ADDING A BREAKWATER TO THE PILOT WHARF AT LES ESCOUMINS, QUEBEC – POTENTIAL IMPACTS ON MARINE MAMMALS

Context

The Laurentian Pilotage Authority (LPA) is planning to build a sheet pile breakwater in the fall of 2011 in Anse-aux-Basques at Les Escoumins. The LPA is a federal Crown corporation whose mandate is to provide piloting services to vessels traveling on the St. Lawrence and the Saguenay Fjord in order to ensure safe navigation. The LPA has a transfer station at Les Escoumins, in Anse-aux-Basques, where their two pilot boats are moored. Having replaced one of its pilot boats, it has become necessary to build a structure to protect against the waves so as to ensure safe docking. In fact, waves are significant in Anse-aux-Basques and adding a breakwater to the existing wharf will reduce the risk of damaging the vessels and will facilitate operations.

The construction of a breakwater in Anse-aux-Basques is subject to a screening under the *Canadian Environmental Assessment Act* (CEAA), because the LPA is the proponent and Fisheries and Oceans Canada must issue an authorization pursuant to subsection 35(2) of the *Fisheries Act* (FA). The Fish Habitat Management Division (FHMD) has undertaken the project analysis under the FA and the *Species at Risk Act* (SARA) and, on August 2nd, 2011, sought the cooperation of scientists from the Regional Science Branch, who have expertise on marine mammals in the St. Lawrence Estuary, to obtain their advice on the potential impacts on cetaceans, particularly species at risk, including the North Atlantic blue whale and the St. Lawrence beluga. Considering the short notice (advice required August 16th, 2011 in order not to hinder the beginning of the work), a *Science Special Response Process* (SSRP) was initiated to provide scientific advice on three specific issues related to this project and its potential impacts on cetaceans:

1. Because no drilling or piling or sheet pile driving will occur between June and August, and a cetacean monitoring program will be implemented, will the sheet pile breakwater construction activities at Les Escoumins cause significant disturbance or major impacts on cetaceans?
2. If so, what additional mitigation measures should the proponent be required to introduce in order to reduce the disturbance and impacts?
3. If there are no measures to reduce the impacts, can we conclude that construction activities would only incidentally affect St. Lawrence beluga and Atlantic blue whale populations and that the following conditions would be met?
    - All reasonable alternatives were considered and the best solution was adopted.
    - All measures were taken to minimize the activity's negative consequences.
    - The activity will not jeopardize the survival or recovery of the species.

This Science response report stems from the meeting held on August 2nd, 2011, under the SSRP on the review of potential impacts on marine mammals by the proposed construction of a

breakwater at the Les Escoumins pilot wharf. Three experts in "underwater" acoustics and in marine mammal behaviour were present. A description of the main aspects of the project, timelines and proposed mitigation measures were presented for consideration in order to formulate this advice.

The proposed project to build a coastal breakwater in an area recognized as a unique habitat for marine mammals (Estuary and Marine Park MPA) has non-negligible risks of negative impacts on animals frequenting the area, including the species under SARA such as belugas and blue whales. This impact is felt through the propagation of noise associated with construction, particularly impulse noise from driving pilings and sheet piles. This strong impulse noise can cause permanent physical damage to the animals near the source. They alter the ambient noise over distances of several tens of km and impact the behaviour of animals, which has been shown, over at least 20 km.

Background

Frequentation of the Maritime Estuary

The St. Lawrence Estuary is a biologically and ecologically significant area for marine mammals because of the diversity of species found there and the functions supported by this environment (Lesage et al. 2007). The St. Lawrence Maritime Estuary (SLME) also supports an important whale watching industry. A portion of the beluga and harbour seal populations live there throughout the year (Michaud et al. 1990, Lesage et al. 2004), while populations of 10 other species, including three pinnipeds and seven cetaceans, visit the SLME seasonally to feed. Except for the harp seal and hooded seal, that frequent the SLME in the winter, the other seasonal visitors usually exploit this sector during periods that are free of ice (review: Lesage et al. 2007). Among the species that frequent the SLME, four are considered at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The blue whale is considered endangered, the beluga threatened, and the fin whale and harbour porpoise are considered of special concern.

