Underwater soundscape and radiated noise from ships in Eclipse Sound, NE Canadian Arctic

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PLAIN LANGUAGE SUMMARY

Commercial shipping is increasing in the eastern Canadian Arctic, raising concerns about changes to the marine soundscape and potential impacts to Arctic marine mammals. In this study, underwater radiated noise was measured for four types of commercial ships (bulk carrier, general cargo, fuel and chemical tankers, and an icebreaker) transiting Eclipse Sound, Nunavut during shipping months from October 2018 through September 2019. To make a comparison of the soundscape with and without ships, monthly (Jul, Aug, Sep, Oct) measurements were made during times when ships were present and when they were not present within 40 km of the recorder. Acoustic data were collected from two locations along the regular shipping route (Figure 1) using seafloor-mounted acoustic recorders. The recorders are listening devices only and do not emit any sound into the water except during a 10-min period when they are recovered from the ocean each year.

When ships are travelling through the Eclipse Sound region, their ship location, speed, heading, and draft is sent every minute by all large ships using the Automated Information System (AIS). This information was combined with the sounds received at the seafloor recorders to understand the characteristics of individual ship sounds during their transits. Ship sound was measured in three different ways to evaluate the potential for disturbance to marine mammal natural behavior and to

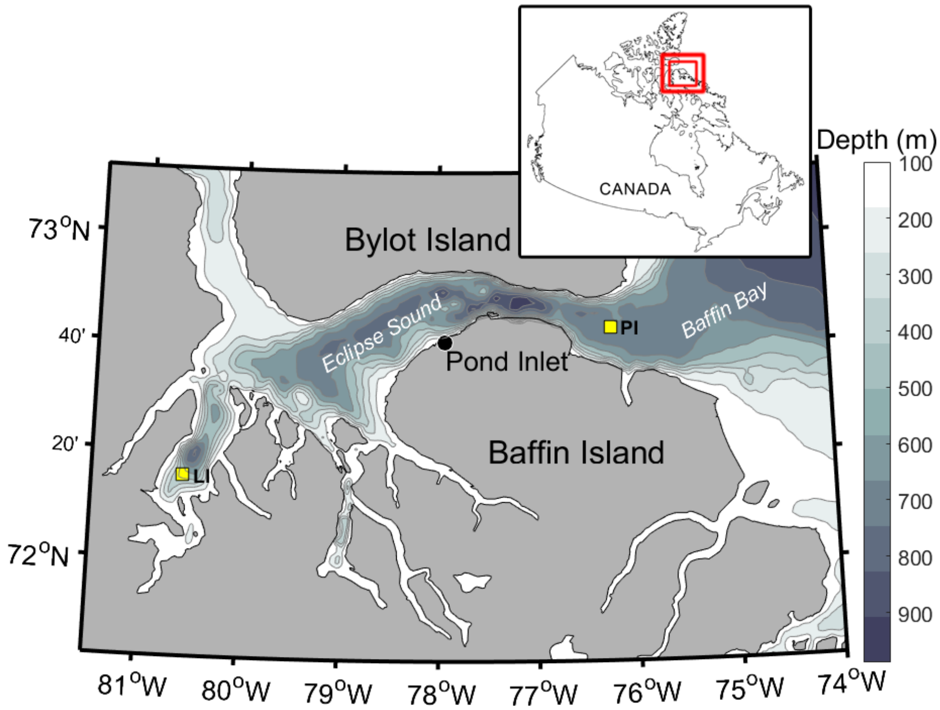

Figure 1. Acoustic recording sites in Eclipse Sound. High-frequency Acoustic Recording Packages (HARPs) were deployed at the Pond Inlet site (PI; depth 670 m) from September 28, 2018 through September 21, 2019. A second location in Milne Inlet (MI; depth 313 m) recorded acoustic data from Sep 29, 2018 to Aug 18, 2019. The recorders are listening devices only and to not emit sound into the water, except for one 10-min period each year during their recovery from the seafloor.

estimate possible masking of communication signals produced by narwhals (whistles and burst-pulse sounds) and ringed seals (barks and growls).

Both behavioral disturbance and communication masking are complex and not well understood for Arctic marine mammals. For the group of whale species most like narwhals, a generalized guideline has been developed by combining results of many studies. With these guidelines, narwhal behavioral disturbance is expected to occur when broadband sound pressure level (SPL) reaches 120 decibels referenced to a pressure of 1 microPascal (abbreviated as dB re 1 μPa) and animals are expected to actively avoid the sound source when the broadband SPL reaches 135 dB re 1 μPa. In reality, disturbance and avoidance are more complicated. Marine mammals, including narwhal and beluga, have shown different levels of responses to the same sound levels in different situations. Sound levels that cause Eclipse Sound narwhals to be disturbed or to avoid the source are not known, but are the focus of ongoing behavioral and acoustic studies.

