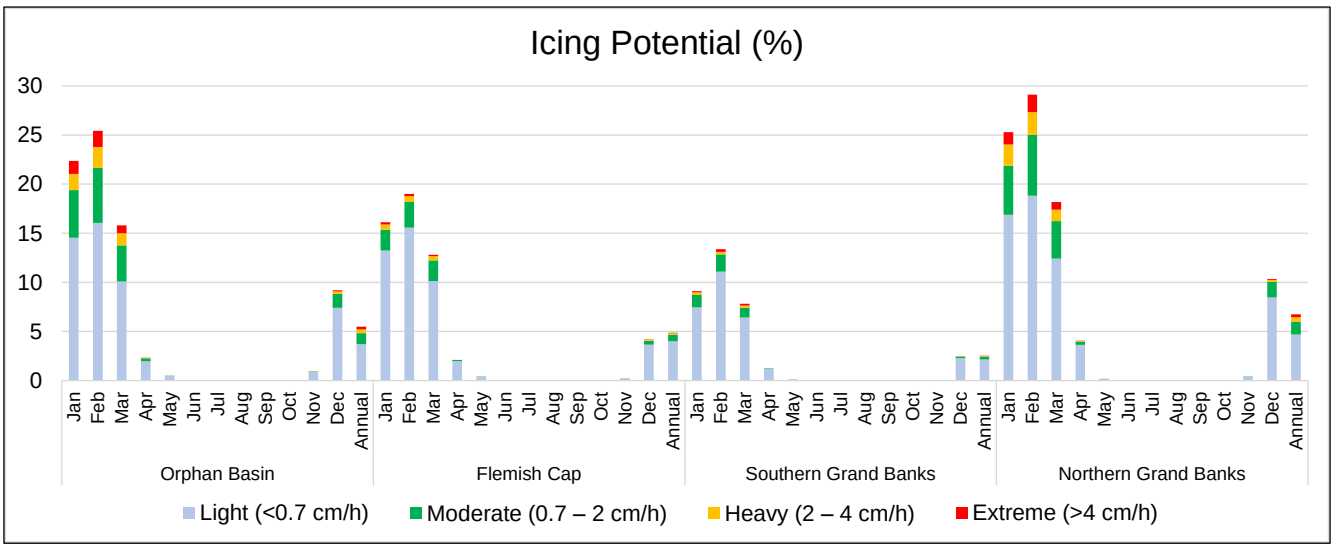
4.1.5.3 Vessel Icing

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

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

The potential for vessel icing varies over the Study Area, being the greatest in the Northern Grand Banks and Orphan Basin. Extreme icing potential is greatest in the Northern Grand Banks in February at 1.8 percent.

Figure 4.17 Icing Potential



4.2 Biological Environment

The following sections present an overview of relevant aspects of the biological environment of the Study Area, including Fish and Fish Habitat, Marine Birds, Marine Mammals and Sea Turtles.

4.2.1 Marine Fish and Fish Habitat

Marine ecosystems are comprised of biological and physical elements that interact to form complex and variable patterns across a seascape. Biological ecosystem elements span primary producers such as phytoplankton to consumers such as zooplankton, benthic invertebrates and fish. In the Study Area many of these species are of ecological, cultural, commercial and/or of conservation importance and such species may rely on specific habitats to fulfil their life cycle.

The following sections provide an overview of the existing ecological setting of the Study Area and describe ecologically sensitive areas, the associated faunal assemblages and key species.

4.2.1.1 Approach, Key Data Sources and Administrative Considerations

The recently completed Eastern Newfoundland Strategic Environmental Assessment (SEA) (Amec 2014) provides a recent and broad-scale description of marine fish and fish habitats across a region that encompasses the Study Area. This information was used and augmented with new contributions to the scientific literature, other offshore project specific EAs and supplemental analysis that is specific to the Study Area.

The Canadian Department of Fisheries and Oceans (DFO) and the North Atlantic Fisheries Organization (NAFO) are the two agencies that regulate marine fish and their habitats in the Study Area. The Canadian government has jurisdiction over fish stocks within their 200 mile limit (36.4% of Study Area) and benthic invertebrates along the continental shelf while NAFO manages the remaining areas for groundfish and shellfish activities respectively (NAFO 2013a).

Data from the Canadian DFO Research Vessel (RV) surveys (up to 2012) were used as the basis for much of the description and analysis that is presented in this section. These data, based on random, stratified sampling from research vessels provide the most up-to-date and unbiased information available (within the area sampled) that can be applied in a consistent manner across a large portion of the Study Area. Consequently, these data are used as the foundation for defining focal species and their contemporary distributions. This information is augmented by NAFO data collected from the Flemish Cap and presented for a subset of commercially important species (Casas and Gonzales-Troncoso 2013). It is recognized that these surveys do not cover some portions of the Study Area (particularly deep water portions beyond the continental slope under NAFO jurisdiction) and that certain taxa (such as various pelagic, abyssal and infaunal species) within the area surveyed are poorly represented. Nonetheless, these sources provide useful information for a considerable portion of the Study Area on many ecologically and commercially important taxa.

DFO's surveys in Newfoundland and Labrador Region take place in different but overlapping areas, in both spring (NAFO Divisions 3LNOPs) and fall (NAFO Divisions 2HJ3KLMNO) (See later Figures in Section 4.3) using the Campelen-1800 shrimp trawl. Data from the most recent period available (2008-2012) were used to describe distributions of fish in the Study Area. Where available, both spring and fall survey data (3LNMO) where used to characterize fish distributions. Mapping of fish

distributions in 3K were derived from fall data only. Qualitative examination suggests that for most species, distributions are similar for the spring and fall survey in 3LMNO.

The data from the surveys were further screened to identify key species that occurred in high abundance within the Study Area (cumulatively exceeded more than 95 percent of individuals captured). From this process, 13 focal taxa (10 fish and three invertebrate species) were identified. The ecology of these species are described in greater detail and maps of their distribution relative to the Study Area are provided in the sections that follow.

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

NAFO RV surveys of the Flemish Cap are also based on a stratified random design (Saborido-Rey and Vázquez 2003) and provide distribution data for a subset of commercially important species (Atlantic cod, American plaice, Greenland halibut, roughhead grenadier and redfish). The area of coverage is approximately 20 percent of the Study Area. Maps from these surveys, generated by Casas and Troncoso (2013), were reproduced for these species and provide additional context to the Canadian RV Surveys.

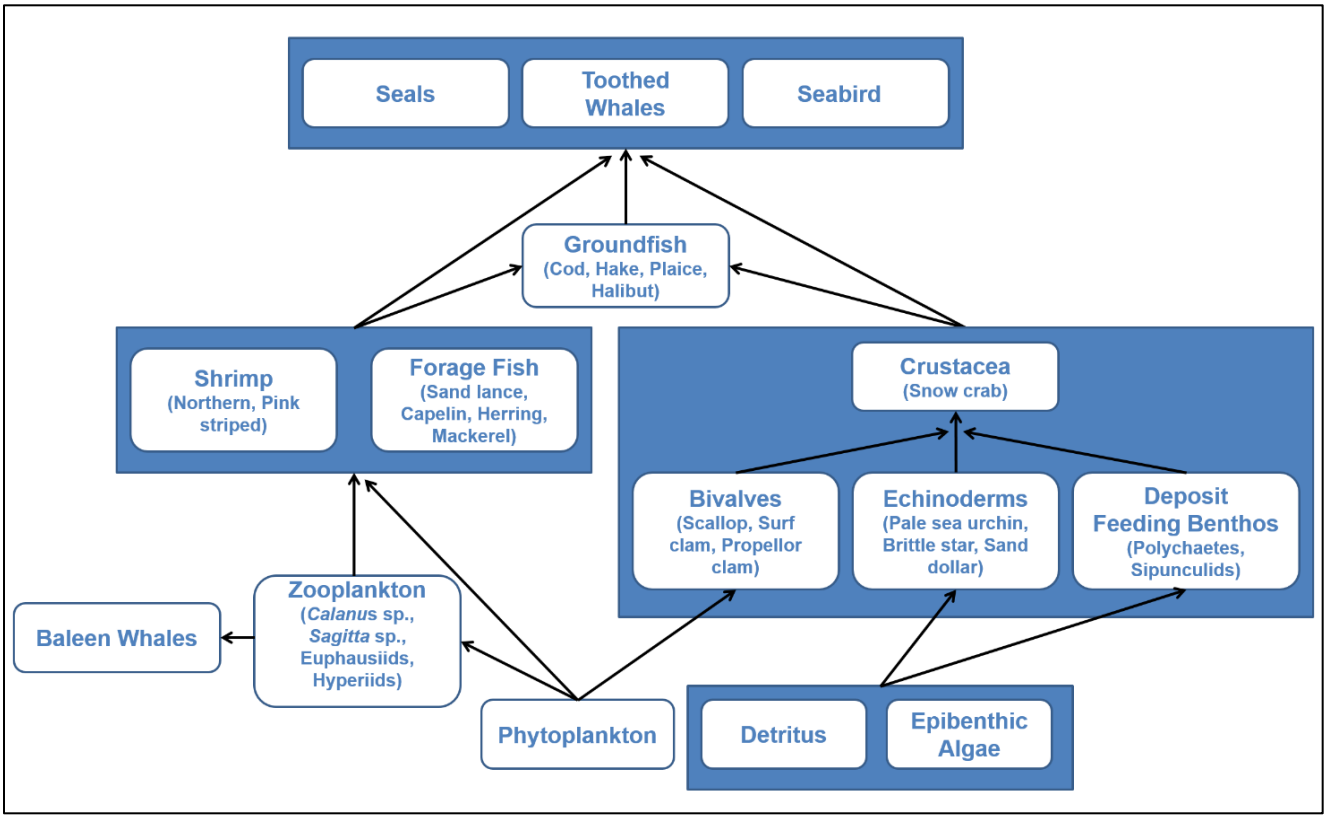
4.2.1.2 The Offshore Marine Ecosystem, Ecological Regimes and Assemblages

The offshore marine ecosystem is made up of species and habitats that are linked together through ecological processes (Gomes et al 1992; Templeman 2010; Dawe et al 2012; Figure 4.18). Primary production is predominantly derived through phytoplankton. These tiny photosynthetic organisms form the base of the food chain, feeding energy to higher trophic levels (fish, marine mammals and birds), through zooplankton, planktivorous fish and invertebrates. Detritivores, which return nutrients from dead organisms back into the food chain (Figure 4.18), complete the energy cycle. Due to the interconnectedness of species and habitats, perturbations (such as overfishing, changing climatic conditions) can affect many elements of the ecosystem (Rose 2004; Koen-Alonso et al 2010; Devine and Haedrich 2011; Dawe et al 2012; Perez-Rodriguez et al 2012) through direct (direct mortality) and indirect (competition or changes in predation rates) means.

In the late 1980s, for example, a shift to colder ocean waters coincided with overexploitation of some demersal fish stocks. This caused a drastic ecosystem response that included increases in primary production and invertebrates (including shrimp and crab) and greatly reduced numbers of many long lived groundfish species (deYoung et al 2004; Koen-Alonso et al 2010; Dawe et al 2012). The collapse of groundfish stocks released some species such as shrimp from predation, further augmenting their abundance (Worm and Myers 2003; Dawe et al 2012). Groundfish were also impeded by declines in capelin, an important prey item, whose low abundance forced many predator species to feed on lower quality prey (Dawe et al 2012). The ecosystem shift persisted for over two decades and had significant ecological, economic and social repercussions. More recently, waters in

the Study Area have been warming. Accordingly, cold water invertebrates such as snow crab and shrimp are declining due to natural and anthropogenic influences, while some groundfish species are showing signs of recovery (Koen-Alonso et al 2010; Templeman 2010; Dawe et al 2012; Nogueira et al 2014). While many contemporary studies document recent ecosystem shifts, observations of such phenomena pre-date modern fisheries science in the western North Atlantic (Rose 2005a).

Figure 4.18 Major Ecosystem Elements of the Study Area and Key Trophic Links



Sources: Adapted from Gomes et al (1992) and Templeman (2010)

Assemblages and Taxonomic Groups in the Study Area

Environment and habitat are key drivers in the distribution of flora and fauna as organisms persist and seek out conditions that suit their physiology and maximize their ecological fitness. These conditions include both abiotic (such as appropriate temperature) and biotic (including adequate food and sufficiently low levels of predation and competition) variables. Often such preferences cause species to overlap in time space, forming an assemblage (Haedrich and Merritt 1990). For example, Amec (2014) categorized fish assemblages across much of the Study Area as follows:

- The “warm water” assemblages (e.g. white hake, argentine, silver hake, Atlantic halibut, longfin hake, butterfish, billfish), resembling those of the Scotian Shelf, occupy Gulf stream influenced waters along the southern Grand Bank;

- The “northern Grand Bank”, influenced by the cold Labrador Current is characterized by species usually found further north along the shelf (e.g. Arctic sculpin, Arctic cod, Northern shrimp and snow crab);

- Depth segregated assemblages with “shallow water” groups (yellowtail flounder, sea ravens and longhorn sculpin) give way to “slope” assemblages (Greenland halibut, wolffish and redfish) and finally to “deep slope-abyssal assemblages” (lanternfish, grenadiers, blue hake, deepwater eels, rocklings, Bean’s saw-toothed eels, deep sea lizardfish);

- Within depth zones, habitat complexity can be a discriminating factor of assemblages. For example, spotted wolffish and some invertebrate species are found primarily associated with structured habitats (Beazley et al 2013), whereas other species avoid habitat complexity (e.g. snub-nosed eels); and

- Some species are widely spread across the Study Area (e.g. American plaice, Atlantic cod, thorny skate and striped wolffish) with no strong association to specific habitat characteristics.

Recent analysis of the Flemish Cap (Nogueira et al 2014) also shows evidence of depth segregated assemblages that include a shallow (less than 250 m) assemblage (American plaice, witch flounder and Atlantic cod), an intermediate depth (250-600 m) assemblage (including species of redfish and thorny skate) and a deep water assemblage (greater than 600 m) dominated by Greenland halibut, roughhead grenadier and blue antimora.

The following sections provide more detailed coverage of specific ecosystem elements in the Study Area.

4.2.1.3 Plankton

The plankton community is comprised of small free-floating microscopic marine plants (phytoplankton), invertebrates (zooplankton), vertebrate eggs and larvae, bacteria, fungi and viruses. These species play an important role as the base of most food webs. Consequently, areas and times of high plankton abundance and concentrations typically correspond with aggregations of animals higher in the food chain (Beazley et al 2013). In addition to being a food source, plankton are the most diverse and abundant group in the ocean. Most commercial finfish and invertebrate species occur as plankton early in their life cycle. Various studies (such as Morales 1999) have also shown the importance that zooplankton play in the carbon and nitrogen cycle in terms of creating a biological pump transferring organic matter from depth to the surface (benthic-pelagic coupling).

Phytoplankton

Phytoplankton depend upon both sunlight and nutrients. Sunlight is most available in surface waters but nutrients can quickly become depleted in these areas if nutrients are not replenished. Therefore highest densities of phytoplankton typically occur in surface waters of frontal zones and areas of upwelling, where nutrients are constantly delivered from deeper water. Upwelling zones are created by both topography and currents and important areas can be found on the shelf break (namely, the area where the shelf meets deeper water) and within the thermal gradients between the shelf and slope waters (Anderson and Gardner 1986; Templeman 2007). Other important areas are where major currents converge, as these places concentrate plankton. For example, high plankton densities are associated where the Labrador Current and the Gulf Stream meet at the Southeast Shoal and Tail of the Grand Bank (Templeman 2007). Similarly, an anticyclonic gyre near the Flemish Cap contributes to elevated temperatures and relatively higher inorganic nutrients which positively affects both primary and secondary producers (Maillet et al 2004).

Plankton communities vary over seasonal time periods. Increased sunlight and surface waters infused with nutrients create conditions for spring blooms (Maillet et al 2004). As waters warm into the summer months, a thermocline forms and impedes plankton production by limiting water mixing and nutrient replenishment from deeper water layers. A fall bloom can occur when thermoclines breakdown as surface waters cool and nutrient exchange is again possible (Afanasyev et al 2001). In the spring, diatoms are generally the dominant primary producer, with mean annual densities of 10,000 to 30,000 cells per cubic meter. However, these taxa usually become supplanted by flagellates and dinoflagellates in fall blooms.

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

Zooplankton

In the marine food chain, zooplankton provide a key energy pathway between primary producers and the species that occupy higher trophic levels (fish, whales and seabirds) (Maillet et al 2004). The temporal and spatial variation in zooplankton abundance mirrors that of phytoplankton, in that peaks occur in spring and decline afterward as the phytoplankton food base is depleted and the zooplankton community is exposed to continual predation by other zooplankton, fish and marine mammals. Within the zooplankton community, copepods make up about 80 percent of the zooplankton species richness in the Northwest Atlantic (Dalley et al 2001). Other important taxa include cladocerans, Limacina, Larvaveans, bivalves (Dalley et al 2001) and Euphausiids (Plourde and McQuinn 2009) (Table 4.3).

Zooplankton community structure and abundance varies across several temporal and spatial scales (Morales 1999; Dalley et al 2001). For example, surveys along the Newfoundland Shelf indicate that zooplankton biomass occurs along a latitudinal gradient, with elevated levels found in the more northerly areas. Peaks in production vary from year to year and can be found in areas from inshore to the shelf edge (Dalley and Anderson 1998). Within this general characterization, there are taxa-specific distributions and trends. For example, jellyfish were predominantly found in inshore areas and on the northern Grand Bank (Dalley and Anderson 1998). Other species have shown trends over long time scales. The copepod *Calanus hyperboreaus* has been increasing in abundance over the last few decades (Maillet et al 2004) and is a reminder that the dynamic nature of the ecosystem discussed above is not restricted to higher trophic levels of commercially important species.

Many zooplankton species (e.g. *C. finmarchicus*) undergo daily vertical migrations as a means to mitigate predation risk. Individuals move to surface waters at night to feed on light-dependent phytoplankton and return to greater depths during the day (Dalley and Anderson 1998). Such migrations benefit biological production by replenishing organic carbon and nitrogen in surface layers (such as thermoclines) and are an important component of benthic-pelagic coupling (Morales 1999).

Important zooplankton taxa from the Newfoundland Shelf and Grand Bank are presented in Table 4.3.

Table 4.3 Dominant Zooplankton Taxa from 1997 Invertebrate Zooplankton Survey on the Newfoundland Shelf and Grand Bank

Group	Taxa / Taxon	% Total Zooplankton
Copepods	**Total**	**86.8**
	Oithona similis	49.6
	Pseudocalanus sp.	11.8
	Centropages hamatus	6.7
	Calanus finmarchicus	4.8
	Temora longicornis	4.5
	Calanus hyperboreus	0.3
	Misc. Copepods	8.9
Other	**Total**	**13.2**
	Cladocerans	5.2
	Limacina	3.0
	Larvaveans	2.3
	Bivalve larvae	1.1
	Tomopteris	0.4
	Cnidarians	0.2
	Euphausids	0.2
	Chaetognaths	0.1
	Snow crab	0.1
	Hyperids	0.0
	Mysids	0.0
	Misc. Zooplankton	0.6
All Zooplankton	**Total**	**100.0**
Source: Dalley and Anderson (1998)		

Ichthyoplankton

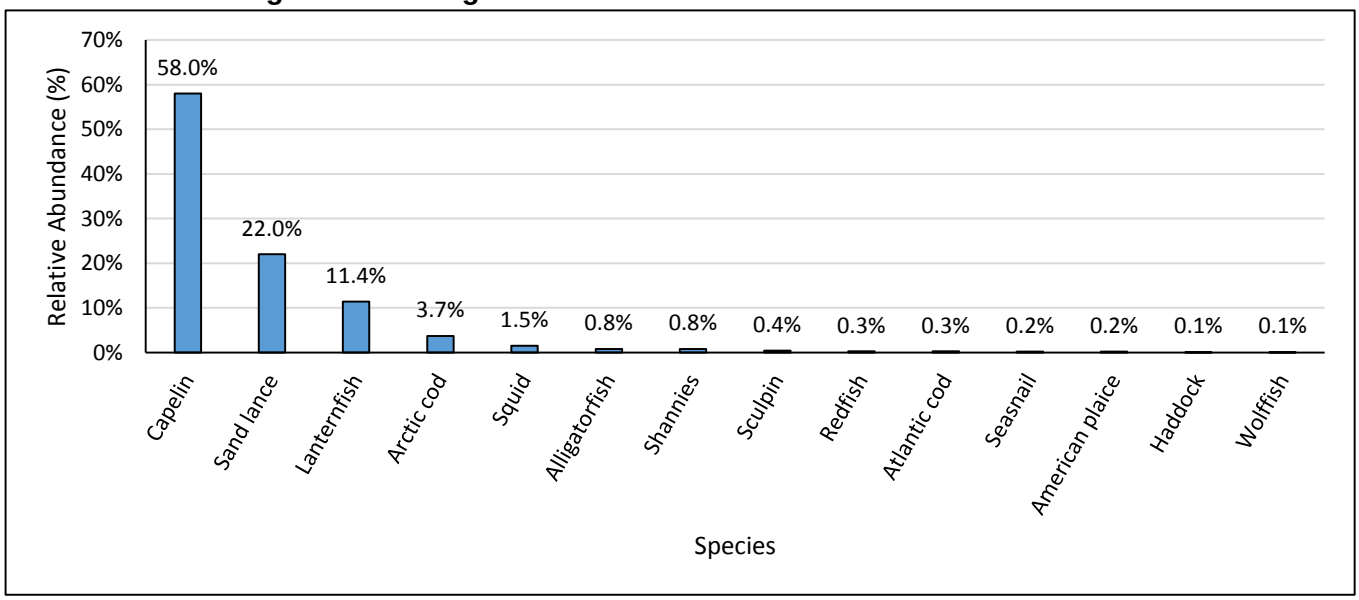
Many marine fish species broadcast spawn, releasing eggs into the water column to be fertilized and passively disperse as they develop. Abundance of fish eggs and larvae vary in time and space (Frank et al 1992; Dalley and Anderson 1998; Bradbury et al 2008) and from year to year this can differ by orders of magnitude (Dalley and Anderson 1998; Bradbury et al 1999; Houde 2008). Mortality of larval stages can be high and therefore the survival of this life stage can define future age-class recruitment success (Cushing 1990; Houde 2008). For decades, fisheries scientists hypothesized that year-class failures were attributable to either asynchrony of larval stages with those of plankton blooms – their primary food source - or to the transport of larvae to habitats unsuitable for future survival (Houde 2008). Such instances can be caused by unusual environmental conditions or changes in spawning behaviour and result in mortality of vulnerable life stages that have little in the way of energy reserves and defense against predation.

It is known, for example, that some oceanographic features such as thermoclines (Frank et al 1992), upwelling zones (Ings et al 2008) and gyres (Bradbury et al 2008) retain ichthyoplankton. As such features are spatially restricted (Bradbury et al 1999; Bradbury et al 2008), changes in spawning location could have large effects on the drift trajectory of larvae. Furthermore, the retentiveness of certain oceanic features can differ across seasons. In Placentia Bay, summer oceanographic conditions are more likely to retain cod larvae than those of the spring, which transport them offshore (Bradbury et al 2008). There is some evidence, however, that the nature of ichthyoplankton drift

differs across the Study Area (Bradbury et al 2008). The coastal areas of the northeast coast of Newfoundland are often receiving areas for drifting larvae originating from offshore areas (Ings et al 2008), whereas the gyre associated with the Flemish Cap leaves the potential that the area retains locally produced ichthyoplankton and receives ichthyoplankton on the currents that create the gyre (Dalley and Anderson 1998).

Dalley and Anderson (1998) described ichthyoplankton communities along both the Northeast Newfoundland Shelf and the Grand Bank as dominated by capelin, sand lance, lanternfish and Arctic cod (Figure 4.19). Other fish larvae that were regularly captured in tows included commercial species such as Atlantic cod, redfish and American plaice and Species at Risk such as wolffish. Squid larvae were also documented as being widespread across both locations. Most species (e.g. blennies, sculpins, squid, seasnails, alligatorfish and wolffish) were more abundant on the Newfoundland Shelf than on the Grand Bank while others (e.g. sand lance and hake) were found predominantly over the Grand Bank (Dalley and Anderson 1998).

Figure 4.19 Relative Abundance of Dominant Ichthyoplankton Caught in the International Young Gadoid Pelagic Trawl 1998



After Dalley and Anderson (1998)

4.2.1.4 Plants and Macroalgae

Macroalgae (including *Laminaria*, *Agarum cribrosum*) and sea grasses (*Zostera marina*) are important habitats for marine animals in coastal areas of Newfoundland (Keats et al 1987; Gotceitas et al 1997; Cote et al 2001, 2013), where they provide enhanced productivity (Waycott et al 2009) and access to refuge (Gorman et al 2009). Consequently, they have been shown to contain fish communities that are more species rich, abundant and stable than adjacent non-vegetated areas (Cote et al 2013). However, as plants and macroalgae are dependent on sunlight, their distribution is typically limited to depths shallower than 50 m (Dayton 1985; Gregory and Anderson 1997; Anderson et al 2002). Other important factors that influence macroalgae distributions and species composition include substrate, sedimentation, nutrients, water motion, salinity, temperature and degree of ice scour (Dayton 1985; LGL 2010).

