Fisheries and Oceans Canada
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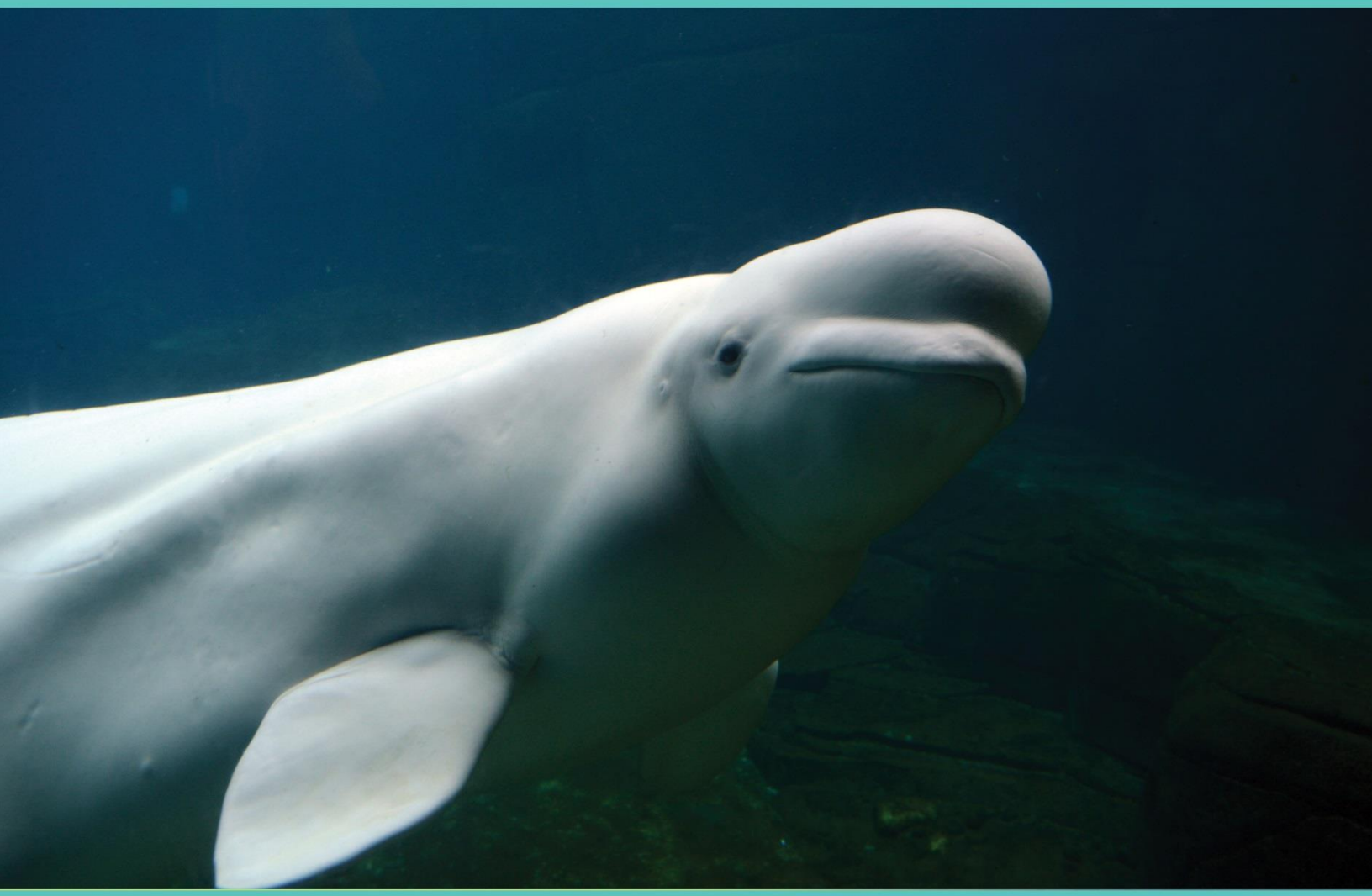
ST. LAWRENCE ESTUARY BELUGA

A science based review of recovery actions for three at-risk whale populations



Canada

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Review of the Effectiveness of Recovery Measures for St. Lawrence Estuary Beluga

1. Context/Background

In November 2016, Canada's Oceans Protection Plan (OPP) was announced, which outlined several new initiatives aimed at addressing the threats to marine mammals in Canadian waters, including the key threats of contaminants, prey availability, and underwater noise. Under the OPP, the Government of Canada will also take action to address the cumulative effects of shipping on marine mammals, and work with partners to implement a real-time whale detection system to alert mariners of the presence of whales. As part of OPP, Fisheries and Oceans Canada (DFO) was tasked with launching a science-based review of the effectiveness of the current management and recovery actions for three at-risk whale populations in Canada: the Southern Resident Killer Whale (*Orcinus orca*), the North Atlantic Right Whale (*Eubalaena glacialis*), and the St. Lawrence Estuary Beluga (*Delphinapterus leucas)*. The review seeks to identify areas for immediate improvement in recovery efforts, and priorities for new or enhanced actions. DFO adopted a phased approach for this review. This document represents the first phase in that process, and is focused on the St. Lawrence Estuary (SLE) beluga population.

Up until recently the St. Lawrence Estuary (SLE) beluga was considered to be a *Threatened* population by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2004), and is currently listed as such under SARA. Population size was estimated at around 1,100 individuals at the time the Recovery Strategy was posted in 2012 (DFO 2012). However, an abnormally elevated number of newborn beluga (calves) reported dead in 2012 triggered a full review of population status, including threats (DFO 2014). This review indicated that the population was stable or increasing at a slow rate (0.13% per year) until the early 2000s, but then declined at a rate of approximately 1% per year, to an estimated 900 individuals in 2012 (Mosnier et al. 2015). Based on the information from the recent review (DFO 2014) on population size and trends, population dynamics, and threats, the COSEWIC reclassified the population as *Endangered* in 2014 (COSEWIC 2014), a status that is in the process of being echoed under SARA.

2. Objective of this Review

This document presents the recovery measures that have been developed as part of the Recovery Strategy for the beluga whale (*Delphinapterus leucas*), St. Lawrence Estuary population in Canada (hereafter referred to as the "Recovery Strategy") (DFO 2012), identifies those that have been implemented (or not yet implemented) to support the conservation and protection of the population throughout its range, and assesses their overall effectiveness for achieving population recovery. This document provides a review from a scientific perspective only, and considers the effectiveness of recovery measures in terms of their ability to reduce threats that have been identified and associated with the endangered status of the population. This review also aims to identify how recovery objectives can be better achieved by accelerating implementation of recovery measures already identified but not

underway, by identifying possible new measures, and by providing guidance on the relative priority that needs to be given to each of these measures to promote recovery.

3. Sources of Information

The Recovery Strategy for SLE beluga was published in 2012 (DFO 2012). The Recovery Strategy outlines the interim recovery goal for the species, recovery objectives, broad strategies, and recovery measures that should be implemented to achieve recovery, as well as performance indicators to define and measure progress toward achieving the population and distribution objectives. In addition to this SARA recovery document, an Action Plan to address noise issues in the St. Lawrence Estuary, which is under development and is to be posted in 2017, was also consulted for the development of this review. Other sources of information used include primarily scientific primary literature, and reports from DFO and other departments or agencies of the Government of Canada.

4. Methods for Assessing Effectiveness of Recovery Measures

Ideally, the effectiveness of recovery measures would be assessed in relative terms, by comparing the degree of threat abatement with the amount of population recovery. In the absence of such precise information for SLE beluga and causation of the lack of recovery, assessing the effectiveness of recovery measures is to be understood in the context of this review as examining the degree to which measures currently underway as well as those proposed in the existing recovery document have, or will, contribute to abating threats to SLE beluga. Specifically, 11 threats to SLE beluga recovery were identified and characterized in the Recovery Strategy, 10 of which were still current (Table 1). For the purposes of this review, such reductions in threats are presumed to contribute to the achievement of recovery objectives for the population.

Achievements associated with recovery measures were compiled in Table 2, using a reference point corresponding to the year of the SLE beluga SARA listing (i.e., 2005). However, trends in level of threats were examined over longer time periods in some cases given that actions to reduce threats have been undertaken well before 2005 in some cases, either as a result of recommendations from the first recovery plan for SLE beluga posted in 1995 (Bailey and Zinger 1995), or because of concerns for human health. An example of a measure addressing a threat to SLE beluga (contaminants) but undertaken as a result of concerns for human health is the implementation of regulations to control or reduce discharges of highly toxic chemical compounds.

It is noteworthy that the recovery objectives included in the recovery document, were developed at a time when the understanding of the Act was different than it is today. As a result, the recovery document did not take into consideration the 2016-tri-departmental Policy on Survival and Recovery that is posted as proposed on the Species at Risk public registry; therefore, neither does this review.

5. Review of Recovery Measures

5.1 Recovery Objectives

At the time of SARA listing, recovery of the SLE beluga population was deemed feasible (Hammill et al. 2007; DFO 2012). Currently, the ultimate recovery goal is to:

Increase population size to 7,070 individuals, or 70 % of the population historical size, to maintain a minimum population growth rate of 2%, and to reach a distribution corresponding to 70% of its historical extent.

Above 1,000 mature individuals, the population would be considered to have achieved a sufficiently large population size to maintain genetic diversity. At a growth rate of 4% (considered a default value for cetaceans), the long-term population objective was projected to be reached by 2050s. However, at the time the Recovery Strategy was published in 2012, the population was thought to be increasing only at a maximum rate of 1%, which extended the projected achievement of the long-term population objective to 2100.

There were six recovery objectives identified in the SLE beluga Recovery Strategy to reach population and distribution objectives, four of which directly address threats to the population. Two further objectives contain approaches that could contribute to address the first four objectives or that help tracking population status, threats and effectiveness of recovery measures. The objectives identified in the Recovery Strategy are:

1) reduce contaminants in beluga, their prey, and their habitat;
2) reduce anthropogenic disturbances;
3) ensure adequate and accessible food supplies;
4) mitigate the effects of other threats to population recovery;
5) protect the beluga habitat in its entire distribution range; and
6) ensure regular monitoring of the St. Lawrence Estuary beluga population.

5.2 Threats

According to the latest COSEWIC status report (2014) and Recovery Strategy (2012), the SLE beluga population has been massively depleted by hunting, which was banned in 1979, and is currently being threatened mainly by:

- industrialization and pollution, which may be responsible for the high rates of chronic diseases such as cancer observed in stranded animals;
- habitat loss and disturbance, especially anthropogenic noise caused by marine navigation and whale-watching activities; and
- competition for food resources with commercial fishermen and increasing populations of certain marine mammals, including some seal species.
- the low genetic diversity (consanguinity) due to small population size, which may affect the reproductive rate.

Among the threats identified in the Recovery Strategy, the following threats represented those of highest concern for the population recovery: high contamination of beluga, their prey and habitat; noise

and disturbance associated with marine development projects, shipping and whale-watching activities; reduction in the abundance, quality and availability of prey; and other habitat degradation (e.g., from construction of docks, marinas, and hydroelectric dams, expanding tourism industry, dredging operations, introduction of exotic species). These threats are further detailed in the sections below and will be assessed for changes since the 2005 baseline, to provide an indication of the collective effectiveness of recovery measures aimed at abating them.

The threat due to low genetic diversity (consanguinity), which is a result of small population size, is not addressed further in this report.

Table 1. Threats to the recovery of SLE beluga as identified in the 2012 Recovery Strategy.

The level of concern has been attributed by the Recovery Team; however, the definition corresponding to each level of concern was not provided in the Recovery Strategy.

Threat	Source of threat (non-exhaustive list)	Level of concern
Contaminants	Industry, municipalities, agriculture	High
Anthropogenic disturbances	Whale-watching, shipping, recreational activities	High
Other habitat degradation	Construction activities, hydroelectric dams, introduction of exotic species, dredging	High
Reduction in the abundance, quality, and availability of prey	Climate variability, fisheries	High
Harmful algal blooms	Industry, municipalities, agriculture via input of nitrogen	Medium
Entanglement in fishing gear	Fisheries	Medium
Vessel strikes	Small (and fast) crafts	Medium
Toxic spills	Ships, port and marinas, industry	Medium
Epizootic diseases	Exotic species, other species (marine or terrestrial) in ecosystems	Medium
Scientific activities	Research vessels and aircrafts	Low

Global warming was not considered as a threat to SLE beluga *per se* in the Recovery Strategy, although it is foreseen to increase mean water temperatures and to reduce sea ice extent and duration in the SLE beluga habitat. Sea ice may affect prey biomass and timing of spawning (e.g., Buren et al. 2014). For an Arctic species like the beluga, it might be expected that effects from a reduction in sea ice extent and increase in water temperature will be negative (Williams et al. in press).

5.3 Review of Recovery Measures

To address these threats, a series of broad strategies, each associated with a set of recovery measures, were proposed and prioritized for actions as part of the Recovery Strategy. Table 2 below is based on that.

Table 2. Recovery measures currently identified for the SLE beluga in the Recovery Strategy (DFO 2012) and achievements made since SARA listing in 2005.

Priority *refers to the priority currently assigned to the recovery measures in the Recovery Strategy.* ***Status of the recovery measure*** *is qualified as either 'Completed': the recovery measure, as currently written and in its entirety, describes an activity or task that was completed at a certain time in the past; 'Completed but ongoing': the recovery measure describes an activity or a task that needs to reoccur at some regular interval or that takes place on a continuum, and likely never has an end date; 'Partially completed': the recovery measure, as currently written and in its entirety, contains multiple elements, some of which have been completed and others that have not; 'Not yet initiated': a situation where, to our knowledge, no actions have been undertaken; 'Unknown': a situation where effort was made to find information on the status of the recovery measure but no information was found in the timeframe of this review.*

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
Objective 1. Reduce contaminants in beluga, their prey, and their habitat that could prevent population recovery					
Study the effects of contaminants on beluga, their key prey species, and sentinel species	Study the effects of contaminants on survival, health, reproduction, and growth	Critical	DFO, Academia	Partially completed	- Cytochrome protein expression, as indicator of stress level, was found to be enhanced in SLE and other Arctic beluga, likely as a result of exposure to polyaromatic hydrocarbons (PAH) which is a class of contaminants found in coal and tar deposits, and produced by aluminum smelters among other sources (Wilson et al. 2005) - Neurotoxicological risk of mercury exposure was estimated for beluga from the Arctic (Ostertag et al. 2014; Krey et al. 2015) - Studies contributing to understanding contaminant effects on beluga were conducted on other marine mammals (reviewed in

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					Desforges et al. 2016) - Several studies hint at potential effects of contaminants on immune system and physiology, and thus on health. The reduced incidence of cancers in SLE beluga since polyaromatic hydrocarbons (PAH) were regulated might represent the strongest indication of a link between exposure to a class of contaminants and effects on health and survival - Information provided at the time of this review did not allow determination of whether measures to study effects of contaminants on key beluga prey and sentinel species were implemented or not
	Evaluate the risks of impacts from different contaminant groups on beluga and the factors influencing these risks	Critical		Unknown	- Information provided at the time of this review did not allow determination whether the measure was implemented or not
Develop new regulations or fully apply existing regulations to control the discharge of toxic pollutants into the environment, especially new contaminants	Improve Canadian and Quebec regulations to reduce toxic chemical discharges into the Great Lakes–St. Lawrence Basin, particularly by reviewing or setting toxicity thresholds for pollutants	Critical	ECCC	Partially Completed	- Under the *Prohibition of Certain Toxic Substances Regulations, 2012,* the manufacture, use and import of many contaminants including polybrominated diphenyl ethers (PBDEs) (added in 2016), perflurooctane sulfonate (added in 2016), short-chained chlorinated alkanes (added in 2013), tributyltins (added in 2012), mirex (added in 1996), and DDT (added in 2005), as well as other types of organobromine compounds and perfluorinated compounds are prohibited in Canada. - the Government of Canada's *PCB Regulations*, implemented in 2008, set specific deadlines for ending the use of PCBs - For dioxins and furans, polycyclic aromatic

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
					hydrocarbons (PAH), mercury, lead and cadmium, the Government of Canada has put in place a number of measures both before and after SARA listing (and strategies such as the 2010 Risk Management Strategy for Mercury, and the 2013 Risk Management Strategy for Lead) aimed at reducing emissions, releases and/or exposure of these contaminants. The information available at the time of this review did not allow the identification of the specific measures. - Internationally the Government of Canada has been working with other countries to minimize exposure to these contaminants from foreign sources. This includes work under the Stockholm Convention on Persistent Organic Pollutants which aims to prohibit many of the contaminants outlined in Appendix 2 of the Recovery Strategy, as well as work under the Minimata Convention on Mercury which aims to protect human health and the environment from the adverse effects of mercury through obligations to control anthropogenic releases of mercury throughout its lifecycle - The Government of Canada is also taking action on other types of organobromine compounds and perfluorinated compounds not listed in Appendix 2 of the SLE beluga Recovery Strategy. These include prohibition on the manufacture, use and import of hexabromocyclododecane (HBCD), on perfluorooctanoic acid (PFOA) and long-chain perfluorocarboxylic acids (LC-PFCAs) via their addition to the *Prohibition of Certain Toxic Substances Regulations, 2012* in 2016.

