Monitoring the State of the
ST. LAWRENCE RIVER

WATER | SEDIMENTS | SHORELINES | BIOLOGICAL RESOURCES | USES

3rd edition

St. Lawrence Estuary Beluga Whale

Issue

The beluga whale is an Arctic species, and the St. Lawrence Estuary (SLE) population is at the southernmost limit of the species distribution. It occurs primarily in the SLE and seasonally in the Gulf of St. Lawrence (Figure 1). A major commercial whale hunt from the end of the 19th century to the mid-20th century, as well as population reduction programs designed to protect commercial fish stocks in the 1920s and 1930s greatly reduced this population, which was estimated at a few hundred individuals in 1979.

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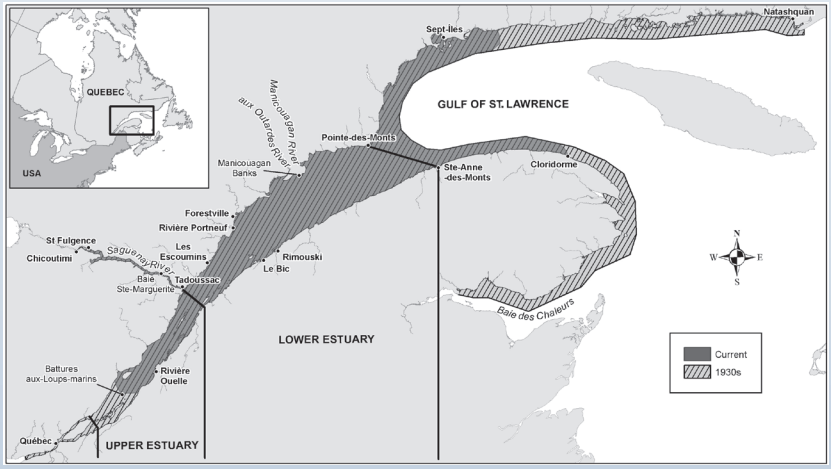

Figure 1 **Current and historical (1930s) distribution of St. Lawrence Estuary beluga whale.**

The significant reduction in abundance in the 20th century was also accompanied by an approximate 65% contraction in the summer range from the 1930s to today. The Manicouagan banks, used in summer in the 1930s, have been abandoned since at least the 1970s. This is a well-documented example of the reduction in the population's geographic range.

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In 2014, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reassessed the population's status, which was changed to "endangered" because of troubling signs of recent declines and cases of unexplained mortality in young belugas. It is now believed that this small population faces a considerably higher risk of extinction than a decade ago when it was designated as "threatened."

Various measures have been introduced since 1986 to preserve and protect the ecosystem and acquire new knowledge to restore the St. Lawrence beluga population. However, despite these protection measures and conservation plans developed over the years, the St. Lawrence beluga population has shown no signs of recovery since the 1979 hunting ban. This lack of recovery may be attributed to changes in several non-exclusive and potentially cumulative factors which increase mortality, decrease fertility, decrease survival of young beluga, or encourage emigration. However, based on current knowledge, the impact of the various potentially harmful factors on the health of the St. Lawrence beluga population cannot be quantified.

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Biologists examining a beach-cast beluga carcass.

Since the 1980s, two long-term monitoring programs have been introduced. The first program, implemented in 1983, involves monitoring beluga carcasses to quantify mortality and identify causes of death. The program involves the St. Lawrence National Institute of Ecotoxicology (SLNIE), the *Université de Montréal* Faculty of Veterinary Medicine in Saint-Hyacinthe, the Group for Research and Education on Marine Mammals (GREMM), Fisheries and Oceans Canada (DFO), Parks Canada and numerous volunteers. The number of carcasses found is recorded and the carcasses are sampled on site or transported to Saint-Hyacinthe for complete necropsy. Samples collected under this program are used to address various issues regarding St. Lawrence beluga genetics, toxicology, pathology, parasitology, microbiology, physiology, ecology and population dynamics. As part of the second monitoring program, aerial photographic surveys were conducted at 2- to 6-year intervals from 1988 to 2009 to estimate beluga abundance and the percentage of newborns in the population. During this period, 8 photographic and 28 visual surveys were completed to estimate beluga abundance and range.

