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Recovery Strategy Series

Recovery Strategy for the Beluga Whale (*Delphinapterus leucas*), St. Lawrence Estuary Population in Canada

The Beluga Whale

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PREFACE

Canada's Minister of Fisheries and Oceans (DFO) is the competent minister under the *Species at Risk Act* (SARA) for aquatic species. Section 37 of SARA requires the competent minister to prepare recovery strategies for listed species that are extirpated, endangered or threatened. The St. Lawrence Estuary beluga population was listed as threatened under SARA in May 2005. The development of this recovery strategy was headed by Fisheries and Oceans Canada – Quebec Region, in collaboration with Parks Canada, Environment Canada, provincial agencies, and several stakeholders. This strategy meets SARA requirements in terms of content and process (Sections 39–41).

Successful recovery of this species will depend on the commitment and cooperation of the many different stakeholders involved in implementing the recommendations put forward under this strategy. It will not be the sole responsibility of Fisheries and Oceans Canada or any other agency. In the spirit of the National Accord for the Protection of Species at Risk, the Minister of Fisheries and Oceans invites all Canadians to join DFO in supporting and implementing this strategy for the benefit of the species and Canadian society as a whole. DFO will support the implementation of this strategy as far as possible, given the available resources and its overall responsibility for protecting species at risk. Other jurisdictions and agencies will participate in implementing the strategy according to their respective policies, allocated resources, priorities, and budgetary constraints.

The goals, objectives, and recovery approaches identified in the strategy are based on the best available knowledge, and are subject to change should new information emerge. The Minister of Fisheries and Oceans will prepare a progress report within five years. This strategy will be complemented by one or more action plans that will provide details on specific recovery measures to be taken to help protect the species. The Minister of Fisheries and Oceans will take steps to ensure that Canadians who are concerned about or affected by these measures will be consulted whenever and wherever possible.

In 1983, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the St. Lawrence beluga population as endangered due to the significant decline in numbers caused by intensive hunting, which was finally banned in 1979. In 1986, Fisheries and Oceans Canada set up the *Ad Hoc* Committee for the conservation of the St. Lawrence beluga, the objectives of which were to identify factors that threatened the population's survival and to make recommendations to favour its recovery. Based on the Committee's report, an interdepartmental Action Plan was drawn up to ensure the survival of the belugas. This project was carried out jointly by Fisheries and Oceans Canada and Environment Canada from 1988 to 1993 as part of the St. Lawrence Action Plan (SLAP), with the following objectives: to minimize disturbance to the beluga population, to combat the discharge and spread of toxic chemical products, and to conduct further research on the beluga. A fourth objective was added in 1989: to facilitate public access to information in order to raise awareness in Canada and Quebec of the St. Lawrence beluga. Conservation and protection of the St. Lawrence ecosystem continued under St. Lawrence Vision 2000 and the St. Lawrence Plan for Sustainable Development 2005–2010.

In 1994, DFO and the World Wildlife Fund (WWF) helped establish a Recovery Team for the St. Lawrence Estuary beluga population. The team included members from federal and provincial departments as well as non-governmental organizations, and its mandate was to develop a recovery plan for this population. This plan was published in December 1995 (DFO and WWF, 1995).

In 1996, the Beluga Committee was formed to implement and oversee the St. Lawrence Beluga Recovery Plan. In 1997, COSEWIC reassessed and confirmed the endangered status of the St. Lawrence Estuary belugas. In 1998, the Beluga Committee published the first status report on the implementation of the St. Lawrence Beluga Recovery Plan (DFO and WWF, 1998).

The Beluga Committee met several times in 2002 and 2003 to update the available information on the St. Lawrence beluga and revise the recommendations of the 1995 recovery plan. In May 2004, COSEWIC revised the status of the St. Lawrence beluga population from endangered to threatened following the adoption of new quantitative classification criteria in line with the International Union for Conservation of Nature. In 2005, DFO assembled a team of beluga specialists to establish the evaluation criteria required to define a recovered population and to gather scientific recommendations on the recovery potential of the different beluga populations in Canada (DFO, 2005a, b; Lawson et al., 2006).

When the *Species at Risk Act* came into effect, the St. Lawrence beluga Recovery Team was formed and mandated to develop a recovery strategy, as required by the Act. This recovery strategy encompasses all the initiatives taken since 1983 for the recovery of the St. Lawrence Estuary beluga population. It was developed with the cooperation or consultation of government agencies, aboriginal organizations, environmental groups, and industry representatives.

ACKNOWLEDGMENTS

DFO would like to thank Andréanne Demers, Hugues Bouchard, Jacinthe Beauchamp, and Paule de Margerie for producing this document. It would also like to acknowledge the members of the St. Lawrence beluga Recovery Team (Appendix 1) for their efforts to provide the authors with information, advice, and recommendations along the way. The Department would also like to thank Gilles Fortin of DFO for his mapping expertise.

DFO would also like to thank the Government of Quebec and the staff of the Saguenay–St. Lawrence Marine Park for their dedication to the recovery of the St. Lawrence beluga. Finally, DFO would like to acknowledge the invaluable contributions of everyone who provided comments on this document.

EXECUTIVE SUMMARY

The beluga (*Delphinapterus leucas*) population in the St. Lawrence Estuary was greatly reduced by hunting, which was finally banned in the St. Lawrence in 1979. In May 2005, this beluga population was officially listed as a threatened species on SARA's List of Wildlife Species at Risk.

Aside from past hunting, ten threats to the recovery of the St. Lawrence beluga population have been identified in this strategy. Four threaten the population as a whole: contaminants, anthropogenic disturbances, reduction in prey availability and quality, and other degradation of habitat. Three threats can disturb or cause the death of a number of individual whales annually: ship strikes, entanglement in fishing gear, and scientific research activities. Finally, three occasional threats can hinder the recovery of the St. Lawrence belugas: the discharge of toxic substances, harmful algal blooms, and epizootic diseases.

Recovery of the St. Lawrence beluga population is feasible, the objective being a long-term increase in population to 7,070 individuals, or 70 % of its historical size. At an optimal population growth rate of 4 %, the long-term population objective can be reached by the 2050s. At the current 1 % growth rate, this will take until 2100. An intermediate objective of 1,000 mature individuals was also established. The current population is estimated at approximately 1,100 individuals. Six recovery objectives have been identified to reach population objectives:

1) Reduce contaminants in belugas, their prey, and their habitat
2) Reduce anthropogenic disturbances
3) Ensure adequate and accessible food supplies
4) Mitigate the effects of other threats to population recovery
5) Protect the beluga habitat in its entire distribution range
6) Ensure regular monitoring of the St. Lawrence Estuary beluga population.

Female belugas and their calves show strong site fidelity for their summering habitat, and this is a fundamental issue in the survival and recovery of this population. The critical habitat, which includes the Upper Estuary, the Saguenay River up to Sainte-Marguerite Bay, and the southern channel of the Lower Estuary, supports the vital functions of calving and rearing of the young. A schedule of the studies required to complete the identification of the critical habitat is included.

This present recovery strategy is a follow-up to the 1995 St. Lawrence Beluga Whale Recovery Plan and may be revised and reposted to the Species at Risk Public Registry as new information is acquired or circumstances change.

RECOVERY FEASIBILITY

Recovery of St. Lawrence Estuary beluga is considered feasible because the four criteria for the technical and biological feasibility of recovery are met.

1. **Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.**

   If direct measures are implemented to eliminate or mitigate current threats, the actual number of belugas in the St. Lawrence Estuary should be sufficient to allow population growth.

2. **Sufficient suitable habitat is available to support the population or could be made available through habitat management or restoration.**

   Although some areas show some degradation, there appears to be sufficient habitat available, as the current population does not use the entirety of its historical distribution area. In theory, therefore, additional habitat for population growth is available.

3. **Significant threats to the species or its habitat may be avoided or mitigated.**

   Although it is impossible at this point to precisely determine the impact of individual threats and their interactions on the recovery of St. Lawrence belugas, several potential threats have been identified. Since the last recovery plan was published in 1995, a number of conservation measures have been implemented. In addition, as part of this recovery program, other measures have been put forward to reduce the impact of human activity on this population. Even though some of these measures have not proven completely effective, they are continuously being assessed and improved.

4. **Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.**

   The decontamination methods exist and aquatic sites have been cleaned up. Methods are also available to restore or mitigate the impacts of development on the prey habitats of belugas. Several techniques and protocols are available to reduce the impact of certain threats such as marine traffic disturbance and entanglement in fishing gear.

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LIST OF ACRONYMS

BAPE	Bureau d'audiences publiques sur l'environnement
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPs	Chlorinated paraffins
DDE	Dichlorodiphenylethane
DDD	Dichlorodiphenyldichloroethane
DDT	Dichlorodiphenyltrichloroethane
DFO	Fisheries and Oceans Canada
EC	Environment Canada
EQA	*Environment Quality Act*
GREMM	Groupe de recherche et d'éducation sur les mammifères marins
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
HSP	Habitat Stewardship Program
IARC	International Agency for Research on Cancer
IPCS	International Program on Chemical Safety
IJC	International Joint Commission
MLOA	Marine life observation activities
MPA	Marine Protection Area
NRC	National Research Council
OC	Organochlorine compounds
PAEQ	Programme d'assainissement des eaux du Québec
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PBDEs	Polybrominated diphenylethers
PFCs	Perfluorinated compounds
PFOS	Perfluorooctane sulphonate
PIZ	Priority Intervention Zone
POP	Persistent organic pollutant
QMMERN	Quebec Marine Mammal Emergency Response Network
ROMM	Réseau d'observation des mammifères marins
SARA	*Species at Risk Act*
SLAP	St. Lawrence Action Plan

SSLMP	Saguenay-St. Lawrence Marine Park
TBT	Tributyltin
WWF	World Wildlife Fund

1. BACKGROUND

1.1 COSEWIC Assessment Summary

COSEWIC Assessment Summary, as presented in the Assessment and Update Status Report (COSEWIC, 2004)[1]:

Date of Assessment: May 2004

Common Name (population): Beluga (St. Lawrence Estuary population)

Scientific Name: *Delphinapterus leucas*

Status: Threatened

Reason for designation: The population was severely reduced by hunting, which continued until 1979. High contaminant loads may have also contributed to the population decline. Aerial surveys since 1973 suggest that the decline has ceased, but do not provide clear evidence of a significant increase in numbers. Levels of many contaminants remain high in beluga tissues. The whales and their habitat are threatened by contaminants, vessel traffic, and industrialization of the St. Lawrence watershed.

Range in Canada: Quebec, Atlantic Ocean

Status History: Designated Endangered in April 1983 and in April 1997. Status re-examined and designated as Threatened* in May 2004. Last assessment based on an update status report.

** Note that the change in the beluga's status from an endangered to a threatened species is not a reflection of an improvement in the situation and condition of the St. Lawrence beluga. This change in status is primarily due to the fact that, in 2003, COSEWIC adopted new quantitative classification criteria to conform to the criteria used by the International Union for Conservation of Nature. At the same time, new research permitted a more accurate, less conservative estimate of the population size. The status of the St. Lawrence beluga was therefore adjusted according to COSEWIC's new quantitative evaluation criteria, and because the population size is now more accurately estimated at approximately one thousand individuals.*

[1] Available on the Public Registry

1.2 Species Description

The beluga is a small, toothed whale of the Monodontidae family, found in the northern hemisphere and adapted to Arctic and subarctic conditions. The species is characterized by the absence of a dorsal fin, a thick skin and tough dorsal ridge (used to break ice), and a rounded structure, called a melon, on the dorsal surface of the head, which is filled with lipids and facilitates echolocation[2]. Adults are distinguished by their white skin. An adult beluga can weigh up to 1,900 kg and grow to between 2.6 and 4.5 m in length, the female adult attaining only 80 % of the male's length, or up to 3.5 m (Vladykov, 1944; Lesage and Kingsley, 1998; COSEWIC, 2004).

Calves are a greyish brown colour with occasional darker markings. Newborn calves measure 150 cm in length, nearly half the size of the mother, and weigh approximately 78 kg. At two years of age, they reach 60 % to 65 % of the mother's length (Brodie, 1971; Lesage and Kingsley, 1998). Older juveniles gradually become lighter coloured up to the age of sexual maturity, when they are completely white (Sergeant, 1973; Heide-Jørgensen and Teilmann, 1994; Lesage and Kingsley, 1998).

1.3 Populations and Distribution

1.3.1 Global Distribution and Populations

The global beluga population can be grouped into 29 different populations spread throughout the circumpolar region between latitudes 47° N and 80° N (Martin and Reeves, 2000). Belugas are found in the waters of Alaska, Canada, Greenland, Norway, and Russia (Figure 1). These populations migrate between habitats, depending on the season and their biological requirements (for example, feeding, calving, or wintering). In summer, belugas show high site fidelity, gathering in specific estuaries and glacier fronts.

There is no reliable estimate of the total numbers of belugas globally. However, Martin and Reeves (2000) gave estimates of the 29 populations that have been identified, which could total between 98,000 and 120,000 individuals. In comparison, according to the COSEWIC status report (2004), beluga stocks in North America could total more than 100,000 individuals, of which 85,000 are in Canadian waters. Based on their summer distribution, belugas in Canadian territory have been grouped into seven populations, as illustrated in Figure 2 (COSEWIC, 2004; MPO, 2005b). COSEWIC assessed all the Canadian populations and designated their status (endangered, threatened, special concern, not at risk). Currently, only the St. Lawrence Estuary population is listed in Appendix 1: List of Wildlife Species at Risk.

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[2] Physiological process for locating objects such as prey, by means of sound waves that are reflected back to the emitter by the objects (like a sonar).

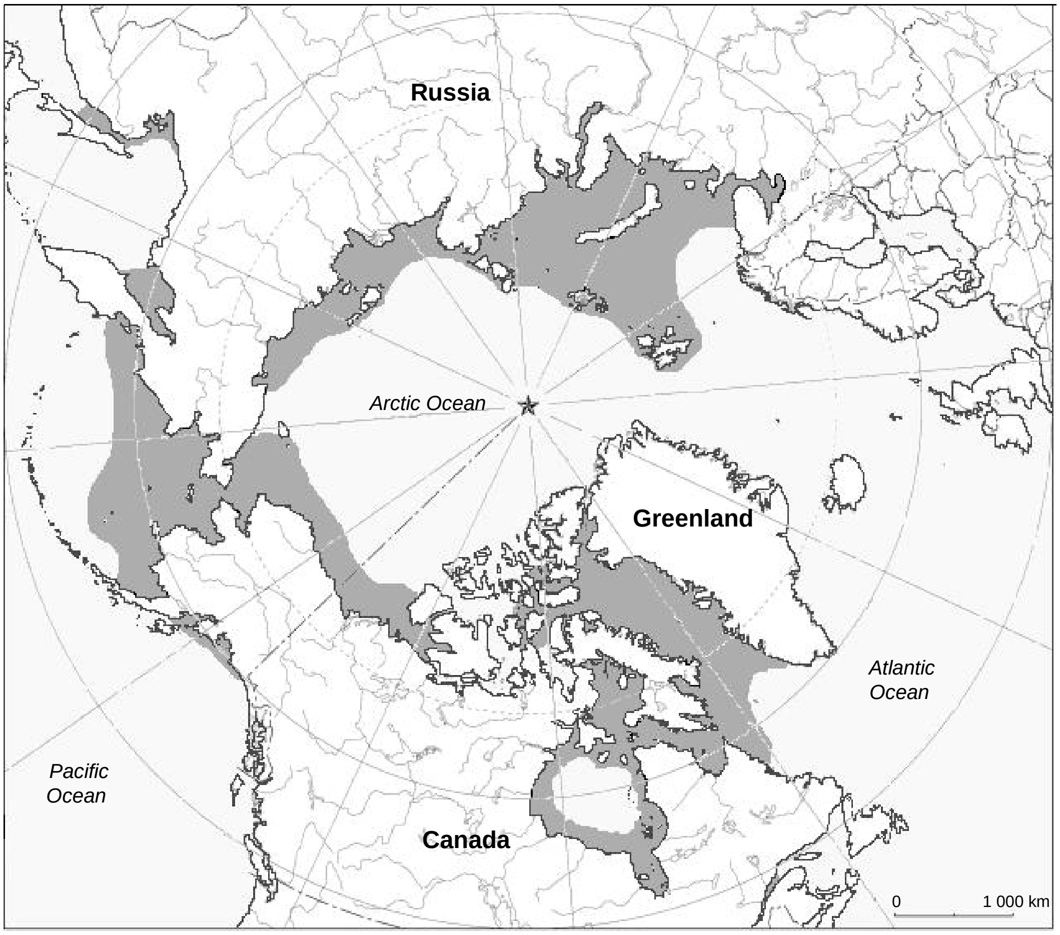

Figure 1. Global distribution of belugas (adapted from Reeves, 1990). Belugas are found in the waters of Alaska, Canada, Greenland, Norway, and Russia

This distribution of the North American beluga population may change as further genetic information becomes available. Nuclear and mitochondrial DNA studies have shown that the North American beluga population is not homogeneous (Brown Gladden et al., 1997; Brown Gladden et al., 1999b; de March et al., 2002; de March and Postma, 2003). In fact, it is divided into two different evolutionary units (east and west) and sub-divided into eight management areas according to their summer distribution.

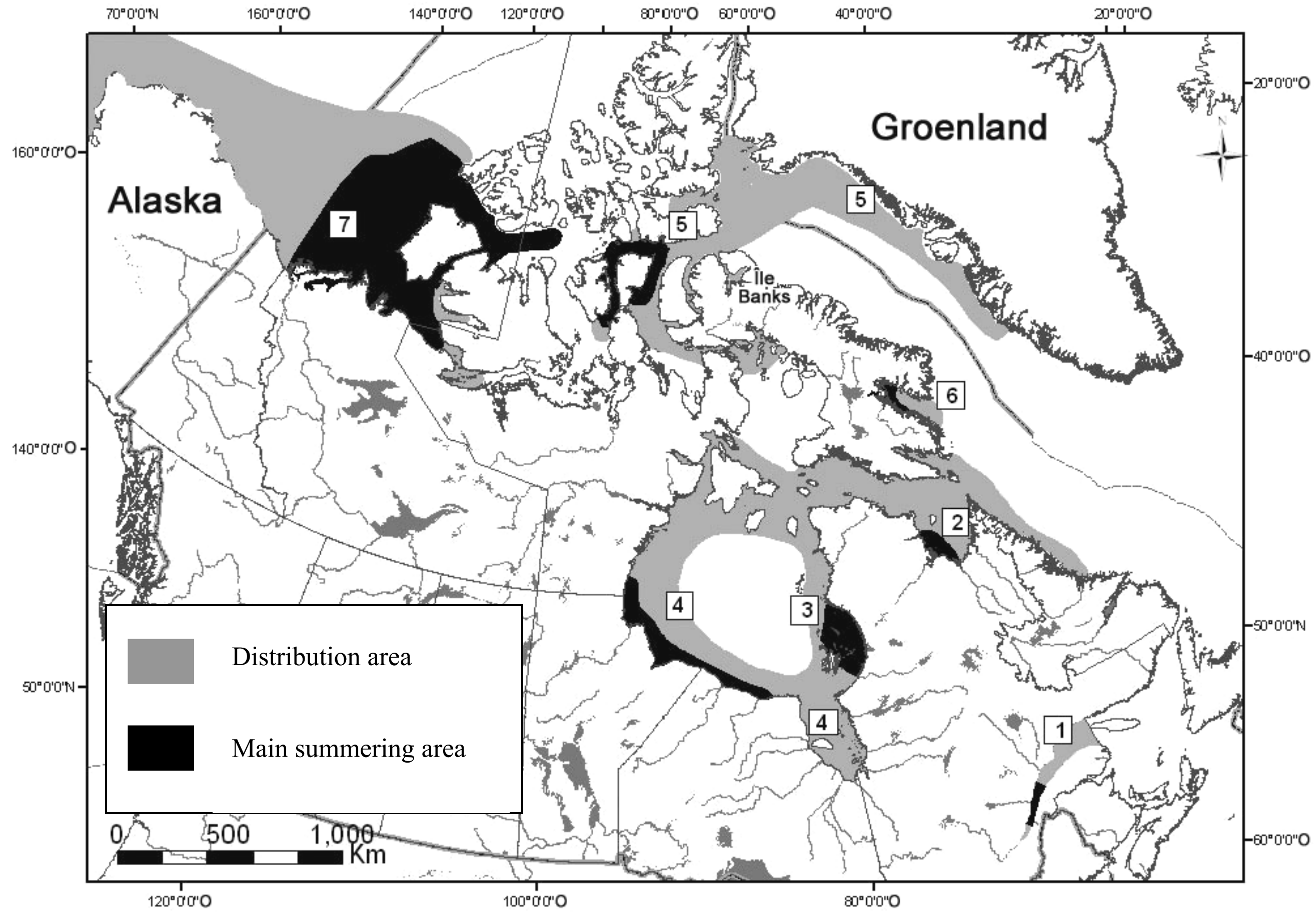

Figure 2. Location of the seven Canadian beluga populations. 1) St. Lawrence Estuary population; 2) Ungava Bay population; 3) Eastern Hudson Bay population; 4) Western Hudson Bay population; 5) Eastern High Arctic and Baffin Bay population; 6) Cumberland Sound population; 7) Eastern Beaufort Sea population. Adapted from COSEWIC, 2004. In grey is the distribution area and in black are the main summering areas.

1.3.2 Distribution of the St. Lawrence Population

The St. Lawrence Estuary belugas live downstream of the densely populated, highly industrialized Great Lakes Region, along a major marine navigation corridor containing a wide range of pollutants. Mitochondrial and nuclear DNA analyses and functional genomic studies reveal that the St. Lawrence belugas are genetically isolated from other populations (Brennin et al., 1997; Brown Gladden et al., 1997; Brown Gladden et al., 1999a; Murray et al., 1999; de March and Postma, 2003). They constitute a lineage whose closest relatives are the belugas of the east coast of Hudson Bay (Brown Gladden and Clayton, 1993; Brown Gladden et al., 1997; Brown Gladden et al., 1999a; COSEWIC, 2004). However, genetic analyses suggest that these two groups have been separate for approximately 8,000 years (de March et al., 2002).

The St. Lawrence belugas are also geographically isolated from other populations in the eastern Arctic, even though the distance that separates them is theoretically not insurmountable. Belugas are occasionally sighted in the northeast and south of the Gulf of St. Lawrence, along the Labrador coast, and close to Newfoundland, Nova Scotia, and the eastern coast of the United States (Reeves and Katona, 1980; Michaud et al., 1990; Curren and Lien, 1998). Vladykov (1944) suggested that the St. Lawrence population was not completely isolated from the more northern populations, and that northern belugas might have immigrated to the St. Lawrence. Nevertheless, it is impossible to accurately evaluate the magnitude of these migrations or to ascertain whether Arctic belugas have penetrated the St. Lawrence Estuary in recent history.

The distribution of the St. Lawrence belugas was first reported by Vladykov (1944). The area covered in summer extended east along the North Shore to Natashquan and along the south shore to Grande-Vallée (Figure 3). Spring distribution extended further west, around l'Île aux Coudres and further east and south to the coastal waters of the Gaspé Peninsula and the north shore of the Bay des Chaleurs. Autumn distribution included the Saguenay Fjord and extended west past Quebec City.

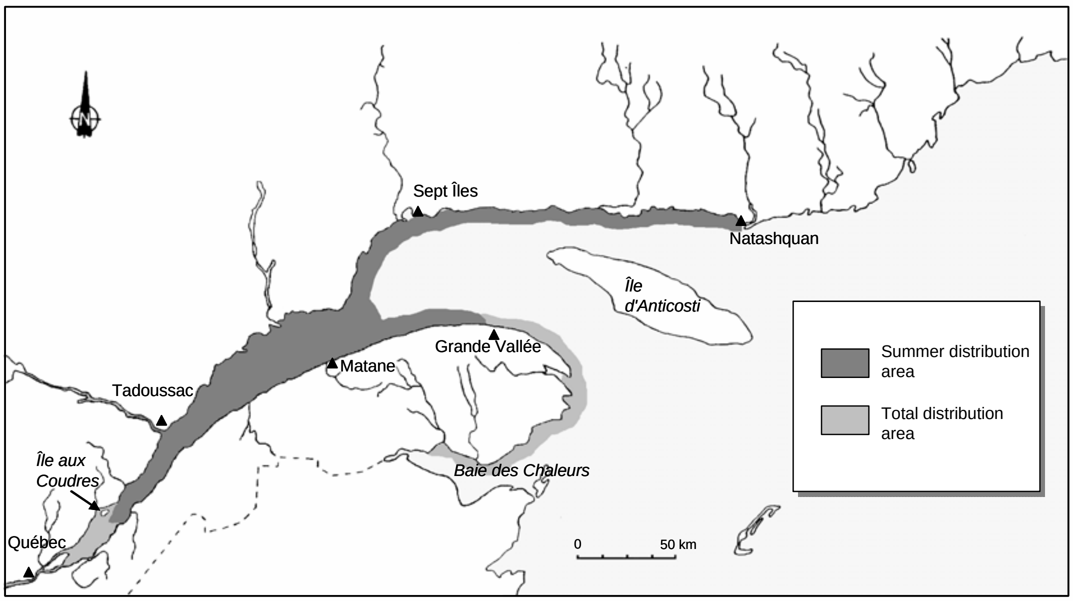

Figure 3. Historical distribution area of the St. Lawrence beluga, adapted from Vladykov, 1944. The area covered in summer extended east along the North Shore to Natashquan and along the south shore to Grande-Vallée. The total distribution area extended to Québec and south of the Gaspé Peninsula.

Although the total distribution area is smaller than it used to be, the St. Lawrence beluga still covers a territory of over 8,000 km² in the St. Lawrence Estuary, the Gulf of St. Lawrence, and the Saguenay River (Michaud, 1993a; DFO and WWF, 1995). The current summer distribution zone, which has changed very little in the last 20 years, is only a portion of what it was historically (Michaud et al., 1990; Lesage and Kingsley, 1998; Gosselin et al., 2007). The population is concentrated at the mouth of the Saguenay River, where it occupies an area of 2,000 km² extending from the Battures aux Loups Marins across from Saint-Jean-Port-Joli to Rimouski on the south shore of the St. Lawrence River and Forestville on the North Shore (Figure 4). In the last few years, almost thirty belugas have been sighted in the Estuary east of Rimouski and Forestville and in the area of Sept-Îles, suggesting a wider distribution than was previously thought (Kingsley and Reeves, 1998; Gosselin et al., 2007). The summer distribution also extends into the Saguenay River, from the mouth of the river to Saint-Fulgence.

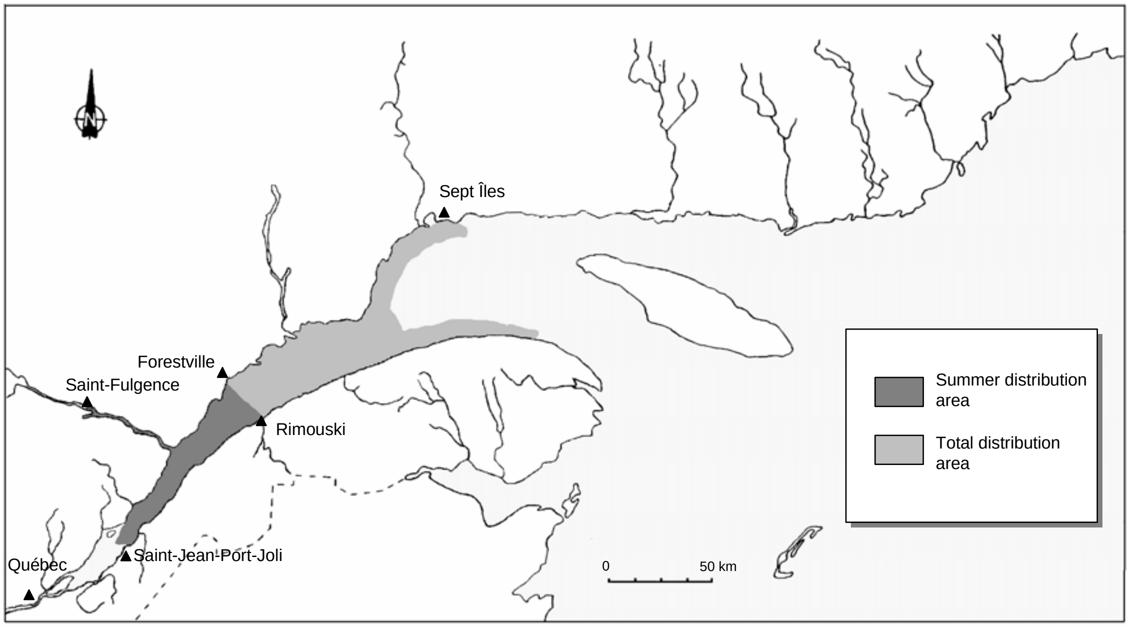

Figure 4. Present distribution area of the St. Lawrence beluga, adapted from Michaud, 1993a. The summer distribution area extends from Saint-Jean-Port-Joli to Forestville, including the Saguenay River up to Saint-Fulgence, and the total distribution area extends to Sept-Îles.

The beluga distribution outside of summer is not well known. Sightings are rare in spring and fall, and the distribution in these seasons is thought to be similar to that for summer (Boivin and Michaud, 1990; Michaud and Chadenet, 1990; Michaud et al., 1990). This population is partially migratory, moving to the northwest sector of the Gulf of St. Lawrence in the winter (Michaud et al., 1990; Lesage and Kingsley, 1998; Kingsley, 1999). Occasional sightings, along with aerial surveys conducted in 1989 and 1990, suggest that the winter distribution area extends downstream into the Gulf, all the way to Sept-Îles on the North Shore (Sears and Williamson, 1982; Boivin and Michaud, 1990). Small groups have also been sighted in the Estuary up to Rivière-du-Loup. It is likely that the winter distribution varies from year to year, depending on ice conditions (Vladykov, 1944; Boivin and Michaud, 1990). In early spring, belugas can be found off the Gaspé Peninsula, all the way upstream to the Battures aux Loups Marins (Michaud and Chadenet, 1990).

1.3.3 Abundance and Trends of the St. Lawrence Population

From an estimated historical population of between 7,800 and 10,100 whales (DFO, 2005b; Hammill et al., 2007), the St. Lawrence belugas dropped to a low of approximately 1,000 whales in the years following the ban on hunting in 1979 (Hammill et al., 2007). It is difficult to compare pre-1998 population estimates with later estimates because early aerial counts did not factor in submerged, non-visible animals. A correction factor of 209 % must therefore be used to account for submerged whales (Kingsley and Gauthier, 2002). This correction factor is similar to those obtained in telemetry surveys of Arctic belugas, from 180 to 290 % (Kingsley and Gauthier, 2002).

