# STATUS OF BELUGA (*DELPHINAPTERUS LEUCAS*) IN THE ST. LAWRENCE RIVER ESTUARY

*Photo: Véronique Lesage*


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

## Context:

*The St. Lawrence Estuary (SLE) beluga are listed as threatened under the Species at Risk Act; a Recovery Strategy is defined, and their summer Critical Habitat has been identified. A review of the SLE beluga status (2007) concluded that the population was stable over the period 1988-2006. However, in recent years there has been an increase in reports of death of young-of-the-year, and an apparent increase in adult female perinatal mortalities, suggesting that the status of SLE beluga may have changed.*

*Fisheries management requests an update of the status of the SLE beluga population, in particular information on current population size and trends, an analysis of factors that are affecting the population trend, including recruitment levels, sources of mortality, environmental conditions, contaminant loads, and their potential impact on mortality and fecundity.*

## SUMMARY

- The beluga 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. Its current range is about 65% of the extent used historically, whereas the size of its annual core distribution is at the lower limit of areas of occupancy described for any population of this species.
- The SLE population of beluga is listed as *threatened* under the Canadian Species at Risk Act (SARA); Critical Habitat has been identified, and corresponds to the summer area occupied by females accompanied by calves and juveniles (FCJ).
- Data from a carcass monitoring program indicate year-to-year variation, but no trend, in the number of adult beluga carcasses (male and female) reported over the period 1983-2012, with a median of 10.5 whales annually. The number of newborn death reports varied annually from 0 to 3 until 2007, but was unusually high in 2008, 2010, and 2012, with 8, 8 and 16 carcasses, respectively, and close to or within the previous range in 2009

(n=1) and 2011 (n=4). The age composition of the carcasses indicates an increase in the mortality of young adult females during the 2000's compared to the 1990's.

- Necropsies conducted on 222 carcasses indicate that the primary cause of death for juvenile beluga was parasitic pneumonia (52%). Cancer (17%) and bacterial diseases (13%) were the most common causes of death in adult beluga. Cancer was not observed in beluga estimated to be born after 1971, which coincides with the regulation of several chemical substances, including polycyclic aromatic hydrocarbons (PAHs) and polychlorinated byphenyls (PCBs).
- Necropsies also show the occurrence of problematic births (dystocias) and post-partum complications. These reproductive issues were associated with the death of 19% of adult females, and increased in frequency over the past decade, with several cases observed since 2010 when numbers of dead calf reports were also high in some years.
- With the exception of one calf caught accidently in a net, none of the calves examined over the years presented any pathologic changes that could have accounted for their death.
- The abundance of the SLE beluga population has been estimated from 8 aerial photographic strip surveys and 28 aerial visual line-transect surveys flown between 1988 and 2009. The 2009 estimates are the lowest in the two times series. However, there was no significant long-term trend in abundance in the visual or photographic time series.
- The proportion of 0-1 year-old calves counted during photographic surveys has declined at the end of the 1990s, from 15.1-17.8% in the 1990s to 3.2-8.4% in the 2000s.
- Abundance estimates and percentage of 0-1 year-old calves, as well as the number of beluga carcasses reported annually during 1983-2012, were incorporated into an age-structured population model. The model estimates that the population was stable or increasing at a slow rate until the early 2000s (reaching approximately 1000 individuals in 2002), and has declined since then to a total population of 889 individuals (95%CI 672-1167) in 2012;
- The model also suggests that the SLE beluga population has experienced changes in vital rates and age-structure, moving from a relatively stable to an unstable period characterized by an apparent shift from a 3-year calving cycle to a 2-year cycle, increasing variability in newborn mortality and pregnancy rates, and a decline in the proportion of immature individuals and newborns in the population;
- A long-term photo-identification program of live SLE beluga (1989-2012) indicated changes in age structure and calf production similar to those suggested by the model. In particular, years of high pregnancy rates predicted by the model for the period 2004-2012 were corroborated by observations of high calf production in the field the following year. The photo-identification program also suggests a slight increase in the proportion of grey individuals (juveniles and young adults) from 1989 to the mid-2000s, with a recent transition to a negative trend echoed in the model as a reduction in the proportion of immature individuals.
- SLE beluga are one of the world's most contaminated marine mammals. While some chemical substances (e.g., PCBs, DDTs) have decreased in beluga over the past decade, others such as the polybrominated diethyl ethers (PBDEs) compounds, increased exponentially during the 1990s, and are at their maxima since then. Their role in the recent elevated frequency of complications at parturition and mortalities of newborns in SLE beluga could not be determined. However, these different classes of chemical substances are known to have various endocrine disrupting effects in mammals, with

possible impacts on reproduction, immune system and behaviour, and on offspring development.