Overview of the situation

Carcass monitoring and causes of death

A total of 469 beluga carcasses were found from 1983 to 2012 as part of the carcass monitoring program. On average, 15 carcasses were found annually (Figure 2). The age of dead animals, estimated by counting growth rings in cross-sections of teeth, provides a more complex and deeper understanding of mortality. Despite annual variations, the number of carcasses of juveniles 1 to 7 years of age, and adults 8 years and older has not followed any identifiable trend during this 30-year period, with respective annual averages of 1 and 10.5 carcasses for these age groups. However, a particularly high number of newborns were found dead in 2008, 2010 and 2012 (8, 8 and 16 individuals respectively) whereas the annual average for the previous 25 years was only about 1 individual, with yearly variations ranging from 0 to 3 individuals (Figure 2).

In general, similar numbers of male and female carcasses are found (a 1.09 female to male ratio). However, since 2006, the proportion of females seems to be increasing in reported adult deaths. Also, a comparison of mortality figures from 1983 to 1999 with those from 2000 to 2012 seems to indicate that females have been dying at a younger age in recent years. This recent tendency to die younger is not apparent in adult males if the same periods are compared.

Necropsies were performed on 222 carcasses from 1983 to 2012 and the main causes of death were infectious diseases (32%) and cancer (14%). Infectious diseases are particularly prevalent (72%) in juveniles under eight years of age, half (52%) of which are related to lungworm (nematode) infection. Cancer was the cause of death in 20% of adult individuals.

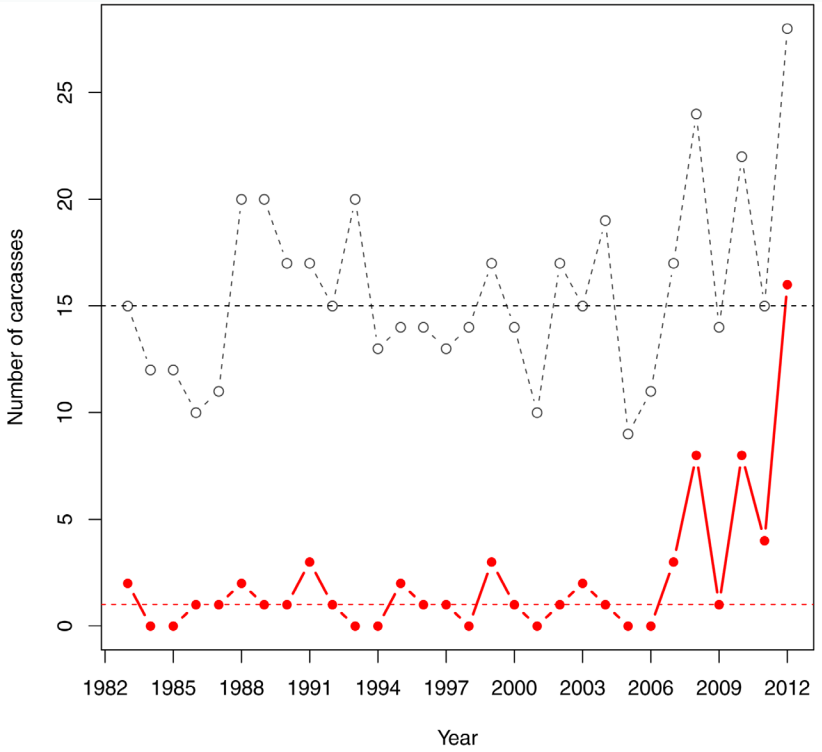

Figure 2 **Total (open circle) annual reports of dead beluga in the Estuary and Gulf of St. Lawrence, 1983-2012, including number of newborn calves (closed circle). The dashed horizontal lines represent the median for each time series.**

However, none of the belugas born after 1971 had cancer, the year regulations were enacted to control many chemicals (e.g., polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)). The cause of death was identified only for one calf accidentally caught in a net. No calves examined during this program showed signs of pathology that could explain death, which suggests separation from the mother (e.g., when the mother becomes ill or dies or as a result of disturbance) may be the leading cause of death in beluga calves. Calving problems were responsible for 19% of adult female mortality, and these problems have become more common in the past 10 years, particularly since 2010. The recent increase in calving problems occurred when especially high numbers of calves were found dead in 2008, 2010 and 2012.