Since 1988, abundance surveys based on aerial photographs have been standardized to allow both accurate comparison of population estimates and the monitoring of trends. However, the reduced number of belugas, their gregariousness, their uneven spatial distribution, and the time they spend submerged can account for some of the variability in population estimates across surveys (Gosselin et al., 2007). Aerial survey data between 1988 and 2005 indicate that the population increased slightly, but not statistically significantly, from 900 whales in 1988 to just over 1,200 in 2005, or approximately 12 % of historical levels (Hammill et al., 2007) (Figure 5). The population growth rate has been estimated, with a great deal of uncertainty, at 1 %. This is very slow for a population that is no longer being harvested (DFO, 2005b). Normally, an unexploited population of belugas whose numbers do not exceed the environmental carrying capacity should grow at an annual rate of 2.5 % to 3.5 % (COSEWIC, 2004) and up to a maximum of 4 % (DFO, 2005a). Note that, given the uncertain estimates of the current beluga population, it should take several years of monitoring to detect any change in size. Michaud and Béland (2001) estimate that with a steady 3 % annual growth rate, it will take 20 years to detect a trend using aerial surveys every 2 to 3 years, and at only 1 %, this should take 40 years, not 24 years, as suggested by the St. Lawrence Beluga Recovery Team (DFO and WWF, 1995).

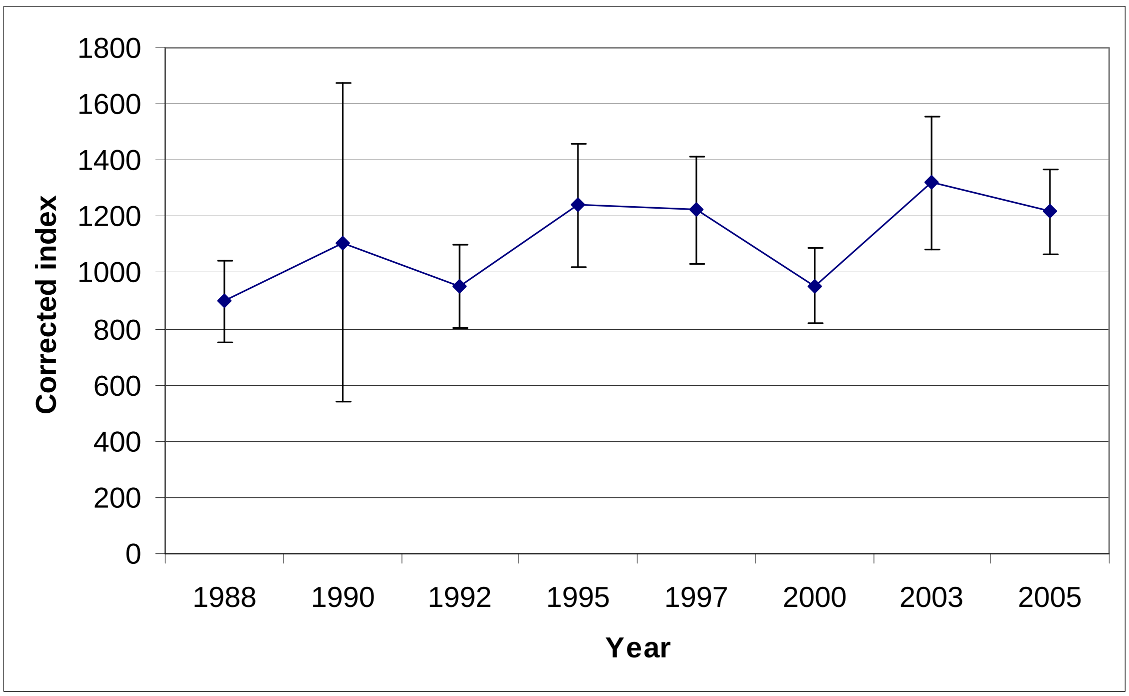

Figure 5. Population estimates for the St. Lawrence beluga from 1988 to 2005, corrected index and standard error (adapted from Gosselin et al., 2007). The population increased slightly, but not statistically significantly, from 900 whales in 1988 to just over 1,200 in 2005.

Since 1982, the causes of beluga deaths have been monitored under the carcass monitoring program carried out by DFO, Parks Canada, the St. Lawrence National Institute of Ecotoxicology (SLNIE), the Faculty of Veterinary Medicine of the University of Montreal, and several other partners (for a review of publications, see Measures, 2007a). The program provides for the transportation of carcasses for post-mortem examination, when possible, or for sampling individual data and tissues.

Between 1983 and 2008, according to the database of the Canadian Cooperative Wildlife Health Centre, 389 beluga carcasses were found along the St. Lawrence, ranging from 9 to 24 each year, for an average of 15 per year. Beluga age was estimated in 296 carcasses: 9 % were calves (less than one year), 12 % were juveniles (from 1 year to sexual maturity, around 10 to 14 years), and 79 % were adults (more than 10 to 14 years). Mean age of the stranded belugas was estimated at 34 years. Most dead individuals were between 41 and 50 years of age. One 80-year-old beluga carcass was found (Yves Morin, DFO, unpublished data). However, the early-age mortality is probably higher than the stranding data suggest, because carcasses of juveniles, which are greyish-brown in colour, are more difficult to spot on shore and less buoyant (Measures, 2007a). There has been no change in the age distribution of stranded whales over the years, and a high proportion are adults (Kingsley, 2002). Both the average age at death and the life expectancy once maturity is reached appear reasonably high, and there are no indications of mass mortality events or unusual mortality rates in belugas of reproductive age (Lesage and Kingsley, 1998; Kingsley, 1999).

Concerning calf production, Béland et al. (1988) calculated that immature animals (not counting yearlings) should account for 28 % to 30 % of the St. Lawrence belugas to enable the population increase required for recovery. Gray beluga counts based on aerial photographs and the proportion of juveniles observed during a ship survey indicate that juveniles make up approximately 30 % of the population (Michaud, 1993b; Desrosiers, 1994; Kingsley, 1996, 2002), a high enough percentage to allow for recovery of the population. The calves counted in aerial surveys amounted to 8 % of all the belugas counted, but this proportion varies considerably across surveys (from 2 % to 16 %). This may reflect a variability in calf production in St. Lawrence belugas, or it may simply be due to the difficulty in spotting calves at their mother's side from the air (Kingsley, 1993, 1996; Hammill et al., 2007). The carcass-based reproductive rate estimates are slightly below the expected rates for a species with a three-year reproductive cycle, but a sample bias could have caused underestimations (Béland et al., 1993).

Nothing in the overall findings suggests either a high mortality rate in adults or a significant deficit in the number of new calves (Lesage and Kingsley, 1998; Hammill et al., 2007). Hammill et al. (2007) hypothesized that the St. Lawrence beluga population has not recovered following the hunting ban because high juvenile mortality rates are preventing individuals of reproductive age from entering the population. Better estimates of reproductive and mortality rates will be needed to confirm this hypothesis.

1.4 Needs of the St. Lawrence Estuary Beluga Population

1.4.1 Habitat and Biological Needs

Biology and reproduction

In the St. Lawrence Estuary, belugas appear to mate between April and June (Vladykov, 1944). After a gestation period of about 14.5 months, females give birth to a single calf sometime between June and August (Béland et al., 1990; Béland et al., 1992). The nursing period lasts an estimated 20 to 32 months (Brodie, 1971; Sergeant, 1973; Seaman and Burns, 1981). Females can therefore produce a young about every three years, during which gestation and lactation overlap for a variable period.

Beluga age is determined by counting the number of growth-layer groups in their teeth. Radiocarbon dating has recently demonstrated that growth-layer groups form only once a year in belugas and not twice a year as was previously believed (Stewart et al., 2006; Lockyer et al., 2007; Luque et al., 2007). Females are now believed to reach sexual maturity at between 8 and 14 years of age, and males slightly later, at between 12 and 14 years (Brodie, 1971; Sergeant, 1973; Heide-Jørgensen and Teilmann, 1994). The longevity of the beluga is estimated at between 30 and 60 years, and possibly more than 80 years, but because their teeth wear down, stop growing, and fall out, it is difficult if not impossible to determine the maximum lifespan (Lesage and Kingsley, 1995; DFO, 2005b). Females can probably continue to reproduce throughout their entire life, although the gestation rate in older females appears to diminish (Burns and Seaman, 1985). McAlpine et al. (1999) discovered the carcass of a 68-year-old female beluga from the St. Lawrence Estuary population that showed signs of recent reproductive activity and was in the final stages of lactation.

Habitat

The beluga is a typical cold-water marine mammal. In winter its distribution is associated with areas of fast ice where open water provides air access (Barber et al., 2001). In the summer, beluga whales concentrate in specific estuaries, with high site fidelity (Fraker et al., 1979; Finley, 1982). In the St. Lawrence Estuary, belugas gather in certain areas more regularly (Pippard and Malcolm, 1978; Michaud, 1993a; Lemieux Lefebvre, 2009).

In summer, the St. Lawrence Estuary belugas break up into herds that are distinguished by age and sex (Sergeant, 1986; Michaud, 1993a, 1996). Groups of adults accompanied by juveniles inhabit mainly the upstream portion of the summer habitat, in the brackish, relatively warm waters of the Middle Estuary and the Saguenay Fjord (Michaud, 1993a). Along with the variability in salinity and temperature that characterizes these two parts of the Estuary, there are substantial differences in structural parameters such as total breadth, the presence of numerous islands, bathymetric configurations, and complex current flow patterns, all of which combine to create a mosaic of highly varied habitats (Michaud, 1993a). Despite the low proportion (less than 5 % on average) of belugas sighted in abundance surveys in the Saguenay River, the regular summer frequentation by these whales makes this area particularly important (Michaud, 1993a; Chadenet, 1997; Gosselin et al., 2007). Groups composed of adults only, on the other hand, prefer the central, downstream sectors of the summering area, in the colder, deeper, more saline waters of the Estuary (Michaud, 1993a). Michaud (1993a) provides a more precise description of the summer distribution of the different beluga herds, defined by the percentage of juveniles included (Figure 6).

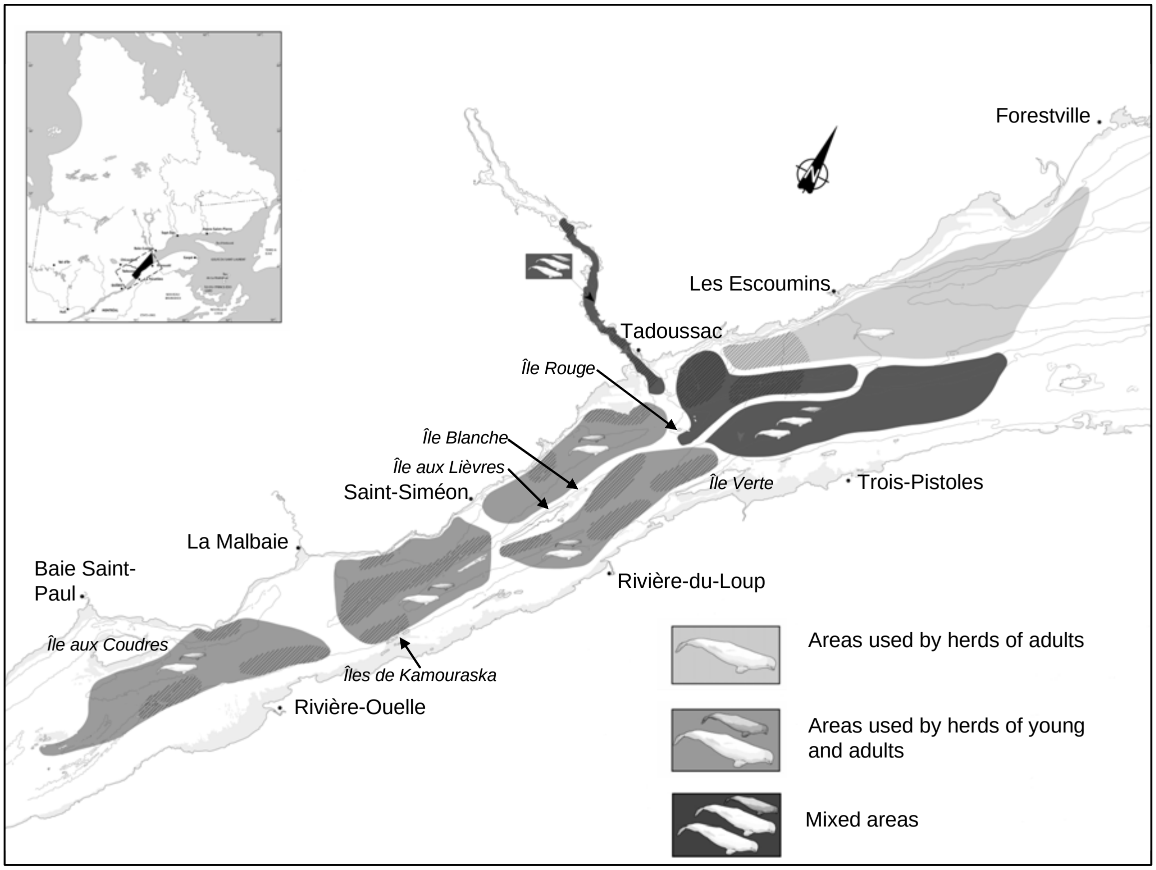

Figure 6. Summer distribution of St. Lawrence belugas by herd composition, adapted from Michaud (1993a). Herds of adults with young are found around Île aux Coudres, Îles de Kamouraska, Rivière-du-Loup, and Saint-Siméon. Herds of adults only are found in the Laurentian channel off Les Escoumins. Mixed herds are found in the Saguenay River, the head of the Laurentian channel and southern portion of the estuary. Inset: the location of the sector in Quebec.

Diet

In terms of the food chain (trophic level) the beluga is a predator, similar to certain seals and sea birds, other cetaceans, and fishermen (Lesage et al., 2001). Its diet consists of approximately 50 different species of fish and invertebrates (Vladykov, 1946; Kleinenberg et al., 1964; COSEWIC, 2004). Vladykov (1946) was the first to document the beluga's diet by analyzing the stomach contents of 165 whales. He identified mainly the following species: capelin (*Mallotus villosus*), American sand lance (*Ammodytes americanus*), cod (*Gadus morhua, G. ogac*), polychaetes (*Nereis* sp.), and cephalopods, including squid (*Illex illecebrosus*). The author found no trace of American eel (*Anguilla rostrata*) or rainbow smelt (*Osmerus mordax*) in his samples, but he did document reports that these two species had served as beluga prey. More recently, observations of belugas feeding and analyses of stomach contents have shown that belugas also prey on eels, herring (*Clupea harengus*), tomcod (*Microgadus tomcod*), and smelt (Bédard and Michaud, 1995; Bédard et al., 1997).

Two recent methods use biological markers such as stable isotopes in muscle tissue and fatty acids in the subcutaneous layer of fat to more accurately describe the beluga's place in the food chain with respect to its competitors (Lesage et al., 2001; Nozères, 2006). Researchers have found that belugas are generally at an intermediate trophic level, but that male and female belugas do not share exactly the same trophic level, females being at a lower level. This difference may be explained by differences in their consumption of benthic organisms (a lower trophic level) and by segregation of the sexes in different habitats, as females feed in less saline, more estuarine waters than males do.

Kastelein et al. (1994) studied the feeding habits of belugas in captivity. They concluded that, at temperatures ranging between 10 and 12 degrees Celsius, a juvenile beluga weighing 200 kg consumes the equivalent of 4.5 % of its body weight per day, whereas an adult beluga weighing 1,400 kg consumes 1.2 %. Thus, in the wild, an adult female weighing between 600 and 700 kg would consume approximately 4,900 kg of fish per year. Kingsley (2002) estimated that if a beluga population of about 1,240 whales consumed 2 % of their combined body weight a year, the total would come to 4,500 metric tons. It is currently impossible to determine the quantity of food available for belugas in the St. Lawrence Estuary due to insufficient information about their diet and the lack of reliable estimates of prey populations.

1.4.2 Ecological Role and Anthropogenic Value

The St. Lawrence Estuary belugas are part of the estuarine food web. Although highly placed predators on the food chain, they are also potential prey for killer whales (*Orcinus orca*) and some shark species such as the Greenland shark. Given the population size changes since the 1930s, the ecological role of the beluga appears to have diminished over the years (DFO, 2005a; Lawson et al., 2006).

In the 1970s, the vulnerable status of the beluga helped raise awareness of the contamination of the St. Lawrence and Saguenay Rivers and the need to protect marine diversity (Ménard et al., 2007). The beluga has become a Canadian symbol of wildlife threatened by industrialization and the over-exploitation of natural resources. Because belugas inhabit a relatively southern region where they are easily accessible to whale watchers, ecologists, and research scientists, they have received considerable attention. Moreover, the high levels of contaminants found in belugas have highlighted the issue of toxic chemical bioaccumulation in the St. Lawrence River (DFO and WWF, 1995). Consequently, the beluga has become an indicator of environmental quality (including human health, Measures, 2007a), and has heightened awareness of the importance of restoring the St. Lawrence ecosystem (DFO and WWF, 1995; Ménard et al., 2007). A recent survey polled Canadians on the economic benefits of rehabilitating marine mammal populations in the St. Lawrence Estuary. The results showed that Canadian citizens were concerned about protecting marine mammals and that they wanted Canada to invest more in protecting the St. Lawrence belugas, for instance, by establishing the St. Lawrence Estuary Marine Protection Area (Olar et al., 2007).

1.4.3 Limiting Factors

Belugas have a long life expectancy, delayed sexual maturity, and low reproductive rate. In the event of mass mortality, the St. Lawrence beluga population would take a long time to return to its current level, compared to species with a shorter generation time.

Beluga hunting drastically reduced the population to a genetic bottleneck (Reeves and Mitchell, 1984; Patenaude et al., 1994; Murray et al., 1999). The number of mature belugas has been estimated at 660, or 60 % of the total estimated population of 1,100 whales (DFO 2005a). This is less than the minimum of 1,000 mature animals required to maintain genetic diversity, as determined by COSEWIC. Greatly reduced populations can lose their genetic diversity, either by random allelic loss, known as genetic drift, or by reproduction between related animals, known as inbreeding. The genetic diversity of the St. Lawrence belugas is low compared to other Canadian beluga populations, which suggests that either genetic drift, inbreeding, or both have influenced the genetic characteristics of this population (Patenaude et al., 1994; Mancuso, 1995; Murray et al., 1999; de March and Postma, 2003). In addition, because this population is isolated from other beluga populations, 'genetic rescue' from other populations is unlikely (Pippard, 1985b; Sergeant and Hoek, 1988; Lesage and Kingsley, 1998).

Low genetic diversity can hinder population recovery by decreasing reproductive rates, increasing mortality rates, or both. Reproductive rates may diminish when genetically similar individuals mate, resulting in greater risk for unsuccessful fertilization or foetal loss, and therefore overall lower reproductive performance (e.g. Knapp et al., 1996). Individuals with low genetic variability also have compromised immune systems, higher vulnerability to pathogens and chemical products, and therefore higher mortality rates as demonstrated in other species (e.g. Paterson et al., 1998; Siddle et al., 2007). The low genetic diversity of the St. Lawrence beluga population, when compared to Arctic populations, could be involved in the lack of recovery.

In 1995, when the first St. Lawrence beluga recovery plan was being drawn up, members of the Recovery Team considered the possibility of introducing Arctic belugas into the St. Lawrence Estuary to increase the population's genetic diversity. They concluded that the St. Lawrence belugas were threatened more by demographic and ecological than genetic factors. It was also believed that introducing Arctic belugas would involve substantial risks, such as introducing new diseases, thereby outweighing the benefits. The current Recovery Team concurs with these conclusions.

Natural factors can cause the loss of a few individuals, and thus contribute to limit the recovery of the beluga population. Killer whales are natural predators of the beluga (Heide-Jørgensen, 1988), but no cases have been reported in the St. Lawrence Estuary in the last few decades. Predation does not appear to be a significant limiting factor for the recovery of the St. Lawrence beluga. Belugas may become trapped by ice and unable to swim to open water. Although no cases have been reported in the St. Lawrence beluga population, entrapment causes the deaths of many whales in northern populations. Belugas can also become trapped in smaller rivers and narrow waterways, and be unable to make their way back to the sea. Each year, some belugas migrate outside their normal distribution area, and some make it all the way south to the New Jersey coast (Reeves and Katona, 1980; Michaud et al., 1990). Although only one to three individuals might emigrate to other regions per year, the long-term cumulative effect on the population is negative (Sergeant and Hoek, 1988; Hammill et al., 2007). It is not known whether these whales ever return to the St. Lawrence.

1.5 Threats

1.5.1 Causes of Mortality in St. Lawrence Belugas

A threat is a factor, natural or anthropogenic (man-made), that affects or could affect the recovery of the St. Lawrence belugas. Causes of mortality are studied to better understand the factors that threaten this population. According to data gathered under the beluga carcass monitoring program, infectious diseases caused by parasites (20.0 %) or bacteria (17.7 %) were the most frequent causes of death found in beluga necropsies (Table 1). Some of the diseases are discussed in detail in the section *Epizootic disease*.

Table 1. Causes of mortality in stranded and necropsied belugas of the St. Lawrence from 1983 to 2006 (n=175) (Database of the Canadian Cooperative Wildlife Health Centre).

Cause of Mortality	Age Group			TOTAL
	Calves	Juveniles	Adults	
	Number (percentage)	Number (percentage)	Number (percentage)	Number (percentage)
Bacterial Infection	2 (13%)	2 (9.5%)	27 (19.4%)	31 (17.7%)
Dystocia (difficult delivery)	10 (67%)	0 (0%)	4 (3%)	14 (8%)
Parasitic Infection	2 (13%)	14 (66.7%)	19 (13.6%)	35 (20%)
Trauma	0 (0%)	0 (0%)	10 (7%)	10 (5.7%)
Tumors	0 (0%)	0 (0%)	28 (20%)	28 (16%)
Unknown	0 (0%)	4 (19%)	42 (30%)	46 (26.3%)
Other	1 (7%)	1 (4.8%)	9 (7%)	11 (6.3%)
Total number of carcasses	15	21	139	175

Necropsies also revealed the presence of one or several terminal malignant tumours (cancer) in 20 % of the 139 adults examined between 1983 and 2006. Tumour formation would be attributable to exposure to one or more carcinogens, weakened resistance to tumour growth due to viral or bacterial infection, or genetic predisposition (De Guise, 1998; Martineau et al., 1999; Martineau et al., 2002a; Martineau et al., 2002c; Measures, 2007a). The section *Contaminants* and Appendix 2 describe the carcinogens in greater detail. Cancer is most often found in older animals (Martineau et al., 2002a; Lair, 2007; Measures, 2008).

Traumatic lesions (for example, vertebrae fractures, deep lacerations in the skin and lungs), possibly caused by ship strikes, were found in 5.7 % of cases (Table 1). Details are provided in the section *Ship Strikes*.

1.5.2 Classification of Threats

According to the latest COSEWIC status report (2004), the St. Lawrence Estuary beluga population was massively depleted by hunting, which was banned in 1979, and is now being threatened by

1) Industrialization and pollution, which may be responsible for the high rates of chronic diseases such as cancer observed in stranded animals
2) The small population size and low genetic diversity (consanguinity), which may affect the reproductive rate

3) Habitat loss and disturbance, especially anthropogenic noise caused by marine navigation and whale watching activities
4) Competition for food resources with commercial fishermen and increasing populations of certain marine mammals, including some seal species.

The St. Lawrence belugas live downstream of the Great Lakes and the St. Lawrence fluvial section, a densely populated, highly industrialized region of Canada and the United States. Although no single factor has been directly linked to the lack of recovery, this population inhabits a highly polluted ecosystem in the middle of a busy commercial shipping corridor. Belugas are consequently exposed to a number of human activities that may cause deaths directly, such as ship strikes and entanglement in fishing nets, or indirectly, such as contaminants, which may increase rates of chronic diseases such as cancer, disrupt immune system efficiency, and increase vulnerability to pathogens. The smaller population and its geographical isolation increase these risks for extinction.

Ten threats to population growth have been identified (Table 2), four of which affect the population as a whole. These are (1) contaminants, (2) anthropogenic disturbances, (3) reduced abundance, availability, and quality of prey, and (4) other degradation of habitat. Three threats can affect or cause the death of several individual animals yearly: ship strikes, entanglement in fishing gear, and scientific research. Three additional threats can limit the recovery of the St. Lawrence beluga population when they occur: toxic spills, harmful algal blooms, and epizootic (animal) diseases. To this list we may add an historical threat: hunting. This list is based on current information, which remains limited and is subject to change as data and the situation evolve.

Because of the reduced size of the population, even activities that affect only a few individual belugas can have serious repercussions on the entire population. It is also important to take into account the cumulative and synergistic effects of these threats on the St. Lawrence beluga population. Furthermore, climate change will most certainly weigh on the impacts of identified threats to the St. Lawrence beluga, and will alter its habitat. The beluga is essentially an Arctic species that is confined to a boreal environment. The semi-arctic conditions of the Estuary have maintained the population since its separation from the Arctic populations 8,000 years ago.

Global warming, which is occurring at a faster rate than was initially forecast, should increase mean temperatures by 1.5° C to 5.5° C by 2050 in central and southern Quebec (Bourque and Simonet, 2008). Between 1960 and 2003, temperature increases of 0.4° C to 2.2° C were recorded in several regions of southern Quebec (Yagouti et al., 2006). Although temperature increases in eastern Quebec have been less than in western Quebec, the impact of this warming trend on the upstream section of the St. Lawrence River basin and in northern Quebec and the Arctic will be felt all the way into the Estuary and the Gulf of St. Lawrence.

Climate change is not considered a threat but rather a factor influencing the impact of other threats. Interaction between climate change and each threat will be discussed below, when applicable.

Table 2. Summary of threats to the recovery of the St. Lawrence beluga

Threat	Extent	Occurrence	Frequency	Causal certainty	Severity	Level of concern
Hunting and harassment	Widespread	Historical	Nil	High	High historically	**Nil**
Contaminants	Widespread	Current	Continuous	Medium	High	**High**
Anthropogenic disturbances	Localized	Current	Seasonal	Medium	High	**High**
Reduction in the abundance, quality, and availability of prey	Widespread	Imminent	Continuous	Low	Medium	**High**
Other habitat degradation	Localized	Current	Continuous	High	High	**High**
Ship strikes	Localized	Current	Recurrent	Medium	Medium	**Medium**
Entanglement in fishing gear	Localized	Current	Seasonal	Medium	Medium	**Medium**
Scientific activities	Localized	Current	Seasonal	High	Low	**Low**
Toxic spills	Widespread	Anticipated	Recurrent	Medium	Low to high	**Medium**
Harmful algal bloom	Localized	Anticipated	Recurrent	Medium	Medium to high	**Medium**
Epizootic diseases	Widespread	Anticipated	Recurrent	Medium	Low to high	**Medium**

1.5.3 Description of Threats

<u>Historic Threat</u>

1) Hunting and harassment

Hunting is considered the main cause of the decline of the St. Lawrence beluga population, which was estimated at several thousand at the end of the 19th century (Vladykov, 1944; Reeves and Mitchell, 1984; Hammill et al., 2007). Commercial whaling began in the 1600s and continued almost uninterrupted until the 1950s. From 1880 to 1950, the period of the most intensive whaling, up to 15,000 belugas were killed (Reeves and Mitchell, 1984). In the 1920s, commercial fishermen considered the belugas competitors, so the government of Quebec offered a $15 bounty for each animal killed and subsidized the use of bombs to drive belugas out of fishing areas (Anon., 1928; Grenfell, 1934; Scharrer, 1983). Subsistence and sport hunting continued into the 1970s. Due to the dramatic decline in beluga stocks and a shrinking distribution area, hunting was officially banned in 1979 under the federal *Fisheries Act*. Some cases of poaching were reported after the ban on hunting came into force (N. Ménard, Parks Canada, pers. comm.). The hunting ban remains in effect today, and poaching is no longer considered a problem.

Current Threats to the Population

Contaminants, anthropogenic disturbances, reduction in the abundance, quality, and availability of prey, and other degradation of habitat are currently considered the most serious threats to the recovery of the St. Lawrence beluga. These threats affect the overall population, and their impacts may be difficult to detect.

2) Contaminants

Contamination of the aquatic environment has a number of different sources (for example, agricultural, industrial and municipal waste, maritime shipping, dredging operations, oil and gas development, aquaculture), and it can also affect marine mammals and their prey in many different ways (Colborn and Smolen, 1996; Aguilar et al., 2002). Water, sediments, and organisms in the St. Lawrence contain a wide variety of contaminants. Consequently, the resident beluga population has been exposed to numerous toxic chemicals for many years (a summary of the main types of contaminants is presented in Appendix 2). The various toxic chemicals that make their way into the St. Lawrence Estuary are present in the water column, and can accumulate in both living organisms and the sediment.

The beluga occupies a high position in the food chain, which means that certain contaminants in their diet can be concentrated within their bodies, a phenomenon known as biomagnification. Concentrations of persistent contaminants increase with increasing level of the food chain. The beluga's tissues therefore contain higher concentrations of contaminants than both its prey and the environment (DFO, 2002). The beluga's thick layer of subcutaneous fat stores persistent contaminants, and due to its longevity, the beluga can accumulate contaminants over a long period of time. Finally, historical data show that belugas feed in part on benthic[3] prey, which are more susceptible to contamination from pollutants that have accumulated in the sediment. Belugas are therefore particularly at risk for the effects of long-term contamination. Belugas are also exposed to contaminants that do not accumulate in tissues but could nevertheless impact their health.

Even after a ban on their use or a reduction in emissions, many contaminants can persist in the environment for decades. A decreasing trend has been observed in the concentrations of some contaminants, notably dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) (Lebeuf et al., 2007; Lebeuf, 2009). Other contaminants are either unregulated or have been regulated only recently. For example, the use of polybrominated diphenyl ethers (PBDEs) in the 1990s led to their exponential increase in beluga tissues and the environment (De Wit, 2002; Lebeuf et al., 2004).

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[3] Benthic animals live on the sediments of the sea floor.

Generally speaking, contaminants can significantly disrupt endocrine, reproductive, immune, and nervous system functioning in animal species (Martineau et al., 1987; Béland et al., 1993; Colborn et al., 1993). Some researchers suspect that contaminants contribute to the high rates of cancer and other diseases in the St. Lawrence belugas (Martineau et al., 1999; Martineau et al., 2002a; Lair, 2007), as well as alterations in the reproductive system (Martineau et al., 1988; Béland et al., 1992; Béland et al., 1993; De Guise et al., 1995; De Guise et al., 1996; Martineau et al., 2002a; Martineau et al., 2003). Between 1983 and 2006, 16 % of the 175 St. Lawrence belugas that were stranded and examined had at least one terminal cancerous tumour (Table 1).

Unfortunately, toxicological studies on belugas and the identification of causal relationships are hampered by difficulties in sampling fresh tissues and conducting experiments. Although the critical thresholds at which these contaminants become toxic in belugas are not known, certain thresholds have been identified in other marine mammal species, such as the harbour seal (Ross et al., 1996). Meanwhile, the Great Lakes Water Quality Agreement, ratified by Canada and the United States, established concentration thresholds for organochlorinated compounds and mercury in prey animals to safeguard the health of fish-eating birds and mammals (IJC, 1978). PCB and mercury concentrations in some potential beluga prey have decreased in recent decades, but remain above the protection threshold for predators (Couillard, 2009). For more information about each group of contaminants, see Appendix 2.

