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National Capital Region

Canadian Science Advisory Secretariat
Science Advisory Report 2023/024

ABUNDANCE AND POPULATION TRAJECTORY OF ST. LAWRENCE ESTUARY BELUGA

Photo: Beluga female with newborn calf (Véronique Lesage, DFO)

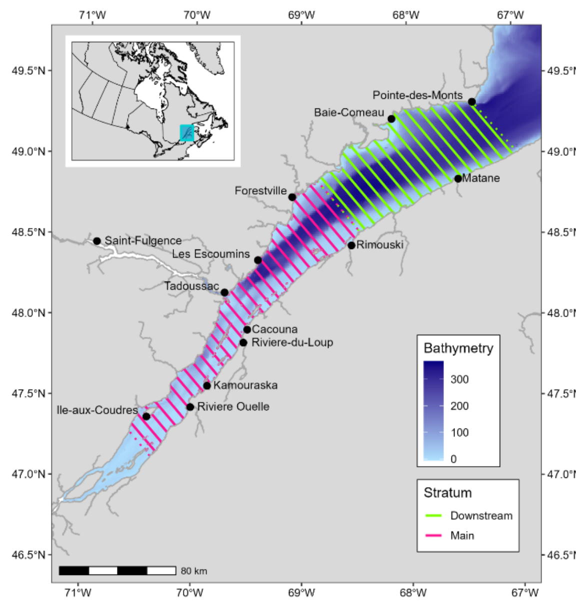

Figure 1. Example of the systematic survey design, here with a 4 nautical mile line spacing (typical of visual surveys). Dotted lines indicate the extremities of the Main and Downstream strata.

Context:

When last assessed in 2012, the St. Lawrence Estuary (SLE) beluga population was declining at an annual rate of ~ 1% per year, and estimated at approximately 900 individuals. Based on this information, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reassessed the population from “Threatened” to “Endangered” in 2014. Accordingly, the status of the population under the Species at Risk Act was also revised in 2017.

Since the last population assessment, multiple aerial surveys have been conducted to estimate abundance of SLE beluga, and new information has been acquired on seasonally important habitats, population health and demography. In addition, a population viability analysis has indicated that the recovery target of 7,070 individuals, set in the 2012 Recovery Strategy for population size over the long term, was unachievable.

In this context, the Species at Risk Program has requested DFO Science to: 1) provide a current abundance estimate and updated trends (current and future) for the SLE beluga population; 2) evaluate the risk of quasi-extinction (less than 50 individuals, as defined by SARA) over a 100-year period (or 3 generations, as appropriate); and 3) provide updated recovery targets over a 100-year period.