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
					- Toxicity thresholds were established for PCB, mercury (Hg), MeHg, and cadmium (Desforges et al. 2016)
	Develop mechanisms to monitor the impacts of regulation	Critical	DFO, Academia, ECCC, Health Canada (HC)	Partially Completed	- Time-series exist (since 1983) to document change in some regulated chemicals in SLE beluga (Lebeuf et al. 2014; Simond et al. in press) - Monitoring the incidence of cancers in beluga since 1983 (Lair et al. 2016) has allowed documenting positive impacts of regulation on the health of the beluga population - Ambient environmental monitoring for a number of the contaminants of concern to the Beluga has been and continues to be undertaken which could support performance measurement of the regulation(s). However, information available at the time of this review did not allow determination of how impacts of regulations are currently monitored for biological components of the ecosystem other than beluga. - ECCC and HC have developed substance based performance measurement and assessment plans for polybrominated diphenyl ethers (PBDEs), mercury, lead and bisphenol A which evaluate the effectiveness of risk management measures in meeting environmental objectives.
	Reduce the number and scope of accidental and illegal discharges of pollutants	Critical	ECCC	Partially completed	- The *Deposit Out of the Normal Course of Events Notification Regulations* (2011) under the *Fisheries Ac*t were finalized to identify the 24-hour emergency telephone service to notify of releases of pollution - Since 2015, The *Wastewater Systems Effluent Regulations* (WSER) under the *Fisheries Act*,

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					addresses the largest point source of pollution in Canadian waters. The WSER set national baseline effluent quality standards achievable through secondary treatment. Owners and operators of wastewater systems are required to meet these standards by the end of 2040.
Reduce emissions and discharges of all types of pollutants at the source	Reduce discharges of pollutants from waste storage sites, landfills, sewage (wastewater) treatment plants, industries, etc.	Critical	ECCC, provinces, municipalities	Partially completed	- Since 2015, the WSER requires minimum regulatory effluent quality standards achievable through secondary wastewater treatment. This level of treatment removes over 95% of the total mass of conventional pollutants in wastewater (i.e. carbonaceous biochemical oxygen demanding matter, suspended solids and nutrients). Significant amounts of non-conventional pollutants and bacteria that may be present are also removed through such treatment. - As a result of implementation of the WSER, all regulated wastewater effluent will be treated to a minimum level of secondary by the end of 2040, including in provinces and territories where equivalency agreements are in place.
Monitor contaminant sources and concentrations in the tissues of beluga and their key prey species	Identify the main sources of contamination, and determine how contaminants spread through the beluga population and its environment, and how beluga and their prey get exposed to different contaminant groups	Necessary	DFO	Partially Completed	- A review of current knowledge was produced as part of the Recovery Strategy (DFO 2012)
	Study the movement and spread of contaminants in the tissues of beluga, key prey species, and sentinel species,	Necessary		Unknown	- Information provided at the time of this review did not allow determination of whether the recovery measure was implemented or not

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	particularly emerging contaminants, and publish results.				
Continue cleanup of contaminated terrestrial and aquatic sites in the Great Lakes–St. Lawrence Basin	Identify priority contaminated sites and use environment-friendly decontamination techniques to clean up identified sites	Necessary	ECCC, DFO	Partially completed	- Priority sites were identified prior to SARA listing, after the first Recovery Strategy was produced in 1995 (Multipartite Committee on Contaminated Sites of Concern for the St. Lawrence beluga 1998) - Contaminated sediment management strategies are completed for a number of Great Lakes Areas of Concern (AOCs), including the Niagara River, Bay of Quinte and St. Lawrence River (Cornwall). The Randle Reef Sediment Remediation Project is currently underway to clean up Randle Reef in the Hamilton Harbour AOC, which is the largest and most severely contaminated sediment site on the Canadian side of the Great Lakes.
Continue coordinating pollution reduction efforts, in collaboration with the International Joint Commission.	Initiate actions with Quebec, Ontario, and the United States to coordinate efforts to reduce pollution in the Great Lakes and the entire St. Lawrence River basin	Necessary	ECCC	Completed but ongoing	- Pursuant to the 2012 Canada-U.S. Great Lakes Water Quality Agreement, and the 2014 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, Environment and Climate Change Canada works with the Province of Ontario and local communities to address the cleanup of contaminated sites in the Great Lakes basin known as Great Lakes Areas of Concern. - Under the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA), eight Chemicals of Mutual Concern (CMCs) have been designated and binational strategies are being developed to reduce the release and impact of these CMCs. Additional CMCs will be assessed in the future and binational strategies for those subsequently designated CMCs will be

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
					prepared. - Under the 2014 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, ten chemicals of concern (which includes the current eight CMCs designated under the GLWQA have been identified to reduce or eliminate their use and release within and into the Great Lakes basin.
Objective 2. Reduce anthropogenic disturbances					
Determine the short- and long-term effects of chronic and acute forms of disturbance	Carry out impact studies of disturbances created by marine traffic, whale-watching activities, aircraft, and development projects in- and off-shore in areas used by beluga	Critical	DFO, Academia	Partially completed	- Volume of traffic from various types of vessels operating at specific sites or within the limits of the *Saguenay–St. Lawrence Marine Park (*SSLMP) (Chion et al. 2009) and co-occurrence with beluga were characterized (Chion and Ménard 2013). However, impacts on beluga were not examined - There is an apparent increase in volume of whale-watching trips specifically targeting beluga in recent years (Martins 2016) - Effects on beluga habitat use were examined for a seismic survey conducted in the Cacouna/Rivière-du-Loup area
	Based on disturbance impact studies, determine management measures to reduce disturbance	Critical	Parks Canada (PC), DFO	Partially Completed	- A series of management measures to reduce disturbance, such as speed reduction, area closure, have been put forward in the context of the *Marine Activities in the SSLMP Regulations*; management measures such as time/area closures, noise-reduction technologies, shut-downs of operation when beluga are present, are also included in marine development projects (MDP) as a necessary step for approval of the MDP by DFO

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Study the impacts of noise pollution on beluga	Identify main noise sources at the various frequencies, monitor beluga exposure, and study the impacts of noise on the beluga's health and behaviour	Critical	DFO, Academia	Partially Completed	- Source level characterized for 255 merchant ships transiting through the SLE (Simard et al. 2016) - Traffic density (on a daily, monthly, and yearly basis) mapped for the SLE and other areas in eastern Canada, both globally and selectively for seven vessel types, five vessel length classes, and five sailing speed classes (Simard et al. 2014) - Beluga exposure to noise varies depending on areas, and is highest near the shipping lane and at the Saguenay River mouth, and lowest in south-shore habitats (Simard et al. 2010; McQuinn et al. 2011; Gervaise et al. 2012; Roy and Simard 2015) - Commercial traffic exposes many times daily a substantial proportion (15-53%) of the SLE beluga population, of which the vast majority (72-81%) are females with calves or juveniles, to noise levels that may induce negative behavioural responses. Merchant ships transiting via the South Channel would expose more beluga and more of its habitat to noise, and contribute to acoustic degradation of habitat currently lightly exposed to shipping noise (Lesage et al. 2014a) - Ferry operations at the mouth of the Saguenay fjord affect the echolocation and communication frequency band of SLE beluga. Half of the time, the acoustic space of SLE beluga is reduced to 30% of its expected value under natural conditions (Gervaise et al. 2012) - Anthropogenic noise reduces the window of time during, or the area over, which beluga can forage effectively for food. Management

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					measures contributing to reduced noise levels should help slow down the decline of beluga by increasing foraging efficiency (Williams et al. in press)
	Based on noise impact studies, determine management measures to reduce noise pollution	Critical	DFO, PC	Partially Completed	- Based on results from Lesage et al. (2014a), it was recommended that merchant ships transit preferentially along the north shore of the SLE to minimize disturbance and noise exposure of beluga and their habitat. This measure was implemented in 2014; the proportion of ships transiting along the south shore was low (around 5% annually), but remains stable since 2014; actions are underway via the Working Group on Marine Traffic and Protection of Marine Mammals in the Gulf of St. Lawrence (G2T3M) to further reduce traffic in this area - Simulations where merchant ships reduce their transit speed were conducted to determine the effectiveness of this measure at reducing beluga instantaneous and cumulative exposure to noise (Chion et al. 2017)
Reduce anthropogenic disturbances in high-use areas	Reduce anthropogenic noise in the St. Lawrence Estuary (construction, navigation, gas exploration, etc.)	Critical	DFO, PC	Partially Completed	- Prohibition by the Quebec Government of any activity related to oil and gas exploration or exploitation, or mining in the northwestern Gulf of St. Lawrence west of the western tip of Anticosti Island and in the SLE, including islands (Québec 2011, reaffirmed in 2014) - Systematic consideration of noise mitigation strategy and monitoring for marine development projects proposed in, or likely to destroy, SLE beluga critical habitat, and likely to produce excessive noise - Incorporation of quieting technology to the docks (e.g., rubber under access slips) at the mouth of the Saguenay River

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					- The dock in Baie-Sainte-Catherine is managed by Parcs Canada, which has contributed to limiting traffic in part of the mouth of the Saguenay Fjord - Voluntary measures to reduce merchant ship speed have been implemented in a sector of the shipping lane near the Saguenay Fjord mouth; these measures were intended for mitigating collision risk with baleen whales, but to a certain extent contributed to a reduced noise footprint of ships in beluga habitat (http://www.qc.dfo-mpo.gc.ca/infoceans/201410/article7-fra.html) - The implementation of mitigation measures reducing noise output or beluga exposure to noise (e.g., time/area closures, operation shut downs in presence of beluga, bubble curtains) are required by DFO for projects likely to affect SLE beluga or their habitat
	Implement protection measures in problematic marine traffic corridors	Critical	DFO, PC	Partially Completed	- Implementation of a voluntary measure, where ships are asked to avoid using the South Channel and the Rivière-du-Loup/Cacouna area when transiting through the SLE, so to minimize noise inputs in important habitats for females and calves (G2T3M). This measure has made pilots aware of the beluga-noise issue and has likely contributed to maintain traffic in this area to a low level (around 5% annually; SSLMP, unpublished data). There has been no decrease of traffic since implementation of the measure and efforts are currently underway via the G2T3M to further reduce the traffic in this area - Under the *Marine Activities in the SSLMP Regulations*, a limit is imposed on the number of whale-watching licenses (not trips per

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					licence) for operation in the SSLMP - Since Jan. 2017, the *Marine Activities in the SSLMP Regulations* have also imposed a speed limit for tour boats (max of 20 knots) and pleasure boats (15 knots) when passing through the mouth of the Saguenay River.
	Reduce the number of incidents (e.g., direct approaches, harassment).	Critical	DFO, PC	Partially Completed	- Prohibited under the *SSLMP Regulations* to actively approach SLE beluga at distances closer than 400 m, to fly an aircraft at an altitude lower than 2000 feet, or to cruise at a speed higher than 25 knots within the limits of the SSLMP - It is also prohibited (under license conditions) for tour boat operators and research vessels to enter Baie Sainte-Marguerite; avoidance of this sector is currently on a voluntary basis for other users of the SSLMP - Prohibition under the revised *SSLMP Regulations* (Jan 2017) of jet skis, hovercraft, and towed water sports within the limits of the SSLMP - A code of practice for eco-friendly observations of marine mammals has been put in place by members of the Éco-Baleine Alliance (http://www.eco-baleine.ca/pdf/Fiche_Guide_Fr.pdf)
	Develop best practice guidelines for when beluga are unexpectedly encountered	Critical	DFO, PC	Completed	- The *Marine Activities in the SSLMP Regulations* prescribe how users must behave in these situations (Jan 2017) - Similar guidelines have been developed for recreational boaters, and have been publicized since 2015 through awareness campaigns in marinas and communities located along the SLE south shore (http://www.qc.dfo-mpo.gc.ca/mammiferes-mammals/bonne-pra-

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
					nav-eng.html)
Protect beluga against anthropogenic disturbances throughout their entire distribution area.	Review, adopt, and enforce the *Marine Mammals Regulations* as well as the *Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations* to better protect beluga from disturbance, particularly by enforcing a 400 m "no boat" zone around beluga throughout the area	Necessary	DFO, PC	Partially Completed	- DFO's intent to modify the *Marine Mammal Regulations* has been announced in the Canada Gazette I, in 2012 (http://www.gazette.gc.ca/rp-pr/p1/2012/2012-03-24/html/reg2-fra.html); once in place, the revised regulations would include provisions for a 400 m limit to approaches of whales, dolphins and porpoises that are considered threatened or endangered under the Species at Risk Act, in a zone contiguous to the SSLMP. Finalization of the revised regulations is pending the Minister's final approval and posting in Canada Gazette II - The *Marine Activities in the SSLMP Regulations* were reviewed (Jan 2017); they maintain the 400 m no-boat zone around beluga, and incorporate new elements to better protect beluga, including 1) prohibition of jet skis, hovercraft, and towed water sports within the limits of the SSLMP, and 2) reduction of boat speed at the mouth of the Saguenay River - Enforcement of the *SSLMP Regulations* is made by three officers; information on the number of patrols or infractions are not available - Enforcement patrols in the waters adjacent to the SSLMP have been initiated by DFO in 2015, and have been conducted jointly with the SSLMP officials. While their number has remained low up until now, there are intentions to pursue these patrols, and increase their frequency
	Improve whale-watching monitoring patrols during the tourist season in the SSLMP	Necessary	DFO, PC	Partially Completed	- In addition to the regular enforcement patrols in the SSLMP, since 2010 there have been regular awareness campaigns conducted within

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	and elsewhere in the Estuary				the limits of the Park - Joint patrols of DFO fishery officers and SSLMP officials were conducted over a period of 5 days in 2016 during the tourist high season in July and August, and will be pursued in the future
Implement the education strategy for species at risk developed by the SSLMP and extend it to cover the entire beluga distribution range.	Identify target groups for awareness campaigns, and develop and implement a communications strategy	Necessary	DFO, PC	Completed but ongoing	- Profiles of users (sail boats, motor crafts, recreational fishers, seadoos, and kayakers) developed by the SSLMP authorities have been used since 2015 to adapt communication strategies and tools to the targeted clients. These tools were distributed during the 2016 tourist season in the context of an awareness campaign about beluga disturbance through various forums (annual general meetings, marina, nautical events, etc.)
	Improve training for captains, kayaking guides, and nature guides in order to reduce disturbances, and make training mandatory	Necessary	DFO, PC	Completed but ongoing	- Since Jan. 2017, the *Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations* formally prescribe the implementation of a certification system for tour boat operators and sea kayak guides, which require attendance to a mandatory training session about the marine park and the new regulations, and completion of an annual knowledge exam in order to receive certification
	Publicize conservation actions and provide educational activities to local residents.	Necessary	DFO, PC	Completed but ongoing	- Establishment of interpretation centers, information tools, and special presentations for visitors of the SSLMP - Presence of specially-formed interpretation guides at sites where beluga can be observed within the SSLMP - In collaboration with the Ministère de l'Éducation du Québec, participation of the SSLMP in a school program to enhance awareness about the environment and the St.

