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IMPACTS OF REROUTING MARINE TRAFFIC IN THE ST. LAWRENCE ESTUARY ON BELUGA (*DELPHINAPTERUS LEUCAS*): SCIENCE IN SUPPORT OF RISK MANAGEMENT

Photo: Véronique Lesage

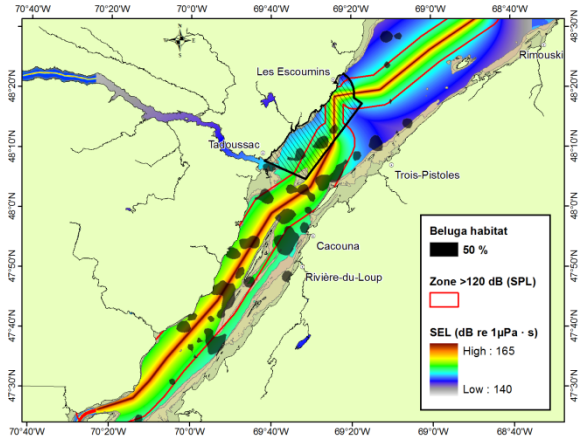

Figure 1. Simulated ZOI (SPL of 120 dB and SEL) produced from a high-noise container ship with reduced speed in the proposed Hybrid speed-reduction zone (contoured in black) transiting by the South Channel proposed Hybrid route relative to beluga core (50%) areas of concentration.

Context:

Marine mammals are regularly exposed to commercial shipping along the St. Lawrence Estuary (SLE) north shore, mostly from the North Channel (NC) shipping lane. During summer, a fleet of approximately 40 whale-watching vessels offering several departures a day adds to marine traffic by concentrating activities in this area. The NC shipping lane overlaps with the main aggregation area used by large baleen whales as well as a portion of whale-watching activity, raising concerns for potential whale/ship or whale-watch vessel/ship interactions. Motivated by the desire to reduce collision risks, authorities from the Saguenay-St. Lawrence Marine Park (Parks Canada), Fisheries and Oceans Canada (DFO), various representatives of the marine shipping industry, as well as researchers working on marine transport and marine mammals, examined various options. Amongst options explored, voluntary protection measures, which included a 10 kt speed reduction area in the lower SLE portion of the Marine Park between Les Escoumins and Tadoussac, called the 'hybrid scenario', was proposed (Figure 1). Pilots would be nonetheless left with the option of diverting their course to the South Channel (SC) southeast of Île Rouge to avoid reducing speed in the Marine Park. However, shifting some of the commercial traffic to the SC would alter the exposure of St. Lawrence Estuary (SLE) beluga and their habitat to marine traffic.

DFO Science was requested to examine marine traffic exposure of SLE beluga under the current and proposed changes to the commercial shipping route, and to determine significance of effects for this SARA-listed population.