SUMMARY

- Abundance for the St. Lawrence Estuary (SLE) beluga population has been estimated using systematic aerial surveys covering their entire summer range since 1990. The current assessment is based on 11 photographic surveys flown over 8 summers between 1990 and 2019, and 52 visual surveys flown over 14 summers between 2001 and 2022.
- Previous assessments of beluga abundance and population trends did not include the visual survey estimates. Updated correction factors for animals missed because they were diving (availability bias), or present at the surface but undetected by observers (perception bias) now allow for the use of both visual and photographic surveys.
- With these updated correction factors, revised abundance estimates from photographic surveys are now 1.3 to 1.5 times higher than previous estimates. Revised visual survey estimates are now 1.2 to 2.8 times higher than previous estimates, and generally more variable than photographic surveys.
- These revised aerial survey estimates along with various other long-term data sources were integrated in a population model to estimate the abundance and trajectory of the SLE beluga population. This model accounts for what is known about SLE beluga, and the level of uncertainty about the dynamics of the population.
- Model-estimated trends were consistent with the previous assessment (2012) from 1980-2007. After 2007, the inferred trends diverge between assessments, with the new model showing an increasing trend instead of a decrease. The observed reduction in the incidence of cancers may have progressively increased survival of older adults, and contributed to the population increase from 2010-2018.
- Although there is always greater uncertainty near the end of a time series, the model results indicate population trends have levelled off between 2018 and 2022, likely reflecting poor survival of calves and pregnant females since 2010, and a possible downturn in survival of other adults over the last few years.
- The model estimated abundance of 1,850 SLE beluga (95% CI: 1,500 – 2,200) in 2022 corresponds to a Potential Biological Removal (PBR) of 3.4 individuals per year.
- The maximum population size that could be sustained in the SLE without anthropogenic sources of mortality is estimated at 6,700 beluga (95% CI: 4,300 – 10,400). This carrying capacity was used to estimate reference levels.
- The mean abundance estimate for 2022 falls below the Precautionary Reference Level (PRL = 3,219) and above the Limit Reference Level (LRL = 1,609), which is the Cautious Zone according to the Precautionary Framework.
- Assuming continuation of recent (2010 – 2022) environmental conditions and natural variation over the next 100 years, there is an 78% probability that the population will remain below the PRL, and a 41% probability it will fall into the Critical Zone, i.e., below the LRL.
- The probability of quasi-extinction (at or below 50 individuals) over 100 years is estimated at 0.06%.
- Proposed recovery targets over the next 28 years (one generation) are to (1) achieve or exceed an average annual growth rate of 1%, (2) reduce calf mortality and pregnancy-associated female mortality by 25%, and (3) reduce annual anthropogenic mortality below

PBR. Longer term goals (over 100 years) for the population would be to increase the number of mature individuals to more than 2,500, and eventually exceed the PRL.

- The factors causing elevated mortality of calves and pregnant females are important drivers in our estimates of abundance and population trajectory, and result in large uncertainty in predictions. The proportion of animals not seen during the survey (due to availability or perception bias) has a large impact on the abundance estimate and contributes to uncertainty about current trends.

BACKGROUND

The St. Lawrence Estuary (SLE) beluga, *Delphinapterus leucas*, is a relict Arctic population that is genetically distinct from all other Canadian beluga populations, and located at the southern limit of the species' distribution. The population's current range is about 65% of that used historically (Figure 1), and its annual core distribution is one of the smallest described for any population of this species. Severely depleted by intensive hunting for commercial products, to protect fisheries, and for recreational purposes, this beluga population was protected 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 cessation of hunting was attributed to a high burden of various persistent and toxic contaminants. A carcass monitoring program initiated in the 1980's to investigate causes of mortality highlighted the plight of the SLE beluga. Concern over the population's fate was a determining factor leading to various research efforts and conservation measures, including the creation in 1998 of the Saguenay-St. Lawrence Marine Park, jointly managed by the federal and provincial governments.

The status of the SLE beluga population was last examined in 2013. That assessment indicated that the population had increased slightly from a low of around 900 individuals in the 1960's to around 1,000 beluga in the early 2000's, when the population started to decline at an annual rate of approximately 1% per year to reach approximately 900 individuals (95% CI: 700 – 1,200) in 2012.

ASSESSMENT

Data sources and model structure

An integrated model was fitted to multiple sources of information, including historical harvest records, abundance data from photographic and visual aerial surveys, age-structure data from aerial and skiff surveys, age-at-death data from carcass stranding records, and cause-of-death data from necropsies of stranded animals. The combination of multiple data sources in a single model, along with environmental correlates of calf survival, allowed for a clearer understanding of the demographic processes driving recent trends in abundance, and a more realistic measure of the level of uncertainty associated with the dynamics of the population.

In past assessments, population size was assessed exclusively from aerial photographic surveys, given that visual surveys were inadequately corrected for animals missed because they were diving (availability bias) or present at the surface but undetected by observers (perception bias). Past surveys (photographic and visual) were also uniformly corrected for availability biases by inflating surface indices by a factor of 2.09. However, biologging data indicate that this correction factor ranges between 2.64 – 3.18 for photographic surveys, and 1.29 – 2.35 for visual surveys, depending on the distribution of sightings and survey platform characteristics. These adjustments are more accurate than the previous one, as they account for environmental and behavioural heterogeneity across the SLE beluga habitat, and for differences in beluga detection times between photographic and visual surveys. With these improved correction factors, revised abundance estimates from photographic surveys are now 1.3—1.5 times higher compared to previous estimates. Revised visual survey estimates, which now also include a correction for perception bias, are 1.2 to 2.8 times higher than previous estimates, but are more variable than photographic surveys (Figure 2).