The SLME is the main habitat for blue whales and fin whales while frequenting the St. Lawrence Estuary, and it is the heart of the beluga habitat because it occurs there year-round (Mosnier et al. 2010, Doniol-Valcroze et al. unpublished data, Lesage et al. 2007). The northern slope of the Laurentian Channel, including the area near Anse-aux-Basques, where the proposed work will take place, is one of the main feeding habitats for blue whales (Doniol-Valcroze et al. unpublished data) and belugas (Lemieux Lefebvre 2009, Mosnier et al. 2010, Mosnier et al., unpublished data). This is also where krill concentrate from the action of specific oceanographic processes, which is the main food source for blue whales (Simard, 2009, and ref. cited).

The proportion of beluga and blue whale populations frequenting the SLME varies seasonally. For the beluga, for example, this area would be home to 35-60% of the population during the summer, and likely the majority of the population in September and October as the relative importance of the upper estuary drops during this period. Existing data, although somewhat patchy, suggests that less than a quarter of the population occurs in the SLME between November and May (reviewed in Mosnier et al. 2010).

The proportion of the blue whale population frequenting the St. Lawrence each year is unknown because its population size is also unknown, though it is believed to include fewer than 250 mature individuals (Sears and Calambokidis 2002). A minimum of 23-96 different blue whales

(mean ± E.T. = 60 ± 21 ind.) annually visit the St. Lawrence, of which forty individuals on average attend the SLME every year (Comtois et al. 2010). This region was visited by at least 220 different individuals between 1987 and 2007. Ninety-four regular visitors to the St. Lawrence are likely loyal to the SLME; i.e. although not all of them are reported each year, they seem to return on a regular basis since they were first observed.

Blue whales are found in the SLME mainly from July to October, with peak abundance occurring at least from early August to late September (Lesage et al., unpublished data, Edds and Macfarlane 1987). The slight decline in numbers observed in October is likely due in part to the drop in observation effort at sea. In fact, the recordings of whale voice activity show an increase in voice activity from early September to the end of December in the Les Escoumins region for fin whales and blue whales (Y. Simard, DFO, unpublished data). These results suggest the persistence of individuals of both species in the area until late fall and early winter. They also show the periodic occurrence of blue whales in the estuary throughout the year including the winter months (Y. Simard, *ibid*.).

Noise Associated with the Work and their Impacts

The construction of a breakwater presented will generate noise that will be irradiated in the surrounding water. The frequency (spectrum) and intensity features of the construction noise (e.g. Hastings & Popper 2005, Greene et al. 2008, Erbe 2009, Mann et al. 2009) allow for detection and audibility (see cf. Au & Hastings 2008, Popper & Hastings 2009, Slabbekoorn et al. 2010) by a wide variety of organisms, including marine mammals that may be present in this habitat.

There are two types of noise: impulse noise, such as the impact of driving pilings and sheet piles, and non-impulse noise, such as anchor drilling and other construction activities. Among the construction noise, impulse noise is likely the most intense, reaching the furthest and causing the greatest impact on fish and marine mammals (Rodkin and Reyff 2004, Madsen et al. 2006, Southall et al. 2007, Erbe 2009, Hildebrand 2009, Mann et al. 2009, Popper & Hastings 2009, Bailey et al. 2010, Hastings 2011, Brandt et al. 2011). Note that navigation in the St. Lawrence Seaway also causes a significant noise level in this habitat (Simard et al. 2010, Y. Simard, unpublished data).

The noise from driving pilings and sheet piles usually has intensities exceeding 220 dB re 1 μPa_{pp} at 10 m from the source (Bailey et al. 2010, Reinhall and Dahl 2011) and levels at 1 km may exceed 180 dB re 1 μPa_{pp} (Tougaard et al. 2009, Bailey et al. 2010, Hastings 2011). The energy is concentrated at low frequencies of a few hundred Hz to a few kHz, but their broadband includes infrasound (<50 Hz) and ultrasound (> 20 kHz) (e.g. Erbe 2009, Bailey et al. 2010, Stockham et al. 2010) used by animals for communication and echolocation (NRC 2003, Au and Hastings 2008). They can be detected up to several tens of km from the source (e.g. Bailey et al. 2010), mitigating the propagation effects, in particular high frequencies, and increasing their duration (e.g. Erbe 2009, Bailey et al. 2010). The repetitive nature of this high cadence impact noise causes a rapid increase in the animals' cumulated level of exposure to this noise.