- SLE beluga are chronically exposed to noise and disturbance due to commercial shipping, recreational activities, and an extensive marine mammal observation industry, especially in the North Channel of the SLE and the lower Saguenay Fjord where most of this activity is taking place. Vessel traffic related to tourism and recreational activities peak in July-August when SLE beluga give birth, and has increased between 2003 and 2012 in some sectors of their Critical Habitat as a result of newly established whale-watching companies operating in the Upper SLE and targeting beluga.
- Currently, there are proposals to reroute some of the shipping traffic from the North to the South Channel in the SLE. While the North Channel is highly ensonified by current marine traffic, islands in the middle of the SLE create a sound shadow for FJC habitat located along the south shore. Increased shipping in the South Channel would considerably reduce the amount of noise-shelter areas available to FCJ beluga.
- Chemical tracers (stable isotope ratios) in beluga carcasses collected over the period 1988 to 2012 indicate a steady change in sources of carbon (and presumably diet) exploited by adult males and females since 2003. Prey species and/or ecosystem factors responsible for this change are unknown;
- The analysis of 28 ecosystem indices describing ecosystem variability of the Gulf of St. Lawrence from 1990 to 2012 indicates that environmental conditions shifted from periods of above, to below long-term averages in the late 1990s, i.e., approximately at the same period as when SLE beluga population shifted from a stable to an unstable age structure, to lower proportion of calves in the population, and increased number of dead calf reports. The period of below long-term average environmental conditions was when large demersal fish and 4T spring herring were at their lowest biomass, ice conditions were below-average, and water temperature above-average. The evolution of these variables since 1971 also identified the period starting in the late 1990s as a sustained 14-y long period when conditions were below long-term average, with unprecedented extreme conditions in 2010 to 2012.
- Many dead marine organisms, including an unusually high number of beluga and their prey, tested positive for saxitoxins during a period coincident with a bloom of the dinoflagellate *Alexandrium tamarense*, indicating the toxic algal bloom was responsible for these deaths, on its own or in conjunction with other unfavourable environmental conditions.
- The 8 and 16 times above-median number of carcasses of newborn calves documented in 2010 and 2012 cannot be explained by high calf production alone, suggesting that the observed mortalities resulted from a combination of increased calf production, and reduced calf survival. This is supported by the high pregnancy rates predicted in 2009 and 2011 by the model, and the high index of calf production observed in the field the following year (2010 and 2012). The above-median numbers of dead calves in the SLE in 2010 and 2012 occurred during an unprecedented period of well-below long-term average ice conditions in the Gulf of St. Lawrence and for 2012, high water temperatures, conditions which were also favourable to increased boating activities, which may have resulted in potentially higher disturbance of FCJ during a sensitive period.
- Sources of uncertainty include 1) the rate of decline of the population, which varies depending on the choice of input data to the model, 2) the summer distribution range which may extend further downstream than currently recognized, 3) biases from using data on beluga carcasses as a proxy for age- and sex-specific mortality rates, 4) mortality

rates outside of the summer period, 5) prey resources important seasonally for SLE beluga, and abundance and availability of these prey in the SLE, 6) importance of sea ice to beluga, 7) sources of anthropogenic disturbance in the Critical Habitat, for which the portrait is incomplete, 8) trends in emerging contaminants and new toxins in beluga and their prey, and effects on beluga.

- The decline of the SLE beluga population since the beginning of the 2000s suggested by the model, occurred during a period of changing environmental conditions in the Gulf of St. Lawrence, concomitant with high levels of some contaminants (PBDEs) in SLE beluga, chronic and increasing exposure to noise and marine traffic, and occasional toxic algal blooms in the SLE.
- Climate variability resulting, among other things, in increased water temperature and associated decline in ice-cover may further affect this beluga population through, for example, changes in food resources and increases in inter-specific competition as other species expand their ranges due to loss of ice cover. In the short term, efforts can be directed to reducing anthropogenic stressors such as disturbance in sensitive areas, chemical contamination, nutrient enrichment, habitat loss for beluga and their prey, and competition for food resources from fisheries.

## INTRODUCTION

The St. Lawrence Estuary (SLE) beluga, *Delphinapterus leucas*, is a relict Arctic population genetically distinct from all other Canadian beluga populations. Along with the Eastern Hudson Bay beluga, the SLE beluga show the lowest genetic diversity of mtDNA and microsatellite alleles within Canadian beluga populations.

SLE beluga is the most southerly of the beluga populations. Their current range is about 65% of that used historically (Figure 1), whereas their annual core distribution is at the lower limit of areas of occupancy described for any population of this species. Severely depleted by intensive hunting for commercial products, to protect fisheries, and for recreation, this beluga population was afforded protection from hunting in 1979. At that time, the population was estimated to number in the low hundreds. An apparent failure of the population to recover after hunting was prohibited was ascribed to the presence of high levels of various persistent contaminants in beluga and their environment. A carcass program investigating causes of mortality initiated in the 1980s, highlighted the plight of the SLE beluga. Concern over its future was a determining factor leading to various research efforts, contaminant reduction measures through the St. Lawrence Action Plan, and the establishment, in 1998, of the Saguenay-St. Lawrence Marine Mark, jointly managed by the federal and provincial governments.

The SLE population of beluga is listed as *threatened* under the *Canadian Species at Risk Act* (SARA); Critical Habitat has been identified, and corresponds to the summer area occupied by females accompanied by calves and juveniles (FCJ). The status of this population was previously examined in 2007. It was concluded that the population had been stable over the period 1988 to 2006. Since its inception, the beluga carcass program had documented an average of about 15 beluga per year (range: 9-20 individuals). When examined by age class, neonates comprised only a small proportion of the beach-cast animals, with 1 to 3 calves reported dead each year. In 2008, 2010 and 2012, reports of death calves were 8-16 times higher than previous median numbers. This change in number and age composition of dead beluga suggested that a new review of the SLE beluga status was warranted.

# ASSESSMENT

## Carcass Monitoring and Cause of Mortality

A carcass program has been collecting reports of dead marine mammal observations in the Quebec Region since 1983. Where possible, beluga carcasses are sampled onsite or collected and sent to the *Faculté de médecine vétérinaire, Université de Montréal* for necropsy.

A total of 469 beluga were found dead between 1983 and 2012, with a median of 15 beluga reported annually (Figure 2). Data indicate year-to-year variation, but no trend, in the number of adult beluga carcasses (male and female) reported over the 30-yr study period, with a median of 10.5 reports annually. Newborn death reports varied annually from 0 to 3 beluga during most of the study period, and followed a 3–4 year cycle. Particularly high newborn mortalities were reported in 2008, 2010, and 2012, resulting in annual reporting rates 8 to 16 times higher than the median number observed over the previous 24 years. The number of reports was close to, or within, the previous range in 2009 (n = 1) and 2011 (n = 4) (Figure 2). The sex ratio among adult beluga was unbiased (1.09 F:M), although adult females tended to be over-represented in the sample in recent years (2006–2012). A comparison of cumulative frequency distribution of age-at-death using carcasses sampled during the periods 1983–1999 and 2000–2012 suggests that adult female beluga died at a younger age in the latter period.