It is important to consider that the toxicity of chemicals may also be augmented by the synergistic effect between the various contaminants. For example, De Guise et al. (1998) showed that in vitro exposure to certain mixtures of PCB congeners leads to lower production of beluga splenocytes (a type of white blood cell that plays an important role in the immune system), whereas individually and in equal concentrations, the same congeners have no discernable effect. Eriksson et al. (2006) demonstrated that PCBs and PBDEs have cumulative effects on behaviour in mice. Contaminants may also interact with other environmental factors (reviewed in Couillard et al., 2008a; Couillard et al., 2008b). For example, a reduction in prey availability at a critical time of the year could lead to the release of contaminants accumulated in the beluga's fatty tissue, and consequently increase the risk of toxic effects. Climate change and pathogens could also amplify the effects of these contaminants. Changes in temperature, pH, and salinity due to climate change could affect the toxicity and bioavailability of contaminants (reviewed in Schiedek et al., 2007).

In short, contamination in the St. Lawrence beluga population is considered a serious threat to its recovery. Despite reductions in discharges of some toxic chemicals, contaminant concentrations in beluga tissues are not decreasing very quickly. Moreover, new persistent contaminants have been introduced into aquatic habitats, and they are accumulating in beluga tissues (see Appendix 2). Belugas could therefore continue to be affected by contaminants for decades to come. Juveniles and adults continue to be exposed through their diet, and calves receive high doses directly from their mothers, which extends the time required for contamination levels to drop. Because some pathologies associated with contaminants require several years to develop (15 to 25 years), past contamination is cause for concern about the health of the current population. In addition, if contaminants are negatively affecting the reproductive system of the belugas, the already low population growth rate of the species would be further reduced.

3) Anthropogenic Disturbances

Marine traffic and marine life observation activities

In order to survive and reproduce, whales must rest, search for food, eat, avoid predators, communicate and socialize with other whales, mate, and raise their calves. If these activities are disrupted, the animal cannot carry out its vital functions and its survival is jeopardized (Kraus et al., 2005; Bejder et al., 2006b; Williams et al., 2006). If the disruption is recurrent and affects several animals, then the survival of the entire population is at risk. Navigation is a source of disturbance because of the presence of vessels and the noise they generate in the beluga habitat. Marine life observation activities (MLOA) and marine traffic are potential sources of disturbance for the St. Lawrence belugas (DFO and WWF, 1995; Lesage and Kingsley, 1995; Lien, 2001). The St. Lawrence Estuary is a major shipping corridor, and in summer, an area of intense MLOA. Since the early 1980s, MLOA has grown spectacularly, and specifically in vital beluga habitats (Ménard et al., 2007). The danger of collisions with ships and other water craft is dealt with below in the section on *Ship Strikes.*

The St. Lawrence Seaway is an exceptionally busy shipping corridor that accommodates all vessels entering or leaving the freshwater reaches of the river and the Great Lakes. Different types of vessels travel through the territory frequented by belugas: freighters, commercial vessels, ferries (approximately 90 ferry crossings per day between Tadoussac and Baie-Sainte-Catherine), ice-breakers, excursion and cruise ships, Coast Guard and Parks Canada patrol boats, National Defence ships, and research vessels. Pleasure craft, inflatable boats, and personal watercraft add to the list. Approximately 52,000 boats trips of all types were counted in the SSLMP from May to October 2007 (Chion et al., 2009). Any form of ship traffic can affect belugas, and the greater manoeuvrability and speed of smaller craft creates an additional problem (Lesage et al., 1999).

St. Lawrence belugas are susceptible to MLOA disturbance from various commercial and pleasure watercraft or aircraft (planes and helicopters). MLOA have become an important component of the regional tourism industry in the St. Lawrence Estuary (Tecsult Environnement, 2000; Lien, 2001). A study on MLOA published in 2001 revealed that over 85 % of marine mammal observation tours offered in Quebec were conducted in this area (Hoyt, 2001). In 2005, more than one million people visited the SSLMP and the observation and interpretation sites around this marine protected area. (SOM, 2006). Even though belugas are not generally targeted by MLOA, monitoring of these activities using excursion boats indicated that up to 5 % of MLOA specifically target belugas from mid-June to September (Michaud et al., 2003). MLOA are also concentrated in an area that contains 50 % of the beluga population, and these areas are heavily used by adult females and their young (Michaud, 1993a; Kingsley, 1999; Gosselin et al., 2007).

Exposure to noise and other sources of disturbance can produce behavioural reactions such as subtle changes in diving patterns, brief or prolonged interruptions in normal activities (rest, feeding, socialization, raising young, vocalization, breathing, diving), and even short- or long-term abandonment of disturbed areas (Richardson et al., 1995; NRC, 2003; Bejder et al., 2006a; Weilgart, 2007). The belugas' reaction depends on the predictability of vessel transit, the approach type, and the length and frequency of the disturbance, combined with the activity level and behaviour of the belugas at the time of the disturbance (for a review, see Lesage, 1993). Blane and Jackson (1994) observed that belugas showed ship avoidance behaviour by prolonging the intervals between surface breathing, increasing swimming speed, and forming tighter groups. It has been suggested that belugas have abandoned the Bay of Tadoussac and altered their movements at the mouth of the Saguenay River as a result of increased marine traffic in that area (Pippard, 1985a; Caron and Sergeant, 1988). Although belugas retain a certain amount of fidelity even to high-use areas (Lesage, 1993), this fidelity may simply be an indication of the importance of these sites for the species and the lack of alternate sites (Brodie, 1989). In the northeast Atlantic, it has been shown that cetaceans avoid ships that use air guns for seismic surveys used to prospect for oil and gas (Stone, 2003). It has also been shown that seismic exploration causes odontocetes (toothed whales) to alter their migration routes, swimming speed, diving patterns, and feeding habits (Stone, 2003). Cases of disturbance caused by low-flying aircraft have also been recorded along the St. Lawrence (Sergeant and Hoek, 1988). The long-term effects on the beluga population of behavioural changes in response to disruption are unknown, but these disturbances may diminish their capacity to maintain the energy reserves required for successful reproduction and survival in times of food scarcity. Disruptions that cause the separation of a mother from her calf may seriously affect the calf's chances of survival and limit potential population growth. This threat is of particular concern for the St. Lawrence belugas, because whale watching activities, which increase noise and marine traffic, peak during the summer months when whales are calving and nursing.

Anthropogenic Noise

Noise disturbance is a problem in the St. Lawrence Estuary, and is more problematic in certain sectors, for instance, at the head of the Laurentian Channel, located at the confluence of the Saguenay and St. Lawrence Rivers (Scheifele et al., 1997; Simard et al., 2006). The bandwidth of noise produced by motorized vessels is very broad, ranging from just a few Hz to over 100 kHz. The maximum energy frequency depends on the vessel's size and propulsion type. For large merchant ships navigating the Saint Lawrence Seaway, this frequency oscillates between 0.02 and 0.20 kHz, whereas the frequency for smaller craft such as inflatable boats is much higher, ranging between approximately 0.5 and 6 kHz (Richardson et al., 1995; Lesage et al., 1999; Simard et al., 2006). In any case, all vessels produce noise at higher frequencies, up to 100 kHz (Simard et al., 2006). Odontocetes produce three different types of sound: whistles, rapid sounds used for echolocation, and a variety of cries, grunts, and barks. They use these sounds to identify themselves, to coordinate their hunting, to maintain social cohesion, and to detect, locate, and identify prey and obstacles by echolocation (Richardson et al., 1995). Belugas use whistles and pulsed tonal signals for communication, generally at frequencies between 0.5 and 3.5 kHz. For echolocation, they use clicks and pulsed tones emitted at much higher frequencies, between 30 and 60 kHz (Bédard and Simard, 2006).

In the last fifty years, anthropogenic noise has increased significantly in oceans around the world. Besides all manner of ship traffic, various industrial and military activities have added to the background noise (Richardson et al., 1995; NRC, 2003; Tyack, 2008). For example, the oil and gas industry generates high noise levels in the ocean, particularly during seismic surveys, when the highest noise levels for oil and gas exploration and development activities are recorded (Richardson et al., 1995).

This higher noise level can be exacerbated by declining pH in the water column. The Intergovernmental Panel on Climate Change has released scenarios showing that the pH in the surface waters of the world's oceans will decrease by 0.3 units by 2050 (Brewer, 1997). Climate change combined with eutrophication[4] has already created a reduction of 0.2 to 0.3 pH units in the deep waters of the St. Lawrence Estuary (M. Starr, DFO, unpublished data). Hester *et al.* (2008) showed that a decrease of 0.3 pH units leads to a 40 % reduction in the capacity of the water mass to absorb sound at frequencies less than 10 kHz. This would allow anthropogenic noise to travel greater distances and further interfere with whale communication in the Estuary.

An important effect of increased ambient noise in oceans is sound masking, which interferes with the beluga's ability to accurately echolocate and communicate with other belugas (NRC, 2003). The intensity and frequency of a sound, combined with the animal's hearing capability (auditory threshold level), determine how well that sound is heard. Species like the beluga, whose hearing is highly directional, have other means of dealing with masking (Erbe and Farmer, 1998; Mooney et al., 2008). In the presence of vessels, belugas reduce the number and variation of sounds they produce, increase the duration and intensity of certain signals, and repeat sounds more often and at frequencies that are subject to less interference from the noise of the vessel (Lesage, 1993; Lesage et al., 1999). Accordingly, higher volume sounds or else a complete cessation of vocalization have been observed in St. Lawrence belugas in the presence of high ambient noise (Lesage et al., 1999; Scheifele et al., 2005; Erbe, 2008).

Lastly, anthropogenic noise can also cause temporary or permanent changes in hearing thresholds, trigger stress hormone production, lead to physical injury such as air bubble formation due to rapid ascent to escape noise (decompression), and even result in death (Ketten et al., 1993; Crum and Mao, 1996; Evans and England, 2001; Finneran, 2003; Jepson et al., 2003; NRC, 2003). Sounds generated by marine traffic in the St. Lawrence Estuary create a disturbing level of noise pollution that threatens to injure belugas' ears, which are critically vital for communication, navigation, and hunting. Furthermore, if this noise creates chronic stress in the animal, the adverse effects could affect many functions, including reproduction, metabolism, growth, immunity, and resistance to certain diseases (Lesage, 1993; NRC, 2003; Tyack, 2008). The ears of marine mammals share structural similarities with those of other vertebrates (Fay and Popper, 2000), and several studies on different vertebrate species have demonstrated that exposure to the intense noise produced by air guns during seismic surveys could injure whales' ears if they cannot avoid the sound (reviewed by Ketten and Potter, 1999; McCauley et al., 2003; Lawson and McQuinn, 2004; Southall et al., 2007).

Little is known about the effects of marine traffic on the St. Lawrence beluga population. Elsewhere in the world, these effects have been studied in several populations of cetaceans, including dolphins, killer whales, and North Atlantic right whales (Kraus et al., 2005; Bejder et al., 2006a; Williams et al., 2006). These studies suggest that high levels of marine traffic and MLOA are a threat to the recovery of the St. Lawrence beluga. Continued monitoring of the effects of these anthropogenic activities on the beluga population is required, along with the ongoing

[4] Overfertilization with nutrients, or excessive phytoplankton, in water bodies.

implementation of measures designed to mitigate their impact.

4) Reduction in the Abundance, Availability, and Quality of Prey

Reduced fish abundance

In recent decades, several fish populations in the Estuary and the Gulf of St. Lawrence have declined significantly. A number of factors can be blamed for this: overfishing, habitat degradation, pollution, and barriers to migration. For example, in the Upper St. Lawrence, the abundance index for American eels that migrate upstream at the Moses-Saunders Dam was reduced by over 99 % between 1980 and 2000, and total catches in the Estuary declined from 452 tonnes in 1980 to 82 tonnes in 2004 (COSEWIC, 2006). The cod population of the Northern Gulf dropped from 559 million in 1980 to 43 million in 2008 (DFO, 2009b). The Atlantic halibut, despite a marked increase in the past decade, remains at a low level compared to stocks in the first half of the 20th century (DFO, 2007). The rainbow smelt population has also declined considerably over the past 30 years (Équipe de rétablissement de l'éperlan arc-en-ciel du Québec, 2008). Despite the belugas' varied diet and their adaptability, changes in the specific composition of fish stocks in the Estuary could affect the nutritional quality and energy content of the available prey species.

Climate change could also affect fish stocks in the St. Lawrence Estuary. Currently, the water masses of the St. Lawrence are cooling as its cold intermediate layer is growing wider and colder (Galbraith et al., 2008). Changes in the abundance and distribution of certain species have been observed: the distribution area of capelin has drifted south and west, and macrozooplankton is less abundant than it was in the early 1990s (Harvey et al., 2005; DFO, 2008). Many fish species are sensitive to water temperature, which impacts their survival, spawning, and growth (Gilbert and Couillard, 1995; Minns et al., 1995; Gilbert, 1996; Gilbert and Pettigrew, 1996). Water temperature also determines the migration periods and routes of several fish species (Narayana et al., 1995). As the ice cover in the Gulf of St. Lawrence is closely related to air temperature, climatic models predict that the Gulf will be ice-free within 50 years (Dufour and Ouellet, 2007). A change in the ice cover can impact the food chain.

In the St. Lawrence Estuary and Gulf, lower proportions of well-oxygenated water of the Labrador current, combined with nutrients from agriculture, industry, and municipal waste in the Estuary, have caused oxygen concentrations in the deep waters of the Estuary to fall (Gilbert et al., 2005). Hypoxia (oxygen deprivation) affects several estuaries around the world, and usually results in significant changes in biodiversity and productivity (Diaz, 2001).

Finally, the tributaries of the Estuary and the coastal marshlands where several species of fish breed and grow have been polluted and degraded. Taken together, these changes could affect the abundance and distribution of species at every level of the food chain, including the beluga's prey.

Competition with other predators

The Gulf of St. Lawrence and the Estuary are inhabited by four seal species and 13 cetacean species (8 species of Odontocetes and 5 species of Mysticetes), including the beluga. Whereas cetaceans other than the beluga frequent the area from spring to fall, seals are either year-round residents, such as the gray seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*), or they are winter transients, such as the hooded seal (*Cystophora cristata*) and the harp seal (*Pagophilus groenlandica*). In winter, up to a million harp seals live in the Estuary and the Gulf (Roff and Bowen, 1983; Sergeant, 1991; Hammill and Stenson, 2005), and the resident gray seal population numbers approximately 50,000 (Hammill, 2005). Large populations of several marine bird species also compete with whales for food. These include the razorbill (*Alca torda*), the double-crested cormorant (*Phalacrocorax auritus*), the herring gull *(Larus argentatus*), the ring-billed gull *(L. delawarensis*), and the great black-backed gull (*L. marinus*) (Lesage and Kingsley, 1995).

Several studies have documented the distribution of food resources among species in the St. Lawrence River, but it is difficult to evaluate the degree of competition among these species. Lesage et al. (2001) showed that harbour seals and hooded seals are at the top of the food chain, while gray seals, harp seals in the Gulf, and male belugas are at an intermediate level, and the harp seals in the Estuary and female belugas are at a lower level. It may be that St. Lawrence belugas are less susceptible to competition for food resources because their diet, like the diet of other beluga populations, is diversified (opportunistic) (Vladykov, 1946; Lowry et al., 1985).

It is also possible that climate change will lead to a lengthening of the season most suitable for marine birds and animals that are not adapted to the icy conditions of the St. Lawrence, thereby increasing competition during winter (Kingsley, 2002; Measures et al., 2004). Ice cover, which determines the winter distribution of marine mammal species in the Estuary, is expected to diminish gradually (Bourque and Simonet, 2008).

Competition with commercial fisheries

In addition to potential competition from other species, belugas must compete with the commercial fishing industry for food. In the wake of recent declining stocks of certain ground fish, the growing interest in the exploitation of smaller pelagic fish, including the capelin, may intensify the current competition between belugas and other marine species in the St. Lawrence. Little is known about the effects of commercial fishing on the beluga population. Because capelin are an important prey for many marine mammals and bird species that summer in the Estuary, they are a key species for the entire Laurentian system (Ménard, 1998; Grégoire, 2005).

Note that no cases of starvation have been reported in retrieved carcasses, aside from two dead belugas found in the Saint-Paul River in 2001 (Lair, 2007). Although there is no direct proof that the recovery of St. Lawrence belugas is limited by prey availability, declining fish stocks could negatively impact this population and pose a serious threat to beluga recovery.

5) Other Habitat Degradation

In the summer, belugas consistently return to their summering habitats in the Estuary and the Saguenay River. This distribution pattern exposes belugas to inshore and offshore human activities such as the construction of docks, marinas, and hydroelectric dams, the expanding tourism industry, and dredging operations. An additional factor is the introduction of exotic species, which can contribute to habitat change and degradation. Certain habitat changes can become problematic for both the belugas and their food sources.

Inshore and Offshore Development

Construction and Dredging

Shoreline projects such as the construction of harbour infrastructures, bridges, and roads can alter the beluga's environment, especially by noise pollution and the destruction of prey habitats. Each year, sediments are dredged up during maintenance operations on the St. Lawrence River's navigable waterway, in ports, and in marinas. Dredging operations designed to maintain or increase the depth and width of navigation corridors or as part of port infrastructure projects, including relatively modest projects such as marina construction, disturb the sediment and resuspend contaminants into the water column. The head of the Laurentian Channel is an area where sediment is deposited and persistent pollutants from the Great Lakes and the St. Lawrence drainage basin accumulate (Lebeuf and Nunes, 2005). Furthermore, one disposal site for dredged sediment is located near Cacouna in beluga habitat and another one between Les Éboulements and Aux Coudres Island. However, concentrations of several contaminants in surface sediment in the St. Lawrence basin, especially in freshwater reaches, have diminished in recent decades, thanks to the deposit of a new layer of less contaminated sediment (Carignan et al., 1994; Lebeuf and Nunes, 2005). Under the *Fisheries Act*, each dredging project involving contaminated sediments is assessed for its impact on the fish habitat.

Hydroelectric Projects

Dams have been built on several tributaries of the St. Lawrence River, and some can form barriers to fish migration and alter habitats used by potential beluga prey. For example, although an increasing number of migrating American eels have been observed recently going up the St. Lawrence River at the Beauharnois and Moses-Saunders dams (Bernard and Desrochers, 2007), the hydroelectric turbines of these dams are an important cause of death for mature American eels migrating downriver (Caron et al., 2007). It is also possible that physical and biological changes (in flow rates, temperature, salinity, water levels, and currents) are caused by hydroelectric installations on the estuary ecosystem downstream. The effects of such changes on belugas have not yet been documented. According to some researchers, the building of hydroelectric dams on the Manicouagan and des Outardes Rivers in the 1960s may have caused belugas to abandon the Manicouagan Banks (Sergeant and Brodie, 1975; Pippard, 1985a; Caron and Sergeant, 1988). However, other authors believe that the site was abandoned due to the decline in the beluga population following a period of intensive commercial hunting from 1965 to 1970 (Reeves and Mitchell, 1984; Michaud et al., 1990). Noise associated with the development and energy production of potential tidal power plants is also cause for concern, although no studies have yet assessed its impact on marine mammals.

Oil and Gas

Seismic surveys and oil and gas developments are being carried out in coastal regions all over the world, including the east coast of Canada, east of Newfoundland and in the Scotian Shelf (Nieukirk et al., 2004). This activity creates high levels of noise in the ocean and is potentially harmful to belugas insofar as it provokes changes in behaviour, masks communication between whales, and physically impacts the hearing mechanism of the animals. Of all the stages involved in oil and gas exploration, seismic surveys create the highest level of noise (Richardson et al., 1995). Operating oil drilling platforms can also release in the environment several toxic substances such as metals, various alkyl phenols and toxic mud (Holdway, 2002; Meier et al., 2007). Seismic surveys and oil and gas developments are banned in the St. Lawrence Estuary. However, they can occur in the Gulf of St. Lawrence where belugas are likely to be present during winter.

Introduction of Exotic Species

The introduction of invasive exotic species is a global environmental issue. The establishment of non-indigenous species can alter the species assemblage and trophic chain of ecosystems. Although this threat is not considered serious at this time, as a precautionary measure, it is necessary to prevent the introduction of new species.

Ballast water[5] discharge can introduce exotic species into the waters of navigation corridors. The ballasts, hulls, and sea-chests[6] of foreign ships entering the St. Lawrence River contain assemblages of living organisms (including non-indigenous taxa, toxic or pest taxa, and potentially threatening taxa) from all over the world (Gauthier and Steel, 1996; Bourgeois et al., 2001; Simard and Hardy, 2004). The invasive exotic species found in the St. Lawrence basin are primarily freshwater species. Nevertheless, it is possible that certain invasive species could colonize environments to the detriment of the beluga's prey species.

The American Coast Guard Regulations, the *Ballast Water Control and Management Regulations* (2006) of Transport Canada, and the Canadian ballast water management guidelines require all ships entering Great Lakes ports from outside the exclusive economic zone to change their ballast water at sea. These regulations reduce the risk of introducing exotic species into the Great Lakes and St. Lawrence ecosystem through ballast waters.

Current Threats to Individual Whales

This section describes the threats that disturb or kill only a small number of whales each year, but which cumulatively increase the mortality rate in a population with low recruitment.

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[5] To ensure ship stability, reservoirs called ballasts are filled with water in a port of call and later emptied into the waters of another port.
[6] A sea-chest is a watertight box built against the hull of the ship communicating with the sea through a grillage, to which valves and piping are attached to allow water in for ballast, engine cooling, and firefighting purposes.

6) Ship Strikes

The St. Lawrence Estuary is used by an increasing variety of vessels, and the threat of ship strikes by belugas is correspondingly high. Although ship strikes can be fatal, they can also wound belugas, thereby reducing their survival rate. This danger is magnified by the occasionally risky behaviour of belugas, such as approaching vessels out of curiosity and engaging in playful behaviour close by (Blane and Jackson, 1994; DFO, 2002).

Belugas are probably at greater risk for ship strikes with tourist vessels and pleasure craft, which travel at higher speeds and in unpredictable directions. Since 1992, Parks Canada has compiled all cases of injury reported within the SSLMP (Laist et al., 2001). Since the entry into force of the *Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations*, all ship strikes must be reported. In addition, from 1983 to 2006, the carcass monitoring program identified in 11 belugas different types of trauma (including cutaneous lacerations, internal haemorrhages, and fractures) that were probably caused by ship strikes (Lair, 2007; Database of the Canadian Cooperative Wildlife Health Centre). However, it was not confirmed whether ship strikes were the main cause of the deaths or whether a disease could have made these individuals more susceptible to collision. Several belugas in the St. Lawrence Estuary have injuries or scars that may be attributable to ship strikes (R. Michaud, GREMM, unpublished data). In fact, these markings are used to differentiate belugas in photo-identification surveys.

Laist et al. (2001) analyzed historical data on ship strikes involving baleen and sperm whales. They showed that juveniles are particularly vulnerable because they spend more time near the surface and lack the experience to avoid ships. Furthermore, Blane and Jackson (1994) showed that juvenile belugas interact more with vessels than adults do. Belugas have a highly developed hearing capacity and an excellent echolocation system that help them detect ships. However, anthropogenic noise (from ships, sonar, and seismic surveys) can cause hearing impairment, making it harder to detect approaching vessels, thereby increasing the risk of collision. Unfortunately, injuries to the auditory mechanism are difficult to identify in a necropsy due to the decomposition of the carcass and other interfering factors (Faulkner et al., 1998; Measures, 2007a).

7) Entanglement in Fishing Gear

Fishing activities, especially when fixed gear or gillnets are used, are a potential cause of death for the St. Lawrence Estuary beluga. Once a beluga becomes entangled in fishing gear, it may injure itself, develop an infection, or even die of anoxia (lack of oxygen). There is not much fishing activity in the St. Lawrence Estuary, and gillnets are rarely used. Only a few cases of belugas being caught or entangled in fishing gear or other rope have been reported. In Quebec, five cases of entanglements have been reported since 1979 (DFO and WWF, 1995; Incident Recording System, Parks Canada; L. Measures, DFO, unpublished data). The risk of entanglement in fishing gear is greater when whales venture out of their regular distribution range into areas of greater fishing activity. Between 1979 and 1991, there were several reports of belugas tangled in gillnets or cod traps off the coast of Newfoundland and Labrador (Curren and Lien, 1998). Ghost fishing[7] poses an additional potential threat. Of the 30,000 gillnets set every year in Quebec, between 600 and 2,000 are abandoned or lost. In 1991, in an effort to recover lost fishing gear, 28,172 metres of net were retrieved from the waters between Matane and Forillon (Drolet, 1998). A similar operation was carried out in Côte-Nord in 2005, where a substantial number of nets were removed from the water (Laberge, 2005).

Accidental entanglement in fishing gear does not appear to be a limiting factor for the recovery of the St. Lawrence beluga population. Very few belugas bear scars caused by fishing gear (DFO and WWF, 1995; Lair, 2007). The echolocation skills of these odontocetes may allow them to detect the presence of fishing gear and avoid entanglement. However, given the low recruitment rate of this population, any source of mortality is cause for concern.

8) Scientific Research

Because it has been listed as a threatened species, the St. Lawrence beluga has been the object of many scientific studies. Fisheries and Oceans Canada, Parks Canada, various universities, and the GREMM have studied diverse aspects of the St. Lawrence Estuary beluga population for many years. Studies use data logger tags, photo identification, biopsies, and herd monitoring from boats and from the coast. Although information gathering would benefit the recovery of St. Lawrence belugas, these research projects are liable to disturb the animals. For example, boats must approach the whales to within 25 m to take photographs to identify individual animals, and within 10 m to perform biopsies using a dart shot from a crossbow (for a description of sampling methods, see Michaud, 1996).

Before any scientific study liable to disrupt marine mammals can be undertaken, a permit from DFO must be obtained, and if the research is to be conducted in the SSLMP, a permit from Parks Canada is also required. In order to obtain a permit, the research protocols and potential effects must be evaluated by an animal care committee established according to the requirements of the Canadian Council on Animal Care.

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[7] Ghost fishing refers to nets and traps that have been lost at sea but continue to trap fish and other marine animals. Because these nets are never hauled in, the fish are left to die and rot in them.

Occasional and Sporadic Threats

The following threats are occasional, arising only at particular times and places. However, when they do occur, they can cause the death of a significant number of belugas and threaten their recovery.

9) Toxic Spills

Many ships traveling through the St. Lawrence Estuary carry petroleum products and other toxic substances. The prevailing oceanographic conditions in the Estuary and Gulf, such as very strong tides and currents, the presence of ice, and the high frequency of fog, combined with continuous marine traffic through the St. Lawrence Seaway, increase the risk of accidents. To date, there have been very few major spills in the St. Lawrence, and most of those have occurred in ports (Villeneuve and Quilliam, 1999). Nevertheless, oil exploration and development can considerably increase the risk of accidents and spills (Kingston, 2005). For example, in November 2004, a large oil spill offshore of St. John’s, Newfoundland, was caused by equipment breakdown on a drilling platform. Avian and marine fauna within a radius of 5 km were affected by the spill. In addition, on April 20, 2010, an oil drilling platform in the Gulf of Mexico exploded, causing a major oil spill. The well, located at a depth of 1.5 km, spewed out approximately 780 million litres of oil into the Gulf over 11 weeks. The oil reached the coastlines of Louisiana, Alabama, and Florida. Given the relatively limited habitat available in the St. Lawrence Estuary and Gulf, a large oil spill poses a serious risk for the beluga population.

The top layer of the beluga’s skin provides an effective barrier against harmful substances, and may provide some protection from oil slicks (Geraci, 1990). Nevertheless, oil spills may still pose a risk for marine mammals due to the toxic vapours that emanate from crude oil, or volatile distillates, which can damage sensitive tissue such as eye, mouth, and lung membranes (Geraci and St. Aubin, 1990). Marine mammals can also ingest spilled material or its metabolites directly or indirectly in contaminated prey. Matkin et al. (2008) have shown how the increased mortality of killer whales off the coast of Alaska was directly linked to the Exxon Valdez oil spill of 1989. The risk of contact increases in winter because oil tends to accumulate along the edges of the ice cover, where belugas spend much of their time. Site fidelity, which is well documented in St. Lawrence belugas, could also be a factor, as it brings the whales in proximity to oil slicks. Furthermore, toxic spills could have long-term consequences on the Estuary ecosystem, for example, by reducing prey abundance through higher fish mortality or through the degradation of spawning and feeding areas (Peterson et al., 2003). Climate change is expected to produce more frequent and severe extreme weather conditions, which could in turn increase the risk of toxic spills. This threat is therefore considered very dangerous for the St. Lawrence beluga population.

10) Harmful Algal Blooms

In the summer of 2008, a red tide covering 600 km^2 appeared in the St. Lawrence Estuary. It was thought to have caused the death of 10 belugas. Proliferation of the toxic alga *Alexandrium tamarense* was responsible for the death of several cetaceans, dozens of seals, and thousands of birds, invertebrates, and fish (Database of the Canadian Cooperative Wildlife Health Centre). The neurotoxin produced by this alga, saxitoxin, causes paralysis in animals, including in the respiratory system, ending in asphyxia. Belugas ingest this neurotoxin through their prey. The effect of chronic exposure to saxitoxin on the health of belugas is unknown. The increase in scope of this natural phenomenon is probably due to the particularly abundant precipitation during the summer of 2008 (M. Starr, DFO, unpublished data). Eutrophication, climate change, and the ensuing change in rainfall regime may lead to an increase in harmful algal blooms, which would be a serious threat to St. Lawrence belugas. There is evidence that the frequency and geographic distribution of toxic algal blooms are increasing worldwide (Van Dolah, 2000). Although the explanations for this increase and its effects on marine mammals are still unclear, high mortality rates are increasingly associated with algal blooms (Scholin et al., 2000).

11) Epizootic Disease

Many factors (small population, gregarious behaviour, limited distribution area, isolation from neighbouring populations, and depressed immune system owing to chronic exposure to contaminants) have combined to make the St. Lawrence belugas more vulnerable to infectious diseases that can become epizootic[8]. A variety of marine mammal species share the relatively restricted habitat of the Estuary, living there permanently or migrating through. They are therefore liable to be exposed to a large number of pathogens (Measures, 2007b). Some of these pathogens are contained in sewage waste or runoff from agricultural land and boats (Measures and Olson, 1999). In addition, climate change could amplify the impact of these pathogens on the St. Lawrence beluga population. Global warming could increase pathogen survival during winter or lead to an influx of new marine mammal species into the Estuary, which would expose belugas to more exotic pathogens (DFO, 2002; Measures, 2004; Burek et al., 2008; Measures, 2008). Moreover, the immune system of belugas may be weakened by contaminants and stress caused by human activity (De Guise et al., 1996; De Guise, 1998), reducing their resistance to pathogens and parasites. Juveniles, with their underdeveloped immune system, are most at risk, which could greatly affect recruitment levels.