Masking is a process that occurs when there are other sounds present around the same frequency as a sound we want to hear. The frequency of sound refers to the pitch – how low or high the sound is. Masking occurs when the other sounds get loud enough that the sound we want to hear must also become louder for us to hear it. Communication masking is not well understood for marine mammals, but it is estimated by examining changes in noise levels at frequencies where animals produce their sounds. When the sounds from ships overlap with the sounds that marine mammals like narwhals and seals produce for communication, it may become harder to hear their own sounds over the sounds made by the ships. 'Masking' noise in the environment is predicted to make the area that marine mammals can communicate in smaller while noise is elevated, an effect that is sometimes called Listening Space Reduction.

Sound levels in four frequency categories were analyzed in 2018-2019 recordings from Eclipse Sound and Milne Inlet. The frequency bands analyzed included a broad frequency band used to evaluate potential for behavioral disturbance (broadband sound pressure level between 20 Hz and 4000 Hz), low (1000 Hz) and medium (3500 Hz) frequency bands used by narwhals for their pulsed and whistle calls, and a low-frequency band (250 Hz) used by ringed seals for their barking sounds. With each ship transit the sound levels in all categories were elevated for periods of minutes to several hours. The icebreaker and tankers had the highest sound levels, followed by general cargo and ore carriers (also called bulk carriers). Lower frequency sounds travel much farther from the ship than the higher frequency sounds. Noise was greater as ships traveled away from the recorder (stern aspect) than as they approached (bow aspect) for all ship types. For example, sounds from bulk carriers reached a broadband sound pressure level of 120 dB re 1 μPa at ranges of around 1 km from the bow and 1 to 3 km from the stern with variety in sound levels between different ships. Received levels above 124 dB re 1 μPa were not recorded for bulk carriers, even at distances a small as 650 m between the ship and the hydrophone. The sound from the icebreaker escorting one or more bulk carriers reached a broadband sound pressure level of 120 dB re 1 μPa at a range of about 5 km from the bow and 5 to 15 km from the stern. Icebreaker received levels of 135 dB re 1 μPa were recorded from distances of 1 to 3 km from the ship. The fuel and chemical tankers had similar or slightly higher distances to 120 and 135 dB re 1 μPa received levels as the icebreaker.

At the deeper, less sheltered recording site (site 'PI' in Fig. 1), low-frequency sounds from ships (less than 200 Hz) traveled long distances and were present during times when ships were more than 40 km away from the recorder. More protected areas along the shipping route, like Milne Inlet, are sheltered from long-range sounds from ships. The shallower more acoustically sheltered recording location (site MI in Fig. 1) had substantially lower sound levels in all months, except during times when a ship was actively transiting through the inlet. One characteristic of this quieter location is that each ship transit changes the sound levels more, compared to what they normally are at the lower frequencies used for marine mammal communication. These frequencies overlap with some common sounds produced by narwhals, ringed seals, and bowhead whales.

An additional analysis was performed to estimate communication masking. Masking is estimated by comparing sound added by the ships to the normal range of background sound when ships are not nearby. This analysis method gives an estimate of Listening Space Reduction (LSR) for each ship transit. Interference for both narwhal and ringed seal communication is predicted to occur with each ship transit at distances that depend on the type of ship, its distance from the listener, and the estimated hearing sensitivity of each species at the frequencies analyzed. Bulk carriers are predicted to cause LSR of 50% for some common ringed seal and narwhal sounds from about 5 to 20 km away from transiting ships. LSR is predicted to be greater than 90% for narwhal at frequencies of 1 kHz and 3.5 kHz from 1 to 5 km away. For the icebreaker escorting one or more bulk carriers, a 90% listening space reduction (LSR) is predicted to happen at distances of 2-10 km in the narwhal frequency bands and 5 to 15 km in the ringed seal frequency band. The reason these estimated ranges of masking are so wide is that there are a lot of differences in sound levels from transit to transit and within each transit. These differences can be caused by the way sound travels through the water, by waves wind and ice, and position or characteristics of specific ships among other factors. Narwhals also make higher frequency sounds that may be less impacted by ship noise, but this is an area for further research effort with a need also for improved understanding of narwhal hearing. These are still predictions and much remains to be learned about how Arctic marine mammals hear, what sounds are most important for their social communication and other uses, and what the effects of reduction in their communication space might be on the health of individuals and their populations.

Shipping has increased substantially in Eclipse Sound and the interior waters along the shipping route to and from the Mary River Mine. In 2015, there were 42 transits of ships through Milne Inlet, with 40 of those transits related to the mine. In 2019, there were 245 ship transits through Milne Inlet, with 243 of those related to the mine. The impacts on marine mammals that may be caused by this rapid increase in ship traffic are being studied as part of the environmental effects assessment of the mine and independently by other groups of researchers. The long-term and cumulative effects on narwhals of repeated daily behavioral disturbance and reduction in their effective communication space are unknown. This uncertainty is motivating additional research within the summer range of the Eclipse

Sound narwhal population. The results of this study are intended to support the assessment of shipping traffic effects on the underwater soundscape and to help predict how underwater sound levels will potentially impact marine mammals at higher levels of shipping traffic in the future.