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ECOSYSTEM RESEARCH INITIATIVE (ERI): INTEGRATED ADVICE ON THE SUMMER HABITAT OF THE ST. LAWRENCE ESTUARY BELUGA (*DELPHINAPTERUS LEUCAS*)

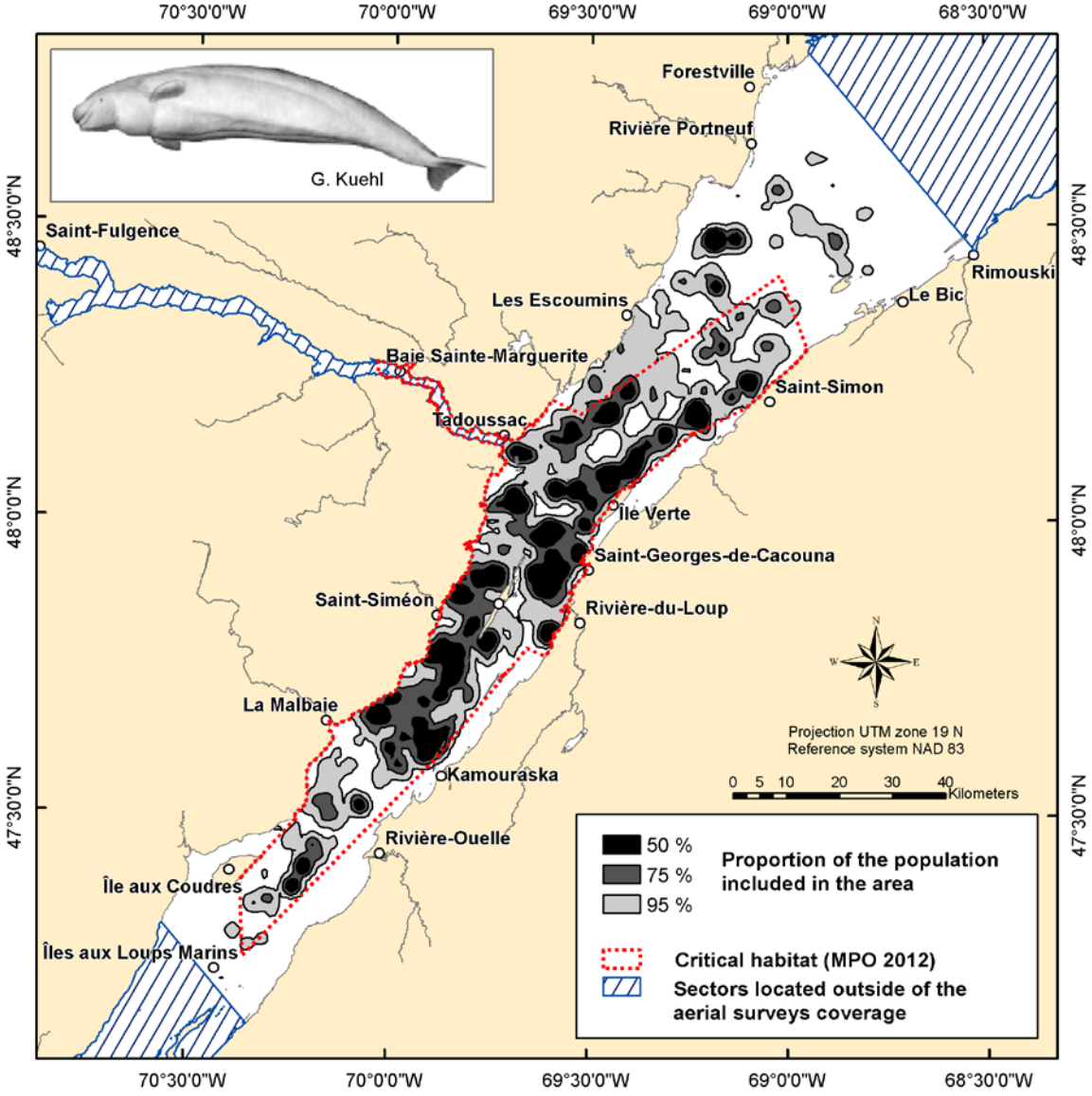

Figure 1: Relative summer density of belugas in the St. Lawrence Estuary based on 35 aerial surveys carried out from 1990 to 2009. The boundaries of the areas were determined by combining the highest densities until the desired proportion of the population was obtained. The dark areas combine the highest densities accounting for 50% of the population. The lighter areas include the areas covered by the darker areas.