The direct and indirect impacts on organisms are diverse and the spatial extent of their behavioural response may reach several tens of km, as was observed for the harbour porpoise (Tougaard et al. 2009, Brandt et al. 2011). They vary between the extremes of no significant impact and death of the animal by physiological damage to internal tissues at a short distance from the source, and include all intermediate levels, including permanent or temporary hearing

loss, stress, small and large spatial scale habitat displacement for varying periods, disappearance of food sources that may affect survival, the masking of communication and auditory perception of the environment, etc. (Hastings & Popper 2005, Southall et al. 2007, Popper & Hastings 2009, Slabbekoorn et al. 2010).

Because marine mammals make extensive use of acoustics to achieve their daily life functions, the impacts of acoustic interference introduced in their environment by humans, such as the proposed project, will have significant impacts on their health status and pose a risk to the recovery of populations of species at risk mentioned above and occurring in the area that will be affected by the noise (Nowacek et al. 2007, Weilgart 2007, Tyack 2008).

Analysis and Response

Response to Questions:

Question 1

Because no drilling or piling or sheet pile driving will occur between June and August, and a cetacean monitoring program will be implemented, will the sheet pile breakwater construction activities at Les Escoumins cause significant disturbance or major impacts on cetaceans?

Response 1

Yes, because blue whales, belugas and other cetaceans are still abundant in the SLME after August. For example, September is a month of peak abundance for the blue whale and of significant concentration for the beluga.

The noise generated by the work, especially from piling or sheet pile driving, is of an intensity and nature to spread over tens of kilometres from the construction site, and far exceeds the audibility threshold for the different marine mammal species occurring in the SLME.

Considering what is mentioned above; documented adverse reactions to similar work from other marine mammal species, including the harbour porpoise; the fact that the area covered is the main habitat for the blue whale and fin whale from June to December for an activity critical to their survival; that this region provides habitat for a substantial proportion of the St. Lawrence beluga population year-round; and that the area near the construction site is a place of high residence for the St. Lawrence beluga and one of the main feeding sites for the blue whale when in the SLME; we believe that the project, as proposed, is highly likely to affect a significant proportion of blue whale and beluga populations, and to a lesser extent, fin whales and harbour porpoises. Although the degree of behavioural and physiological response of the animals is difficult to predict, the consequences could be serious even if the area was only partially abandoned. The proposed mitigation measures are deemed insufficient to avoid altering the normal behaviour of individuals, and causing potentially significant impacts on the blue whale, fin whale and beluga.

Moreover, available data show that levels in this area can exceed 180 dB re 1 uPa pp, as mentioned above. Therefore, maintaining an exclusion zone of 1,000 m is necessary to minimize the risk of physical harm to animals.

Question 2

If so, what additional mitigation measures should the proponent be required to introduce in order to reduce the disturbance and impacts?

Response 2

The project should be amended to extend the exclusion period from June to September inclusively, so as not to disrupt the blue whale feeding period which abounds in August and September in the SLME, and whose activity is mainly concentrated near the work site. This will also reduce the proportion of the St. Lawrence beluga population that could be affected by the work. In addition, no piling or sheet pile driving should be allowed until December because it is the noisiest activities and he most likely to interfere with the normal behaviour of individuals.