There are few instances of macroalgae reported from other offshore habitat studies (Houston and Haedrich 1984; Schneider et al 1987; Kenchington et al 2001); which is not surprising given the vast majority of the Study Area is too deep to support macroalgae and plant growth. However, localized areas of macroalgae do exist in the offshore areas of the Study Area in depths of up to 100 m (R. Hooper pers. comm. in Amec 2014). At the extremes in depth, species diversity and biomass are low. In other areas, such as the Virgin Rocks, there is a diverse and profuse seaweed flora resembling that found in Labrador. Dominant species in this area include (Phaeophyta: Laminariales): *Laminaria digitata*, *Alaria esculenta*, *Saccharina longicruris,* and *Agarum cribrosum*, understory seaweeds: *Desmarestia viridis, D. aculeata, Palmaria* (Dulse), *Ptilota, Phycodrys, Membranoptera, Polysiphonia* and numerous other cold-water species. Furthermore, almost all available substrate was covered by coralline seaweeds: *Lithothanionglaciale*, *L. lemoineae, Clathromorphum compactum, C. circumscriptum* and *Corallina*. The deepest seaweed was the coralline *Leptophyum leave*, which remained abundant at depths beyond 70 m (R. Hooper, pers. comm. in Amec 2014).

4.2.1.5 Benthic Invertebrates

Benthic invertebrates represent a very broad group of animals that associate with the seafloor for at least part of their life cycle. While benthic invertebrates (particularly crab and shrimp) are the biggest contributors to commercial landings (Dawe et al 2012), they also play a variety of important trophic roles in the Study Area (detritivores, filter feeders, carnivores), facilitate energy transfer through the ecosystem (see Figure 4.18; Templeman 2010) and generate habitat heterogeneity through excavations and castings (Hasemann and Soltwedel 2011). Limited mobility and sensitivity to anthropogenic disturbance makes benthic communities particularly useful for assessing potential effects related to offshore developments (Warwick 1993; Husky Energy 2010; Suncor Energy 2010; Beazley et al 2013). Studies to date indicate that benthic assemblages respond to environmental variables such as depth, substrate, bathymetry, temperature, flow field and disturbance (Houston and Haedrich 1984; Schneider et al 1987; Desrosiers et al 2000, Frojan et al. 2012) and also exhibit interannual variability (Kenchington et al 2001).

Much of the existing and available information on benthic communities in the Study Area is for the Grand Banks area, where relatively shallow depths make research initiatives (Houston and Haedrich 1984; Schneider et al 1987; Kenchington et al 2001; Beazley et al 2013) more feasible and where environmental effects studies for the offshore oil and gas industry (e.g. Husky Energy 2010; Suncor Energy 2010; Stantec 2012) are common. Typically, such efforts have been localized in extent but have detected up to 246 benthic taxa (more than all the fish species known to occur in Newfoundland waters; Kenchington et al 2001, Templeman 2010). Other surveys are more widespread and include the DFO multispecies RV trawl surveys (LGL 2012, 2013) and targeted industry trap surveys for snow crab (DFO 2013a, 2014) and trawl surveys for shrimp (DFO 2013a).

The outcomes of field research results on benthic community structure is very much influenced by the particular sampling method involved (Prena et al 1999; Kenchington et al 2001). Video systems and trawls, for example, are somewhat biased towards larger epibenthic fauna whereas grab samples are restricted to soft bottoms but can capture and detect small and/or infaunal species. Not surprisingly, studies using grabs (Kenchington et al 2001, Husky Energy 2010; Suncor Energy 2010; Frojan et al 2012) tend to be dominated by infaunal polychaetes, amphipods and bivalves whereas studies employing epibenthic sampling methods (Houston and Haedrich 1984; Schneider et al 1987; LGL 2012, 2013, Prena et al 1999) have been dominated by sponges, anemones, shrimp, crab, echinoids and soft corals.

Ecology and Significance of Key Benthic Invertebrates in the Study Area

The ecology and significance of important benthic invertebrate taxa in the Study Area (LGL 2010; Amec 2014) are summarized in Table 4.4. Additional information on reproduction is provided in Figure 4.20 while regional distributions of key species are provided later.

Table 4.4 Overview of Benthic Invertebrate Species Known or Likely to Occur in the Study Area

Species	Details
Annelida – Segmented Worms	
Polychaete worms	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Distributed throughout the North Atlantic • Variety of species found on the Grand Bank • Prey species for groundfish and invertebrates • Major component of marine benthic communities **Environmental Preferences** - | <50 | Silt *Temperature (^{o}C)* | *Depth Range (m)* | *Substrate*
Arthrodopa – Shrimp and Crabs	
Amphipods (Amphipoda)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Feeds on seaweed and algae (Duffy and Hay 1991) • Prey for commercially important species including American plaice and yellowtail flounder (Pitt 1973) **Environmental Preferences** - | 100-300 | Silt, sand, gravel *Temperature (^{o}C)* | *Depth Range (m)* | *Substrate*
Hooded shrimp (Cumacea)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Northwest Atlantic distribution from Newfoundland to Cape Cod (Gosner 1979) • Prey species for American plaice, yellowtail flounder, and cod (Bruno et al 2000, Pitt 1976)
	Environmental Preferences - | - | Gravel, sand *Temperature (^{o}C)* | *Depth Range (m)* | *Substrate*

Species	Details
Northern shrimp (*Pandalus borealis*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Distributed from west Greenland to Georges Bank • Most commonly observed species in NAFO areas 3NLOPs • Feeds on polychaetes, small crustaceans, detritus, marine plants, copepods, and euphausiids • Northern Shelf Assemblage • Important prey species for halibut, cod, redfish, and harp seals **Environmental Preferences** - - - *Temperature (^oC)* *Depth Range (m)* *Substrate*
Snow crab (*Chionoecetes opilio*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Northwest Atlantic distribution from Greenland to the Gulf of Maine • Feeds on polychaetes, bivalves, echinoderms, and fish carcasses • Commonly observed species in NAFO area 3NLOPs • Commonly observed during Orphan Basin remote video surveys (LGL 2012) • Dominated otter trawl sampling of sandy areas of the Grand Bank (Prena et al 1999) • Prey species for various groundfish other snow crabs and seals • Cold Shelf Assemblage **Environmental Preferences** - 600-400 Mud, sand *Temperature (^oC)* *Depth Range (m)* *Substrate*
Striped pink shrimp (*Pandalus montagui*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Undertakes diurnal vertical feeding migrations (Hudon et al 1992) • Feeds mainly on copepods in pelagic waters and on polycheaetes and foraminiferans at benthic depths (Hudon et al 1992) • Northern Shelf Assemblage • Prey species for halibut, cod, redfish and seals
	Environmental Preferences - 140-260 Sand *Temperature (^oC)* *Depth Range (m)* *Substrate*

Species	Details
Cnidaria – Jellyfish and Anemones	
Jellyfish (Scyphozoa)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Main species observed on Grand Bank are *Cyanea capillata* and *Aurelia aurita* • Commonly captured during Grand Bank plankton tows (LGL 2012) • Primarily a pelagic species • Distributed inshore and offshore • Feeds on fish eggs and larvae **Environmental Preferences** 5-20 — *Temperature (^oC)* 20-40 — *Depth Range (m)* - — *Substrate*
Sea anemone (Actiniaria)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Commonly observed during Orphan Basin remote video surveys (LGL 2012) • Variety of species found on the Grand Bank • Feeds on echinoderms and other invertebrates **Environmental Preferences** - — *Temperature (^oC)* Variable — *Depth Range (m)* Cobble, Rubble. Boulder — *Substrate*
Echinodermata – Urchins and Seastars	
Basket star (*Gorgonocephalus arcticus*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Primarily feeds on euphausids (Emson et al 1991) • Associated with deep sea corals (Rosenberg et al 2005) **Environmental Preferences** - — *Temperature (^oC)* Subtidal - >1,200 — *Depth Range (m)* Variable — *Substrate*
Brittlestar (Ophiuroidea)	**Status and Use** • No conservation status in study area • No commercial fishery in study area

Species	Details
	Biology and Ecology • Comprised of several species of brittle star • Distributed from the Arctic to Cape Cod region (Gosner 1979) • Feeds on small crustaceans, polychaetes and detritus • Important prey species for American lobster and American plaice **Environmental Preferences** - | Intertidal - >300 | Gravel, cobble, coralline algae, shell *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Pale sea urchin (*Strongylocentrotus pallidus*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • High abundance on sandy bottoms of the Grand Bank (Kenchington et al 2001) • Feeds on epibiotics on stones, infauna meiobenthos and detritus (Bluhum et al 1998) • Prey species for commercially important fish species including American plaice (Gilkinson et al 1998) **Environmental Preferences** - | 60-1,600 | Sand, cobble *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Sand dollar (*Echinarachnius parma*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Northwest Atlantic distribution from Labrador to North Carolina • Burrows in soft substrates • Reaches densities of 100 individuals / m^2 • High abundance on sandy bottoms of the Grand Bank (Kenchington et al 2001) • Stomach contents include diatoms, sand grains, sponge spicules and detritus • Important food source for many commercial groundfishes **Environmental Preferences** - | >800 | Sand *Temperature (^oC)* | *Depth Range (m)* | *Substrate*

Species	Details
Mollusca – Bivalves and Whelk	
Icelandic scallop (*Chlamys islandica*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Northwest Atlantic distribution • Inhabits area with strong currents and high salinity • Size portioning in relation to depth with larger individuals at higher depths • Suspension feeders on phytoplankton **Environmental Preferences** - | >55 | Sand, gravel, shell, boulder *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Propellor clam (*Cyrtodaria siliqua*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • High abundance on sandy bottoms of the Grand Bank (Kenchington et al 2001) • Population is dominated by clams older than 100 years (Kilada et al 2009) • Prey species for cod, American plaice and wolffish (Kilada et al 2009; Templeman 1985) **Environmental Preferences** - | 120-150 | Sand *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Sea scallop (*Placopecten magellanicus*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Northwest Atlantic distribution from Labrador to North Carolina • Suspension feeders on phytoplankton and detritus • Prey species for crab, lobster, seastars, gastropods, cod, plaice and wolffish **Environmental Preferences** - | 20-70 | Sand, gravel, pebble *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Surf clam (*Spisula*	**Status and Use** • No conservation status in study area • Commercial fishery

Species	Details
***solidissima*)**	**Biology and Ecology** • Northwest Atlantic distribution from the Gulf of St. Lawrence to North Carolina • High abundance along the eastern edge of the Grand Bank (Ollerhead et al 2004) • Prey species for benthic invertebrates (rock crabs, seastars, hermit crabs, moon snails, whelks) and groundfish (cod, flounder, sculpin, ocean pout) **Environmental Preferences** - | 8-66 | Silt, sand *Temperature (^oC* | *Depth Range (m)* | *Substrate*
Whelk (*Buccinum* sp.)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Distributed in cold waters from Labrador to New Jersey • Common in otter trawl sampling on sandy areas of the Grand bank (Prena et al 1999) • Feeds on urchins, polychaetes, amphipods, crustaceans and fish eggs • Scavenges on animal carcasses • Prey species for lobster, cod, crab, seastars and dogfish **Environmental Preferences** - | Tidal-180 | Mud, sand, gravel, rock *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Porfirea - Sponges	
Sponges (*Geodia* sp.)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Commonly observed during Orphan Basin remote video surveys (LGL 2012) • Variety of species found on Grand Bank • *Geodia* sp. most dominant species observed on sponge grounds on the Grand Bank, Flemish Cap and Flemish Pass (Murillo et al 2012) **Environmental Preferences** - | 800-1,450 | Cobble *Temperature (^oC)* | *Depth Range (m)* | *Substrate*
Sipincula – Unsegmented Worms	
Sipunculan worms (*Sipuncula*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area

Species	Details
	Biology and Ecology • Burrowing worms • Many species are deposit feeders (McMahon et al 2006) • Preyed upon by groundfish and other invertebrates **Environmental Preferences** - Intertidal to subtidal Mud, sand, rock, coral *Temperature (^{o}C)* *Depth Range (m)* *Substrate*
Source: Christian et al (2010) + See species-specific information references throughout the Table.	

Figure 4.20 Spawning Periods and Reproductive Biology for Key Benthic Invertebrate Taxa in the Study Area

Species	Spawning Time												Spawning Locations
	J	F	M	A	M	J	J	A	S	O	N	D	
Whelk [1]													
Deep sea corals [2,3]													
Sponges [4]													
Surf clam [1,6]													NAFO area 3N
Snow crab [1,7]													
Icelandic scallop [1,6]													NAFO areas 3LNP
Northern shrimp [1,6]													NAFO areas 3LNP
Pink shrimp [8]													
Sea scallop [1,6]													NAFO area 3P

Note: Green bars represent mating periods and blue bars indicate spawning periods.
Sources: [1] Christian et al (2010); [2] Sun et al (2010); [3] Mercier et al (2011); [4] Spetland et al (2007); [5] Dawe et al (2012); [6] Ollerhead et al(2004); [7] Hooper (1986); [8] Allen (1963)

Benthic Invertebrate Distributions

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

Shrimp

Northern shrimp, and to a lesser degree striped pink shrimp, are important commercial species in the Study Area (Dawe et al 2012). Northern shimp was the most abundant species captured in the DFO RV survey catches, having benefitted from cooling water temperatures and groundfish collapses of the 1990s (Lilly et al 2000; Ramseier et al 2000). More recently, shrimp stocks are decling in the southern part of their range (Orr et al 2011). Northern shrimp recruitment is affected by the strength of

phytoplankton blooms and sea surface temperatures (Ouellet et al 2011) and growth rates are influenced by latitude (Fuentes-Yaco et al 2007) and the availability of particulate organic carbon (such as detritus from decomposing phytoplankton; Ramseier et al 2000). Like many other types of zooplankton, young male Northern shrimp exhibit nocturnal feeding migrations. However, as they age, they morph into females and become more associated with the seafloor (Fuentes-Yaco et al 2007; Templeman 2010).

Northern shrimp in the Study Area are concentrated primarily in the Flemish Pass and northern Grand Bank areas (Figure 4.21). High concentrations of Northern shrimp on the western side of the Flemish Cap are retained in the area due the anticyclonic gyre associated with the Labrador and North Atlantic Currents (Parsons et al 1998). In comparison, striped pink shrimp are more abundant closer to shore in areas west of the Study Area. Within the Study Area, moderate densities are found on the Grand Bank and the Bonavista Corridor (Figure 4.22).

Snow Crab

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

Snow crab are known to undergo temporal fluctuations in abundance, which are thought to be related to density dependent effects (Conan et al 1996; Ste Marie et al 1996) and/or environmental conditions (Dawe et al 1997). Stocks in the northwest Atlantic have declined in recent years; a trend that is expected to continue as waters warm (Dawe et al 2012; Mullowney et al 2013). In recent years, snow crab have been abundant along the northern slopes of the Grand Bank and the Bonavista Corridor (Figure 4.23). They are much less abundant along the shallows of the southern Grand Bank and the continental slope.

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

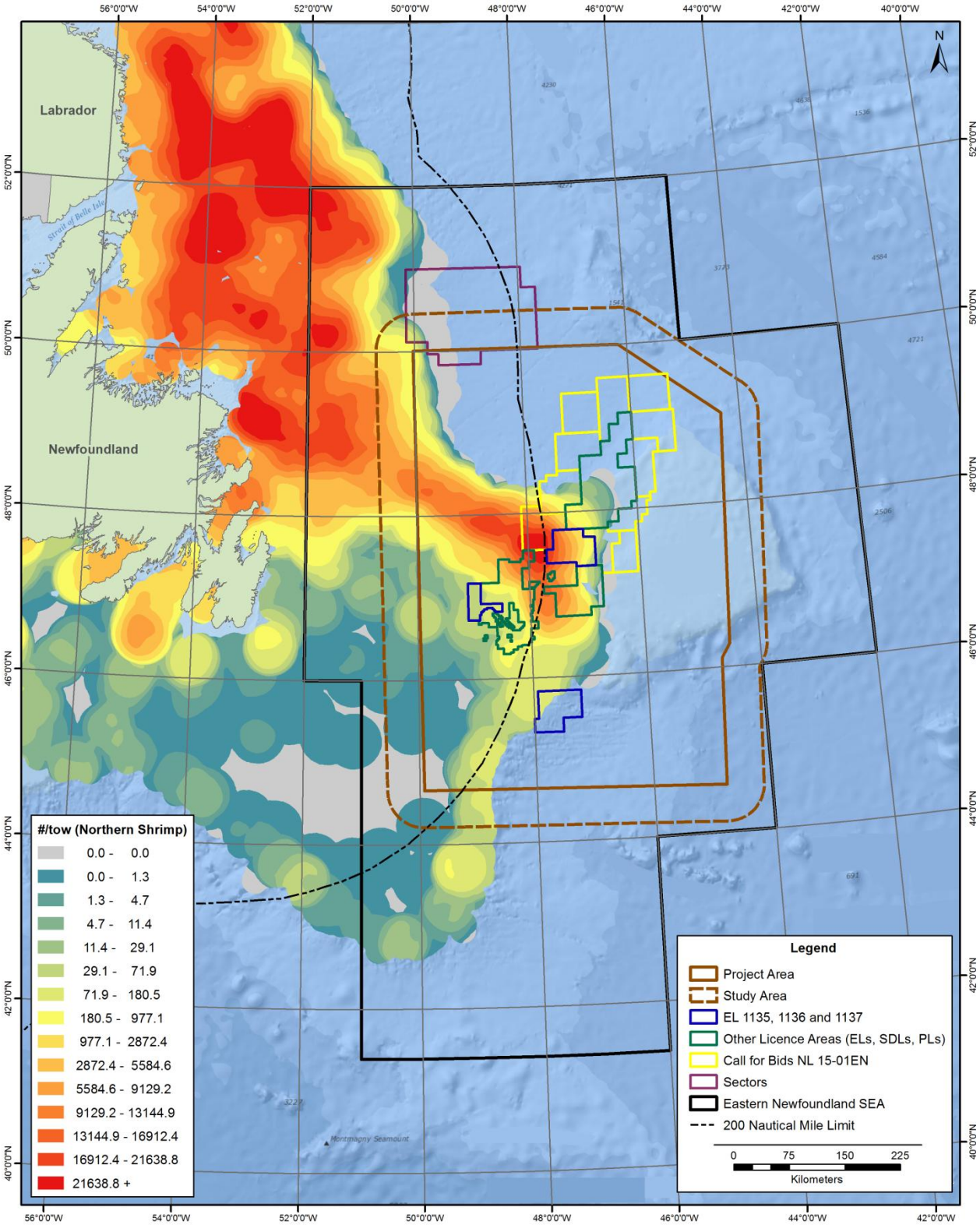


Figure 4.22 Distribution of Striped Pink Shrimp in the Study Area (Canadian RV Surveys, 2008-2012)

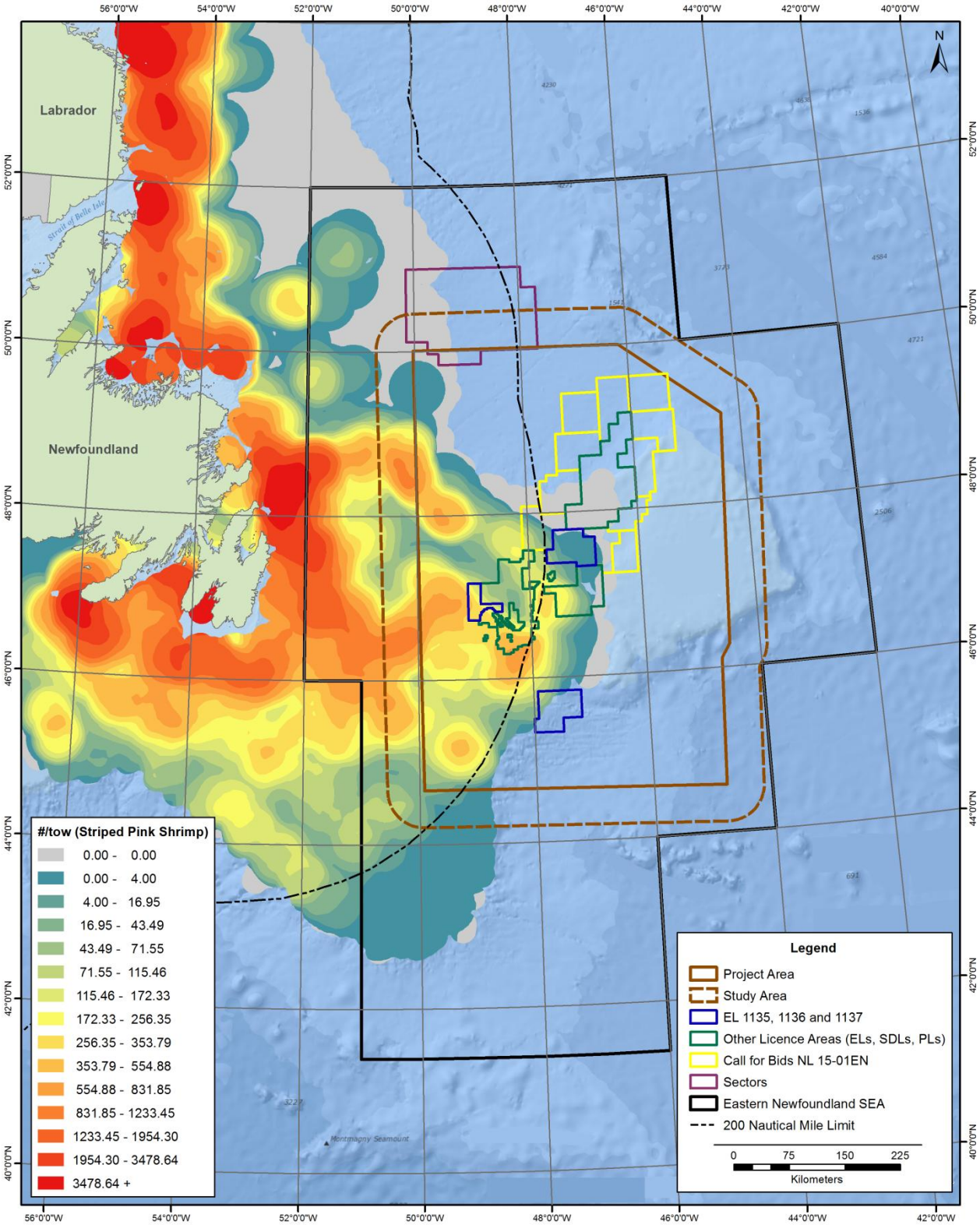
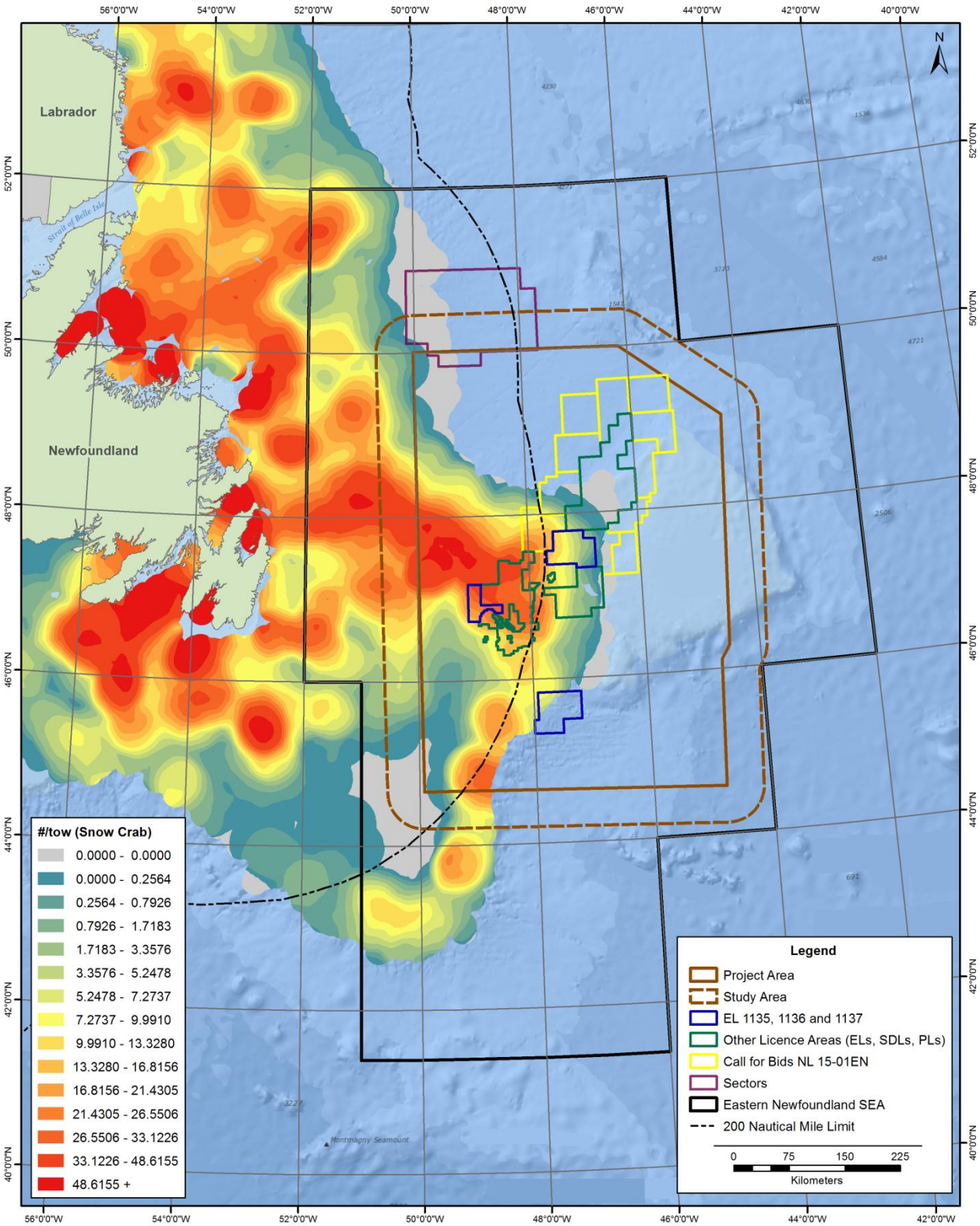


