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Canadian Science Advisory Secretariat
Quebec Region **Science Advisory Report 2018/003**

IDENTIFICATION OF HABITAT IMPORTANT TO THE BLUE WHALE IN THE WESTERN NORTH ATLANTIC

Credit: Fisheries and Oceans Canada.

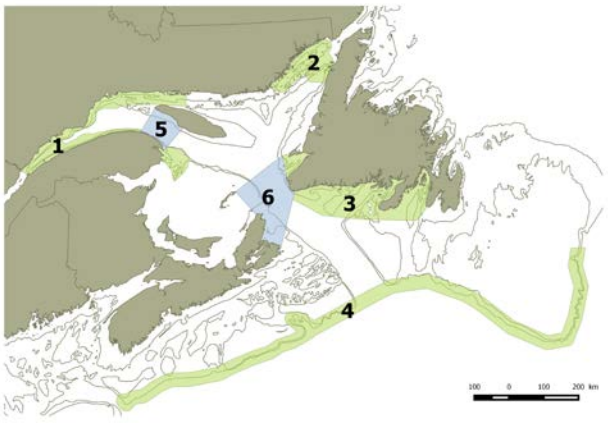

Figure 1. Polygons delimit areas in Canadian waters that are important to blue whales for foraging (green) and transit (blue): (1) lower St. Lawrence Estuary – northwestern Gulf of St. Lawrence, (2) Mecatina Trough, (3) south and southwestern Newfoundland, (4) continental shelf edge, (5) Honguedo Strait, (6) Cabot Strait.

Context:

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the Atlantic blue whale (Balaenoptera musculus) population as Endangered in 2002, and reaffirmed this status in 2012. The population is currently listed as Endangered under Canada's Species at Risk Act (SARA) and a Recovery Strategy was produced in 2010. Data gaps precluded the identification of Critical Habitat in the Recovery Strategy, which included instead a Schedule of Studies that, when completed, would allow Critical Habitat to be identified. A Recovery Potential Assessment report has not been produced for this population. However, a target of 1,000 mature individuals was set as the recovery goal for population size in the Recovery Strategy. No such target was defined for distribution range. The Species at Risk Program has requested Science advice on available information and the current state of knowledge about the habitat of blue whales in the northwest Atlantic. Specifically, the best available information on the habitat requirements of the population was requested, including a description of the habitat properties needed for successful completion of the life cycle processes necessary for survival and recovery of blue whales, a description of the functions, features and attributes of this habitat, the spatial extent of the areas likely to have these habitat properties, and the activities likely to destroy these habitat properties in the areas identified.

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, National Marine Mammal Peer Review Committee meeting, February 23 to 26, 2016. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- Commercial hunting in the North Atlantic between the late 1800's and the 1960's severely depleted blue whale populations, removing over 11,000 individuals, including approximately 1,500 individuals in eastern Canadian waters.
- Blue whales in the western North Atlantic and those in the eastern North Atlantic are currently managed as separate stocks.
- Population size and trend are unknown for blue whales in the Atlantic; however, blue whales in the western North Atlantic probably number in the low hundreds.
- Information on the current and historical seasonal distribution of blue whales comes from: 1) whaling catch records, 2) photo-identification studies, 3) land, aerial and ship-board surveys, 4) passive acoustic monitoring, 5) satellite and radio telemetry, 6) ice entrapment reports, 7) opportunistic sighting reports, and 8) species distribution modelling.
- Blue whales feed while in Canadian waters and their distribution is linked to aggregations of euphausiids (krill). Arctic krill (*Thysanoessa* spp.) and northern krill (*Meganyctiphanes norvegica)* are their main preys, but the species consumed likely varies seasonally, geographically, and among individuals. As a result, habitats important for blue whales were identified using information on blue whale distribution in combination with that on areas of observed or predicted prey (krill) aggregations.
- Evidence from blue whale diving behaviour, and from krill and blue whale distributions indicate that in the St. Lawrence Estuary (SLE) and northwestern Gulf of St. Lawrence (nwGSL), blue whales preferentially seek krill aggregations within 80-100 m from the surface, although they may feed at deeper depths in other areas. Krill aggregations are generally correlate with abrupt topography, including slopes, channel and canyon heads, vertical current, convergent surface currents, and to a lesser extent persistent phytoplankton concentrations.
- Whaling data indicate a historical distribution in the western North Atlantic extending from Davis Strait south to northern Florida. Whether the current range of blue whales in the western North Atlantic is smaller than that historically is unclear given the generally limited data available for most areas except the SLE and nwGSL. There are still occasional reports of blue whales throughout their historical range.
- In general, blue whale seasonal movements follow a north-south pattern where feeding occurs in productive waters at high-latitudes and breeding/calving likely takes place during winter in warmer, less productive waters at low latitudes. In the western North Atlantic, wintering areas of blue whales are poorly defined; satellite telemetry, passive acoustic monitoring, and whaling data suggest that it is relatively diffuse, and includes the Gulf of St. Lawrence (GSL), southwestern Newfoundland, and Scotian Shelf, as well as the mid-Atlantic Bight off the U.S. coast and warm and deep oceanic waters off this area. Whether breeding occurs in the latter region is unknown. There are also indications that part of the population remains in Canadian waters year-round.
- Multiple data sources indicate that a near-continuum of habitat suitable to foraging blue whales occur in the shelf, slope and deep waters of the Lower SLE and nwGSL between Tadoussac and Mingan along the north shore, and the Gaspé Peninsula along the south shore. It is estimated that 20 to 100 blue whales use areas within this region each year, with some using it year-round.