Epizootic diseases are caused primarily by viruses. The *Morbillivirus*[9] poses a particular threat to the St. Lawrence belugas, having caused the death of somewhere between hundreds and thousands of seals and whales worldwide in recent years. The *Morbillivirus* is particularly dangerous because it very rapidly reaches epidemic proportions, causes broncho-pneumonia and encephalitis, and generally results in death (Kennedy, 1998; Di Guardo et al., 2005). Belugas can become infected with the *Morbillivirus* through contact with terrestrial or marine mammal carriers (Mamaev et al., 1996; Barrett, 1999). If the St. Lawrence belugas were to become infected with the *Morbillivirus* virus, to which they have never been exposed, the consequences could be disastrous for the population: their gregariousness would facilitate propagation of the virus, and given their restricted distribution area, a great number of whales would be exposed to infection (Nielsen et al., 2000).

Other pathogens, such as the *Brucella* bacteria and the protozoa *Toxoplasma gondii*, can cause

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[8] Epidemic in an animal population.
[9] A genus that includes the human measles virus and the canine distemper virus.

infectious diseases in belugas (Measures, 2007b). Brucellosis is a concern because it affects the reproductive system, causing mastitis, abortions, neonatal mortality, and infertility (Tryland, 2000; Nielsen et al., 2001). Despite the presence of several pathogens in the St. Lawrence beluga population, no severe epizootic outbreak has been reported.

Albeit hypothetical for the time being, the threat of epizootic disease remains worrisome because a reduced St. Lawrence beluga population would be vulnerable to extinction in the case of an outbreak. Due to the risk of transmitting exotic pathogens to the St. Lawrence beluga, there is currently a moratorium on the rehabilitation of marine mammals in Quebec, particularly seals (Measures, 2004, 2007a).

1.6 Actions Already Completed or Underway

1.6.1 Protective Laws and Regulations

International Legal Protection

The beluga is listed as a vulnerable species by the International Union for Conservation of Nature, and it is protected under the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). The signatory countries, including Canada, monitor international trade in products derived from wild animal and plant species in order to ensure the survival of these species. In Canada, CITES is administered and enforced under the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act.* The St. Lawrence Estuary beluga population is listed in Schedule II of the Convention, which stipulates that a permit is required to import or export a beluga specimen.

Federal and Provincial Legal Protection

Hunting of the St. Lawrence beluga has been prohibited since 1979 by the *Beluga Protection Regulations* (1979) under the *Fisheries Act* (1985). In 1993, these regulations were replaced with the *Marine Mammal Regulations* (1993), and the regulations concerning marine mammal observation in Canadian waters became more specific. These regulations stipulate that it is unlawful to disturb a marine mammal. The Regulations are currently being revised with a view to adapting them to the different regional requirements across Canada. The *Fisheries Act* protects marine mammal habitat by prohibiting the carrying out of works or undertakings that may entail the alteration, disruption, or destruction of fish habitat, which, as defined by the Act, includes marine mammal habitat. In addition, section 36 of the *Fisheries Act* is designed to control the introduction of toxic substances into the habitat. Additionally, according to DFO’s internal policy, fishing with mobile gear is not allowed in the Upper Estuary and the Saguenay Fjord. Although not specifically aimed at protecting belugas, this measure provides some protection for its prey.

Moreover, since 2005, the St. Lawrence Estuary beluga population has been listed as a threatened species under the Canadian *Species at Risk Act*. Consequently, it is prohibited to kill, harm, harass, capture, or take any individual animal of this species, or to damage or destroy the residence of one or more individuals. The Act also prohibits the destruction of any part of the critical habitat of the species.

The regional community's concern to protect the beluga and its habitat was a determinant factor in the creation of the Saguenay–St. Lawrence Marine Park (SSLMP) (Figure 7). The Marine Park was officially established on June 10, 1998 under the so-called "mirror" laws enacted by the Canadian and Quebec government, the *Saguenay–St. Lawrence Marine Park Act* and the *Act respecting the Saguenay–St. Lawrence Marine Park*. The Marine Park, which spans 1245 km², is administered jointly by the two governments, through Parks Canada and the Ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEP). The *Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations* (2002) are derived from the federal Act. These Regulations set out protective measures for endangered or threatened species, for example, prohibiting any approach within 400 m of the animal. In addition, the number of tour boats allowed to operate as well as their speed and length of stay at the observation sites within the Park are limited and controlled by a permit system. Seismic surveys and oil and gas development are prohibited within the Park under provincial law.

The SSLMP regulations also call for the implementation of zoning. Zoning will be a vital management tool to achieve conservation objectives and ecologically sustainable use of the Marine Park. In 2006, the Sainte-Marguerite Bay Beluga Whale Committee was formed with a mandate to define protective measures for this habitat and implement actions to preserve the bay, an important summering ground for the beluga. In 2008, a management plan for marine activities was initiated in the Marine Park. Both projects aim in particular to develop specific management strategies for marine activities in the Marine Park, which is an important beluga habitat as well as a site of considerable vessel traffic of all kinds.

Furthermore, the beluga could be protected by Canadian and Quebec laws providing for the creation of marine protected areas (MPAs) in the future. The *Oceans Act* (1996) gives DFO the authority to establish MPAs in order to protect one or more components of an ecosystem where species are at risk. Quebec's *Natural Heritage Conservation Act* (R.S.Q. chapter C-61.01) grants the MDDEP the authority to designate protected areas in its territory in order to protect the diversity and important components of the marine ecosystem. Since 2007, the Bilateral Group on Marine Protected Areas (BGMPA) made up of representatives from the two governments has coordinated efforts to establish a network of marine protected areas in Quebec. This group is currently working to develop an MPA approximately 500 km² in size in the Manicouagan sector. This proposed MPA will cover the territory that the beluga occupies from fall to spring. In the past, belugas occupied this territory in summer. A protected marine space around the Manicouagan peninsula will ensure good quality habitat for belugas from the St. Lawrence should they widen their summer distribution area. The BGMPA will then examine the St. Lawrence Estuary Marine Protected Area Project, which covers a 6000 km^2 area adjacent to the SSLMP and is occupied by belugas in summer (Figure 7). This project specifically aims to protect and conserve marine mammals, their habitats, and their food sources over the long term, while maintaining sustainable economic activities. The area under consideration covers the sector where human pressures on marine mammals (MLOA, maritime traffic) are the strongest outside the Marine Park.

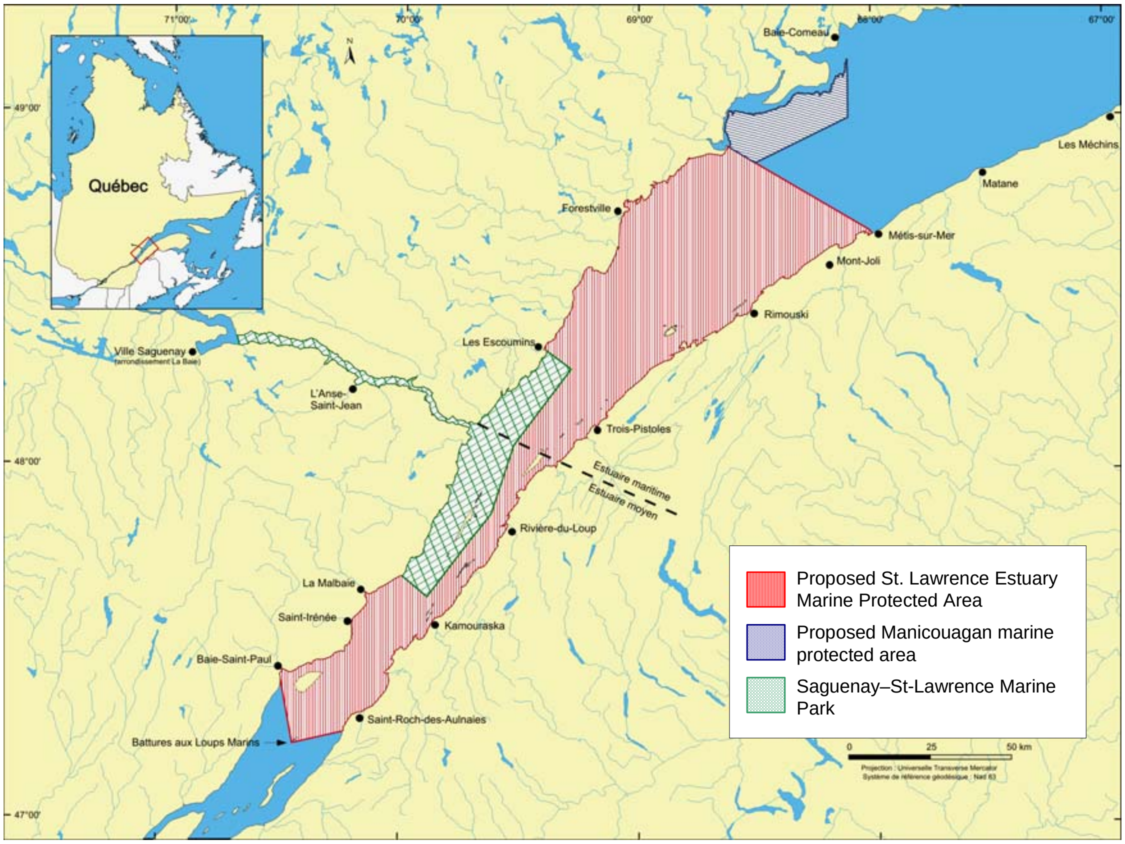


Figure 7. Map of the Saguenay-St. Lawrence Marine Park and the two proposed marine protected areas (MPAs), the proposed Manicouagan marine protected area and the proposed St. Lawrence Estuary Marine Protected Area. Inset: the location of the sector in Quebec.

Other federal regulatory or legislative measures to control activities liable to impact the St. Lawrence Estuary beluga population include the *2001 Canada Shipping Act*, the *Canadian Environmental Assessment Act* (1992), and the *Canadian Environmental Protection Act* (1999). Certain provisions in the *2001 Canada Shipping Act* provide the framework for the activities of a Regional Response Team, whose role is to initiate cleanup operations in case of a spill. Environment Canada, DFO, the Ministère des Ressources Naturelles et de la Faune du Québec, and some non-governmental organizations are required to work together to rescue animal species in case of a spill. The SSLMP has developed its own emergency response plan in cooperation with emergency coordination agencies (Auger and Quenneville, 2001). Response capabilities to an accidental oil spill in the Saguenay Fjord were tested and a number of recommendations were issued (Dinel and Duhaime, 1997; Auger and Quenneville, 2001). However, implementing an effective contingency plan to preventing belugas from being exposed to toxic spills is a challenge, given the numerous constraints in real situations.

The Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment specifies "the mitigation requirements that must be met during the planning and conduct of marine seismic surveys, in order to minimize impacts on life in the oceans. These requirements are set out as minimum standards, which will apply in all non-ice covered marine waters in Canada".

St. Lawrence belugas are also protected under the *Act respecting threatened or vulnerable species* (L.R.Q., c.E-12). Other provincial laws can contribute to the protection of belugas, particularly by controlling pollutant emissions: the *Environment Quality Act* (L.R.Q., c. Q-2), the *Act respecting the conservation and development of wildlife* (L.R.Q., c. C-61.1), and the *Water Act* (L.R.Q., c. R-13).

1.6.2 Water Quality Improvement Programs in the St. Lawrence Estuary

In 1972, the Quebec Legislature passed the *Environment Quality Act* (EQA). In 1978, as part of the EQA, the government launched a wastewater treatment program called the *Programme d'assainissement des eaux du Québec* (PAEQ). This program invested almost seven billion dollars into the construction of municipal sewage treatment plants across the province. The PAEQ also required industries not linked to municipal sewage plants to build their own wastewater treatment facilities. The result was a significant decrease in wastewater discharge into waterways across the province. The *Programme de réduction des rejets industriels*, or industrial waste reduction program, also a part of the EQA, targets Quebec's main industrial sectors in an attempt to reduce polluting emissions. In 1988, the Quebec and Canadian governments joined both efforts and investments to launch the *St. Lawrence Action Plan* (SLAP) in an attempt to clean up the St. Lawrence River. The primary objective was the elimination of chemical pollution from the river. Fifty major enterprises were targeted and required to reduce their toxic liquid waste by 90 % over five years. In 1993 and 1998, two new phases of the program were initiated, called *St. Lawrence Vision 2000*, in which 56 more plants were added to the priority list for reducing toxic emissions. At the end of this campaign, measurable improvements were noted and concrete measures had been taken, and most of the targeted plants reduced their toxic effluents (Dartois and Daboval, 1999). Among others, the SLAP led to a reduction in polycyclic aromatic hydrocarbon (PAH) emissions from aluminum smelters, which led in turn to lower concentrations of these contaminants in the surface sediments of the Saguenay River (Gearing et al., 1994; White and Johns, 1997). In addition, Priority Intervention Zone (PIZ) Committees were set up during the second phase. The action plan also includes strategies for biodiversity conservation, clean agricultural practices, public protection, and the management of water levels and ship traffic. The discharge of toxic chemicals has decreased immensely since the implementation of the PAEQ, the SLAP, and the application of regulations for the reduction of polluting emissions from pulp mills and refineries (Rondeau, 2002; Painchaud and Villeneuve, 2003; Pelletier, 2005).

Furthermore, in 1996, a committee was formed to define issues in contaminated aquatic sites and to identify sites requiring immediate attention due to their impact on the St. Lawrence beluga. Based in the information available at the time, they identified 38 sites where high toxic chemical concentrations in sediment posed a potential threat to belugas (Gagnon and Bergeron, 1997).

Several Canadian and American programs have been set up to improve water quality in the Great Lakes, which flow into the St. Lawrence: the Canada-Ontario Accord, the Great Lakes Water Quality Accord, the Great Lakes Binational Toxics Strategy, the federal Great Lakes Program, and

Lakewide Management Plans. Canada has also made international commitments[10] to effectively control the trade of hazardous chemical products.

1.6.3 Ban on oil and gas exploration and development

Following a 2004 BAPE inquiry and public consultation concerning seismic surveys and a strategic environmental assessment, started in 2009 to assess the environmental, social, and economic issues surrounding oil and gas exploration and development in the St. Lawrence Gulf and Estuary, the Government of Quebec banned drilling in the lower estuary and northwest Gulf of St. Lawrence. This ban covers the greater part of the St. Lawrence beluga's distribution area.

1.6.4 Stewardship

Quebec Marine Mammal Emergency Response Network (QMMERN)

From 1982 to 2002, DFO and the SLNIE monitored stranded marine mammals in the St. Lawrence Estuary. GREMM took over this project in 2003, and in 2004 created the Quebec Marine Mammal Emergency Response Network to help distressed animals, in collaboration with thirteen partners, including DFO and Parks Canada. The mandate of this network is to organize, coordinate, and implement measures to reduce accidental marine mammal mortalities, to rescue distressed animals, and to gather information from animals that are dead, stranded, or adrift in the Quebec waters of the St. Lawrence. GREMM coordinates the network and runs the call center.

Awareness raising at the SSLMP

Each year, the SSLMP offers a training course for tour boat operators to familiarize them with good practices in marine mammal observation (including the regulations for activities at sea, biology, and tips on how to diversify tours). Since 2008, this course has been mandatory for anyone wishing to obtain a permit to operate in the Park. Parks Canada plans to expand this training to cover kayaking guides and naturalists. Parks Canada and Parcs Québec are also carrying out a number of initiatives in the park, such as educational tours and patrols designed to raise the awareness of recreational boaters about Park regulations. A pamphlet outlining the current Park regulations is also available to the general public. In 2007, DFO and Parks Canada, in collaboration with the marine mammal observation industry, published guidelines for best practices for watching marine mammals in Quebec.

Habitat Stewardship Program

Several different projects have been initiated as part of the Canadian Habitat Stewardship Program

[10] Stockholm Convention of Persistent Organic Pollutants, Prior Informed Consent Procedure for the export of chemicals of the Rotterdam Convention, Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

(HSP) for Species at Risk:

- In 2003, the PIZ Committee for the north shore of the Estuary created a network for shore-based whale observation and interpretation sites. An awareness project was also initiated to inform kayakers of appropriate boating behaviour around endangered marine mammals.
- The Marine Mammals Ecowatch Network has launched an awareness project to encourage tourism employees and directors to rethink their approach to whale watching activities. The Network has been monitoring MLOA in Gaspésie since 2006, and has been visiting public schools since 2005 to raise youth awareness of endangered species.
- The Corporation PARC Bas-Saint-Laurent has designed and implemented a school program to raise awareness of marine mammals.
- GREMM publishes a weekly newsletter called *Whale Echo* during the tourist season. Aimed at boat captains and naturalists, it provides the latest news on current projects and initiatives to protect whales.
- The coordination centre for the QMMERN also receives support from the HSP.

1.6.5 Measures to mitigate disturbance by scientific activities

There are many ways of minimizing disturbance to belugas during field surveys, for example, reducing speed when approaching a herd, waiting 15 minutes before approaching a herd within 300 m, working close to a herd for a maximum of three hours at a time, and not taking biopsy samples from groups that include calves. In studies on the effects of biopsy sampling on beluga behaviour, it was found that whales that were shot with a dart would generally make a sudden dive, followed by the accompanying herd of whales. Fifteen to 20 minutes later, however, the targeted whale, along with the rest of the herd, seemed to exhibit no after-effects of the dart, and were as easily approachable as before (Michaud, 1996; De la Chenelière, 1998).

1.6.6 Research

In addition to the beluga carcasses monitoring program, several research groups from different programs are studying St. Lawrence Estuary belugas. The following is a non-exhaustive list of these research programs:

- In order to monitor population size and trends, aerial surveys have been carried out every two or three years, since 1988, by DFO scientists.

- For several years now, Parks Canada has been conducting a beluga observation research project at two sites in the SSLMP (Pointe Noire, at the mouth of the Saguenay River, and Sainte-Marguerite Bay) to better understand the beluga’s use of these sectors and to assess marine traffic intensity. The collected data will be used to develop a management plan for marine activities in these areas. A portrait of navigation in the SSLMP was completed in 2007. In 2009, a study on beluga prey in high-use areas was initiated.

- GREMM has been conducting research on the distribution and social organization of belugas, using photo-identification, biopsies, and close monitoring of herds over a 20-year period. A project to study marine life observation activities conducted by GREMM and Parks Canada since 1994 was expanded with the participation of DFO in 2005. The research project aims to characterize MLOA, assess the distribution of marine animals, and eventually develop regulations and evaluate the impact of current management measures in the SSLMP and the proposed MPA in the St. Lawrence Estuary.

- Since 2001, GREMM and DFO, in collaboration with Parks Canada, have carried out a joint study on beluga diving patterns and movement in the Estuary to better understand their use of the habitat.

- Since 2004, DFO and the Department of National Defence have conducted a joint study of the intensity of noise pollution to which belugas are exposed in different habitats.

- Since 2004, DFO has monitored whale distribution in the St. Lawrence Estuary and used a computerized continuous hydrophone system to assess their exposure to noise. The objective is to characterize the use level of beluga habitats through acoustic analysis and to understand the processes behind the creation and maintenance of an important and regularly frequented habitat for the St. Lawrence belugas: the mouth of the Saguenay River.

- The University of Connecticut, in collaboration with GREMM, DFO, Parks Canada, the Department of National Defence, and Park Foundation, is conducting a research program to evaluate the effects of noise pollution on this threatened population.

2. RECOVERY

2.1 Population and Distribution Objectives

In the *St. Lawrence Beluga Recovery Plan* published in 1995, the recovery goal was: "*to bring population numbers and conditions to a state at which natural events and human activity will not threaten the survival of the St. Lawrence beluga whale population…it appears that reducing pollution and disturbance should ensure that humans and belugas will continue sharing the St. Lawrence Estuary*" (DFO and WWF, 1995). The goal of the current recovery strategy remains to restore the beluga population to a level where its survival is no longer threatened by natural and anthropogenic disturbances.

The historical population is estimated at 10,100 individuals (DFO, 2005b). The long-term population objective of the St. Lawrence Estuary beluga is 7,070 individuals, or 70 % of its historical population, which corresponds to the precautionary approach adopted by DFO for managing various marine resources (DFO, 2006; Hammill and Stenson, 2007). However, this population could be considered no longer at risk before this objective is reached (DFO, 2005b). At the current 1 % annual growth rate, this long term objective could be achieved by 2100. If limiting factors for population growth are identified and eliminated, the growth rate could attain a theoretical maximum of approximately 4 %, in which case the long-term population objective would be achieved by 2050 (Figure 8). This recovery strategy also aims for a minimum 2 % population growth rate. In order to have an intermediate population objective that could maintain genetic diversity, an objective of 1,000 mature individuals was also determined. According to the COSEWIC assessment criteria, achievement of this intermediate objective could result in "at less risk" status. As the population increases, it is hoped that the distribution area of the St. Lawrence beluga will also increase to a minimum level corresponding to 70 % of the historical distribution area (DFO, 2005b).

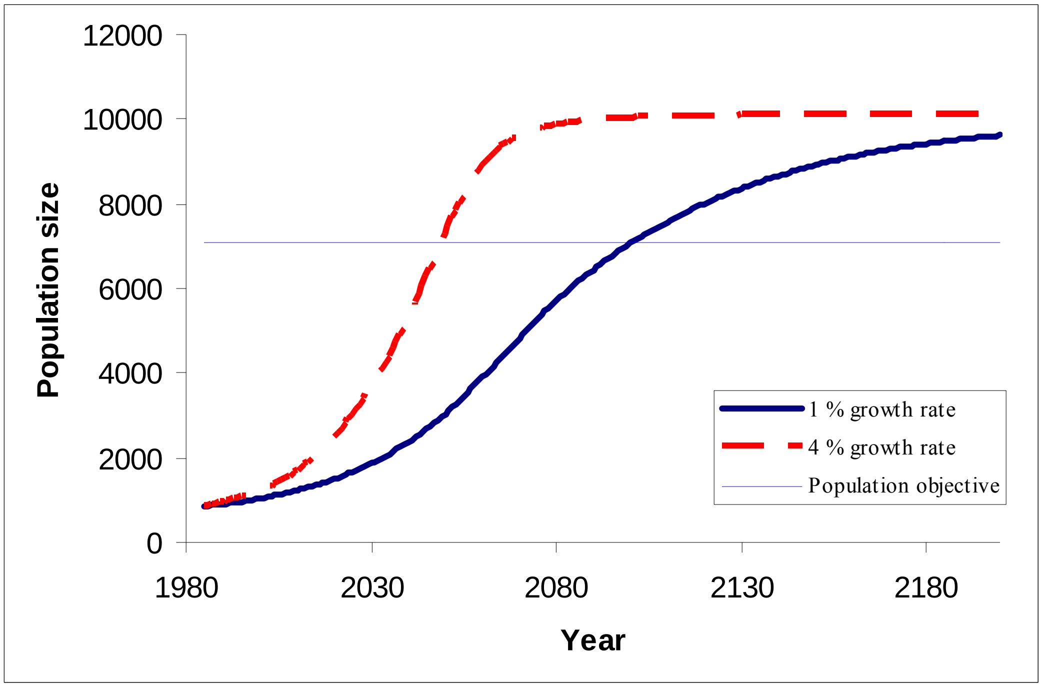


Figure 8. Time to meet the population objective of 7,070 individuals at the current growth rate of approximately 1 % and at the theoretical maximum rate of 4 % (M. Hammill, DFO, unpublished data).

2.2 Recovery Objectives

To achieve the population and distribution objectives of this recovery strategy, six recovery objectives have been identified:

1) Reduce contaminants in belugas, their prey, and their habitat that could prevent population recovery;
2) Reduce anthropogenic disturbances;
3) Ensure adequate and accessible food supply;
4) Mitigate the effects of other threats to population recovery;
5) Protect beluga habitat throughout the entire distribution range;
6) Ensure regular monitoring of the St. Lawrence Estuary beluga population.

Strategies to reach these recovery objectives are put forward in the following table.

2.3 Strategies and measures to Achieve Recovery Objectives

2.3.1 Recovery Planning

Table 3. Recovery Planning Table for the St. Lawrence beluga.
(Level of priority: Beneficial, or useful for recovery; Necessary, or having great potential for recovery; Critical, or indispensable for recovery.)

Priority	Threat	Recovery Strategies	Measures
Objective 1. Reduce contaminants in belugas, their prey, and their habitat that could prevent population recovery			
Critical	Contaminants	Study the effects of contaminants on belugas, their key prey species, and sentinel species.	Study the effects of contaminants on survival, health, reproduction, and growth.
			Evaluate the risks of the potential impacts of different contaminant groups on belugas and the factors that influence these risks.
Critical	Contaminants	Develop new regulations or fully apply existing regulations to control the discharge of toxic pollutants into the environment, especially new contaminants.	Improve Canadian and Quebec regulations to reduce toxic chemical discharges into the Great Lakes–St. Lawrence Basin, particularly by reviewing or setting toxicity thresholds for pollutants.
			Develop mechanisms to monitor the impacts of regulation.
			Reduce the number and scope of accidental and illegal discharges of pollutants.
Critical	Contaminants	Reduce emissions and discharges of all types of pollutants at the source.	Reduce discharges of pollutants from waste storage sites, landfills, sewage treatment plants, industries, etc.
Necessary	Contaminants	Monitor contaminant sources and concentrations in the tissues of belugas and their key prey species.	Identify the main sources of contamination, and determine how contaminants spread through the beluga population and its environment, and how belugas and their prey are exposed to different contaminant groups.
			Study the movement and spread of contaminants in the tissues of belugas, key prey species, and sentinel species, particularly emerging contaminants, and publish results.
Necessary	Contaminants	Continue cleanup of contaminated terrestrial and aquatic sites in the Great Lakes–St. Lawrence Basin.	Identify priority contaminated sites and use environmentally sensitive decontamination techniques to clean up identified sites.
Necessary	Contaminants	Continue coordinating pollution reduction efforts, in collaboration with the International Joint Commission.	Initiate actions with Quebec, Ontario, and the United States to coordinate efforts to reduce pollution in the Great Lakes and the entire St. Lawrence River basin.

Priority	Threat	Recovery Strategies	Measures
Objective 2. Reduce anthropogenic disturbances			
Critical	Disturbance	Determine the short- and long-term effects of chronic and acute forms of disturbance.	Carry out impact studies of disturbances created by marine traffic, MLOA, aircraft, and development projects in- and off-shore in areas used by belugas.
			Based on disturbance impact studies, determine management measures to reduce disturbance.
Critical	Disturbance	Study the impacts of noise pollution on belugas.	Identify main noise sources of various frequencies, monitor beluga exposure, and study the impacts of noise on the beluga’s health and behaviour.
			Based on noise impact studies, determine management measures to reduce noise pollution.
Critical	Disturbance	Reduce anthropogenic disturbances in high-use areas.	Reduce anthropogenic noise in the St. Lawrence Estuary (construction, navigation, gas exploration, etc.).
			Implement protection measures in problematic marine traffic lanes.
			Reduce the number of incidents (e.g., direct approaches, harassment).
			Develop best practice guidelines for chance meetings with belugas.
Necessary	Disturbance	Protect belugas against anthropogenic disturbances throughout their entire distribution area.	Review, adopt, and enforce the *Marine Mammals Regulations* as well as the *Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations* to better protect belugas from disturbance, particularly by enforcing a 400 m “no-boat” zone around belugas throughout the area.
			Improve MLOA monitoring patrols during the tourist season in the SSLMP and elsewhere in the Estuary.
Necessary	Disturbance	Implement the education strategy for species at risk developed by the SSLMP and extend it to cover the entire beluga distribution range.	Identify target groups for awareness campaigns, and develop and implement a communications strategy.
			Improve training for captains, kayaking guides, and nature guides in order to reduce disturbances, and make training mandatory.
			Publicize conservation actions and provide educational activities to local residents.
			Set up a recognition program for sea excursion companies that adopt best practices.

Priority	Threat	Recovery Strategies	Measures
			Define specific best practice guidelines for each type of user navigating the St. Lawrence Estuary.
Necessary	Disturbance	Improve the decision-making process for granting research permits and permits for other activities requiring approaches within 400 m.	Establish the rules and a decision-making committee, and set up a single-window system, in collaboration with all the responsible authorities, to evaluate the relevance, methods, and issuance of permits for projects involving belugas or their critical habitat.
Objective 3. Ensure adequate and accessible food supply			
Critical	Food supply	Protect spawning and rearing sites and migration corridors of key prey species.	Strengthen measures to protect important sites for key prey species.
			Prohibit trawl nets from the Upper St. Lawrence Estuary and the Saguenay River.
			Maintain the moratorium on forage species.
Necessary	Food supply	Continue research on the diet and feeding habits of belugas.	Study diet habits and feeding strategies.
			Study prey availability and factors that influence their quantity and quality.
			Based on studies of prey availability, determine management measures to protect the beluga's food resources.
Beneficial	Food supply	Prevent new fisheries with the potential to significantly impact belugas and their prey.	Consider the beluga's food requirements when assessing new fisheries.
Objective 4. Mitigate the effects of other threats to population recovery			
Critical	Other habitat degradations	Develop and implement adequate protective measures for all inshore and offshore projects that could have an impact within the beluga distribution area.	Include protective measures in inshore and offshore projects.
			Conduct an environmental impact assessment for all oil and gas exploration and development projects in the St. Lawrence Gulf.
Critical	All	Maintain and improve the carcass monitoring program, with a focus on determining causes of death.	Improve the reliability and accessibility of the carcass monitoring program database (since 1983) and improve data processing and integration methods.
			Regularly publish results.
			Based on studies of causes of death, determine management measures to reduce sources of mortality.

Priority	Threat	Recovery Strategies	Measures
Necessary	Algal blooms, spills, and disease	Prepare emergency plans for belugas in case of spills, harmful algal blooms, and epizootic diseases	Prepare or update emergency plans for the St. Lawrence Estuary.
Necessary	Entanglement	Reduce the impact of ship strikes and entanglement in fishing gear.	Develop tools to detect and prevent strikes and entanglements.
			Ensure the continued operation of the Marine Mammal Emergency Response Network.
			Ensure monitoring of incidents involving belugas (ship strikes, wounds, incidental catches, harassment).
Beneficial	Toxic spills	Inform and raise awareness of navigators (all boat types) on the regulations and the impacts of pollutant discharges.	Carry out an awareness and education campaign on the regulations on pollutant discharges.
			Monitor the number of incidents.
Beneficial	Algal blooms, spills, and disease	Detect and prevent spills, algal blooms, and epizootic diseases.	Develop tools to detect and prevent spills, algal blooms, and epizootic diseases.
Beneficial	Collisions	Reduce ship strikes, in particular with tourist vessels and pleasure craft.	Carry out awareness campaigns targeting captains of tourist vessels and pleasure craft.
Beneficial	New threats	Examine other potential obstacles to recovery.	If new threats are identified, initiate additional research and management strategies to reduce the impact.
Objective 5. Protect beluga habitat in all its distribution range			
Critical	All	Increase our understanding of the seasonal distribution and potential habitats of belugas.	Identify beluga high-use areas according to season, including the characteristics that make them favourable to belugas and the vital functions they support, and identify potential new habitats should the distribution area expand as well as threats to these habitats.
Critical	All	Protect beluga habitat using diverse legal tools.	Set up Marine Protected Areas in beluga territory, such as the St. Lawrence Estuary Marine Protected Area Project and the Manicouagan Aquatic Reserve.
			Enact zoning regulations in the SSLMP to protect high-use areas.
			Study the feasibility of extending the boundaries of the SSLMP, in accordance with the management plan of the marine park (PCA and MDDEP, 2010), to include a more significant portion of the belugas' summering area.