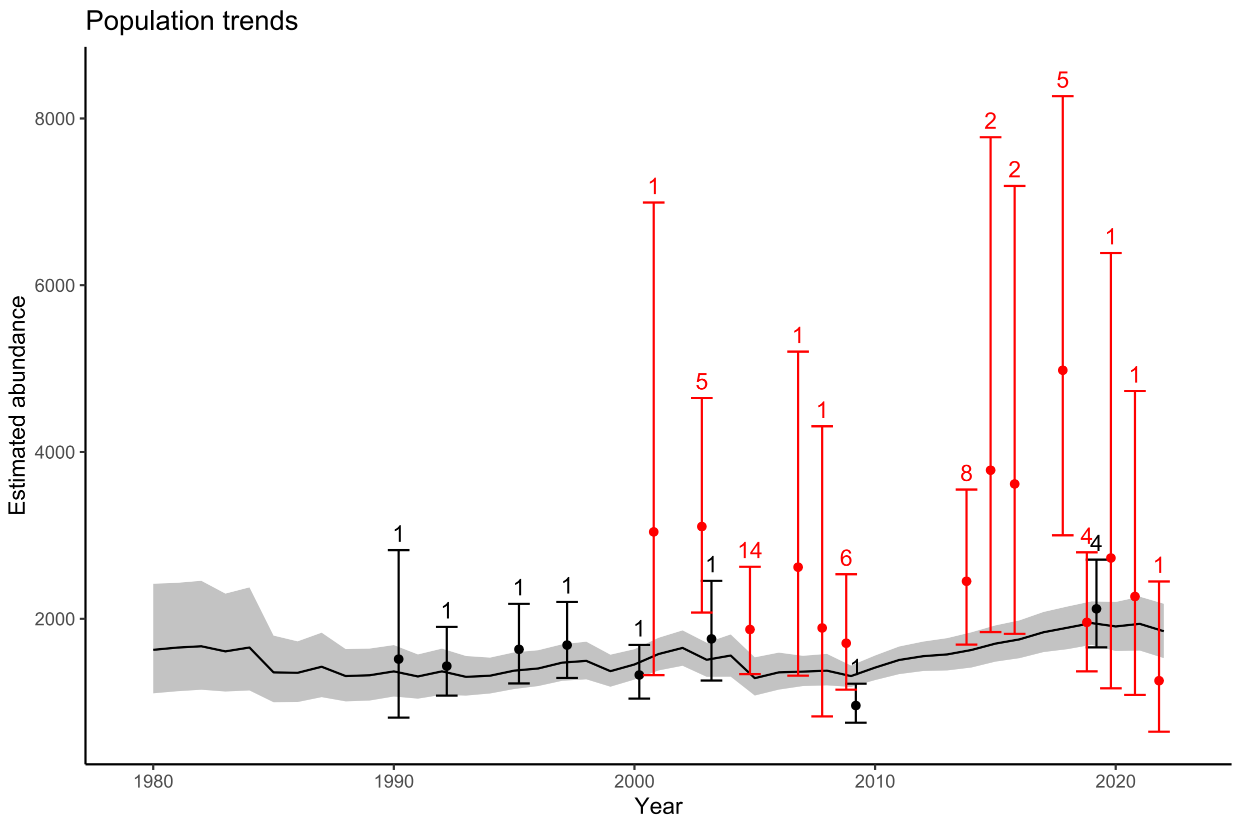

Figure 2. Estimated trends in abundance from an Integrated Population Model fit to the St. Lawrence Estuary beluga population data. The solid line shows the mean annual abundance estimated by the model, while the shaded band shows the uncertainty (95% credible interval) around these estimates. The points represent survey-based estimates of abundance from aerial photo-based surveys (in black) and aerial visual surveys (in red), and the associated error bars represent the 95% CI around each point estimate, calculated from the total variance asssociated with each survey. The number of times surveys were repeated in a year are also indicated. The 2019 photographic survey is the only one using small format cameras (Nikon D800).