The following mitigation measures would help reduce the noise produced and propagated in the water:

- The gradual introduction of noise sources prior to normal operation, in particular the pile driving noise, would help minimize impact and provide time for the animals to leave the area
- The use of impact mitigation caps (Laughlin 2006)
- Use an air chamber around the pilings or sheet piles during driving (Hastings 2011, Laughlin 2006, Lee et al. 2011)
- Construction of the exterior wall before the interior wall, so as to form a screen limiting the spread of sound off-shore generated during the construction of the interior wall
- Use of an air-bubble curtain

These mitigation measures should drastically reduce the impacts on blue whales (and fin whales and harbour porpoises), and diminish those on belugas. However, given that the maritime estuary is frequented year-round by a portion of the beluga population, the effects, if they occurred, would not be totally avoided for this species by the proposed additional mitigation measures. However, they could reduce the risk of significant impact to a more acceptable level.

Visual monitoring of the proposed exclusion zones will not be effective in poor visibility. To allow detection and more effective monitoring of animals underwater before they enter the exclusion zone, these observations should be complemented by monitoring the presence of animals in the region using PAM technologies (passive acoustic monitoring, e.g. Simard and Roy 2008).

The proponent should be encouraged to monitor underwater noise in real time, including via the PAM system introduced to identify animals underwater by their vocalizations, their occurrence in the area near the work, as well as an extended area as soon as work begins in order to document the noise levels generated and the degree of reaction of large whales and belugas to various types of work. Should the reactions of belugas be important, other mitigation measures to reduce the project's impacts on this species should be considered. Monitoring of noise introduced into the water and its attenuation along the propagation path should be done throughout the construction period and a few weeks after the work is complete, for example, by introducing to the real time PAM system, autonomous hydrophones anchored at a few distance points in the cove and offshore, based on the usual deployment methods (e.g. Simard and Roy 2008).

Question 3

If there are no measures to reduce the impacts, can we conclude that construction activities would only incidentally affect St. Lawrence beluga and Atlantic blue whale populations and that the following conditions would be met?

- All reasonable alternatives were considered and the best solution was adopted;
- All measures were taken to minimize the activity's negative consequences.
- The activity will not jeopardize the survival or recovery of the species.

Response 3

Based on the information provided about the proposed project, as well as existing data on marine mammals and the impact of anthropogenic noise in their habitat, and if the project is implemented as proposed and is not altered to include additional mitigation measures mentioned above, a negative response must be given to all aspects of this issue.

Conclusion

The proposed project to build a coastal breakwater in an area recognized as a unique habitat for marine mammals (Estuary and Marine Park MPA) has non-negligible risks of negative impacts on animals frequenting the area, including species under SARA such as belugas and blue whales. This impact is transmitted through the propagation of noise associated with construction, particularly impulse noise from driving pilings and sheet piles. These strong impulse noises can cause permanent physical damage to the animals at short distances from the source. They can change the ambient noise over distances of several tens of km and, as has been shown, can impact animal behaviour over at least 20 km.

As usual, the means to minimize the impacts are in order: 1) restricting the temporal and spatial window of the work, 2) mitigating the impact sources, 3) monitoring the exclusion zones, 4) the gradual introduction of impact sources, 5) monitoring the impacts during and after the construction period (see Jefferson et al. 2009).

1) For the first point, according to the plan received for the work, the driving impulse noise should only be made in late fall, around December or January. As large whales essentially complete their annual visit to the area in late fall, the later the noise begins, the lower the risk of impact for these animals. It is difficult to assume whether this would also be the case for the beluga due to the lack of accurate information on their winter habitat. The plan for driving pilings and sheet piles indicates that this activity will occur only during the day and on working days. This schedule provides rest periods - and recovery periods if necessary - for the animals at night and between impulse noise periods. Maintaining these rest periods for the animals is recommended.

2) To mitigate the impact sources, the use of vibrating piling and sheet pile driving would be better than standard driving in order to minimize the impact of construction noise. The use of vibrating pile driving should be used for all pile driving work. To reduce pile driving noise, the optimal use of the various recent mitigation methods, mentioned above and tested in various locations around the world, is necessary to reduce impact noise: mitigation caps, air chamber and air bubble curtain. Attenuation of noise propagation offshore during the construction of the

structure's inner wall is possible if the outer wall is built and supported first, before the inside wall; it would serve as a shield for the noise generated during the construction of the inner wall.