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					Lawrence via the special case of SLE beluga - Since 2015, a summer awareness campaign about beluga disturbance has been conducted with recreational boaters from the SLE south shore (http://www.qc.dfo-mpo.gc.ca/infoceans/201608/article2-eng.html); SSLMP authorities conduct similar activities in communities from the north shore - SSLMP representatives are present during nautical festivals and on social networks to raise awareness
	Set up a recognition program for sea excursion companies that adopt best practices	Necessary	PC, DFO	Completed but ongoing	- Creation of the Eco-Whale Alliance (2010)
	Define specific best practice guidelines for each type of user navigating the St. Lawrence Estuary	Necessary	DFO, PC	Completed	- Best practice guidelines for tour boats and pleasure craft users operating within the limits of the SSLMP are implemented under the *Marine Activities in the SSMPL Regulations* (reviewed in Jan 2017) - Similar guidelines have been developed for recreational boaters, and have been publicized since 2015 through awareness campaigns in marinas and communities located along the SLE south shore
Improve the decision-making process for granting research permits and permits for other activities requiring approaches within 400 m.	Establish the rules and a decision-making committee, and set up a single-window system, in collaboration with all the responsible authorities, to evaluate the relevance, methods, and issuance of permits for projects involving beluga or their critical habitat	Necessary	DFO, PC	Partially Completed	- Permit issuance for activities conducted within the limits of the SSLMP is considered only once permits have been obtained from DFO - Permit issuance by DFO is coordinated among the Resource management, Fisheries protection, and Species at Risk programs, in consultation with the Science sector when needed. However, there is currently no system to assess cumulative effects that these activities might have on beluga

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
Objective 3. Ensure adequate and accessible food supplies					
Protect spawning and rearing sites and migration corridors of key prey species	Strengthen measures to protect important sites for key prey species	Critical	DFO, Provincial Gov.	Partially Completed	- Systematic consideration of potential impacts and mitigation strategy for marine development projects proposed in, or likely to affect beluga key prey species and thus, that might lead to destruction of SLE beluga critical habitat - A protection plan for smelt spawning sites in the Saguenay fjord was proposed in 2010 (Comité ZIP Saguenay, 2010); the Quebec Government was approached in 2015 to support the creation of an aquatic reserve to protect this resource. The outcome of this initiative was not known at the time this review was completed - The *Fisheries Act* includes prohibition against carrying out of any work, undertaking or activity that results in serious harm to fish that are a part of or support a commercial, recreational or Aboriginal fishery. These prohibitions cover the SLE beluga's preys
	Prohibit trawl nets from the Upper St. Lawrence Estuary and the Saguenay River	Critical	DFO, PC, Provincial Gov.	Partially Completed	- Commercial fisheries are prohibited in the Saguenay River, within the limit of the SSLMP - Trawl net fishery is prohibited in the Saguenay River under the 'Règlement des pêches de l'Atlantique', Appendix XXXI, alinea 7 - In the Upper Estuary, there exists an informal agreement between DFO and the shrimp fishermen to not conduct trawl fishing
	Maintain the moratorium on forage species	Critical	DFO	Not Completed	- In the Gulf of St. Lawrence, the absence of fishing on some forage species helped mitigate the threat of inadequate food supplies to some extent, since it prevented fisheries for some

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
					forage species that the beluga either prey upon (e.g., sandlance), or that the beluga's prey depend on (e.g., krill and copepods). - However, capelin and herring are considered forage species for Beluga, and fisheries targeting these two species are conducted in the St. Lawrence - In 2009, a new policy 'New Fisheries for Forage Species' was introduced (http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/forage-fra.htm). Under this new policy, a fishery can be allowed to proceed if it can be demonstrated, in a reasonable manner, that the fishery will not jeopardize the ecological role of the species or ecosystem functioning by reducing abundance. There is currently no fishery for Beluga's forage species other than herring and capelin
Continue research on the diet and feeding habits of beluga	Study diet habits and feeding strategies	Necessary	DFO, Academia	Partially Completed	- Diet estimates were obtained using prey remains in stomach and intestine (Lesage - 2014), as well as using indirect dietary methods based on chemical tracers such as stable isotopes (Lesage 2014), fatty acids (Nozères 2006), and contaminant levels (Lebeuf in Savenkoff et al. 2017)
	Study prey availability and factors that influence their quantity and quality	Necessary	DFO, Academia	Partially Completed	- Ecosystem studies examining climate factors, abundance and quality of beluga prey, and their relationship with beluga calf mortality were conducted (Plourde et al. 2014; Williams et al. in press) - A study examining capelin spawning and larvae abundance determined a unit of the GSL capelin population use the SLE and is composed of individuals that are retained in this area following hatching (Ouellet et al. 2013)

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
					- Capelin and smelt recruitment depends on the production and retention of larvae in the Saguenay fjord whereas redfish and cod species depend on juvenile immigration from the SLE (Sirois et al. 2009)
	Based on studies of prey availability, determine management measures to protect the beluga's food resources	Necessary	DFO, PC, Provincial Gov.	Partially Completed	- Given their apparent importance for beluga and their potential role in the current decline, it was recommended that groundfish stocks as well as 4T spring herring be protected in the Estuary and Gulf of St. Lawrence (DFO 2014) - Maximum length for a tuck seine to fish for capelin is fixed at 80 fathoms, so to reduce fishery efficiency and thus, impact on capelin stocks - Herring exploitation is managed under a Conservation fishing plan for 2016-2017 (https://inter-l01.dfo-mpo.gc.ca/applications/opti-opei/notice-avis-detail-fra.php?pub_id=871&todo=view&type=1&region_id=4&sub_type_id=5&species=200&area=1915) - The Atlantic Fishery Regulations set a minimum length for captures to protect juvenile herring - The fishery directed toward the Atlantic cod stock that feeds prey into the SLE (i.e., the southern Gulf of St. Lawrence cod stock) has been under moratorium since 2009 to allow population recovery; a 300 bycatch is allowed (DFO 2016a)
Prevent new fisheries with the potential to significantly impact beluga and their	Consider the beluga's food requirements when assessing new fisheries	Beneficial	DFO	Not yet initiated	- Technically, the Policy for New Fisheries of Forage Species requires that beluga food requirements be taken into account when assessing new fisheries ((http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
prey					cpd/forage-fra.htm). - There is no such measure for fisheries targeting non-forage species. - New fisheries authorized by DFO since SARA-listing in 2005 do not concern beluga potential prey
Objective 4. Mitigate the effects of other threats to population recovery					
Develop and implement adequate protective measures for all inshore and offshore projects that could have an impact within the beluga distribution area	Include protective measures in inshore and offshore projects	Critical	DFO, Provincial Gov.	Completed but ongoing	- Other habitat degradation resulting from inshore and offshore development (e.g., dredging and construction, seismic surveys, hydroelectric dams) is limited by the systematic scrutiny of these projects by DFO for potential impacts on beluga critical habitat; which includes the physical and acoustic environment, and beluga prey. Mitigation measures have to be applied when available and efficient (e.g., DFO 2007; 2011a; 2011b; 2014; 2016b)
	Conduct an environmental impact assessment for all oil and gas exploration and development projects in the Gulf of St. Lawrence	Critical	National Energy Board (NEB), DFO, CLNOPB, ECCC	Completed but ongoing	- Potential impacts from marine development projects, oil and gas exploration and exploitation, are prevented or mitigated through systematic scrutiny by DFO; DFO Science regularly is requested to participate to impact assessments of marine development projects in the SLE and Gulf of St. Lawrence. For instance, DFO Science has contributed to impact assessment of oil and gas specific projects in different areas (e.g., Old Harry, Cabot Strait, Sidney Bight, western Newfoundland, western Gulf) and to several other smaller-scale projects (e.g., DFO 2007; 2011a; 2011b; 2014; 2016b)
Maintain and improve the carcass	Improve the reliability and accessibility of the carcass	Critical	DFO, RQUMM, Academia	Partially Completed	- The beluga carcass monitoring program has been in place since 1982, and fully

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
monitoring program, with a focus on determining causes of death	monitoring program database (since 1983) and improve data processing and integration methods				implemented since 1983; it is currently maintained via the financial support from DFO, and collaboration from various institutions (e.g., academia, aquaria and federal departments and agencies) - DFO remains the curator of the central database, which has been rebuilt and standardized in 2012 - Following the increase in mortality events of calves in 2012, calves are now systematically subjected to a full necropsy regardless of the preservation condition of carcasses (unless they are mummified)
	Regularly publish results	Critical	DFO, Academia	Completed but ongoing	- A summary of causes of deaths for beluga necropsied between 1983 and 2012, and mortality patterns based on results from the program, were recently published (Lesage et al. 2014; Lair et al. 2016)
	Based on studies of causes of death, determine management measures to reduce sources of mortality	Critical	DFO, ECCC, PC	Partially Completed	- Recommendations, based on causes of mortality, were made in the context of the DFO beluga status review (DFO 2014). 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, high nutrient inputs, habitat loss, and competition for food resources from fisheries
Prepare emergency plans for beluga in case of spills, harmful algal blooms, and epizootic diseases	Prepare or update emergency plans for the St. Lawrence Estuary	Underway	DFO, ECCC	Partially Completed	- An emergency plan in case of accidental spill of toxic chemic substances is in place for the SLE, The Emergency Plan for at-sea spillage – Regional Chapter explains in general terms how the Canadian Coast Guard Environmental Response Group will proceed in case of a spill. This plan is not specific to SLE beluga
Reduce the impact	Develop tools to detect and	Necessary	DFO, PC	Partially	- Vessel speed limited to 25 knots in the SSLMP,

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
of vessel strikes and entanglement in fishing gear	prevent strikes and entanglements			Completed	and seasonally (1 May to 31 October) to 20 knots (tour boats) and 15 knots (pleasure boats) for the Saguenay River mouth, under the *Marine Activities in the SSLMP Regulations* - Prohibition of jet skis, hovercraft, and towed water sports within the limits of the SSLMP - Code of practice when in presence of beluga are incorporated in the SSLMP Regulations and in the SSLMP and DFO communication tools, and aim partly at reducing collision risks
	Ensure the continued operation of the Marine Mammal Emergency Response Network	Necessary	DFO, RQUMM	Completed but ongoing	- The Network has been in place since 2004, and receives continued financial support by DFO and other partners, and logistical support by various institutions (e.g., academia, aquaria and federal departments and agencies)
	Ensure monitoring of incidents involving beluga (collisions, wounds, incidental catches, harassment)	Necessary	DFO, PC	Completed but ongoing	- Under the SSLMP licensing conditions, it is mandatory for tour boat operators and fishermen to report collisions or incidental catch of beluga - The beluga carcass monitoring program allows detection of some of these cases - An awareness campaign conducted annually since 2015 in communities of the SLE south shore increases the probability of detection of these events (http://www.qc.dfo-mpo.gc.ca/infoceans/201608/article2-fra.html)
Inform and raise awareness of navigators (all boat types) on the regulations and the impacts of pollutant discharges	Carry out an awareness and education campaign on the regulations on pollutant discharges	Beneficial		Unknown	- Information provided at the time of this review did not allow determination of whether the recovery measure was implemented or not
	Monitor the number of	Beneficial		Unknown	- Information provided at the time of this review

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
	incidents (toxic spills)				did not allow determination of whether the recovery measure was implemented or not
Detect and prevent spills, algal blooms, and epizootic diseases	Develop tools to detect and prevent spills, algal blooms, and epizootic diseases	Beneficial	ECCC, DFO	Partially Completed	- Monitoring program for toxic algal blooms was reduced in 2009, but maintained for the Tadoussac dock and for 4 to 5 other stations in the St. Lawrence. However, sample analysis is now done on an opportunistic basis, according to budgetary surpluses, and thus would not allow detecting harmful blooms in a timely manner - There is currently an informal agreement among members of the Marine Mammal Emergency Response Network to not proceed with the reintroduction of rehabilitated marine mammals held in captivity
Reduce ship strikes, in particular with tourist vessels and pleasure craft	Carry out awareness campaigns targeting captains of tourist vessels and pleasure craft	Beneficial	DFO, PC	Completed but ongoing	- Since Jan. 2017, the *Marine Activities in the Saguenay–St. Lawrence Marine Park Regulations* formally prescribe the implementation of a certification system for tour boat operators and sea kayak guides, which require attendance to a mandatory training session about the marine park and the new regulations, and completion of an annual knowledge exam in order to receive certification - A summer awareness campaign focused on reducing disturbance of beluga and ways to navigate in their presence has been conducted with recreational boaters from the SLE south shore since 2015 (http://www.qc.dfo-mpo.gc.ca/infoceans/201608/article2-fra.html)
Examine other potential obstacles to recovery	If new threats are identified, initiate additional research and management strategies to reduce the impact	Beneficial		Completed and ongoing	- No new threats identified

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
Objective 5. Protect beluga habitat in all its distribution range					
Increase our understanding of the seasonal distribution and potential habitats of beluga	Identify beluga high-use areas according to season, including the characteristics that make them favourable to beluga and the vital functions they support, and identify potential new habitats should the distribution area expand as well as threats to these habitats	Critical	DFO, Academia, ENGOs	Partially Completed	- Fine-scale habitat use (e.g., relative to tides, time of day, season) of some important areas within the Critical Habitat (e.g., Cacouna/Ile Verte, mouth of the Saguenay Fjord) has been characterized (Conversano 2013; Roy and Simard 2015) - Summer high-use areas have been identified using long-term data from both aerial survey and beluga herd tracking (Mosnier et al. 2016; Lemieux Lefebvre et al. 2012) - A summary of current knowledge on beluga habitat was produced (Mosnier et al. 2010)
Protect beluga habitat using diverse legal tools	Set up Marine Protected Areas in beluga territory, such as the SLE Marine Protected Area Project and the Manicouagan Aquatic Reserve	Critical	DFO, Provincial Gov.	Partly Completed	- A *Planned Aquatic Reserve* has been in place since 2013 under the *Loi sur la conservation du patrimoine naturel du Québec*. The conservation plan is available at: http://www.mddelcc.gouv.qc.ca/biodiversite/aquatique/manicouagan/plan-conservation.pdf.
	Enact zoning regulations in the SSLMP to protect high-use areas	Critical	PC	Partly completed	- The new *Marine Activities of the SSLMP Regulations* include provisions to create temporary exclusion zones in specific areas, and limit access to sensitive areas by tour boats - Access to some important habitat of beluga in the SSLMP (e.g., Baie Ste-Marguerite) is limited through license permitting conditions to tour boats, and awareness campaigns for recreational users
	Study the feasibility of extending the boundaries of the SSLMP, in accordance with the management plan of the marine park (PCA and MDDEP, 2010), to include a	Critical	PC	Partly completed	- Discussions between SSLMP and MMFP have been initiated but nothing concrete to implement this measure has emerged so far