Background:

At Fisheries and Oceans Canada (DFO), the ecosystem approach is used as a tool for planning operations, carrying out projects and preparing advice. In response to this policy direction, DFO Science is committed to implementing an ecosystem approach in its activities. Six pilot projects in the form of ecosystem research initiatives (ERIs) have been created in DFO's six administrative regions. These ERIs were also one of the three foundations of DFO Science's Five-Year Research Plan.

*Over the course of workshops held in 2007 at the Maurice Lamontagne Institute (MLI) in Mont-Joli, DFO scientists from the Quebec Region met to discuss how to define the ecosystem approach and apply it in the context of regional ERIs. Two topics were selected for pilot projects, one looking at forage species responsible for the presence of the blue whale (*Balaenoptera musculus*) in the St. Lawrence Lower Estuary, and the other looking at the habitat of the St. Lawrence Estuary beluga population (*Delphinapterus leucas*).*

This science advisory report is the result of the February 14–16, 2012 meeting on the St. Lawrence Estuary Ecosystem Research Initiative: Formulation of scientific advice in support of ecosystem management. It summarizes the results and recommendations of the ERI project on the definition and characterization of the habitat of the St. Lawrence Estuary beluga population, a vital issue in the protection of this endangered population.

SUMMARY

- The analyses presented in this advisory report support the critical habitat identification in the most recent recovery strategy for the St. Lawrence Estuary beluga population.
- This population is present throughout almost the entire St. Lawrence Estuary in summer, as demonstrated in systematic aerial surveys, the tracking of individuals and the tracking of groups. Analysis of data from summer aerial surveys carried out from 1990 to 2009 shows that there is a nearly continuous network of 36 concentration areas that, according to estimates, account for an average of 50% of the population. The tracking of individuals and groups shows that this distribution is dynamic, with belugas visiting more than one site in a given day.
- Based on a statistical analysis of the available environmental characteristics, the 36 concentration areas were classified into three separate groups according to the probability of sand lance being present on the sea floor, sediment hardness and the spatial and temporal variations in surface current speed and direction, which can cause gyres and fronts. These groups are divided mainly along an upstream-downstream gradient. The areas in the first group are mainly in the upper estuary, and the two other groups are mainly where the upper and marine estuaries meet.
- The spatial distribution of these three groups of concentration areas closely matches the spatial segregation of the different types of beluga herds in the St. Lawrence Estuary in summer. The first group of areas matches the sectors thought to be mainly occupied by herds of adult belugas with young. The second and third groups are thought to be occupied by a combination of herds of adults only and mixed herds.
- Statistical models show that the environmental variables currently available cannot explain the variations in beluga distribution in the estuary. These models do not show the belugas avoiding busy navigation corridors or areas with high concentrations of contaminants in sediment.
- However, the limits of these models have to be considered for their ability to explain the variations in beluga density and occurrence in the estuary in summer. Certain variables that may be important in supporting the biological functions of belugas, such as the distribution

of potential prey, salinity and temperature, were not available in the required coverage or in the spatial or temporal resolution.

- Analysis performed under the ERI does not contradict the finding that belugas are generalists in terms of their diet. Data to estimate the relative importance of prey in various areas and in different seasons remain limited.
- The results cannot be used to recommend simple habitat quality indicators. However, the systematic aerial surveys currently monitor the abundance and distribution of the St. Lawrence beluga and are good indicators for the population status and habitat use in the long term, despite the fact that coverage is currently limited to summer.
- The summary map produced through analysis of the 35 summer aerial surveys carried out from 1990 to 2009 is a useful management tool. This map can be used to assess the exposure of belugas to development projects with effects in defined areas of the estuary. However, map users must take into account the fact that beluga distribution is dynamic; the animals visit more than one concentration area in any given day. Moreover, this map represents only the average summer distribution and does not take into account age groups.
- A summary map specific to calves (age 0 and 1 year) is also available, but it is based on only seven aerial photography surveys. If it is used as a management tool, the same limitations in terms of dynamic distribution as for the overall summary map must be taken into account.