Objective 6. Ensure regular monitoring of the St. Lawrence Estuary beluga population			
Critical	All	Monitor the St. Lawrence beluga population.	Continue to conduct population surveys, at least every three years.
			Monitor juvenile recruitment rates and causes of juvenile mortality.
			Continue the population monitoring program (distribution, size, structure, dynamics, social organization, and genetics).

2.3.2 Narrative to Support the Recovery Planning Table

Each of the first three objectives targets a specific threat to the recovery of the St. Lawrence beluga: contaminants, anthropogenic disturbances, and prey availability. Many toxic chemicals discharged by past, current, and future industrial processes and modern consumer products can hinder the recovery of the St. Lawrence belugas by interfering with their vital functions or by inducing potentially fatal pathologies. A reduction in contaminant levels is therefore a priority objective to ensure the recovery of this population. Anthropogenic disturbances, on the other hand, stem primarily from the high volume of commercial and recreational marine traffic along the St. Lawrence Estuary, including observation activities at sea. There is a need to propose approaches to reduce the risk related to anthropogenic disturbances from the different types of vessels or noise associated with human activities. Many fish stocks in the St. Lawrence Estuary have been reduced in recent decades. Despite their varied diet, belugas may no longer be able to find prey in sufficient quantity or quality to ensure population recovery in the Estuary. Another objective of the recovery strategy is therefore to ensure adequate and accessible food supply.

Other threats to the recovery of the St. Lawrence beluga have been included under the fourth objective: "Mitigate the consequences of other threats to population recovery." It is critical that approaches be proposed to mitigate or eliminate all threats, and that vigilance be maintained to identify new threats. It is equally critical to deepen our understanding of habitat use in order to protect important areas in the St. Lawrence. Belugas occupy various habitats, depending on the season, and we know little about what are the important features of the habitat, or about the functions they support.

Finally, despite the ban on hunting, the growth rate of the St. Lawrence Estuary beluga population remains very low. Continued monitoring of the population status, particularly the juvenile mortality rate, is required to determine the effectiveness of any recovery measures. Monitoring is also essential to identify and better understand the most serious threats to this population and to find the means to mitigate or eliminate them.

2.4 Critical Habitat

The *Species at Risk Act* stipulates that a recovery strategy must include *"an identification of the species' critical habitat, to the extent possible, based on the best availa*ble *information, […], and examples of activities that are likely to result in its destruction"* (paragraph 41(1)(c)). This identification is designed to facilitate the protection of the critical habitat of the St. Lawrence beluga from human activities that can destroy it and compromise the survival and recovery of the species.

Critical habitat is defined in the *Species at Risk Act* (2002) section 2(1) as:

> *"…the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in a recovery strategy or in an action plan for the species."* [s. 2(1)]

SARA defines habitat for aquatic species at risk as:

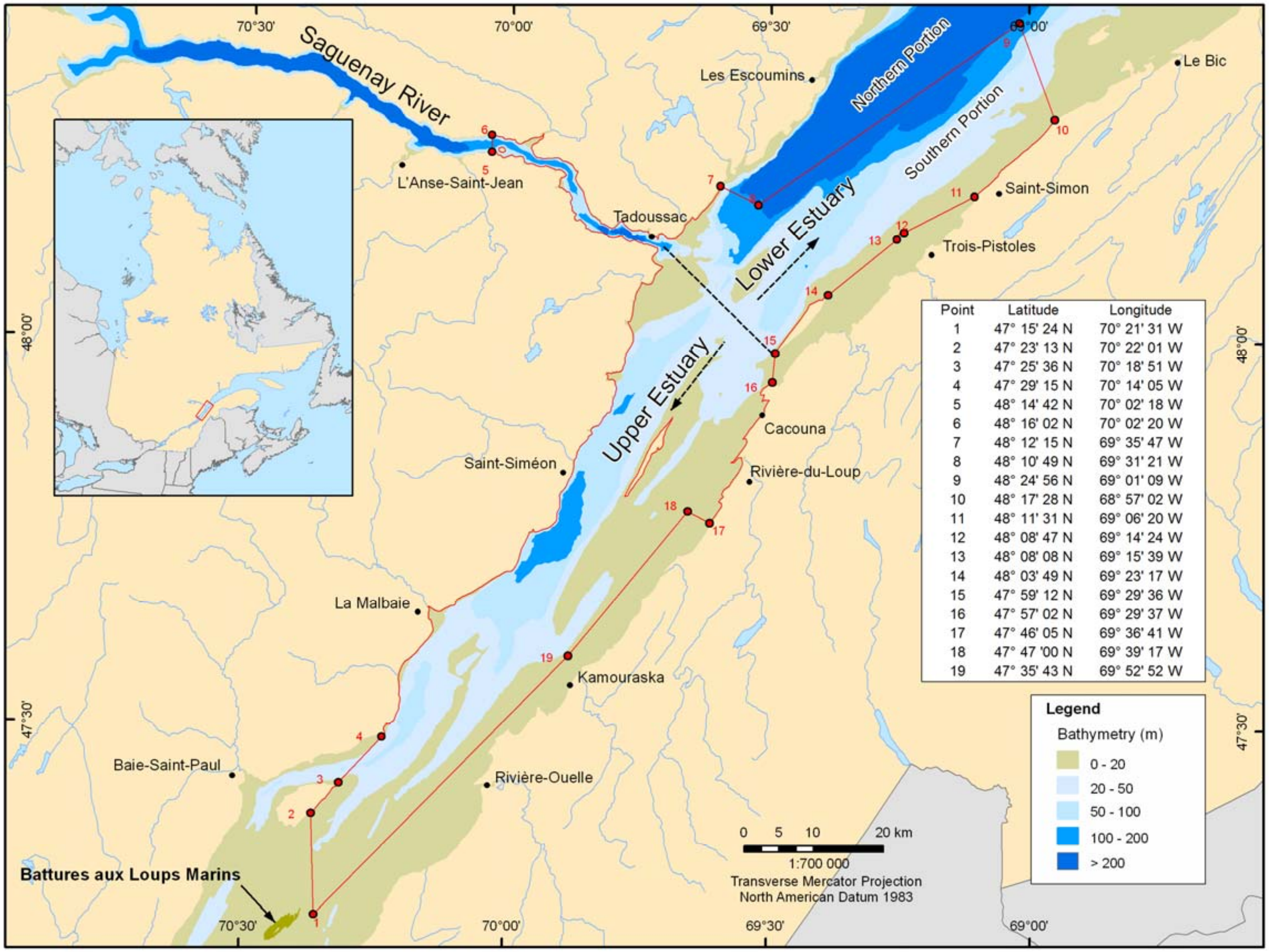
> *"… spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced."* [s. 2(1)]

For the St. Lawrence beluga, critical habitat is identified to the extent possible, using the best available information. The critical habitat identified in this recovery strategy is necessary for the survival and recovery of the species, but, due to inadequate information, it is not possible to know whether it is sufficient to achieve the population and distribution objectives for the species. In particular, knowledge on critical habitat features and their attributes which support vital functions is insufficient. The schedule of studies outlines the research required to obtain better knowledge on the critical habitat and to identify additional critical habitat necessary to support the population and distribution objectives for the species.

2.4.1 Information and methods used to identify critical habitat

In order to identify the critical habitat of the St. Lawrence beluga, all the available information on the beluga's habitat requirements, its prey, seasonal distribution, use and characteristics of its habitat has been reviewed (Mosnier et al., 2009). The information was gathered from academic, governmental, and non-governmental sources. This literature review was used to produce a science advisory report on the identification of critical habitat for the St. Lawrence beluga that was peer-reviewed and published (DFO, 2009a). The identification of critical habitat was then discussed with the St. Lawrence beluga Recovery Team in May 2010. This team includes marine mammal experts. Using the available information and the scientific advisory report (DFO, 2009a), the Recovery Team recommended the identification of the critical habitat as it is presented in this strategy.

To date, the knowledge of the beluga's habitat is largely based on the current summer use. Historical use and current winter habitat use are less well known. Present knowledge suggests a spatial segregation of belugas based on sex and age, which is typical of this species in the summer. The Upper Estuary, where the females with calves and juveniles are concentrated, is likely an important habitat for calving and rearing of the young. The reasons why this segregation occurs and the habitat's attributes that make it critical to the survival of females, calves and juveniles are not clearly defined. The identification of the St. Lawrence beluga critical habitat is based on the summer distribution range of females and their calves because this habitat supports the function of calving and rearing of the young and thus juvenile survival. Based on the hypothesis of juveniles having difficulties to survive that was put forward to explain the absence of recovery since the hunting ban, the Minister of Fisheries and Oceans considers this habitat critical to the survival and recovery of the St. Lawrence beluga. The northern portion of the Lower Estuary is known to be used for feeding by groups of adults only, which are not as strongly attached to this habitat as groups of females with calves and juveniles to their summer habitat. Only groups of adults exhibit a greater mobility for feeding and likely occupy a larger area, even in the summer. The use of this area by the beluga will have to be further studied as indicated in the schedule of studies to identify critical habitat (Table 5).



Point	Latitude	Longitude
1	47° 15' 24 N	70° 21' 31 W
2	47° 23' 13 N	70° 22' 01 W
3	47° 25' 36 N	70° 18' 51 W
4	47° 29' 15 N	70° 14' 05 W
5	48° 14' 42 N	70° 02' 18 W
6	48° 16' 02 N	70° 02' 20 W
7	48° 12' 15 N	69° 35' 47 W
8	48° 10' 49 N	69° 31' 21 W
9	48° 24' 56 N	69° 01' 09 W
10	48° 17' 28 N	68° 57' 02 W
11	48° 11' 31 N	69° 06' 20 W
12	48° 08' 47 N	69° 14' 24 W
13	48° 08' 08 N	69° 15' 39 W
14	48° 03' 49 N	69° 23' 17 W
15	47° 59' 12 N	69° 29' 36 W
16	47° 57' 02 N	69° 29' 37 W
17	47° 46' 05 N	69° 36' 41 W
18	47° 47 '00 N	69° 39' 17 W
19	47° 35' 43 N	69° 52' 52 W

Figure 9. Critical habitat of the St. Lawrence beluga. It extends from the Battures aux Loups Marins to the southern portion of the Estuary, off Saint-Simon. It includes the lower reaches of the Saguenay River. Inset: the location of the sector in Quebec.

2.4.2 Description of critical habitat

Critical habitat has been identified using the area of occupancy approach and corresponds to the summer distribution of groups made up of adults and new-born calves and juveniles, i.e. the Upper Estuary, from the Battures aux Loups Marins to the Saguenay River and the southern portion of the Lower Estuary (Figure 9).

Oceanographic processes leading to mineral-rich and productive cold water upwelling offer a suitable environment and favour continous beluga presence. The distribution pattern of the beluga throughout its summering ground probably reflects the different ecological and behavioral needs of the different social groups. In summer, i.e. from June to October, belugas congregate in groups according to sex and age. In the St. Lawrence, groups made up of adult females accompanied by their new-born calves and juveniles concentrate in the Upper Estuary, while groups of adults only tend to gather in the northern section of the Lower Estuary (Figure 6). Females are very strongly attached to their summer habitat, characterized by an abundance of prey and shallower waters (Table 4), to which they return every year. The identified critical habitat (Figure 9) clearly provides support for calving and the rearing of the young, a fundamental issue in the survival and recovery of this threatened species (DFO, 2009a; Mosnier et al., 2009). The rearing of the young requires access to quality food sources and an environment that is conducive to communication. The shallower waters preferred by females, new-born calves, and juveniles may offer protection from predators and ensure access to adequate food resources for smaller belugas with limited diving capabilities.

Although the physical, chemical and biological characteristics that make these habitats critical for the survival and recovery of the beluga are not well known, the fact that females and their calves return so faithfully to sites in the Upper Estuary, the Saguenay River, and the southern portion of the Lower Estuary supports the critical importance of these areas (DFO, 2009a).

Table 4. Essential functions, features and attributes of critical habitat for the St. Lawrence beluga.

Location	Functions	Features	Attributes
Upper Estuary (Battures aux Loups Marins down to the Saguenay River) Saguenay River (Sainte-Marguerite Bay to mouth) Lower Estuary (southern portion)	Calving, suckling, feeding, rearing of the young, socialization, seasonal migration	Food Availability	Quality and quantity of prey (e.g. capelin, Atlantic herring, sandlance, rainbow smelt)
		Oceanographic processes leading to mineral-rich and highly productive cold water upwelling	
		Shallow waters	Depth of <100 m.
		Suitable acoustic environment	As an indication only: <120 dB continuous sound <160 dB pulse sound

2.4.3 Schedule of studies to identify critical habitat

Paragraph 41(1) c.1 of SARA calls for "*a schedule of studies to identify critical habitat, where available information is inadequate*." This recovery strategy includes the identification of critical habitat to the extent possible based on the best available information. Further studies are needed to fully identify the St. Lawrence beluga critical habitat, meaning the critical habitat needed to support the population and distribution objectives. As few studies have been conducted on the critical habitat used by the beluga outside the area between Kamouraska and Rimouski, it is impossible at this time to determine the contribution of these other areas to the critical habitat. Moreover, the beluga's preferred habitat outside the summer season is largely unknown. More information is also needed on the attributes of the identified critical habitat in order to make sure that they are of adequate quality and quantity to support vital functions of the species. In particular, a better understanding of the attributes is needed to understand the requirements of the beluga towards its acoustic environement and the various biophysical caracteristics of the habitat (underwater topography, currents, water temperature, salinity, oxygen, pH, nutrients, freshwater discharge and turbidity) that can influence presence of belugas or their prey.

The schedule of studies presented in Table 5 describes the research activities required to identify all critical habitat of the St. Lawrence beluga in accordance with the population and distribution objectives.

Table 5. Schedule of studies

Description of activity	Result/justification	Deadline
Better define the beluga's summering grounds and their characteristics upstream of Kamouraska and La Malbaie, and downstream of Rimouski and Forestville.	Identify the critical habitat of the beluga outside the area usually studied. Ensure critical habitat is identified to support all vital functions and to fully meet population and distribution objectives.	2016
Identify the areas used by the beluga outside the summer season.	Identify the critical habitat of the beluga outside the summer season. Ensure critical habitat is identified to support all vital functions and to fully meet population and distribution objectives.	2016
Define the attributes of the critical habitat.	Relate attributes to the vital functions they support.	2016

2.4.4 Examples of activities likely to destroy critical habitat

The definition of destruction is interpreted in the following manner:

> "*Destruction of critical habitat would result if any part of the critical habitat were degraded, either permanently or temporarily, such that it would not serve its function when needed by the species. Destruction may result from single or multiple activities at one point in time or from cumulative effects of one or more activities over time*."

Under SARA, critical habitat must be legally protected from destruction once it is identified. This will be accomplished through a s.58 Order, which will prohibit the destruction of the identified critical habitat unless permitted by the Minister of Fisheries and Oceans Canada pursuant to the conditions of SARA.

It is important to mention that any human activity must be assessed on a case-by-case basis and mitigation measures have to be applied when available and efficient. The activities described in Table 6 are not exhaustive and have been guided by the "Threats" described in section 1.5 of this recovery strategy. The absence of a specific human activity does not preclude, or fetter the department's ability to regulate it pursuant to SARA. Furthermore, the inclusion of an activity does not result in its automatic prohibition because it is destruction of critical habitat that is prohibited. Activities generating high levels of noise and those that could destroy the habitat attributes likely to impact significantly prey abundance can result in the destruction of critical habitat.

Excessive noise pollution can prevent belugas from carrying out these vital functions, and would therefore constitute the destruction of critical habitat. Although the threshold level of acoustic degradation that would destroy the St. Lawrence beluga's critical habitat has not yet been established, the scientific literature (Richardson et al., 1990; Richardson et al., 1995) and the U.S. National Marine Fisheries Services (NMFS, 2003) have established the threshold level of disturbance for marine mammals at 120 dB from continuous sources and 160 dB from pulse sources. The threshold for physical damage is set at 180 dB. These thresholds are given as an indication only; they can vary according to several factors such as sound frequency or oceanographic conditions.

A marked decrease in the availability of sufficient quantity and quality of beluga prey within the critical habitat would compromise that habitat's function as a food source. Underwater topography, currents, water temperature, salinity, oxygen, pH, nutrients, water regime or freshwater discharge, and turbidity can potentially affect the beluga's prey. Barriers to fish migration can also affect their abundance and their availability.

Table 6. Examples of activities likely to destroy critical habitat

Activity	Pathway of effect	Function affected	Attribute affected
▪ Commercial or military sonar ▪ Construction ▪ Dredging	Activities generating excessive noise pollution (frequency and intensity)	Rearing of the young Socialization Feeding	Suitable acoustic environment (e.g. <120 dB continuous sound, <160 dB pulse sound)
▪ Construction ▪ Dredging	Disruption or destruction of attributes likely to impact the presence of prey	Feeding	Abundance, availability and quality of prey (e.g. capelin, Atlantic herring, sandlance, rainbow smelt)

2.5 Knowledge Gaps

Although many threats have been identified, only a few, such as contaminants, have been closely studied, while others remain hypothetical. It is therefore imperative to conduct further research on the population status and limiting factors for population growth. The following is a partial list of the main research priorities to fully implement this recovery strategy:

<u>Biology and Ecology</u>

- Population dynamics (particularly juvenile survival rate)
- Distribution and seasonal behaviour (especially outside summer)
- Social structure and reproduction strategies
- Diet and energy requirements

<u>Habitat</u>

- Key prey species distribution, abundance, habitat, biology, and threats

<u>Threats</u>

- The complete spectrum of anthropogenic environmental contaminants to which belugas and their prey are exposed, in space and over time, with particular attention to the identification of sources of environmental contaminants, in particular emerging contaminants and their effects on belugas, their prey, and their habitat
- Short- and long-term effects of disturbance due to noise levels and physical proximity to human activity
- Anthropogenic sources of pathogens
- Frequency and intensity of ship strikes and entanglement

- Threat mitigation measures
- Other obstacles to recovery
- The influence of climate change on the impacts of threats to recovery

As mentioned in the previous section, many research and monitoring programs are currently gathering more information on threats to the recovery of St. Lawrence belugas, its population status, and the impact of current or proposed management strategies. It is important to continue this research while focusing on actual, potential, and anticipated threats to the St. Lawrence beluga population. In addition, a full evaluation of the impacts of these threats on recovery will require a better understanding of the population dynamics, in particular the juvenile recruitment rate and seasonal habitat use. The research activities required to identify critical habitat are described in section 2.4.3 *Schedule of studies to identify critical habitat.*

2.6 Measuring Progress

The performance indicators presented below provide a way to define and measure progress toward achieving the population and distribution objectives. Specific progress towards implementing the recovery strategy will be measured against indicators outlined in subsequent action plans.

- Increase in population size
- Increase in the number of mature individuals to 1,000 adult belugas
- Increase in the distribution area
- Increase in the yearly recruitment rate
- Steady state calving percentage
- Decrease in the mortality rate of juveniles

2.7 Statement on Action Plans

An action plan for the St. Lawrence Estuary beluga population will be completed within 5 years, by 2016.

APPENDIX 1. RECOVERY TEAM

Members of the St. Lawrence Estuary beluga Recovery Team

Alain Armellin	Environment Canada
Pierre Béland	Institut National d'Ecotoxicologie du Saint-Laurent
David Berryman	Ministère du Développement durable, de l'Environnement et des Parcs du Québec
Hugues Bouchard	Fisheries and Oceans Canada
Guy Cantin	Fisheries and Oceans Canada
Catherine Couillard	Fisheries and Oceans Canada
Michel Fournier	INRS, Institut Armand-Frappier
Édouard Hamel	Croisière AML
Hélène Pinard	Rio Tinto Alcan
Michel Lebeuf	Fisheries and Oceans Canada
Isabelle Gauthier	Ministère des Ressources naturelles et de la Faune du Québec
Véronique Lesage	Fisheries and Oceans Canada
Lena Measures	Fisheries and Oceans Canada
Nadia Ménard	Parks Canada, Saguenay-Saint-Laurent Marine Park
Robert Michaud	Groupe de Recherche et d'Éducation pour les Mammifères Marins
Tom Smith	EMC Corporation
Chantale Thiboutot	Fisheries and Oceans Canada
Tonya Wimmer	World Wildlife Fund (Canada)

APPENDIX 2. CONTAMINANTS

This appendix provides an overview of the principal groups of chemical compounds that have found their way into the habitat of the belugas, mainly from human sources. Some contaminants are persistent in the environment. A compound is considered persistent when its half-life (the time it takes for the concentration of a compound to be reduced by one half) is greater than two months when suspended in water or six months when deposited in sediment (as defined in Schedule D of the Stockholm Convention). Moreover, chemical compounds that are fat-soluble tend to bioaccumulate in adipose tissues and are biomagnified throughout the food chain. Other contaminants are either not persistent or only minimally so, and consequently do not bioaccumulate in the biota or do so only slightly. Situated between these two categories are certain contaminants that can bioaccumulate without bioamplification (such as lead), or are bioaccumulated as organic molecules (such as mercury). Belugas are exposed to chemical compounds through their diet and environment.

Species that belugas prey on constitute the primary source of contamination. However, water, air, and sediments are also potential sources. It is difficult to identify precise trends in contaminant concentrations in individual whales because of the significant differences across individuals, even in animals of the same age and sex (Muir et al., 1996a; Lebeuf et al., 2001). These differences include variability in size, growth rate, ratio of fat to body weight, energy efficiency, ability to assimilate contaminants in food sources, and of course, history of exposure to contaminants (Hickie et al., 1999). Males and females show evidence of different concentrations of several contaminants. This discrepancy may be explained by the transfer of contaminants from mother to calf (Addison and Brodie, 1977) and possibly by differences in the diet of males and females (Lesage et al., 2001; Nozères, 2006). Several contaminants are fat-soluble and accumulate in the fatty tissues. These tissues perform critical functions during gestation and lactation, and the females of many species of marine mammals transmit a portion of their contaminants to their young (Addison and Stobo, 1993; Gauthier et al., 1998; Hickie et al., 1999). This accounts for the high contaminant concentrations in newborn calves and throughout the critical periods of growth as the endocrine, immune, and nervous systems develop (Colborn and Smolen, 1996; Gauthier et al., 1998).

Tissues from belugas in the St. Lawrence show significantly higher concentrations of most contaminants than tissues from Arctic belugas (Massé et al., 1986; Martineau et al., 1987; Muir et al., 1990; Ray et al., 1991; McKinney et al., 2006). This is attributable in large measure to the proximity of contamination sources (Lebeuf and Nunes, 2005).

Organochlorine Compounds (OC)

Most organochlorines are composed of persistent organic pollutants (POPs). They are synthesized primarily for use in industry and agriculture. Their toxic by-products and their effects on the environment have led to their regulation or even outright prohibition in many countries. In 2004, more than 100 countries, including Canada, signed the Stockholm Convention on POPs, which aims to restrict or prohibit the use of twelve organochlorine compounds: polychlorinated biphenyls (PCBs), dichloro-diphenyl-trichloro-ethane (DDT), aldrin, chlordane, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, dioxins, and furans. Nevertheless, despite regulation and prohibition, organochlorine compounds and their by-products are still found in St. Lawrence Estuary belugas (for a review, see Lebeuf, 2009). Concentrations of certain organochlorine compounds found in St. Lawrence belugas up to 100 times higher than in Arctic belugas, depending on the contaminant (Martineau et al., 1987; Muir et al., 1990; Béland et al., 1993; McKinney et al., 2006). Collectively, OCs are known to produce alterations in the endocrine, reproductive, immune, metabolic, and neurological functions of many species (De Guise et al., 1995; Kingsley, 2002). Moreover, even at low concentrations, the synergistic effect of OCs combined with long-term exposure, stress, other health issues, poor nutrition, and foetal exposure could present a threat to the belugas. The effects on the endocrine system could be particularly serious due to this system's critical role in growth, development, and metabolic regulation (Colborn et al., 1993). An alteration in immune response can suffice for a pathogen to infect certain organs and cause disease. The seriousness of these effects on newborn calves depends in large measure on the time of exposure, and the effects may differ between mother and foetus. Some authors have suggested that high organochlorine concentrations may be responsible for the apparent stagnation in the population growth of the St. Lawrence belugas (Massé et al., 1986; Martineau et al., 1987; Béland et al., 1992; Hammill et al., 2007). However, there is little information available about the direct and indirect effects of organochlorines on belugas at this time.

Organochlorine Pesticides

Dichloro-diphenyl-trichloro-ethane (**DDT**) is a pesticide that is currently prohibited in North America but was once widely used. Although it has been prohibited in Canada since 1978, present-day sources of this chemical continue to pollute the St. Lawrence River. These sources include leachate from landfill sites, long-range atmospheric transport of DDT evaporated from contaminated soil, incineration of municipal waste, and sediments created by the erosion of DDT-contaminated soil (Pham et al., 1993). Several authors have measured DDT levels (or levels of the by-products dichloro-diphenyl-dichloro-ethane [DDD] or dichloro-diphenyl-ethane [DDE]) in St. Lawrence belugas (Massé et al., 1986; Muir et al., 1996a; Metcalfe et al., 1999; Lebeuf et al., 2007). DDT levels are generally higher in males than in females. (Martineau et al., 1987; Muir et al., 1996a; Letcher et al., 2000). Lebeuf et al. (2007) reported a decrease in DDT levels in the tissues of St. Lawrence belugas between 1987 and 2002, although the decrease in DDE (a metabolite of DDT) was observed in females only. DDT and its metabolites are believed to be endocrine disruptors in many species (Subramanian et al., 1987; Bernard et al., 2007; Leaños-Castañeda et al., 2007).

Toxaphene is a complex mix of at least 1,000 compounds, and was primarily used as a pesticide in replacement of DDT in the southern United States and northern Mexico in the 1970s, becoming the most widely used pesticide in the United States in the mid 70s. Although it has been prohibited in Canada and the United States since the early 1980s, it remains a contaminant of concern because of its persistence, volatility, and ability to bioaccumulate in organisms. It has been detected in the tissues of St. Lawrence belugas, but studies indicate a continuous decrease in concentrations since 1987 (Gouteux et al., 2003; Lebeuf et al., 2007). Arctic belugas show similar toxaphene levels to those in Estuary belugas, which suggests that this pollutant is transported via the atmosphere rather than issuing from a local source in the Great Lakes or along the St. Lawrence River (Muir et al., 1996a; MacLeod et al., 2002). Concentrations tend to be higher in male belugas (Muir et al., 1996a; Gouteux et al., 2003; Hobbs et al., 2003). Toxaphene is known to disrupt the thyroid gland, and it is hepatotoxic and immunotoxic in many animal species (IPCS, 2001). Although reported toxaphene levels are relatively low, this chemical has been shown to be two to six times more toxic than DDT, and it should be considered a contaminant of major concern in the St. Lawrence Estuary (Gouteux and Lebeuf, 2000).

Chlordane was used as an insecticide from the 1950s to the early 1990s, especially for termite control. It has been found in the tissues of St. Lawrence belugas (Muir et al., 1990; Muir et al., 1996a; Metcalfe et al., 1999; Hobbs et al., 2003). Lebeuf et al. (2007) detected no significant trend in chlordane concentrations in adult belugas between 1987 and 2002. The toxicity to fish of chlordane is well documented (IPCS, 1984a).

Mirex is another organochlorine pesticide that has been prohibited since the 1970s, and is still found in the tissues of St. Lawrence belugas (Muir et al., 1996a; Metcalfe et al., 1999). Mirex is an extremely stable, highly chlorinated molecule that was used as a pesticide and flame retardant in the United States. The primary source of mirex in the St. Lawrence Estuary is Lake Ontario, the sediments of which were contaminated by two American producers of the pesticide (Kaiser, 1978). Concentrations of this pesticide in the fatty tissues of belugas do not appear to have varied over the past decades (Lebeuf et al., 2007). Lake Ontario eels could have been the primary source of the mirex found in St. Lawrence belugas (Hodson et al., 1994; Gagnon and Bergeron, 1997). This contaminant is one of the rare organochlorines for which concentrations are similar in both males and females (Muir et al., 1996b; Lebeuf, 2009). Mirex is known to be toxic to aquatic organisms (Canada, 1977; IPCS, 1984b).

Lindane, the active ingredient in **hexachlorocyclohexane** (HCH), was prohibited for use as an insecticide in the United States and Canada, but it is still used as an ingredient in certain medications, especially for the treatment of lice. **Hexachlorobenzene** (HCB) is a fungicide that has not been used since the mid 1970s. According to Lebeuf et al. (2007) and Muir et al. (1996b), HCH and HCB levels in St. Lawrence belugas decreased between 1987 and 2002. Lindane likely affects the nervous system and provokes histological alterations in fish (IPCS, 1991; Pesce et al., 2008). HCB itself has been shown to be carcinogenic in laboratory animals, and it can affect several organs, most notably the liver (IPCS, 1997; Plante et al., 2007; Reed et al., 2007).

Dieldrin, endrin and **aldrin** are persistent organochlorine insecticides that are found in beluga tissues (Muir et al., 1996a; Hobbs et al., 2003). These pesticides were curtailed in the mid1970s, and they were no longer approved for use in Canada after 1991. Muir et al. (1996a) reported stable concentrations in male belugas and a decrease in concentrations in females between 1986 and 1994. These compounds are considered highly toxic to aquatic organisms, and studies in laboratory animals have shown them to be hepatotoxic (IPCS, 1989, 1992a).

Dioxins and Furans

Dioxins and furans are the most toxic contaminants, even at low concentrations. **Polychlorodibenzene-*p*-dioxins** are the by-products of chemical reactions produced by waste incinerators, paper mills, the plastics industry, steel mills, pesticide manufacturers, and fuel combustion. They can also occur naturally as a result of volcanic eruptions and forest fires. Once they are introduced into the environment, they do not begin to biodegrade for many years. **Polychlorodibenzene-*p*-furans** are released into the air through the incineration of PCBs. The concentrations of dioxins and furans found in tissues of St. Lawrence belugas range from very low to undetectable (Muir et al., 1996a). The low concentrations found in both the narwhal (*Monodon monoceros*) and the killer whale (*Orcinus orca*) indicate that some Odontoceti species may possess an enzyme that metabolizes these contaminants (Ono et al., 1987; Muir et al., 1996a; Norstrom et al., 1990). However, it should be kept in mind that any amount of exposure to dioxins and furans could be harmful. Dioxins remain highly toxic even in infinitely small quantities (Boening, 1998).