SUMMARY

- The St. Lawrence Estuary (SLE) beluga population is listed as *threatened* under the Canadian *Species at Risk Act* (SARA), which protects species at risk from being killed or harmed (section 32; Appendix I) and protects any part of their Critical Habitat from destruction (section 58; Appendix I).
- Marine traffic may affect SLE beluga mainly through generated noise as risks of collision with large, slow moving vessels are considered low for beluga given their high maneuverability and acute hearing. Based on a review of studies, negative behavioural responses to continuous noise sources are expected at a threshold of 120 dB re 1 µPa (rms) for cetaceans such as the beluga, with best hearing sensitivity in the mid-frequencies.
- Data on marine traffic volume, ship acoustic characteristics, local sound propagation conditions and summer SLE beluga densities from 35 aerial surveys were used to determine areas of beluga concentration, the proportion of the population, and of Critical Habitat exposed to marine traffic under (a) the current traffic conditions and route (mainly through the North Channel (NC)) and (b) an alternate Hybrid scenario, which involves a speed limit of 10 knots and a probable increase in deviation of route to the South Channel (SC).The extent of negative effects on the beluga population associated with these two scenarios was evaluated.
- From our simulations, each commercial ship transiting by the current North Channel (NC) shipping route exposes between 15-48% of the beluga population to noise levels likely to cause behavioural responses in a majority of individuals, depending on its source level and direction of transit. The vast majority (72-80%) of the beluga exposed are females with calves or juveniles (FCJ).
- Vessels currently diverting part of their path toward the SC increase beluga exposure to noise of this magnitude by 7–11% per transit compared to those staying in the NC, resulting in 16–53% of the population being exposed to shipping depending on the vessel source level, direction of transit and specific route in the SC. Vessels using the SC during part of their transit reduce their overall encroachment on the beluga areas of concentration by 2-3% depending on SL, but increase exposure of beluga designated Critical Habitat by 3%.
- Under the proposed *Hybrid* scenario, there would be a 10-12% lesser exposure of the beluga population, and 7-11% lesser exposure of their Critical Habitat, simply by the effect of reducing speed to 10 knots for those noisy ships which remain in the NC.
- The ships most likely to choose the alternate route, therefore to spend the least time in the speed-reduced zone, are the largest, fastest and noisiest (i.e., with cruising speeds >14 kt). Considering only these vessels (mainly container ships), noise exposure under the alternate SC *Hybrid* scenario increases beluga exposure by 21%, and exposure of their Critical Habitat by 17% relative to the NC route with reduced speed, i.e., without deviation to the SC. As with other deviations to the SC, this scenario reduces exposure of herds of adult beluga and their habitat, but increases exposure of FCJ and of the population Critical Habitat.
- Commercial shipping is currently concentrated in the North Channel of the SLE, with 90-94% of the vessels following the NC. As a result of this traffic and commercial whale-

watching, this zone is highly ensonified. Islands in the middle of the SLE create a sound shadow for FJC habitat located along the south shore. Diverting some of the shipping traffic to the South Channel would considerably reduce the amount of noise-shelter areas for FJC.

- The above findings are for a single ship transit and need to be expanded to the volume of traffic. Commercial transits of all vessel types occur on average 18 times daily, resulting in each beluga being exposed several times a day to noise likely to affect their behaviour. Considering only those vessels likely to use the SC, there is a potential for an almost tripling of the frequency of exposure of FCJ in this lightly exposed habitat (2 additional exposures / day).
- The proportion of exposed beluga that is likely to be negatively affected by noise to the point where reproduction, health or survival is compromised is unknown. However, SLE beluga are not immune to disturbance and displacement, as they have abandoned Tadoussac Bay when a marina was established, and were documented to modify their vocal behaviour in response to masking by ferry noise.
- The SLE population size had shown little change for several decades, but seems to have been recently declining, suggesting that harmful natural or anthropogenic factors are at play in their lack of recovery. The relative role of natural and anthropogenic pressures, including environmental change, contamination, toxic algal blooms and marine traffic on individual health, reproduction and survival and thus, on the potential for population growth cannot be determined;
- The proposed *Hybrid* scenario with route diversion to the SC is likely to have negative, at best neutral, effects on SLE beluga recovery as it increases the vessel-noise footprint in FCJ habitats, and the beluga Critical Habitat, and contributes to the acoustic degradation of some areas of concentration previously only lightly exposed to shipping noise.
- Maintaining or concentrating as much as possible commercial traffic in the NC constitutes the scenario which minimizes impacts on the STL beluga.

INTRODUCTION

The St. Lawrence Estuary (SLE) beluga population is listed as threatened under the *Species at Risk Act* (SARA), which aims to protect species at risk from being killed or harmed (section 32) and protects any part of their Critical Habitat from destruction (section 58). The SARA Recovery Strategy for this population lists noise/disturbance as one of the primary potential threats to recovery. Critical Habitat has been identified, and corresponds to the summer distribution area of what is presumed to be herds of females accompanied by calves or juveniles (FCJ).