INTRODUCTION

The St. Lawrence Estuary beluga population is one of seven currently recognized populations in Canadian waters. Hunting reduced this population from an estimated 7,800–10,000 individuals in 1886 to about 1,000 from the 1980s to the early 2000s. A model of the population in 2013 suggests that the population has been declining slightly since the early 2000s, and it was estimated at 890 individuals in 2012. Although a hunting ban has been in effect since 1979, the population has not shown signs of recovery. There are several hypotheses to explain this situation, including high levels of persistent contaminants in belugas and the environment; competition for prey with commercial species such as turbot; habitat loss and degradation through chemical spills, noise, hydroelectric development, disruption by marine traffic, and episodic losses related to epizootic diseases. The population was designated "endangered" in the most recent Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessment in 2014. It is currently listed under Schedule 1 of the *Species at Risk Act* (SARA) and therefore subject to a recovery strategy (DFO 2012). This recovery strategy designates the critical habitat, which covers the summer range of groups composed of adults with newborns and juveniles: the upper estuary from Battures-aux-Loups-Marins to the southern portion of the lower estuary, including the southern slope of the Laurentian Channel, the plateau off Saint-Simon, and the Saguenay River from its mouth to Sainte-Marguerite Bay (Figure 1).

The pilot project developed under the Ecosystem Research Initiative (ERI) is a complementary effort to define and characterize the summer habitat of the St. Lawrence beluga. An ecosystem approach was applied by summarizing and integrating this information on beluga habitat. The new data acquired during the ERI are presented and compiled with historical data to determine their relevance in describing the habitat and assessing its use by belugas. The pilot project reviews the data on presence of belugas in different areas, characterization of physical, chemical and biological features of the habitat, the recent diet of the belugas, and the potential threats to the belugas and their habitat, which could compromise the recovery of this population. The data were integrated using several statistical approaches with two main goals: to explain

the distribution of belugas observed in systematic aerial surveys based on several environmental variables, and to detect any habitat features common to several identified concentration areas.

The purpose of this project was to identify and characterize the main areas where belugas are present in summer. This information can be used to decide on the protection measures to apply to these areas and find any areas where belugas are not currently seen that may have similar features to allow the population to grow and potentially increase its range. This initiative will also serve to support the selection of beluga habitat monitoring indicators and identify the limitations of available data to guide future studies to improve the description of beluga habitat and the understanding of its functions.

ANALYSIS

Summary of data

Mosnier et al. (2016) review the available physical, chemical and biological data that may help us understand habitat use by the St. Lawrence beluga.

The analysis of aerial survey data from 1990 to 2009, provided an estimation of the relative density of belugas over the summer range for each survey. A summary map was then completed by combining these estimates. Using this map, 36 beluga concentration areas were identified within their summer range (boundaries of the highest-concentration areas containing on average 50% of the population, Figure 1).

The beluga habitat was described using physical, chemical and biological variables and factors related to human use of the environment. Information on the bathymetry, type of seabed relief and sediment hardness were taken from high-resolution surveys performed by the Canadian Hydrographic Service. Towed benthic imaging (photo and video) was conducted under the ERI at 121 sites from 2008 to 2010, resulting in maps of the benthic habitats classified by particle-size distribution and several predictive maps of the occurrence and density of epibenthic species for a large portion of the summer range of the St. Lawrence beluga. Of these species distributions, only the probability of occurrence of the sand lance was considered in the ERI, since this was the only species recognized as a potential prey for belugas (see below). The speed and direction of the surface tidal current, based on a hydrodynamics model, were also used. Variables associated with human activities with direct or indirect negative effects that could lead belugas to avoid an area were also considered. These variables were also used to determine the geographical distribution of beluga exposure to these activities. The concentrations of certain persistent organohalogens[1] in surface sediments were measured in 2009 in a survey of 51 sites and interpolated to the area of interest. The intensity of marine traffic, including cruise ships, tour vessels, freighters, pleasure craft and ferries, was also described, using a summary map of trips taken by these different types of vessels for the period from May 1 to October 31, 2007.