Polychlorinated Biphenyls (PCBs)

PCBs constitute a group of 209 related compounds (congeners) that are flame retardant, lubricant, and non-conducting. These qualities have made them very useful in the manufacture of electrical components. PCB production peaked in 1970 and was discontinued after 1979. However, contaminated sites and landfills remain sources of PCB contamination to this day. PCBs are still permitted in closed systems such as electrical transformers. A large part of the PCBs found in St. Lawrence belugas are believed to have come from Lake Ontario (Gagnon and Bergeron, 1997).

Belugas do not metabolize the different types of PCBs equally, and in certain cases, degradation of contaminants by the organism can produce metabolites that are sometimes even more toxic than the original compound. However, since 1987 contaminant concentrations in the fatty tissues of the St. Lawrence beluga have decreased (Muir et al., 1996b; Lebeuf et al., 2007). Some of the PCB congeners are alarmingly toxic, and are responsible for the most harmful effects of commercial PCB mixtures. Again, some of these contaminants are highly toxic even at low concentrations. PCBs are known to be hormone disrupting chemicals, neurotoxic agents, and immunosuppressors, and they are carcinogenic to fauna in general (IARC, 1978; Hall et al., 1992; IPCS, 1992b; De Guise et al., 1995; McKinney et al., 2004). Jauniaux and Coignoul (2001) note that there is still plenty of controversy surrounding the role of marine pollution, and more particularly PCBs, in epizootic outbreaks of *Morbillivirus* in marine mammals. Some researchers believe that PCBs contribute to the severity of an outbreak, while others say that the *Morbillivirus* is sufficiently virulent on its own and is unaffected by contaminant levels (O'Shea, 2000; Ross et al., 2000).

Tris(4-chlorophenyls)

Tris(4-chlorophenyls) are some of the most recently discovered environmental contaminants, found at different stages of the food chain. Sources of contamination are as yet unknown, and these compounds are not regulated. In the St. Lawrence Estuary, high concentrations of these organochlorinated compounds are found in both belugas and seals (Lebeuf et al., 2001; Lebeuf et al., 2007). There is little documentation on the health hazards that tris(4-chlorophenyls) pose to marine mammals. Some studies suggest that they are hormone disrupting chemicals like the other organochlorines (Poon et al., 1997; Foster et al., 1999). One study conducted in several species of seals revealed that these compounds have high potential for biomagnification in marine mammals (Watanabe et al., 1999).

Chlorinated Paraffins (CPs)

Polychloro-n-alkanes, also known as **chlorinated paraffins**, are widely used in various industries as lubricants, flame retardants, plasticizers, and anti-corrosives. They are grouped by carbon chain length, the shortest (C_{10} – C_{13}) of which accumulates the most easily in fish tissues, thus presenting a greater risk of toxicity (IPCS, 1996). However, medium-chain CPs are the most commonly used in Canada (Health Canada, 2004). CPs adhere readily to particles (adsorption) and are transported into water in sediments or into the atmosphere in suspended particles, short-chain CPs being the most volatile (Drouillard et al., 1998). Although CP production was halted for the most part in the early 1980s, their widespread and unrestricted use contaminated the environment at many levels (Muir et al., 1999). Chlorinated paraffins are persistent and can bioaccumulate. Analyses of St. Lawrence beluga carcasses revealed general CP contamination (both short- and medium-chain), most likely originating from local sources such as the Great Lakes or the Upper St. Lawrence River (Bennie et al., 2000; Tomy et al., 2000). Their precise origin and toxicity has yet to be determined. Short-chain chlorinated paraffins are considered toxic under the *Canadian Environmental Protection Act* (Canada, 1993).

Organotin Compounds

Organotins[11] (organometallic compounds) are toxic industrial organic compounds that are particularly harmful for the environment and very slow to biodegrade once they have accumulated in sediment. In the form of tributyltin oxide (**TBT**), they are used in antifouling paints to prevent algae and invertebrates from adhering to boat hulls. The Pest Management Regulatory Agency has decreed that they present a risk that is “unacceptable for the marine environment.” Although prohibited in Canada and withdrawn from the market since January 1, 2003, the partial ban on this type of paint up to 2003 was insufficient to protect marine organisms (St-Louis et al., 2000). TBT is toxic to many invertebrates (whelks, marine worms, amphipods) and fish, and has been found in the tissues of marine mammals, including the beluga (Pelletier and Normandeau, 1997; St.-Louis et al., 1997; St-Louis et al., 2000). Organotins have been detected in all sediments and core samples taken from the Saguenay Fjord and the St. Lawrence Estuary and Gulf (St.-Louis et al., 1997; Viglino et al., 2004). There is evidence that contamination has spread throughout the entire St. Lawrence River Estuary system, with particularly high concentrations close to harbours (St.-Louis et al., 1997). Organotin

[11] Tributyltin (TBT), dibutyltin (DBT), and monobutyltin (MBT).

concentrations found in stranded belugas appear to increase with the age of the animal (Yang et al., 1998; St-Louis et al., 2000). Moreover, like all organochlorines, this contaminant can be transferred from mother to foetus (St-Louis et al., 2000). Significant accumulation of organotins in whelks has been shown to act as an immunosuppressor by disrupting the endocrine system (Tester and Ellis, 1995). They are suspected of having contributed to massive mortalities in the Ganges dolphin (Kannan et al., 1997). Several studies have shown the harmful effects of TBT on immune system cells in mammals (Tanabe, 1999; Nakata et al., 2002; Nakanishi, 2007).

Organobromine Compounds

Organobromines[12] are used as flame retardants in many manufactured products. Several polybromodiphenylether (**PBDE**) congeners are found in consumer goods. They are grouped into three commercial formulae: penta-, octa-, and deca-BDE. Because PBDEs were considered unacceptable risks to the environment and human health, they were withdrawn from the European and North American markets (Ward et al., 2008). Canada now bans two formulae and restricts the use of deca-BDE. PBDEs are ubiquitous in the environment, and they bioaccumulate. These compounds are also extremely persistent, sometimes more so than the organochlorines (de Boer et al., 1998). The primary sources of these contaminants in the global environment are undoubtedly waste incinerators, landfills, and effluent from municipal sewage treatment plants (Rahman et al., 2001; Ross et al., 2008). Concentrations in the environment are increasing exponentially (De Wit, 2002; Ikonomou et al., 2002). Concentrations found in belugas between 1997 and 1999 are 20 times higher than those measured in 1988 and 1990 (Lebeuf et al., 2004). In females, concentrations levelled off in 1999 and significantly decreased after 2003, whereas PBDE concentrations in males continued to increase between 2000 and 2007, albeit at a lower rate (Lebeuf et al., 2010). Organobromine compounds likely disrupt the human and animal endocrine system, especially the thyroid gland, and are potentially carcinogenic, but their mode of toxicity is still not completely understood (IPCS, 1994; Eriksson et al., 2001; Hardy, 2002; McDonald, 2002; Lebeuf et al., 2006; Ross et al., 2008). Studies in mice have shown that these compounds have a deleterious effect on behaviour and learning capacity (Branchi et al., 2002; Branchi et al., 2003).

Perfluorinated Compounds (PFCs)

Perfluorinated compounds have anti-adhesive and stain-resistant properties, and are used in household products, among others. Perfluorooctane sulphonate (PFOS) is the most significant perfluorinated compound found in mammals, and the most extensively studied (Giesy and Kannan, 2001; Hansen et al., 2001; Kannan et al., 2001a; Martin et al., 2004). PFCs have the same characteristics of persistence, bioaccumulation, and biomagnification as the organochlorine and organobromine contaminants (Martin et al., 2004). Being volatile, and thanks to their resistance to biotic and abiotic degradation, they are ubiquitous in the environment, despite

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[12] Polybromodiphenylether (PBDE), tetrabromobisphenol-A (TBBP-A), hexabromocyclododecane (HBCD).

reductions in production (USEPA, 2002). PFOS has been added to the Virtual Elimination List under the *Canadian Environmental Protection Act*. PFCs have many sources, including landfill sites and a vast array of consumer products. PFOS has been found in organisms at every level of the food chain (for a review, see Houde et al., 2006), including marine mammals (Kannan et al., 2001b; Martin et al., 2004) and St. Lawrence River belugas (Lebeuf, 2009). The toxicity of PFCs is not fully understood, but studies in laboratory rats indicate that they may cause liver damage and are potentially carcinogenic (Upham et al., 1998; Berthiaume and Wallace, 2002).

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons include a vast group of organic compounds, of which **benzo-*α*-pyrene** is the constituent chemical compound of most concern for the environment. Their presence in the environment is primarily due to the incomplete combustion, natural or anthropogenic, of organic matter. The St. Lawrence River belugas were particularly exposed to PAHs in effluent discharged from the Saguenay aluminum smelters into the fjord (Martel et al., 1986; Smith and Levy, 1990; Laliberté, 1991). However, aluminum smelters have greatly reduced PAH emissions since 1988, and concentrations in the Saguenay fjord sediments have decreased (Smith and Levy, 1990). Part of the beluga’s diet derives from foraging in sediments for invertebrates that accumulate PAHs in their tissues (Dalcourt et al., 1992; Ferguson and Chandler, 1998). Direct contact with the sediments may provide additional exposure to the contaminants. These non-persistent compounds degrade very rapidly, which may explain the absence or low levels of PAHs in tissue samples from St. Lawrence River belugas (Béland et al., 1992). Benzo-α-pyrene metabolites can bind with DNA to form adducts that can cause mutations and cancerous lesions. DNA adducts have been detected in St. Lawrence beluga tissues, confirming their exposure to genotoxic PAHs (Ray et al., 1991; Martineau et al., 1994). The presence in the Saguenay region of aluminum smelters that discharge substantial amounts of PAHs into the environment may be a contributing factor to the high cancer rate among belugas, but a causal link has yet to be established (Martineau et al., 2002a; Thériault et al., 2002; Hammill et al., 2003; Martineau et al., 2003). Martineau et al. (2002b) suggest a link between PAH occurrence, beluga contamination by these compounds, and the abnormally high prevalence of cancers of the digestive tract in this population. To gain a full understanding of the impact of these contaminants on the St. Lawrence River beluga, further studies are needed on the toxicity of complex assemblages of PAHs, their synergistic effect when combined with other contaminants and pathogens, and precise exposure levels to PAHs through diet and contact with sediments. There is no provision in the present carcass monitoring program to assay non-persistent contaminants such as PAHs. Tissue samples from stranded specimens are consequently of little use, and non-persistent toxic contaminants must be characterized in the beluga’s prey species and habitat. Indicator species can be useful in monitoring habitat contamination (Couillard, 2009).

Common-use pesticides

Most **pesticides** in use today have a low potential to bioaccumulate, and are subsequently not found in the beluga’s fatty tissues. Nevertheless, some pesticides have harmful and toxic effects. **Atrazine** is an herbicide commonly used in corn cultivation, which is widespread throughout most of the St. Lawrence River watershed. The fact that some of these substances do not accumulate in the beluga does not mean that they are harmless, as atrazine has a relatively long half-life in surface waters (Ulrich et al., 1994; Schottler and Eisenreich, 1997). There is little information on how these chemicals are transported throughout the drainage basin, their impact on the fluvial ecosystem, or the effects of their degradation by-products. Pesticide concentrations that exceed accepted limits for the protection of aquatic life have been detected at the mouths of several tributaries of the St. Lawrence (Giroux et al., 2006; Giroux, 2007). Nevertheless, Lake Ontario is considered the main source of the pesticides found in the St. Lawrence River (Pham et al., 2000). Even very low concentrations of atrazine can have deleterious effects on the reproductive and endocrine systems of humans and many animal species (Colborn et al., 1993).

Heavy Metals

Many metals occur naturally in the environment, but their concentration and distribution can be modified by industrial processes such that they become toxic to flora and fauna. The effluent from Montreal's sewage treatment plant, which filters 45 % of all the municipal waste water in Quebec, accounts for 1 % to 5 % of the total heavy metal content in the St. Lawrence River, with the exception of silver (Ag), 25 % of which comes from the plant (Gobeil et al., 2005). A study on the lead found in sediments from various sampling stations along the Laurentian Channel showed that the lead originated from three different sources, two natural and one linked to recent industrial pollution (Gobeil et al., 1995). The main source of mercury in the estuary is shoreline and river bottom erosion, although tributaries and atmospheric deposits also contribute (Quémerais et al., 1999). In contrast, in the Saguenay River, a major historical source of mercury contamination was a chloralkali manufacturing plant, which ceased operating in 1978 (Couillard and Lebeuf, 2007). Since then, trawl fishing has been banned in the Saguenay River due to mercury persistence in the deep sediments of the river bed. Even though certain anthropogenic inputs have diminished, toxic metals remain a source of contamination because they do not biodegrade and they concentrate in sediment. Dredging, marine traffic, and underwater sediment depression release these toxins back into circulation. Mercury, lead, and cadmium are particularly harmful, and can adversely affect immune defence efficiency by disrupting lymphocyte proliferation in mammals (Wong et al., 1992; Bernier et al., 1995; De Guise et al., 1996). The effects of chronic exposure on marine mammals are not well known, but researchers suspect they have contributed to the beluga population's failure to recover (De Guise et al., 1996). The St. Lawrence Estuary beluga population shows mercury and lead levels 2 to 15 times higher than in Arctic populations (DFO, 2002).

Other Contaminants

Several other compounds found in the waters and sediments of the St. Lawrence River can potentially affect the beluga's recovery. Effluents from municipal sewage treatment plants contain residues of detergents, pharmaceutical products, and various other contaminants that are known hormone disrupting chemicals (Aravindakshan et al., 2004b; de Montgolfier et al., 2008). The impact of these compounds on the beluga is unknown, but it appears that they have the potential to accumulate in the food chain (Aravindakshan et al., 2004a). To add to this, a number of new contaminants, such as nanoparticles and phenols, are introduced into the environment each year. Their effects on belugas or their prey is as yet unknown.

APPENDIX 3. EFFECTS ON NON-TARGET SPECIES AND THE ECOSYSTEM

Thirteen species of cetaceans, eight species of toothed whales (Odontoceti), and five species of baleen whales (Mysticeti) frequent the St. Lawrence (Table 1). Studies conducted under the current recovery strategy (for example, impact assessments of anthropogenic activity) and the proposed mitigation measures to deal with identified threats (for example, restrictions on whale watching activities) will certainly have spin-off effects that are liable to be beneficial to a wide variety of organisms in the St. Lawrence Estuary, including cetaceans, invertebrates, and fish. As stated by the St. Lawrence Beluga Recovery Team concerning the actions proposed in the 1995 recovery plan, *"not only will beluga benefit from these actions, but also the ecosystem as a whole and human health in particular"* (DFO and WWF, 1995).

Table 1. COSEWIC status assessments of marine mammal species in the St. Lawrence

Common Name (population)	**Latin Name**	**Date of last status assessment**	**Last COSEWIC designation**	**Status under the List of Wildlife Species at RiskP**
Northern bottlenose whale (Scotian Shelf)	*Hyperoodon ampullatus*	November 2002	Endangered	Endangered
North Atlantic right whale	*Eubalaena glacialis*	May 2003	Endangered	Endangered
Beluga (St. Lawrence Estuary)	*Delphinapterus leucas*	May 2004	Threatened	Threatened
Sperm whale	*Physeter nacrocephalus*	April 1996	Not at risk	Not listed
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	April 1991	Not at risk	Not listed
White-beaked dolphin	*Lagenorhynchus albirostris*	April 1998	Not at risk	Not listed
Killer whale (Northwest Atlantic/Eastern Arctic)	*Orcinus Orca*	November 2008	Special concern	Not listed
Long-finned pilot whale	*Globicephala melas*	April 1994	Not at risk	Not listed
Harbour porpoise (Northwest Atlantic)	*Phocoena phocoena*	April 2006	Special concern	Not listed
Common minke whale North Atlantic subspecies	*Balaenoptera acutorostrata*	April 2006	Not at risk	Not listed
Humpback whale (North Atlantic)	*Megaptera novaeangliae*	May 2003	Not at risk	Not listed
Blue whale (Atlantic)	*Balaenoptera musculus*	May 2002	Endangered	Endangered
Fin whale (Atlantic)	*Balaenoptera physalus*	May 2005	Special concern	Special concern

On the other hand, should the St. Lawrence Estuary beluga population increase, this could have potentially negative effects at certain levels of the food chain, particularly for prey species and potential competitors such as seals. However, the current population objective is 30 % less than the historical population. For the time being, it is impossible to determine whether the environmental conditions are sufficient to support a beluga population seven times larger than what exists now.

APPENDIX 4. REFERENCES

Addison, R. F. and P. F. Brodie. 1977. Organochlorine residues in maternal blubber, milk, and pup blubber from grey seals (*Halichoerus grypus*) from Sable Island, Nova Scotia. *Journal of the Fisheries Research Board of Canada.* **34**:937-941.

Addison, R. F. and W. T. Stobo. 1993. Organochlorine residue concentrations and burdens in grey seal (*Halichoerus grypus*) blubber during the first year of life. *Journal of Zoology.* **230** (3):443-450.

Aguilar, A., A. Borrell and P. J. H. Reijnders. 2002. Geographical and temporal variation in levels of organochlorine contaminants in marine mammals. *Marine Environmental Research.* **53**:425-452.

Anon. 1928. Quebec will war on porpoises. Organize reduction plants to use carcasses. *The Canadian Fisherman.* **15** (11):24.

Aravindakshan, J., M. Gregory, D. J. Marcogliese, M. Fournier and D. G. Cyr. 2004a. Consumption of Xenoestrogen-Contaminated Fish during Lactation Alters Adult Male Reproductive Function. *Toxicological Science.* **81** (1):179-189.

Aravindakshan, J., V. Paquet, M. Gregory, J. Dufresne, M. Fournier, D. J. Marcogliese and D. G. Cyr. 2004b. Consequences of Xenoestrogen Exposure on Male Reproductive Function in Spottail Shiners (*Notropis hudsonius*). *Toxicological Science.* **78** (1):156-165.

Auger, C. and R. Quenneville. 2001. *Plan d'urgences environnementales, Parc marin du Saguenay-Saint-Laurent*. Parcs Canada. 43p.

Barber, D. G., E. Saczuk and P. R. Richard. 2001. Examination of beluga-habitat relationships through the use of telemetry and a geographic information system. *Arctic.* **54** (3):305-316.

Barrett, T. 1999. Morbillivirus infections, with special emphasis on morbillivirus of carnivores. *Veterinary Microbiology.* **69**:3-13.

Bédard, C. and R. Michaud. 1995. *Étude des activités d'observation en mer des cétacés de l'estuaire maritime du Saint-Laurent. Rapport final*. Groupe de recherche et d'éducation sur le milieu marin. Tadoussac.

Bédard, C. and Y. Simard. 2006. Automated detection of white whale (*Delphinapterus leucas*) vocalizations in St. Lawrence estuary and occurrence pattern. *Canadian Acoustics - Acoustique Canadienne.* **34** (3):84-85.

Bédard, J., A. Nadeau, J.-P. Savard and M. C. S. Kingsley. 1997. *La Passe de l'Île aux Lièvres; importance stratégique pour la faune marine de l'Estuaire*. Service canadien de la faune, région du Québec. Série de rapports techniques No 283.

Bejder, L., A. Samuels, H. Whitehead and N. Gales. 2006a. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour.* **72** (5):1149-1158.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. W. Capps, C. Flaherty and M. Krützen. 2006b. Decline in Relative Abundance of Bottlenose Dolphins Exposed to Long-Term Disturbance. *Conservation Biology.* **20** (6):1791-1798.

Béland, P., A. Faucher and P. Corbeil. 1990. Observation on the birth of a beluga whale (*Delphinapterus leucas*) in the St. Lawrence estuary, Québec, Canada. *Journal of Zoology.* **68**:1327-1329.

Béland, P., S. D. Guise, C. Girard, A. Lagacé, D. Martineau, R. Michaud, D. C. G.Muir, R. J. Norstrom, E. Pelletier, S. Ray and L. R. Shugart. 1993. Toxic compounds and health and reproduction effects in St. Lawrence beluga whales. *Journal of Great Lakes Research.* **19**:766-775.

Béland, P., S. D. Guise and R. Plante. 1992. *Toxicologie et pathologie des mammifères marins du Saint-Laurent*. Fonds pour la toxicologie faunique du Fonds mondial pour la nature. 99p.

Béland, P., A. Vézina and D. Martineau. 1988. Potential for growth of the St. Lawrence (Québec, Canada) beluga whale (*Delphinapterus leucas*) population based on modelling. *Journal du conseil international pour l'exploration de la mer.* **45**:22-32.

Bennie, D. T., C. A. Sullivan and R. J. Maguire. 2000. Occurence of chlorinated paraffins in beluga whales (*Delphinapterus leucas*) from the St. Lawrence River and rainbow trout (*Oncorhyncus mykiss*) and carp (*Cyprinus carpio*) from Lake Ontario. *Water Quality Research Journal of Canada.* **35** (2):263-281.

Bernard, L., N. Martinat, C. Lécureuil, P. Crépieux, E. Reiter, A. Tilloy-Ellul, S. Chevalier and F. Guillou. 2007. Dichlorodiphenyltrichloroethane impairs follicle-stimulating hormone receptor-mediated signaling in rat Sertoli cells. *Reproductive Toxicology.* **23** (2):158-164.

Bernard, P. and D. Desrochers. 2007. *Suivi des passes migratoires à anguille à la centrale de Beauharnois et au barrage de Chambly - 2007*. Par Milieu inc. pour l'unité Environnement, division Production, Hydro-Québec. 81p.

Bernier, J., P. Brousseau, K. Krzystyniak, H. Tryphonas and M. Fournier. 1995. Immunotoxicity of Heavy Metals in Relation to Great Lakes *Environmental Health Perspectives.* **103** (supp9):23-34.

Berthiaume, J. and K. B. Wallace. 2002. Perfluorooctanoate, perflourooctanesulfonate, and N-ethyl perfluorooctanesulfonamido ethanol; peroxisome proliferation and mitochondrial biogenesis. *Toxicology Letters.* **129** (1-2):23-32.

Blane, J. M. and R. J. Jackson. 1994. The impact of ecotourism boats on the St. Lawrence beluga whales. *Environmental conservation.* **2**:267-269.

Boening, D. W. 1998. Toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin to Several Ecological Receptor Groups: A Short Review. *Ecotoxicology and Environmental Safety.* **39** (3):155-163.

Boivin, Y. and R. Michaud. 1990. *Survols aériens pour l'estimation de la distribution saisonnière et des déplacements des bélugas*. Institut national d'écotoxicologie du Saint-Laurent. 91p.

Bourgeois, M., M. Gilbert and B. Cusson. 2001. *Évolution du trafic maritime en provenance de l'étranger dans le Saint-Laurent de 1978 à 1996 et implications pour les risques d'introduction d'espèces aquatiques non indigènes*. MPO. Rapport technique canadien des sciences halieutiques et aquatiques 2338. 31p.

Bourque, A. and G. Simonet. 2008. Québec. In: *Vivre avec les changements climatiques au Canada : édition 2007*. D. S. Lemmen, F. J. Warren, J. Lacroix and E. Bush (Ed.). Gouvernement du Canada. Ottawa. p.171-226.

Branchi, I., E. Alleva and L. G. Costa. 2002. Effects of Perinatal Exposure to a Polybrominated Diphenyl Ether (PBDE 99) on Mouse Neurobehavioural Development. *NeuroToxicology.* **23** (3):375-384.

Branchi, I., F. Capone, E. Alleva and L. G. Costa. 2003. Polybrominated diphenyl ethers: Neurobehavioral effects following developmental exposure. *NeuroToxicology.* **24** (3):449-462.

Brennin, R., B. W. Murray, M. K. Friesen, L. D. Maiers, J. W. Clayton and B. N. White. 1997. Population genetic structure of beluga whales (*Delphinapterus leucas*): Mitochondrial DNA sequence variation within and among North American populations. *Canadian Journal of Zoology.* **75** (5):795-802.

Brewer, P. G. 1997. Ocean chemistry of the fossil fuel CO2 signal: The haline signal of "business as usual". *Geophysical Research Letters.* **24** (11):1367-1369.

Brodie, P. F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale (*Delphinapterus leucas*), with reference to the Cumberland Sound, Baffin Island, population. *Journal canadien des sciences halieutiques et aquatiques.* **28**:1309-1318.

Brodie, P. F. 1989. The white whale, *Delphinapterus leucas* (Pallas, 1776). In: *Handbook on marine mammals. Vol. 4.* . S. H. Ridgway and R. Harrison (Ed.). Academic Press. London. p.119-144.

Brown Gladden, J. G., P. F. Brodie and J. W. Clayton. 1999a. Mitochondrial DNA used to identify an extralimital beluga whale (*Delphinapterus leucas*) from Nova Scotia as originating from the St. Lawrence population. *Marine Mammal Science.* **15**:556-558.

Brown Gladden, J. G. and J. W. Clayton. 1993. *Variable nucleotide sequences of control region mitochondrial DNA and population structure in North American beluga whales*. Tenth biennal conference on the biology of marine mammals. November 11-15, 1993. Galveston, Texas.

Brown Gladden, J. G., M. M. Ferguson and J. W. Clayton. 1997. Matriarchal genetic population structure of North America beluga whales (*Delphinapterus leucas*) (Cetacea: *Monodontidae*). *Molecular Ecology*. **6**:1033-1046.

Brown Gladden, J. G., M. M. Ferguson, M. K. Frieses and J. W. Clayton. 1999b. Population structure of North America beluga whale (*Delphinapterus leucas*) based on nuclear DNA microsatellite variation and contrasted with the population structure revealed by mitochondrial DNA variation. *Molecular Ecology*. **8**:347-363.

Burek, K. A., F. M. D. Gulland and T. M. O'Hara. 2008. Effects of climate change on arctic marine mammal health. *Ecological Applications*. **18** (SUPPL.2):S126-S134.

Burns, J. J. and G. A. Seaman. 1985. *Investigations of beluga whales in coastal waters of western and northern Alaska. II. Biology and Ecology*. Alaska Department of Fisheries and Game. NA 81 RAC 00049. 129p.

Canada. 1977. *Mirex in Canada*. Fisheries and Environment Canada. Task Force on Mirex. Technical report 77-1. 153p.

Canada. 1993. *Paraffines chlorées. Liste des substances d'intérêt prioritaire, rapport d'évaluation*. Environnement Canada - Santé et bien-être social Canada. 41p.

Carignan, R., S. Lorrain and K. Lum. 1994. A 50-yr record of pollution by nutrients, trace metals, and organic chemicals in the St Lawrence River. *Canadian Journal of Fisheries and Aquatic Sciences*. **51** (5):1088-1100.

Caron, F., P. Dumont, Y. Mailhot and G. Verreault. 2007. L'anguille au Québec, une situation préoccupante. *Le Naturaliste Canadien*. **131** (1):59-66.

Caron, L. M. J. and D. E. Sergeant. 1988. Yearly variation in the frequency of passage of beluga whales (*Delphinapterus leucas*) at the mouth of the Saguenay River, Québec, over the past decade. *Canadian Field Naturalist*. **178**:111-116.

Chadenet, V. 1997. *Fréquentation et bilan d'activité du béluga, Delphinapterus leucas, du Saint-Laurent dans la baie Sainte-Marguerite*. Masters thesis. Université Laval, Département de biologie. Québec. 75p.

Chion, C., S. Turgeon, R. Michaud, J.-A. Landry and L. Parrott. 2009. *Portrait de la navigation dans le parc marin du Saguenay-Saint-Laurent. Caractérisation des activités sans prélèvement de ressources entre le 1er mai et le 31octobre 2007*. Présenté à Parcs

Canada. 86p.

Colborn, T. and M. J. Smolen. 1996. Epidemiological analysis of persistent organochlore contaminants in cetaceans. *Review of Environmental Contamination and Toxicology.* **146**:91-173.

Colborn, T., F. S. vom Saal and A. M. Soto. 1993. Developmental effects of endocrine-disrupting chemicals in wildlife and humans. *Environmental Health Perspectives.* **101**:378-384.

COSEWIC. 2004. *COSEWIC assessment and update status report on the beluga whale Delphinapterus leucas in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 70p.

COSEWIC. 2006. *COSEWIC assessment and status report on the American eel Anguilla rostrata in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 71p.

Couillard, C. M. 2009. Utilisation des poissons pour évaluer les effets biologiques des contaminants dans l'estuaire du Saint-Laurent et le fjord du Saguenay. *Revue des Sciences de l'eau.* **22** (2):291-314.

Couillard, C. M., S. C. Courtenay and R. W. Macdonald. 2008a. Interactions between toxic chemicals and other environmental factors affecting the risk of impacts on aquatic organisms: a review with a Canadian perspective - interactions affecting vulnerability. *Environmental Review.* **16**:19-44.

Couillard, C. M. and M. Lebeuf. 2007. *Toxic chemicals and their impacts in the St. Lawrence Estuary and Saguenay Fjord, Quebec, Canada: from a chemical to an ecosystem-based risk management*. ICES Annual Science Conference. Helsinki, Finland.

Couillard, C. M., R. W. Macdonald, S. C. Courtenay and V. P. Palace. 2008b. Interactions between toxic chemicals and other environmental factors affecting the risk of impacts on aquatic organisms: a review with a Canadian perspective - interactions affecting exposure. *Environmental Review.* **16**:1-17.

Crum, L. A. and Y. Mao. 1996. Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. *Journal of the Acoustical Society of America.* **99**:2898-2907.

Curren, K. and J. Lien. 1998. Observations of white whales, *Delphinapterus leucas*, in waters off Newfoundland and Labrador and in the Gulf of St. Lawrence, 1979-1991. *Canadian Field Naturalist.* **112** (28-31)

Dalcourt, M.-F., P. Béland, E. Pelletier and Y. Vigneault. 1992. *Caractérisation des communautés benthiques et études des contaminants dans des aires fréquentées par le bélugas du Saint-Laurent*. 86p.

Dartois, J. and B. Daboval. 1999. *25 ans d'assainissement des eaux usées industrielles au Québec*. Ministère de l'environnement du Québec. 81p.

de Boer, J., P. G. Wester, H. J. C. Klamer, W. E. Lewis and J. P. Boon. 1998. Do flame retardants threaten ocean life? *Nature.* **394** (6688):28-29.

De Guise, S. 1998. Effects of in vitro exposure of beluga whale leukocytes to selected organochlorines. *Journal of Toxicology and Environmental Health, Part A.* **55** (7):479 - 493.

De Guise, S., J. Bernier, D. Martineau, P. Béland and M. Fournier. 1996. Effects of in vitro exposure of beluga whale splenocytes and thymocytes to heavy metals. *Environmental Toxicology and Chemistry.* **15** (8):1357-1364.

De Guise, S., D. Martineau, P. Béland and M. Fournier. 1995. Possible mechanisms of action of environmental contaminants on St. Lawrence Beluga whales (*Delphinapterus leucas*). *Environmental Health Perspectives.* **103** (suppl 4):73-77.