The North Channel (NC) traffic route where shipping is currently concentrate overlaps with the main aggregation area for large baleen whale as well as associated whale-watching activity, raising concerns for potential whale/ship or whale-watching/ship interactions. Amongst options explored, voluntary protection measures, which included a 10 kt speed reduction area in the lower SLE portion of the Marine Park between Les Escoumins and Tadoussac, called the '*hybrid* scenario', was proposed to reduce collision risks (Figure 1). As an alternative, pilots had the option of diverting their route into the South Channel (SC) southeast of Île Rouge to avoid the sensitive sector altogether as well as the speed reduction (Figure 1). However, this option would have the consequence of increasing shipping in the SLE beluga Critical Habitat.

Beluga are unlikely to be at risk of collision with large, slow moving vessels given their high maneuverability and acute hearing. However, shipping may affect beluga through radiated noise, although the degree of reaction to noise depends on a number of factors including the noise's physical characteristics, as well as environmental, operational and biological factors (context of exposure), and the receiver's motivation, experience and conditioning. However, there is little information to assess these factors in an objective and quantitative way.

Exposure to ship noise or overlap in distribution with shipping routes may or may not lead to negative effects on health, behaviour, or habitat use. There are currently no data available to assess with any degree of certainty the proportion of the exposed marine mammals which will suffer from shipping noise to the point where detrimental effects on health, reproduction, or survival would be observed. One step towards estimating the significance of impacts is to determine the number of potential individual-exposures relative to total population size. Another is to determine whether specific segments of the population are likely to be impacted more than others (e.g., calving females). This approach has been used as a standard by the National Marine Fisheries Service (NMFS, US) when assessing potential impacts of various types of projects and noise sources on marine mammals, including shipping noise.

DFO Science was requested to examine exposure of SLE beluga to marine traffic under the proposed commercial shipping guidelines (hereafter known as the *Hybrid* scenario) as compared to current traffic conditions, and to assess the possible consequences for this SARA-listed population.

ASSESSMENT

Methodology

Beluga spatial densities were obtained from 35 replicate systematic line-transect or photographic surveys conducted in late August between 1988 and 2009. Beluga densities at the end of August were assumed to be representative of the beluga distribution during the summer period and thus, during most if not all of the period of interest (May to October).

Information on vessel type, and temporal and spatial density of traffic was obtained from the INNAV database (Canadian Coast Guard) which gave the monthly transit frequency along the NC and SC per vessel class from 2002 to 2007, and in 2012.

Acoustic data used for these analyses were acquired from the study area in 2004-2005 as part of a project describing the ambient and vessel-generated noise characteristics in the SLE, specifically targeting beluga habitat. As part of that study, noise signatures of various vessel types including merchant ships plying the St. Lawrence Estuary were recorded to determine their frequency composition and source levels. At the same time, vessels were actively tracked to determine the ship's trajectory, speed and identity. Finally, sound propagation measurements were conducted to determine transmission losses at the various sites to parameterized sound-propagation models for the estimation of site-specific zones of influence (ZOI) around ship tracks with varying source levels.

Projected ZOIs were overlaid on beluga density distribution by herd composition, (1) females accompanied by calves or juveniles (FCJ), (2) adults only (presumed to be males), and (3) mixed herds (adults only or FCJ) to estimate the proportion of the population by mixture group exposed to a vessel's passage. Changes in exposure as a function of route, scenario and vessel group was quantified in terms of the proportion of the population, as well as the amount of their habitat, exposed to noise levels likely to induce negative behavioural responses. Habitat

exposure was described with two metrics, i.e., amount of area used by the different mixture groups, and amount of the designated Critical Habitat, which essentially corresponds to areas used by FCJ or mixed herds.

A received sound pressure level of 120 dB re 1µPa (rms) was used as the threshold where it is expected that 50% of the exposed individuals will react negatively to a continuous noise source. This criterion is the same as the one used by the National Marine Fisheries Service of the US for their assessment of the impacts of development projects on cetaceans.