It is reasonable to think that beluga density may be shaped, at least in part, by the search for prey concentrations. Consequently, knowledge of the recent diet of belugas is essential, and it was examined through several methods, including direct (stomach content analysis) and indirect (stable isotopes, fatty acids, contaminants) approaches. The results of these analyses did not contradict the finding that St. Lawrence Estuary belugas have a varied diet. Certain results support the possibility of a wide range of prey being consumed, including worms of the genus

[1] Polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), polybrominated diphenyl ethers (PBDEs), hexachlorobenzene (HCB), mirex, chlordanes.

Nereis, squid, cod, herring, tomcod, smelt, capelin, sand lance and eel. However, the relationship between contaminants and stable isotopes in prey and belugas can be explained considering only a few dominant prey species. Given the significant limitations of the methods used, it is difficult to obtain accurate estimates of the relative importance of various prey for belugas.

Several other important pieces of information on beluga habitat were reported in the research document by Mosnier et al. (2016). However, much of this information was limited in its spatial or temporal range. For example, the majority of regularly and systematically collected data on demersal fish and invertebrates cover the area below Île Rouge, which is only the downstream portion of the summer range of beluga. In addition, data integration (see next section) also required information on the spatial position in the summer range of beluga, which was not available in some cases. Examples include the potential impact of reduced abundance and quality of prey, the construction of dams on tributaries of the St. Lawrence, the development of the oil and gas industry, the occurrence of epizootic diseases, toxic algae blooms, and, on a larger scale, climate change.

Data integration

Statistical data integration was limited to the summer habitat of beluga covered by the series of aerial surveys conducted from 1990 to 2009. Environmental data were limited to those with a sufficiently large spatial coverage and a temporal coverage applicable to the summer.

Several types of statistical models were used to relate beluga distribution in the St. Lawrence Estuary to the available environmental variables.

The physical and biological characteristics available for 22 of the 36 beluga concentration areas were examined through a cluster analysis (Figure 2). This analysis identified three groups of which spatial distribution coincides fairly well with the spatial segregation of the different types of herds. The areas in the first group, mainly located in the upper estuary, are used by herds of both young and adults. They are characterized by a higher probability of sand lance occurrence on the sea floor, lower reflectiveness due to fine sediments, and lower, less variable surface currents than other areas. The areas in the second group, located in the upper estuary slightly upstream and at the mouth of the Saguenay River, and extending downstream to the north of Île Verte, are mainly used by mixed herds, some with adults only and some with both adults and young. These areas are characterized by a low probability of sand lance occurrence, a hard bottom and a surface current that is generally stronger, but also more variable in both speed and direction than the other areas, causing frequent gyres and fronts. Both areas in the third group are located on the south slope of the Laurentian Channel and are also used by mixed herds. They have a steep sea floor slope (bathymetry) and a laminar, swift surface current. Although there are beluga concentration areas in the Laurentian Channel, an area that seems to be used by herds of adults only, they could not be taken into account in the analyses because of a lack of complete environmental data for this area (Figure 2).

The static models used in an attempt to link variations in beluga density in the St. Lawrence Estuary with a static or average description of the conditions in the area were unable to demonstrate a relationship between these variables. The same result was found when taking into account the existence of a potential spatial segregation of belugas in summer, by performing separate analyses for the areas where groups of adults and young are present and the areas where groups of adults only are present.

Dynamic models were used to take into account the highly variable and dynamic nature of the environmental conditions in the St. Lawrence Estuary. These models were used to examine the relationships between beluga presence or density and the dynamic and static variables

specifically observed at the time of each aerial survey. Dynamic models were also considered to relate the variations in beluga density within each concentration area to dynamic environmental variables like tides, surface current speed, and the presence of hydrological structures. However, as with the static models, no relationship was established between beluga density and environmental conditions.