- Satellite telemetry and passive acoustic monitoring indicate that blue whales enter and leave the GSL through Cabot Strait, and access the nwGSL and SLE via the Honguedo Strait located between Anticosti and the Gaspé Peninsula.
- There is also evidence for a nearly year-round presence of blue whales in the waters off southwestern Newfoundland, and along the continental shelf edge south of Nova Scotia, Newfoundland and the Grand Banks.
- Southern Newfoundland, the nwGSL, Mecatina Trough, western Scotian Shelf and to a lesser extent Davis Strait were historically important areas of concentration for blue whales, based on reported harvests or sightings during whaling activities. An area located in the nwGSL to the northwest of Anticosti, where blue whales occurred regularly in the 1980s and early 1990s but are now seen only occasionally, is also considered an area of historical concentration. There are indications from observed or predicted krill aggregation areas and sightings data that several of these historically important areas remain suitable foraging habitat for blue whales. A possible exception is western Scotian Shelf. The current importance of Davis Strait for blue whales remains uncertain given the lack of data.
- Given the evidence provided above and using the bounding box approach, four areas were identified as important foraging (and potentially socializing) areas for blue whales: the lower SLE and nwGSL, the shelf waters south and southwest of Newfoundland, Mecatina Trough area, including the head of the Esquiman Channel, and the continental shelf edge of Nova Scotia, Newfoundland and the Grand Banks. Two areas were identified as transit corridors: the Honguedo and Cabot Straits (Figure 1).
- Important features and attributes of these areas include sufficient quantity and quality of prey, access to transit corridors, sufficient physical space to freely maneuver, water of sufficient quality as to not result in loss of habitat function, and an acoustic environment that does not interfere with communication or navigation, or impede use of important habitat by blue whales or their prey (Table 1).
- Anthropogenic activities that are likely to result in the loss of functions of these important habitats include those that would result in reduced prey availability or accessibility, acoustic disturbance, environmental contamination, and physical disturbance (Table 2).
- Based on new research, shipping noise is predicted to mask the main call types of blue whales and to reduce their potential communication space, with effects increasing with proximity to shipping lanes and density of traffic. Currently, most of the SLE and GSL is considered quiet for blue whales low-frequency communication band. However, several important habitats of blue whales occur in proximity to shipping lanes.
- There remain uncertainties about the diet of blue whales in areas other than the ESL and GSL, the relative proportion of the population occurring in Canadian waters in general or in specific regions, importance of deep oceanic waters and shelf break areas for blue whales, and location and extent of wintering areas. Further studies are needed to determine the characteristics that make an area attractive to blue whales, minimum energy requirements for successful reproduction, and amount of disturbance that blue whales can sustain before their body condition and fitness are affected.
- Climate change may also affect habitat functions by altering prey availability and physical properties of the ocean. Anthropogenic activities and their effects on habitat functions need to be managed in the context of this ongoing issue.

- It is unknown whether the important habitats identified in this report are sufficient to ensure the survival of the northwest Atlantic blue whales and to meet population recovery goals outlined in the Recovery Strategy. There is a need to expand research efforts outside of the summer period, and to offshore waters and other areas where blue whale sightings are limited but where significant krill aggregations suggest they may be important to blue whales.

BACKGROUND

The blue whale is ubiquitous, ranging in all the world oceans. In the North Atlantic, stranding and sighting data indicate a distribution ranging from Iceland, Spitzbergen and Davis Strait, south to New England, the Caribbean, and West Africa (Senegal, Mauritania, Canary Island and Cape Verde). However, the genetic structure and interconnections among these areas of potential aggregation are not well understood. While blue whales in the western North Atlantic are currently managed separately from those in the eastern North Atlantic, data are insufficient to determine whether they constitute a single panmictic population distributed across the North Atlantic or distinct populations. However, photo-identification and satellite telemetry data indicate that blue whales seen during the ice-free period in eastern Canada, eastern U.S. and West Greenland/Davis Strait belong to the same population.

Intensive whaling has considerably reduced blue whale populations. In the North Atlantic, at least 11,000 blue whales were taken between the late 1800's and the 1960's, including approximately 1,500 individuals in eastern Canadian waters. Although the exact population size for the western North Atlantic blue whales is unknown, it is currently estimated to be in the low hundreds, with no estimate of population trends. The current population therefore represents a fraction of historic abundance.

The reproductive rate of blue whales in the western North Atlantic is unknown as few calves have been observed off eastern Canada in general, or in the St. Lawrence Estuary (SLE) and Gulf of St. Lawrence (GSL) specifically, over the past 37 years. Whether the small number of calf observations is because females wean their calves before entering these waters, use areas other than the SLE and GSL when with their calf, or simply have abnormally low reproductive success is unknown. Habitat degradation through shortage of food, increase in anthropogenic noise, introduction of persistent marine contaminants, or occurrence of human activities limiting access to foraging habitat may affect body condition, health and fitness of blue whales. Collisions with ships and sporadic natural mortality events such as ice entrapments can also remove one or several individuals at a time, contributing to limited population growth.

ANALYSIS

Blue Whale Foraging Ecology and Habitat Requirements

Habitat requirements are poorly understood for blue whales, but probably vary according to age, sex, size, and reproductive status as a result of different energy requirements and survival strategies. Like in most marine mammals, the distribution of blue whales is likely dictated by key drivers such as food requirements and availability, sea ice, and to a lesser extent in the case of blue whales, predation risks.