Figure 4.23 Distribution of Snow Crab in the Study Area (Canadian RV Surveys, 2008-2012)



Corals, Sea Pens and Sponges

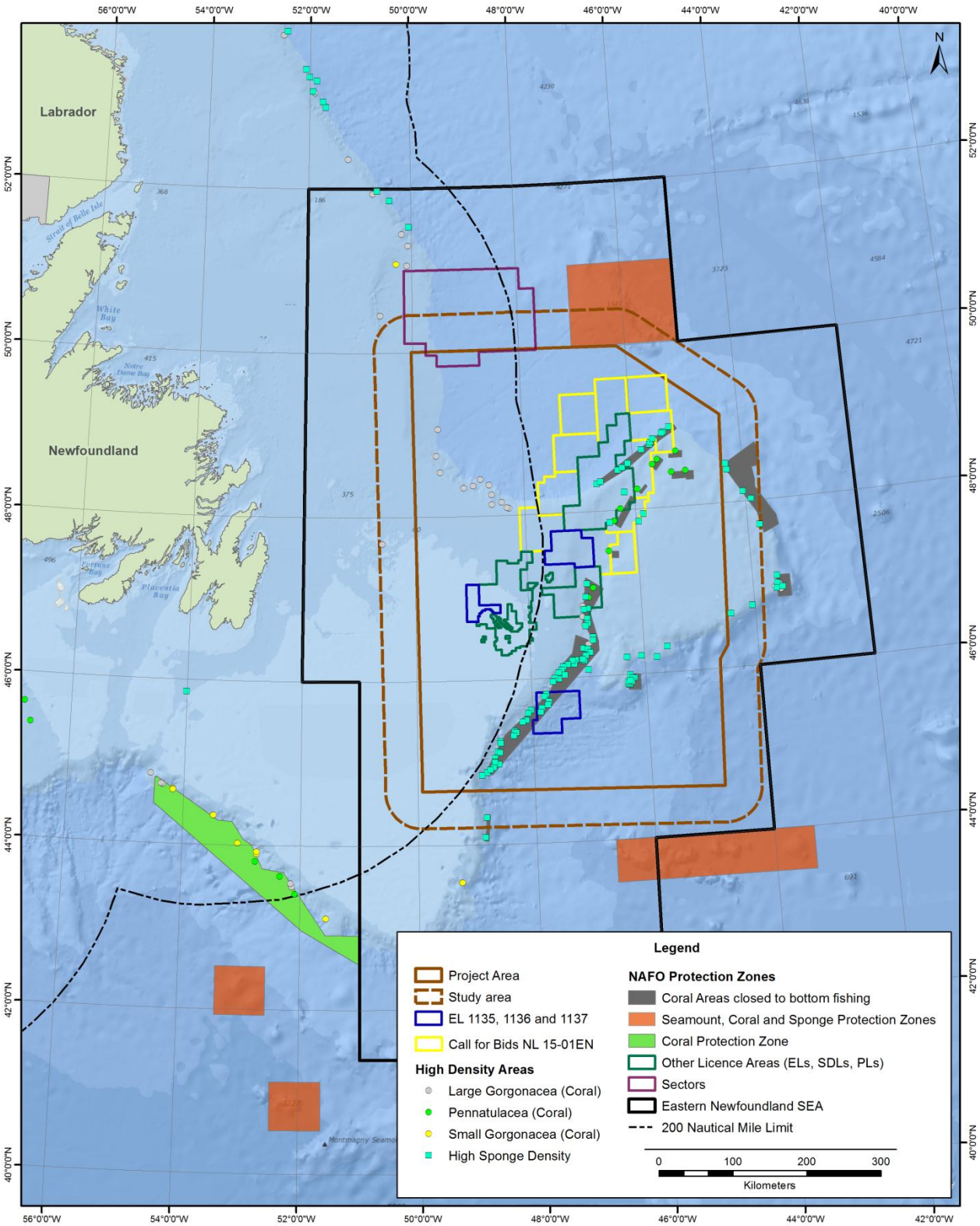
Deep-sea corals, sea pens and sponges are a subset of benthic invertebrates that are of particular conservation interest due to their habitat-forming capacity and their sensitivity to anthropogenic stressors (Murillo et al 2011; Beazley et al 2013). Deep-sea corals and sponges increase biodiversity and habitat heterogeneity in the deep sea system (WGEFAM 2008; Buhl-Mortensen et al 2010; Beazley et al 2013) by creating vertical structure that is used as refuge and foraging habitat (Watanabe et al 2009; WGEFAM 2008) for a variety of species that include those of commercial importance (Gilkinson and Edinger 2009; Baillon et al 2012). The fragile nature and slow growth of these animals mean that disturbance to bottom habitats (such as trawling, infrastructure placement) can have strong and long lasting effects (Campbell and Simms 2009, Watanabe et al 2009; Frojan et al 2012). Black corals as well as large and small gorgonian corals, which have carbonate skeletons, are most sensitive to disturbance because they can be permanently dislodged from substrate (Gilkinson and Edinger 2009). This vulnerability has resulted in partial fishing closures to several known coral and sponge areas (Figure 4.24).

Sea pens, soft corals, stony corals, and sponges are well represented in the Study Area (Gilkinson and Edinger 2009; DFO 2010a; WGEFAM 2008; Murillo et al 2012). Within the Canadian Exclusive Economic Zone (EEZ), gorgonians are found at their highest densities along the northeast Grand Bank near the Flemish Pass and the edge of the Newfoundland Shelf (DFO 2010a). Sea pens are most abundantly distributed outside the Study Area in the Laurentian Channel, whereas sponges predominantly occur in northern parts of the Study Area (along the Newfoundland Shelf and slope).

Corals are also abundant outside the Canadian EEZ along the slopes (600 m to 1,300 m) of the Flemish Cap (Murillo et al 2011), the northern and southern portions of the Flemish Pass (WGEFAM 2008). In these areas, Murillo et al (2001) reported 21 species of soft corals and gorgonian sea fans (alcyonaceans), 11 species of sea pens (pennatulaceans), two species of cup corals (solitary scleractinians), and three species of black coral (antipatharians) in the bycatch associated with fisheries surveys. Studies also indicate taxa-specific differences in habitat associations. For example, sea pens and cup corals are typically found on mud substrates while black corals, soft corals and sea fans are common on bedrock and gravel.

Predictive habitat modelling, conducted by Knudby et al (2013) indicate that within the Study Area, the slopes of the Flemish Cap are important for black corals, the northern Flemish Pass is important for large gorgonians and the slopes of the Flemish Cap (except the southern portion) is important for sea pens. Sponges are abundant along the slopes of the Flemish Cap (axinellid and polymastid taxa; Beazley et al 2013) and in the Flemish Pass (geodiids and *Asconema* sp; Beazley et al 2013) (WGEFAM 2011), where they are dominated by axinellid and polymastid (Flemish Cap) and geodiids and *Asconema* sp (Flemish Pass) taxa (Beazley et al 2013).

Figure 4.24 High Density Areas and Protection Zones for Corals, Seamounts and Sponges



4.2.1.6 Marine Fish

Marine fish in the Study Area collectively exhibit a broad range of ecological roles, habitat requirements and morphologies that often change over their life history. The group includes many species that are recognized for their commercial, cultural and/or ecological importance. This section identifies key demersal and pelagic marine fish species that occur in the Study Area and describes their general ecology. A subset of these species are detailed further to delineate their distributions relative to the Study Area as well provide additional information on spawning and migration.

Species Ecology, Status and Habitat

A number of fish species in the Study Area are considered important based on general criteria of abundance, commercial or cultural importance or their conservation status. An overview of commercial importance, conservation status and life histories of key species is presented in Table 4.5.

Table 4.5 Overview of Fishes that are Known or Likely to Occur in the Study Area

Species	Details
Anguilliformes – Eels and Morays	
American Eel (*Anguilla rostrate)*	**Status and Use** • Provincial (Vulnerable) and COSEWIC (Threatened) status • Recreational and commercial fishery **Biology and Ecology** • Found in freshwater systems, throughout the western North Atlantic with access to the sea • Catadromous species; migrate to freshwater to feed and grow and to saltwater to spawn • Larval eels feed on plankton, while juveniles and adults feed on benthic invertebrates and small fish **Environmental Preferences** 15.4-19.4 — *Temperature (^{o}C)* <35 — *Depth Range (m)* Pelagic — *Habitat*
Longnose Eel (*Synahobranchus kaupi*)	**Status and Use** • No conservations status in region • Not a commercial or recreational species in region **Biology and Ecology** • Found in deep waters in all the world's oceans • Commonly observed on the Grand Banks (Baker et al. 2012; LGL 2012) • Feed on squid, copepods, polychaetes and fish remains (Gordon and Mauchline 1996) **Environmental Preferences** <1.4 — *Temperature (^{o}C)* 240-3,650 — *Depth Range (m)* Benthic — *Habitat*

Species	Details
Carcharhiniformes – Ground Sharks	
Blue Shark (*Prionace glauca*)	**Status and Use** • COSEWIC (Special Concern) and IUCN (Near Threatened) status • Commercial fishery **Biology and Ecology** • Wide-ranging pelagic species in temperate waters • Worldwide distribution in inshore and offshore waters • Undertakes large vertical migrations at night • Feeds mainly on fish (herring, hake, cod, haddock, pollock, mackerel, butterfish, sea raven, flounders) and squid • Unlike many other sharks, blue sharks are known to leap out of the water **Environmental Preferences** 7.0-16.0 — *Temperature (^oC)* 10-220 — *Depth Range (m)* Pelagic — *Habitat*
Clupeiformes - Herrings	
Atlantic Herring (*Clupea harengus harengus*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Occurs on both sides of the North Atlantic Ocean • Undertakes annual migrations to spawning grounds, feeding areas and wintering areas • Multiple stocks / populations occur in Canadian waters • Feeds on phytoplankton, copepods and euphausiids • Schooling species **Environmental Preferences** 5.0-9.0 — *Temperature (^oC)* 5-200 — *Depth Range (m)* Pelagic — *Habitat*
Gadiformes – Codfishes	
Atlantic cod (*Gadus morhua*)	**Status and Use** • COSEWIC (Endangered) and IUCN (Vulnerable) status • Recreational and commercial fishery

Species	Details
	Biology and Ecology • Occurs on both sides of the North Atlantic • Areas of concentration on the Grand Bank include the Northeast Slope, Virgin Rocks, and upper Southwest Slope (Kulka et al 2003a) and the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • Found from inshore regions to the edge of the continental shelf • Occurs throughout the Atlantic Canada with regionally unique stocks • Juvenile cod are abundant in inshore areas (Gregory and Anderson 1997) • Commonly observed species in NAFO areas 3NLOPs • Widespread Shelf Assemblage • Feeds on fish and benthic invertebrates **Environmental Preferences** 0.5-10.0 — 150-200 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Blue hake (*Antimora rostrata*)	**Status and Use** • No conservation status in region • Not a commercial or recreational species in region **Biology and Ecology** • Benthopelagic species associated with mud bottoms • Distributed in slope waters along the eastern Grand Bank (Kulka et al 2003b) • Feeds on benthic invertebrates including crustaceans and squids **Environmental Preferences** 3.0-4.5 — >1,400 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Cusk (*Brosme brosme*)	**Status and Use** • COSEWIC (Endangered) Status • Not a commercial or recreational species in region **Biology and Ecology** • Occurs on both sides of the North Atlantic Ocean on hard, rough or rocky bottoms • Sporadically observed on Grand Bank around the Flemish Cap, around the Nose and Southwest Slope of the Grand Banks (Kulka et al 2003a) • Common on southwestern Scotian Shelf and Slope and Fundian Channel • Warm Southern Shelf Assemblage • Feed on crustaceans, molluscs and echinoderms **Environment Preferences** 2.0-12.0 — 20-549 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Haddock (*Melanogrammus aeglefinus*)	**Status and Use** • No conservation status in study area • Commercial Fishery

Species	Details
	Biology and Ecology • Found off southwest Newfoundland and St. Pierre Bank • Areas of concentration include the Laurentian Channel Slope, and Southwest Slope of the Grand Bank (Kulka et al 2003a). • Occurs in a variety of habitats; juveniles have higher survival rates when they settle on sand or gravel bottoms • Feed on crustaceans, molluscs, echinoderms, polychaetes and fish **Environmental Preferences** 1.0-13.0 — 27-366 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Longfin hake (*Physis chesteri*)	**Status and Use** • No conservations status in region • Not a commercial or recreational species in region **Biology and Ecology** • Occurs along Labrador to the southern edge of the Grand Bank • Commonly observed species in NAFO area 3NLOPs • Feeds mainly on invertebrates (shrimp, euphausiids and amphipods) and vertically migrating fishes (hatchetfish and lanternfish) **Environmental Preferences** 3.5-6.5 — 300-450 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Marlin-spike (*Nezumia bairdi*)	**Status and Use** • No conservations status in region • Not a commercial or recreational species in region **Biology and Ecology** • Distributed from the southwestern Grand Bank, to the banks of the Scotian Shelf • Commonly observed species in NAFO areas 3NLOPs • Usually found on mud bottoms • Feeds on benthic euphausiids and amphipods. • Preyed upon by swordfish **Environmental Preferences** 3.0-8.0 — 183-732 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Pollock (Pollachius virens)	**Status and Use** • No conservations status in region • Not a commercial or recreational species in region **Biology and Ecology** • Areas of concentration on the Grand Bank include the southwest edge of the Bank and the Laurentian Channel slope (Kulka et al 2003a)

Species	Details
	• Juveniles are common in shallow inshore waters, while adults live in deeper inshore waters or on offshore banks • Distributions mainly restricted to the slope waters of the Burgeo and St. Pierre Banks • Warm Southern Shelf Assemblage • Feeds mainly on copepods
	Environmental Preferences 7.2-8.6 — 110-181 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Roughhead grenadier (*Macrourus berglax*)	**Status and Use** • COSEWIC (Special Concern) status • Commercial and bycatch fishery **Biology and Ecology** • Areas of concentration on the Grand Bank include the Flemish Pass and Nose of the Grand Banks (Kulka et al 2003a) and slopes of the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • Feeds on benthic invertebrates (bivalves, shrimp, echinoderms) and some fish (redfish, grenadier, sand lance, skate) • Slow growing species with late maturation **Environmental Preferences** 2.0-3.5 — 700-800 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Roundnose grenadier (*Coryphaenoides rupestris*)	**Status and Use** • COSEWIC (Endangered) status • Not a commercial species **Biology and Ecology** • Inhabits continental slopes and shelves in the North Atlantic • Areas of concentration on the Grand Bank include areas between the Flemish Cap and Nose of the Grand Banks (Kulka et al 2003a) • Feeds on small crustaceans, euphausiids, squid and small fishes • Adults are preyed upon by Greenland halibut and juveniles are preyed upon by redfishes • Undergoes diurnal vertical feeding migrations **Environmental Preferences** 3.5-4.5 — 400-1,500 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
White hake (*Urophycis tenuis*)	**Status and Use** • COSEWIC (Threatened) status • Not a commercial species

Species	Details
	Biology and Ecology • Areas of concentration on the Grand Bank include the Southwest Slope and Laurentian Channel slope (Kulka et al 2003a) • Occurrence on the Grand Banks mainly along the southwest slope (Templeman 2007) • Warm Southern Shelf Assemblage • Inhabits areas with mud bottoms • Young hake utilize sand-hiding behavior • Feeds mainly on fish (herring, mackerel, other hake species) **Environmental Preferences** 4.0-8.0 / 50-600 / Benthic *Temperature (^oC)* / *Depth Range (m)* / *Habitat*
Lamniformes – Mackeral Sharks	
Basking shark (*Cetorhinus maximus*)	**Status and Use** • No conservations status in region • Not a commercial or recreational species in region **Biology and Ecology** • Species is highly migratory; occurring in coastal warm waters around Newfoundland during the summer and fall • Distributed mainly off southern Newfoundland, on the Scotian Shelf and in the Gulf of Maine (DFO 2008a) • Pelagic, filter feeding shark that mainly feeds on plankton **Environmental Preferences** 8.0-12.0 / 0-750 / Pelagic *Temperature (^oC)* / *Depth Range (m)* / *Habitat*
Porbeagle shark (*Lamna nasus*)	**Status and Use** • COSEWIC (Endangered) and IUCN (Vulnerable) status • Not a commercial species **Biology and Ecology** • Common on continental shelves with occurrences offshore • Distributed in Atlantic, Pacific and Indian Oceans • Occurs in Canadian waters during spring, summer and fall • Feeds primarily on both pelagic (herring and mackeral) and benthic (cod and hake) fish and squid **Environmental Preferences** 6.0-16.0 / 0-710 / Pelagic *Temperature (^oC)* / *Depth Range (m)* / *Habitat*
Shortfin mako shark (*Isurus*	**Status and Use** • COSEWIC (Threatened) and IUCN (Vulnerable) status • Commercial fishery

Species	Details
***oxyrinchus*)**	**Biology and Ecology** • Circumglobal distribution in temperate and tropical waters • Individuals in Canadian waters part of the North Atlantic Population • Migrate to Atlantic Canadian Waters in late summer and fall (DFO 2010b) • Feeds on fish (Mackerel, tuna, swordfish, bonito) • Estimate lifespan of 24 years with maximum life expectancy of up to 45 years (DFO 2010b) • Extremely active species, considered the fastest shark **Environmental Preferences** *17.0-22.0* — *100-150* — *Pelagic* *Temperature (^oC)* — *Depth Range (m)* — *Habitat*
White shark (*Carcharodon carcharias*)	**Status and Use** • SARA (Endangered), COSEWIC (Endangered) and IUCN (Vulnerable) status • Not a commercial species **Biology and Ecology** • Widespread distribution in temperate seas of all oceans • Occurs in coastal and offshore waters from surface waters to more than 1,280 m • Feeds on fish (salmon, hake, halibut, mackerel, tunas, other sharks) sea turtles, seabirds and marine mammals **Environmental Preferences** 6.0-22.0 — 0-150 — Pelagic *Temperature (^oC)* — *Depth Range (m)* — *Habitat*
Lophiformes - Anglerfishes	
Monkfish (*Lophius americanus*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Areas of concentration on the Grand Bank are the Southwest Slope and within the Laurentian Channel (Kulka et al 2003a) • Migrates to shallow waters of the banks in summer and migrate to deeper waters in winter • Associated with deep waters along the western Grand Bank (Gomes et al 1992) • Warm Southern Shelf Assemblage • Feeds on fish (herring, sand lance, smelt, cod, haddock, cunner, sculpin, flounder, skates) and invertebrates (crab, squid, molluscs, echinoderms, polychaetes) **Environmental Preferences** 6.0-10.0 — 0-320 — Benthic *Temperature (^oC)* — *Depth Range (m)* — *Habitat*

Species	Details
Myctophidae (family) - Lanternfishes	
Lanternfish (Myctophidae sp.)	**Status and Use** • No conservation status within the study area • No commercial fishery within the study area **Biology and Ecology** • Commonly observed species in NAFO area 3NLOPs • Opportunistic planktivores feeding on copepods, euphausiids, ostracods, fish eggs and larvae • Prey item for many species within the study area • Characterized by light organs on the head and body • Undertakes diurnal vertical migrations. **Environmental Preferences** 4.0-16.0 — *Temperature (^oC)* 30-1,200 — *Depth Range (m)* Benthic — *Habitat*
Osmeriformes - Smelts	
Capelin (*Mallotus villosus*)	**Status and Use** • No conservation status within the study area • Commercial fishery **Biology and Ecology** • The largest concentrations in Canadian waters are found off Newfoundland and the Labrador Coast • Inhabits cold, deep waters, in the Atlantic Ocean on the offshore banks and in coastal areas • Seasonal migrations to inshore spawning areas • Feeds on planktonic organisms; mainly euphausiids and copepods • Important food source for other fish, marine birds and marine mammals • Commonly observed species in NAFO area 3NLOPs **Environmental Preferences** -1.0-6.0 — *Temperature (^oC)* 0-280 — *Depth Range (m)* Pelagic — *Habitat*
Perciformes – Perch-like Fishes	
Albacore tuna (*Thunnus alalunga*)	**Status and Use** • IUCN (Near Threatened) status • Commercial fishery **Biology and Ecology** • Cosmopolitan species captured on the Grand Banks • Epipelagic and mesopelagic oceanic species • Feeds on pelagic fish, crustaceans and squid (Pusineri et al 2005) • Forms mixed schools with skipjack tuna, yellowfin tuna and bluefin tuna (Collette et al 2011)

Species	Details
	Environmental Preferences 15.6-19.4 — 0-600 — Pelagic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Atlantic bluefin tuna (*Thunnus thynnus*)	**Status and Use** • COSEWIC (Endangered) and IUCN (Endangered) status • Commercial fishery **Biology and Ecology** • Undertakes extensive migrations; moves northward into Canadian waters in summer and southward again in late fall • Occurs over the continental shelf, off Newfoundland, and in the Gulf of St. Lawrence • Feeds on pelagic and benthic fishes (capelin, saury, herring, mackerel and lanternfishes) • Squid and capelin are important food sources in Newfoundland waters • Predators include sharks, orca whales and pilot whales **Environmental Preferences** >13.0 — 70-200 — Pelagic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Atlantic mackerel (*Scomber scombrus*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Occurs on both sides of the North Atlantic Ocean • Distributed in Canadian coastal and inshore waters during summer and fall • Schooling species common to temperate waters • Plankton feeder; filters organisms from water with gill rakers **Environmental Preferences** 9.0-12.0 — 70-200 — Pelagic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Atlantic wolffish (*Anarhichas lupus*)	**Status and Use** • SARA (Special Concern) and COSEWIC (Special Concern) status • No commercial fishery **Biology and Ecology** • Occurs on both sides of the North Atlantic Ocean • Areas of concentration on the Grand Bank include the Northeast Newfoundland Shelf and the northern edge of the Grand Bank (Kulka et al 2003a) and the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • Commonly an inhabitant of deep water along the shelf (Dutil et al 2010) • Warm Southern Shelf Assemblage • Feeds on benthic invertebrates (echinoderms, molluscs, crustaceans) and some fish

Species	Details
	Environmental Preferences 1.0-4.0 — *Temperature (^{o}C)* 25-250 — *Depth Range (m)* Benthic — *Habitat*
Bigeye tuna (*Thunnus obesus*)	**Status and Use** • IUCN (Vulnerable) Status • Commercial fishery **Biology and Ecology** • Worldwide distribution; Atlantic, Indian and Pacific Oceans (FAO 2013) • Young fish school with other tuna species in surface waters (DFO 1998) • Migrates through temperate waters after spawning • Feeds on fish and squid (Logan et al 2012) **Environmental Preferences** 13.0-29.0 — *Temperature (^{o}C)* 0-250 — *Depth Range (m)* Pelagic — *Habitat*
Northern sand lance (*Ammodytes dubius*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • High densities observed on the eastern and South East Shoal of the Grand Bank • Grand Bank Shelf Assemblage • Adults burrow into sandy or fine gravel bottoms to avoid predation • Feeds on plankton with preference towards copepod • Important prey species for numerous fishes within the study area **Environmental Preferences** 3.0-6.0 — *Temperature (^{o}C)* 73-90 — *Depth Range (m)* Benthic — *Habitat*
Northern wolffish (*Anarhichas denticulatus*)	**Status and Use** • SARA (Threatened) and COSEWIC (Threatened) status • No commercial fishery in the study area **Biology and Ecology** • Occurs in Arctic seas on both sides of the North Atlantic Ocean • Widespread Shelf Assemblage • Also found on the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • Feeds on benthic invertebrates (echinoderms, molluscs, crustaceans) and some fish **Environmental Preferences** <5.0 — *Temperature (^{o}C)* 150-1,000 — *Depth Range (m)* Benthic — *Habitat*