3) The proposed visual monitoring of zones of 0.6 km in the case of vibrating pile driving and drilling, and 1 km in the case of standard driving, by experienced observers for the duration of the loud operations is required. However, as weather (fog, wind, waves) and the surface behaviour of animals, which is sometimes short and concealed, observations are not consistently effective. A real-time acoustic monitoring of animal vocalizations from the observation post is recommended to better detect their ongoing presence and follow them before they enter the exclusion zone.

4) The gradual introduction of sources of impact, especially pile driving noise, is a common precaution used to minimize impacts and allows animals to leave the area before normal operations begin. It is therefore recommended to apply this measure for 15 minutes, for all loud work.

5) Finally, among the mitigation measures, a monitoring of the impact generated during and after the construction period must be included to ensure the effectiveness of the mitigation measures and that pre-work conditions have been restored at the end of the project as proposed in the mitigation measures.

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Date: August 11th, 2011

Sources of Information

Au, W. W. L. et Hastings, M. C. 2008. Principles of marine bioacoustics. Springer, NY.

Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G. and Thompson, P. M. 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Mar. Poll. Bull. 60: 888-897.

Brandt, M. J., Diederichs, A., Betke, K. and Nehls, G. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Mar. Ecol. Prog. Ser. 421: 205-216.

Comtois, S., Savenkoff, C., Bourassa, M.-N., Brêthes, J.-C. and Sears, R. 2010. Regional distribution and abundance of blue and humpback whales in the Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2877: 1-48.

Doniol-Valcroze, T., Lesage, V., Giard, J., Michaud, R. *Submitted*. Modelling the habitat of endangered blue whales on a North Atlantic feeding ground: insights from the identification of feeding events. Endangered Species Research

Edds, P. L. and MacFarlane, J. A. F. 1987. Occurrence and general behavior of balaenopterid cetaceans summering in the St. Lawrence Estuary, Canada. Can. J. Zool. 65: 1363-1376.

Erbe, C. 2009. Underwater noise from pile driving in Moreton Bay, Qld. Acoust. Aust. 37: 87-92.

Greene , C. R. J., Blackwell, S. B. and McLannan, M. W. 2008. Sounds and vibrations in the frozen Beaufort Sea during gravel island construction. J. Acoust. Soc. Am. 123: 687-695.

Hastings, M. C. 2011. Comparative performance of attenuation treatments designed to mitigate underwater noise from pile driving. J. Acoust. Soc. Am. 129: 2460.

Hastings, M. C. and Popper, A. N. 2005. Effects of Sound on Fish, California Department of Transportation Contract 43A0139, Task Order 1.

Hildebrand, J. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Mar. Ecol. Prog. Ser. 395: 5-20.

Jefferson, T. A., Hung, S. K. and Würsig, B. 2009. Protecting small cetaceans from coastal development: Impact assessment and mitigation experience in Hong Kong. Mar. Policy 33: 305-311.

Laughlin, J. (2006). Underwater sound levels associated with pile driving at the Cape Disappointment boat launch facility, wave barrier project. Washington State Park Wave Barrier Project. Washington State Department of Transportation, Office of Air Quality and Noise, 15700 Dayton Avenue North, P.O. Box 330310. Seattle, WA 98133-9710. http://www.beamreach.org/wiki/images/4/4f/Cape_Disappointment_Pile_Driving_Report_Final_3-06revised_.pdf

Lee, K. M., Hinojosa, K. T., Wochner, M. S., Argo, T. F., Wilson, P. S. and Mercier, R. S. 2011. Mitigation of low-frequency underwater sound using large encapsulated bubbles and freely-rising bubble clouds. J. Acoust. Soc. Am. 129: 2462.

Lemieux Lefebvre, S. 2009. Déplacements et patrons de résidence chez la population de bélugas de l'estuaire du St-Laurent. M.Sc. thesis, UQAR, Québec. 111 p.

Lesage, V., Gosselin, J.-F., Hammill, M. O., Kingsley, M. C. S. and Lawson, J. W. 2007. Ecologically and Biologically Significant Areas (EBSAs) in the Estuary and Gulf of St. Lawrence - A marine mammal perspective. Can. Sci,Adv. Sec. , Res. Doc. 2007/046: 1-94.