The main activity of blue whales while in Canadian waters is foraging. A study conducted in the SLE indicates that blue whales spend on average 69% of their time foraging during the period from July to September, with the majority of their foraging effort occurring during nighttime. In the fall (September-November), satellite telemetry data indicates that foraging likely remains a

predominant activity, occupying 60-75% of the time budget of blue whales. Whether this foraging schedule prevails in the spring (March-June) is unknown as no comparable data are available.

Blue whales are stenophageous predators, relying almost exclusively on euphausiids (or krill) as their sole diet. Data on blue whale diet in the western North Atlantic are limited, but confirm their strong reliance on krill in Canadian waters. The species consumed likely varies among regions depending on local environmental conditions that affect the relative abundance of the various krill species. In the SLE and GSL, stable isotopes indicate a diet dominated by the cold-water Arctic krill *Thysanoessa* spp. However, variability exists among individuals and seasons, and the consumption of northern krill *Meganyctiphanes norvegica,* a species found at deeper depths and in warmer waters, appears to have increased since the early 2000's. While there are little data available for areas outside the SLE and GSL, indirect evidence for a diet likely composed of northern krill on the Scotian Shelf, and of Arctic krill in waters around Newfoundland come from information known about the diet of other rorquals, studies of fish-prey relationships, and data gathered for the establishment of a potential krill fishery.

Studies documenting feeding attempts by individual blue whales, or coupling surface observations of blue whales with hydroacoustic mapping of krill densities by species indicate that prey depth strongly interplays with prey density and biomasses in defining habitat quality and the bioenergetics of foraging, and thresholds beyond which a prey patch may no longer be of interest to a blue whale. In the SLE and nwGSL, blue whales associate more strongly with prey patches consisting of Arctic krill than of northern krill, and with prey patches located within 80-100 m from the surface, but not necessarily with the highest biomasses or integrated density of krill aggregations. This does not preclude that blue whales may exploit northern krill or dive deeper in this or other areas.

Available data for Identification of Important Habitat

This analysis aimed to gather and review available data relevant for identifying important blue whale habitat off eastern Canada. Information on historical and current blue whale seasonal distribution and areas of concentration in eastern Canadian waters come from: 1) whaling catch records, 2) photo-identification studies, 3) land, aerial and ship-board surveys, 4) passive acoustic monitoring efforts, 5) satellite and radio telemetry, 6) ice entrapment reports, 7) opportunistic reports, and 8) species distribution modelling.

Data on krill distribution for areas outside of the SLE and GSL are generally lacking, but predictions using krill hydroacoustic survey data from the SLE and GSL with static and dynamic environmental variables were used to identify areas where significant krill aggregations are likely to occur throughout eastern Canadian waters (Figure 3: layer 'Model Krill Occurrence'). Similarly, given the limited data available on blue whale distribution outside of the SLE and GSL (Figure 3: layer 'Blue Whale Sightings'), species distribution models were developed to predict suitable blue whale habitat based on presence-only blue whale sightings data in combination with environmental variables that impact the distribution of blue whales.

Habitats important for blue whales were identified using sources of information on blue whale occurrence mentioned above, in combination with the information available on observed or predicted areas of prey (krill) aggregations.

Important Habitat Identified

Blue whale distribution in the western North Atlantic changes seasonally, with a portion of the population migrating south during winter, and part of the population remaining in Canadian

waters year-round. Globally, blue whales likely occur from Davis Strait south to the Gulf of Maine including Canadian waters during the feeding season, and at a minimum, from the SLE and GSL south to South Carolina, USA, during winter. Limited survey efforts in the extremes of the blue whale distribution prevent a clear definition of their seasonal range. Whaling data indicate a historical distribution extending from Davis Strait south to northern Florida. Whether the current range of Northwest Atlantic blue whales is smaller than the historical range is unclear given the generally limited data available for most areas except the SLE and northwestern GSL (nwGSL). There are still occasional reports of blue whales throughout their historical range, with a few sightings reported off western Greenland, and documented winter movements by two satellite-tagged individuals south to South Carolina (Figure 2).

Blue whales use Canadian waters mainly for feeding, although other behaviours such as socializing and mating may also occur. Based on the available data (described above) and using the bounding box approach, four areas in eastern Canadian waters were identified as important foraging (and potentially socializing) habitat for blue whales: the Lower SLE and nwGSL (zone 1), the shelf waters south and southwest of Newfoundland (zone 3), Mecatina Trough area, including the head of the Esquiman Channel (zone 2), and the continental shelf edge of Nova Scotia, Newfoundland and the Grand Banks (zone 4) (Figure 1). With the exception of the Mecatina Trough area, multiple data sources indicate that blue whales use these areas year-round, although likely less during winter as a result of departure of some individuals to southern latitudes. In addition, two areas were identified as transit corridors that provide access to important habitat: the Honguedo Strait (zone 5) and Cabot Strait (zone 6) (Figure 1).