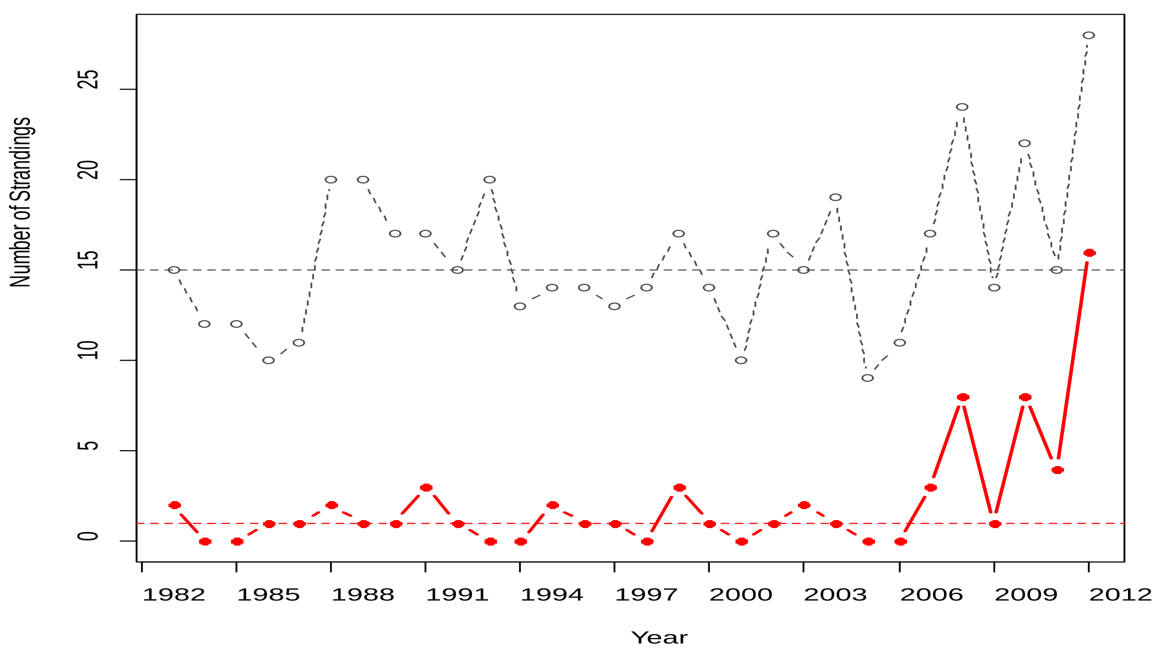


*Figure 2. Total (open circle) annual reports of dead beluga in the Estuary and Gulf of St. Lawrence, 1983-2012, including number of newborn calves (closed circle). The dashed horizontal lines represent the median for each time series.*

Standard necropsies were conducted on 222 carcasses. Primary causes of death were infectious diseases (32%), and cancer (14%). Verminous (nematode) pneumonia was the most common cause of mortality in juvenile beluga (52%), whereas bacterial diseases and other parasitic diseases were mainly seen in adults. With the exception of one calf caught accidently in a net, none of the calves examined over the years presented any pathologic changes that could have accounted for their death, suggesting that a break of the mother-calf bond as a result of the death of the dam, or illness of the dam, the calf or both was probably the main reason for calf death. Males appeared to have an overall increased susceptibility to infectious diseases compared to females. Cancer was the primary cause of death of 20% of the adult beluga, with adenocarcinomas of the gastro-intestinal mucosa being the most commonly observed cancer (7% of the mature adults) followed by mammary carcinomas (10% of the mature females). The occurrence of cancer increased with age, and decreased over the study period. Cancer was not observed in beluga with an estimated year of birth after 1971, which coincides with the regulation of several chemical substances, including polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Occurrences of fatal dystocias (problematic births) and post-partum complications accounted for 19% of the mortality of adult females. These reproductive problems have increased in frequency over the past decade, with several cases observed since 2010 when high numbers of dead calves were also reported in some years. Comparison with other populations of marine mammals, and inferences from other studies suggest that chronic exposure to industrial contaminants may play a role in the development of some of the pathological conditions observed in this population.

## Population Trends and Dynamics

Beluga abundance in the SLE has been estimated from photographic aerial surveys (n = 8) and multiple visual line transect surveys (n = 28) flown between 1988 and 2009 (Table 1). Both the visual and photographic indices are the highest in 2003, and the lowest in 2009. However, there is no significant long-term trend in abundance in the two time series; confidence intervals around survey estimates are wide due primarily to the highly clumped distribution of beluga.

*Table 1. Aerial survey estimates of SLE beluga abundance including both photographic and visual line transect surveys, and corrected estimates to account for beluga not at the surface when the plane flew over.*

| Year | Method | Number of surveys | Estuary estimate | Saguenay count | Corrected abundance index | 95% CI |
|---|---|---|---|---|---|---|
| 1988 | Photo | 1 | 417 | 22 | 893 | 751-1062 |
| 1990 | Photo | 1 | 527 | 28 | 1129 | 446-2860 |
| 1992 | Photo | 1 | 454 | 3 | 952 | 702-1291 |
| 1995 | Photo | 1 | 568 | 52 | 1239 | 881-1742 |
| 1997 | Photo | 1 | 575 | 20 | 1222 | 903-1654 |
| 2000 | Photo | 1 | 453 | 6 | 953 | 724-1254 |
| 2001 | Visual | 1 | 529 | 15 | 1122 | 555-1675 |
| 2003 | Photo | 1 | 630 | 2 | 1319 | 896-1942 |
| 2003 | Visual | 5 | 658 | 7 | 1378 | 1039-1828 |
| 2005 | Visual | 14 | 492 | 39 | 1068 | 891-1280 |
| 2007 | Visual | 1 | 822 | 29 | 1746 | 1047-2583 |
| 2008 | Visual | 1 | 502 | 11 | 1053 | 636-1744 |
| 2009 | Photo | 1 | 319 | 10 | 676 | 499-915 |
| 2009 | Visual | 6 | 460 | 17 | 979 | 750-1277 |

The photographic surveys also provide information on the proportion of 0-1 year-old calves in the population. This proportion has decreased in the 2000s compared to the 1990s, with calves accounting for 3.2 to 8.4% of the total population in the 2000s, compared to the 15.1 to 17.8% observed in the 1990s.