Population status and trajectory

Pre-1980s

The model indicated that historical abundance was higher than estimated in previous analyses, with estimated numbers between 12,400 and 17,400 in 1865 (Table 2). Increased harvest mortality after 1865 resulted in a dramatic decline in abundance over the following century. In addition to harvest mortality, this decline was driven by density-dependent reductions in reproduction and increases in calf mortality, likely reflecting habitat degradation, as well as density-independent increases in adult mortality reflecting increased pollution and other environmental impacts. This increased mortality was responsible for the lack of population recovery after human harvests were banned in the late 1970s.

Post-1980s

Variable survival rates of all age/sex classes resulted in fluctuating but generally stable trends from 1980 – 2000. Similar to the previous assessment (2012), the current model indicates that survival rates became even more variable after 2000, with several downward spikes in survival (especially for calves and yearlings) causing a decline in abundance through 2007. After 2007, the inferred trends diverge between assessments, likely as a result of the addition of 10 more years of data and other information sources not included in the 2012 assessment. While the earlier model indicated a decline beginning after 2007, the current model results indicate that trends stabilized and then began to increase after 2010. The increasing trend masked divergent patterns of survival among age/sex classes: increased survival of older animals, likely reflecting the observed reduction in incidence of cancers, appears to have driven an increase in abundance between 2010 and 2018. At the same time, calf survival rates showed the opposite pattern to older animals, with reduced survival occurring after 2010, leading to a dramatic increase in the number of calves appearing in the carcass records (Figure 3). Pregnant females also experienced higher mortality during this period as a result of higher pregnancy-related mortality, leading to a decline in the proportion of adult females with calves. Although there is always greater uncertainty near the end of a time series, the continued decline in the survival of calves and pregnant females, combined with a more recent uptick in mortality of all adult age classes after 2018, appears to have caused abundance trends to level off over the last few years (Figure 2).

The model estimated abundance of 1,850 SLE beluga (95% CI: 1,500 – 2,200) in 2022, corresponds to a Potential Biological Removal (PBR) of 3.4 individuals per year.

A sensitivity analysis indicates that the most influential datasets on model results were the age structure data from the carcass monitoring program, the proportion of 0-1 y calves on aerial photographs and the photographic survey estimates. The large variance associated with visual surveys limited their influence on model results.

Sources of Uncertainty

The tagging study to estimate availability biases was conducted in the early 2000s, and excluded females with newborn calves. Changes in diving patterns and habitat use over time or differences between age and sex classes would affect this correction factor and, thus, our survey estimates.

Aerial survey estimates for beluga are known to be highly variable. Much of this variability is associated with group size, and whether or not large groups are encountered, and how often. Factors affecting group size are poorly understood, but may be related to social behaviour, bathymetry, local foraging conditions, and population size.

The degree of synchrony among individuals when surfacing and the time available to observers for counting whales affect group size estimates, with an unmeasured impact on availability bias estimates and on abundance estimates.

New perception bias correction factors were developed from surveys flown in 2015, 2019, and 2022. The visual survey estimates flown in all other years were adjusted using the average of these correction factors, based on the assumption that there has been no major change over time in this correction factor. Inter-annual variation in this correction factor will affect our survey estimates.

The multiple factors affecting mortality of calves and pregnant females are important drivers in our model estimates of abundance and population trajectory, and result in large uncertainty in these predictions.

The 2022 aerial survey estimate was lower and more precise than previous visual surveys and, thus, exerted more influence on the estimated trends over the final few years of the time series.