There is considerably more information on blue whales in the more accessible inshore waters of the SLE and nwGSL than in any other regions of Atlantic Canada. In those two regions, habitat use is also better documented from June and October than at other times of the year. The perception until now was that the main area of concentration for blue whales in Canadian waters was the SLE and nwGSL. This area was, and remains, unequivocally important for blue whales, with a minimum of 20 to 100 blue whales using this area each year. Multiple data sources (all but ice-entrapment data) indicate that a near-continuum of habitat suitable to foraging blue whales occur in the shelf, slope and deep waters of the lower SLE and nwGSL between Tadoussac and Mingan along the north shore, and all along the Gaspé Peninsula on the south shore near Matane / Les Méchins, and between Rivière-au-Renard south to the Shediak Valley and offshore to the American and Orphan banks (zone 1; Figure 1). Passive acoustic monitoring and anecdotal blue whale sightings as well as more systematic survey efforts indicate that blue whales use the SLE and nwGSL nearly year-round. The area located to the northwest of Anticosti near Mingan was used regularly by blue whales in the 1980’s and early 1990’s, but is now only occasionally used, despite the availability of krill aggregations in the region. In the southern GSL, passive acoustic monitoring, prey densities, local oceanography and ice entrapment data highlight the area located off St. Georges Bay (southwestern Newfoundland) as another habitat important for blue whales (zone 3).

Whaling data suggest that blue whales were relatively abundant on the western Scotian Shelf, in southern Newfoundland (zone 3) and in the Mecatina Trough area (zone 2) and to a lesser extent in Davis Strait. After the whaling period, survey efforts in these areas have been limited. However, there are indications from observed or predicted krill aggregation areas and sightings data that several of these historically important areas remain suitable foraging habitat for blue whales. A possible exception is western Scotian Shelf. Current importance of Davis Strait for blue whales remains unknown given the lack of data.

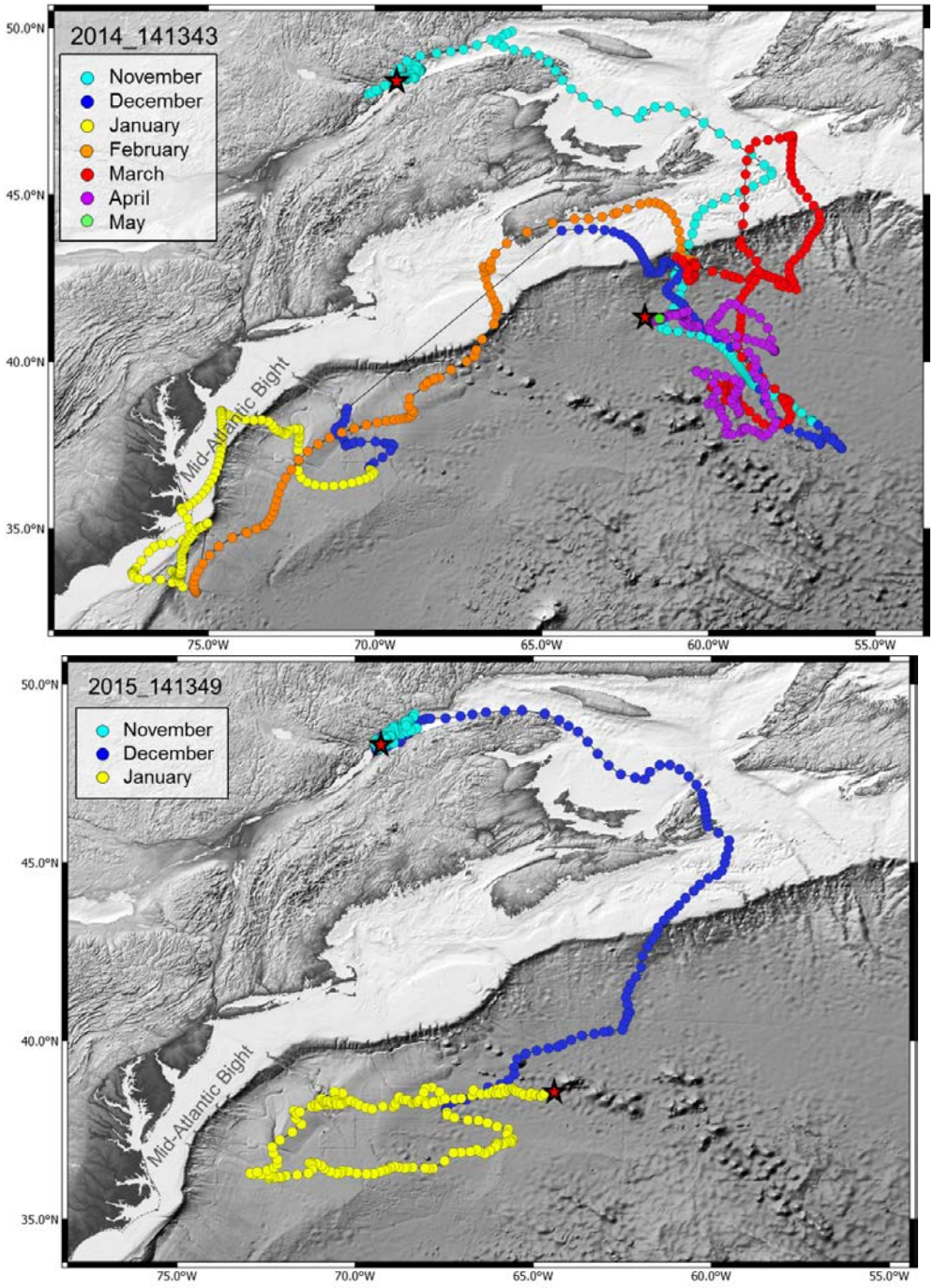

Figure 2. Seasonal movements of two female blue whales tagged in November of 2014 (B244 Upper panel) and 2015 (B197 Lower panel) in the St. Lawrence Estuary, Quebec. Stars indicate where tag was deployed in the St. Lawrence Estuary, and where transmissions ceased (1 May 2015 and 30 January 2016, respectively) off the mid-Atlantic Bight.