Species	Details
Spotted wolffish (*Anarhichas minor*)	**Status and Use** • SARA (Threatened) and COSEWIC (Threatened) status • No commercial fishery in the study area **Biology and Ecology** • Occurs on both sides of the North Atlantic • Areas of concentration on the Grand Bank include the Northeast Newfoundland Shelf, the Flemish Cap and the north and east edges of the Grand Banks (Kulka et al 2003a; Casas and Gonzalez-Troncoso 2013) • Migrations are local and limited • Warm Deep Offshore Shelf Assemblage • Feeds mainly on invertebrates (mollusks, crustaceans, echinoderms, polychaetes) and some fish **Environmental Preferences** <5.0 — *Temperature (^{o}C)* 300-500 — *Depth Range (m)* Benthic — *Habitat*
Swordfish (*Xiphias gladius*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Seasonal migrant from southern areas that occurs off Canada from June to November (Neilson et al. 2014) • Distributed throughout a variety of depths • Undertakes diurnal vertical migrations • Opportunistic feeders of fish (mackerel, hake, redfish, herring, lanternfish) and squid • Young swordfish preyed upon by blue sharks, tunas and marlins **Environmental Preferences** 8.0-27.0 — *Temperature (^{o}C)* 0-500 — *Depth Range (m)* Pelagic — *Habitat*
Vahl's eelpout (*Lycodes vahlii*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Occurs on both sides of the Atlantic Ocean • Captured at average depths of 410 m in the Orphan Basin (LGL 2012) • Northern Shelf Assemblage • Feeds on polychaetes, small crustaceans and mollusks **Environmental Preferences** 2.0-4.5 — *Temperature (^{o}C)* 200-600 — *Depth Range (m)* Benthic — *Habitat*

Species	Details
Pleuronectiformes - Flatfishes	
American plaice (*Hippoglossoides platessoides*)	**Status and Use** • COSEWIC (Threatened) status. • Commercial fishery **Biology and Ecology** • Occurs on both sides of the Atlantic • Areas of concentration on the Grand Bank include the north and south areas of the Bank (Kulka et al 2003a) and the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • Tolerates salinities as low as 20 – 22 ppt • Commonly observed species in NAFO area 3NLOPs • Widely distributed on the shelf • Feeds on polychaetes, echinoderms, molluscs, crustaceans and fish **Environmental Preferences** 0.0-1.5 — *Temperature (^{o}C)* 90-250 — *Depth Range (m)* Benthic — *Habitat*
Atlantic halibut (*Hippoglossus hippoglossus*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Areas of concentration on the Grand Bank include the Southwest Slope and Laurentian Channel Slope (Kulka et al 2003a) • The largest of the flat fishes, and typically found along the slopes of the continental shelf • Moves seasonally between deep winter waters and the shallow waters of the Gulf where they feed • Avoids temperatures below 2.5°C • Feeds on polychaetes, molluscs, crustaceans and fish **Environmental Preferences** 3.0-9.0 — *Temperature (^{o}C)* <1,000 — *Depth Range (m)* Benthic — *Habitat*
Greenland halibut (*Reinhardtius hippoglossoides*)	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Areas of concentration include the slope of the Northeast Newfoundland shelf, northeast edge of the Grand Bank (Kulka et al 2003a), Flemish Pass (Morgan et al 2013) and slopes of the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • Spends considerable time in the pelagic zone (Morgan et al 2013) • Bathypelagic predator that feeds fish (capelin, Atlantic cod, polar cod, roundnose grenadier, redfishes, sand lance), and invertebrates (shrimp, squid, benthic invertebrates)

Species	Details
	Environmental Preferences 0.0-4.5 — *Temperature (^{o}C)* 200-800 — *Depth Range (m)* Benthic — *Habitat*
Witch flounder (*Glyptocephalus cynoglossus*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Benthic species that prefers living over mud or mud-sand bottoms • Areas of concentration on the Grand Banks include northeast edge, Southwest Slope and Laurentian Channel (Kulka et al 2003a) • Captured at average depths of 432 and 487m in the Orphan Basin during the spring and fall respectively (LGL 2012) • Feeds mainly on polychaetes, amphipods, molluscs and small fishes **Environmental Preferences** 2.0-6.0 — *Temperature (^{o}C)* 185-368 — *Depth Range (m)* Benthic — *Habitat*
Yellowtail flounder (*Limanda ferruginea*	**Status and Use** • No conservation status in study area • Commercial fishery **Biology and Ecology** • Offshore benthic species that prefers living over sand or mud-sand bottoms • Areas of concentration include the Laurentian Channel slope and Tail of the Bank (Kulka et al 2003a) • Commonly observed species in NAFO area 3NLOPs • Undertakes seasonal migrations to shallow water in spring and deep waters in fall and winter • Grand Bank Shelf Assemblage • Feeds mainly on polychaetes and amphipods and some small fish (sand lance and capelin). **Environmental Preferences** 3.1-4.8 — *Temperature (^{o}C)* 57-64 — *Depth Range (m)* Benthic — *Habitat*
Rajiformes – Skates and Rays	
Barndoor skate (*Dipturus laevis*)	**Status and Use** • IUCN (Endangered) status • No commercial fishery in study area **Biology and Ecology** • Migrates offshore to seek cool temperatures • Warm Southern Shelf Assemblage • Feeds on bivalves, squid, rock crabs, lobster, shrimp and polychaetes

Species	Details
	Environmental Preferences <12.0 — 650-750 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Smooth skate (*Malacoraja senta*)	**Status and Use** • COSEWIC (Endangered) and IUCN (Endangered) status • No commercial fishery in study area **Biology and Ecology** • Generally occur on soft mud and clay substrates over a range of depths (COSEWIC 2012a) • Widespread Shelf Assemblage • Feed mainly on crustaceans, euphausiids, mysids and some fish • Egg capsules are eaten by gastropods, halibut, monkfish and Greenland sharks (COSEWIC 2012a) **Environmental Preferences** 2.7-10.0 — 70-480 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Thorny skate (*Amblyraja radiata*)	**Status and Use** • COSEWIC (Special Concern) and IUCN (Vulnerable) status • Commercial fishery **Biology and Ecology** • Occurs on both sides of the North Atlantic • Areas of concentration on the Grand Bank include the Southwest Slope, edges of the Grand Bank, and Tail of the Bank. Concentrations vary seasonally (Kulka et al 2003a) • Widespread Shelf Assemblage • Boreal to Arctic species that inhabits offshore areas with hard and soft bottoms • Concentrated on the Grand Banks edge from December to June and on the Banks from July to November • Single stock across NAFO area 3LNOPs • Feeds mainly on polychaetes amphipods, decapods and fishes • Egg capsules are consumed by Greenland sharks and halibut **Environmental Preferences** -1.4-14.0 — 18-966 — Benthic *Temperature (^{o}C)* — *Depth Range (m)* — *Habitat*
Winter skate (*Leucoraja ocellata*)	**Status and Use** • COSEWIC (Special Concern, Threatened, Endangered) and IUCN (Endangered) status • No commercial fishery in study area **Biology and Ecology** • Distribution restricted to the northwest Atlantic • Benthic species that prefers living over sand and gravel bottoms

Species	Details
	• Warm Southern Shelf Assemblage • Feeds mainly on invertebrates (amphipods and polychaetes) and some fish (sand lance)
	Environmental Preferences 5.0-9.0 — *Temperature (^oC)* 36-90 — *Depth Range (m)* Benthic — *Habitat*
Salmoniformes – Salmon	
Atlantic salmon (*Salmo salar*)	**Status and Use** • COSEWIC (Special Concern, Threatened, Endangered) and IUCN (Least Concern) status • Recreational fishery • Historical commercial fishery **Biology and Ecology** • Occurs on both sides of the North Atlantic Ocean • Anadromous species; lives in fresh water and estuaries the first 2 to 7 years of life before migrating to sea • Cool rivers with extensive gravelly bottom headwaters are important habitat • When about 15 cm long, young salmon migrate to sea, where they may live for 1, 2, or more years before returning to freshwater **Environmental Preferences** 2.0-9.0 — *Temperature (^oC)* 1-10 — *Depth Range (m)* Pelagic — *Habitat*
Scorpaeniformes – Scorpionfishes	
Redfish (*Sebastes mentella*, *S. fasciatus*)	**Status and Use** • *S. mentella* - COSEWIC (Threatened) and IUCN (Least Concern) status • *S. fasciatus* – COSEWIC (Threatened) and IUCN (Endangered) status • Commercial fishery **Biology and Ecology** • In the western Atlantic, redfish species range from Baffin Island in the north to the waters off New Jersey in the south • Areas of concentration on the Grand Bank include the Northeast Newfoundland Shelf and the Flemish Cap (Casas and Gonzalez-Troncoso 2013) • The three redfish species that occur in the Northwest Atlantic include *Sebastes mentella*, *S. fasciatus*, and *S. marinus* the latter species is relatively uncommon except in the area of the Flemish Cap • *S. mentella* is typically distributed deeper than *S. fasciatus* (Gascon 2003) • *S. mentella* a commonly observed species in NAFO area 3NLOPs • Warm Deep Offshore Shelf Assemblage • Bathypelagic or pelagic feeders, consume amphipods, copepods, euphausiids **Environmental Preferences** ~0.0 — *Temperature (^oC)* 100-700 — *Depth Range (m)* Benthic — *Habitat*

Species	Details
Sculpin (*Triglops* sp.)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Boreal cool-water group of species that occur from shallow to deep depths • Occurs on both sides of the Atlantic Ocean • Commonly observed species in NAFO area 3NLOPs • Grand Bank Shelf Assemblage • Feeds on small crustaceans including mysids and amphipods • Preyed upon by cod and murres **Environmental Preferences** ~0.0 — *Temperature (^oC)* 135-930 — *Depth Range (m)* Benthic — *Habitat*
Squaliformes – Dogfish Sharks	
Black dogfish (*Centroscyllium fabricii*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area • **Biology and Ecology** • Distributed along the Canadian slope, with concentrations in the Laurentian Channel (Kulka 2006) • Feeds mainly on squid, crustaceans, jellyfish and small redfish • Small, deepwater shark occurring near bottom, at times forming schools **Environmental Preferences** 3.5-4.5 — *Temperature (^oC)* 350-500 — *Depth Range (m)* Benthic — *Habitat*
Greenland shark (*Somniosus microcephalus*)	**Status and Use** • No conservation status in study area • No commercial fishery in study area **Biology and Ecology** • Distribution restricted to the North Atlantic Ocean • Occupies near surface areas in winter months and deep cool waters during summer months • Feeds on fish (herring, salmon, char, capelin, redfish, sculpin, lumpfish, cod, haddock, halibut and skate), invertebrates (squid, gastropods, crustaceans), seabirds and marine mammals **Environmental Preferences** 0.6-12.0 — *Temperature (^oC)* 10-1,200 — *Depth Range (m)* Pelagic — *Habitat*

Species	Details
Spiny dogfish (*Squalus acanthias*)	**Status and Use** • COSEWIC (Threatened) and IUCN (Vulnerable) status • Commercial fishery **Biology and Ecology** • Widely distributed in coastal waters of temperate seas throughout the world • Small, schooling shark that frequents coastal and inshore waters • Tolerant of low salinities and may ascend into estuaries • Resident population that migrates between inshore and offshore areas in Canadian waters • Warm Southern Shelf Assemblage • Opportunistic feeder that consumes mainly small fishes • Juvenile dogfish are prey to various fish and sharks • Slow-growing and long-lived **Environmental Preferences** 6.0-15.0 — *Temperature (^{o}C)* 100-250 — *Depth Range (m)* Benthic — *Habitat*
Source: Adapted from Scott and Scott (1988) + See species-specific information references throughout the Table.	

Spawning

The fish species that are found in the Study Area exhibit diverse reproductive strategies that include demersal spawning (such as skates, capelin) and broadcast spawning (Atlantic cod) as well as more specialized strategies such as diadromy (Atlantic salmon, American eels) and ovivipary (species such as sharks and redfish that give birth to live young). In many cases, spawning migrations take fish species well beyond Newfoundland's offshore to freshwater rivers, more shallow waters or tropical locations whereas others are able to fulfill their whole life cycle in the Study Area. Of those that remain, most are spring and early summer spawners. However a few spawn in winter, such as Greenland halibut and roughhead grenadier (Figure 4.25).

Figure 4.25 Spawning Periods and Reproductive Biology for Key Species

Species	Spawning Time												Spawning Locations
	J	F	M	A	M	J	J	A	S	O	N	D	
Sand Lance													Grand Bank[2,3]
Capelin													Southeast shoal of Grand Bank[4]
Deepwater Redfish													Southwest Shelf Edge and Slope of Grand Bank[4,5]
Yellowtail Flounder													Grand Bank
American Plaice													Grand Bank
Sculpin													
Lanternfish													
Atlantic Cod[6]													Southeast shoal of Grand Bank and Virgin Rocks[4]
Greenland Halibut													Davis Strait
Roughhead Grenadier													Grand Bank

Sources: [1] Scott and Scott (1988); [2] Winters 1983; [3] Gilman 1994; [4] Templeman (2007); [5] COSEWIC (2010a); [6] COSEWIC (2010b)

Migration Patterns

Migration of fish in temperate latitudes is common, as it allows individuals to seek out seasonally abundant resources, avoid harsh environmental conditions and/or aggregate for activities such as spawning (Dingle and Drake 2007). Progressively more is being learned about fish migration of open ocean species. Researchers are increasingly able to overcome challenges of studying fish movements in the extensive depths and scales of offshore areas through new telemetry technologies and data sharing networks (e.g. the Ocean Tracking Network). Key migration strategies used by fish found in the Study Area are described in Amec (2014) and include:

- Migrations from offshore wintering habitats to shallow coastal areas in summer (cod and capelin);

- Summer feeding migrations from southerly latitudes into the Study Area by large warm water pelagic species such as tunas, swordfish and a variety of sharks;

- Migrations of freshwater spawners like Atlantic salmon, which often transit through the Study Area between offshore feeding migrations and their natal rivers;

- Catadromous migrations of American eel, that may pass through offshore environments as they migrate between freshwater rearing environments and the Sargasso Sea spawning areas; and

- Movements within offshore habitats that can be exhibited by deep water species (such as redfish, wolffish and Greenland halibut) and some stock components of other species (including inshore populations of Atlantic cod).

An important consideration of migratory species is that they are a derived from a region that extends well beyond the Study Area. For example, Atlantic salmon populations that have to migrate through the Study Area could originate from rivers on the south coast of Newfoundland, the Maritimes or even the northeast United States (COSEWIC 2010c). Large pelagics (such as sharks) could have migration pathways that carry them across large portions of the Atlantic Ocean (Ocearch 2015).

Some migrations are conducted across wide areas of the Study Area, such as inshore-offshore migrations, whereas in other cases some generalized migration corridors can be identified. These include:

- Warm, deep water channels that are used to access inshore areas (such as the Bonavista Corridor); and

- The Southern Grand Bank, which likely experiences traffic from pelagics migrating to and from southerly latitudes.

Species Distributions

Densities and biomass of fish vary considerably within the Study Area and are a reflection of species' habitat preferences. These general distributions can be visualized for demersal species using data collected during the 2008-2012 DFO RV Surveys, and for a subset of commercial species, using the EU RV surveys on the Flemish Cap (Casas and Gonzalez-Troncoso 2013).

The 20 most abundant species during the DFO RV surveys are identified in Figure 4.26 and 4.27 (abundance and biomass respectively), while the top five reported by the EU on the Flemish Cap are shown in Figure 4.28. Species that make up the top ten for measures of abundance and biomass (based on DFO RV 2008-2012 data) are mapped. These species also represent the main fish species of commercial importance in the Study Area. Maps for fish Species at Risk, where appropriate data is available, are also provided in later Figures. Finally, maps presenting aggregate measures of fish community strength (such as zones of high species richness, abundance and total biomass) are presented later in this Section and are based on DFO RV Survey data. Where available, data from recent EU RV Surveys (2012) are also provided and described for key species.

Figure 4.26 Abundance of Finfish Taxa from DFO RV Surveys (2008-2012) in the Study Area

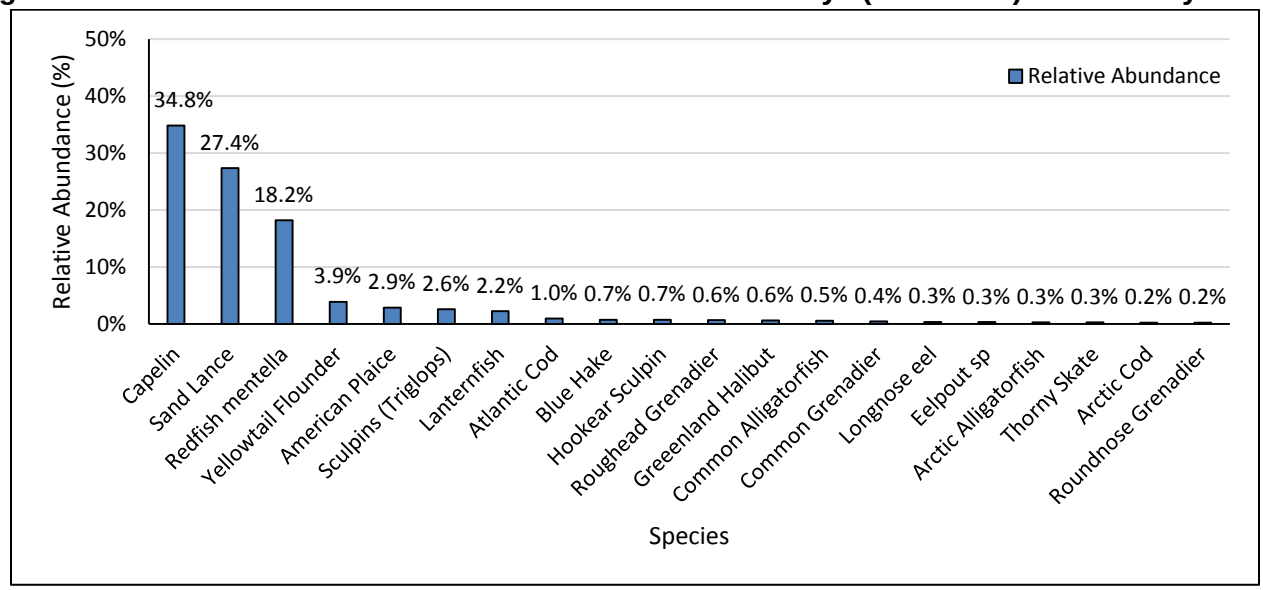


Figure 4.27 Biomass of Finfish Taxa from DFO RV Surveys (2008-2012) in the Study Area

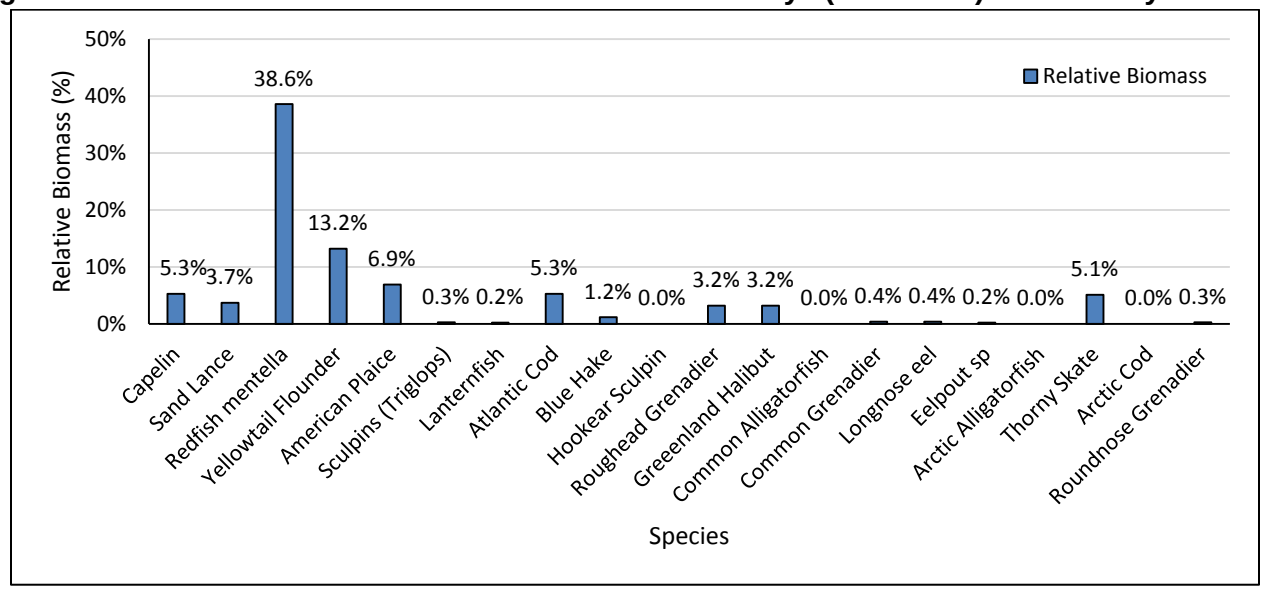
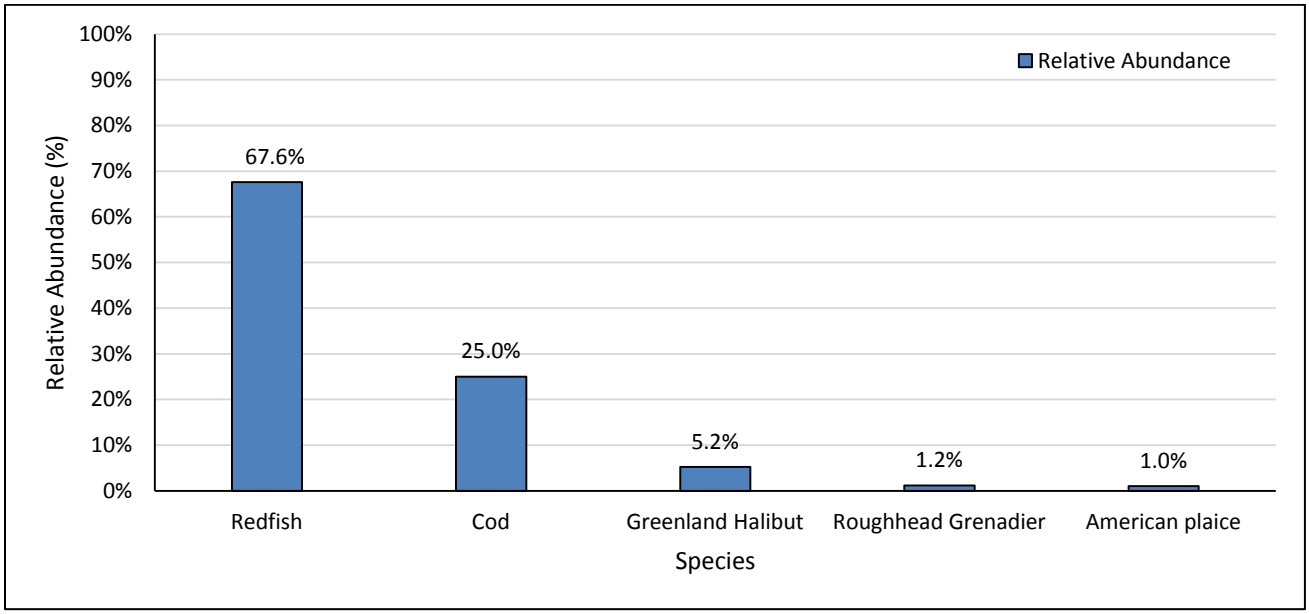


Figure 4.28 Relative Abundance of Finfish Taxa from EU Bottom Trawl Surveys of the Flemish Cap (2012)



Capelin

Capelin are a small, commercially harvested fish that feed on zooplankton. They migrate in impressive aggregations from the Study Area to inshore spawning grounds (Scott and Scott 1988). As they are an abundant and important food source for a multitude of species (fish, birds and marine mammals), they are considered a key element in the marine ecosystem (Scott and Scott 1988; Gomes et al 1992; Davoren and Montevecchi 2003; Rose 2005; Templeman 2010; Dawe et al 2012). Capelin represent 34.8 percent and 5.3 percent of the fish in the DFO RV Surveys for abundance and biomass respectively (Figure 4.29). They are found in greatest abundance in the Flemish Pass and along the Bonavista Corridor. They are much less common in the southwest corner of the Study Area and along the deep slope. However, capelin are typically associated with cold water and can quickly alter their distributions to changing temperature conditions (Rose 2005b).

Sand Lance

Sand lance are small, planktivorous schooling fish (Scott and Scott 1988) that are a critical part of the food web in parts of the Study Area. Although not commercially fished themselves, they serve as prey for other valued species such as Atlantic cod, American plaice and Yellowtail flounder (Gomes et al 1992). Of the species captured in DFO RV Surveys, they were second most abundant, representing approximately 27 percent of fish species captured and approximately four percent of fish biomass. Within the surveyed portion of the Study Area, sand lance was found primarily over the Grand Bank (Figure 4.30). This species was noticeably absent from areas north of the Grand Bank.

Deepwater Redfish

Deepwater redfish are a long-lived (up to 40 years in age; DFO 2011a) commercially harvested species associated with the Flemish Pass and the continental slope. Its abundance within the latter habitat is most pronounced along the southern portions of the Study Area (Figure 4.31). The

distribution map for redfish indicates that the species increases with depth to the depth limits of the survey. NAFO RV Surveys of the Flemish Cap indicate that redfish are predominantly found at the shelf edge (Casas and Gonzalez-Troncoso 2013; Figure 4.32). Redfish were the third most abundant species captured in the DFO RV Surveys (18.17 percent) and represented the highest biomass in both DFO (38.55 percent) and targeted NAFO trawl surveys (68 percent; Casas and Gonzalez-Troncoso 2013). Redfish engage in nocturnal vertical migrations to to feed on zooplankton and fish (Scott and Scott 1988; Templeman 2010) but are not known to undertake the seasonal migrations exhibited by many shelf species. The redfish stock in the Study Area are considerd to be in poor condition and consequently are listed as Threatened by COSEWIC (DFO 2011a). Exploitation (nothern portions of the Study Area) and environmental conditions (northern and southern portions) are affecting stock health (Devine and Haedrich 2011).