Previous work on population trends has focused on survey estimates. In this assessment, an age-structured Bayesian model was used to include more information to describe the dynamics of the population. The model was fitted to four datasets from two data sources: 1) population abundance and 2) proportion of 0-1 year-old calves estimated from 8 photographic surveys flown between 1988 and 2009 (Table 1, Figure 3), along with 3) the number of newborns and 4) individuals other than newborns documented by the carcass program over the period 1983-2012 (Figure 2). The dynamics of the population was modelled by considering 11 age classes grouped into 4 stages, each characterized by specific mortality and fecundity rates. The model assumed no density-dependence, and a 3-year reproduction cycle including gestation (~14 months) and lactation (12-18 months). If a female lost her calf during the first year, she was assumed to be available to mate the following year, i.e., one year earlier than if her calf had survived. Annual changes in mortality, pregnancy rates, and probability of detecting beluga carcasses were estimated by the model over the period 1983-2012.

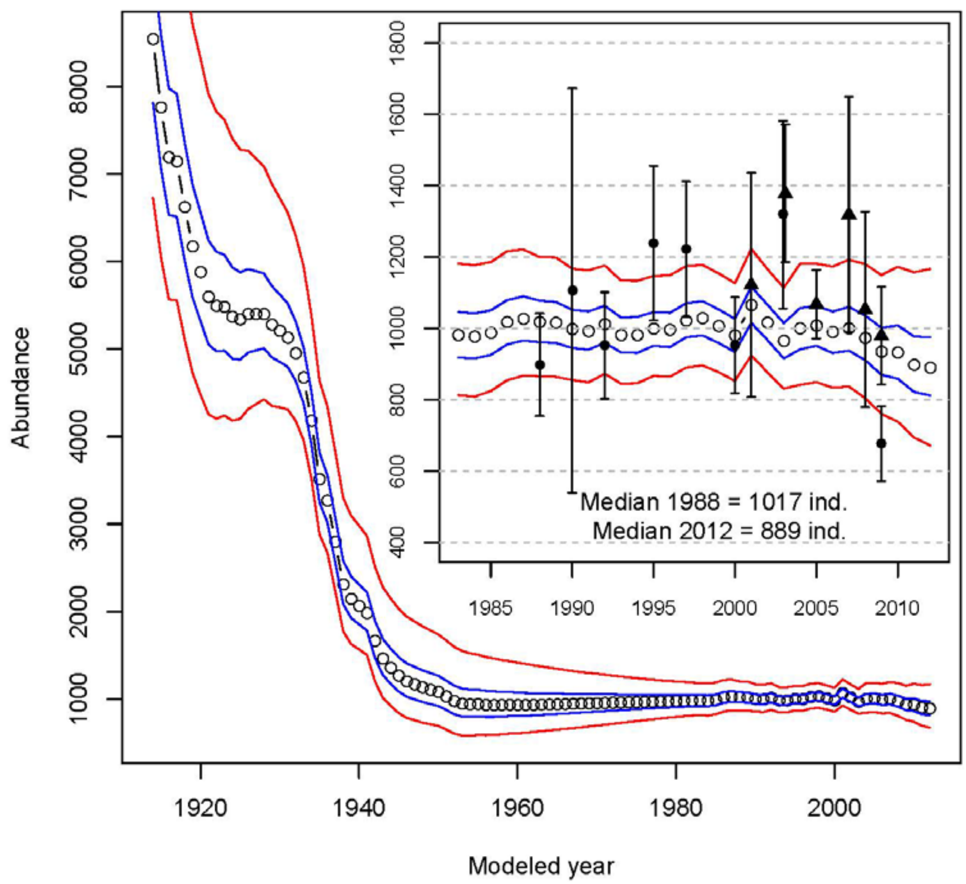


*Figure 3. Evolution of the SLE beluga population size estimated by the population dynamics model for the period 1913-2012. Median values (black curve with open circles) along with 50 and 95% confidence intervals (blue and red curves, respectively) are presented. An inset shows the period 1983-2012 trajectory including estimated mean population size (+/- SE) obtained from the photographic (●) and visual (▲) aerial surveys. The 2003 survey is offset slightly for illustration.*

The model estimates that the SLE beluga population was stable or increasing at a slow rate (~ 0.13% per year) since the end of the hunt in the 1960s up until the early 2000s, with around 1000 individuals in 2002 (Figure 3). This result is in agreement with previous trend analyses (Hammill et al. 2007). The model then suggests a decline (-1.13% per year) in abundance to an estimated 889 individuals (95%CI 672-1167) in 2012. The rate of decline depends on which dataset is fitted (the steepest decline is obtained when fitting only to aerial survey data), but all versions of the model agree that numbers have been decreasing since the early 2000s.

The model also suggests internal changes in vital rates and age-structure. Two periods stand out. The period 1984-1998 is characterized by relatively stable newborn mortality (median values from 14% to 27% with peaks every 3 to 4 years) and stable pregnancy rates (around 30%, with small peaks every 3 years). During this period, population age structure was stable with the ratio of mature : immature beluga close to 59 : 41, including 7.5% of newborns among the immature individuals. In contrast, the period 1999-2012 is characterized by demographic instability and major changes in population parameters and age structure. According to the model the year 1999 with unusually high newborn mortality (~40%) was followed by high pregnancy rates (>50%) in 2000, presumably because the 1999 calf mortalities led to more females being available for reproduction. From then on, the period was marked by peaks of high newborn mortality (2002-2003, 2008, 2010, 2012) interspersed by peaks of high pregnancy rates (2003, 2007, 2009, 2011), themselves separated by periods of lower-than-average fecundity (e.g., ~15% in 2001-2002).