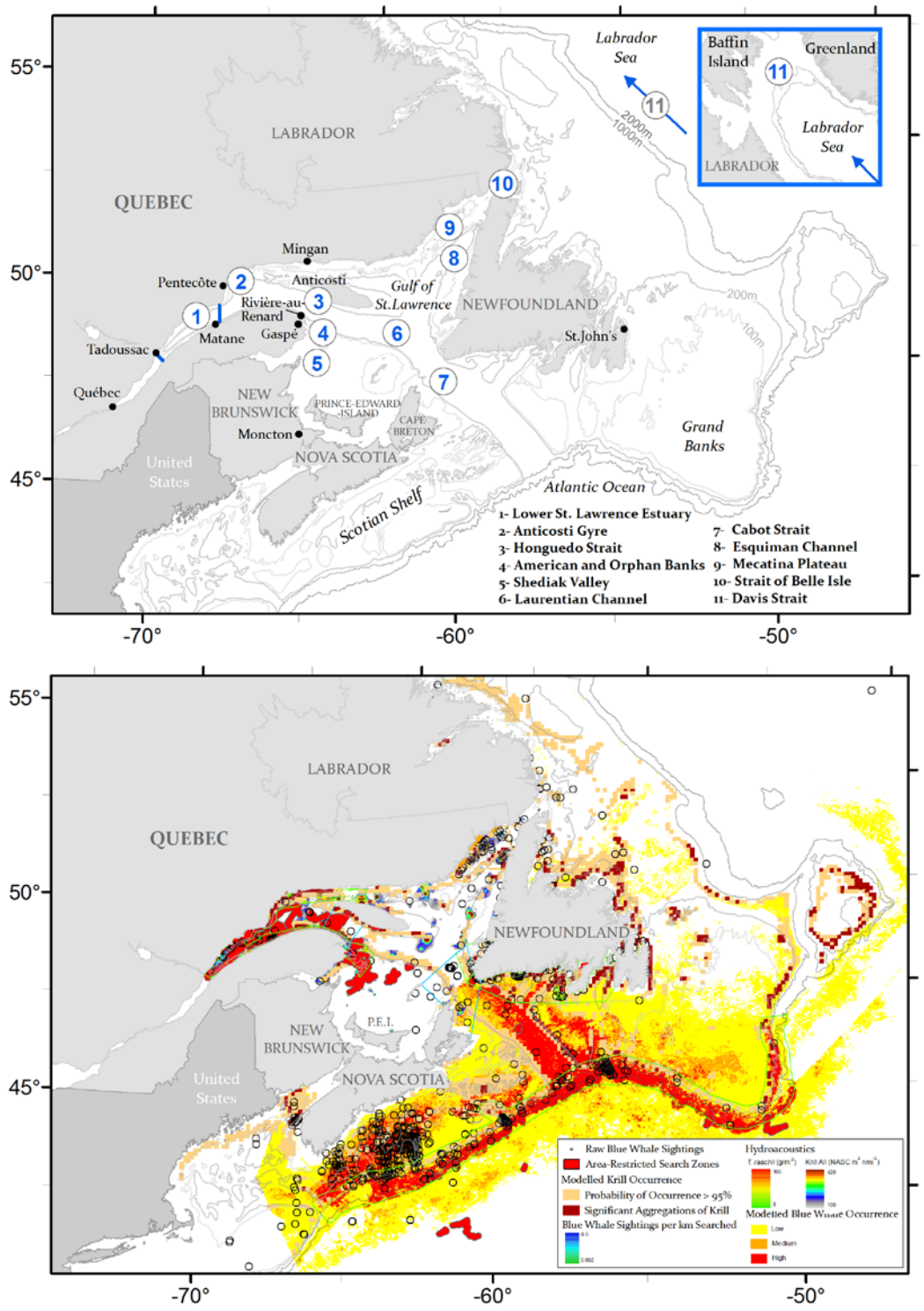

Figure 3. Study area (top panel), including major data sources that have contributed to define the relative importance of habitats (lower panel). An interactive pdf of this map is presented in appendix. To visualize the data, double-click the vocatmap to open in Acrobat. Select the double diamonds in the navigation tools on the left panel. The different data layers can be selected or deselected. Polygons delimit areas important to blue whales for foraging (green) and transit (blue) (see also Figure 1).

Similarly, observed or predicted krill aggregation areas and sightings data, along with passive acoustics data suggest that the continental shelf edge south of Nova Scotia, Newfoundland and the Grand Banks is also an important habitat for foraging blue whales, which appears to be used nearly year-round.

Satellite telemetry and passive acoustic monitoring indicate that blue whales enter and leave the GSL through Cabot Strait, and access the nwGSL and SLE via the Honguedo Strait located between Anticosti and the Gaspé Peninsula (Figure 1). Satellite telemetry data has identified these two areas as bottlenecks where there is an obliged transit for the animals to access some important habitats.