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
	more significant portion of the beluga' summering area				
6. Ensure regular monitoring of the St. Lawrence Estuary beluga population					
Monitor the St. Lawrence beluga population	Continue to conduct population surveys, at least every three years	Critical	DFO	Completed but ongoing	- Photographic aerial surveys have been conducted at least every three years since 1988 and up until 2003. Since SARA-listing, a single photographic survey was conducted (in 2009) - A time-series of visual aerial surveys, where multiple surveys can be conducted in a given year, was initiated in 2001. Surveys continue to be flown regularly since SARA-listing in 2005. A total of 36 surveys were flown so far (in 2001, 2003, 2005, 2007, 2008, 2009 and 2014; Gosselin et al. 2014; in press). *Note:* these two methods are not comparable, and visual surveys don't allow determination of the proportion of calves in the population, a key component of population monitoring
	Monitor juvenile recruitment rates and causes of juvenile mortality	Critical	DFO, Academia	Completed but ongoing	- Indices of recruitment were obtained via the photographic aerial surveys (from 1988-2009: Gosselin et al. 2014), and long-term photo-identification surveys (from 1989-2012; Michaud 2014). These studies indicate that the proportion of calves and juveniles have decreased over time in the population - Necropsies are conducted on beluga found dead to determine cause of mortality but juveniles represent a small proportion of this sample (Lair et al. 2014). Verminous pneumonia was the primary cause of death in over 70% of non-calf juveniles
	Continue the population monitoring program (distribution, size, structure,	Critical	DFO, Academia, ENGOs	Completed but ongoing	- Aerial surveys to monitor population size and distribution are conducted regularly (summarized in Gosselin et al. 2014; Mosnier et

Broad Strategy	Recovery Measures	Priority	Achievement contributors	Status of recovery measure	Achievements since SARA listing (2005)
	dynamics, social organization, and genetics)				al. 2016) - Population parameters and dynamics continue to be monitored via the carcass monitoring program and aerial surveys and have been recently summarized (Lesage et al. 2014b; Mosnier et al. 2016) - A sampling program has been in place for over 25 years to document the social organization and genetic structure of the population

6. Effectiveness of Recovery Measures and Recommended Changes or Additions

In the following sections, the recovery measures that have been implemented to reduce each of the identified threats are described in general terms, along with any information available on population demography or health to illustrate the effectiveness of the measures. As it is difficult to assess the effectiveness of individual recovery measures and their associated impacts on the population, all recovery measures aimed at reducing a specific threat are considered collectively to evaluate whether they have been effective at reducing the threat.

The recovery measures listed under objective 6 in the Recovery Strategy do not directly reduce threats to SLE beluga. However, monitoring programs that fall under this objective are important for informing threat-based mitigation measures. The effectiveness of recovery measures implemented to more directly reduce or mitigate threats often relies on information obtained under these non-threat-based measures. Additionally, knowledge gained through completing measures under Objective 6 can be used to inform the development of new recovery measures to reduce the impacts of threats. As this objective is not threat-based, nor directly related to recovery, a measure of their effectiveness is not possible; however, their importance for assessing recovery and the effectiveness of other recovery measures is further discussed in the following sections.

6.1 Overall Assessment of the Effectiveness of Recovery Measures

The decline (1% per year) in the SLE beluga population size documented over the past 15 years after a period of relative stability (Mosnier et al. 2015), and the apparent absence of expansion in beluga distribution (Mosnier et al. 2010; Gosselin et al. in press), indicate that recovery objectives for population size and distribution range have not been achieved. They also indicate that, while recovery actions completed had allowed the population to stabilize prior to 2000, they did not permit the population to grow at the targeted 2% growth rate and they have since been insufficient for this population to cease decreasing.

A recent population viability analysis (PVA), which assumed a warming climate and various levels of what are now considered to be the three main threats to the population (i.e., noise/disturbance, persistent organochlorine contaminants, and reduced availability of prey), was recently performed for SLE beluga (Williams et al. in press). It was concluded that the SLE beluga population was unlikely to reach the recovery goal of 7,070 individuals by 2100, even under the most optimistic management scenarios of these threats. While uncertainty exists as to the relative importance of the three threats that were considered in the model in terms of preventing recovery, the strong negative anomalies observed since 2010 in sea ice extent and duration and water temperatures, if they persist, come out as factors potentially reducing the ability of the SLE beluga (or resilience) to cope with the other three threats (Williams et al. in press).

Given the above information, it is evident that collectively, the recovery measures laid out in the Recovery Strategy that have been completed to date, have not led to the achievement of recovery

objectives, and current population trend is also not indicative of progress towards recovery. The following section will assess progress towards abating threats preventing beluga recovery.

6.2 Effectiveness of Threat-based Recovery Measures, and Recommended Improvements

6.2.1 Recovery measures associated with objective 1. Reduce contaminants in beluga, their prey, and their habitat

Recovery measures that fall under the first recovery objective aim to reduce the threat of contaminants. SLE beluga are exposed to a variety of toxic chemical compounds mainly through their diet, but also through their environment (sediments, water, air). Some pollutants have existed for a long time in the beluga environment, and have been regulated well before concerns were raised about their potential effects on beluga health (e.g., PCBs, DDTs, PAH). Other toxic chemical compounds were introduced in the environment more recently (e.g., polybrominated dichloroethane or PBDEs) and have been regulated after 2005 (i.e., after SARA listing) but not necessarily as a result of recovery measures in the beluga Recovery Strategy. Others (e.g., other flame retardants) are emergent and remain unregulated.

The monitoring of levels of persistent organochlorine compounds (e.g., DDTs, PCBs, Mirex, dioxins, furans) and some metals (e.g., mercury) in SLE beluga and studies of their potential effects were initiated in the early 1980s, i.e., prior to the SARA listing of the population (e.g., Martineau et al. 1987; Muir et al. 1996a; 1996b; DFO 2012 for review). These studies have shown that SLE beluga are among the most contaminated marine populations on the planet, which raised concerns for their health. There were also concerns about a class of contaminants (polyaromatic hydrocarbons or PAH) originating from aluminum smelters that were detected in SLE beluga; PAH were thought to be responsible for the high rates of cancers documented in the population (Martineau et al. 2002).

A number of recovery measures have been proposed which aimed primarily at enhancing efforts to reduce contaminant levels in beluga, their prey and habitat, and at understanding their pathways of effects (Table 2). Research on the physiological effects of contaminants on SLE beluga has been limited since SARA listing. The studies advancing our understanding of health effects of contaminants have come primarily from other Arctic populations of beluga and other marine mammal species.

Regulatory actions to reduce toxic chemical compound discharges have been put in place for a number of compounds after 2005, although regulations were already in place for several chemical compounds before that time (Table 2). Contaminated terrestrial and aquatic sites have been identified and prioritized for decontamination long before SARA listing (in 1998), and decontamination initiatives have been put forward at various sites in the Great Lake region since then (see Table 2).

6.2.1.1 Effectiveness of actions

Given that beluga are exposed to a variety of pollutants that have different histories in terms of introduction date, abundance and persistence in the environment, as well as regulatory actions, it is challenging to assess whether the threat from contaminants as a whole, has decreased for beluga.

Beluga are long-lived and several contaminants are persistent and volatile. As a result, expectations were that it would take several years for changes in contaminants in beluga prey or the environment to cascade into significant changes in beluga contaminant burdens and health. Overall, there are signs that actions undertaken over the past several decades have improved the quality of SLE beluga habitat and prey for some contaminants. These improvements have had cascading effects into beluga. Concentrations of several persistent organochlorine compounds that are now regulated, such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyl (PCBs), or mirex remain high in SLE beluga, but they have stopped increasing. Some of these compounds have started to show declining trends, especially in reproductive females, who can offload some of their contaminant burden to their newborn calf (Gouteux et al. 2003; Lebeuf et al. 2007; 2012; 2014).

Conversely, highly toxic flame retardants such as the polybrominated diphenylether (PBDEs), for which regulations have been implemented only recently, increased exponentially in beluga tissues during the 1990s. Since then, levels either stabilized or continued increasing but at a slower rate (Lebeuf et al. 2014; Simond et al. in press). Other, emerging and currently unregulated contaminants remain unquantified in beluga tissues given the currently limited research efforts steered toward contaminants and SLE beluga (but see Simond et al. in press).

There is some indication that for some classes of contaminants, the recovery measures completed to date have had positive effects on beluga habitat, with cascading effects on beluga health. A notable example is the apparent decrease in the incidence of cancer in beluga born after the abrupt decline of PAH concentrations in surface sediments of their summer area (Lair et al. 2016). It is also possible that the decrease in cancer is linked to PCB reductions, which indirectly acts on levels of PAH by altering their degradation into carcinogenic metabolites (Lair et al. 2016). It is not possible to determine the specific contribution of the various management actions undertaken (e.g., regulations for certain contaminants vs cleaning of contaminated sites) to the overall improvement in beluga health and contamination.

These results are encouraging and indicate that actions that have been undertaken in the Great Lakes or other sectors upstream of, or within the SLE beluga habitat have been effective to some extent in reducing the overall input of contaminants in the beluga environment over a time scale of a few decades. However, levels of regulated contaminants continue to be high in beluga even if some have stabilized or declined in their tissue. Others such as PBDEs continue to increase, indicating that current actions are not sufficient to abate this threat.

6.2.1.2 Focus of improvements to current recovery measures and additional measures

PBDEs and other highly toxic flame retardants are currently of great concern as they are suspected to be playing a role in the lack of beluga recovery, and the worsening of their situation. Since 2008, an abnormally high number of beluga newborn calves were found dead in the SLE (Lesage et al. 2014b), a trend which has been accompanied since 2010 by a new phenomenon of regular reports of peripartum complications among dead adult females (Lair et al. 2016). Interference of PBDEs with normal thyroid activity has the potential to induce such effects, or to make neonates less fit to survive (Lair et al. 2016).

In light of the achievements of recovery measures that have been completed, and of these recent findings, recovery measures to reduce threat from contaminants should aim primarily at continuing to

reduce toxic chemical compound discharges and transport to beluga habitat. Measures need to include additional regulations, full application or expansion of existing regulations (see Table 2 for specific regulations), adequate enforcement, as well as decontamination of aquatic and terrestrial sites (Table 3). PBDEs and emergent flame retardants need to receive particular attention given their high toxicity, and possible role in the current increase in mortality of adult females and calves. It is important to note that improvements resulting from the implementation of any measure aimed at reducing the threat of contaminants will only become evident over the longer-term (i.e.: >10 years) due to the nature of the threat.

6.2.1.3 Monitoring and research to support recommended recovery measures

Given the wide and changing variety of toxic chemical compounds in the environment, there is a need to review the information available on contaminant loads in beluga, toxicity thresholds and expected health effects in order to ensure regulatory actions are steered toward the top priority toxic chemical compounds.

Time series exist for the incidence of cancer, peripartum problems, and for levels of several toxic organochlorine compounds in beluga; time series may exist for sentinel species and habitat, but this could not be determined within the timeframe that this review was completed. Existing time series have proved to be useful indicators of effectiveness of actions taken to reduce beluga exposure to toxic chemical compounds. As such, monitoring of these aspects needs to be maintained. Time series should also be built to monitor levels and trends of emergent flame retardants and other toxic chemical compounds in beluga and their habitat, to help assess the effectiveness of the recommended recovery measures addressing those contaminants (e.g. regulations). Such a time series can inform the adaptation or refocusing of management measures as needed over time.

Table 3. Suggested immediate improvements to recovery measures to reduce contaminant levels in beluga, their prey, and their habitat, and to monitor effectiveness of these measures.

The rank for implementing measures is determined based on whether the scope of the measure or the benefits to the population with regards to abating the threat is large or small, and whether its impact in terms of threat abatement is direct or indirect. Timing can be 'immediate' (within 1 year), 'short-term (1-5 years), medium-term (5-10 years) or longer-term (10 + years), and represents the horizon for acquiring the scientific information necessary to implement the measure and for the effects of implementation to become evident, either in terms of a reduction of threat level or benefits to the population. A rank of 1 is given to measures that directly abate most effects from a threat; a rank of 2 is given to measures with a large scope, but with indirect impacts on the threat. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Continue to reduce toxic chemical compound discharges at the source by new regulations, or expansion of existing regulations	Large	Direct	Short-term	Longer-term	1
Continue pollution reduction efforts, in the Great Lakes system and other areas located upstream or within the beluga habitat, through inter-provincial, national and international initiatives (particularly with the U.S. and Ontario governments)	Large	Direct	Short-term	Longer-term	1
Ensure adequate enforcement of existing regulations related to toxic chemical compound discharges in Canada (see Table 2 for list of relevant regulations)	Large	Direct	Immediate	Longer-term	1
Reduce the number and scope of accidental and illegal discharges of pollutants	Large	Indirect	Short-term	Longer-term	2
Determine the areas outside of beluga habitat where the deposition, discharge, or immersion of chemical substances can eventually alter the quality of beluga habitat and prohibit the deposition, discharge or immersion of chemical substances in those areas.	Small	Direct	Short-term	Longer-term	2
Continue the clean-up of the top priority terrestrial and aquatic sites identified for beluga	Small	Direct	Short-term	Longer-term	2
Make stakeholders (municipalities, ZIP committee, etc.) aware of the concerns related to pollutant inputs from agricultural and other activities, wastewater treatment, waste storage sites, landfills, etc.	Large	Indirect	Short-term	Longer-term	2
Data gaps and needs for monitoring					
Based on a scientific review of beluga contamination loads, toxicity thresholds when known, and expected physiological effects for each groups of chemical			Immediate		

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
compounds, identify those most likely to result in health effects in beluga to inform and prioritize regulatory actions					
Ensure monitoring of indicators for reductions in high-risk contaminants in beluga (cancer incidence, loads) by maintaining the carcass monitoring and sampling program			Immediate		
Monitor the number and size of accidental and illegal discharges in the St. Lawrence system			Short-term		
Establish performance indicators for reductions in high-risk contaminants in beluga habitat, and ensure monitoring at an appropriate scale and frequency (to be defined).			Immediate		
Improve our understanding of toxicity thresholds, pathways of effects, and impacts of key contaminants on beluga and other sentinel species. This information will allow determination of the levels at which different classes of contaminants represent a threat or are no longer a threat to beluga, and could inform adaptive management and regulations			Longer-term		

6.2.2 Recovery measures associated with objective 2. Reduce anthropogenic disturbances

Recovery measures that fall under the second recovery objective aim to reduce the threat of anthropogenic disturbances. A variety of anthropogenic activities can interfere with the normal activities of SLE beluga either by masking important acoustic signals, or by inducing behavioural or stress responses (Clark 2009). These activities mainly include: shipping, ferry operations, whale-watching, recreational boating (either motorized or non-motorized), research activities and marine development projects. While shipping has existed in the SLE for over a century, whale-watching and other activities are more recent. Similarly, time series to evaluate trends in these activities are limited to only one or two decades, and to only a few years in the case of their impacts (e.g., noise levels) (see Appendix 1).