Comparisons with other marine mammal populations and deductions based on findings of other studies suggest that chronic exposure to contaminants in the St. Lawrence could play a role in the development of certain pathological conditions observed in beluga whales.

Population trends and dynamics

Based only on estimates of eight photographic aerial surveys from 1988 to 2009 or 28 visual aerial surveys from 2001 to 2009, no significant abundance trends were identified. In both types of surveys, estimated maximum abundance occurred in 2003, and estimated minimum abundance occurred in 2009. It is difficult to detect variations in abundance with surveys only, because each survey contains considerable uncertainty resulting from the very gregarious nature of beluga whales, i.e., the animals are not evenly distributed in their summer range: they form large groups that may or may not be detected during surveys. Repeated visual surveys which are less costly than photographic surveys help minimize this problem.

Photographic surveys also provide an estimate of the percentage of calves in the population aged 0 to 1 year. This percentage decreased from 15% to 18% in the 1990s to 3% to 8% in the 2000s.

This information was included in a model developed to describe potential changes in abundance, reproduction and mortality in the St. Lawrence beluga whale population from 1983 to 2012. This population dynamics model was needed to simultaneously consider current knowledge of the species' biology and integrate estimates and uncertainty associated with aerial survey data (population size and percentage of calves aged between 0 and 1 year) and carcass monitoring program data (number of newborns and other age groups). This model estimates that the St. Lawrence Estuary beluga whale population was stable or grew slightly from 1979 when the hunting ban was introduced, to the early 2000s, with a peak abundance of 1,000 individuals in 2002 (Figure 3). Subsequently, the population declined to 889 individuals in 2012, which represents the most recent estimated population. According to this model, pregnancy and newborn mortality rates and the age structure of the population were stable from 1984 to 1998. The model also indicated that demographic parameters and age structure were unstable from 1999 to 2012. The calf mortality rate appeared to be particularly high in 1999, 2002, 2003, 2008, 2010 and 2012.

The model also estimated a change in the female reproductive cycle from 2006 to 2012. Before this, a third of mature females were pregnant each year, with a three-year reproductive cycle (14-month pregnancy and 12 to 18 months of nursing). During the last six years modelled, about half the females were pregnant each year, indicating a two-year reproductive cycle. This phenomenon is due to an increase in newborn mortality. Females who lose their calves during the first year can reproduce again the following year. Newborns accounted for 6% to 8% of the population in 1999, which decreased to 4% to 6% after 2007. The results of the model are supported by completely independent data from a 1989 to 2012 photo-identification monitoring program of live individuals in the population. The data show age structure and calf production trends similar to those of the model. This similarity with independent data increases our confidence in predictions of the population dynamics model.