Yellowtail Flounder

Yellowtail flounder are a flatfish associated with warm, shallow, offshore banks, (Scott and Scott 1988; Gomes et al 1992). The distribution of this commercially valuable species is focused in the shallow, southwestern portion of the Study Area. In contrast, individuals are at low abundance from the Flemish Pass and the Newfoundland Shelf north of Bonavista (Figure 4.33). The species was considered to be at low levels in the 1990s but have since rebounded (Templeman 2010). In DFO RV Surveys of the Study Area, yellowtail comprised almost four percent of the individuals captured but 13.2 percent of biomass (following only redfish).

American Plaice

American plaice is a commercially important flatfish that is widespread and abundant (2.88 percent and 6.87 percent of DFO RV Survey abundance and biomass respectively; Figure 4.34) through much of the shelf areas of the Study Area, including the shallows portions of the Flemish Cap (Casas and Gonzalez-Troncoso 2013; Figure 4.35). Their widespread distibution is partially attributed to their tolerance of cold water (Scott and Scott 1988; Morgan and Brodie 1991). DFO RV Survey data show them occupying habitats such as the Bonavista Corridor in high abundance, but also in shallow areas of the Grand Bank that are not used as frequently by other species. This demersal species feeds on a variety of invertebrates and fish (Scott and Scott 1988) and is a prey source for larger fish such as cod and sharks. While adults are not known to undertake significant migrations, eggs and larvae are dispersed more widely by the currents (Scott and Scott 1988; Frank et al 1992). American plaice once supported the largest flatfish fishery in the world. Unfortunately, like several other commercially exploited groundfish species in the Study Area, the stock collapsed to a fraction of its former abundance. It has since been listed as Threatened by COSEWIC and shows few signs of recovery on the Flemish Cap unlike some other collapsed stocks (e.g. Atlantic cod; Nogueira et al 2014).

Sculpins (Triglops sp.)

Small sculpins are found across much of the surveyed portions of the Study Area, particularly in the Bonavista Corridor and the northern and eastern extents of the Grand Bank (Figure 4.36). Its lowest abundance occurs near the deep water survey extent and they are not expected to occur in high abundance in most areas beyond the survey. As a morphologically small species, it ranks higher relative to other Study Area species in measures of abundance (2.60 percent) than it does for biomass (0.33 percent). Their abundance suggests they are ecologically important as predators of invertebrate prey but their ecology is poorly understood (Scott and Scott 1988).

Lanternfish

The lanternfish are a small, pelagic fish family that are widespread in deep waters of the globe and characterized by having light producing organs on their bodies (Scott and Scott 1988). They serve an important ecological role in the systems they inhabit as prey for commercially valued species such as cod, hake, tunas, salmon and marine mammals (Scott and Scott 1988). This characterization is corroborated by DFO RV Surveys, which show a near absence in shallow areas on the Grand Bank and the highest abundances at the deep water margins of the surveyed area (particularly in the Flemish Pass). As the DFO RV Survey program does not capture areas beyond the continental slope, the importance of this species in the Study Area is most likely underrepresented (Figure 4.37).

Atlantic Cod

Atlantic cod is an iconic species that dominanted the groundfish fishery for centuries and has long been associated commercially and culturally with Newfoundland (COSEWIC 2010b). However, poor environmental conditions and excessive fishing caused the collapse of the stock and resulted in significant and broad socioeconomic and ecological consequences (Worm and Myers 2003; Dawe et al 2012). The stock coinciding with the Study Area remains a small percentage (less than three percent) of historical levels and is listed as Endangered by COSEWIC (COSEWIC 2010b). Cod, with the help of improving environmental conditions, are showing signs of recovery after two decades of restricted fishing (Koen-Alonso et al 2010; Nogueira et al 2014). They are most prevalent in the northwestern (in the vicinity of the Bonavista Corridor) and southwestern (on the eastern slope of the Grand Banks) corners of the Study Area and in the Flemish Pass (Figure 4.38). EU RV surveys on the Flemish Cap show Atlantic cod's distribution largely restricted to the shallow waters (less than 250 m) of the Cap (Figure 4.39; Nogueira et al 2014). Even in their depleted state, this species still contributes 0.96 percent of total fish abundance and 5.29 percent of total fish biomass in the DFO RV Surveys.

Blue Hake

Blue hake is the most abundant hake species in the Sudy Area (Figure 4.40, 0.73 percent of DFO RV Survey fish abundance and 1.16 percent of biomass) and are concentrated along the eastern slope of the Grand Banks (Kulka et al 2003b) and the deep slope of the Flemish Cap (Noguiera et al 2014). They primarily rely upon benthic invertebrates, such as crustaceans and squids, as a food source (Scott and Scott 1988). Given the depth that blue hake area generally found in (greater than 1,400 m) their total abundance may be underrepresented in the DFO RV Surveys.

Roughhead Grenadier

Roughhead grenadier is the most abundant grenadier species in the Study Area (0.64 percent of DFO RV Survey fish abundance and 3.22 percent of biomass) and are concentrated along the eastern slope of the Grand Banks and the Flemish Pass (Figure 4.41) and the remainder of the continental slope around the Flemish Cap (Figure 4.42). They are an important member of the deep water ecosystem (Nogueira et al 2014), preying on benthic invertebrates and small fish and serving as prey to other piscivorous fish (Scott and Scott 1988). Like other deepwater species, the abundance of roughhead grenadier is likely underestimated as their preferred habitat is underrepresented in the Study Area by the DFO RV Surveys.

Figure 4.29 Distribution of Capelin in the Study Area (Canadian RV Surveys, 2008-2012)

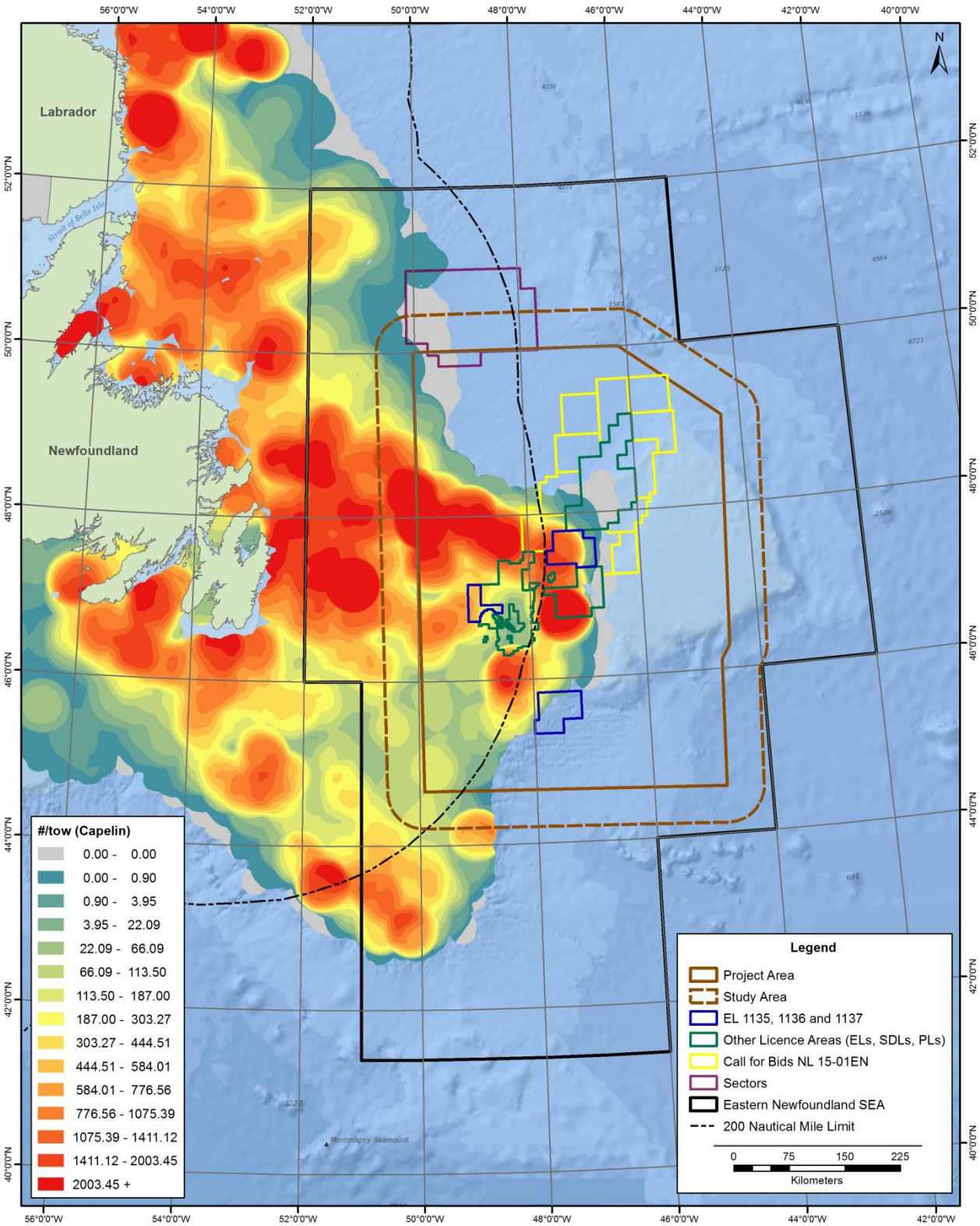


Figure 4.30 Distribution of Sand Lance in the Study Area (Canadian RV Surveys, 2008-2012)

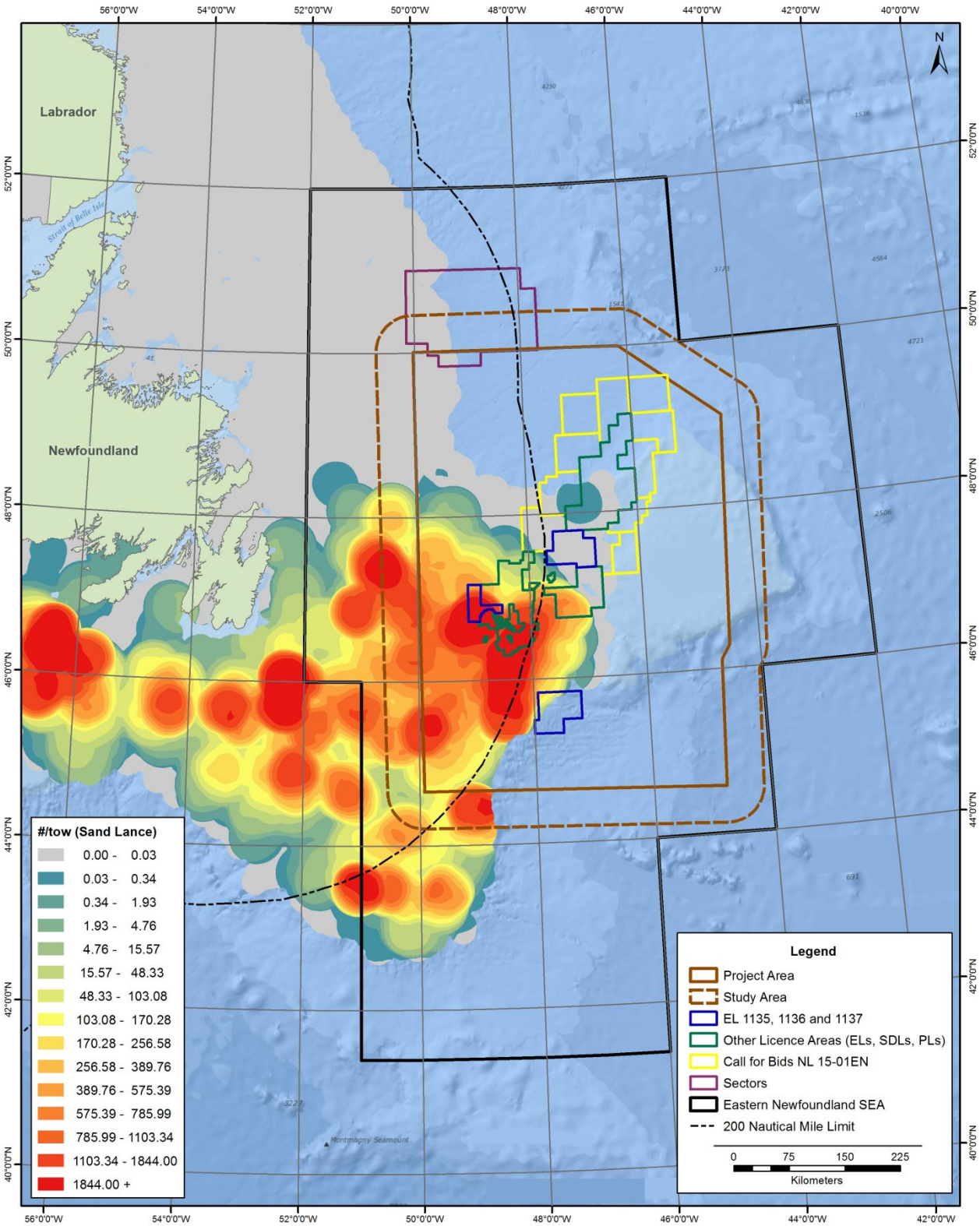


Figure 4.31 Distribution of Redfish in the Study Area (Canadian RV Surveys, 2008-2012)

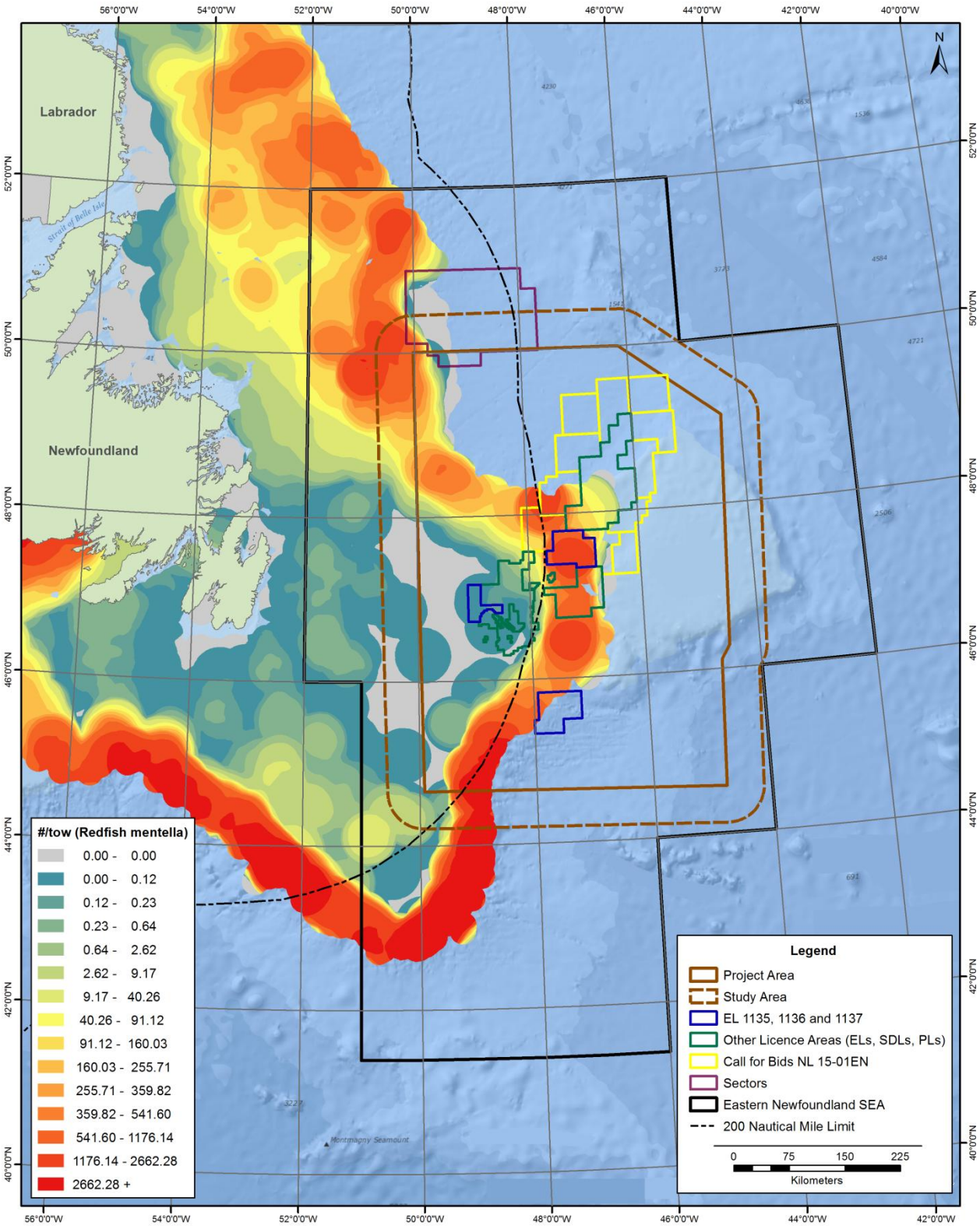


Figure 4.32 Distribution of Redfish on the Flemish Cap (EU RV Surveys, 2012)

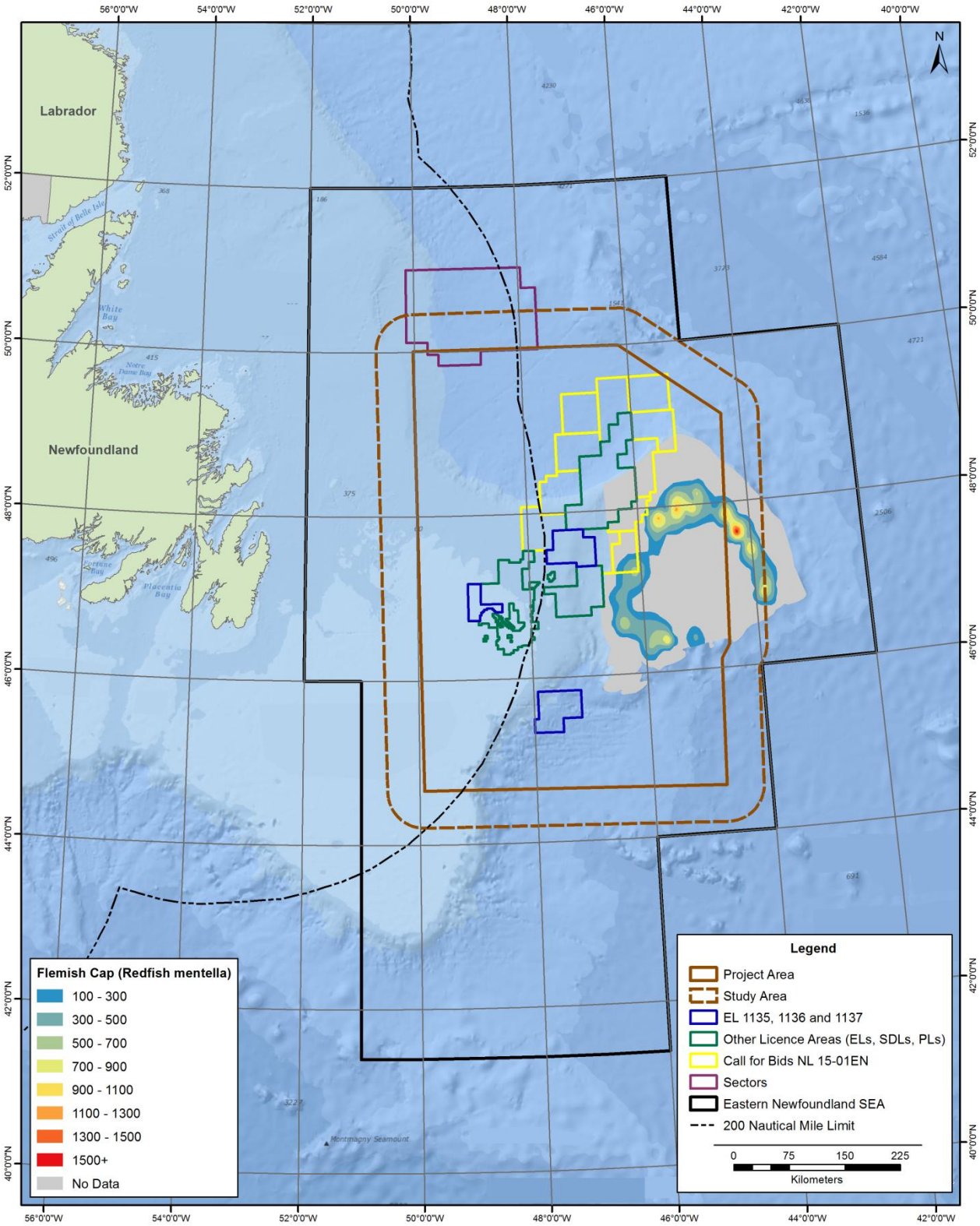


Figure 4.33 Distribution of Yellowtail Flounder in the Study Area (Canadian RV Surveys, 2008-2012)

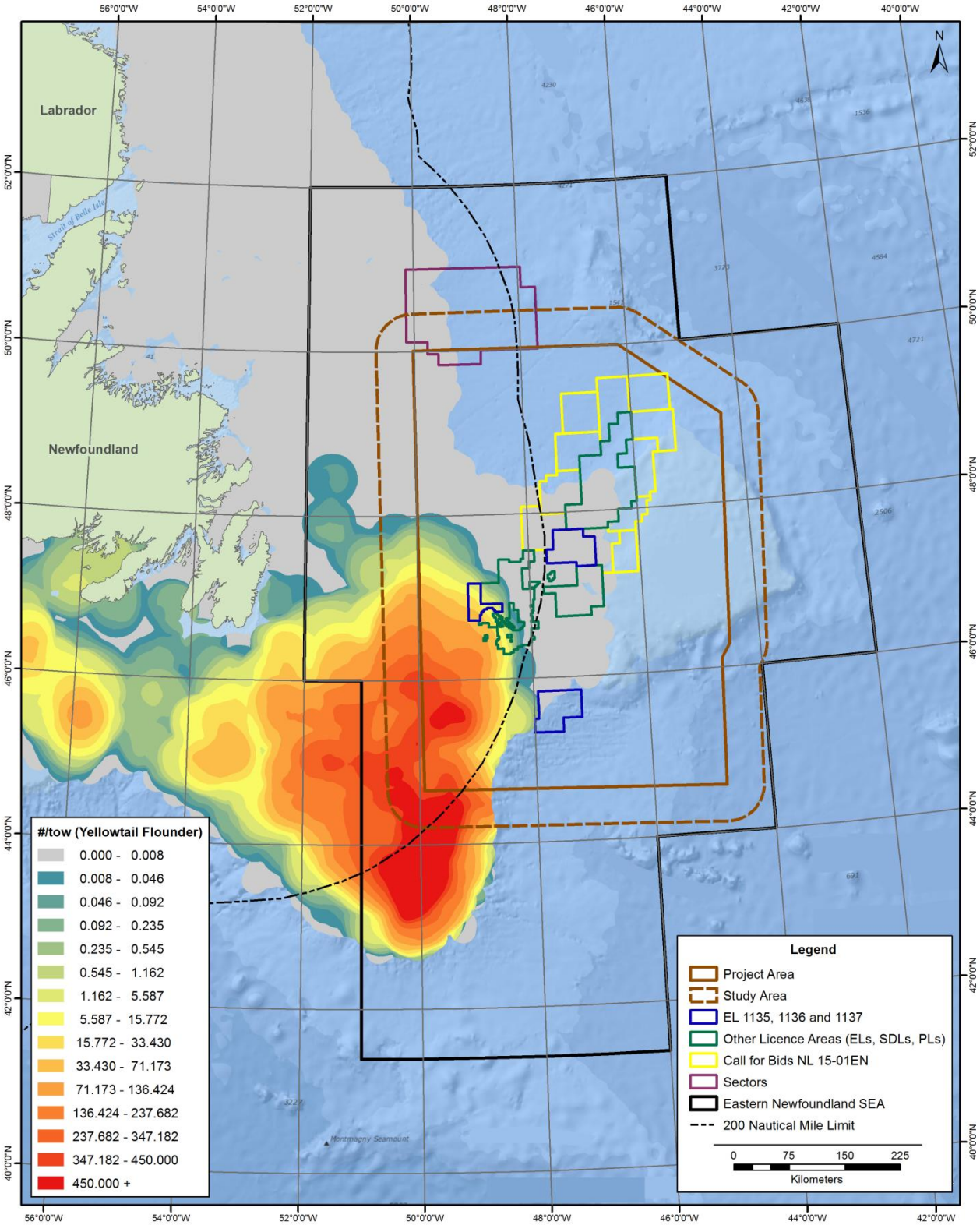


Figure 4.34 Distribution of American Plaice in the Study Area (Canadian RV Surveys, 2008-2012)