The mitigation of effects from disturbance and noise is a relatively new phenomenon, with the first studies being conducted in the Arctic in the 1970s. Therefore, very few actions were undertaken to mitigate this threat prior to posting of the first SLE beluga recovery plan in 1995, and several others were implemented after SARA listing 2005. Some of these measures aimed at better defining levels where significant effects might occur, while others intended to reduce physical disturbance of beluga, or noise levels in their habitat (Table 2).

6.2.2.1 Effectiveness of actions

The research conducted under the auspices of the Recovery Strategy led to a better understanding of the vessel fleet characteristics and composition, and of the vessels that are most likely to interfere with the SLE beluga's normal behaviour. This potential for interference exists, either because of vessel noise output (e.g., container ships), the amount of transits they represent (e.g., ferries), their location (overlap with important habitats for females and calves), or their acoustic overlap with beluga echolocation or communication frequency bands (e.g., whale-watching vessels) (McQuinn et al. 2011; Gervaise et al. 2012; Simard et al. 2014; 2016). Impact studies indicate that merchant ship traffic exposes a substantial proportion of the SLE beluga population to noise levels likely to induce negative responses many times a day, the vast majority of exposed animals being females with calves or juveniles (Lesage et al. 2014b). Studies also indicate that ferries and other large ships can reduce the acoustic habitat of beluga to a fraction of what it is expected to be under natural conditions (Gervaise et al. 2012), and that the noisiest areas are located along the north shore and at the mouth of the Saguenay River, with the quietest areas being found along the south shore and in the Upper Estuary (McQuinn et al. 2011; Lesage et al. 2014a; Roy and Simard 2016).

Several of the recovery measures implemented have likely raised awareness about the conservation status of SLE beluga, or have contributed to limiting disturbance or noise output in beluga habitat. However, there is no indicator available to assess changes since the species was listed in underwater noise levels, beluga exposure to noise, compliance with regulations, or the extent to which development projects where noise mitigation measures were to be implemented effectively complied with these requirements. Therefore, the effectiveness of recovery measures aimed at reducing the noise aspects of the disturbance threat cannot be assessed in quantitative terms here.

A review of the evolution of marine traffic and interactions with SLE beluga indicates that more can be done to reduce beluga exposure to whale-watching activities, which contribute both to the noise and

physical disturbance aspects of the threat. Beluga are targeted by a small percentage of the whale-watching activities in the Lower SLE, but this percentage might have slightly increased over recent years. In the Upper SLE, an area used almost exclusively by females and calves and juveniles, whale-watching operations are limited, but are focused largely or exclusively on beluga (Ménard et al. 2014; Martins 2016).

Overall, there is currently no indication that interactions of beluga with vessels or the amount of traffic (merchant, recreational, whale-watching) in their habitat, a proxy for underwater noise levels and level of disturbance have decreased since SARA-listing in 2005. Therefore, we consider the recovery measures implemented to date to have been collectively ineffective at reducing the threat from underwater noise and physical disturbance.

6.2.2.2. Focus of improvements to current recovery measures and additional measures

Unusually high numbers of dead beluga calves were reported in 2010 and 2012 (Lesage et al. 2014b). These anomalies coincided with peaks in recreational boating activities at the Tadoussac marina, higher-than-usual co-occurrences between beluga and boats in the Saguenay Fjord, and good weather conditions during July and August in the critical habitat of SLE beluga (Ménard et al. 2014). These results have raised concerns about a potential link between anthropogenic disturbance during the calving period, and increased calf and female peripartum mortalities reported in those years.

Under the new Quebec Maritime Strategy, and other recent or proposed economic development initiatives within and outside the SLE beluga's habitat, it is expected that the number of merchant ship transits through the beluga habitat will increase. These new activities may add traffic in areas located outside the main shipping lane, and that are currently relatively quiet and only lightly exposed to marine traffic. This increased activity is of concern as it might result in an overall decrease in the quantity of quiet habitat available to beluga.

There are several recovery measures that could be undertaken relatively rapidly that would result in immediate reductions of beluga exposure to noise and interactions with vessels, and would help mitigate impacts from future developments. Identifying and protecting areas of the SLE that are both currently relatively quiet and important for SLE beluga could result in the creation of acoustic refuges or 'opportunity sites', allowing important conservation gains to be made for the future, at little societal costs (Williams et al. 2015). Within the limits of the SSLMP, a review of the zoning plan to implement exclusion zones could enhance protection of important habitats from noise and physical disturbance. Examining the placement of shipping routes relative to important beluga habitat can also be done in the short-term and might reveal areas where minor adjustments can be made that result in significant gains in terms of acoustic quality of the habitat or reduction in beluga exposure to noise. Replacing noisy highly-used ferries such as the Baie Sainte-Catherine/Tadoussac ferry by road infrastructure or quieting down ferries could considerably reduce noise levels in an important habitat of beluga.

Actions also need to be undertaken to increase awareness and compliance of users with regulatory and voluntary measures. Research-based actions leading to a better characterization of the fleet (both merchant ships and whale-watching vessels) would help steer efforts toward the most problematic vessels.

Currently, new development projects, including their associated vessel traffic, are assessed on a case-by-case basis for their impacts, without consideration of impacts they might generate outside the immediate vicinity of project location, or of impacts from other projects or activities allowed in the same region. A strategic (or programmatic) review of all activities and development projects contributing to noise and vessel traffic in the SLE is greatly needed, as it will provide a framework to set management objectives (e.g., in terms of noise levels or amount of traffic not to exceed), improve spatial planning, and assess and manage cumulative or aggregated effects of economic activities on the beluga and its habitat (Wright and Kyhn 2014).

6.2.2.3 Monitoring and research to support recommended recovery measures

No indicator of effectiveness exists for any of the past recovery measures dealing with this threat. Indicators should be developed in priority to assess the evolution of noise levels and traffic in key habitats for beluga, as well as the degree of interactions between SLE users and beluga. Research that helps better understanding how chronic sources of noise negatively impact beluga health and behaviour could help better target recovery actions and inform management objectives for noise and traffic levels.

Table 4. Suggested immediate improvements to recovery measures to reduce anthropogenic noise and disturbance, and to monitor effectiveness of these measures.

Definitions are provided in Table 3. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Identify candidate acoustic refuge areas, and undertake actions for their creation	Large	Direct	Short-term	Immediate	1
Increase the distance between shipping lanes and areas important to SLE beluga (e.g., moving shipping lane, pilot station)	Large	Direct	Short-term	Immediate	1
Increase distance between pleasure crafts and whale-watching vessels by revising the SSLMP zoning plan and implementing exclusion zones	Large	Direct	Short-term	Immediate	1
Reduce the acoustic footprint of vessels that generate a large amount of traffic in the beluga habitat (e.g., ferries, Canadian merchant ships), which could be done by replacing some ferry traffic with road infrastructure or by using quieting technologies on vessels contributing the most to traffic.	Large	Direct	Medium-term	Immediate	1
Enhance enforcement of the *SSLMP Regulations*, and of the *MM Regulations* outside of the SSLMP, especially in important habitats of the Upper Estuary	Large	Direct	Short-term	Immediate	1

Extend the no-boat 400 m zone for beluga observations within the SSLMP to areas outside of the SSLMP	Large	Direct	Immediate	Immediate	1
Develop and promote incentives to reduce noise output from vessels, and to eliminate the noisiest vessels	Large	Direct	Medium-term	Immediate	1
Make mitigation of noise and monitoring of the effects of the mitigation mandatory for marine development projects likely to affect beluga habitat	Small	Direct	Immediate	Immediate	2
Proceed with a strategic review of all activities and development projects that have, or could, contribute to noise and vessel traffic in beluga habitat, in order to set management objectives, and be able to account for cumulative effects and current and new development initiatives occurring both inside and outside SLE beluga habitat	Large	Indirect	Short-term	Medium-term	2
Enhance awareness among merchant ship captains about how changing their behaviour can effect change in beluga habitat acoustic quality, with the aim of increasing compliance with voluntary measures	Large	Indirect	Short-term	Immediate	2
Data gaps and needs for monitoring					
Develop indicators for effectiveness of recovery measures (either existing or new) (e.g., degree of enforcement, compliance with regulatory or voluntary measures, noise levels in key areas, acoustic space of beluga) and monitor them at an appropriate temporal scale (specific to the recovery measure)			Short-term		
Complete characterization of the fleet in order to identify vessels most contributing to the acoustic footprint, either in terms of number of transits or source level			Short-term		
Review innovations and technical solutions available worldwide that would be applicable to shipping or whale-watching vessels to reduce noise output, and assess their feasibility in the SLE			Immediate		
Develop a framework to assess and monitor cumulative disturbance and noise effects associated with whale-watching, shipping and other development initiatives			Short-term		
Carry out studies to determine the short- and long-term effects of chronic forms of disturbance on beluga health and condition			Short-term		

6.2.3 Recovery measures associated with objective 3. Ensure adequate and accessible food supplies

Recovery measures that fall under the third recovery objective aim to reduce the threat of inadequate and inaccessible food supplies. The effectiveness of recovery measures addressing this threat ultimately depends on the ability to identify the key prey species of SLE beluga. While an extensive diet study was conducted in the 1930s (Vladykov 1946), this information remains of limited use to assess current diet given it was mostly acquired from a site that is no longer used by SLE beluga today. Contemporary diet information is limited given that beluga found dead of illness often have empty guts. However, some insights into beluga spring and summer diet have been gained from continued sampling efforts of beluga guts, as well as through indirect methods using various chemical tracers such as stable isotopes, fatty acids and contaminants (Nozères 2006; Lesage 2014; Lesage et al. 2017). While data indicate a diverse diet, they also suggest that the bulk of the beluga diet is formed of only a handful of prey species, and that the species targeted varies by month, location and season. Groundfish such as cod species, redfish, white hake, and several forage species such as capelin, herring and sandlance, along with tomcod and rainbow smelt are probably important for SLE beluga. As a result, actions directly or indirectly protecting or increasing the abundance of these species are likely to be beneficial to SLE beluga.

Recent studies also highlighted a link between a decline in sea ice cover and water temperature and a decrease in beluga calf survival (Williams et al. in press). These warming conditions may have affected beluga directly, but more likely, indirectly by affecting prey distribution and biomass and thus, their availability to adult females (e.g. Buren et al. 2014).

The management and monitoring of fish and invertebrate populations that may constitute potential prey of beluga is conducted by DFO and has been implemented well before posting of the recovery plan (1995) or Recovery Strategy (2005), with an implementation date varying among species. Currently, there is little effort to specifically monitor marine fish and invertebrate stocks in the SLE simply because of the low levels of fishery. Exceptions exist for some anadromous and diadromous species such as the American eel, tomcod and rainbow smelt.

Recovery measures proposed in the Recovery Strategy were meant to enhance protection of prey spawning and rearing sites and limit removals by fisheries or other activities likely to affect prey or their habitat (Table 2).

6.2.3.1 Effectiveness of actions

Scientific studies indicate that some of the prey available to beluga are produced locally while some are imported from the Gulf of St. Lawrence. Therefore, in order to be effective, recovery measures need to target prey in the two regions. Recovery measures that were put in place to limit commercial fisheries or protect fish or their habitat in the SLE have likely been beneficial to beluga, although there is no direct quantitative indicator of the effectiveness of these measures for improving prey availability to beluga. In the Gulf of St. Lawrence, the absence of fishing for some forage species helped mitigate the threat of inadequate food supplies to some extent, since it prevented fisheries for some forage species that the beluga either prey upon (e.g., sandlance), or that the beluga's prey depend on (e.g., krill and copepods). In 2009, a new policy `New Fisheries for Forage Species` was introduced. The policy allows a forage fish

fishery in cases where all the conservation objectives prescribed by the directive are met. However, no new fishery of this type has been proposed or undertaken since SARA-listing or since the 2009 directive was implemented.

Groundfish stocks in the Gulf of St. Lawrence collapsed in the early 1990s and some of these species represent beluga prey (e.g., cod, redfish). These once abundant resources were never replaced by pelagic fish or other species, leaving the ecosystem in an overall biomass deficit (Plourde et al. 2014). A moratorium on the Atlantic cod fishery has been implemented in the SLE and southern Gulf of St. Lawrence since 2009 to allow population recovery, and remains in place today. However, stock size remains at a small fraction of levels that prevailed in the 1970s or 1980s. Globally, several of the groundfish stocks, and forage species that might be particularly important for beluga (e.g., 4T spring herring) remain at low levels. Therefore, we conclude that recovery measures implemented since SARA-listing have been ineffective at increasing beluga access to adequate prey biomasses. In fact, little has been done to address this threat, which up until recently, was only considered a potential threat.

6.2.3.2 Focus of improvements to current recovery measures and additional measures

The decline of the beluga population in the late 1990s and changes in population dynamics coincided with changes in several environmental conditions, including a decline in the abundance of demersal fish and some pelagic prey (Plourde et al. 2014), suggesting that food supply may have become limited and may still be playing a role in the current decline. A population viability analysis indicated that management actions leading to an improvement in demersal fish and 4T spring herring availability would have beneficial effects on the SLE beluga population growth rate (Williams et al. in press). Therefore, recovery measures acting on the levels of current and new fisheries, or protecting the habitat of beluga prey, including their food supply (forage fish and invertebrates), could help increase prey availability to beluga (Table 5). For instance, there is currently a fishery for 4T spring herring, a prey that might be particularly important for SLE beluga in the spring, and whose stock has collapsed around the year 2000 (Plourde et al. 2014). This stock is currently in the critical zone of the DFO Precautionary Approach and while reduction in commercial catches were applied since 2000, poor recruitment has constrained the rebuilding of this stock. Further reduction of harvest levels on herring (targeting mainly the spring component) could help the rebuilding of this key forage species to a healthy status, which would benefit beluga.

6.2.3.3 Monitoring and research to support recommended recovery measures

Our understanding of the beluga diet is still highly imperfect. Studies underway and using chemical tracers and gut contents need to be completed to ensure that recovery measures are focused on the most important prey species. These studies could be complemented by field studies of beluga feeding strategy and habitat use in order to gain insights into diet via habitat functions and characteristics. Approaches using bio-energetic models could help estimate beluga energy requirements and food supplies needed to support the population and allow recovery.

In parallel, there is a need to develop trend indicators that are specific to forage species and other beluga prey. Given the potential role of the receding sea ice cover, and of warming temperatures in explaining changes in prey distribution, biomass, or quality, monitoring programs for these physical aspects of the

beluga environment need to be maintained to provide the context for interpreting changes in population dynamics of SLE beluga or other biological components of their ecosystem

Table 5. Suggested immediate improvements to recovery measures to ensure adequate and accessible food is supplied to beluga, and to monitor effectiveness of these measures.