A particularly striking pattern has emerged over the last 6 years of the model with female reproduction apparently changing from a 3-year cycle (with a third of mature females pregnant each year) to a 2-year cycle (with about half of the females pregnant). This phenomenon was associated with increased newborn mortality. These changes had strong effects on the population age structure. The estimated proportion of newborns in the population deviated from its 3-year cycle and started to oscillate strongly in the early 2000s, while showing a decreasing trend from 6-8% before 1999 to 4-6% after 2007. At the same time, the estimated proportion of immature individuals in the population declined, resulting in a concurrent increase in that of mature beluga even though their absolute numbers remained constant for a ratio of mature : immature of 66 : 34% by 2012. The median of the annual adult mortality was 6% but varied from 4% (1987, 2005) to 8% in 1989 and 1993 and 9% in 2004.

A long-term program using photo-identification of live SLE beluga conducted over the period 1989-2012 revealed patterns in age structure and calf production, particularly in the 2000s, similar to the model results. The proportion of grey individuals (juveniles and young adults) in the population estimated from the photo-identification program increased slightly during the 1990s and early 2000s, with a transition to a decreasing trend in the mid- to late-2000s, a result predicted by the population model. The photo-identification time series provided an index of year-to-year variation in calf production, and revealed lower-than-average calf production in 1999-2004, followed by high calf production in the mid and late 2000s in the years following those estimated by the model to be characterized by high pregnancy rates.

## Potential Stressors

The SLE is located downstream of heavily industrialized and urbanized regions, and is exposed to discharges of diverse chemical substance. The concentrations of legacy persistent organic pollutants (POPs), such as PCBs and DDTs, in beluga have decreased or remained constant since at least 1987. However, polybrominated diphenyl ethers (PBDEs), often used as flame retardants, have a different history as they were regulated in the early 2000s in Canada and the US. PBDE loads in 181 adult males, females and newborns found dead between 1987 and 2012 increased exponentially in the 1990’s, and have remained at maximum levels since then. Similar concentrations of PBDEs in adult females and newborns indicate that the transfer of PBDEs from mother to newborn is very efficient. The role of the PBDEs and other POPs in the recent elevated frequency of complications at parturition and mortalities of newborn SLE beluga could not be determined. However, a number of toxicological studies have demonstrated that several POPs, including PBDEs, can have endocrine disrupting effects in a variety of species including humans and other mammals with possible impacts on reproduction, immune system, behaviour, and offspring development.

Beluga in the SLE are also chronically exposed to noise and potential disturbance as a result of commercial shipping, recreational activities, and operations of an extensive marine mammal observation industry worth several million dollars to the local economy, especially in the North Channel and the lower Saguenay Fjord where most of this activity is taking place.

The mouth of the Saguenay River is considered to be the area with the most intensive marine traffic, and is a key transit area for beluga moving in and out of the Saguenay River. There are 11 marinas located in the immediate vicinity of what has been designated the SLE beluga Critical Habitat, as well as four ferry services, and the marine mammal observation industry operating within its boundary. While rorquals are the focus of the marine mammal observation industry in the Lower SLE, beluga are the main target of the industry in the Upper SLE, which constitutes most of the beluga Critical Habitat. Vessel traffic related to tourism and recreational activities peak in July-August when SLE beluga give birth, and has increased between 2004 and 2012 in some sectors of their Critical Habitat. Whale-watching has increased in the Upper SLE since 2004, with newly-established companies operating out of Kamouraska, Rivière-du-Loup and Saint-Siméon.

Commercial shipping has been relatively stable between 2003 and 2012. Each ship transiting through the SLE exposes up to 53% of the beluga population to noise levels likely to alter the behaviour of a majority of individuals. Based on daily traffic volume, each beluga can be exposed up to 18 times a day to these levels of noise. Of the exposed beluga, 72-81% are FCJ. While the proportion of exposed beluga that will suffer from negative effects on their health, reproduction or survival is difficult to assess, previous studies indicate that SLE beluga are not immune to disturbance or displacement, and can suffer from noise and traffic exposure.

## Diet and Ecosystem Perspective

Beluga diet and environmental conditions, including food resource quality and abundance, were examined to identify potential changes over the study period. A study examining the trophic ecology of SLE beluga over the period 1988-2012 identified a steady decline of approximately 1‰ in a tracer of carbon sources ($^{13}C/^{12}C$ ratio) over the period 2003-2012, which is equivalent to nearly one trophic level. The prey items and/or ecosystem factors responsible for this decline are unknown. Isotopic mixing models using 11 potential prey of SLE beluga suggested sandlance, squid, capelin, herring and tomcod are important dietary sources for adult beluga during summer, with contributions of groundfish species such as Atlantic cod, hake and redfish.

A time series analysis over the period 1990-2012 that included variables related to broad scale climate (e.g., freshwater discharge indicative of continental precipitation), bio-physical indices (e.g., water temperature, salinity, ice cover, zooplankton) and abundance indices for beluga potential fish prey in the northern Gulf of St. Lawrence, identified four periods of significant environmental changes (regime shift) in the ecosystem. An analysis of the available time series for environmental parameters in the Gulf of St. Lawrence most likely to be pertinent for SLE beluga revealed a similar pattern (Figure 4), with significant changes in physical environmental conditions during 1996-1998 and 2010-2012, and in pelagic fish biomass indices in 1995, 1998-1999, 2003 and again in 2011. After the major collapse of large demersal fish biomass in 1993, significant changes in demersal fish indices driven by increases in biomass of small demersal species were mainly observed in 2004-2006 and again in 2009-2012 (Figure 4).