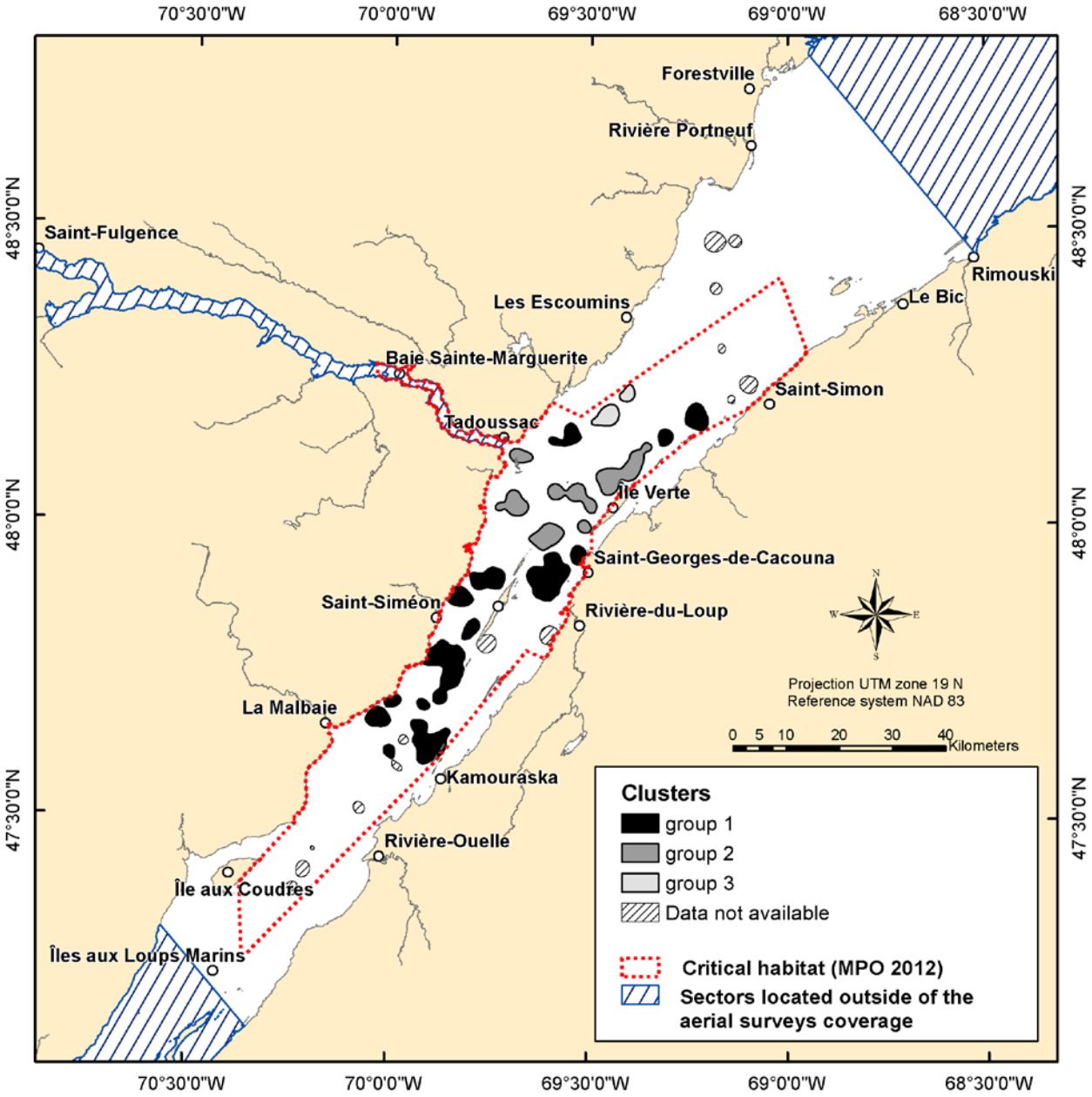

Figure 2. Results of the cluster analysis of the environmental characteristics of 22 of the 36 beluga concentration areas where physical and biological characteristics were available (i.e. areas with the highest densities and including on average 50% of the population. See Figure 1).

Sources of uncertainty

The overall distribution maps and juvenile distribution maps are based on summer surveys and do not represent the seasonal variations in beluga distribution in the St. Lawrence Estuary.

Furthermore, these maps do not show the dynamic nature of beluga distribution and the fact that individuals may visit more than one concentration area within a single day, as demonstrated by the tracking of individuals and herds.

A large number of variables that could significantly affect beluga distribution were reported in the research document by Mosnier et al. (2016). However, several of these variables had limited spatial or temporal coverage, meaning they could not be used in spatial analysis.

It is reasonable to think that beluga density may be shaped, at least in part, by the search for prey concentrations. Given the significant limitations of the different methods of estimating diet composition of belugas in the St. Lawrence Estuary, it is difficult to accurately estimate the relative importance of different prey species for this population.