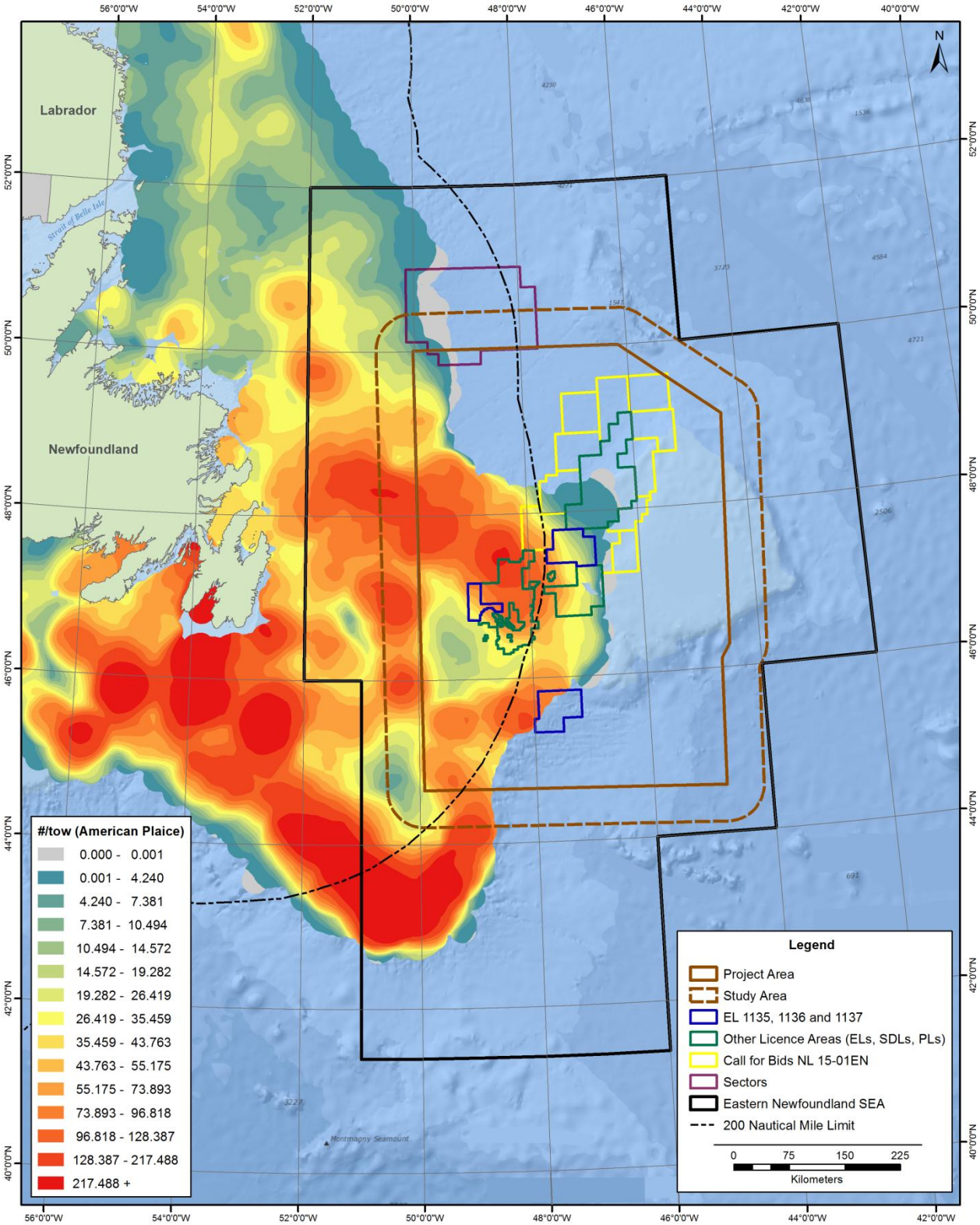


Figure 4.35 Distribution of American Plaice on the Flemish Cap (EU RV Surveys, 2012)

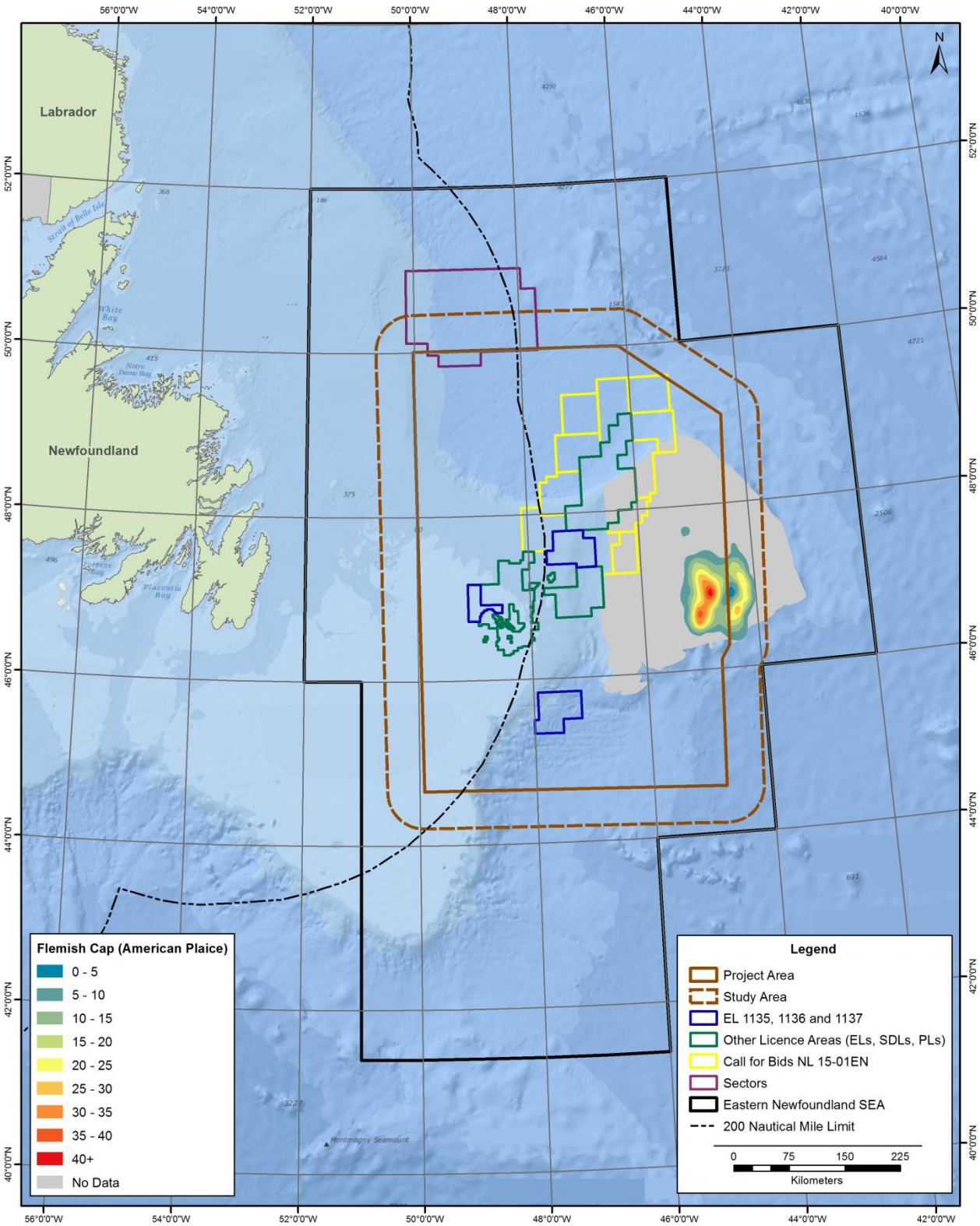


Figure 4.36 Distribution of Sculpins in the Study Area (Canadian RV Surveys, 2008-2012)

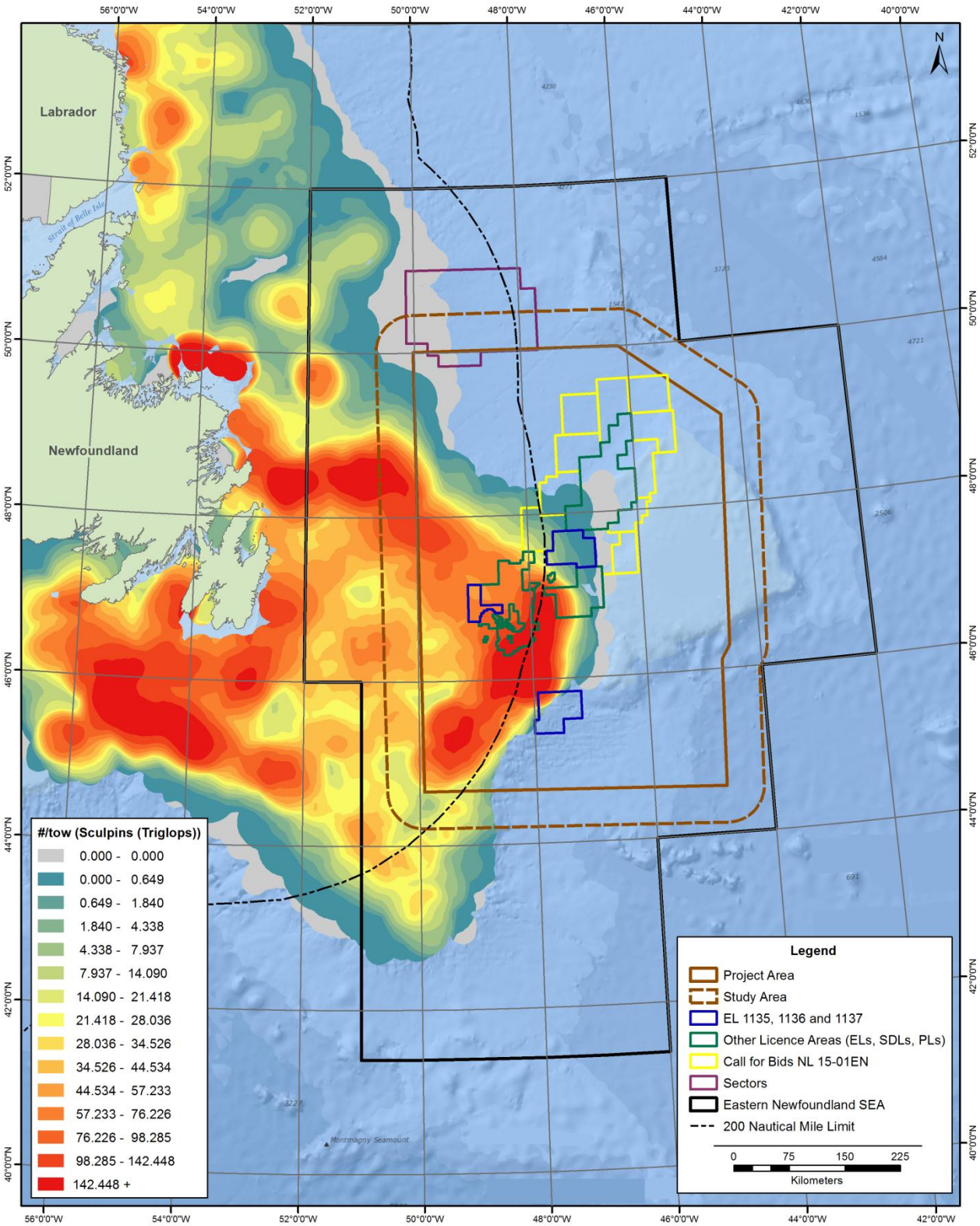


Figure 4.37 Distribution of Lanternfish in the Study Area (Canadian RV Surveys, 2008-2012)

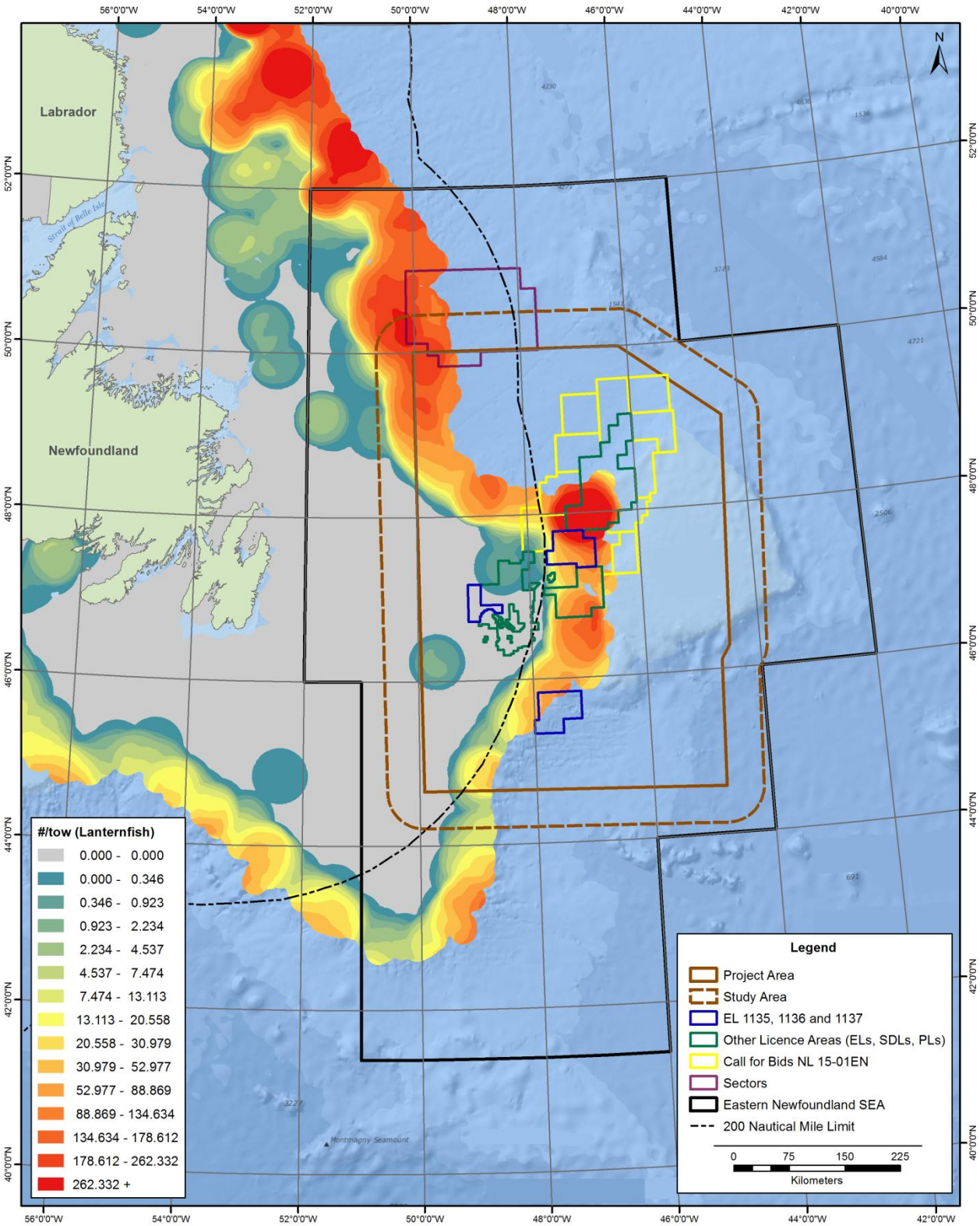


Figure 4.38 Distribution of Atlantic Cod in the Study Area (Canadian RV Surveys, 2008-2012)

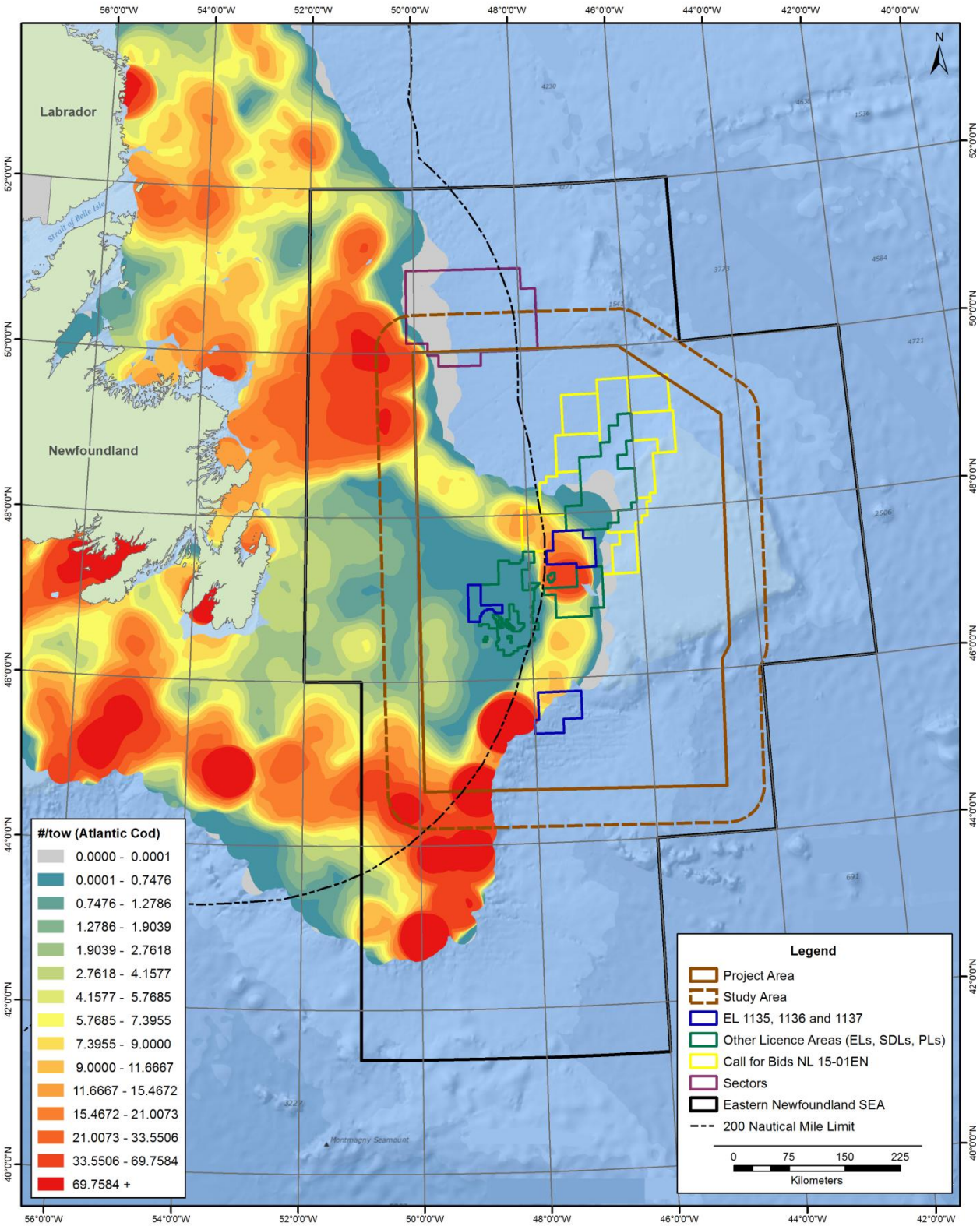


Figure 4.39 Distribution of Atlantic Cod on the Flemish Cap (EU RV Surveys, 2012)

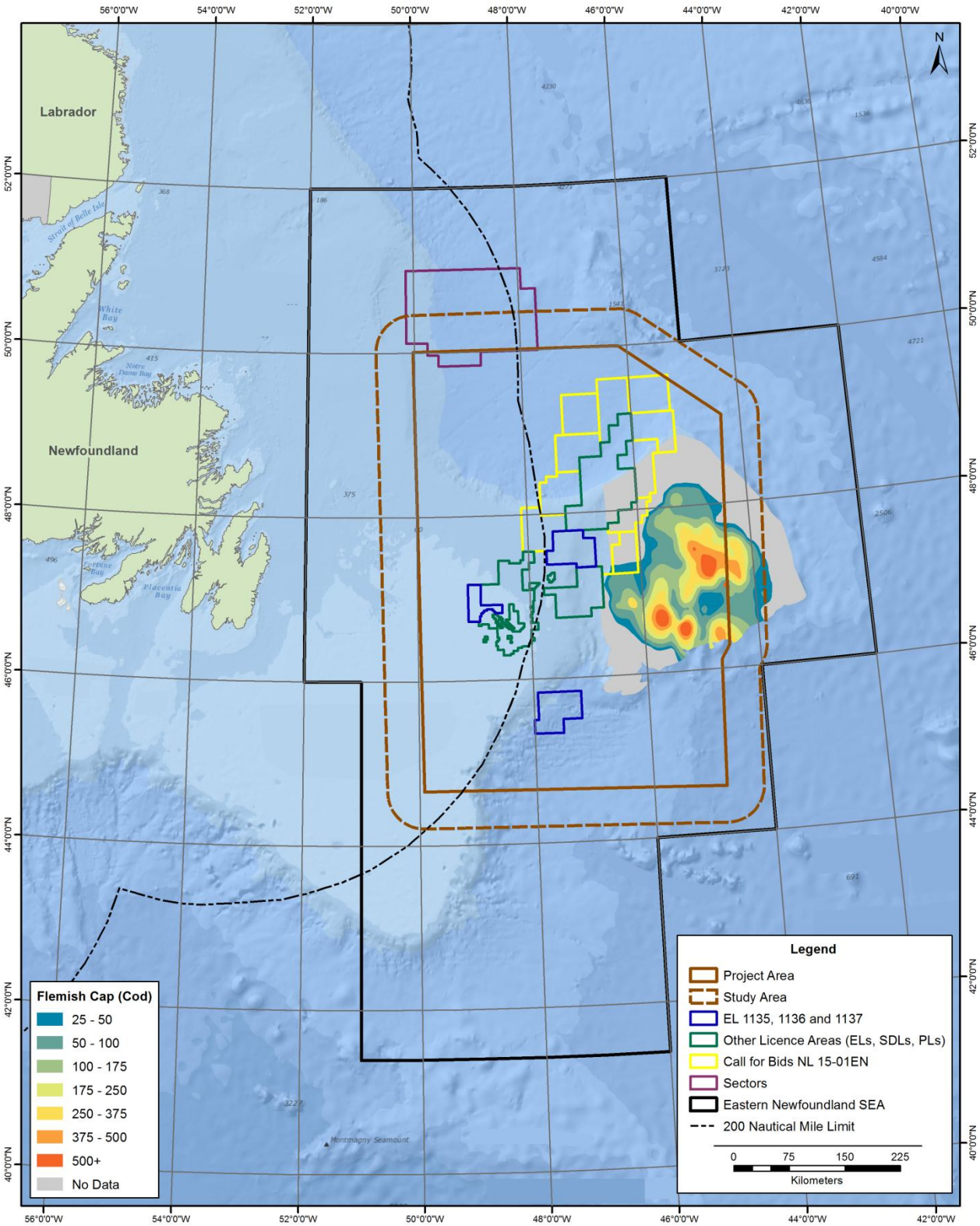


Figure 4.40 Distribution of Blue Hake in the Study Area (Canadian RV Surveys, 2008-2012)

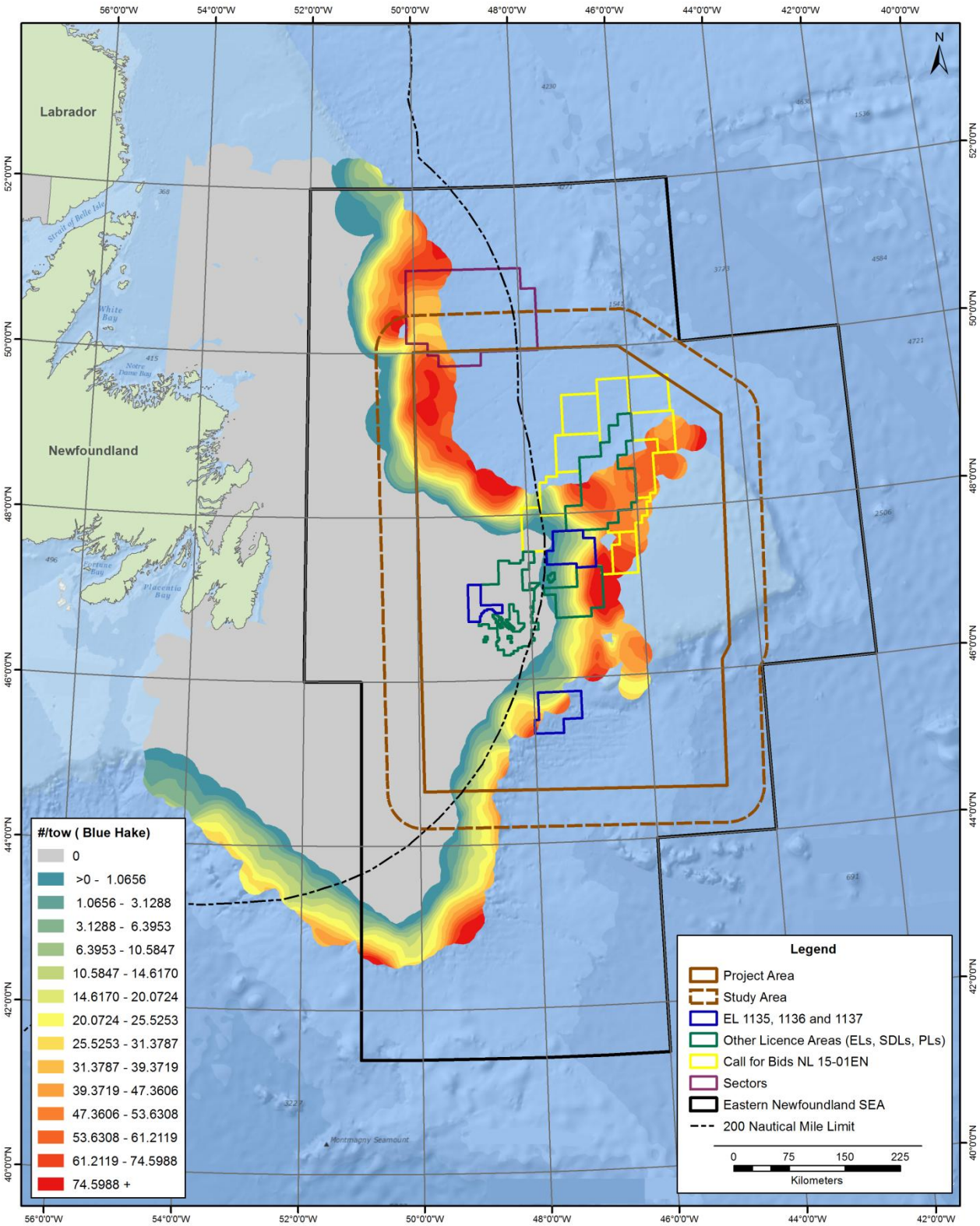


Figure 4.41 Distribution of Roughhead Grenadier in the Study Area (Canadian RV Surveys, 2008-2012)