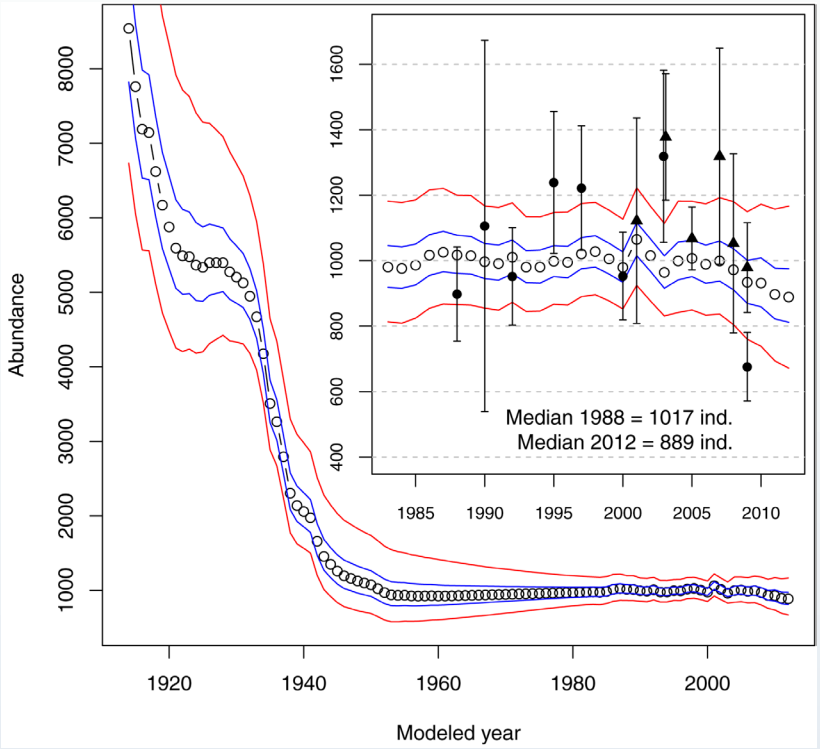

Figure 3 **Evolution of the St. Lawrence Estuary beluga population size estimated by the population dynamics model for the period 1913-2012. Median values (black curve with open circles) along with 50 and 95% confidence intervals (blue and red curves, respectively) are presented. An inset shows the period 1983-2012 trajectory including estimated mean population size (+/- SE) obtained from the photographic (●) and visual (▲) aerial surveys.**

Factors correlated to high calf mortality rates

The number of carcasses of newborns found every year is the product of the number of calves born and a variable mortality rate. A combination of factors is likely responsible for the unusually high number of carcasses of newborns reported in 2008, 2010 and 2012. One of the hypotheses under consideration is poisoning by saxitoxin produced by the dinoflagellate *Alexandrium tamarense*, which causes recurring blooms in the St. Lawrence Estuary. This extremely toxic substance can be transferred throughtout the food web and was found in high concentrations in beluga carcasses and other marine organisms collected during a persistent proliferation of *A. tamarense* in the summer of 2008. The beluga population model did not predict high numbers of newborns that year, and the unusually high number of carcasses found could be chiefly due to an especially high mortality rate. Unfortunately, no data are available on the abundance of *A. tamarense* for 2010 and 2012.

The large number of newborn deaths in 2010 and 2012 also coincided with an abnormal reduction in ice coverage and duration, particularly warm surface waters, as well as an increased number of interactions between vessels and belugas. Mechanisms through which environmental conditions may have affected the beluga are not clearly identified. Interactions with vessels and other anthropogenic disturbances in summer could harm the calving process as well as the establishment and maintenance of contact between mothers and their calves during nursing. Since no signs of disease were identified as the cause of death for any of the newborns examined, factors that can contribute to separation from the mother may be a major cause of calf mortality.

Potential stressors

The St. Lawrence Estuary is downstream from heavily industrialized and urbanized areas, which exposes the estuary to various chemical flows, including persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and polybrominated diphenyl ethers (PBDEs). PCB and DDT

concentrations have decreased or remained stable in belugas since at least 1987. PBDEs have been regulated since the late 1990s. However, PBDE concentrations grew exponentially in belugas in the 1990s and these concentrations remained high until 2012 (Figure 4). A connection cannot be established between concentrations of PBDEs or other POPs in belugas and increased calving problems and high calf mortality in recent years. However, some toxicological studies have shown that several POPs, including PBDEs, can have a disruptive effect on the endocrine system of several species, including humans and marine mammals, as well as potential effects on reproduction, the immune system, behaviour and the development of juveniles.

St. Lawrence Estuary belugas also suffer from chronic exposure to noise and disturbance from commercial shipping, pleasure boating and the marine mammal observation industry, especially in the north channel of the estuary and the lower Saguenay. The marine mammal observation industry focuses primarily on whales in the lower estuary, but belugas are targeted in the upper estuary, which includes most of the population's critical habitat. Vessel traffic related to tourism and recreational activities peak in July and August when belugas are calving in the estuary. Tourism activities in critical habitat have increased since 2004 off the coast of Kamouraska, Rivière-du-Loup and Saint-Siméon. Commercial shipping was stable from 2003 to 2012. Each vessel transiting the St. Lawrence Estuary exposes up to 53% of the beluga population to noise levels likely to modify the behaviour of most individuals and each beluga is exposed to noise levels up to 18 times a day. While it is difficult to estimate how this exposure affects beluga health, reproduction and survival, studies indicate that the beluga could be disturbed or forced to relocate, and suffer from exposure to noise and marine traffic.