Of the various potential prey for belugas in the St. Lawrence Estuary, only the sand lance occurrence probability distribution was available with sufficient spatial coverage in summer for spatial analysis. Data on the distribution of demersal fish and invertebrates cover only the area downstream of Île Rouge, which is only a small part of the summer range of beluga.

CONCLUSION AND ADVICE

The purpose of this project was to improve our understanding of interactions between belugas in the St. Lawrence Estuary and their habitat in order to support advice on management issues. These issues include the definition and characterization of the habitat used by a population listed under Schedule 1 of the *Species at Risk Act*, the assessment of the abundance and quality of food resources, the study of the impact of vessel traffic and contaminants, and more generally, the development of indicators or tools to better assess the potential impacts of future development projects, taking into account different components of the ecosystem. Some important issues were not considered in this study, since the ERI did not provide the relevant additional information.

Issue: Definition and characterization of beluga habitat

The results of this project indicate that the entire estuary is an important area for belugas in summer, which objectively and quantitatively supports the critical habitat identification of the recovery strategy (DFO 2012, Figure 1).

Analysis of data from 35 systematic surveys conducted from 1990 to 2009 shows that there are 36 concentration areas including on average 50% of the population in the summer beluga distribution area (Figure 1). However, each of these concentration areas generally contains less than 6% of the total population, and the extent of the area that includes 95% of the population shows that belugas are present in almost the entire area of the St. Lawrence Estuary covered by the summer surveys (Figure 1). Moreover, analysis of the tracking of individuals and herds was used to identify the sites where the animals spend most of their time, some of which match the concentration areas from the systematic surveys. This tracking also showed that belugas generally spend a few hours at a given site, and with their average travel speed (5.8 km/h), they can move from one site to another within a given day.

The lack of demonstrated relationship between beluga presence or density and static or dynamic variables could be due to a lack of information on certain variables, such as the distribution of potential prey. The varied diet and complex social behaviour of belugas could also explain why statistical models have a hard time explaining their distribution. The cluster analysis shows that there are significant differences in environmental features in certain beluga concentration areas. The functions of these different concentration areas have yet to be determined. Summer use of the St. Lawrence Estuary could also be the result of a larger scale

habitat selection process pushing belugas to come an area where the diverse environmental conditions allow them to carry out several essential life cycle and social organization activities within a relatively small area.

It was not possible to identify variables to more accurately predict beluga distribution in the St. Lawrence Estuary or determine the habitat features that explain distribution or suggest the functions of different areas. The systematic aerial surveys determine the abundance of St. Lawrence belugas and are in fact an indicator of the population status. The spatial distribution determined through these surveys and the tracking of individuals and herds provide complementary information on habitat use. The data currently available are not sufficient to suggest other indicators to monitor summer beluga habitat use. Better information on spatial and temporal distribution of beluga activities related to their biological functions in the estuary would likely help refine these analyses.

The summary map (Figure 1) showing the intensity of habitat use by beluga could be used to assess the relative risk of development projects with effects on a defined portion of the estuary. The black areas are the highest risk areas, since these are the areas likely to have the highest concentrations of individuals in summer, with up to 6% of the population in certain areas. The lighter shading shows areas with relatively low risk; however, the risk is still present. This map has some limitations. Assessments based on this map would be adequate only for effects spanning a very short period of time, and only in the summer. For construction lasting several hours, days or weeks, the results of tracking of individuals and groups of belugas must be considered: they show that belugas visit more than one concentration area over a given day. An assessment of the proportion of the St. Lawrence beluga population affected by longer-term construction would require information on animal movements among these areas over a length of time corresponding to the duration of the effects. This information is not available at this time.

An equivalent map to the previous one, but only for young and juveniles, is also available (Figure 3). It confirms the boundaries of the critical habitat as defined in the recovery strategy (DFO 2012), including all the areas used by these age groups. If this map is used as a management tool, the same reservations as for the overall summary map must be taken into account. Furthermore, this map is based on only seven aerial photography surveys (1990, 1992, 1995, 1997, 2000, 2003, 2009) where the age group of the individuals observed could be identified with more certainty.