Definitions are provided in Table 3. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Review fisheries allocations and make changes if needed to protect and enhance standing stocks for key prey species and their availability to beluga	Large	Direct	Short-term	Short-term	1
Implement more stringent measures or a ban for some fisheries targeting forage species (e.g. capelin, herring, sandlance), or the food on which the forages species rely (e.g. krill and copepods) in the Gulf of St. Lawrence, and/or SLE, to ensure that all species associated with beluga food requirements are maintained in a healthy state.	Large	Direct	Short-term	Short-term	1
Acknowledging that prey origin may not be just the SLE, systematically implement measures to protect beluga prey and their habitat when assessing environmental impacts of inshore and offshore projects	Large	Direct	Short-term	Immediate	1
Enhance protection of spawning and rearing sites and migration corridors of key beluga prey species	Large	Direct	Short-term	Short-term	1
Explicitly consider the beluga's food requirements when assessing new or existing fisheries in the Gulf of St. Lawrence and the SLE	Large	Direct	Medium-term	Immediate	1
Formalize the prohibition of trawl nets in the Upper St. Lawrence Estuary to protect beluga prey habitat	Large	Direct	Short-term	Immediate	1
Data gaps and needs for monitoring					
Complete dietary studies, and undertake studies on feeding strategies and habitat functions			Short-term		
Develop indicators of prey availability in the SLE and monitor them regularly (to be defined)			Short-term		
Maintain monitoring programs for sea ice cover and seawater temperature in the SLE and Gulf of St. Lawrence			Immediate		

6.2.4 Recovery measures associated with objective 4. Mitigate the effects of other threats to population recovery

Recovery measures that fall under the fourth recovery objective aim to reduce the effects of other threats to population recovery. Among these other threats, collisions with small vessels (non-merchant ships) and entanglement in fishing gear have been responsible for a small number of deaths. Out of a sample size of 222 documented beluga deaths, 8 (4%) and 2 (1%) deaths were attributed to collisions and entanglement, respectively (Lair et al. 2016). Collision risk increases with speed and manoeuvrability, therefore the risk is relatively higher for smaller vessels than larger ones. Risk of entanglement is likely associated with gillnets in the SLE, although the type of gear involved in the documented deaths was not confirmed (Lair et al. 2016). Fisheries in the SLE currently operate at very low levels and therefore, incidents involving bycatch or entanglements of beluga have been rare in recent times.

Beluga also face a number of sporadic anthropogenic threats, which have the potential to cause multiple deaths in a short time, including spills of toxic substances, harmful algal blooms, and epizootic diseases (an epidemic in an animal population). As in many other temperate coastal areas, blooms of the harmful dinoflagellate *Alexandrium tamarense* occur on a regular basis in the SLE, with three major red tides documented in the past two decades (Scarratt et al. 2014). This algae has been associated with mortality of SLE beluga and other marine species in 2008 (Scarratt et al. 2014). Eutrophication (an increase in nutrients that promotes the growth of plants that take up oxygen and cause death of fish or mollusks), climatic variability, and changes in rainfall patterns may increase the frequency and severity of these events (Van Dolah 2000; Anderson et al. 2012). Given its small size, the SLE beluga population could be significantly affected by a single intoxication event (Scarratt et al. 2014).

There have been very few major toxic spills in the St. Lawrence, and so far, most have occurred in ports (Villeneuve and Quilliam 1999). However, the occurrence of strong tides and currents, seasonal ice cover, and frequent fog in the SLE and Gulf of St. Lawrence do increase the risk of toxic spills. The St. Lawrence River and Gulf of St. Lawrence has been identified among the zones where the probability of a large spill occurring is the highest (WSP Canada Inc. 2014). Because the area occupied by SLE beluga is limited, a large toxic spill could affect a significant number of individuals simultaneously and have long-term consequences for a large proportion of their range (Peterson *et al.* 2003).

Epizootic diseases have not been documented in SLE beluga. However, viruses such as papillomavirus and herpesvirus, which are the primary cause for these epidemic events, have been reported in SLE beluga (De Guise et al. 1994; Lair et al. 2014). Other pathogens such as the cetacean distemper virus or cetacean morbillivirus (CeMV) pose a high risk to SLE beluga because the population apparently has not been previously exposed to either of these pathogens (Mikaelian et al. 1999; Nielsen et al. 2000). Beluga could become exposed via range expansion of exotic infected marine mammal species as a result of climate change, or via biological contamination from municipal sewage, waste and ballast waters, and coastal runoff discharged into the St. Lawrence ecosystem. The small size of the beluga population, their gregariousness, potentially weakened immune system from chronic exposure to contaminants, and low genetic diversity make the SLE beluga population vulnerable to epizootic diseases.

6.2.4.1 Effectiveness of actions

A time series of nearly 30 years was needed to qualify the level of threat that collision risk and entanglement represent for SLE beluga (Lair et al. 2016). As a result, recovery measures were only recently put in place to reduce collision risks for SLE beluga, which represents about one individual every 4-5 years. These measures were meant to reduce the unpredictability of vessel movement to the beluga, by reducing their speed and avoiding abrupt changes in direction. While these measures have most likely been beneficial, the time series to document changes in this risk is currently too short to directly evaluate the effectiveness of this measure at reducing collision risk.

There have been very few recovery measures undertaken to address threats from toxic algal blooms, epizootic diseases, toxic spills, and fishing gear entanglement, presumably because of their relatively lower likelihood of occurrence when compared to the other threats identified for the population. However, the harmful algal bloom of 2008 indicates that when they occur, these events can remove several individuals from a population.

DFO has implemented systematic reviews of marine development projects on an individual basis since beluga Critical Habitat identification to assess impacts on beluga and their habitat, and incorporate mitigation measures when necessary. This increased scrutiny of individual projects has likely contributed to limiting habitat degradation. It must be noted that this measure did not aim at improving beluga habitat, but at limiting further degradation although again here, there is no quantitative measure of the effectiveness of this measure.

Data is currently too sparse to evaluate trends in harmful algal blooms, toxic spills, entanglements or collisions since SARA-listing. Therefore, the effectiveness of the recovery measures being implemented to address these threats remains difficult to assess.

6.2.4.2 Focus of improvements to current recovery measures and additional measures

The number of tankers travelling through the St. Lawrence transporting petroleum products and other toxic substances began to increase in 2014 with oil from Alberta being offloaded in Sorel, QC from the railway system using existing facilities, and is expected to continue to increase in the near- and medium-term future (COSEWIC 2014). As a result, risk of an accidental spill has also likely increased. There is an emergency plan for the SLE in case of an accidental toxic spill, but there are no guidelines dealing specifically with beluga (Government of Canada 2015) (Table 6).

Speed limits and codes of practice when in the presence of beluga have been put in place, but need to be better advertised. Promoting these measures with tour boat operators or pleasure craft owners through enforcement of regulations and awareness campaigns would contribute to reducing collision risk, also in addition to reducing disturbance and stress.

There is little that can be done to prevent epizootic disease outbreaks, once they have started. Reintroducing into the wild rehabilitated marine mammals that might have been in contact with pathogens can trigger such events. There is a need to formalize a directive regarding how to deal with ill marine mammals and their rehabilitation and relocation to ensure that the SLE beluga population benefits from as many individuals as possible, while minimising the risk of epizootic diseases.

Actions aiming at reducing anthropogenic inputs of nitrogen into the marine environment may help lower the likelihood of harmful algal bloom events.

6.2.4.3 Monitoring and research to support recommended recovery measures

The SLE beluga carcass monitoring program and systematic necropsies have allowed the monitoring of incidents (e.g., collisions, entanglement, intoxication), and the assessment of the relative impact of these threats on SLE beluga. The program also provides the opportunity to detect epizootic disease outbreaks. These examples demonstrate the value in maintaining the carcass monitoring program, but there remains a need for instating indicators to directly monitor trends in threat levels over time. Since 2012, the Automatic Identification System (AIS) system which is mandatory for vessels over a certain tonnage could be used to build a time series for threats from larger vessels; however, there is no similar technology available to systematically monitor traffic for smaller vessels, including the small whale-watching vessels and tour boats operating in the SLE. A monitoring program exists in the Lower SLE for harmful algal blooms, although the current situation does no longer ensure timely analysis of the collected samples. There is a need to fully reinstate the harmful algal bloom monitoring program in the SLE and to include urea among the nutrients that are monitored in the Lower SLE, as well as expanding these two monitoring programs to the Upper SLE. These programs, assuming support for timely analyses of collected samples is also provided, would allow the evaluation of trends in eutrophication, and the early detection of harmful algal bloom events, with the recognition that avoiding effects on beluga might be highly challenging. These programs are especially needed to gauge the relative importance of threats in the future, considering the potential for increase in frequency of these events due to climate change, and their value for understanding the environmental conditions favorable to such events and potentially predicting them.

Techniques currently available to recover oil in cold and ice-covered waters are known to be inefficient. Given that such environmental conditions prevail in the St. Lawrence for more than half of the year, there is an urgent need for new research to be conducted to identify ways to deal with accidental oil spills under these environmental conditions.

Indicators for compliance with regulations within the SSLMP, or with voluntary measures to reduce collision risks are also needed.

Table 6. Suggested immediate improvements to recovery measures to mitigate the effects of other threats to population recovery, and to monitor effectiveness of these measures.

Definitions are provided in Table 3. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Reduce euthophication by implementing regulations to reduce industrial, agricultural, and atmospheric inputs of nitrogen, particularly urea, a nutrient that promotes harmful algal blooms in the marine environment	Large	Indirect	Short-term	Medium-term	2
Reduce the likelihood of toxic spills (e.g., by reducing tanker traffic, improving ship hull resistance, handling methods, etc.)	Large	Direct	Medium-term	Immediate	1
Incorporate information on collision risks in the awareness campaigns targeting captains of tourist vessels and pleasure craft that are primarily aimed at reducing disturbance (see Table 4)	Large	Direct	Short-term	Immediate	1
Maintain an intervention capacity for events such as entanglements, toxic spills, diseases, and collisions through the continued operation of the Marine Mammal Emergency Response Network to increase odds of saving beluga in distress	Large	Direct	Immediate	Immediate	1
Develop and apply a formal directive on rehabilitation of ill marine mammals and their re-introduction into the wild that takes into account the risks of epidemic diseases in SLE beluga	Large	Direct	Short-term	Immediate	1
Update the environmental emergency plan for the SLE to include specific measures for SLE beluga, with clear roles and responsibilities in case of accidental spill of oil or other toxic substance	Large	Indirect	Short-term	Immediate	2
Data gaps and needs for monitoring					
Ensure the continued operation of the carcass monitoring program to detect collisions and entanglements over time, and provide the samples necessary to document potential epidemic diseases, toxic algal blooms, and the impact of these various stressors on the SLE beluga population.			Medium-term		
Develop indicators to evaluate trends in tanker traffic, and the frequency and size of toxic spill incidents			Short-term		
Carry out new research to increase our efficiency at recovering oil from cold and ice-			Medium-term		

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
covered waters					
Reinstate the toxic algae monitoring program in the SLE in order to maintain a detection capacity for harmful algal blooms, and formalize and support the monitoring program of toxins in SLE beluga			Immediate		
Include urea in the nutrients monitored in the Lower SLE, and instate a monitoring program for nutrients and algal blooms in the Upper SLE to evaluate trends in eutrophication and chances of harmful algal blooms			Immediate		
Develop indicators for compliance with regulations within the SSLMP to reduce collision risks			Immediate		

6.2.5 Recovery measures associated with objective 5. Protect the beluga's habitat in its entire distribution range

Recovery measures that fall under the fifth recovery objective do not aim to abate any one specific threat, but rather aim to fill data gaps regarding beluga distribution and high-use areas, including the functions they provide, and list broad protection measures for SLE beluga over their entire habitat.

6.2.5.1 Effectiveness of actions

Since SARA-listing, time series of aerial surveys and beluga herd tracking data have been extended and compiled to identify important habitat within the summer distribution range of SLE beluga (Lemieux-Lefebvre et al. 2012; Mosnier et al. 2016). This information was incorporated in a literature review, and largely formed the basis for identifying beluga Critical Habitat for the period from June to October (DFO 2012). Outside of this period, data remains relatively scarce (see Mosnier et al. 2010 for a review) although it suggests some beluga move to the Gulf of St. Lawrence during the fall and winter, with some remaining in the SLE.

The Government announced its intention to protect the beluga Critical Habitat in Canada Gazette I in May 2016 (http://www.gazette.gc.ca/rp-pr/p1/2016/2016-05-14/pdf/g1-15020.pdf). Once protected, any activity or undertaking likely to destroy any part of Critical Habitat will be deemed illegal. DFO currently operates under the spirit of this future protection, by systematically scrutinising marine development projects or activities on an individual basis that are likely to destroy beluga Critical Habitat, and by requiring mitigation measures when deemed appropriate. This procedure has improved the protection of SLE beluga habitat, although there is no direct indicator of effectiveness.

Currently, functions and key features of important areas of habitat within the Critical Habitat, and inter-connectivity among them, remain generally unknown, which limits our understanding of their relative importance for the recovery of the population. This knowledge is key for assessing potential impacts of marine development projects that are proposed in various parts of the beluga habitat.

Awareness campaigns and tour boat operation permit conditions that limit access to sensitive areas (e.g., limited access of tour boats to Baie Ste-Marguerite) have also likely contributed to the protection of beluga habitat, although again, direct indicators of the effectiveness of these measures do not exist.

Overall, scientific research was conducted since SARA-listing that contributed to filling data gaps and enabled Critical Habitat identification during part of the year. This identification has triggered an increased screening and mitigation of development projects and their impacts and thus contributed to increased protection of beluga habitat, which may have indirectly prevented increases in certain threats, such as underwater noise and physical disturbance. Other protective measures, including identification of Critical Habitat for the period of November through May, are pending.

6.2.5.2 Focus of improvements to current recovery measures and additional measures

The creation of a marine protected area (MPA) in the SLE, where certain restrictions similar to those enacted in the SSLMP could be in effect (e.g., limited access to sensitive areas), would help extend protection of beluga habitat to areas located along the south shore that are important to females and

calves. Enacting of the zoning regulations in the SSLMP would further enhance protection of habitat, acknowledging that adequate enforcement is needed for those to be effective (Table 7).

Currently, the Critical Habitat identified covers only areas used between June and October given that data is insufficient outside of the summer period to identify important habitats. Critical Habitat identification should be extended as needed to include habitats used at other times of the year.

6.2.5.3 Monitoring and research to support recommended recovery measures

There is a need to identify high-use areas for the spring, fall and winter periods in order to extend Critical Habitat as needed and enhance protection via the Species at Risk Act. There is also a need to have a better understanding of the social structuring of the beluga population, and of the inter-connectivity among high-use areas, which currently impairs our capacity to fully assess potential impacts of development projects. Data exist to address these questions; it should be analyzed and results made available.

Table 7. Suggested immediate improvements to recovery measures to protect the beluga habitat in its entire distribution range, to monitor effectiveness of these measures.

Definitions are provided in Table 3. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Set up the St. Lawrence Estuary Marine Protected Area Project and the Manicouagan Aquatic Reserve, and use them as a framework for instating additional protective measures directed toward SLE beluga as needed	Large	Direct	Short-term	Short-term	1
Enact zoning regulations in the SSLMP to protect high-use areas, and enhance enforcement	Large	Direct	Short-term	Immediate	1
Publish the Critical Habitat Order in Canada Gazette II to formalize the legal protection of the critical habitat that is currently identified for SLE beluga	Large	Indirect	Short-term	Short-term	1
Data gaps and needs for monitoring					
Develop indicators for effectiveness of habitat protection measures			Short-term		
Identify and protect important habitat that are used by SLE beluga outside of the summer months, including the characteristics that make these habitats favourable to beluga, and the vital functions they support			Short-term		
Determine the proportions of the SLE beluga population using the different sections of their distribution range to better assess potential impacts of marine development projects on population recovery			Short-term		
Publish the data accumulated over the past 25 years that documents the social organization and spatial structure of social units in the SLE Estuary so to bring an important perspective to impact assessments and protective measures			Short-term		

6.2.6 Recovery objective 6. Ensure regular monitoring of the St. Lawrence Estuary beluga population

Since SLE beluga were first assessed as Endangered by COSEWIC in 1983, several programs have been implemented to monitor different aspects of the population. These include a beluga carcass monitoring program (begun in 1982 and fully implemented starting in 1983), which comprises of full necropsies of carcasses that are relatively well preserved. This program has been maintained since 1983.