De la Chenelière, V. 1998. *The risks and benefits of an invasive technique, biopsy sampling, for an endangered population, the St. Lawrence beluga (Delphinapterus leucas)*. Masters thesis. McGill University, Montréal.

de March, B. G. E., L. D. Maiers and M. K. Friesen. 2002. An overview of genetic relationships of Canadian and adjacent populations of belugas (*Delphinapterus leucas*) with emphasis on Baffin Bay and Canadian eastern Arctic populations. *NAMMCO Scientific Publications.* **4**:17-38.

de March, B. G. E. and L. D. Postma. 2003. Molecular genetic stock discrimination of belugas (*Delphinapterus leucas*) hunted in eastern Hudson bay, northern Québec, Hudson strait, and Sanikiluaq (Belcher island), Canada, and comparisons to adjacent populations. *Arctic.* **56**:111-124.

de Montgolfier, B., M. Fournier, C. Audet, D. J. Marcogliese and D. G. Cyr. 2008. Influence of municipal effluents on the expression of connexins in the brook trout (*Salvelinus fontinalis*) testis. *Aquatic Toxicology.* **86** (1):38-48.

De Wit, C. A. 2002. An overview of brominated flame retardants in the environment. *Chemosphere.* **46** (5):583-624.

Desrosiers, J. 1994. *Analyse photogrammétrique de la structure et la dynamique de la population de bélugas du Saint-Laurent*. Masters thesis. Université Laval, Québec. 84p.

DFO. 2002. *Atelier scientifique sur les mammifères marins, leurs habitats et leurs ressources alimentaires dans le cadre de l'élaboration du projet de zone de protection marine de l'estuaire du Saint-Laurent du 3 au 7 avril, 2000*. Maurice-Lamontagne Institute. Mont-Joli. Proceedings. 344p.

DFO. 2005a. *Proceedings of the meeting on recovery potential assessment of Cumberland Sound, Ungava Bay, Eastern Hudson Bay and St. Lawrence beluga populations (Delphinapterus leucas)*. Canadian Science Advisory Secretariat. Proceedings 2005/011. 86p.

DFO. 2005b. *Recovery Assessment Report on Cumberland Sound, Ungava Bay, Eastern Hudson Bay, and St. Lawrence Beluga Populations (Delphinapterus leucas)*. Canadian Science Advisory Secretariat. Science Advisory Report 2005/036. 14p.

DFO. 2006. *A Harvest Strategy Compliant with the Precautionary Approach*. DFO Canadian Science Advisory Secretariat Science Advisory Report 2006/023.

DFO. 2007. *Stock Assessment of Atlantic Halibut of the Gulf of St. Lawrence (NAFO Divisions 4RST) in 2006*. Canadian Scientific Advisory Secretariat. Science Advisory Report. 2007/007. 13p.

DFO. 2008. *Assessment of the Estuary and Gulf of St. Lawrence (Divisions 4RST) Capelin Stock in 2007*. Canadian Scientific Advisory Secretariat. Science Advisory Report. 2008/037. 12p.

DFO. 2009a. *Advice relevant to the identification of critical habitat for St. Lawrence beluga (Delphinapterus leucas)*. Canadian Science Advisory Secretariat. Science Advisory Report 2009/070.

DFO. 2009b. *Assessment of cod stock in the northern Gulf of St. Lawrence (3Pn,4RS) in 2008*. Canadian Scientific Advisory Secretariat. Ottawa. Scientific Advisory Report. 2009/010. 15p.

DFO and WWF. 1995. *St. Lawrence beluga recovery plan*. Department of Fisheries and Oceans and World Wildlife Fund. Prepared by the St. Lawrence beluga recovery team. 73p.

DFO and WWF. 1998. *Implementation of the St. Lawrence beluga recovery plan*. Department of Fisheries and Oceans and World Wildlife Fund. Prepared by the beluga recovery team. 102p.

Di Guardo, G., G. Marruchella, U. Agrimi and S. Kennedy. 2005. Morbillivirus infections in aquatic mammals: A brief overview. *Journal of Veterinary Medicine Series A: Physiology Pathology Clinical Medicine*. **52** (2):88-93.

Diaz, R. J. 2001. Overview of hypoxia around the world. *Journal of Environmental Quality*. **30** (2):275-281.

Dinel, S. and C. Duhaime. 1997. *Essais techniques d'intervention pour contrer un déversement d'hydrocarbures dans le fjord du Saguenay. Rapport d'opération présenté au Parc Marin du Saguenay-Saint-Laurent*. Environnement Canada. Montréal. 22p.

Drolet, R. 1998. *Le dérangement des espèces fauniques du Saint-Laurent*. Environnement Canada, MPO, MDDEP. Rapport sur l'état du Saint-Laurent. 105p.

Drouillard, K. G., G. T. Tomy, D. C. G. Muir and K. J. Friesen. 1998. Volatility of chlorinated n-alkanes (C10-C12): Vapor pressures and Henry's law constants. *Environmental Toxicology and Chemistry.* **17** (7):1252-1260.

Dufour, R. and P. Ouellet. 2007. *Rapport d'aperçu et d'évaluation de l'écosystème marin de l'estuaire et du golfe du Saint-Laurent*. Rapport technique canadien des sciences halieutiques et aquatiques 2744F. 123p.

Équipe de rétablissement de l'éperlan arc-en-ciel du Québec. 2008. *Plan de rétablissement de l’éperlan arc-en-ciel (Osmerus mordax) au Québec, population du sud de l’estuaire du Saint-Laurent - mise à jour 2008-2012*. Ministère des Ressources naturelles et de la Faune du Québec. 48p.

Erbe, C. 2008. Critical ratios of beluga whales (*Delphinapterus leucas*) and masked signal duration. *Journal of the Acoustical Society of America.* **124** (4):2216-2223.

Erbe, C. and D. M. Farmer. 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. *Deep-Sea Research II.* **45**:1373-1388.

Eriksson, P., C. Fischer and A. Fredriksson. 2006. Polybrominated diphenyl ethers, a group of brominated flame retardants, can interact with polychlorinated biphenyls in enhancing developmental neurobehavioral defects. *Toxicological Science.* **94** (2):302-309.

Eriksson, P., E. Jakobsson and A. Fredriksson. 2001. Brominated flame retardants: A novel class of developmental neurotoxicants in our environment? *Environmental Health Perspectives.* **109** (9):903-908.

Evans, D. L. and G. R. England. 2001. *Joint interim report Bahamas marine mammal stranding event of 15-16 March 2000*. NOAA, US Department of Commerce and Department of the Navy.

Faulkner, J., L. N. Measures and F. G. Whoriskey. 1998. *Stenurus minor* (Metastrongyloidea: Pseudaliidae) infections of the cranial sinuses of harbour porpoise, *Phocoena phocoena*. *Canadian Journal of Zoology.* **76** (7):1209-1216.

Fay, R. R. and A. N. Popper. 2000. Evolution of hearing in vertebrates: the inner ears and processing. *Hearing Research.* **149**:1-10.

Ferguson, P. L. and G. T. Chandler. 1998. A laboratory and field comparison of sediment polycyclic aromatic hydrocarbon bioaccumulation by the cosmopolitan estuarine polychaete Streblospio benedicti (Webster). *Marine Environmental Research.* **45** (4-5):387-401.

Finley, K. J. 1982. The estuary habit of the beluga or white whale *Delphinapterus leucas*. *Cetus.* **4**:4-5.

Finneran, J. J. 2003. Whole lung resonance in a bottlenose dolphin (*Tursiops truncatus*) and white whale (*Delphinapterus leucas*). *Journal of the Acoustical Society of America.* **114**:529-535.

Foster, W. G., D. Desaulniers, K. Leingartner, M. G. Wade, R. Poon and I. Chu. 1999. Reproductive effects of tris(4-chlorophenyl)methanol in the rat. *Chemosphere.* **39** (5):709-724.

Fraker, M. A., C. D. Gordon, J. W. McDonald, J. K. B. Ford and G. Cambers. 1979. *White whale (Delphinapterus leucas) distribution and abundance and the relationship to physical and chemical characteristics of the Mackenzie Estuary*. Fisheries and Marine Service. Rapport technique 863. 59p.

Gagnon, M. and P. Bergeron. 1997. *Identification et description des sites aquatiques contenant des contaminants préoccupants pour le béluga du Saint-Laurent*. Rapport de Biorex inc. au Comité multipartite sur les sites contaminés pouvant affecter le béluga. 180p.

Galbraith, P. S., D. Gilbert, R. G. Pettipas, J. Chassé, C. Lafleur, B. Pettigrew, P. Larouche and L. Devine. 2008. *Physical Oceanographic Conditions in the Gulf of St. Lawrence in 2007*. Canadian Scientific Advisory Secretariat. Research document 2008-001. 59p.

Gauthier, D. and D. A. Steel. 1996. *Sommaire de la situation concernant l'introduction d'espèces non-indigènes par l'eau de lest des navires au Canada et dans d'autres pays*. Pêches et Océans Canada. Rapport manuscrit canadien des sciences halieutiques et aquatiques 2380. 62p.

Gauthier, J. M., E. Pelletier, C. Brochu, S. Moore, C. D. Metcalfe and P. Béland. 1998. Environmental contaminants in tissues of a neonate St Lawrence beluga whale (*Delphinapterus leucas*). *Marine Pollution Bulletin.* **36** (1):102-108.

Gearing, J. N., P. J. Gearing, M. Noël and J. N. Smith. 1994. Polycyclic aromatic hydrocarbons in sediment of the St. Lawrence estuary. In: *Proceedings of the Twentieth Annual Aquatic Toxicity Workshop, October 17-21, 1993, Québec*. R. Coillie, Y. Roy, Y. Bois, P. G. C. Campbell, P. Lundahl, L. Martel, M. Michaud, P. Riebel and C. Thellan (Ed.). Rapport Technique Canadien sur les pêcheries et les sciences aquatiques 1989. p.58-64.

Geraci, J. R. 1990. Physiologic and toxic effects on cetaceans. In: *Sea mammals and oil: confronting the risks*. J. R. Geraci and D. J. St. Aubin (Ed.). Academic Press. San Diego. p.167-197.

Geraci, J. R. and D. J. St. Aubin. 1990. *Sea mammals and oil: confronting the risks*. Academic Press. San Diego. 282p.

Giesy, J. P. and K. Kannan. 2001. Global distribution of perfluorooctane sulfonate in wildlife. *Environmental Science and Technology*. **35** (7):1339-1342.

Gilbert, D., B. Sundby, C. Gobeil, A. Mucci and G. H. Tremblay. 2005. A seventy-two-year record of diminishing deep-water oxygen in the St. Lawrence estuary: The northwest Atlantic connection. *Limnology and Oceanography*. **50** (5):1654-1666.

Gilbert, M. 1996. Mortalités de sébastes dans la région de la baie des Ha! Ha!, fjord du Saguenay : choc thermique. *Le Naturaliste Canadien.* **120** (1):61-63.

Gilbert, M. and C. M. Couillard. 1995. *Observations de mortalités de sébastes (Sebastes sp.) dans la région de la baie des Ha! Ha!, fjord du Saguenay : examen des causes possibles*. Canadian Bulletin of the Fisheries and Aquatic Sciences. 2278. 15p.

Gilbert, M. and B. Pettigrew. 1996. Variation de la couche froide intermédiaire du golfe du Saint-Laurent de 1984 à 1995. *Le Naturaliste Canadien.* **120** (2):69-71.

Giroux, I. 2007. *Les pesticides dans quelques tributaires de la rive nord du Saint- Laurent : Rivières L'Assomption, Bayonne, Maskinongé et du Loup*. MDDEP. 28p.

Giroux, I., C. Robert and N. Dassylva. 2006. *Présence de pesticides dans l'eau au Québec : bilan dans des cours d'eau de zones en culture de maïs et de soya en 2002, 2003 et 2004, et dans les réseaux de distribution d'eau potable*. MDDEP. 57p.

Gobeil, C., W. K. Johnson, R. W. MacDonald and C. S. Wong. 1995. Sources and burden of lead in St. Lawrence Estuary sediments: isotopic evidence. *Environmental Science and Technology*. **29**:193-201.

Gobeil, C., B. Rondeau and L. Beaudin. 2005. Contribution of Municipal Effluents to Metal Fluxes in the St. Lawrence River. *Environmental Science and Technology*. **39** (2):456-464.

Gosselin, J.-F., M. Hammill and V. Lesage. 2007. *Comparison of photographic and visual abundance indices of belugas in the St. Lawrence Estuary in 2003 and 2005*. Canadian Scientific Advisory Secretariat. Research document 2007/025. 14p.

Gouteux, B. and M. Lebeuf. 2000. Le toxaphène dans les mammifères marins de l'estuaire du Saint-Laurent. *Nouvelles des Sciences, Bulletin d'informations des directions des sciences et des océans, région Laurentienne.* **11**:4-7.

Gouteux, B., M. Lebeuf, D. C. G. Muir and J.-P. Gagné. 2003. Levels and Temporal Trends of Toxaphene Congeners in Beluga Whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Canada. *Environmental Science & Technology*. **37** (20):4603-4609.

Grégoire, F. 2005. *Capelan de l'estuaire et du golfe du Saint-Laurent (4RST) en 2004*. Secrétariat canadien de consultation scientifique. Avis scientifique 2005/002. 9p.

Grenfell, W. 1934. *The romance of Labrador*. MacMillan Company. New York. 329p.

Hall, A. J., R. J. Law, D. E. Wells, J. Harwood, H. M. Ross, S. Kennedy, C. R. Allchin, L. A. Campbell and P. P. Pomeroy. 1992. Organochlorine levels in common seals (*Phoca vitulina*) which were victims and survivors of the 1988 phocine distemper epizootic. *Science of the Total Environment.* **115** (1-2):145-162.

Hammill, M. 2005. *Abundance of northwest Atlantic grey seals in the Gulf of St. Lawrence and along the Nova Scotia eastern shore = Abondance des phoques gris du nord-ouest de l'Atlantique dans le golfe du Saint-Laurent et le long de la cote est de la Nouvelle-Ecosse*. Secrétariat canadien de consultation scientifique. Document de recherche 2005/036. 11p.

Hammill, M. and G. Stenson. 2005. *Abundance of Northwest Atlantic harp seals (1960-2005) = Abondance du phoque du Groenland dans l'Atlantique nord-ouest (1960-2005).* Secrétariat canadien de consultation scientifique. Document de recherche 2005/090. 34p.

Hammill, M. O., V. Lesage and M. C. S. Kingsley. 2003. Cancer in the beluga from the St. Lawrence estuary. *Environmental Health Perspectives.* **111**:A77-A78.

Hammill, M. O., L. N. Measures, J.-F. Gosselin and V. Lesage. 2007. *Absence de rétablissement du béluga de l'estuaire du Saint-Laurent*. Secrétariat canadien de consultation scientifique. Document de recherche 2007/026. 23p.

Hammill, M. O. and G. B. Stenson. 2007. Application of the precautionary approach and conservation reference points to management of Atlantic seals. *ICES Journal of Marine Science.* **64** (4):702-706.

Hansen, K. J., L. A. Clemen, M. E. Ellefson and H. O. Johnson. 2001. Compound-specific, quantitative characterization of organic fluorochemicals in biological matrices. *Environmental Science and Technology.* **35** (4):766-770.

Hardy, M. L. 2002. The toxicology of the three commercial polybrominated diphenyl oxide (ether) flame retardants. *Chemosphere.* **46** (5):757-777.

Harvey, M., J.-F. St.-Pierre, L. Devine, A. Gagné and S. Guittard. 2005. *Oceanographic conditions in the estuary and the gulf of St. Lawrence during 2005: zooplankton*. Secrétariat canadien de consultation scientifique. Document de recherche 2008/043. 30p.

Health Canada. 2004. *Follow-up Report on a PSL1 Substance for Which There Was Insufficient Information to Conclude Whether the Substance Constitutes a Danger to the Environment* Government of Canada. 5p.

Heide-Jørgensen, M. P. 1988. Occurrence and hunting of killer whales in Greenland. *Rit Fiskideildar.* **11**:115-135.

Heide-Jørgensen, M. P. and J. Teilmann. 1994. Growth, reproduction, age structure and feeding habits of white whales (*Delphinapterus leucas*) in West Greenland waters. *Meddr Grønland, Bioscience.* **39**:195-212.

Hester, K. C., E. T. Peltzer, W. J. Kirkwood and P. G. Brewer. 2008. Unanticipated consequences of ocean acidification: A noisier ocean at lower pH. *Geophysical Research Letters.* **35** (19):L19601.

Hickie, B. E., D. Mackay and J. D. Koning. 1999. Lifetime pharmacokinetic model for hydrophobic contaminants in marine mammals. *Environmental Toxicology and Chemistry.* **18**:2622-2633.

Hobbs, K. E., D. C. G. Muir, R. Michaud, P. Béland, R. J. Letcher and R. J. Norstrom. 2003. PCBs and organochlorine pesticides in blubber biopsies from free-ranging St. Lawrence River Estuary beluga whales (*Delphinapterus leucas*), 1994-1998. *Environmental Pollution.* **122** (2):291-302.

Hodson, P. V., M. Castonguay, C. M. Couillard, C. Desjardins, E. Pelletier and R. McLeod. 1994. Spatial and temporal variations in chemical contamination of American eels, *Anguilla rostrata*, captured in the estuary of the St. Lawrence River. *Canadian Journal of Fisheries and Aquatic Sciences.* **51**:464-478.

Holdway, D. A. 2002. The acute and chronic effects of wastes associated with offshore oil and gas production on temperate and tropical marine ecological processes. *Marine Pollution Bulletin.* **44**:185-203.

Houde, M., J. W. Martin, R. J. Letcher, K. R. Solomon and D. C. G. Muir. 2006. Biological Monitoring of Polyfluoroalkyl Substances: A Review. *Environmental Science & Technology.* **40** (11):3463-3473.

Hoyt, E. 2001. *Whale watching 2001: Worldwide tourism numbers, expenditures and expanding socioeconomic benefits*. International fund for animals. Yarmouth Port, USA. 158p.

IARC. 1978. *Monographs on the Evaluation of Carcinogenic Risk of Chemicals : PCBs*. OMS. International Agency for Research on Cancer. Genève. Volume 18.

IJC. 1978. *Great Lakes Water Quality Agreement*. International Joint Commission. Canada and United States.

Ikonomou, M. G., S. Rayne and R. F. Addison. 2002. Exponential increases of the brominated flame retardants, polybrominated diphenyl ethers, in the Canadian Arctic from 1981 to 2000. *Environmental Science and Technology.* **36** (9):1886-1892.

IPCS. 1984a. *Chlordane*. Environmental Health Criteria 34. O. I. P. o. C. Safety.

IPCS. 1984b. *Mirex*. Environmental Health Criteria 44. O. I. P. o. C. Safety.

IPCS. 1989. *Aldrin and Dieldrin*. Environmental Health Criteria 91. O. I. P. o. C. Safety.

IPCS. 1991. *Lindane*. Environmental Health Criteria 124. O. I. P. o. C. Safety.

IPCS. 1992a. *Endrin*. Environmental Health Criteria 130. O. I. P. o. C. Safety.

IPCS. 1992b. *Polychlorinated biphenyls and terphenyls*. Environmental Health Criteria 140. O. I. P. o. C. Safety.

IPCS. 1994. *Brominated Diphenylehters*. Environmental Health Criteria 162. O. I. P. o. C. Safety.

IPCS. 1996. *Chlorinated paraffins*. Environmental health criteria 181. O. I. P. o. C. Safety.

IPCS. 1997. *Hexachlorobenzène*. Environmental Health Criteria 195. O. I. P. o. C. Safety.

IPCS. 2001. Toxaphene (Group 2B). *International Agency for Research on Cancer - Summaries & Evaluations.* **79**:569.

Jauniaux, T. and F. Coignoul. 2001. Pathologie des infections par les morbillivirus chez les mammifères marins. *Annales de médecine vétérinaire.* **145**:76-96.

Jepson, P. D., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herràez, A. M. Pocknell, F. Rodríguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham and A. Fernàndez. 2003. Gas bubble lesions in stranded cetaceans. *Nature.* **425**:575.

Kaiser, K. L. E. 1978. Pesticide Report: The rise and fall of mirex. *Environmental Science & Technology.* **12** (5):520-528.

Kannan, K., J. C. Franson, W. W. Bowerman, K. J. Hansen, P. D. Jones and J. P. Giesy. 2001a. Perfluorooctane sulfonate in fish-eating water birds including bald eagles and albatrosses. *Environmental Science and Technology.* **35** (15):3065-3070.

Kannan, K., J. Koistinen, K. Beckmen, T. Evans, J. F. Gorzelany, K. J. Hansen, P. D. Jones, E. Helle, M. Nyman and J. P. Giesy. 2001b. Accumulation of perfluorooctane sulfonate in marine mammals. *Environmental Science and Technology.* **35** (8):1593-1598.

Kannan, K., K. Senthilkumar and R. K. Sinha. 1997. Sources and Accumulation of Butyltin Compounds in Ganges River Dolphin, Platanista gangetica. *Applied Organometallic Chemistry.* **11** (3):223-230.

Kastelein, R. A., J. Ford, E. Berghout, P. R. Wirpkema and M. v. Boxsel. 1994. Food consumption, growth and reproduction of belugas (*Delphinapterus leucas*) in human care. *Aquatic mammals.* **20**:81-97.

Kennedy, S. 1998. Morbillivirus infections in aquatic mammals. *Journal of Comparative Pathology*. **119** (3):201-225.

Ketten, D. R., J. Lien and S. Todd. 1993. Blast injury in humpback whale ears: Evidence and implication. *Journal of the Acoustical Society of America*. **94**:1849-1850.

Ketten, D. R. and D. Potter. 1999. Anthropogenic ocean noise: negligible or negligent impact? . *Journal of Acoustical Society of America*. **105**:993.

Kingsley, M. C. S. 1993. *Census, trend, and status of the St. Lawrence beluga population in 1992*. Canadian technical report of fisheries and aquatic sciences 1938. 17p.

Kingsley, M. C. S. 1996. *Estimation d'un indice d'abondance de la population de bélugas du Saint-Laurent en 1995*. Rapport technique canadien des sciences halieutiques et aquatiques 2117. 42p.

Kingsley, M. C. S. 1999. *Indices d'abondance et estimations de la population de bélugas de l'estuaire du Saint-Laurent*. Rapport technique canadien des sciences halieutiques et aquatiques 2266. 27p.

Kingsley, M. C. S. 2002. Status of the belugas of the St. Lawrence estuary, Canada. *NAMMCO Scientific Publications*. **4**:239-257.

Kingsley, M. C. S. and I. Gauthier. 2002. Visibility of St. Lawrence belugas to serial photography, estimated by direct observation. *NAMMCO Scientific Publications*. **4** (259-270)

Kingsley, M. C. S. and R. R. Reeves. 1998. Aerial surveys of cetaceans in the Gulf of St. Lawrence in 1995 and 1996. *Canadian Journal of Zoology*. **76** (8):1529-1550.

Kingston, P. 2005. *Recovery of the marine environment following the Braer spill, Shetland*. 2005 International Oil Spill Conference, IOSC 2005. p.6797-6815.

Kleinenberg, S. E., A. V. Yablokov, B. M. Bel'kovich and M. N. Tarassevich. 1964. *Beluga, Delphinapterus leucas, investigation of the species*. Academy Nauk. USSR. Traduction de Israel Programme of Scientific Translation. 376p.

Knapp, L. A., J. C. Ha and G. P. Sackett. 1996. Parental MHC antigen sharing and pregnancy wastage in captive pigtailed macaques. *Journal of Reproductive Immunology*. **32**:73-88.

Kraus, S. D., M. W. Brown, H. Caswell, C. W. Clark, M. Fujiwara, P. K. Hamilton, R. D. Kenney, A. R. Knowlton, S. Landry, C. A. Mayo, W. A. McLellan, M. J. Moore, D. P. Nowacek, D. A. Pabst, A. J. Read and R. M. Rolland. 2005. North Atlantic right whales in crisis. *Science*. **309** (5734):561-562.

Laberge, K. 2005. Filets fantômes : la pêche a été bonne. *Infocéans.* **8** (4)

Lair, S. 2007. Programme de nécropsie - Suivi de la santé de la population de béluga de l'estuaire du Saint-Laurent à l'aide de l'examen post-mortem des carcasses échouées. In: *Compte-rendu de l'atelier sur le béluga de l'estuaire du Saint-Laurent - Revue du programme des carcasses*. MPO (Ed.). Secrétariat canadien de consultation scientifique. Compte-rendu 2007/005. p.11-14.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet and M. Podesta. 2001. Collisions between ships and whales. *Marine Mammal Science.* **17**:35-75.

Laliberté, D. 1991. *Teneurs en HAP dans les sédiments près de cinq alumineries du Québec en 1988*. Ministère de l'environnement du Québec. Rapport QE-91-10.

Lawson, J., M. Hammill and G. Stenson. 2006. *Caractéristiques pour le rétablissement : Béluga*. Secrétariat canadien de consultation scientifique. Document de recherche 2006/075. 16p.

Lawson, J. and I. McQuinn. 2004. *Revue des problématiques potentielles liées à l'hydrophysique au Canada, leurs risques pour les mammifères marins et des stratégies de monitorage et d'atténuation dans le contexte d'activités sismiques*. Secrétariat canadien de consultation scientifique. Document de recherche 2004/121. 53p.

Leaños-Castañeda, O., G. Van Der Kraak, R. Rodríguez-Canul and G. Gold. 2007. Endocrine disruption mechanism of o,p'-DDT in mature male tilapia (*Oreochromis niloticus*). *Toxicology and Applied Pharmacology.* **221** (2):158-167.

Lebeuf, M. 2009. La contamination du béluga de l'estuaire du Saint-Laurent par les polluants organiques persistants: en revue. *Revue des Sciences de l'eau.* **22** (2):199-233.

Lebeuf, M., K. E. Bernt, S. Trottier, M. Noël, M. O. Hammill and L. Measures. 2001. Tris (4-chlorophenyl) methane and tris (4-chlorophenyl) methanol in marine mammals from the Estuary and Gulf of St. Lawrence. *Environmental Pollution.* **111** (1):29-43.

Lebeuf, M., C. M. Couillard, B. Légaré and S. Trottier. 2006. Effects of DeBDE and PCB-126 on hepatic concentrations of PBDEs and methoxy-PBDEs in Atlantic tomcod. *Environmental Science and Technology.* **40**:3211-3216.

Lebeuf, M., B. Gouteux, L. Measures and S. Trottier. 2004. Levels and temporal trends (1988-1999) of polybrominated Diphenyl Ethers in beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Canada. *Environmental Science and Technology.* **38**:2971-2977.

Lebeuf, M., M. Noël, S. Trottier and L. Measures. 2007. Temporal trends (1987-2002) of persistent, bioaccumulative and toxic (PBT) chemicals in beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Canada. *Science of the Total Environment.* **383**:216-231.

Lebeuf, M. and T. Nunes. 2005. PCBs and OCPs in sediment cores from the lower St. Lawrence Estuary, Canada: Evidence of fluvial inputs and time lag in delivery to coring sites. *Environmental Science and Technology.* **39** (6):1470-1478.

Lebeuf, M., S. Trottier, M. Noël, M. Raach and L. Measures. 2010. A twenty years (1987-2007) trend of PBDEs in beluga from the St. Lawrence Estuary, Canada. *Organohalogen Compounds.* **71**:372-376.

Lemieux Lefebvre, S. 2009. *Déplacements et patrons de résidence chez la population de bélugas (Delphinapterus leucas) de l'estuaire du Saint-Laurent*. Masters thesis. Université du Québec à Rimouski, Rimouski. 112p.

Lesage, V. 1993. *Effet de la circulation plaisancière et d'un traversier sur le comportement vocal et social du béluga du Saint-Laurent (Delphinapterus leucas)*. Masters thesis. Université Laval, Québec. 141p.

Lesage, V., C. Barrette, M. C. S. Kingsley and B. Sjare. 1999. The effects of vessel noise on the vocal behaviour of beluga in the St. Lawrence River estuary, Canada. *Marine Mammal Science.* **15**:65-84.

Lesage, V., M. O. Hammill and K. M. Kovacs. 2001. Marine mammals and the community structure of the Estuary and Gulf of St. Lawrence, Canada: evidence from stable isotope analysis. *Marine Ecology Progress Series.* **210**:203-221.

Lesage, V. and M. C. S. Kingsley. 1995. *Bilan des connaissances de la population de bélugas (Delphinapterus leucas) du Saint-Laurent*. Rapport technique canadien des sciences halieutiques et aquatiques 2041. 44p.

Lesage, V. and M. C. S. Kingsley. 1998. Updated status of the St. Lawrence river population of the beluga, *Delphinapterus leucas*. *Canadian Field Naturalist.* **112**:98-114.

Letcher, R. J., R. J. Norstrom, D. C. G. Muir, C. D. Sandau, K. Koczanski, R. Michaud, S. De Guise and P. Béland. 2000. Methylsulfone polychlorinated biphenyl and 2,2-bis(chlorophenyl)-1,1- dichloroethylene metabolites in beluga whale (*Delphinapterus leucas*) from the St. Lawrence River estuary and western Hudson Bay, Canada. *Environmental Toxicology and Chemistry.* **19** (5):1378-1388.

Lien, J. 2001. *Les principes de conservation justifiant la réglementation de l'observation des baleines au Canada par le ministère des Pêches et des Océans : une approche prudente*. Pêches et Océans Canada. Rapport technique canadien des sciences halieutiques et aquatiques 2363. 27p.

Lockyer, C., A. A. Hohn, D. W. Doidge, M. P. Heide-Jørgensen and R. Suydam. 2007. Age determination in belugas (*Delphinapterus leucas*): a quest for validation of dentinal layering. *Aquatic mammals.* **33**:293-304.

Lowry, L. F., K. J. Frost and G. A. Seaman. 1985. *Investigations of beluga whales in coastal waters. III Food habits*. Alaska Department of Fish and Game. Fairbanks. Final Report, OCSEAP es. Unit 512. 24p.

Luque, S. P., J. W. Higdon and S. H. Ferguson. 2007. Dentine deposition rates in belugas (*Delphinapterus leucas*): an analysis of the evidence. *Aquatic mammals.* **33**:241-245.

MacLeod, M., D. Woodfine, J. Brimacombe, L. Toose and D. Mackay. 2002. A dynamic mass budget for toxaphene in North America. *Environmental Toxicology and Chemistry.* **21** (8):1628-1637.

Mamaev, L. V., I. K. G. Visser, S. I. Belikov, N. N. Denikina, T. C. Harder, L. Goatley, B. K. Rima, B. Edginton, A. D. M. E. Osterhaus and T. Barrett. 1996. Canine distemper virus in lake Baïkal seals (*Phoca sibirica*). *The Vetenary Record.* **138**:437-439.

Mancuso, S. J. 1995. *Population genetics of Hudson Bay beluga whales (Delphinapterus leucas): an analysis of structure and gene flow using mitochondrial DNA sequences and multilocus DNA fingerprinting*. Masters thesis. McMaster University, Department of Biology. Hamilton. 118p.

Martel, L. M., J. Gagnon, R. Massé, A. Leclerc and L. Tremblay. 1986. Polycyclic aromatic hydrocarbons in sediments from the Saguenay Fjord, Canada. *Bulletin of Environmental Contamination and Toxicology.* **37**:133-140.

