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Potential impacts of shipping noise on marine mammals in the western Canadian Arctic☆

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ABSTRACT

As the Arctic warms and sea ice decreases, increased shipping will lead to higher ambient noise levels in the Arctic Ocean. Arctic marine mammals are vulnerable to increased noise because they use sound to survive and likely evolved in a relatively quiet soundscape. We model vessel noise propagation in the proposed western Canadian Arctic shipping corridor in order to examine impacts on marine mammals and marine protected areas (MPAs). Our model predicts that loud vessels are audible underwater when > 100 km away, could affect marine mammal behaviour when within 2 km for icebreakers vessels, and as far as 52 km for tankers. This vessel noise could have substantial impacts on marine mammals during migration and in MPAs. We suggest that locating the corridor farther north, use of marine mammal observers on vessels, and the reduction of vessel speed would help to reduce this impact.

1. Introduction

Noise pollution is pervasive throughout marine environments (Merchant et al., 2014). Anthropogenic noise sources include resource exploration (e.g., seismic surveys) and extraction activities (e.g., drilling), construction and demolition (e.g., pile driving), military activities (e.g. sonar), and transportation (e.g., shipping). Shipping is the most widespread and continuous noise source of all of these sources (McDonald et al., 2006). It has been estimated that increased global shipping has led to an increase in ocean ambient noise levels off the coast of California by 2.5 to 3 dB re 1 μPa per decade from the 1960s to the 2000s (Andrew et al., 2002; McDonald et al., 2006) or even as high as 0.5 dB re 1 μPa per year (Ross, 2005). Changes in ambient noise levels like this can potentially affect all marine life, especially animals that rely on sound for predator/prey/conspecific detection, communication, or navigation. If animals evolved under specific ambient noise conditions, then changes to these conditions could alter the effectiveness of their auditory response or propagation of their vocalizations. A more direct effect of shipping is the impact of individual vessels on marine mammals. Individual vessels can have source levels close to 200 dB re 1 μPa at 1 m (Erbe and Farmer, 2000; Simard et al., 2016; Veirs et al., 2016). Levels this high can cause behavioural disturbance and mask other important acoustic signals (Erbe and Farmer, 2000), and can also increase stress levels (Rolland et al., 2012). If individual vessels are even louder or if multiple loud vessels are in the same area, vessel noise could cause temporary or permanent threshold shifts (TTS and PTS, respectively) or even injury (Southall et al., 2007). Noise pollution is such an important issue for marine life that policy makers have guidelines for projects that create noise (National Marine Fisheries Service, 2016; National Oceanic and Atmospheric Administration, 2016; Reeves et al., 2012).

The majority of the Arctic Ocean represents a unique and nearly pristine acoustic environment. Sea ice is present throughout much of the Arctic Ocean for most of the year and shipping is restricted mainly to the open ice season, typically between August and October. The combination of sea ice and reduced shipping makes the Arctic a particularly quiet environment. Ice typically dampens the effect of other noise-making factors, such as increased wind speed (Insley et al., 2017; Kinda et al., 2013; Roth et al., 2012). Since vessels can only access Arctic waters for a short period each year, they currently have relatively little impact on the year-round acoustic environment. Moreover, most shipping through the Arctic is currently limited to providing services to local communities rather than as a route for long-distance transportation, although the Northern Sea Route along the coast of Russia is

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already used for some long distance transport (Zhang et al., 2016). However, the rapid decrease in sea ice caused by climate change is expected to make many shipping routes through the Arctic viable by 2050 (Stephenson et al., 2011), and shipping has been increasing in the Arctic in recent history (Pizzolato et al., 2016). Although viability of the Northwest Passage through the Canadian Arctic is estimated to take longer than other shipping routes (Stephenson et al., 2011), Canadian policy makers are still planning for increased shipping traffic by proposing shipping corridors through the Canadian Arctic (Dawson et al., 2016). Unfortunately, the preliminary shipping corridors were identified based on historical average vessel routes traveling through the Canadian Arctic, and do not consider important environmental factors, such as core use areas by marine mammals, fish, or sea birds (Oceans North Canada, 2016). In addition, the potential acoustic impacts have not been assessed for the proposed shipping corridor, which are an important aspect of shipping impacts. There is an urgent need to assess the impacts of shipping on the Arctic before major increases in noise levels occur (Moore et al., 2012).