Satellite telemetry provides evidence for north-south seasonal movements of blue whales in the western North Atlantic, whereas passive acoustic monitoring (PAM) data, systematic surveys and anecdotal reports indicate that a portion of the population remains in Canadian waters throughout the year. While wintering areas remain poorly defined and more information is required to delineate its boundaries, they would include: the GSL, northwestern Newfoundland, and the Scotian Shelf, as well as the mid-Atlantic Bight off the U.S. coast, and warm and deep oceanic waters off this area (Figure 2). Whether breeding occurs in this latter area is unknown. Movement towards subtropical, warmer waters for breeding or calving may contribute to reducing energy expenditures of calves, and that of the fasting and nursing mothers, in addition to reducing risks of ice entrapment.

Functions, Features and Attributes of Important Habitat

The habitat identified as important to blue whales serve various functions, including feeding/foraging, socializing, and likely breeding/calving. The features and attributes associated with each of these functions are listed in Table 1. They mainly relate to blue whale prey (krill) and processes leading to krill aggregation, and to physical properties of the habitat allowing blue whales to successfully forage or communicate.

Abrupt changes in bottom depth, including slopes and channels, and surface circulation features such as convergent currents and to a lesser extent persistent phytoplankton concentrations are features of the habitat often associated with krill aggregations. Multi-frequency hydroacoustic surveys in the SLE and GSL over several years and at different times of the year have determined that significant krill patches aggregate in the Laurentian Channel and along the north and south shores of the SLE, in the Pentecôte area at the mouth of the SLE, in the western Anticosti Gyre and to the northeast of Anticosti Island, and along the Gaspé peninsula and off Gaspé (Figure 3: layers ‘Krill All Hydroacoustics’ and ‘*T. raschii* Hydroacoustics’).

Activities likely to Destroy Important Habitats

Activities likely to result in the destruction of the biophysical functions, features and attributes of the important blue whale habitats identified here are summarized in Table 2.

There is only a limited understanding of what constitutes an attractive food patch for a blue whale, and thresholds beyond which exploitation is no longer profitable. By reducing krill densities and biomasses, a fishery may affect habitat functions by lowering local biomass density below a threshold of profitability, rendering it unattractive to a blue whale, or so that time to depletion below this threshold is reduced, forcing the animal to move to an alternative prey patches earlier than in a non-exploitation scenario.

Whale-watching is a prominent activity in the Lower SLE, an important habitat for blue whales. New research indicates that vessels, when present within 400 m from a blue whale, may reduce

prey access by inducing a 35-42% reduction in the time available to blue whales at depth for foraging, through shortening of time at surface for breathing, and dive duration.

Table 1. Functions, features and attributes of habitat considered important for blue whales in the western North Atlantic.

Life stage	Function	Feature(s)	Attribute(s)
All Adult females and calves Adult males and females	Feeding/Foraging Rearing Courtship/mating	Prey (*Thysanoessa* spp. and *Meganyctiphanes norvegica*) Features contributing to krill aggregations and primary productivity, such as spatiotemporal variability of the circulation, including surface currents, topography and krill swimming behaviour	Krill in densities and of quality adequate to support life cycle and the population (e.g., in the SLE and GSL, krill aggregations at depth < 100 m from the surface)
All Adult females and calves Adult males and females	Feeding/Foraging Rearing Courtship/mating Transit/Migration	Acoustic Environment	Received sound levels below a level that would impact acoustic social communication, passive detection of prey or navigation, or impede use of important habitat by blue whales or their prey.
All Adult females and calves Adult males and females	Feeding/Foraging Rearing Courtship/mating Transit/Migration	Physical Space	Enough space to maneuver in vertical and horizontal planes, and not alter normal behaviour at and below the surface
All Adult females and calves Adult males and females	Feeding/Foraging Rearing Courtship/mating Transit/Migration	Water and Air	Sufficient water quality to sustain prey species, and air quality to not cause adverse health effects or result in loss of function
All Adult females and calves Adult males and females	Feeding/Foraging Rearing Courtship/mating Transit/Migration	Access corridor	Free access to obliged transit corridors leading to the Estuary or the Gulf of St. Lawrence (e.g., Cabot Strait, Honguedo Strait)
Adult females and calves	Rearing	Water Temperature	Oceanographic and atmospheric processes providing the Gulf Stream with its thermal and circulation properties

New research indicates that shipping noise is predicted to mask the two main call types of blue whales and to reduce their potential communication space, with effects increasing with proximity to shipping lanes and density of traffic. Currently, most of the SLE and GSL is considered quiet for blue whales low-frequency band. However, several habitats considered important for blue whales occur in proximity to shipping lanes (all except no. 4 on Figure 1).

Other activities that have the potential to destroy important habitat include those associated with oil and gas exploration and coastal development (e.g., port construction, etc.), particularly those generating extremely powerful sounds, sometimes over prolonged periods. These activities and the noise they produce may prevent blue whales from accessing important habitats, or may modify their attributes by affecting the behaviour and distribution of krill and thus, their availability to blue whales.

Table 2. Activities that have the potential of affecting functions, features or attributes of habitats important to blue whales.