Results

Between 2002 and 2007, 90-94% of all commercial vessel traffic followed the NC of the SLE to the North of Île Rouge. Of the remaining 6-10% which took the SC, most were barges and tugs, followed by bulk carriers and container ships. A preliminary analysis of the possible effects of the voluntary speed limits on the choice of route taken by pilots suggested that it would not be advantageous to choose the SC unless the vessels operating speed exceeded 14 kt. Over the period from May to October, there is potential for an increase of 376 vessel passages via the SC, or 2.5 times the normal traffic, of which the vast majority would be container ships.

Thirteen vessels were tracked and measured for their noise source level, including general cargo, bulk carrier, tanker and container ships. Estimated SL varied from 180.0 to 190.0 dB RMS re 1 µPa @ 1m, with the mean at 185.4 dB. Container ships had a higher SL than the other ships. Source level showed weak but increasing trends with vessel length, speed and gross tonnage although little relationship with the vessel's age. Therefore in general, bigger, faster vessels were the loudest. Most of the sound energy from these ships was concentrated in the low-frequency band.

Simulations were run for three groups of vessels, relatively quiet, medium-noise and noisy vessels. Simulations accounted for differential noise propagation characteristics between the NC and SC, with better sound propagation in the shallower SC than the deeper NC. From these simulations, the ZOI width expanded with vessel source level, resulting in a 3-fold increase in exposure of beluga and its habitat between the quietest and noisiest vessels. Even the quietest ships had an acoustic footprint of 3 km.

The simulation also showed that a commercial ship transiting by the current NC shipping route with no speed reduction exposes 15–48% of the beluga population to noise of 120 dB re 1 µPa (rms) or more depending on its SL and direction of transit, of which 72-80% would be FCJ. The ZOI along the NC increased with source level of the vessels. Partial diversion of traffic route toward the SC resulted in a 7–11% increase in beluga exposure compared to vessels staying in the NC, with 16 to 53% of the population exposed depending on source level, direction of transit and route.

None of the ZOIs of vessels transiting exclusively through the NC exposed the beluga habitats along the south shore of the Upper Estuary. The footprint of the ZOIs was different for vessels using the SC route during part of their transit, all of which encroached to some degree on previously weakly-exposed (and relatively quiet) beluga habitat whether considering low-, medium- or high-noise vessels.

Under the proposed *Hybrid* scenario where a reduction of speed to 10 kt is proposed, it is expected that at least some of the current NC traffic will deviate to the SC resulting in an increase in vessel noise exposure of beluga along the south shore. Under this scenario, a 10-12% decrease in exposure of the beluga population, and 7-11% decrease in exposure of their

Critical Habitat are expected simply by the effect of reducing speed to 10 knots for those noisy ships which remain in the NC.

The ships most likely to choose the alternate route so to spend the least time in the speed-reduced zone are the largest, fastest and noisiest (i.e., with cruising speeds >14 kt).

Considering only these vessels (mainly container ships), noise exposure under the alternate SC *Hybrid* scenario increases beluga exposure by 21%, and exposure of their Critical Habitat by 17% relative to the NC route with reduced speed, i.e., without deviation to the SC. As with other deviations to the SC, this scenario reduces exposure of herds of adult beluga and their habitat, but increases exposure of FCJ and of the population Critical Habitat.

The alternate SC shipping route systematically increases the footprint in FCJ habitat, resulting in an overall increase of the shipping footprint in what is designated as the Critical Habitat of SLE beluga under the Species at Risk Act. Although there was a 2% decrease in exposure to adult beluga by taking this alternate route, there was a 3 % increase in exposure to mixed groups of adults and FCJ along the south shore.

There are no criteria in the literature with which to compare received levels that account for auditory sensitivity for an indication of possible impacts on marine mammals. Yet, in some studies such weighting functions have been applied against unweighted criteria when evaluating impacts of man-made noise on marine mammals. In beluga, these functions greatly attenuate auditory sensitivity in the frequency band where most of the energy of large ships is concentrated. As an example, we calculated the projected M-weighted and C-weighted ZOI for a container ship along the SC route. If these weighting functions are reflective of the auditory sensitivity of wild beluga, clearly the impact of even the noisiest vessels would be greatly attenuated. However, this is inconsistent with other evidence that beluga and other cetaceans with hearing sensitivity similar to beluga can detect and react to commercial vessels at distance in the 10’s of kilometers and at received levels equivalent to those uncorrected for hearing sensitivity.