There is uncertainty about what influence the loss of genetic variation and inbreeding may have on some of the life history parameters used to model the recovery and extirpation scenarios for this isolated population. If the size of the breeding population becomes too small (often estimated as the "effective population size"), or if the sex ratio of breeding animals is strongly unbalanced, inbreeding and loss of genetic diversity could compromise the health of the gene pool. In marine mammal population, inbreeding may result in increased occurrence of diseases, and potentially, in decreased resilience to stressors in the environment.

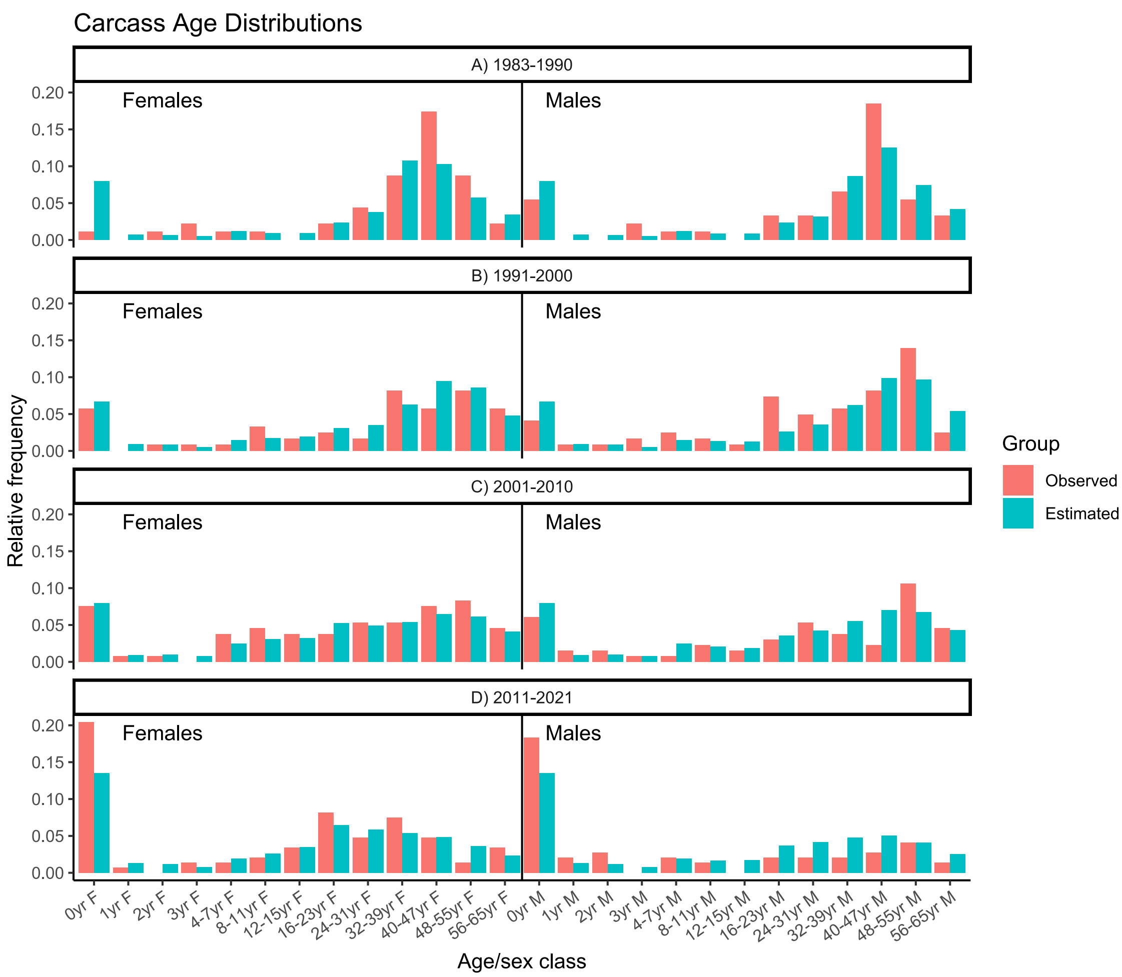

Figure 3. Age/sex distribution of dead stranded animals for four time periods. Age/sex classes are ordered along the horizontal axis by age (females on left and males on right), and the vertical axis shows the relative frequency of dead individuals within each class. The red bars show observed data (i.e., from counts of dead beluga collected each year, grouped by age/sex class) and the blue-green bars show the age/sex distribution of animals dying each year estimated by the population model.

CONCLUSIONS

The current assessment has improved the accuracy of abundance estimates and our understanding of the status of the SLE beluga population. The integration of abundance estimates into a comprehensive population model, along with 30 to 40 years of data from multiple sources, has highlighted several processes underlying SLE beluga population trends.

An increase in survival of older adults, most likely as a result of a reduction in the rate of cancers, led to a slight population increase between 2010 and 2018. However, lower calf survival since 2010, combined with a higher mortality of young adult females as a result of an increased occurrence of pregnancy-related female mortality, have impacted recruitment in recent years. These sources of mortality will likely continue to limit population recovery in the future. The current trend appears to be stable or slightly decreasing, although additional aerial survey data will be needed to clarify recent trends.

The model estimated the population at 1,850 individuals (95% CI 1,500 – 2,200) in 2022, resulting in a PBR of 3.4 individuals per year. While historical population size (prior to when recording of harvest statistics began in 1866) was likely between 12,400 and 17,400, the maximum population size that could be sustained in the SLE under current conditions, but without direct anthropogenic sources of mortality, is estimated at 6,700 beluga (95% CI: 4,300 – 10,400).