Threat	Activity	Effect Pathway	Function Affected	Feature Affected	Attribute Affected
Reduced prey availability	Capture and removal of prey species (e.g., a plankton fishery) Other activities that are detrimental to habitat of prey	Reduction in abundance and availability of prey	Feeding and foraging	Quantity and quality of prey	Krill stocks (*Thysanoessa* spp. and *Meganyctiphanes norvegica*) sufficient to support the population
Acoustic disturbance	Vessel traffic Acute and chronic in-water and/or land-based industrial sounds (e.g. pile driving, production drilling etc.) Seismic surveys using airgun arrays Military and commercial low- and mid-frequency sonars	Interference with hearing and communication or alterations from normal behaviour Acoustic disturbance resulting in loss of habitat availability or function	Feeding and foraging Reproduction, socializing, resting	Acoustic environment	Ambient noise levels that allow efficient acoustic social signaling and do not impede use of important habitat by blue whales
Environmental contaminants	Deposit of deleterious substances into marine environment (multiple sources could include ocean dumping, industrial developments and persistent vessel discharges in and around critical habitat)	Loss of prey or reduction in prey quality	Feeding and foraging Reproduction, socializing and resting	Prey quantity and quality Water and air	Sufficient water quality to sustain prey species and maintain access to area of prey aggregations Air quality at levels not causing adverse health effects for prey or blue whales
Physical disturbance	Vessel traffic in close proximity to whales	Reduction of physical space available to whales	Feeding and foraging Reproduction, socializing, resting	Physical space	Enough space to maneuver in vertical and horizontal planes, and not alter normal behaviour at and below the surface

Sources of Uncertainty

Most of our understanding of the foraging ecology of blue whales in the western North Atlantic comes from the SLE and nwGSL. Although it can be assumed that krill remain the primary focus of foraging efforts of blue whales in other regions and throughout the year, the species targeted are likely to vary among regions within eastern Canadian waters, and among seasons. However, these assumptions should be examined and the importance of other species of krill quantified.

There is evidence for blue whales vacating what appears to be a suitable foraging habitat off northwest Anticosti near Mingan. This apparent conflict emphasizes the complexity of the foraging energetics of blue whales and underscores several data gaps, including the characteristics that make an area attractive to blue whales, minimum energy requirements for successful reproduction, and the amount of disturbance that blue whale can sustain before their body condition and fitness are affected. A better understanding of area-specific diet and foraging energetics may also bring perspective and help predict effects of climate variability on blue whale distribution, survival and recovery.

There also remains considerable uncertainty about the number of blue whales in this population, the relative proportion that occur in Canadian waters in general and within specific regions, the relative importance of deep oceanic waters located off the shelf break both for feeding and breeding or calving, and the location and boundaries of wintering areas. Whether mating occurs in Canadian waters is uncertain; the detection of tonal calls, which are thought to be produced by males in a breeding display context, raises questions about this additional function for habitats in Canadian waters. There is also a need to increase research efforts in offshore waters and other areas where blue whale sightings have been limited, but where the occurrence of krill aggregations or blue whales is predicted to be high. Analyses of the acoustic records for instruments that are currently deployed in eastern Canada will provide some insights into blue whale occurrence in areas where research efforts has been so far limited.

CONCLUSIONS AND ADVICE

The six habitat areas identified in this report are considered important for the survival and recovery of blue whales from the western North Atlantic population. The mid-Atlantic Bight and warm, deep oceanic waters adjacent to this area are part of the wintering and possibly breeding area of blue whales but requires further research. In Canadian waters, the lower SLE and nwGSL, the shelf waters south and southwest of Newfoundland, the Mecatina Trough area, including the head of the Esquiman Channel, and the continental shelf edge of Nova Scotia, Newfoundland and the Grand Banks are important foraging/feeding areas that appear to be exploited nearly year-round. The Honguedo Strait and Cabot Strait represent two obliged transit corridors that provide access to important habitat in the GSL or SLE.

Blue whales most likely need to use several of these important habitats to fulfill their biological needs. As a result, access corridors and habitat they connect need to be considered equally important for the population.

The functions, features and attributes of these habitats have been described, and activities likely to destroy the habitats' functions are, to the extent known, those that would result in reduced prey availability or accessibility, acoustic disturbance, environmental contamination, and physical disturbance (Table 1).

It is unknown if the important habitats identified here are sufficient to achieve the population objectives of the Recovery Strategy for blue whales from the western North Atlantic. There is a

need for a Schedule of Studies to refine the information known about the functions, features and attributes of identified habitats, and to identify additional areas of potential importance, especially in offshore or other remote waters.

OTHER CONSIDERATIONS

Climate change may also affect habitat functions by altering prey availability and physical properties of the ocean. Anthropogenic activities and their effects on habitat functions need to be managed in the context of this ongoing process.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 23 to 26, 2016 National Marine Mammal Peer Review Committee (NMMPRC): Part II. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Aulanier, F., Simard, Y., Roy, N., Gervaise, C., and Bandet, M. 2016. Spatial-temporal exposure of blue whale habitats to shipping noise in St. Lawrence system. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/090. vi + 26 p.

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McQuinn, I.H., Gosselin, J.-F., Bourassa, M.-N., Mosnier, A., St-Pierre, J.-F., Plourde, S., Lesage, V., and Raymond, A. 2016. The spatial association of blue whales (*Balaenoptera musculus*) with krill patches (*Thysanoessa* spp. and *Meganyctiphanes norvegica*) in the estuary and northwestern Gulf of St. Lawrence. DFO Can. Sci. Advis. 2016/104. iv + 19 p.

Moors-Murphy, H.B., J.W. Lawson, C. Gomez, B. Rubin, E. Marotte, and Renauld, G. 2018. Occurrence of blue whales (*Balaenoptera musculus*) off Nova Scotia, Newfoundland, and Labrador. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/007.

Plourde, S., Lehoux, C., McQuinn, I.H., and Lesage, V. 2017. Describing krill distribution in the western North Atlantic using statistical habitat models. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/111. v + 34 p.