Monitoring of population size and distribution, as well as recruitment rate, using a standardized method (photographic aerial surveys) has also continued over time. However, these surveys were conducted on a more irregular basis after 2000, reducing our capacity to detect population trends thereafter. Another monitoring time series (based on visual aerial surveys) was initiated in 2001, which offers a parallel, although not comparable, index estimate of population trends. However, visual surveys do not allow detection of calves and so, cannot provide an index of recruitment.

A photo-identification study, conducted by the Group of Research and Education on Marine Mammals (GREMM) has been ongoing since the late 1980s. This program has the potential to contribute to documenting and explaining changes in recruitment rate, habitat use and other ecological questions.

6.2.6.1 Effectiveness of actions

The carcass monitoring program has provided long-term information on population parameters (Lesage et al. 2014b) and causes of death (Lair et al. 2016), and the value of this program for assessing the status of the beluga population has been examined (DFO 2007). This program also provided tissue samples that have allowed monitoring different kinds of toxic chemical compounds (e.g., Lebeuf et al. 2014; see also DFO 2012 for a review), and of other chemical tracers that provided insights into changes in trophic ecology and diet (Nozères 2006; Lesage 2014; Lesage et al. 2017).

The aerial surveys have allowed an age-structured population dynamics model to be built, which enables examining population trends in a biologically meaningful framework (Mosnier et al. 2015). Both population size estimates and recruitment indices from the surveys are used in this exercise. Surveys also provided the necessary information to conclude that there is currently no indication of an expansion or shrinkage of the population's distribution (Gosselin et al. 2014). However, abundance estimates are highly variable and sometimes comprise large uncertainty. This, combined with the small number of estimates obtained due to large time intervals between surveys, reduces the capacity to detect changes in population abundance in a timely manner.

The photo-identification program of the GREMM provided an index of the evolution of recruitment rate over 25 years (Michaud 2014). This data contributed to the validation of model outputs about population dynamics and trends (Mosnier et al. 2015; DFO 2014).

6.2.6.2 Focus of improvements to current and additional monitoring measures

The outcome of the recent DFO review (DFO 2014) of the status of SLE beluga highlights the importance of these monitoring programs in understanding the fate of the SLE beluga population. Therefore, these programs (e.g., the carcass monitoring program, population survey program) should be maintained. However, there are currently very few tools to document changes in health condition or reproduction rate and so there is a need to put in place additional monitoring activities to document these aspects which are key indicators of the sub-lethal and population-level effects of human and natural stressors.

Table 8. Recovery measures to ensure regular monitoring of the SLE beluga population.

Data gaps and needs for monitoring	**Anticipated timing**
	Initiate implementation
Maintain the carcass monitoring program and necropsy program to continue to document population parameters, causes of mortality, and incidence of various threats over time	Immediate
Continue to conduct systematic aerial surveys, at least every three years, to document changes in distribution, population size, and proportion of calves	Short-term
Develop methods to assess health, body condition, and reproductive rate, and monitor on a yearly basis	Short-term

7. Conclusions

When the review to estimate the potential for recovery of the SLE beluga population was conducted after SARA listing in 2005, the population was considered to be stable or increasing at a maximum of 1% per year (Hammill et al. 2007). The subsequent DFO review in 2013 revealed that at the time of SARA listing the population was actually already on the decline and had been doing so since about 2000 (DFO 2014). The major changes in population dynamics and trends at that time coincided with a worsening of several environmental parameters that were considered to already be unfavorable to beluga recovery; and thus the situation deteriorated further. These included: further decreases in prey availability relative to long-term averages for the Gulf of St. Lawrence; a warming climate; chronic exposure to shipping traffic, and disturbance from increasing whale-watching activities in parts of the beluga Critical Habitat; high levels of a larger number of contaminants (e.g., PCBs, DDTs, PBDEs); and episodic harmful algal blooms. The population is now considered *Endangered* and is still declining. From this, we conclude that collectively, recovery measures implemented following the first Recovery Plan (Bailey and Zinger 1995) and those implemented after SARA listing have not succeeded in abating threats sufficiently to allow population growth and recovery.

Data that has become available through the recent DFO review (DFO 2014) has not identified any additional threats to the SLE beluga recovery that were not included in the recovery strategy. However, it has changed our perception of the relative importance of the previously identified threats. High contamination, high noise levels and potential for disturbance, and shortage of food supplies continue to

be considered the main threats to SLE beluga recovery. However, shortage of food supplies, which was viewed as a likely imminent but undocumented threat at the time the Recovery Strategy was published in 2012, is now seen as one of the main factors likely involved in the current decline of the population (Plourde et al. 2014; DFO 2014; Williams et al. in press). Similarly, harmful algal blooms were considered a potential threat of medium concern. While there was no evidence that two of the three harmful algal blooms documented over the past two decades (see Scarratt et al. 2014) increased mortality in SLE beluga, the die-off of several beluga and other marine species in 2008, most likely as a result of a harmful algal blooms (Scarratt et al. 2014), has brought a very concrete perspective to the potential effects of such events on population dynamics, and has raised the level of concern for this threat.

Recovery measures implemented to date have been a mix of science/research and management-based measures. While nothing has really been done since 2005 to increase beluga access to food supplies, or to effectively mitigate noise and disturbance, we can conclude that recovery measures aiming at reducing legacy organochlorines in the beluga environment have been effective at reducing mortality from cancer in beluga. However, these efforts were counterbalanced by parallel exponential increases of other toxic chemical compounds (e.g., PBDEs), which might today be at least partly responsible for the high incidence of peripartum problems in females and newborn calves.

A cumulative model incorporating the top threats with the exception of harmful algal blooms (i.e., food supply shortage, high contamination, and noise and disturbance from marine activities) and their effect on population dynamics failed to determine which of these three threats needed to be the most urgently addressed to allow the population to grow (Williams et al. in press). Instead, this analysis indicated that simultaneous and aggressive mitigation of all three threats is needed in order for the population to maintain the necessary resilience to cope with effects from the warming climate. This report proposes recovery measures to abate threats. However, scientific evidence to identify the level below which a threat is no-longer likely to induce biologically significant effects on SLE beluga are generally lacking. Therefore, our capacity to even qualify the benefits for the population from specific recovery measures is also limited. Notwithstanding this, abating the three main threats is under our control, cannot harm the population, and provides the best chance for population growth.

To abate the threat from contaminants, there is a need to undertake actions promptly to reduce, or further reduce, levels of PBDEs and other flame retardants, and to enhance control over the discharge of other highly toxic substances (e.g., PAH, Mirex, PCBs, DDTs), in areas located upstream or within the beluga habitat.

Given that noise attenuates with distance, and in general with vessel proximity, the most effective way to reduce threats from noise and disturbance is to increase the distance separating ships, ferries and small crafts from the beluga or their important habitats. The replacement of ferries by road infrastructure at the mouth of the Saguenay Fjord would result in high and immediate gains for abating one of the top threats contributing to the prevention of recovery, as it would remove thousands of vessel transits each year in important beluga habitat where ensonification is the highest and the most chronic (McQuinn et al. 2011). Priority should also be given to re-examining the placement of shipping lanes and the pilot station as it is probable that adjustments could be made that would result in significant and rapid gains in terms of quieting important beluga habitats. In parallel, there is also a need to limit beluga interactions with

recreational and whale-watching vessels, or activities resulting from marine development projects. An extension of the limit to beluga approaches (i.e., the 400 m no-boat zone) for sectors located outside of the SSLMP by including this measure in the Marine Mammal Regulations, and the creation of exclusion zones (e.g., acoustic refugees) in and outside the limits of the SSLMP, combined with adequate enforcement and awareness campaigns, would be highly effective at rapidly abating threat from noise and disturbance. These high priority measures are particularly important to implement promptly, considering the foreseen increase in noise and marine traffic as a result of recently implemented, or recently proposed, projects to expand oil and mineral transportation from ports located upstream or within the beluga habitat.

Effects of a warming climate on ecosystem structure and prey availability for beluga are difficult to prevent on the short-term. However, actions aiming at increasing standing stocks of potentially important prey of beluga, such as herring, rainbow smelt, tomcod, American eel, and some of the groundfish species, could provide beluga with a greater access to prey. Such actions include reductions of removals by existing fisheries, or even possible bans on additional forage species fisheries, and increased protection of spawning sites. Promptly completing the research on diet and habitat use would help identify key prey species, and focus management actions on the most important species.

The 2008 harmful algal bloom strikingly highlighted how these events can affect survival and population dynamics. Eutrophication through the increase in nitrogen and urea levels in water in particular, and climate change, which has circumstantially been identified as the cause for novel algal bloom episodes, may make these events more frequent (Anderson et al. 2012). Therefore, there is a need to implement regulatory actions to reduce inputs of some nutrients such as urea-enriched compounds (e.g., from agricultural fertilizers, improperly treated effluent) in the beluga habitat or upstream of it, to help limit the occurrence of these deadly events.

In parallel to these actions, performance indicators need to be instated and monitored to assess trends in threats and how they are affecting beluga health over time in order to inform adaptive management; currently very few such indicators exist (see Appendix 1). Indicators are especially needed for monitoring beluga exposure to contaminants and to vessel noise, interactions with vessels, and access to adequate prey. Monitoring programs exist to document population dynamics and trends, distribution, level of some threats (e.g., collision, entanglement), and causes of mortality. A monitoring program also existed within DFO for contaminants, but this program was abolished in 2014 and was not transferred to other institutions, which might impair our capacity to monitor recovery measure effectiveness in the future. The 2013 DFO review has demonstrated the importance of these programs, as they helped understand the complex and combined interactions among natural and human stressors.

These monitoring programs should also be accompanied by scientific research (see Tables 3-8 for specific data gaps) to provide the context needed for interpreting trends and to ensure that focus of recovery measures remains on components that are the most likely to contribute to abating threats. The development of models and other predictive tools would be particularly useful to test the effects of various management scenarios (e.g., traffic rerouting, speed reductions) on the level of specific threats, or on the probability of biologically significant effects on SLE beluga.

By virtue of its location downstream of important industrial centers, and the variety of valued socio-economic activities it supports, the SLE and its marine species are exposed to a myriad of human stressors. Currently, there is no mechanism for integrated spatial planning of activities in the SLE, or for setting stressor-specific management objectives, as there is no centralized tracking of authorized activities or projects, or their cumulative impacts on specific species. This is especially relevant for activities or projects that occur outside of the SLE beluga habitat, but that generate impacts in the beluga habitat (e.g., through increased marine traffic). There is an urgent need for a strategic (or programmatic) review to define upper limits to the level of specific threats we are willing to accept, and to provide context for current or planned activities and development projects that add to those threats. Such a review is especially needed for activities and projects that generate noise and disturbance, as it would provide a framework for setting management objectives in terms of noise levels or amount of traffic not to be exceeded, while improving spatial and temporal planning of economic activities such as shipping and marine development projects, and the assessment and management of their cumulative or aggregated effects on the beluga and its habitat.

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9. Literature Cited

Anderson, D.M., Cembella, A.D., Hallegraeff, G.M. 2012. Progress in understanding harmful algal blooms: paradigm shifts and new technologies for research, monitoring, and management. Ann. Rev. Mar. Sci. 4: 143-176.

Bailey, R., Zinger, N. 1995. St Lawrence beluga recovery plan. World Wildlife Fund, Toronto and Department of Fisheries and Oceans, Mont-Joli, Québec. 73 p.

Chion, C., Lagrois, D., Dupars, J., Turgeon, S., McQuinn, I.H., Michaud, R., Ménard, N., Parrott, L. 2017. Underwater acoustic impacts of shipping management measures: Results from a socio-ecological model of boat and whale movements in the St. Lawrence River Estuary (Canada). Ecol. Model. 354: 72-87.

Chion, C., Turgeon, S., Michaud, R., Landry, J.-A., Parrott, L. 2009. Portrait de la navigation dans le parc marin du Saguenay–Saint-Laurent. Caractérisation des activités sans prélèvement de ressources entre le 1er mai et le 31 octobre 2007. Présenté à Parcs Canada. 86 p. Available from: Saguenay-St. Lawrence Marine Park, 182 Rue de l'Église, Tadoussac QC G0T 2A0

Chion, C., Ménard, N. 2013. Documentation des activités de navigation et des interactions avec le béluga du Saint-Laurent dans son habitat estival entre 2003 et 2012. Unpublished report presented to Parks Canada. 28 p. Available from: Saguenay-St. Lawrence Marine Park, 182 Rue de l'Église, Tadoussac QC G0T 2A0

Conversano, M. 2013. Analyses des données de trafic maritime et sur l'utilisation de l'embouchure du Saguenay par le béluga (*Delphinapterus leucas*) du Saint-Laurent de 2003 à 2012 et comparaison de la structure d'âge des troupeaux à l'embouchure du Saguenay et à la baie Sainte-Marguerite. Unpublished report prepared for Parks Canada. Contract No. 45323586. 38 p. Available from: Saguenay-St. Lawrence Marine Park, 182 Rue de l'Église, Tadoussac QC G0T 2A0.

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

COSEWIC. 2014. COSEWIC assessment and status report on the beluga whale *Delphinapterus leucas*, St. Lawrence Estuary population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 64 p. (www.registrelepsararegistry.gc.ca/default_e.cfm) Written by K. Gavrilchuk and V. Lesage. Available from: http://www.registrelep.gc.ca/virtual_sara/files/cosewic/sr_Beluga%20Whale_2014_e.pdf)

De Guise, S., Lagacé, A., Béland, P. 1994. Gastric papillomas in eight St. Lawrence beluga whales (*Delphinapterus leucas*). J. Vet. Diag. Invest. 6: 385–388.

Desforges, J.-P. W., Sonne, C., Levin, M., De Guise, S., Dietz, R. 2016. Immunotoxic effects of environmental pollutants in marine mammals. Environ. Int. 86: 126-139.

Desforges, J.P., Ross, P.S., Dangerfield, N., Palace, V.P., Whiticar, M., Loseto, L.L. 2013. Vitamin A and E profiles as biomarkers of PCB exposure in beluga whales (*Delphinapterus leucas*) from the western Canadian Arctic. Aquat. Toxicol. 2013, 142-143: 317-328.

DFO. 2007. Impacts de la construction d'un port méthanier à Gros-Cacouna sur les mammifères marins. Secr. can. de consult. sci. du MPO., Rép. des Sci. 2007/010. Available at: http://www.dfo-mpo.gc.ca/csas

DFO. 2011a. Ajout d'un brise-lame au quai des pilotes de Les Escoumins, Québec - Effets potentiels sur les mammifères marins. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2011/007. Available at: http://www.dfo-mpo.gc.ca/csas

DFO. 2011b. Réfection des embarcadères de Tadoussac et Baie Ste-Catherine, Québec – Effets sur les mammifères marins. Secr. can. de consult. sci. du MPO, Rép. des sci. 2011/009. Available at: http://www.dfo-mpo.gc.ca/csas

DFO. 2012. Recovery Strategy for the beluga whale (*Delphinapterus leucas*) St. Lawrence Estuary population in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. x + 87 p.