Different scenarios of future ecological changes have been evaluated. Of particular concern is the relationship observed between calf mortality and water temperature. If this relationship persists, and water temperature continues to increase, then the population is expected to decline.

If the warm water conditions observed in recent years (2010-2022) persist in the future but do not increase further, and there are no reductions in other mortality factors, there is a low probability (< 13%) of the population reaching the Healthy Zone (according to the Precautionary Framework) within the next 100 years. There is also a 41% probability that the population will fall below the Limit Reference Level (the Critical Zone) over that period, and a 0.06% probability of quasi-extinction (at or below 50 individuals) over 100 years. However, reductions in other sources of anthropogenic mortalities could allow the population to recover.

A long-term (100 year) recovery target could be to maintain population abundance above this lower reference limit, with a goal of eventually exceeding 2,500 mature individuals and the Precautionary Reference Level of 3,219 individuals in the population. More proximate objectives could be to achieve, over the next 28 years (one generation), an average annual growth rate of at least 1%, a 25% decrease in calf mortality and pregnancy-related female mortality, and an overall reduction of annual anthropogenic mortality below PBR, including interactions with fishing gear and vessels.

Table 1. Scenarios evaluated using forward projections of the best-fit model, with modifications to parameters as described. All model projections were run for 100 years and replicated 10,000 times to capture parameter uncertainty and sampling variance.

Scenario	Description	Explanation
Scenario 0	Base model	Project model with no management action or expected change in conditions: parameters drawn from estimated joint posterior distribution, and environmental variables and random effects drawn from observed distributions over most recent 12 years (2010-2022)
Scenario 1	10% incr. Temp.	Same as base, but Gulf water temperature increases by 10% over 100 years (i.e., one half degree Celsius higher than 2010-2022 values)
Scenario 2	20% incr. Temp.	Same as base, but Gulf water temperature increases by 20% over 100 years (i.e., one degree Celsius higher than 2010-2022 values)
Scenario 3	25% reduced Base Hz.	Same as base, but reduce baseline hazards (L_B) by 25%
Scenario 4	25% increased Base Hz.	Same as base, but increase baseline hazards (L_B) by 25%
Scenario 5	25% reduced DyPP Hz.	Same as base, but reduce dystocia/postpartum hazards (a) by 25%
Scenario 6	25% increased DyPP Hz.	Same as base, but increase dystocia/postpartum hazards (a) by 25%