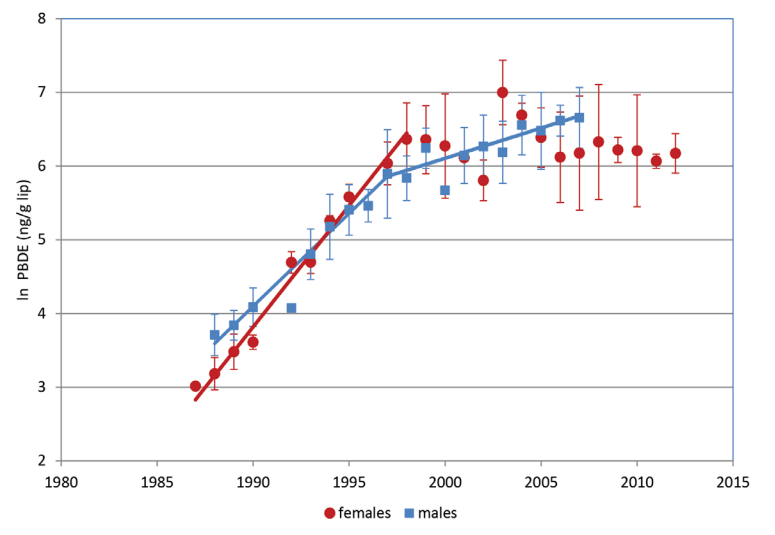

Figure 4 **Temporal trend in PBDE contamination among male beluga whales (blue) and female beluga whales (red). The vertical lines represent standard deviations.**

Diet and Ecosystem Perspective

It is difficult to use traditional methods such as stomach content analysis to study the diet of species at risk like the beluga whale. A study based on chemical analyses of beluga blubber sampled from 1988 to 2012 identified a change in diet from 2003 to 2012 almost equivalent to a drop of one trophic level (i.e. a 1‰ decrease in the carbon isotope ratio $\delta^{13}C$). This could mean a change in the composition of the beluga diet or changes in the prey's carbon isotope ratio signature caused by habitat change, but these results show there was a change in the 2000s. Modelling of the isotope signatures of beluga and 11 potential prey suggests that sand lance, squid, capelin, herring and tomcod are important prey for adult beluga who also consume demersal fish such as cod, hake and redfish.

To better understand the relationship between the St. Lawrence Estuary beluga whale and its habitat, existing relationships were estimated between time series of various environmental factors and those of indices describing beluga population dynamics, including abundance indices, estimated percentage of juveniles from 0 to 1 year in the population, number of carcasses found and changes in trophic level (carbon isotope ratio signatures, $\delta^{13}C$). Changes in certain environmental factors coincide with changes in beluga population parameters. Although this does not demonstrate a causal relationship, it identifies factors that could be indicators of beluga habitat quality. This analysis suggests that surface water temperature, the volume and extent of winter ice cover, and the biomass of large demersal fish and spring herring in the Southern Gulf of St. Lawrence would be good indicators of beluga habitat quality. Changes in these indicators since 1971 show that since the late 1990s, warmer surface water, reduced ice coverage and duration, and low availability of small groundfish and spring herring characterize the St. Lawrence Estuary beluga whale habitat (Figure 5). These changes appear to coincide with a

destabilization of the population's age structure, a decrease in the percentage of juveniles from 0 to 1 year and an increase in the number of calf carcasses reported. Negative anomalies such as those observed since 1999 for all these potential habitat quality indicators did not occur between 1971 and 1998.