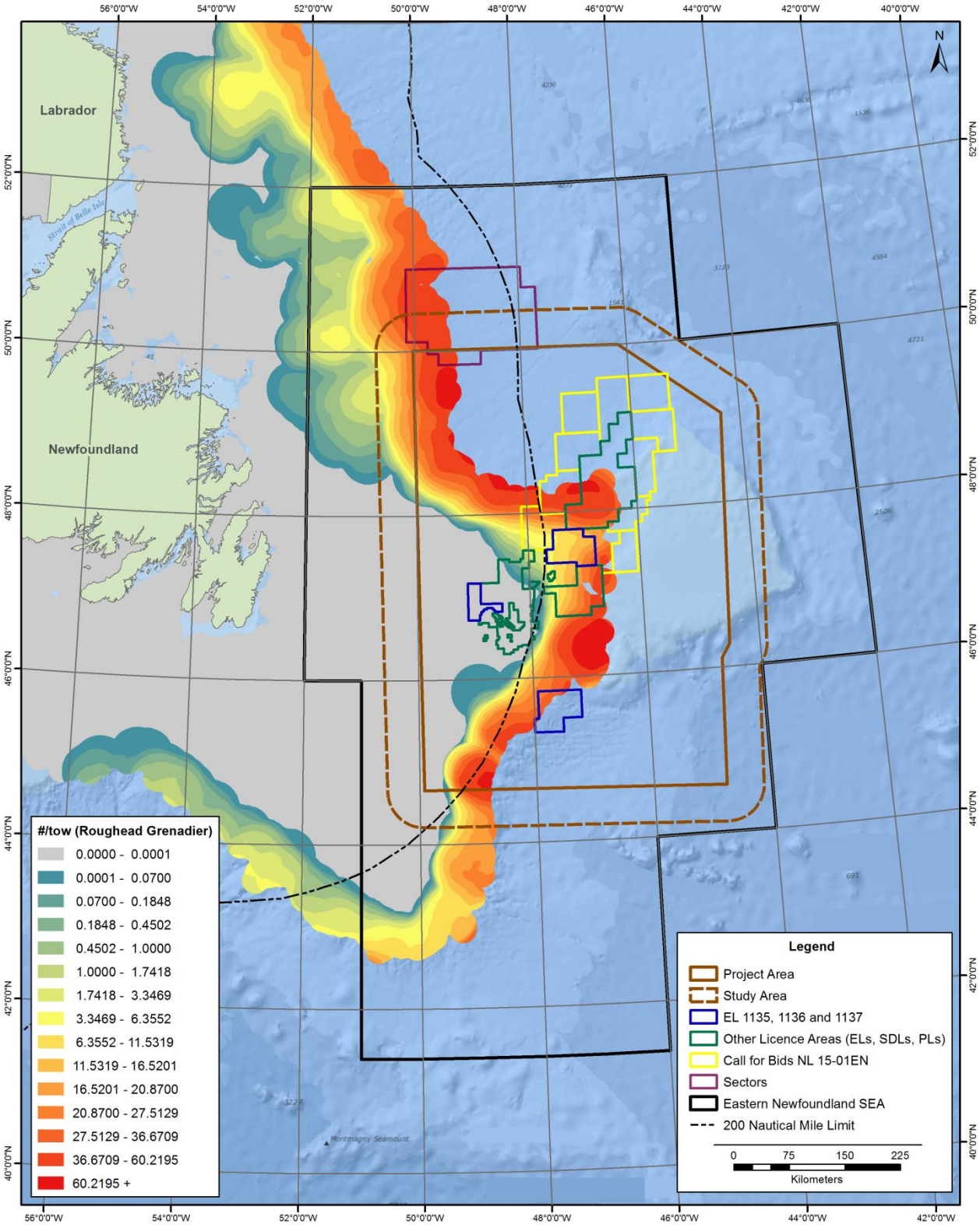
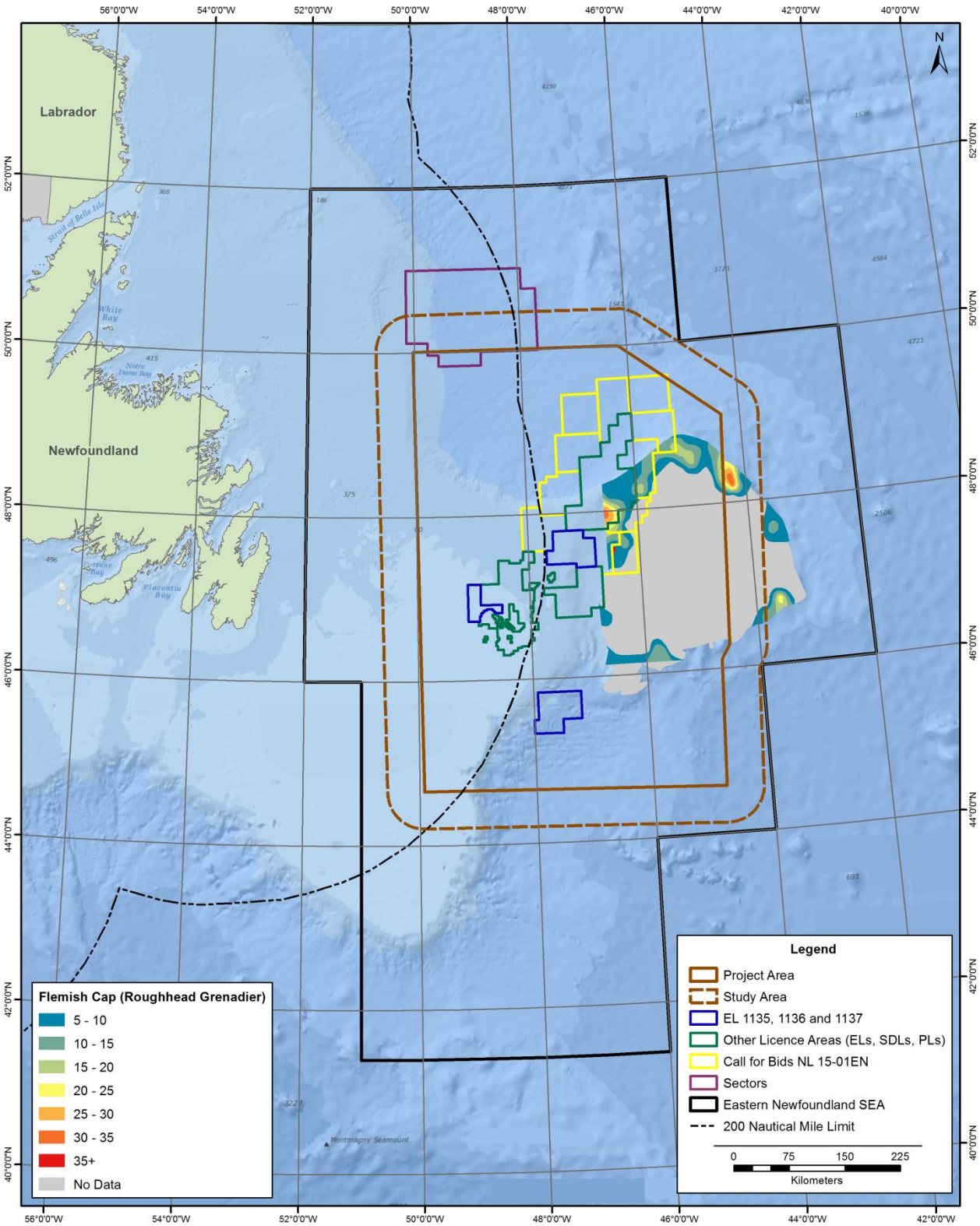


Figure 4.42 Distribution of Roughhead Grenadier on the Flemish Cap (EU RV Surveys, 2012)



Fish Species at Risk and Otherwise of Special Conservation Concern

Species of conservation concern (SOCC) are identified by 'arms length' conservation organizations such as COSEWIC (Committee on the Status of Endangered Wildlife in Canada) and the IUCN (International Union for the Conservation of Nature). Some of these species are provided with legislative protection within Canadian (federal *Species at Risk Act - SARA*) and provincial (Newfoundland and Labrador Endangered Species Act - *NL ESA*) jurisdictions.

Within the Study Area, 26 species have been identified as SOCC (23 species have been identified by COSEWIC and 18 species have been identified on the IUCN Redlist; Table 4.6). Several species identified by COSEWIC and IUCN (such as large migratory pelagics) may never have occurred in great densities in the Study Area because the area is peripheral to their typical range. Other species (including American plaice, Atlantic cod, redfish) remain common but have experienced population declines, particularly during the groundfish collapse of the early 1990s. Only five are listed under *SARA* (four species) or *NL ESA* (one species) and these include three species of wolffish (family *Anarhichadidae*), the white shark and the American eel (Table 4.6).

Three wolffish species of the genus *Anarhichas* are listed by *SARA*. All three species share traits of being slow-growing and long-lived fish, ecological traits that leave them vulnerable to stressors (such as bycatch mortality or trawling-related habitat alteration) and reduce their recovery potential. Both Northern and Spotted wolffish species have experienced declines in excess of 90 percent and are currently listed as Threatened under *SARA*. The Striped wolffish has been assigned the lower conservation status of Special Concern. Associated with the *SARA* process is the requirement for the development of a Recovery Strategy and Management Plan to increase population levels and distributions. Proposed measures in the existing plan include mitigating human impacts, identifying and protecting critical habitats, improving knowledge of the species' biology and life history, and implementing education programs (DFO 2013b).

Habitat requirements and preferences differ considerably across these three species. Extremes in depth preferences are associated with Striped (50-450 m) and Northern wolffish (300 – 1,200 m), with Spotted wolffish frequenting more intermediate water depths (100-800 m). It is noteworthy, however, that Northern wolffish are considered a pure shallow water assemblage on the Flemish Cap, whereas the other wolffish species span shallow and intermediate depths (Nogueira et al 2014). In addition to depth preferences, Northern wolffish are typically found over finer substrates (sand, shell and/or pebble) (reviewed in DFO 2013b) while Spotted (Baker et al 2012) and Striped (Kulka et al 2004) species are thought by some authors to associate with rocky substrates, although some (such as DFO 2013b) indicate that Striped and Spotted species show no substrate preference.

American eels are a catadromous species that are listed as Vulnerable under the *NL ESA*. They spawn in the Sargasso Sea off Bermuda after migrating from freshwater rearing environments (COSEWIC 2012b). The larvae (leptocephalii) are passively transported on the Gulf Stream to coastal areas of North America as far north as Labrador (COSEWIC 2012b). On the continental shelf the larvae transform to glass eels which move into estuaries along the coast. In the Cabot Strait, young eels arrive in May (Dutil et al 2009). Eels then transform to the adult yellow eel phase, which they maintain through maturity. While eels occupy a variety of habitats that include freshwater lakes and rivers, coastal areas and oceanic environments, their movements are not well understood. Limiting factors for eel populations are thought to include habitat fragmentation (e.g. hydrodams), contaminants, parasites and changing environmental conditions (COSEWIC 2012b).

The white shark was assessed as Endangered in 2006 under Schedule 1 of *SARA*. Its numbers have declined by about 80 percent over 14 years in areas of the northwest Atlantic Ocean outside Canadian waters. The understanding of this species ecology and habitat use in Canadian waters remains poor (DFO 2006a), and critical habitat for this species has not been defined (COSEWIC 2006a). However the long-line fishery, which is thought to be the greatest source of human-induced mortality for this species, is not pursued in Canadian waters (DFO 2006a). Recent tagging initiatives (Ocearch 2015) are providing new and surprising insight into the movements of these animals, which range widely across the north Atlantic in areas that include at a minimum the southern, warm water extents of the Study Area.

The DFO RV Survey data support the scientific literature conclusions for wolffish distributions, including that the Northern wolffish was typically distributed in deeper waters (Figures 4.43 to 4.45). Areas of high abundance for all three species were associated with deep slope areas and the Flemish Pass. However, the Striped wolffish was more widespread, occurring in many areas of the continental shelf at lower abundance. An area of high spotted wolffish concentration was observed in the Bonavista Corridor.

Table 4.6 Fish Species at Risk or Otherwise of Special Conservation Concern

Family	Species		Status / Designation[1,2]				Population
	Common Name	Scientific Name	NL Provincial Designation	SARA Status	COSEWIC Designation	IUCN	
Anarhichadidae	Atlantic wolffish	*Anarhichas lupus*		SC	SC		AO
Anarhichadidae	Northern wolffish	*Anarhichas denticulatus*		T	T		AO
Anarhichadidae	Spotted wolffish	*Anarhichas minor*		T	T		AO
Anguillidae	American eel	*Anguilla rostrata*	V		T		NL, AO
Carcharhinidae	Blue shark	*Prionace glauca*			SC	NT	AO
Cetorhinidae	Basking shark	*Cetorhinus maximus*			SC	V	AO
Gadidae	Atlantic cod	*Gadus morhua*			E	V	NL, AO
Gadidae	Cusk	*Brosme brosme*			E		AO
Lamnidae	Porbeagle	*Lamna nasus*			E	V	AO
Lamnidae	Shortfin mako	*Isurus oxyrinchus*			T	V	AO
Lamnidae	White shark	*Carcharodon carcharias*		E	E	V	AO
Macrouridae	Roughhead grenadier	*Macrourus berglax*			SC		AO
Macrouridae	Roundnose grenadier	*Coryphaenoides rupestris*			E		AO
Pleuronectidae	American plaice	*Hippoglossoides platessoides*			T		NL, AO
Rajidae	Barndoor skate	*Dipturus laevis*				E	AO
Rajidae	Smooth skate	*Malacoraja senta*			E	E	NL, AO
Rajidae	Spinytail skate	*Bathyraja spinicauda*				NT	AO
Rajidae	Thorny skate	*Amblyraja radiata*			SC	V	NL, AO
Rajidae	Winter skate	*Leucoraja ocellata*			E, T, SC	E	AO

Family	Species		Status / Designation[1,2]				Population
	Common Name	Scientific Name	NL Provincial Designation	SARA Status	COSEWIC Designation	IUCN	
Salmonidae	Atlantic salmon	*Salmo salar*			E, T, SC	LC	NL, AO
Scombridae	Albacore tuna	*Thunnus alalunga*				NT	AO
Scombridae	Bigeye tuna	*Thunnus obesus*				V	AO
Scombridae	Bluefin tuna	*Thunnus thynnus*			E	E	AO
Scorpaenidae	Acadian redfish	*Sebastes fasciatus*			T	E	AO
Scorpaenidae	Deepwater redfish	*Sebastes mentella*			T	LC	AO
Squalidae	Spiny dogfish	*Squalus acanthias*			T	V	AO

[1] Least Concern (LC), Vulnerable (V), Near Threatened (NT), Special Concern (SC), Threatened (T), Endangered (E)
[2] Multiple designations refer to multiple populations or sub-populations
[3] Newfoundland and Labrador (NL), Atlantic Ocean (AO)

Figure 4.43 Distribution of Northern (Broadhead) Wolffish in the Study Area (Canadian RV Surveys, 2008-2012)

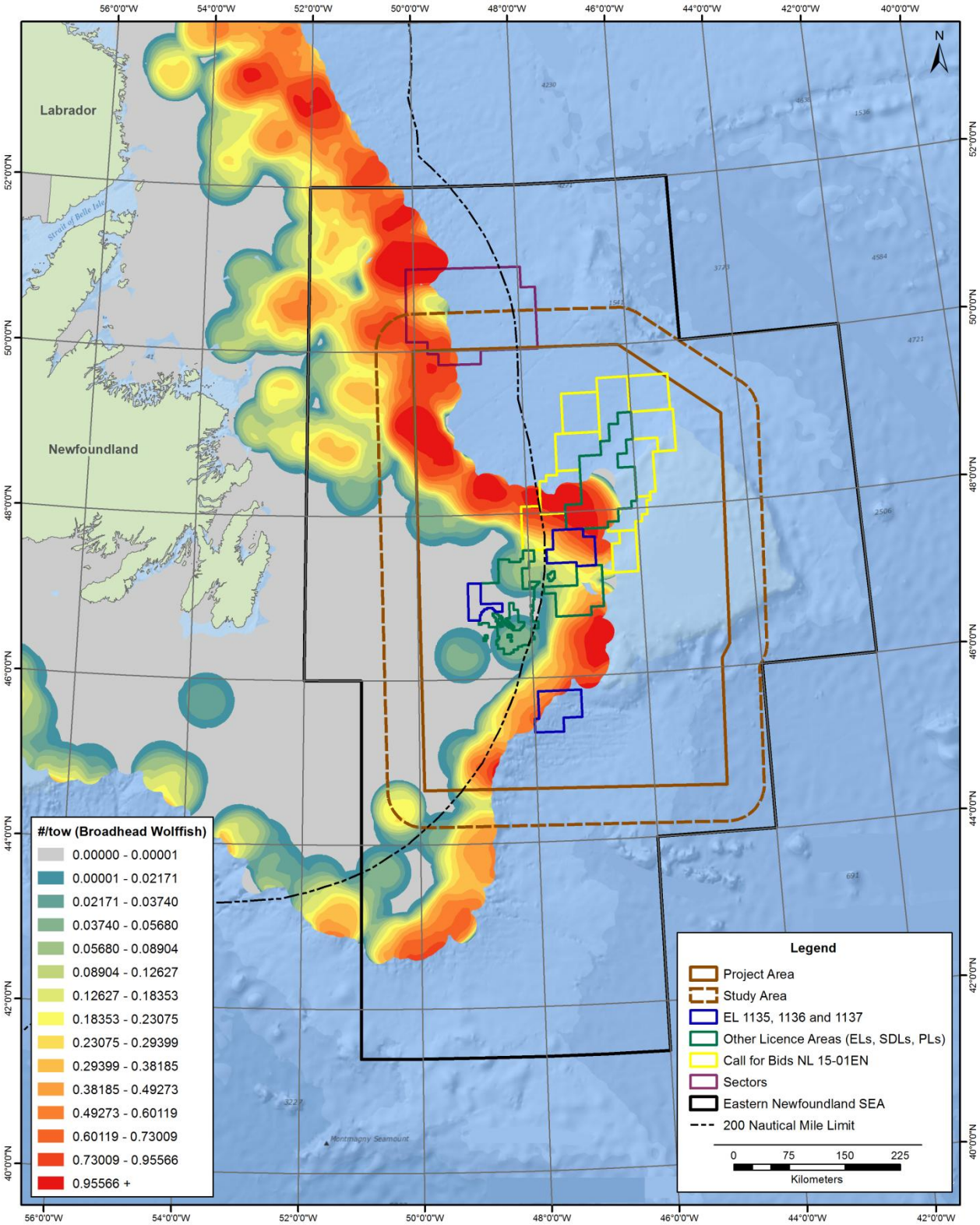


Figure 4.44 Distribution of Striped Wolffish in the Study Area (Canadian RV Surveys, 2008-2012)

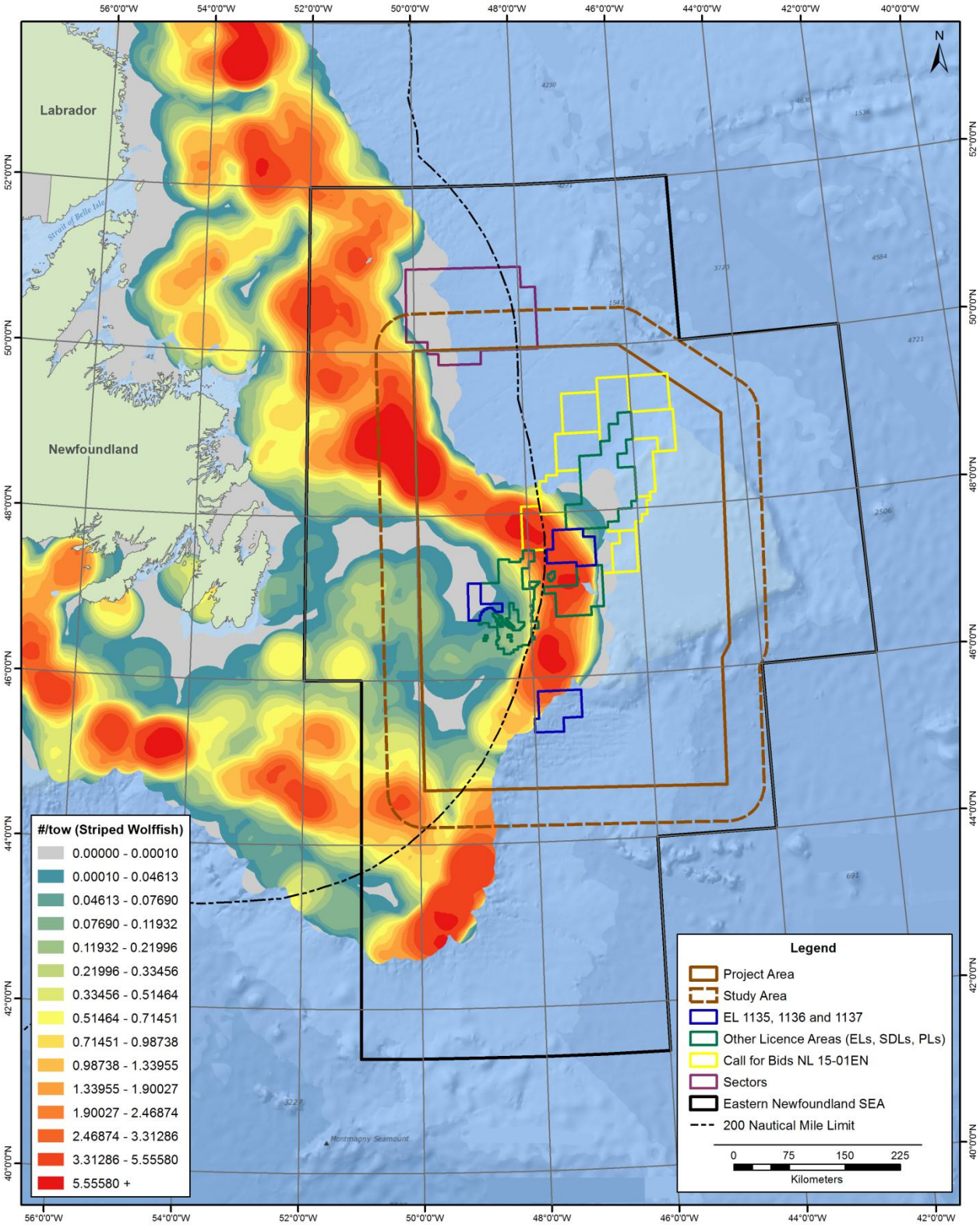
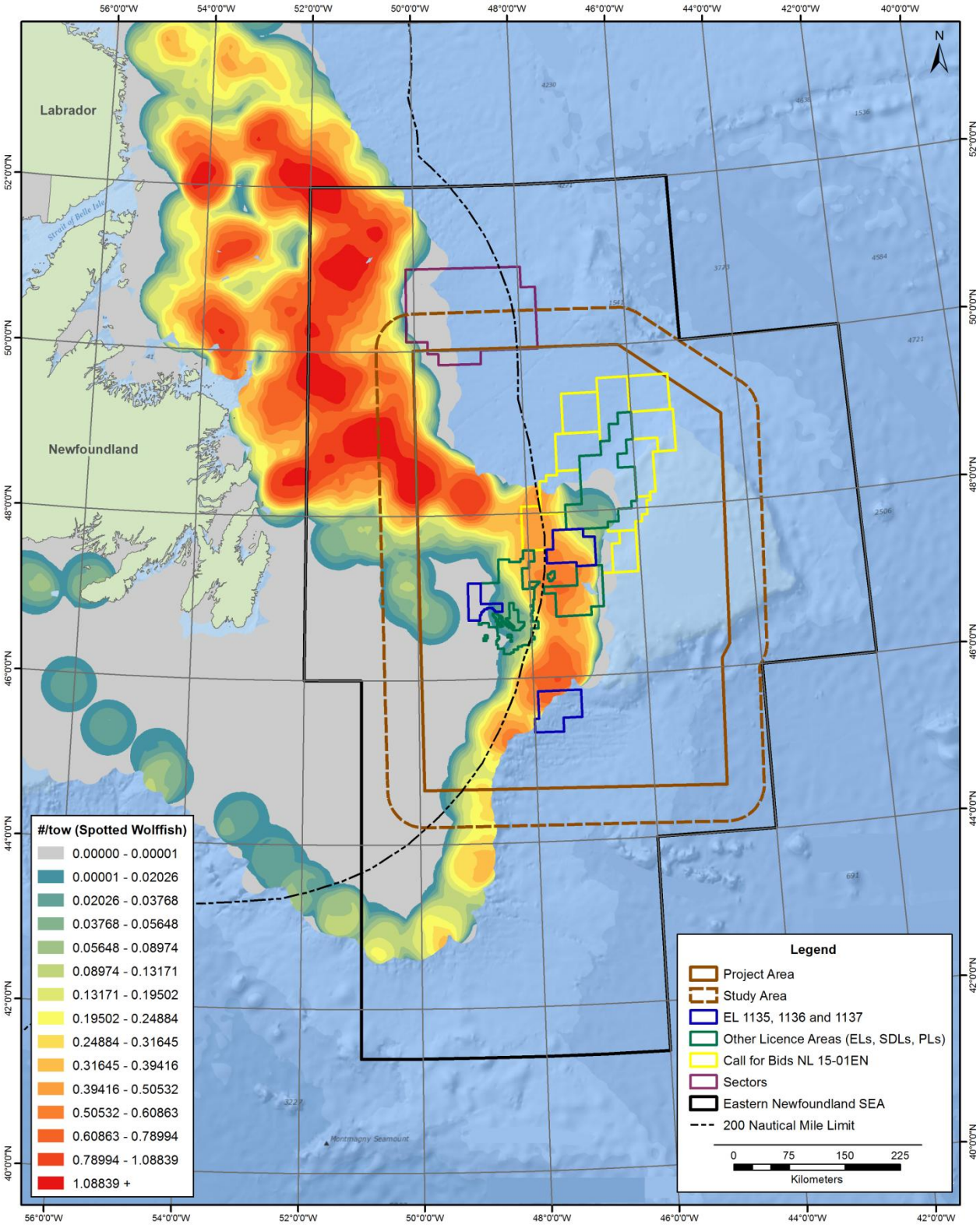


Figure 4.45 Distribution of Spotted Wolffish in the Study Area (Canadian RV Surveys, 2008-2012)



4.2.1.7 Aquatic Invasive Species

Invasive species threaten ecosystems around the globe (Molnar et al 2008). Their capacity for rapid population growth can disrupt ecosystems and their native species through processes that include predation, competition or habitat alteration. Such species can also have negative impacts economically by affecting fisheries, fouling marine infrastructure and even altering human health (Molnar et al 2008). Consequently, within the Study Area, invasive species are a concern to local fishermen (Amec 2014), where increased industrial traffic serves as a potential vector for invasive species (McKenzie et al 2010; Benoit et al 2012).