OTHER CONSIDERATIONS

This assessment highlighted the influence of aerial survey design and platform characteristics on availability and perception biases. Corrections for these two biases can have a large impact on abundance estimates as they are multipliers applied directly to surface abundances: they range from 1.3 to 3.2 for availability depending on survey aircraft and design (photographic or visual), and from 1.3 to 7.0 for perception depending on survey aircraft and observer search patterns. Implementation of a double platform protocol (two sets of observers) in future visual surveys will allow us to better account for perception bias and improve our estimation of the corrections to apply to visual surveys that were flown with a single set of observers.

The clumped distribution of beluga observed during aerial surveys leads to large variance within surveys, and to differences in abundance estimates between consecutive surveys that may not be biologically plausible. This variance can be reduced for both photographic and visual surveys by increasing survey coverage and/or by repeating surveys multiple times during a survey year.

Incorporating more information on age-specific causes of mortality into the model would help partition density-dependent and density-independent mortalities, and thereby reduce uncertainty in model projections.

Table 2. Results from future simulations generated using an integrated population model for St. Lawrence Estuary beluga under various scenarios (see Table 1). The distributions of simulation results were compared to target thresholds, including 60% of carrying capacity K, (MNPL) = 4,024, PRL = 3,219, LRL = 1,609, and QE = 50 adult females. The probability that the mean instantaneous rate of growth (r) over a single generation (28 years) would exceed 1% or be less than -1% is also shown.

Scenario	Description	Mean N	CI95_lo	CI95_hi	Min_N	% Change vs Base	Prob. >60%K	Prob. >PRL	Prob. >LRL	Prob. <QE	Prob. r > 1%	Prob. r < -1%
Historical K	Pre-harvest est. K	13,558	12,428	17,432	-	-	-	-	-	-	-	-
Current K	Model est. K	6,706	4,309	10,435	-	-	-	-	-	-	-	-
Scenario 0	Base model	2,285	338	6,289	1,235	-	0.1308	0.2230	0.5944	0.0006	0.181%	0.2592
Scenario 1	10% incr. Temp.	1,687	155	5,503	1,043	-26.2	0.0710	0.1264	0.3918	0.0030	0.069%	0.2312
Scenario 2	20% incr. Temp.	1,272	67	4,949	842	-44.3	0.0476	0.0830	0.2660	0.0144	-0.044%	0.2056
Scenario 3	25% redc. Base Hz.	5,335	1,352	11,721	1,674	133.5	0.6418	0.7728	0.9582	0.0000	1.419%	0.6798
Scenario 4	25% incr. Base Hz.	945	84	3,148	686	-58.6	0.0098	0.0224	0.1600	0.0098	-0.926%	0.0602
Scenario 5	25% redc. DyPP Hz.	2,484	376	6,738	1,280	8.7	0.1618	0.2570	0.6450	0.0000	0.279%	0.286
Scenario 6	25% incr. DyPP Hz.	2,099	306	5,861	1,191	-8.1	0.1022	0.1864	0.5380	0.0004	0.087%	0.2304

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SOURCES OF INFORMATION

This Science Advisory Report is from the February 20-24, 2023 national peer review meeting on Population size and trends of St. Lawrence Estuary beluga in 2022. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Hammill, M.O., Stenson, G.B., and Doniol-Valcroze, T. 2017. A management framework for Nunavik beluga. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/060. v + 34 p.

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Tinker, M.T., Mosnier, A., St-Pierre, A.P., Gosselin, J-F., Lair, S., Michaud, R. and Lesage, V. 2023. An Integrated Population Model for St. Lawrence Estuary Belugas (*Delphinapterus leucas*). DFO Can. Sci. Advis. Sec. Res. Doc. 2023/047. iv + 64 p.

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