Martin, A. R. and R. R. Reeves. 2000. Status of Monodontid whales. Reports of the International Whaling Commission, scientific committee. Annex 1. *The Journal of Cetacean Research and Management.* **2**:243-251.

Martin, J. W., M. M. Smithwick, B. M. Braune, P. F. Hoekstra, D. C. G. Muir and S. A. Mabury. 2004. Identification of Long-Chain Perfluorinated Acids in Biota from the Canadian Arctic. *Environmental Science and Technology.* **38** (2):373-380.

Martineau, D., P. Béland, C. Desjardins and A. Lagacé. 1987. Levels of organochlorine chemicals in tissues of beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Québec, Canada. *Archives of Environmental Contamination and Toxicology.* **16**:137-147.

Martineau, D., S. Deguise, M. Fournier, L. Shugart, C. Girard, A. Lagacé and P. Béland. 1994. Pathology and toxicology of beluga whales from the St. Lawrence Estuary, Quebec, Canada - Past, present and future. *Science of the Total Environment.* **154** (2-3):201-215.

Martineau, D., A. Lagacé, P. Béland, R. Higgins, D. Armstrong and L. R. Shugart. 1988. Pathology of stranded beluga whales (*Delphinapterus leucas*) from the St. Lawrence estuary, Québec, Canada. *Journal of Comparative Pathology*. **98**:287-311.

Martineau, D., S. Lair, S. D. Guise, T. Lipscomb and P. Béland. 1999. Cancer in beluga whales from the St. Lawrence Estuary, Quebec, Canada: A potential biomarker of environmental contamination. *Journal of Cetacean Research and Management.* **1** (special issue):249-265.

Martineau, D., K. Lemberger, A. Dallaire, P. Labelle, T. P. Lipscomb, P. Michel and I. Mikaelian. 2002a. Cancer in wildlife, a case study: Beluga from the St. Lawrence estuary, Québec, Canada. *Environmental Health Perspectives.* **110** (3):285-292.

Martineau, D., K. Lemberger, A. Dallaire, P. Labelle, T. P. Lipscomb, P. Michel and I. Mikaelian. 2002b. Cancer in wildlife, a case study:beluga from the St. Lawrence estuary, Québec, Canada. *Environmental Health Perspectives.* **110**:285-292.

Martineau, D., K. Lemberger, A. Dallaire, P. Michel, P. Béland, P. Labelle and T. P. Lipscomb. 2002c. St. Lawrence beluga whales, the river sweepers? *Environmental Health Perspectives.* **110** (10):285-292.

Martineau, D., K. Lemberger, A. Dallaire, P. Michel, P. Béland, P. Labelle and T. P. Lipscomb. 2003. Cancer in the Beluga: Response. *Environmental Health Perspectives.* **111**:A78-A79.

Massé, R., D. Martineau, L. Tremblay and P. Béland. 1986. Concentrations and chromotographic profile of DDT metabolites and polychloro-biphenyl (PCB) residus in stranded beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Canada. *Archives of Environmental Contamination and Toxicology.* **15**:567-579.

Matkin, C. O., E. L. Saulitis, G. M. Ellis, P. Olesiuk and S. D. Rice. 2008. Ongoing population-level impacts on killer whales *Orcinus orca* following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. *Marine Ecology Progress Series.* **356**:269-281.

McAlpine, D. F., M. C. S. Kingsley and P.-Y. Daoust. 1999. A lactating record-age St. Lawrence beluga (*Delphinapterus leucas*). *Marine Mammal Science.* **15**:854-859.

McCauley, R. D., J. Fewtrell and A. N. Popper. 2003. High intensity anthropogenic sound damages fish ears. *Journal of Acoustical Society of America.* **113**:638-642.

McDonald, T. A. 2002. A perspective on the potential health risks of PBDEs. *Chemosphere.* **46** (5):745-755.

McKinney, M. A., A. Arukwe, S. De Guise, D. Martineau, P. Béland, A. Dallaire, S. Lair, M. Lebeuf and R. J. Letcher. 2004. Characterization and profiling of hepatic cytochromes P450 and phase II xenobiotic-metabolizing enzymes in beluga whales (*Delphinapterus leucas*) from the St. Lawrence River Estuary and the Canadian Arctic. *Aquatic Toxicology.* **69** (1):35-49.

McKinney, M. A., S. De Guise, D. Martineau, P. Béland, M. Lebeuf and R. J. Letcher. 2006.

Organohalogen contaminants and metabolites in beluga whale (*Delphinapterus leucas*) liver from two Canadian populations. *Environmental Toxicology and Chemistry*. **25** (5):1246-1257.

Measures, L. 2004. *Marine mammals and "wildlife rehabilitation" programs*. Canadian Scientific Advisory Secretariat. Research Document 2004/122. 39p.

Measures, L. 2007a. *Compte-rendu de l'atelier sur le béluga de l'estuaire du Saint-Laurent - Revue du programme des carcasses*. Secrétariat canadien de consultation scientifique. Compte-rendu 2007/005. 94p.

Measures, L. 2007b. Maladies parasitaires et infectieuses du béluga de l'estuaire du Saint-Laurent. In: *Compte-rendu de l'atelier sur le béluga de l'estuaire du Saint-Laurent - Revue du programme des carcasses*. MPO (Ed.). Secrétariat canadien de consultation scientifique. Comte-rendu 2007/005. p.15-17.

Measures, L. 2008. Les causes de mortalité du béluga du Saint-Laurent. *Le Naturaliste Canadien*. **132** (2):75-79.

Measures, L. and M. Olson. 1999. Giardiasis in pinnipeds from eastern Canada. *Journal of Wildlife Diseases*. **35**:779-782.

Measures, L., B. Roberge and R. Sears. 2004. Stranding of a Pygmy Sperm Whale, *Kogia breviceps*, in the Northern Gulf of St. Lawrence, Canada. *Canadian Field-Naturalist*. **118** (4):495-498.

Meier, S., T. E. Andersen, B. Norberg, A. Thorsen, G. L. Taranger, O. S. Kjesbu, R. Dale, H. C. Morton, J. Klungsøyr and A. Svardal. 2007. Effects of alkylphenols on the reproductive system of Atlantic cod (*Gadus morhua*). *Aquatic Toxicology*. **81**:207-218.

Ménard, N. 1998. *Répartition spatiale et structure des bancs de poissons pélagiques dans une aire d'alimentation des cétacés de l'estuaire du Saint-Laurent*. Masters thesis. Université Laval, Département de biologie. 107p.

Ménard, N., M. Pagé, V. Busque, I. Croteau, R. Picard and D. Gobeil. 2007. *Rapport sur l'état du parc marin du Saguenay–Saint-Laurent 2007*. Agence Parcs Canada. Parc marin du Saguenay-Saint-Laurent. 81p.

Metcalfe, C., T. Metcalfe, S. Ray, G. Paterson and B. Koenig. 1999. Polychlorinated biphenyls and organochlorine compounds in brain, liver and muscle of beluga whales (*Delphinapterus leucas*) from the Arctic and St. Lawrence estuary. *Marine Environmental Research*. **47**:1-15.

Michaud, R. 1993a. *Distribution estivale du béluga du St-Laurent : synthèse 1986-1992*. Rapport technique canadien des sciences halieutiques et aquatiques 1906. 28p.

Michaud, R. 1993b. *Évaluation de la structure de la population des bélugas du Saint-Laurent. 1. Potentiel d'accroissement de la population*. Institut national d'écotoxicologie du Saint-Laurent. 48p.

Michaud, R. 1996. *Les bélugas du Saint-Laurent, étude de la distribution et de l'organisation sociale 1995-1997*. INESL. Institut national d'écotoxicologie du Saint-Laurent, rapport annuel 1995-1996. 36p.

Michaud, R. and P. Béland. 2001. Looking for trends in the endangered St. Lawrence beluga population. A critique of Kingsley, M.C.S., 1998. *Marine Mammal Science.* **17**:206-212.

Michaud, R. and V. Chadenet. 1990. *Survols aériens pour l'estimation de la distribution printanière des bélugas du Saint-Laurent*. INESL. Tadoussac. Rapport présenté à Pêches et Océans Canada. 36p.

Michaud, R., V. de la Chenelière and M. Moisan. 2003. *Les activités d'observation en mer des cétacés dans le parc marin du Saguenay-Saint-Laurent 1994-2002 : Une étude de la répartition spatiale des activités et des facteurs favorisant la concentration des bateaux sur les sites d'observation.* GREMM et PMSSL. Tadoussac. 13p.

Michaud, R., A. Vézina, N. Rondeau and Y. Vigneault. 1990. *Distribution annuelle et caractérisation préliminaire des habitats du béluga (Delphinapterus leucas) du Saint-Laurent*. Rapport technique canadien des sciences halieutiques et aquatiques 1757. 31p.

Minns, C. K., R. G. Rendall, E. M. P. Chadwick, J. E. Moore and R. Green. 1995. Potential impact of climate change on the habitat and population dynamics of juvenile Atlantic Salmon (*Salmo salar*) in Eastern Canada. In: *Climate change and northern fish populations*. R. J. Beamish (Ed.). Canadian special publication of fisheries and aquatic sciences. 121. p.699-708.

Mooney, T. A., P. E. Nachtigall, M. Castellote, K. A. Taylor, A. F. Pacini and J. A. Esteban. 2008. Hearing pathways and directional sensitivity of the beluga whale, *Delphinapterus leucas*. *Journal of Experimental Marine Biology and Ecology.* **362** (2):108-116.

Mosnier, A., V. Lesage, J.-F. Gosselin, S. Lemieux Lefebvre, M. O. Hammill and T. Doniol-Valcroze. 2009. *Information relevant to the documentation of habitat use by St. Lawrence beluga (Delphinapterus leucas), and quantification of habitat quality*. Canadian Scientific Advisory Secretariat. Research document 2009/098. 36p.

Muir, D. C. G., C. A. Ford, B. Rosenberg, R. J. Notstrom, M. Simon and P. Béland. 1996a. Persistent organochlorines in beluga whales (*Delphin apterus leucas*) from the St Lawrence River Estuary - I. Concentrations and patterns of specific PCBs, chlorinated pesticides and polychlorinated dibenzo-p-dioxins and dibenzofurans. *Environmental Pollution.* **93** (2):219-234.

Muir, D. C. G., C. A. Ford, R. E. A. Stewart, T. G. Smith, R. F. Addison, M. E. Zinck and P.

Béland. 1990. Organochlorine contaminants in belugas, *Delphinapterus leucas*, from Canadian waters. *Bulletin Canadien des sciences halieutiques et aquatiques.* **224**:165-190.

Muir, D. C. G., K. Koczanski, B. Rosenberg and P. Béland. 1996b. Persistent organochlorines in beluga whales (*Delphinapterus leucas*) from the St. Lawrence River Estuary. II Temporal trends, 1982-1994. *Environmental Pollution.* **93**:235-245.

Muir, D. C. G., G. A. Stern and G. T. Tomy. 1999. Chapter 8. In: *Handbook of environmental chemistry : New types of persistent halogenated compounds*. J. Paasivirta (Ed.). Springer-Verlag. Berlin. 3K.

Murray, B. W., R. Michaud and B. N. White. 1999. Allelic and haplotype variation of major histocompatibility complex class II DRB1 and DQB loci in St. Lawrence beluga, (*Delphinapterus leucas*). *Molecular Ecology.* **8**:1127-1139.

Nakanishi, T. 2007. Potential toxicity of organotin compounds via nuclear receptor signaling in mammals. *Journal of Health Science.* **53** (1):1-9.

Nakata, H., A. Sakakibara, M. Kanoh, S. Kudo, H. Watanabe, N. Nagai, N. Miyazaki, Y. Asano and S. Tanabe. 2002. Evaluation of mitogen-induced responses in marine mammal and human lymphocytes by in-vitro exposure of butyltins and non-ortho coplanar PCBs. *Environmental Pollution.* **120** (2):245-253.

Narayana, S., J. Carscadden, J. B. Dempsin, M. F. O'Connell, S. Prinsenberg, D. G. Reddin and N. Shackell. 1995. Marine climate off Newfoundland and its influence on salmon (*Salmo salar*) and capelin (*Mallotus villosus*). In: *Climate change and northern fish populations*. R. J. Beamish (Ed.). Canadian special publication of fisheries and aquatic sciences. 121. p.461-474.

Nielsen, O., R. E. A. Stewart, L. Measures, P. Duignan and C. House. 2000. A morbillivirus antibody survey of Atlantic walrus, narwhal and beluga in Canada. *Journal of Wildlife Diseases.* **36** (3):508-517.

Nielsen, O., R. E. A. Stewart, L. Nielsen, L. Measures and P. Duignan. 2001. Serologic survey of *Brucella* spp. antibodies in some marine mammals of North America. *Journal of Wildlife Diseases.* **37**:89-100.

Nieukirk, S. L., K. M. Stafford, D. K. Mellinger, R. P. Dziak and C. G. Fox. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. *Journal of the Acoustical Society of America.* **115**:1832-1843.

NMFS. 2003. Taking marine mammals incidental to conducting oil and gas exploration activities in the Gulf of Mexico. *Federal register.* **68** (41):9991-9996.

Norstrom, R. J., M. Simon and D. C. G. Muir. 1990. Polychlorinated dibenzo-p-dioxins and dibenzofurans in marine mammals in the Canadian. *Environmental Pollution.* **66**:1-19.

Nozères, C. A. 2006. *Régime alimentaire du béluga, Delphinapterus leucas, de l'estuaire du Saint-Laurent, Canada, tel que révélé par l'analyse des acides gras du lard*. Masters thesis. Université Laval, Département de biolgie. Québec. 207p.

NRC. 2003. *Ocean noise and marine mammals*. The National Academy of Science. United States. 151p.

O'Shea, T. J. 2000. PCBs not to blame [3]. *Science.* **288** (5473):1965-1966.

Olar, M., W. Adamowicz, P. Boxall and G. E. West. 2007. *Estimation of the Economic benefits of marine mammal recovery in the St. Lawrence estuary*. Centre de recherche en économie agroalimentaire. SR.2007.05.01. 62p.

Ono, M., N. Kannan, T. Wakimoto and R.Tatsukawa. 1987. Dibenzofurans a greater pollutant than dioxins ? *Marine Pollution Bulletin.* **18**:640-643.

Painchaud, J. and S. Villeneuve. 2003. *Portrait global de l'état du Saint-Laurent*. Saint-Laurent Vision 2000. 18p.

Patenaude, N. J., J. S. Quinn, P. Béland, M. Kingsley and B. N. White. 1994. Genetic variation of the St. Lawrence beluga whale population assessed by DNA fingerprinting. *Molecular Ecology.* **3**:375-381.

Paterson, S., K. Wilson and J. M. Pemberton. 1998. Major histocompatibility complex variation associated with juvenile survival and parasite resistance in a large unmanaged ungulate population (*Ovis aries* L.). *Proceedings of the National Academy of Science U.S.A.* **95**:3714-3719.

PCA and MDDEP. 2010. *Saguenay-St.Lawrence Marine Park Management Plan*. Parks Canada and Ministère du Développement Durable, de l'Environnement et des Parcs du Québec. 84p.

Pelletier, E. and C. Normandeau. 1997. Distribution of butyltin residues in mussels and sea stars of the St Lawrence estuary. *Environmental Technology.* **18** (12):1203-1208.

Pelletier, M. 2005. *La contamination des sédiments par les toxiques – Le lac Saint-Pierre : dernière halte avant l'estuaire*. Saint-Laurent Vision 2000. En153-114/6-2005F. 8p.

Pesce, S. F., J. Cazenave, M. V. Monferrán, S. Frede and D. A. Wunderlin. 2008. Integrated survey on toxic effects of lindane on neotropical fish: *Corydoras paleatus* and *Jenynsia multidentata*. *Environmental Pollution.* **156** (3):775-783.

Peterson, C. H., S. D. Rice, J. W. Short, D. Esler, J. L. Bodkin, B. E. Ballachey and D. B. Irons. 2003. Long-Term Ecosystem Response to the Exxon Valdez Oil Spill. *Science.* **302**:2082-

2086.

Pham, T.-T., B. Rondeau, H. Sabik, S. Proulx and D. Cossa. 2000. Lake Ontario: the predominant source of triazine herbicides in the St. Lawrence River. *Canadian Journal of Fisheries and Aquatic Sciences.* **57** (S1):78-85.

Pham, T., K. Lum and C. Lemieux. 1993. The occurrence, distribution and sources of DDT in the St. Lawrence River, Quebec (Canada). *Chemosphere.* **26**:1955-1606.

Pippard, L. 1985a. *Patterns of movement of the St.Lawrence white whales (Delphinapterus leucas)*. Canadian wildlife service et Parcs Canada. Rapport technique. 225p.

Pippard, L. 1985b. Status of the St. Lawrence River Population of beluga (*Delphinapterus leucas*). *Canadian Field Naturalist.* **99**:438-450.

Pippard, L. and H. Malcolm. 1978. *White whales (Delphinapterus leucas): observations on their distribution, population and critical habitats in the St. Lawrence and Saguenay Rivers*. Department of lndian and Northern Affairs, Parks Canada. 159p.

Plante, I., M. Charbonneau and D. G. Cyr. 2007. Regulation of cell-cell interactions in hexachlorobenzene-induced hepatocarcinogenesis in rat. *Bulletin de la Société Zoologique de France.* **132** (1-2):23-30.

Poon, R., P. Lecavalier, A. Bergman, A. Yagminas, I. Chu and V. E. Valli. 1997. Effects of tris(4-chlorophenyl)methanol on the rat following short-term oral exposure. *Chemosphere.* **34** (1):1-12.

Quémerais, B., D. Cossa, B. Rondeau, T. T. Pham, P. Gagnon and B. Fortin. 1999. Sources and Fluxes of Mercury in the St. Lawrence River. *Environmental Science and Technology.* **33** (6):840-849.

Rahman, F., K. H. Langford, M. D. Scrimshaw and J. N. Lester. 2001. Polybrominated diphenyl ether (PBDE) flame retardants. *The Science of The Total Environment.* **275** (1-3):1-17.

Ray, S., P. Dunn, J. F. Payne, L. Fancey, R. Helbig and P. Béland. 1991. Aromatic DNA-Carcinogen Adducts in Beluga Whales from the Canadian Arctic and Gulf of St. Lawrence. *Marine Pollution Bulletin.* **22**:392-396.

Reed, L., V. Buchner and P. B. Tchounwou. 2007. Environmental toxicology and health effects associated with hexachlorobenzene exposure. *Reviews on Environmental Health.* **22** (3):213-243.

Reeves, R. R. 1990. An overview of the distribution, exploitation and conservation status of belugas, worldwide. In: *Pour l'avenir du béluga : Compte rendu du forum international*. J. Prescott and M. Gauquelin (Ed.). Les Presses de l'Université du Québec. Québec. p.47-58.

Reeves, R. R. and S. K. Katona. 1980. Extralimital records of white whales (*Delphinapterus leucas*) in eastern North American waters. *Canadian Field Naturalist.* **94**:239-247.

Reeves, R. R. and E. Mitchell. 1984. Catch history and initial population of white whales (*Delphinapterus leucas*) in the river and Gulf of the St.Lawrence, eastern Canada. *Naturaliste Canadien.* **111**:63-121.

Richardson, W. J., C. R. Greene, C. R. Malme and D. H. Thompson. 1995. *Marine mammals and noise*. Academic Press. San Diego. 576p.

Richardson, W. J., B. W. Würsig and C. R. G. Jr. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. *Marine Environmental Research.* **29**:135-160.

Roff, D. A. and W. D. Bowen. 1983. Population dynamics and management of the N.W. Atlantic harp seal. *Canadian Journal of the Fisheries and Aquatic Sciences.* **40**:919-932.

Rondeau, B. 2002. *La qualité de l'eau du secteur fluvial : la contamination par les toxiques*. Saint-Laurent Vision 2000. ENV/2002/0353. 6p.

Ross, P. S., C. M. Couillard, M. Ikonomou, S. Johannessen, M. Lebeuf, R. Macdonald and G. Tomy. 2008. *Polybrominated Diphenylethers (PBDEs) in the Canadian Marine Environment: An Emerging Health Risk for Fish, Marine Mammals and their Habitat*. Canadian Scientific Advisory Secretariat. Research Document 2008/036. 23p.

Ross, P. S., R. L. DeSwart, R. Addison, H. VanLoveren, J. Vos and A. Osterhaus. 1996. Contaminant-induced immunotoxicity in harbour seals : wildlife at risk? *Toxicology.* **112**:157-169.

Ross, P. S., J. G. Vos, L. S. Birnbaum and A. D. M. E. Osterhaus. 2000. PCBs are a health risk for humans and wildlife. *Science.* **289**:1878-1879.

Scharrer, E. 1983. *A small whale hunt in Canada*. Canadian Translation for Fisheries and Aquatic Sciences. 4973. 16p.

Scheifele, P., R. Michaud, P. Béland and I. G. Babb. 1997. *Évaluation des niveaux de bruits ambiants et de source anthropogénique dans l'habitat du béluga du Saint-Laurent et leurs impacts potentiels*. Rapport non publié de l'Institut national d'écotoxicologie du Saint-Laurent. Tadoussac. 16p.

Scheifele, P. M., S. Andrew, R. A. Cooper, M. Darre, F. E. Musiek and L. Max. 2005. Indication of a lombard vocal response in the St. Lawrence river beluga. *Journal of Acoustical Society of America.* **117**:1486-1492.

Schiedek, D., B. Sundelin, J. W. Readman and R. W. Macdonald. 2007. Interactions between climate change and contaminants. *Marine Pollution Bulletin.* **54** (12):1845-1856.

Scholin, C. A., F. Gulland, G. J. Doucette, S. Benson, M. Busman, F. P. Chavez, J. Cordaro, R. DeLong, A. De Vogelaere, J. Harvey, M. Haulena, K. Lefebvre, T. Lipscomb, S. Loscutoff, L. J. Lowenstine, R. Marin Iii, P. E. Miller, W. A. McLellan, P. D. R. Moeller, C. L. Powell, T. Rowles, P. Silvagni, M. Silver, T. Spraker, V. Trainer and F. M. Van Dolah. 2000. Mortality of sea lions along the central California coast linked to a toxic diatom bloom. *Nature.* **403** (6765):80-84.

Schottler, S. P. and S. J. Eisenreich. 1997. Mass balance model to quantify atrazine sources, transformation rates, and trends in the Great Lakes. *Environmental Science and Technology.* **31**:2616-2625.

Seaman, G. A. and J. J. Burns. 1981. Preliminary results of recent studies of belukhas in Alaskan waters. *Reports of the International Whaling Commission, scientific committee.* **31**:567-574.

Sears, R. and J. M. Williamson. 1982. *A preliminary aerial survey of marine mammals for the gulf of St. Lawrence to determine their distribution and relative abundance*. Mingan island cetacean study. Sept-Îles. Rapport préparé pour Parcs Canada. 70p.

Sergeant, D. E. 1973. Biology of white whales (*Delphinapterus leucas*) in Western Hudson Bay. *Journal of Fisheries Research Board of Canada* **30**:1065-1090.

Sergeant, D. E. 1986. Present status of white whales (*Delphinapterus leucas*) in the St. Lawrence estuary. *Naturaliste Canadien.* **113**:61-81.

Sergeant, D. E. 1991. *Harp seals, man and ice*. MPO. Canadian special publication in fisheries and aquatic sciences 114. 153p.

Sergeant, D. E. and P. F. Brodie. 1975. Identity, abundance and present status of white whales (*Delphinapterus leucas*) in North America. *Journal of Fisheries Research Board of Canada.* **32**:1047-1054.

Sergeant, D. E. and W. Hoek. 1988. A update of the status of white whales, *Delphinapterus leucas*, in the St. Lawrence Estuary, Canada. *Biological Conservation.* **45**:287-302.

Siddle, H. V., A. Kreiss, M. D. B. Eldridge, E. Noonan, C. J. Clarke, S. Pyecroft, G. M. Woods and K. Belov. 2007. Transmission of a fatal clonal tumor by biting occurs due to depleted MHC diversity in a threatened carnivorous marsupial. *Proceedings of the National Academy of Science U.S.A.* **104**:16221-16226.

Simard, N. and M. Hardy. 2004. *Le chenal Laurentien comme zone auxiliaire d'échange des eaux de lest : risques, analyse et recommandations*. Secrétariat canadien de consultation scientifique. Document de recherche 2004/120. 74p.

Simard, Y., N. Roy and C. Gervaise. 2006. *Shipping noise and whales: World tallest ocean liner vs largest animal on earth*. OCEANS 2006, 18-21 Sept. 2006. p.1-6.

Smith, M. C. and E. M. Levy. 1990. Geochronology for polycyclic aromatic hydrocarbon contamination in sediments of the saguenay fjord *Environmental Science and Technology.* **24**:874-879.

SOM. 2006. *Estimation de la fréquentation du parc marin Saguenay-Saint-Laurent*. Parcs Canada. 44p.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. G. Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas and P. L. Tyack. 2007. Marine mammal noise exposure criteria. *Aquatic mammals.* **33** (4):411-521.

St-Louis, R., S. De Mora, E. Pelletier, B. Doidge, D. Leclair, I. Mikaelian and D. Martineau. 2000. Hepatic Butyltin concentrations in beluga whales (*Delphinapterus leucas*) from the St Lawrence Estuary and Northern Quebec, Canada. *Applied Organometallic Chemistry.* **14** (4):218-226.

St.-Louis, R., C. Gobeil and E. Pelletier. 1997. Le tributyletain et ses produits de dégradation dans l'estuaire du Saint-Laurent (Canada). *Environmental Technology.* **18**:1209-1218.

Stewart, R. E. A., S. E. Campana, C. M. Jones and B. E. Stewart. 2006. Bomb radiocarbon dating calibrates beluga (*Delphinapterus leucas*) age estimates. *Canadian Journal of Zoology.* **84**:1840-1852.

Stone, C. J. 2003. *The effects of seismic activity on marine mammals in UK waters,1998-2002*. Joint Nature Conservation Committee. Peterborough, U.K. 78p.

Subramanian, A., S. Tanabe, R. Tatsukawa, S. Saito and N. Miyazaki. 1987. Reduction in the testosterone levels by PCBs and DDE in Dall's porpoises of Northwestern North Pacific. *Marine Pollution Bulletin.* **18** (12):643-646.

Tanabe, S. 1999. Butyltin contamination in marine mammals - A review. *Marine Pollution Bulletin.* **39** (1-12):62-72.

Tecsult Environnement. 2000. *Étude socio-économique d'un secteur retenu pour l'identification d'une zone de protection marine pilote: Estuaire du Saint-Laurent*. Pêches et Océans Canada. Québec.

Tester, M. and D. Ellis. 1995. TBT controls and the recovery of whelks from imposex. *Marine Pollution Bulletin.* **30** (1):90-91.

Thériault, G., G. Gibbs and C. Tremblay. 2002. Cancer in belugas from the St. Lawrence estuary. *Environmental Health Perspectives.* **110** (A562)

Tomy, G. T., D. C. G. Muir, G. A. Stern and J. B. Westmore. 2000. Levels of C10-C13 Polychloro-*n*-Alkanes in Marine Mammals from the Arctic and the St. Lawrence river Estuary. *Environmental Science and Technology*. **34**:1615-1619.

Tryland, M. 2000. Zoonoses of arctic marine mammals. *Infectious disease review*. **2**:55-64.

Tyack, P. L. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. *Journal of Mammalogy*. **89** (3):549-558.

Ulrich, M. M., S. R. Muller, H. P. Singer, D. M. Imboden and R. P. Schwarzenbach. 1994. Input and dynamic behavior of the organic pollutants tetrachloroethene, atrazine, and NTA in a lake: a study combining mathematical modelling and field measurements. *Environmental Science and Technology*. **28**:1674-1685.

Upham, B. L., N. D. Deocampo, B. Wurl and J. E. Trosko. 1998. Inhibition of gap junctional intercellular communication by perfluorinated fatty acids is dependent on the chain length of the fluorinated tail. *International Journal of Cancer*. **78** (4):491-495.

USEPA. 2002. Perfluoroalkyl Sulfonates; Significant New Use Rule; Final Rule and Supplemental Proposed Rule. *Federal register*. **67**:11008-11013.

Van Dolah, F. M. 2000. Marine algal toxins: Origins, health effects, and their increased occurrence. *Environmental Health Perspectives*. **108** (SUPPL. 1):133-141.

Viglino, L., E. Pelletier and R. St.-Louis. 2004. Highly persistent butyltins in Northern marine sediments: a long-term threat for the Saguenay Fjord (Canada). *Environmental Toxicology and Chemistry*. **23** (11):2673-2681.

Villeneuve, S. and L. Quilliam. 1999. *Les risques et les conséquences environnementales de la navigation sur le Saint-Laurent*. Centre Saint-Laurent. Montréal. Rapport scientifique et technique ST-188. 160p.

Vladykov, V. D. 1944. *Études sur les mammifères aquatiques. III. Chasse, biologie et valeur économique du marsouin blanc ou béluga (Delphinapterus leucas) du fleuve et du golfe du Saint-Laurent*. Département des pêcheries. Province de Québec. 194p.

Vladykov, V. D. 1946. *Études sur les mammifères aquatiques. IV. Nourriture du marsouin blanc (Delphinapterus leucas) du fleuve Saint-Laurent*. Département des Pêcheries, Province de Québec. Numéro 17. 119p.

Ward, J., S. P. Mohapatra and A. Mitchell. 2008. An overview of policies for managing polybrominated diphenyl ethers (PBDEs) in the Great Lakes basin. *Environment International*. **34** (8):1148-1156.

Watanabe, M., S. Tanabe, N. Miyazaki, E. A. Petrov and W. M. Jarman. 1999. Contamination of Tris(4-chlorophenyl) methane and tris(4-chlorophenyl) methanol in marine mammals from Russia and Japan: Body distribution, bioaccumulation and contamination status. *Marine Pollution Bulletin.* **39** (1-12):393-398.

Weilgart, L. S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Canadian Journal of Zoology*. **85** (11):1091-1116.

White, L. and F. Johns. 1997. *Évaluation du milieu marin de l'estuaire et du golfe du Saint-Laurent*. Pêches et Océans Canada. Dartmouth, Mont-Joli. 128.

Williams, R., D. Lusseau and P. S. Hammond. 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation.* **133** (3):301-311.

Wong, S., M. Fournier, D. Coderre, W. Banska and K. Krzystyniak. 1992. Environmental toxicology. In: *Animal biomarkers as pollution indicators*. D. Peakall (Ed.). Chapman & Hall. New York. p.167-281.

Yagouti, A., G. Boulet and L. Vescovi. 2006. *Homogénéisation des séries de température et analyse de la variabilité spatio-temporelle de ces séries au Québec méridional*. Ouranos. Rapport No 4. 154p.

Yang, F., Y. K. Chau and R. J. Maguire. 1998. Occurrence of butyltin compounds in beluga whales (*Delphinapterus leucas*). *Applied Organometallic Chemistry.* **12** (8-9):651-656.