Sources of uncertainty

The major source of uncertainty about the effect of sound exposure on marine mammals is the variability in the severity of reaction amongst studies. Behavioural reactions range from none to brief or prolonged avoidance behaviour in response to similar sources, making generalisations difficult. It is clear that reactions are context-specific, and depend also on previous experience and motivation of the animal exposed.

Our analyses estimated commercial vessel acoustic footprints based on individual transits. We also considered the maximum annual number of vessels, which could choose the SC to approximate the worst possible scenario. A major source of uncertainty is how many ships would choose the SC route.

Our sample size of tracked vessels (13) was limited, and may not represent the total range of vessel types and source levels of the commercial fleet. However, estimated source levels were similar to values reported in the literature for these vessel types.

Exposure of the various social groups of the SLE beluga for the current assessment is based on a large sample of aerial surveys, of which the vast majority were conducted in late August. We made the assumption that this distribution persisted throughout the summer period. However, there is no data to validate this assumption.

Habitat located along the NC and SC may not fulfill the same functions/needs for SLE beluga. There is no data available on site-specific functions.

CONCLUSIONS AND ADVICE

Commercial traffic transiting through the SLE exposes many times daily a substantial proportion of the SLE beluga, of which the vast majority are FCJ, to noise levels likely to induce negative behavioural responses in a majority of exposed individuals. Exposure is the greatest when vessels are large and fast, such as container ships.

The proposed *Hybrid* scenario with route diversion to the SC increases the vessel-noise footprint in FCJ habitats, and the beluga Critical Habitat, and contributes to the acoustic degradation of some areas of concentration previously only lightly exposed to shipping noise. Maintaining or concentrating as much as possible commercial traffic in the NC constitutes the scenario which minimizes impacts on the SLE beluga and their habitat.

While local studies indicate that SLE beluga are more tolerant to marine traffic than their Arctic counterparts where shipping is practically non-existent, short-term behavioural effects from exposure to ferry and small vessel, as well as abandonment of preferred areas following construction of a marina were documented in SLE beluga, indicating that they are not immune to disturbance and displacements. However, the proportion of exposed beluga that is likely to be affected negatively by noise to the point where reproduction, health or survival is compromised is unknown.

The SLE beluga population has been greatly reduced by past overhunting, and has failed to show the anticipated increase despite 30 years of protection. They are highly contaminated, face sporadic toxic algal bloom events, and are currently experiencing profound changes in their physical and biological environment, which appear to be detrimental to recruitment. In the current context where the beluga population appears to be evolving in a changing and possibly sub-optimal environment, an increase in exposure of FCJ and their habitat to shipping are likely to have negative, at best neutral, effects on SLE beluga recovery.

OTHER CONSIDERATIONS

An increase in marine recreational activities in specific portions of the Critical Habitat of the SLE beluga population has been documented over the past decade. These new sources of potential disturbance target FCJ herds and as such, may add to recent anthropogenic and natural pressures on this segment of the population, which will also experience the largest increase in exposure to noise under the proposed scenario of rerouting of shipping traffic to the SC.

Strategies to lower the acoustic footprint of transiting ships (e.g., newly-built, quieter ships, reduced speed, regular maintenance, etc.) would reduce noise exposure of FCJ and preserve or increase the number of quieter habitats for this crucial segment of the population.

SOURCES OF INFORMATION

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

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. 88 pp + X pp.

DFO. 2014. Status of the beluga whales (*Delphinapterus leucas*) in the St. Lawrence River Estuary. DFO Can. Sci. Advis. Sec., Sci. Advis. Rep. 2013/076.

Lesage, V., McQuinn, I.H., Carrier, D., Gosselin, J.-F., and Mosnier, A. 2014. 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.

McQuinn, I.H., Lesage, V., Carrier, D., Larrivée, G., Samson, Y., Chartrand, S., Michaud, R., and 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: 1-13.

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