Outlook

The St. Lawrence beluga population was significantly reduced in the 20th century, mainly due to hunting which was banned in 1979. In the 1990s, the St. Lawrence Estuary beluga population grew more slowly than expected compared to actual or estimated maximum potential growth rates for other populations of odontoceti (i.e., toothed whales, belugas, dolphins, porpoises). At the beginning of this decade, several species of large groundfish stocks collapsed because of overfishing, including cod, a known beluga prey. Aside from a decrease in food resources, environmental changes, pollution and disturbances by marine traffic could have limited population growth. The relative importance of these factors is unknown. The decline of the beluga population in the early 2000s could be due to an increase in the calf mortality rate, which may, among other things, have been caused by toxic algal blooms, climate disruption and changes in prey availability. However, the mechanisms linking these factors to the increase in newborn mortality are not well understood.

In order to improve St. Lawrence Estuary beluga recovery planning, ongoing monitoring of beluga population dynamics and habitat is paramount (i.e., environmental conditions, prey abundance, contaminant loads, anthropogenic stress level, etc.). It is also necessary

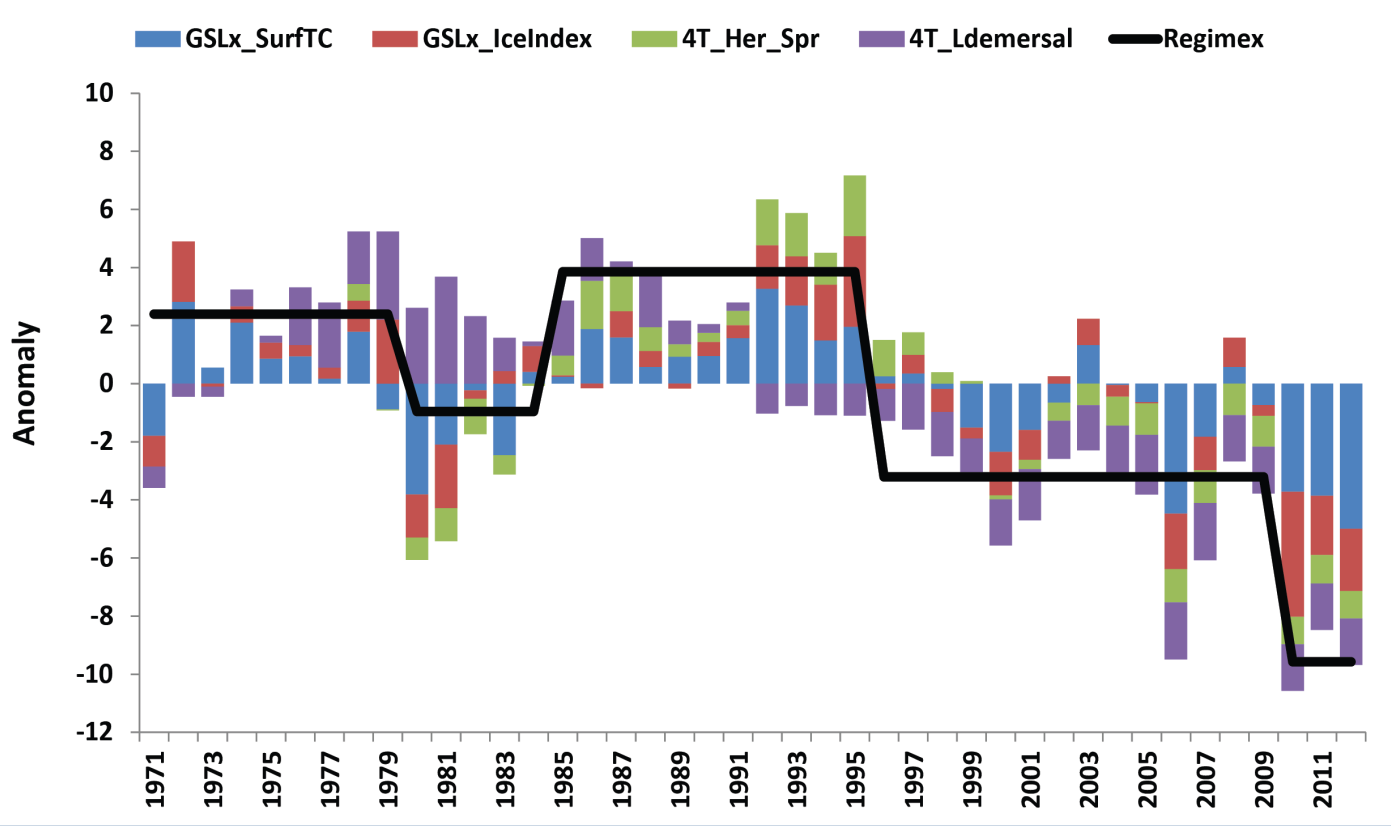

Figure 5 **Changes in physical and biological conditions potentially important to St. Lawrence Estuary beluga habitat from 1971 to 2012. Stacked bar: annual anomalies in terms of physical conditions (surface temperature, ice index) and potential food sources (Southern Gulf of St. Lawrence spring herring and large demersal fish). Black line: Different periods separated by shifts derived from a STARS analysis performed on the sum of all environmental anomalies. Note that the time series of Southern Gulf of St. Lawrence herring begins in 1978.**

to improve the level of knowledge on the ecology of the species and the relative importance and mechanisms of action of environmental and anthropogenic factors likely to affect the St. Lawrence Estuary beluga whale.

It is therefore essential that aerial surveys and carcass monitoring programs be maintained to continue monitoring changes in the population. Also, efforts must be made to estimate changes in beluga habitat quality (i.e., physical factors, abundance of prey, contaminant loads, toxic algal blooms and coastal navigation and development activities in the St. Lawrence Estuary). It is important to extend and develop this work in areas identified as critical habitat for this population, used in summer by females with calves and juveniles. Currently, little is being done in this part of the estuary and especially in the upper estuary to assess physical and biological conditions and pressures from the anthropogenic factors described above due to the absence of major commercial fisheries. The majority of knowledge of the St. Lawrence Estuary beluga whale population has been gathered in summer. It is therefore important that research continue from fall to spring, seasons during which we have limited information on the beluga's range. This should help to better assess the habitat needs and quality of the St. Lawrence Estuary beluga whale and, therefore, identify appropriate management measures for conservation of the beluga population.