Ramp, C., and Sears, R. 2013. Distribution, densities, and annual occurrence of individual blue whales (*Balaenoptera musculus*) in the Gulf of St. Lawrence, Canada from 1980–2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/157. vii + 37 p

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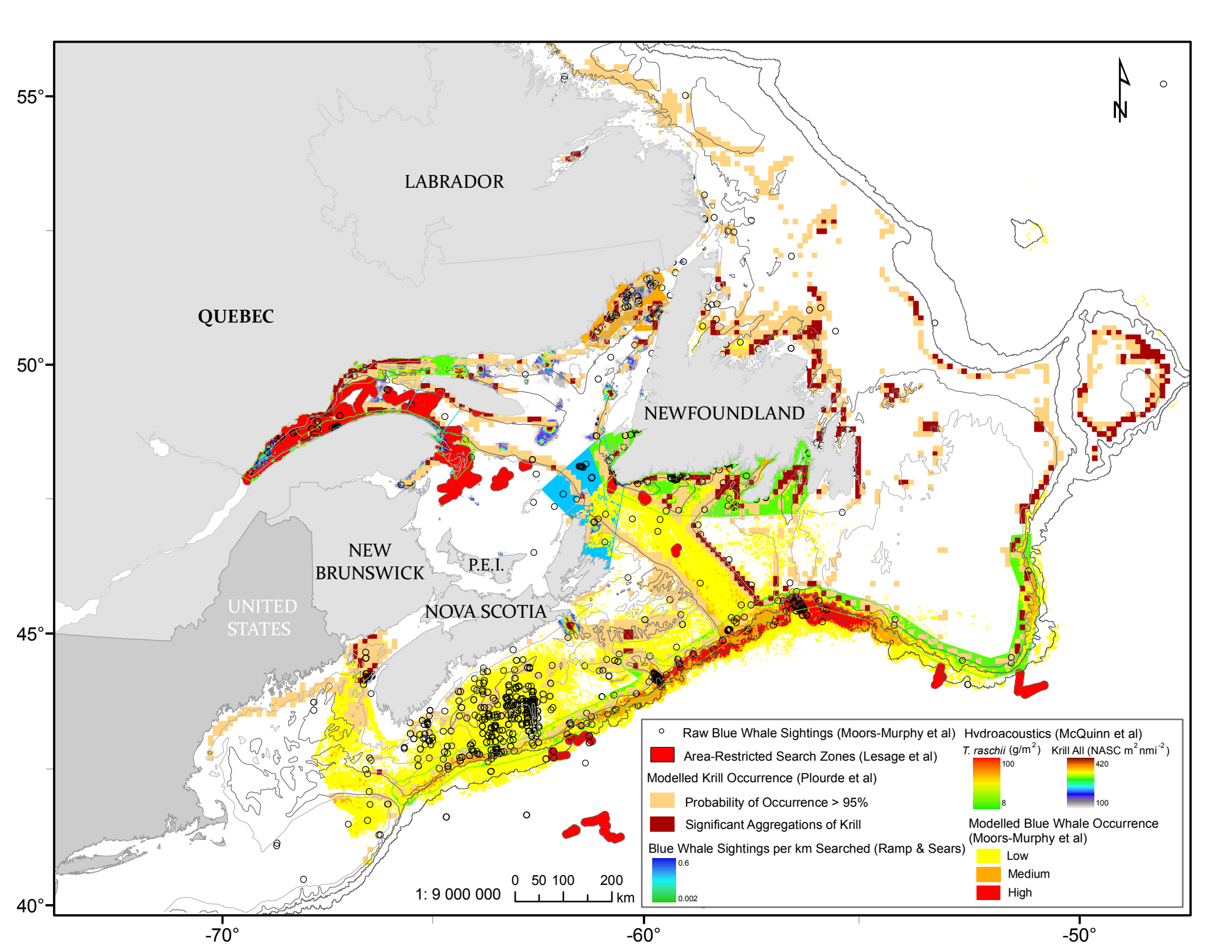
APPENDIX

Map showing the relative importance of Blue Whale habitats. To visualize the data, double-click the vocatmap to open in Acrobat. Select the double diamonds in the navigation tools on the left panel. The different data layers can be selected or deselected. Polygons delimit areas important to blue whales for foraging (green) and transit (blue) (see also Figure 1), (On next page)


55°
50°
45°
40°
-70°
-60°
-50°
N
LABRADOR
QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
P.E.I.
NOVA SCOTIA
UNITED STATES
1: 9 000 000
0 50 100 200
km
Raw Blue Whale Sightings (Moors-Murphy et al)
Area-Restricted Search Zones (Lesage et al)
Modelled Krill Occurrence (Plourde et al)
Probability of Occurrence > 95%
Significant Aggregations of Krill
Blue Whale Sightings per km Searched (Ramp & Sears)
0.6
0.002
Hydroacoustics (McQuinn et al)
T. raschii (g/m2)
100
8
Krill All (NASC m2 nmi-2)
420
100
Modelled Blue Whale Occurrence (Moors-Murphy et al)
Low
Medium
High

THIS REPORT IS AVAILABLE FROM THE :

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2018. Identification of habitats important to the blue whale in the western North Atlantic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/003.

Aussi disponible en français :

MPO. 2018. Identification des habitats importants pour le rorqual bleu dans l'ouest de l'Atlantique Nord. Secr. can. de consult. sci. du MPO, Avis sci. 2018/003.