DFO. 2014. Impacts de levés géophysiques au port de Cacouna sur les bélugas du Saint-Laurent. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2014/020. Available at: http://www.dfo-mpo.gc.ca/csas

DFO. 2014. Status of beluga (*Delphinapterus leucas*) in the St. Lawrence River estuary. DFO Can. Sci. Advis. Sec., Sci. Advis. Rep. 2013/076. Available at: http://www.dfo-mpo.gc.ca/csas

DFO. 2016a. Assessment of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence (NAFO Div. 4T-4Vn (Nov. – April)) to 2014. DFO Can. Sci. Advis. Sec., Sci. Advis. Rep. 2015/061. Available at: http://www.dfo-mpo.gc.ca/csas

DFO. 2016b. Effets des activités de dragage sur le béluga du Saint-Laurent et son habitat. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2016/033. Available at: http://www.dfo-mpo.gc.ca/csas

Gervaise, C., Simard, Y., Roy, N., Kinda, B., Ménard, N. 2012. Shipping noise in whale habitat: Characteristics, sources, budget, and impact on beluga in Saguenay–St. Lawrence Marine Park hub. J. Acoust. Soc. Am. 132: 76-89.

Gosselin, J.-F., Hammill, M.O., Mosnier, A. 2014. Summer abundance indices of St. Lawrence estuary beluga (*Delphinapterus leucas*) from a photographic survey in 2009 and 28 line transect surveys from 2001 to 2009. DFO Can. Sci. Advis. Sec., Res. Doc. 2014/021: iv + 51 p. Available at: http://www.dfo-mpo.gc.ca/csas

Gosselin, J.-F., Hammill, M.O., Mosnier, A., Lesage, V. 2017. Abundance index of St. Lawrence beluga, *Delphinapterus leucas*, from visual line transect surveys in August 2014. DFO Can. Sci. Advis. Sec., Res. Doc. 2017/019 : v + 28 p. Available at: http://www.dfo-mpo.gc.ca/csas

Government of Canada. 2015. Plan d'urgence pour les déversements en mer Région du Centre et de l'Arctique – Chapitre Régional. Secteur Saint-Laurent. Garde côtière canadienne. Intervention environnementale. 60 p.

Hammill, M.O., Measures, L.N., Gosselin, J.-F., Lesage, V. 2007. Lack of recovery in St. Lawrence estuary beluga. DFO Can. Sci. Advis. Sec., Res. Doc. 2007/026. 19 p. Available at: http://www.dfo-mpo.gc.ca/csas

Krey, A., Ostertag, S.K., Chan, H.M. 2015. Assessment of neurotoxic effects of mercury in beluga whales (*Delphinapterus leucas*), ringed seals (*Pusa hispida*), and polar bears (*Ursus maritimus*) from the Canadian Arctic. Sci. Total Environ. 509-510: 237-247.

Lair, S., Measures, L.N., Martineau, D. 2016. Pathologic findings and trends in mortality in the beluga (*Delphinapterus leucas*) population of the St Lawrence Estuary, Quebec, Canada, from 1983 to 2012. Vet. Pathol. 53: 22-36.

Lebeuf, M., Noël, M., Trottier, S. et al. 2007. Temporal trends (1987–2002) of persistent, bioaccumulative and toxic (PBT) chemicals in beluga whales (*Delphinapterus leucas*) from the St. Lawrence estuary, Canada. Sci. Total Environ. 383: 216–231.

Lebeuf, M., Measures, L.M., Noël, M., Raach, M., Trottier, S. 2014. A twenty-one year temporal trend of persistent organic pollutants in St. Lawrence Estuary beluga, Canada. Sci. Total Environ. 485-486: 377-386.

Lemieux-Lefebvre, S., Michaud, R., Lesage, V., Berteaux, D. 2012. Identifying high residency areas of the threatened the St. Lawrence beluga whale from fine-scale movements of individuals and coarse-scale movements of herds. Mar. Ecol. Prog. Ser. 450: 243-257.

Lesage, V. 2014. Trends in the trophic ecology of St. Lawrence beluga (*Delphinapterus leucas*) over the period 1988-2012, based on stable isotope analysis. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/126. iv + 25 p. Available at: http://www.dfo-mpo.gc.ca/csas

Lesage, V., McQuinn, I.H., Carrier, D., Gosselin, J.-F., and Mosnier, A. 2014a. Exposure of the beluga (*Delphinapterus leucas*) to marine traffic under various scenarios of transit route diversion in the St. Lawrence Estuary. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/125. iv + 28 p. Available at: http://www.dfo-mpo.gc.ca/csas

Lesage, V., Mosnier, A., Measures, L., Lair, S., Béland, P. 2014. Mortality patterns in St. Lawrence Estuary beluga (*Delphinapterus leucas*), inferred from the carcass recovery data, 1983-2012. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/118. ii + 24 p. Available at: http://www.dfo-mpo.gc.ca/csas

Lesage, V., Gosselin, J.-F., Mosnier, A., Larocque, R., Lebeuf, M. 2017. Définition et caractérisation de l'habitat du béluga du Saint-Laurent par une approche écosystémique. In Savenkoff, C., Gagné, J.A., Gilbert, M., et al. *Le concept d'approche écosystémique appliqué à l'estuaire du Saint-Laurent (Canada).* Environ. Rev. 25: 26-96.

Martineau, D., Lemberger, K., Dallaire, A., Labelle, P., Lipscomb, T.P., Michel, P., Mikaelian, I. 2002. Cancer in wildlife, a case study: beluga from the St Lawrence Estuary, Quebec, Canada. Environ. Health Perspect. 110: 285–292.

Martins, C.C.A. 2016. Les activités d'observation en mer dans le Parc Marin du Saguenay-Saint-Laurent et en périphérie. Portrait 2011-2015. Unpublished report prepared by Tryphon Océans for Parks Canada and the Groupe de Recherche et d'Éducation sur les Mammifères Marins (GREMM). 67p + iii appendices. Available from: Saguenay-St. Lawrence Marine Park, 182 Rue de l'Église, Tadoussac QC G0T 2A0.

McQuinn, I., Lesage, V., Carrier, D., Larrivée, G., Samson, Y., Chartrand, S., Michaud, R., Theriault, J. 2011. A threatened beluga (*Delphinapterus leucas*) population in the traffic lane: vessel-generated noise characteristics of the Saguenay-St. Lawrence Marine Park, Canada. J. Acoust. Soc. Am. 130: 3661-3673.

Michaud, R. 2014. St. Lawrence Estuary beluga (*Delphinapterus leucas*) population parameters based photo-identification surveys, 1989-2012. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/130: iv + 27 p. Available at: http://www.dfo-mpo.gc.ca/csas

DFO, 2007. Proceedings of the workshop on the St. Lawrence Estuary beluga – review of carcass program. DFO Can. Sci. Advis. Sec. Proc. Ser. 2007/005

Mikaelian, I., M.-P., Tremblay, C., Montpetit, S.V., Tessaro, H.J., Cho, C., House, L., Measures, L.M., Martineau, D. 1999. Seroprevalence of selected viral infections in a population of beluga whales (*Delphinapterus leucas*) in Canada. Vet. Rec. 144: 50-51.

Mosnier, A., Lesage, V., Gosselin, J.-F., Lemieux Lefebvre, S., Hammill, M.O., Doniol-Valcroze, T. 2010. Information relevant to the documentation of habitat use by St. Lawrence beluga (*Delphinapterus leucas*), and quantification of habitat quality. DFO Can. Sci. Advis. Sec., Res. Doc. 2009/098 : iv + 35 p. Available at: http://www.dfo-mpo.gc.ca/csas

Mosnier, A., Doniol-Valcroze, T., Gosselin, J.-F., Lesage, V., Measures, L.M., Hammill, M.O. 2015. Insights into processes of population decline using an integrated population model: the case of the St. Lawrence beluga (*Delphinapterus leucas*). Ecol. Model. 314: 15-31.

Mosnier, A., Larocque, R., Lebeuf, M., Gosselin, J.-F., Dubé, S., Lapointe, V., Lesage, V., Lefaivre, D., Senneville, S., Chion, C. 2016. Définition et caractérisation de l'habitat du béluga du Saint-Laurent selon une approche écosystémique. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/052: vi + 93 p. Available at: http://www.dfo-mpo.gc.ca/csas

Multipartite committee on contaminated sites of concern for the St. Lawrence beluga (1998) Contaminated sites of concern for the St. Lawrence beluga. Report presented to the St. Lawrence Vision 2000 Action Plan Management Committee. Environment Canada, Fisheries and Oceans Canada, Canadian Heritage and the Ministère de l'Environnement et de la Faune du Québec. 26 p.

Nielsen, O., Stewart, R.E.A., Measures, L.M., Duignan, P., House, C. 2000. A morbillivirus antibody survey of Atlantic walrus, narwhal and beluga in Canada. J. Wild. Dis. 36: 508-517.

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

Ostertag, S.K., Stern, G.A., Wang, F., Lemes, M., Chan, H.M. 2013. Mercury distribution and speciation in different brain regions of beluga whales (*Delphinapterus leucas*). Sci. Total Environ. 456–457: 278–286.

Ostertag, S.K., Shaw, A.C., Basu, N., Chan, H.M. 2014a. Molecular and neurochemical biomarkers in Arctic beluga whales (*Delphinapterus leucas*) were correlated to brain mercury and selenium concentrations. Environ Sci Technol. 48:11551-11559.

Ostertag, S.K. 2014b. Assessing the neurotoxicological risk of methylmercury exposure for beluga whales (Delphinapterus leucas) harvested in the Mackenzie Delta Estuary. Ph.D. Thesis. University of Manitoba. Winnipeg, Canada.

Peterson, C.H., Rice, S.D., Short, J.W., Esler, D., Bodkin, J.L., Ballachey, B.E., Irons, D.B. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. Science 302: 2082-2086.

Plourde, S., Galbraith, P., Lesage, V., Grégoire, F., Bourdage, H., Gosselin, J.-F., McQuinn, I., and Scarratt, M. 2014. Ecosystem perspective on changes and anomalies in the Gulf of St. Lawrence: a context in support to the management of the St. Lawrence beluga whale population. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/129: vi + 27 p. Available at: http://www.dfo-mpo.gc.ca/csas

Roy, N., Simard, Y. 2015. Bruit ambiant et fréquentation de la région de Cacouna par le béluga du Saint-Laurent à l'été 2014 par monitorage acoustique continu. Rapp. tech. can. sci. halieut. aquat. 3141 : vi + 22 p.

Scarratt, M., Michaud, S., Measures, L., Starr, M. 2014. Phytotoxin analyses in St. Lawrence Estuary beluga. DFO Can. Sci. Advis. Sec., Res. Doc. 2013/124: v + 16 p. Available at: http://www.dfo-mpo.gc.ca/csas

Schwacke, L.H., Voit, E.O., Hansen, L.J., Wells, R.S., Mitchum, G.B., Hohn, A.A., et al. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. Environ. Toxicol. Chem. 21: 2752–2764.

Simard, Y., Lepage, R., and Gervaise, C. 2010. Anthropogenic sound exposure of marine mammals from seaways: Estimates for lower St. Lawrence Seaway, eastern Canada. Appl. Acoust. 71: 1093-1098.

Simard, Y., Roy, N., Giard, S., and Yayla, M. 2014. Canadian year-round shipping atlas for 2013: Volume 1, East Coast marine waters. Can. Tech. Rep. Fish. Aquat. Sci. 3091(Vol.1)E: xviii + 327 p. Available at: http://www.dfo-mpo.gc.ca/Library/352593.pdf

Simard, Y., Roy, N., Gervaise, C., Giard, S. 2016. Analysis and modeling of 255 ship source levels from an acoustic observatory along St. Lawrence Seaway. J. Acoust. Soc. Am. 130: 2002-2018.

Simond, A., Houde, M., Lesage, V., Verreault, J. *in press.* Temporal trends of PBDEs and emerging flame retardants in beluga from the St. Lawrence Estuary (Canada) and comparisons with minke whales and beluga from the Canadian Arctic. Environ. Rev. (accepted 20 March 2017)

Van Dolah, F.M. 2000. Marine algal toxins: Origins, health effects, and their increased occurrence. Environ. Health Perspect. 108: 133-141.

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

Williams, R., Lacy, R.C, Ashe, E., Hall, A., Lehoux, C., Lesage, V., McQuinn, I., Plourde, S. *In press.* Predicting responses of St. Lawrence beluga to environmental changes and anthropogenic threats to orient effective management actions. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/027. v + 43 p.

Wilson, J.Y., Cooke, S.R., Moore, M.J., Martineau, D., Mikaelian, I., Metner, D.A., Lockhart, W.L., Stegeman, J.J. 2005. Systemic effects of Arctic pollutants in beluga whales indicated by CYP1A1 expression. Environ. Health Perspect. 113: 1594-1599.

WSP Canada Inc.. 2014. Risk assessment for marine spills in Canadian waters. Phase 1: Oil spills South of 60th Parallel. Prepared for Transport Canada. Report number 131-17593-00.

Appendix 1. Time series available to document the evolution of threat, and effects on SLE beluga or other components of the ecosystem.

Threat	Data type	Start date	End date	Lead
Contaminants				
	Contaminant levels in beluga	1983	On-Going	Academia, DFO
	Insufficient information available at the time of the review for contaminant levels in biological or physical components other than beluga			ECCC, DFO
	Insufficient information available at the time of the review from existing monitoring programs under the responsibility of ECCC (e.g., water quality, sediment)			ECCC
Noise/Disturbance				
	Noise levels in the beluga habitat (various stations)	2003	On-going	DFO
	Volume of merchant ship traffic (AIS)	2012	On-going	TC, DFO, Academia
	volume of merchant ship traffic (other data sources, e.g., number of trips assigned to pilots)	2003	On-going	TC, DFO
	Whale-watching trips in the SSLMP	1993	On-going	PC
	Whale-watching trips outside of the SSLMP		On-going	DFO
	Percentage of whale-watching excursions targeting beluga	2003	On-going	
	Infractions to SSLMP regulations	2003	On-going	PC
	Recreation boating activities in the SSLMP and outside its limits	2003	On-going	PC, municipalities
	Co-occurrence of beluga at the Saguenay Fjord mouth and at Baie-Ste-Marguerite	2003	On-going	PC
	Compliance with voluntary measures to reduce ship speed and avoid certain areas within the SSLMP	2012	On-going	Academia, PC, G2T3M

Threat	Data type	Start date	End date	Lead
SLE beluga				
	Abundance estimates (photographic aerial surveys)	1988	On-going	DFO
	Abundance estimates (visual aerial surveys)	2001	On-going	DFO
	Extent of summer distribution, and habitat use	1988	On-going	DFO
	Number of deaths (and age-, sex- structure)	1983	On-going	DFO, RQUMM, and various other institutions (e.g., academia, aquaria and federal departments and agencies)
	Causes of death (intoxication, cancers, infections, etc.)	1983	On-going	DFO, FMV
	Diet (digestive tracts)	1983	On-going	DFO
	Diet and trophic role (chemical tracers FA, SI)	1988	On-going	DFO
	Ecosystem structure and functioning (isotopes in key invertebrate and fish species)	1994	On-going	DFO
	Index of recruitment (photographic surveys)	1988	On-going	DFO
	Index of recruitment (beluga herd follows)	1989	On-going	ENGOs (GREMM)
Harmful algal bloom				
	Harmful algal blooms in the Lower SLE (4-5 stations, including Tadoussac)	1995	On-going	DFO
Collision risk and entanglements				
	via necropsy program	1983	On-going	PC, RQUMM
	via reports to Parks Canada	1994	On-going	PC
Environmental data				
	Sea-ice extent and duration	at least 1971	On-going	DFO
	Physical oceanographic parameters	at least 1971	On-going	DFO

Threat	Data type	Start date	End date	Lead
	Commercial species landings, index of abundance, distribution, condition, but mostly for the Gulf of St. Lawrence, not the SLE	varies according to species	On-going	DFO