Issue: Abundance, quality and diversity of food resources

Despite the variety of approaches used to try to determine the recent diet of belugas, it is still difficult to determine the relative importance of various prey. Results tend to show that St. Lawrence belugas, at least on a population level, are generalists rather than specialists.

Information on the occurrence and density of potential prey is mostly absent in the summer range of beluga, especially for non-commercial species. At best, availability is one time or irregular, which means it is not useful in the approach used in this project. Given these facts, assessing the abundance and quality of food resources is not feasible for the time being with existing data.

To correct this lack of information, an adapted research program should be implemented. It should cover the benthic habitat, pelagic habitat and seasonal component of the distribution and abundance of the preys of belugas in their habitat. It is also suggest to maintain the study on the diet of belugas and adding a component on quality of prey.

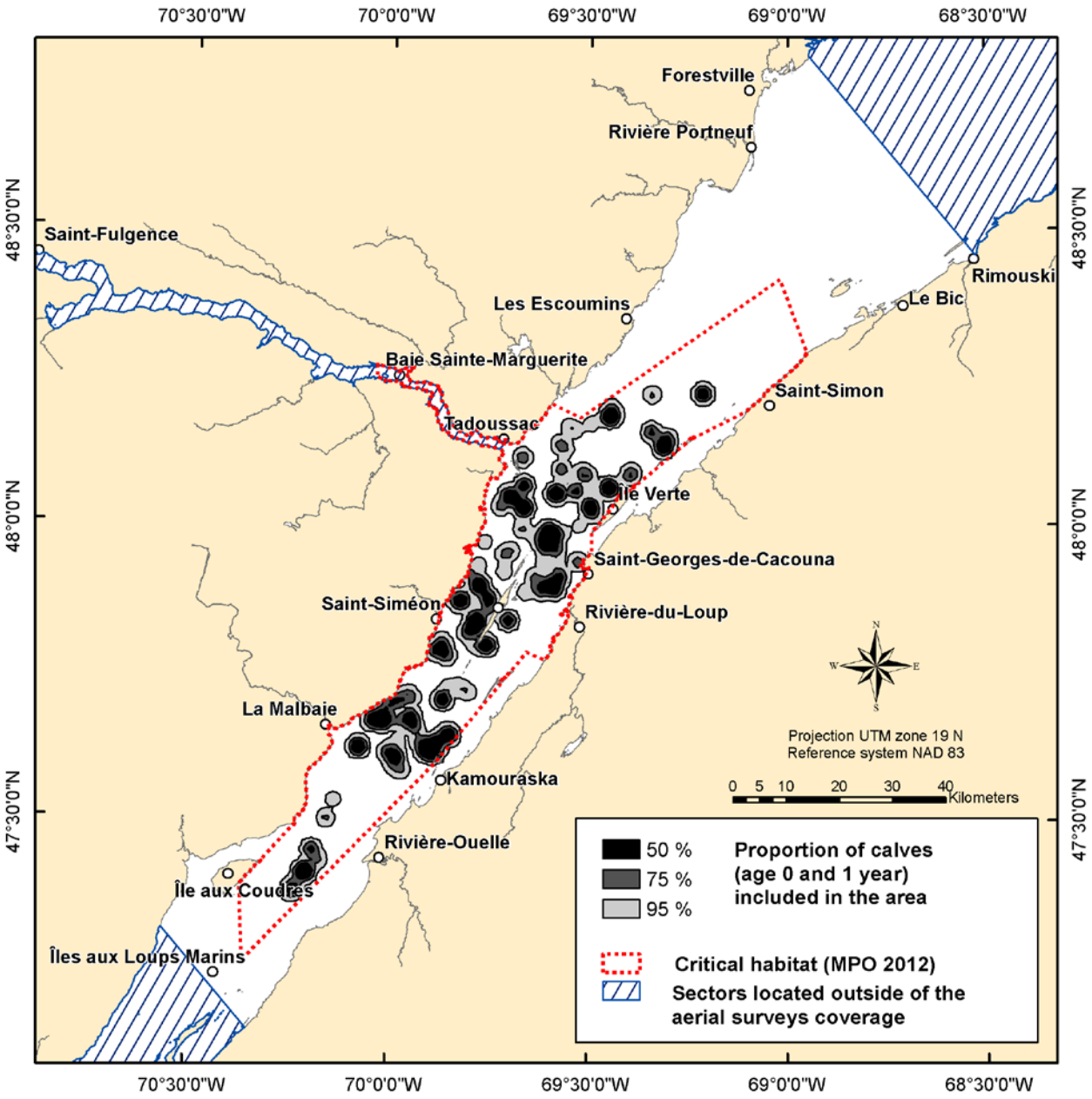

Figure 3. Relative density of beluga calves (age 0 and 1 year) and juveniles in the St. Lawrence Estuary based on 7 aerial photography surveys (1990, 1992, 1995, 1997, 2000, 2003, 2009).

Issue: Vessel traffic, collisions, disturbance

Statistical analysis does not show belugas avoiding shipping corridors in the St. Lawrence Estuary in summer. There were no data to allow this analysis to consider the spatial and temporal progress of vessels and thus assess the short-term effects of vessel traffic on beluga behaviour. The data available for this project did not allow for quantitative or relative estimates of the risk of collision. However, the overlap of beluga distribution with the shipping corridors shows that these risks exist.

More specific analysis taking into account these two aspects is needed to provide a complete response to this issue, both by looking at the spatial and temporal progress of vessel traffic and

by studying interaction, disturbance and reaction (e.g. behavioural budget) of belugas in the presence of different types of vessels.

Issue: Contaminants

An assessment of the quality of surface sediments in the beluga summer range shows that two areas have DDT levels with a probable biological effect. However, statistical analysis has not shown that belugas avoid more contaminated areas, which could have lower abundance or diversity of potential prey. The presence of areas of concentration of contaminants in the summer range and the associated toxicity risk show that belugas area dealing with a deteriorated habitat.

The surface sediment quality results in the beluga summer range suggest that monitoring should be implemented in this area to study contamination in sediments and epibenthic organisms as well as the effects of contaminants on biological diversity in the most contaminated areas.

Issue: Use of an ecosystem approach