Seven invasive species have been identified in the Newfoundland and Labrador Shelf, including: the European green crab, the Japanese skeleton shrimp, the golden star tunicate, the violet tunicate, the vase tunicate, the coffin box bryozoans and oyster thief algae (Table 4.7). These species are generally thought to have greater effects on benthic coastal communities compared to the open ocean environments that characterize the Study Area (Templeman 2010).

Table 4.7 Invasive Marine Species Present on the Newfoundland Continental Shelf

Taxa	Species	Taxonomic Name	Dispersal Routes	Potential Effects
Crustacean	European green crab[1]	*Carcinas maenas*	• Spread through movement of fishing gear, and transport via ballast water.	• Prey on invertebrates. • Extremely efficient predators and colonizers.
	Japanese skeleton shrimp	*Caprella mutica*	• Spread through movement of fishing gear, offshore buoys, and boats (Cook et al 2007)	• Interferes with aquaculture operations.
Tunicate	Golden star tunicate	*Botryllus schlosseri*	• Spread through movement of fishing gear, shellfish and boats	• Interferes with bivalve larvae settlement. • Interferes with aquaculture operations.
	Violet tunicate	*Botrylloides violaceus*		
	Vase tunicate	*Ciona intestinalis*		
Bryozoan	Coffin box bryozoan	*Membranipora membranacea*	• Spread through movement of boats and planktonic larvae	• Destroys kelp beds.
Algae	Oyster thief	*Codium fragile* spp. *fragile*	• Spread through movement of fishing gear, shellfish and boats	• Replaces native species including eel grass and kelp.

Source: Modified from DFO (2014a); Matheson (2013); Templeman (2010)
[1] This is a coastal species but has been included here for completeness

4.2.1.8 Identified Important and Sensitive Ecological Environments

The Study Area includes several important and sensitive ecological habitats, some of which have been identified through protective legislation and/or management measures (such as DFO and NAFO closure areas), whereas others have been identified as Ecologically and Biologically Significant Areas (EBSAs) or Vulnerable Marine Ecosystems but have no formal protection. Protected and Sensitive Areas within and adjacent to the Study Area are discussed and mapped in greater detail in Section 4.2.4 of this EA Report, but those that have particular relevance for marine fish and fish habitat are also outlined and summarized below.

Protected Areas (Existing and Potential)

The Study Area includes no Marine Conservation Areas (administered by Parks Canada) or Marine Protected Areas (administered by DFO).

While the existing Eastern Newfoundland SEA (Amec 2014) does identify several areas protected by regulatory fisheries closures, only two of these fall within the Study Area itself: 1) the Orphan Knoll Seamount and 2) the NAFO Coral Closure Areas (Figure 4.46).

Large Ocean Management Areas

DFO, via the Canada's *Oceans Act*, has identified the *Placentia Bay / Grand Bank Large Ocean Management Area* as an area that is home to important living and non-living marine resources, areas of high biological diversity and productivity and increasing development pressures and competition for ocean space and resources (PB / GBLOMA 2013). While this designation provides no formal protection, it is a framework that promotes collaborative planning and resource management of the area.

Ecologically and Biologically Significant Areas

Other areas that are not formally protected through legislation include EBSAs. Such areas have been defined by DFO within the Placentia Bay-Grand Bank Large Ocean Management Area (Templeman 2007) and the Newfoundland and Labrador Shelf (DFO 2013c) through a ranking system of candidate areas using criteria of fitness consequences, aggregations, uniqueness, naturalness and resilience.

A number of EBSAs fall within the Study Area (Figure 4.47; Table 4.8). Those whose designations have been at least partially based on their importance and relevance for fish and fish habitat are summarized below, based on information from Templeman (2007) and DFO (2013c).

Figure 4.46 Fishery Closure Areas

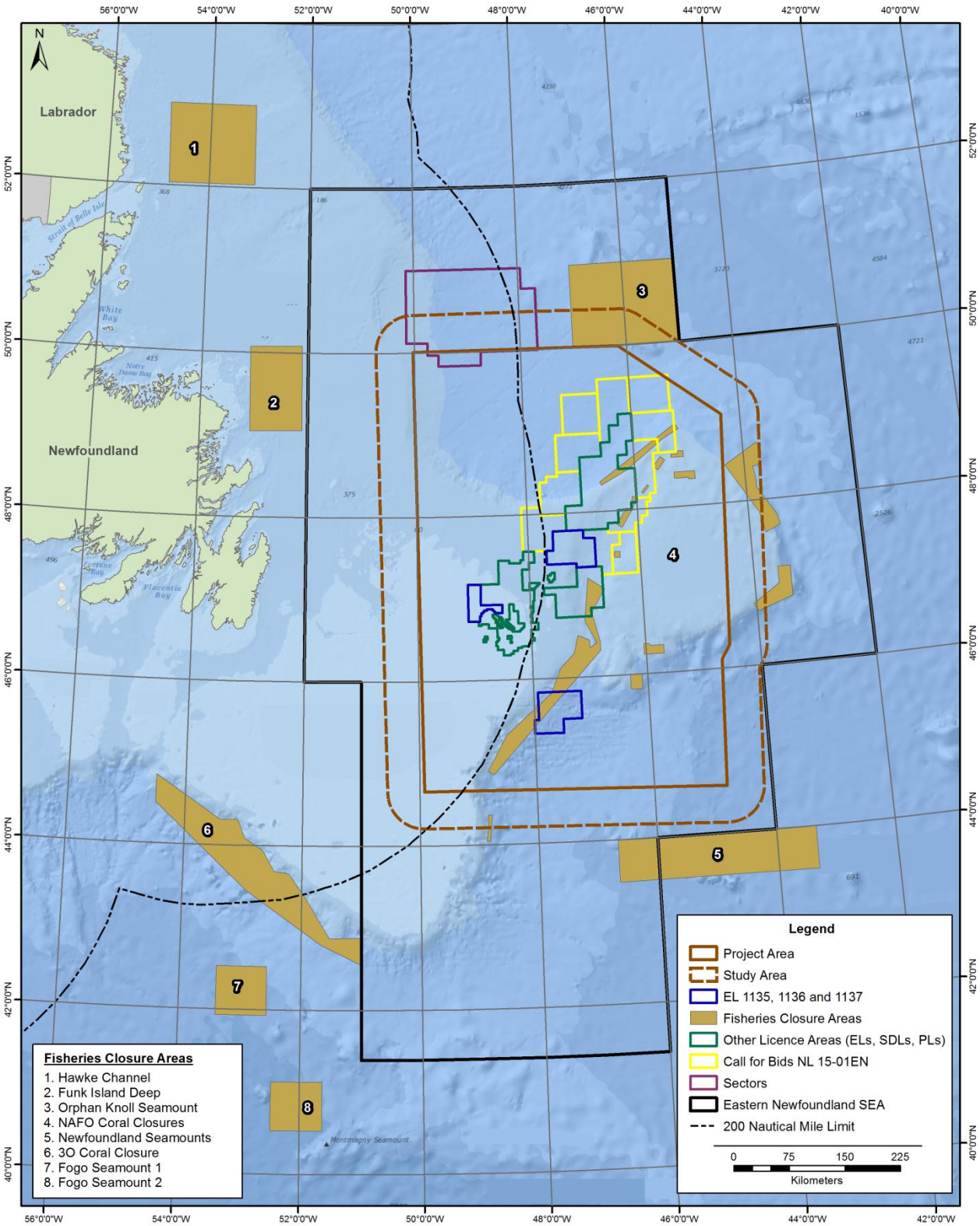


Figure 4.47 Ecologically and Biologically Significant Areas

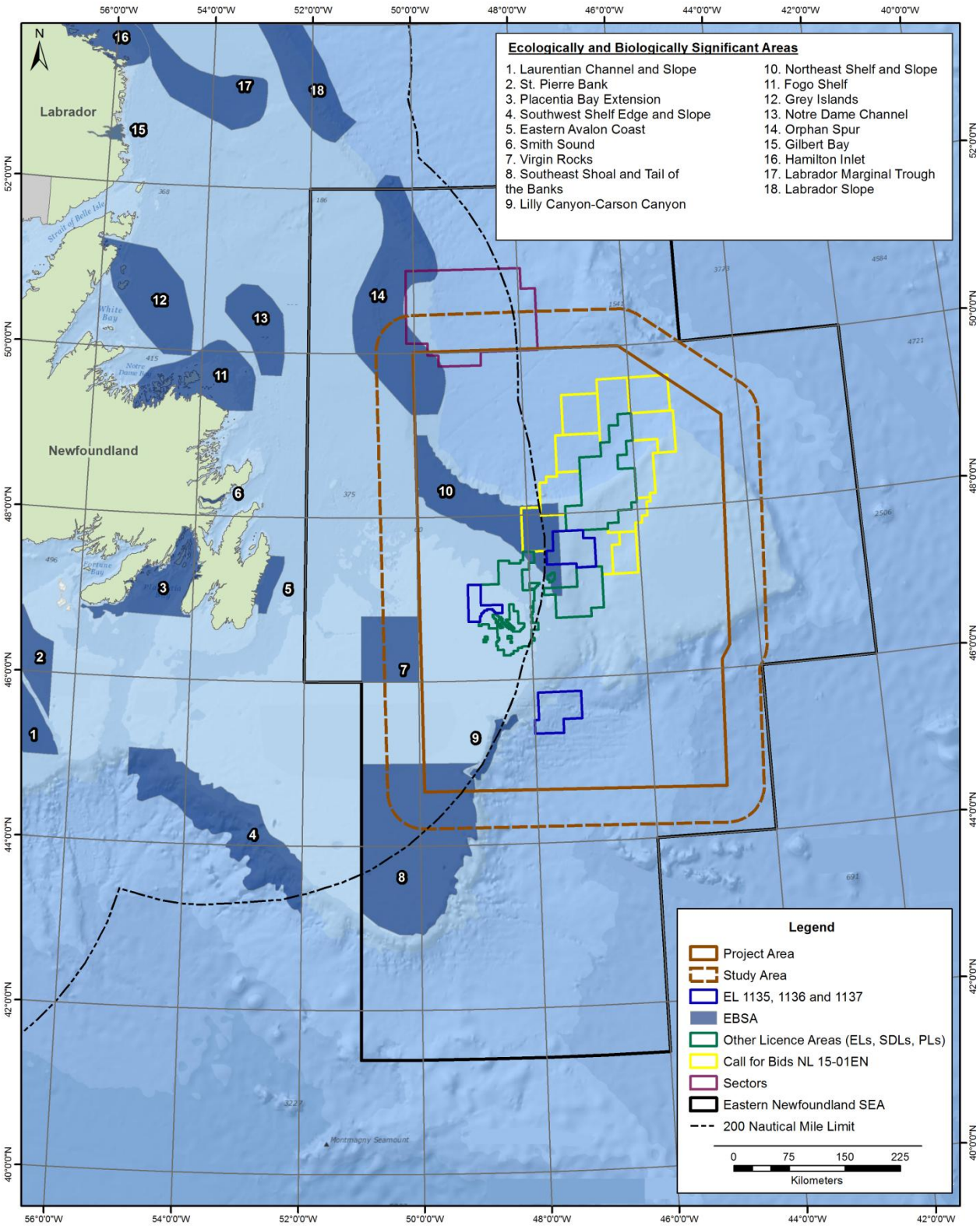


Table 4.8 Study Area EBSAs: Characteristics Relevant to Fish, Invertebrates and Macroalgae

EBSA Name	Description as it Relates to Benthic Invertebrates and Finfish
Virgin Rocks	*Finfish:* This EBSA was put in place to reflect the aggregations of capelin and other spawning groundfish that include Atlantic cod, American plaice and yellowtail flounder *Macroalgae*: This area is also a rare offshore location for macroalgae, though this feature was not listed as a reason for designation
Southeast Shoal and Tail of the Grand Bank	*Benthic invertebrates:* Wedge clams and blue mussels in this area are found at the highest densities observed across the Grand Bank *Finfish:* The importance of this region to finfish includes: • An important spawning area for capelin, American plaice, yellowtail flounder, Atlantic cod and sand lance • The capelin spawning area is a rare offshore site, while the yellowtail flounder stock is only known to spawn in this location • Yellowtail flounder and American plaice occur in high densities in this area • Striped wolffish occur at high densities at this location
Lilly Canyon - Carson Canyon	*Benthic invertebrates:* This area is recognized for its importance as a feeding and high production area for Iceland scallops
Northeast Shelf and Slope	*Finfish*: This EBSA has the highest concentrations of Greenland halibut and spotted wolffish in the region. These species aggregate in the area in the spring
Orphan Spur	*Benthic invertebrates*: This area has been identified as an area where corals occur *Finfish*: This area was defined in part by several attributes that relate to finfish including: • High species diversity • Elevated densities of witch flounder, American plaice and redfish • Elevated densities of species at risk, including northern, spotted and striped wolffish, the skates and roundnose grenadier • An important area for several species of shark

Other Ecologically Important Habitats in the Study Area

Aggregate examinations of the fish communities from DFO RV surveys also provide indication of ecologically important areas within the Study Area (Figures 4.48 to 4.50). For example, trawlable fish species richness was highest in the Flemish Pass and (surveyed areas of the) Cap as well as on the northern slope of the Grand Banks. Similarly, overall fish abundance and biomass was high in the Flemish Pass and the northern slope of the Grand Banks but the eastern Grand Bank slope was also important for measures of biomass. These areas are often coincident with other formally designated areas such as the Northeast Shelf and Slope EBSA, Southeast Shoal and Tail of the Grand Banks EBSA (biomass), some coral areas and NAFO coral protection zones (all measures). In contrast, the shallow areas of the Grand Banks (including the area within the Virgin Rocks EBSA) were relatively poor for all fish community measures, while the eastern slope of the Grand Banks was poor for richness and abundance.

Other important areas, identified in previous SEAs (LGL 2003; Amec 2014) include the “Bonavista Corridor” and the Frontal Extrusion Zone. The former is an important spawning area and migration route for Atlantic cod, American plaice and redfish. The latter is a high productivity zone located on the continental slope in the northern portions of the Study Area.

Figure 4.48 Areas of Relatively High Faunal Abundance (Canadian RV Surveys, 2008-2012)

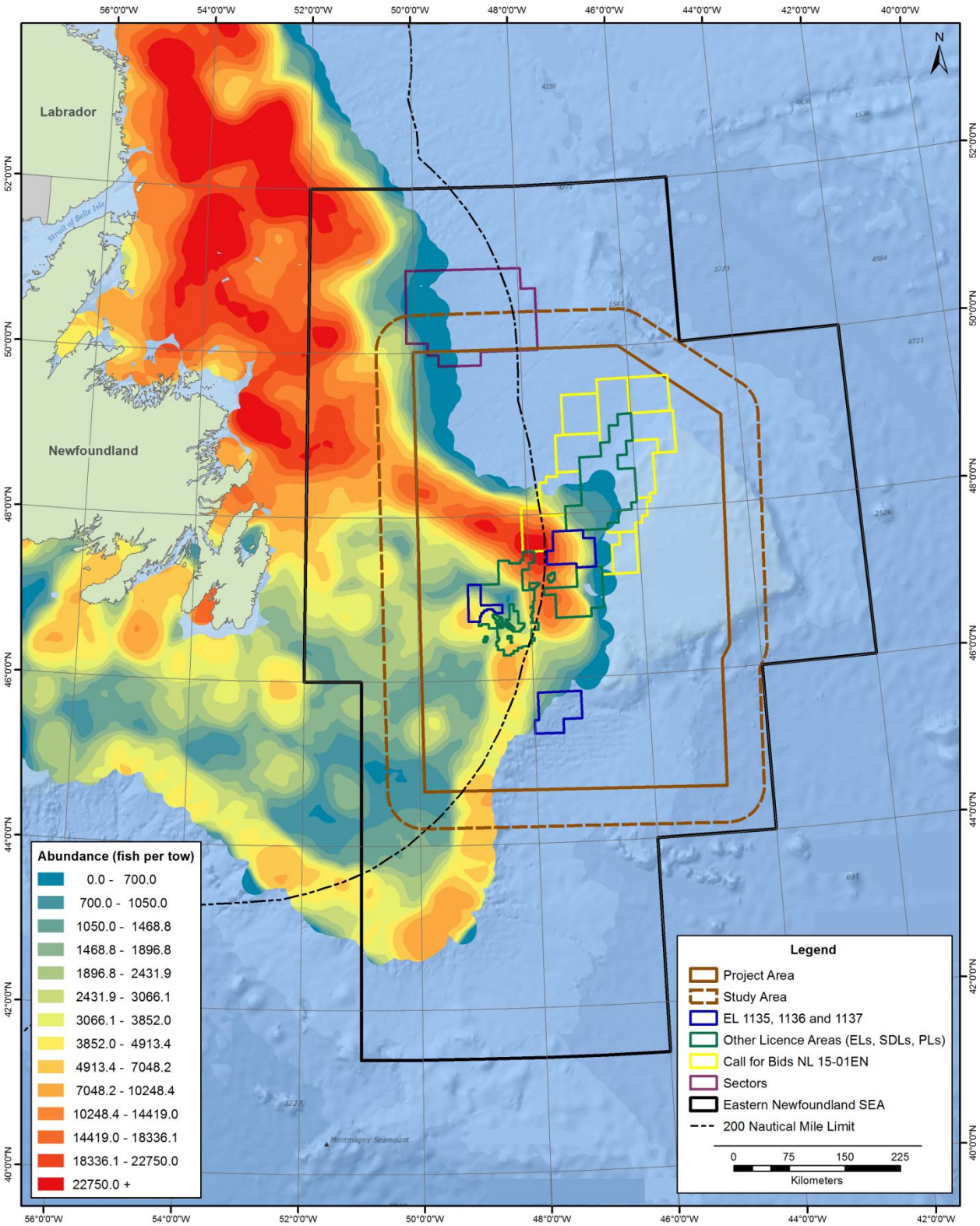


Figure 4.49 Areas of Relatively High Faunal Biomass (Canadian RV Surveys, 2008-2012)

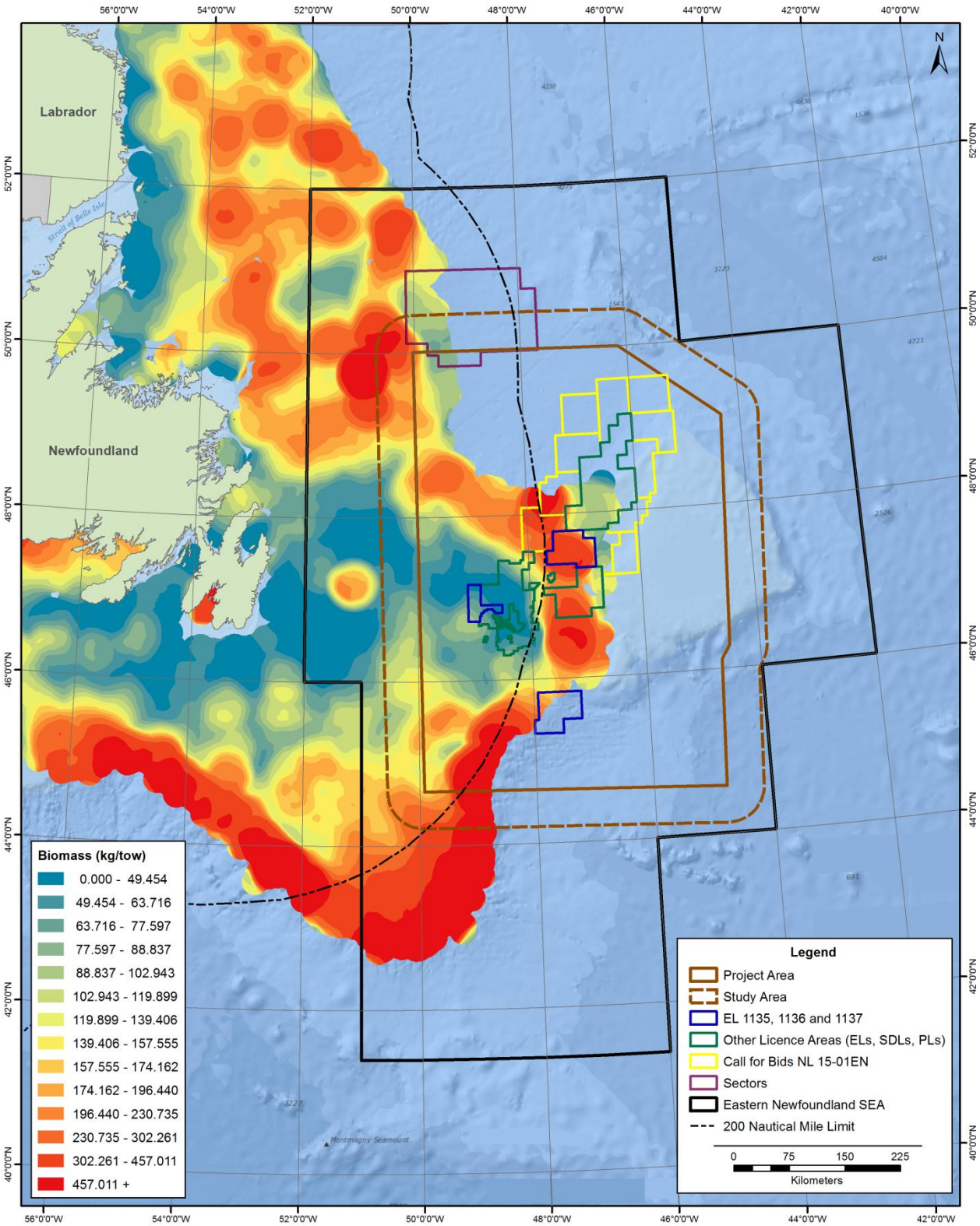


Figure 4.50 Areas of Relatively High Taxonomic Richness (Canadian RV Surveys, 2008-2012)