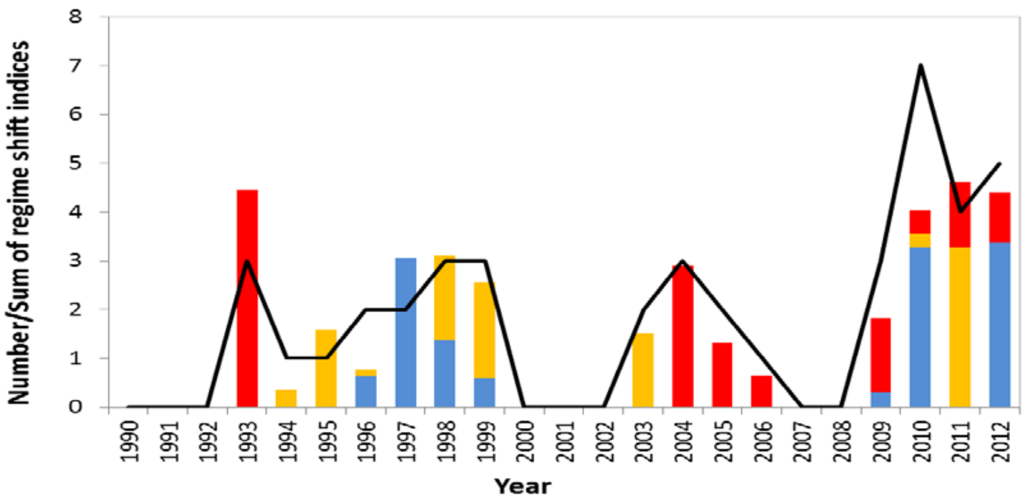


*Figure 4: Results of the major environmental change detection method (called STARS): It examines 28 environmental indices from the Estuary and Gulf of St. Lawrence thought to be most relevant to SLE beluga. Shown is evidence for major environmental changes (black line), and sum of the changes (stacked bars) documented for the variables related to the physical environment (blue), and selected potential pelagic (orange) and demersal (red) fish prey of SLE beluga.*

Environmental parameters most likely to affect beluga were then related to the time series of beluga population indices, including the number of beluga and newborns found dead each year, proportion of 0-1 year-old calves from photographic aerial surveys, and temporal changes in $^{13}C/^{12}C$ isotope ratios). Changes in surface water temperature, ice index (duration, volume), and biomass of large demersal fish and of 4T spring herring in the Gulf of St. Lawrence were coincident with changes in indices for the SLE beluga population, suggesting that these environmental conditions may be good indicators of beluga habitat quality. The evolution of these variables since 1971 reveals that all four environmental indices displayed a sustained 14-yr long period of below long-term average conditions characterized by high temperature, short ice season with small coverage, low demersal fish prey and 4T spring herring biomass starting in the late 1990s, with even more extreme conditions in 2010 to 2012 (Figure 5).

The shift to negative anomalies in large scale habitat quality during the late 1990s corresponded approximately with the shift from a stable to an unstable age structure in SLE beluga, lower than average proportion of calves, and increased number of dead calf reports. High numbers of dead calves found in 2010 and 2012 occurred during a period of strong negative anomalies in ice condition (short duration, low volume/coverage), and for 2012, high water temperatures. The period of above-average number of dead calf reports from 2008 to 2012 also occurred during years (1999-2012) of reduced biomass of large demersal fish and 4T spring herring compared to the long-term average. Such negative anomalies in habitat quality were not observed from 1971 to 1998. High surface temperature, low ice index and lower-than-average spring 4T herring biomass were briefly observed from 1980 to 1984, but large demersal fish indices well above the long-term average resulted in a short environmental regime characterized by near-average overall habitat quality. This short period was preceded and followed by highly positive anomalies in 1971-1979 and 1985-1995 (Figure 5).

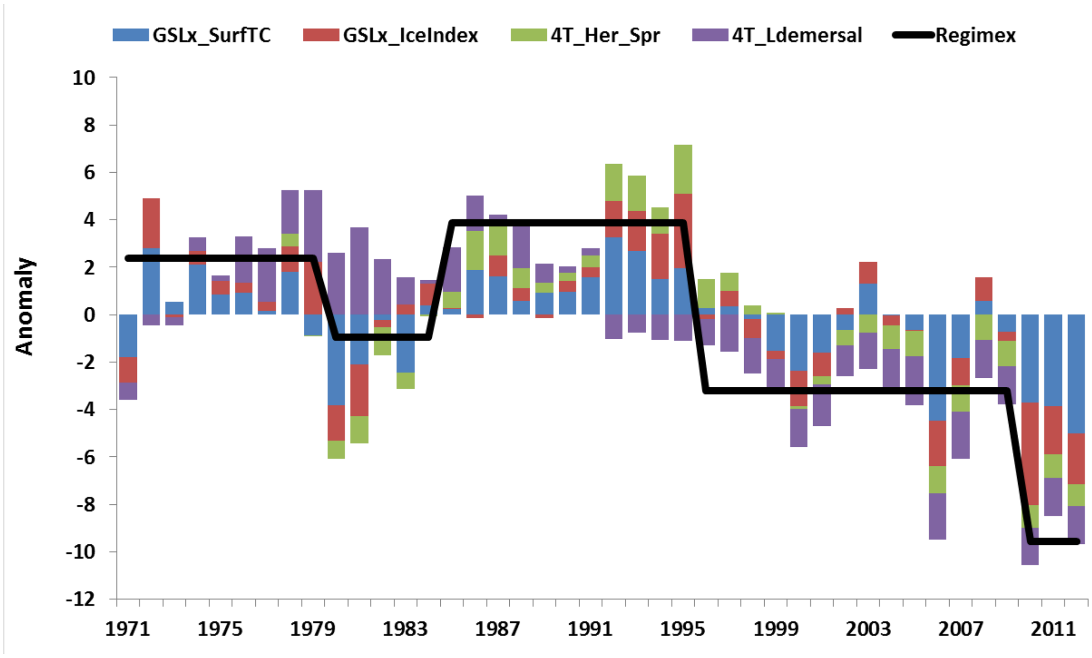


*Figure 5: Long-term changes in physical and biological conditions potentially important to SLE beluga habitat for the period 1971-2012. Stacked bars: annual anomaly of physical (surface temperature, ice index) and potential food sources (4T spring herring, large demersal fish). Black line: different periods separated by shifts determined by the STARS analysis performed on the sum of all environmental anomalies. The sign of the temperature anomaly was changed to reflect its potential negative effect on SLE beluga. Note that the time series of 4T herring begins in 1978.*

## Correlates of High Calf Mortality

These findings suggest that the 8 to 16 times above-median number of carcasses reported for newborn calves in 2008, 2010 and 2012 likely resulted from a combination of factors.