Lesage, V., Hammill, M. O. and Kovacs, K. M. 2004. Long-distance movements of harbor seals (*Phoca vitulina*) from a seasonally ice-covered area, the St. Lawrence River estuary, Canada. Can. J. Zool. 82: 1070-1081.

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. 2006. Wind turbine underwater noise and marine mammals: Implications of current knowledge and data needs. Mar. Ecol. Prog. Ser. 309: 279-295.

Mann, D., P. Cott, and Horne, B. 2009. Under-ice noise generated from diamond exploration in a Canadian sub-arctic lake and potential impacts on fishes. J. Acoust. Soc. Am. 126: 2215-2222.

Michaud, R., Vézina, A., Rondeau, N., and Vigneault, Y. 1990. Distribution annuelle et caractérisation préliminaire des habitats du béluga, *Delphinapterus leucas*, du Saint-Laurent. Rapp. tech. can. sci. halieut. aquat. 1757: 1-31.

Mosnier, A., Lesage, V., Gosselin, J.-F., Lemieux Lefebvre, S., Hammill, M.O. et Doniol-Valcroze, T. 2010. Information relevant to the documentation of habitat use by St. Lawrence beluga (*Delphinapterus leucas*), and quantification of habitat quality. CSAS Doc. Res. 2010/098: iv + 36 p. Available at http://www.dfo-mpo.gc.ca/csas

Nowacek, D. P., Thorne, L.H., Johnston, D. W. and Tyack, P. L. 2007. Responses of cetaceans to anthropogenic noise. Mamm. Rev. 37: 81-115.

NRC 2003. Ocean noise and marine mammals. National Academy Press.

Popper, A. N. and Hastings, M. C. 2009. The effects of anthropogenic sources of sound on fishes. J. Fish Biol. 75: 455-489.

Reinhall, P. G. and Dahl, P. H. 2011. Acoustic radiation during marine pile driving. J. Acoust. Soc. Am. 129: 2460.

Rodkin, R. B. and Reyff, J. A. 2004. Underwater sound pressures from marine pile driving. J. Acoust. Soc. Am. 116: 2648.

Sears,R. and Calambokidis, J. 2002. Update COSEWIC status report on the Blue Whale *Balaenoptera musculus* in Canada. *In* COSEWIC assessment and update status report on the Blue Whale *Balaenoptera musculus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. pp. 1-32.

Simard, Y. 2009. Le Parc Marin Saguenay–Saint-Laurent: processus océanographiques à la base de ce site d'alimentation unique des baleines du Nord-Ouest Atlantique. Rev. Sc. Eau / J. Water Sci. 22: 177-197.

Simard, Y. and Roy, N. 2008. Detection and localization of blue and fin whales from large-aperture autonomous hydrophone arrays: a case study from the St. Lawrence estuary. Can. Acoust. 36: 104-110.

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

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C. and Popper, A. N. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Trends Ecol. Evol. 25: 419-427.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Green, C. R., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E. Richardson, W. J., Thomas, J. A. and Tyack, P. L. 2007. Marine mammal noise exposure criteria. Aquat. Mamm. 33: 411-521.

Stockham, M. L., Dahl, P. H. and Reinhall, P. G. 2010. Characterizing underwater noise from industrial pile driving at close range. IEEE Oceans 2010, 20-23 Sept., Seattle, WA. p 1-4.

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H. and Rasmussen, P. 2009. Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)). J. Acoust. Soc. Am. 126: 11-14.

Tyack, P. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. J. Mamm. 89:549–558.

Weilgart, L. S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management." Can. J. Zool. 85: 1091-1116.

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ISSN 1919-3750 (Print)
ISSN 1919-3769 (Online)

La version française est disponible à l'adresse ci-dessus.

Correct citation for this publication:

DFO. 2011. Adding a breakwater to the pilot wharf at Les Escoumins, Quebec: Potential impacts on marine mammals. DFO Can. Sci. Advis. Sec. Sci. Resp. 2011/007.