In this project, the relevant available information was summarized to describe and assess habitat use by belugas in the St. Lawrence Estuary. The relationships among different components of an ecosystem make up a complex network of interactions, and a complete and adequate assessment of this network requires a large amount of information organized in equally complex databases. To be useable, these databases must have appropriate temporal and spatial coverage, and this coverage must be comparable for the entire area and period of interest. Unfortunately, data on several habitat features that likely play an important role in the ecology and use of this habitat by belugas did not meet these conditions or were not available. One such issue is that information on beluga spatial distribution and habitat use is limited to summer. The sources of data on spatial distribution of potential prey are also limited to summer and cover only part of the summer distribution of belugas. The temperature and salinity data produced by physical models are acceptable on the scale of the Gulf, but their spatial resolution is not sufficient to distinguish the conditions belugas are exposed to in different areas of the estuary on a scale of hundreds of metres. The impact of human activity has barely been studied, despite its potential significance for beluga habitat. Sampling and modelling over the entire estuary or the entire beluga distribution area in summer and the other seasons are required to complement previous studies presented as part of this exercise. Studies should also focus directly on the biological functions and interactions between belugas and various habitat features. This knowledge is needed to identify the habitat features that perform essential biological functions and the activities or phenomena that could lead to degradation of these features and affect the recovery of the St. Lawrence Estuary beluga population. Lastly, it would be interesting to explore other methods that do not necessarily include the spatial aspect of the issue, which would make it possible to consider variables that were not considered, including the impact of short-term coastal activity.

SOURCES OF INFORMATION

This science advisory report is the result of the February 14–16, 2012 meeting on The St. Lawrence Estuary Ecosystem Research Initiative: formulation of scientific advice in support of ecosystem management. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

Mosnier, A., Larocque, R., Lebeuf, M., Gosselin, J.-F., Dubé, S., Lapointe, V., Lesage, V., Bourdages, H., Lefaivre, D., Senneville, S. and Chion, C. 2016. Définition et caractérisation de l'habitat du béluga (*Delphinapterus leucas*) de l'estuaire du Saint-Laurent selon une approche écosystémique. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/052. [Available in French only]

DFO. 2012. Recovery Strategy for the Beluga Whale (*Delphinapterus leucas*), St. Lawrence Estuary Population in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, 88 pp + X pp.

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