The SLE is subject to recurrent blooms of the harmful dinoflagellate *Alexandrium tamarense*, a producer of saxitoxins, the cause of paralytic shellfish toxins. The strain of *A. tamarense* native to the SLE is extremely toxic compared with those found in other regions. PSP toxins can be transferred throughout the food web, and have been observed in a wide variety of organisms other than shellfish, both in the SLE and elsewhere.

There was an apparent lack of correspondence between toxic algal bloom indicators (normalized average abundance) and death of SLE beluga (ex: 1990s, 2010). However the unusually high number of beluga carcasses found in 2008, including 8 newborn calves, was coincident with the persistent high abundance of *A. tamarense* and reports of carcasses of a wide variety of other organisms washing ashore over a short period, within the summer range of the beluga. Many dead marine organisms, including beluga, tested positive for high levels of saxitoxins. It is unknown if saxitoxins can be transferred through the placenta or milk in beluga, and if recurrent sub-lethal exposure to saxitoxins can affect reproduction and health of beluga and other marine mammals. It should also be noted that carcass decomposition may reduce the sensitivity of toxin tests and lead to an underestimation of the degree of intoxication of stranded animals.

The death of several calves in 2008 and associated release of females for earlier-than-normal reproduction probably resulted in a higher calf production in 2010, and again in 2012 following well above-average number of deaths of newborn calves in 2010. This is revealed in model predictions through high pregnancy rates in 2009 and 2011, and is supported by field observations suggesting high calf production the following year (2010 and 2012). The well above-average numbers of dead newborn calves in 2010 and 2012 occurred during a period of strong negative anomalies in ice conditions, and for 2012, high water temperatures. These unexplained high calf mortalities in 2010 and 2012 also coincided with high pleasure boating in a marina at the mouth of the Saguenay River, and higher-than-usual interactions between beluga and boats in the Saguenay River.

## Sources of uncertainty

- Abundance estimates of SLE beluga are obtained through systematic surveys presumed to cover their entire summer range. However, sightings outside the presumed summer distribution such as seen in 2007, and highly variable abundance estimates between years, suggest that summer distribution may extend further downstream than presently recognized.
- The number and characteristics of beluga carcasses reported annually through the carcass program were used to infer mortality patterns among age and sex classes, and to estimate mortality rates in the model. The level of bias associated with this sample is uncertain.
- Analyses also assume that mortality rates are homogenous throughout the year. However, there is limited information on mortality rates outside of the summer period when most of the carcasses are reported.
- Results of the model are sensitive to our previous understanding about population dynamic parameters. In particular, postulating higher adult mortality induced a steeper decline of the population in model outputs. The rate of decline predicted by the model was also affected by the choice of input data. Using only the survey abundance estimates predicted the steepest decline in abundance. Adding proportions of young beluga seen during surveys and the beluga carcass data resulted in a slower decline. Carcass data may have a disproportionate weight in the model because, unlike surveys, they are available every year.
- The analysis of environmental condition indices describing ecosystem variability of the Gulf of St. Lawrence was conducted using indices of biomass and quality for various potential prey of the beluga. However, biomass estimates may not be equally reliable. Biomass estimates of demersal fishes for NAFO zones 4T, 4S, and 4R were available, but there is less information on pelagic fish species. The lack of regular assessment for Atlantic herring in NAFO zone 4S and 4R limited our analyses to the 4T herring stock, and we were forced to use a highly uncertain index of capelin biomass (dispersion index) based on DFO bottom trawl surveys due to a lack of adequate stock assessment for this species. Other species such as sandlance and a number of invertebrates including squid, which may form a substantial part of the beluga diet, could not be included in the analysis because we lack time series or data on biomass.
- Data for potential pelagic or demersal prey biomass in the SLE beluga summer distribution is lacking as a result of the absence of fisheries. The relationship between the biomass of selected species in the Gulf of St. Lawrence (e.g., 4T herring) and those available to beluga in the SLE is often unknown. Biomass of diadromous species (ex. tomcod, smelt, eels, salmons) previously reported as SLE beluga prey were not included in the analysis. The SLE estuary is a migration corridor and/or a nursery ground for several of these species which could be seasonally important in the beluga’s diet.

- The analysis indicates a change in SLE beluga vital rates during a period when water temperatures were warmer, and ice conditions poorer than observed in the previous period in the Gulf of St. Lawrence. Whether changes observed in beluga were directly associated with these physical characteristics or through their effects on the trophic structure and productivity of the ecosystem is uncertain. While the beluga is an Arctic and ice-adapted species, its capacity to adapt to an environment where ice may be reduced is unknown.
- The current decline in beluga population has been proposed as a corollary of an environmental shift resulting in what appears to be poor foraging conditions. The difficulty in obtaining current diet information impairs our ability to identify prey species or assemblages that constitute an essential part of the beluga habitat. This knowledge gap is particularly patent for the winter period as data is non-existent, but also for summer when diet data remains fragmentary.
- Various databases and information were used to examine trends in recreational nautical activities and interactions with beluga. The portrait of sources of potential anthropogenic disturbance in the Critical Habitat is known to be incomplete.
- There is a lack of information on new contaminants (other than PBDEs), new algal toxins (other than saxitoxins), and new infectious agents in the SLE beluga habitat. The SLE beluga are exposed to a complex and changing mixture of persistent and non-persistent toxic compounds. The toxic contribution of the different components of this mixture, and impacts on beluga, are poorly understood.

## CONCLUSIONS AND ADVICE

The SLE is thought to be favorable to the beluga’s continued presence as a result of an upwelling of cold, mineral-rich waters, high productivity and sea ice coverage. It is an important migration route and spawning/nursery grounds for several prey fish species. The oceanographic and atmospheric processes responsible for these conditions are likely crucial to the continuing presence and recovery of SLE beluga.