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Key measures

Aerial photographic surveys, conducted by Fisheries and Oceans Canada, provide abundance indices for assessing the status of the St. Lawrence Estuary beluga population. Correction factors are used in order to consider the area not covered by the survey and the animals diving.

The carcass monitoring program, in place since 1983, provides mortality indices according to age structure. Since 2003, stranded carcasses are reported to Fisheries and Oceans Canada by the Quebec Marine Mammal Emergency Response Network, managed by the Group for Research and Education on Marine Mammal. Scientits from the St. Lawrence National Institute of Ecotoxicology takes samples from beach strandings, or transport the carcasses to the *Université de Montréal* Faculty of Veterinary Medicine where pathologists may determine the cause of death (e.g., infectious disease, cancer, trauma).

The carcass samples are analysed in order to establish the temporal trend of the beluga whale population's contamination by persistent and toxic anthropogenic organic compounds (PCBs, DDT, Mirex, PBDEs). Targeted studies aim to provide information on the species' biology and behaviour, and the impact of human activities on the St. Lawrence Estuary beluga whale population.

The abundance of the St. Lawrence beluga population is estimated using a population dynamics model, which is used to integrate knowledge of the species' biology with information specific to this population (i.e., abundance indices and percentage of juveniles estimated by aerial surveys, as well as mortality indices estimated by the carcass monitoring program).

State of the St. Lawrence Monitoring Program

Five government partners—Environment Canada, Fisheries and Oceans Canada, Parks Canada, Quebec's *Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques* and the *Ministère des Forêts, de la Faune et des Parcs*—in collaboration with *Stratégies Saint-Laurent*, a non-governmental organization that works actively with riverside communities, are pooling their expertise and efforts to provide Canadians with information on the state of the St. Lawrence and its long-term changes.

To this end, environmental indicators have been developed on the basis of data collected as part of each organization's ongoing environmental monitoring activities over the years. These activities cover the main components of the environment, namely water, sediments, biological resources, uses and shorelines.

For more information on the State of the St. Lawrence Monitoring Program, please visit our website at www.planstlaurent.qc.ca/en/home.html.

For more information

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