The population size was stable or increasing at a slow rate until the beginning of the 2000s. It also appeared stable in terms of calf production, pregnancy rate, age structure, and adult mortality. During this period, environmental conditions such as sea ice and water temperature were favourable to an Arctic species, although several of the groundfish stocks, including known prey of beluga such as Atlantic cod, collapsed in the early 1990s. The lower-than-expected population growth observed during the 1990s suggests that food, environmental conditions or other factors were limiting population growth. Other limiting factors may include high contaminant loads, negative effects from marine traffic, or high mortality rate associated with occasional events such as toxic algal blooms. The relative importance of all these factors in limiting population growth is not known.

The model suggests that the SLE beluga population began to decrease in the early 2000s. This decline was concomitant to an increased, and more variable newborn calf mortality with cascading effects on the reproductive pattern of females, and to an observed and predicted decrease in the proportion of younger age classes in the population, and unchanged adult mortality rates. During this period, females having lost their calf became available for reproduction earlier than the normal 3-year cycle, resulting in years with over half of the mature females being pregnant at the same time. These peaks were usually followed by peaks of high newborn mortality. This in turn likely freed more females for reproduction the next year. Based on the analysis of some ecosystem indices in the Gulf of St. Lawrence, this change in population dynamics coincided with a period of warming temperatures, decline in ice cover, negative 4T spring herring and large demersal prey abundance indices, and change in indices of beluga diet. This period also followed one characterized by an exponential increase in some chemical substances such as PBDEs in beluga and their environment, and when these substances were at their maxima.

The decrease in population size documented in recent aerial surveys appears to be a lagged response resulting from lower recruitment propagating through the population. Although the events that initially triggered this perturbation are not fully understood, the problem seems to have worsened in the last six years, following a harmful algal bloom of *Alexandrium tamarense* in the SLE beluga summer range. The death of several calves and associated release of females for earlier reproduction resulted in a highly synchronized 2-year reproductive cycle, and higher calf productions in some years such as 2010 and 2012. The effect of chronic sub-lethal exposure to saxitoxins on beluga reproduction and health is not known.

The absence in the population model of a peak in pregnancy in the year preceding the observed peak in dead calves in 2008 suggests that the toxic algal bloom probably played a major role in the high mortalities observed in 2008, on its own or in conjunction with other unfavourable environmental and anthropogenic factors. The 2010 and 2012 anomalies in the numbers of newborn calf washing ashore cannot be explained by higher calf production alone. These anomalies resulted from a combination of an increased calf production, and reduced calf survival, likely related partly to unfavorable environmental conditions for the species, although the mechanisms leading to these additional mortalities in newborn calves are not understood.

The results suggest that SLE beluga live in an environment less favorable to an Arctic species since the late 1990s, also characterized by chronic exposure to potentially aggravating stressors such as marine traffic, persistent organic pollutants, and occasional toxic algal blooms.

Marine traffic and interactions between ships/boats and beluga in areas used by FJC have increased over the last decade. Whether female give birth to their calf in these areas specifically is, however, unknown. Anthropogenic disturbance could be an aggravating factor in calving situations or for females and newborn calves, especially if the animals are weakened by other causes (dystocia, health problems due to toxicity or other illnesses). Calving may take many hours, and is likely to be physically very tiring for the female. At this time, females would be more visible and less likely to move away from boaters. Disturbance at this time could interfere with calving and/or initiating nursing, resulting in increased mortality among the calves because they fail to bond with the female, or among females, which results in the death of the calf as well. Warm and dry conditions in July and August 2010 and 2012, i.e., in months when calving occurs and tourism peaks, were favourable to navigational activities, and potentially exposed belugas to additional anthropogenic disturbance as compared to years with summers of average meteorological conditions.

Climate variability resulting, among other things, in increases in water temperature and associated declines in ice-cover may further affect this beluga population, for instance through changes in food resources and increases in inter-specific competition as other species expand their range due to loss of ice cover. In the short term, efforts can be directed to reducing anthropogenic stressors such as disturbance in sensitive areas and critical periods for females and calves, chemical contamination, nutrient enrichment, habitat loss, and competition for food resources from fisheries. This underlines the importance of maintaining a critical population to withstand periodic downturns, in particular by addressing anthropological factors that could delay recovery.

Environmental shifts resulting in poor foraging conditions have been observed in other ecosystems and have resulted in several years of little or no population growth, e.g., North

Atlantic Right Whale in response to low copepod abundance; northern resident killer whales in the Pacific in response to declines in salmon abundance. However, observations from other systems also show that populations of long-lived mammals do respond to favourable conditions when they occur.

There is a need to continue monitoring the SLE beluga population dynamics, as well as trends in habitat quality, including environmental conditions, prey abundance, and current and emerging natural and anthropogenic stressors. Monitoring of habitat quality needs to be extended to encompass the habitat of females with calves and juveniles (Critical Habitat). There is also a need to further our understanding of the ecological needs of beluga, and the mechanisms of action and relative importance of current environmental stressors in order to implement actions that are the most appropriate to help recovery of this population.

## OTHER CONSIDERATIONS

Currently there are proposals to reroute some of the shipping traffic from the North to the South Channel in the SLE. While the North Channel is highly ensonified by current marine traffic, islands in the middle of the SLE create a sound shadow for FJC habitat located along the south shore. Increased shipping in the South Channel would considerably reduce the amount of noise-shelter areas available to FCJ beluga.

There is currently little effort to document environmental conditions, contaminants, algal toxins, ecosystem structure and prey biomasses available to beluga and other marine species in the SLE, and particularly in the Upper SLE, primarily as a result of the absence of important fisheries in this region. Although navigational activities are numerous and diverse, systematic documentation of these activities are lacking in the SLE beluga Critical Habitat. There is also a lack of understanding of the relationships between the environmental conditions in the Gulf of SL and in the SLE. These knowledge gaps hamper our ability to understand the evolution of the quality of the habitat available to SLE beluga, and to identify and recommend management actions.

## SOURCES OF INFORMATION

This Science Advisory Report is from the October 7-11 2013 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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