For this study, we examine the acoustic impacts of shipping in the western Canadian Arctic by modelling the propagation of noise from ships, and compare received noise levels to sound levels that are audible to marine mammals and are known to affect their behaviour. We model acoustic propagation from a ship that we recorded near Sachs Harbour, Northwest Territories, as well as from a tanker vessel from a different site that might be expected to represent future shipping in the Arctic. We specifically apply this model to the proposed shipping corridor (Dawson et al., 2016) through the eastern Beaufort Sea and Amundsen Gulf (see Fig. 1). This geographic area is home to two year-round resident seal species (bearded seals, *Erignathus barbatus*; and ringed seals, *Pusa hispida*) and two seasonally resident cetacean species (bowhead whales, *Balaena mysticetus*; and beluga whales, *Delphinapterus leucas*). Bowhead whales are listed as Special Concern in Canada (COSEWIC, 2009), and beluga whales are considered Near Threatened globally (IUCN, 2012). The Department of Fisheries and Oceans Canada created a management plan for the Bering-Chukchi-Beaufort population of bowhead whales in Canada (Fisheries and Oceans Canada, 2014), which lists underwater noise as the greatest threat to this population. The management plan suggests that if shipping does increase in the Beaufort Sea, that lower speed limits for vessels could be enforced in known congregation areas, or shipping routes could be developed that avoid important areas for bowheads. The current shipping corridor does not avoid important areas for bowhead whales and does not include recommendations for speed limits.

The Canadian Beaufort Sea and Amundsen Gulf also have two marine protected areas (MPAs), the Tarium Niryutait Marine Protected Area (TNMPA), located in the Mackenzie River Delta near the communities of Aklavik, Inuvik, and Tuktoyaktuk, and the Anguniaqvia Niqiqyuam Marine Protected Area (ANMPA), located at Darnley Bay near the community of Paulatuk. The TNMPA is specifically focussed on preserving important feeding/congregating habitat for beluga whales, whereas the ANMPA is focused on preserving habitat for a more diverse species assemblage including Arctic char, cod, beluga whales, ringed and bearded seals, polar bears, and a variety of sea birds. The TNMPA management plan (Fisheries and Oceans Canada, 2013) recognizes the impacts of noise on belugas, and suggests that commercial vessels follow the Canadian Coast Guard buoys that demarcate the community supply routes. Vessels are still allowed to travel through the TNMPA; however, suggestions are provided for reducing noise. The ANMPA was officially designated in November 2016 and does not currently have a management plan.

Given that no legislation or management plan in the Canadian Beaufort Sea or Amundsen Gulf effectively addresses the acoustic impacts of shipping, this study provides useful basic information for policy makers about the acoustic impacts of shipping on marine mammals in this region. Two other studies have modelled the effects of ship noise on marine mammals in the Beaufort Sea: Erbe and Farmer (2000) modelled the zones of impact for beluga whales around icebreakers while icebreaking, and Ellison et al. (2016) modelled the acoustic impact of multiple simultaneous industrial activities, including vessel noise, on bowhead whales. Both of these studies focused on very specific aspects of shipping. In contrast, we offer a wider geographic perspective on vessels traveling along the proposed shipping corridor through the Canadian Beaufort Sea.

2. Methods

2.1. Estimating vessel source levels

We used acoustic data from hydrophones near Sachs Harbour, Northwest Territories, to estimate source levels of vessels in Arctic waters. We collected acoustic data using Wildlife Acoustics (Maynard, Maryland, USA) SM3M bioacoustics recorders fitted with a low noise HTI 92-WB hydrophone (High Tech, Inc., Gulfport, Mississippi, USA; sensitivity between − 175 and − 165 dB re 1 V μPa^{-1} in the range of analysis). We deployed recorders between 2014 and 2016: one between July and August 2014, one between May and August 2015 along with a second recorder between July and August 2015, and one from August 2015 to July 2016. Only our deployment from August 2015 to July 2016 recorded any large vessels. We deployed this recorder from 20 August 2015 to 8 July 2016 roughly 8 km southwest of Sachs Harbour (71°55.621′N, 125°23.447′W), anchored at a depth of 23.5 m (water depth = 28.5 m), recording on a duty cycle of 5 min recording followed by 30 min off, 48 kHz sampling rate at a 16 bit resolution, and + 18 dB of gain.

We used Automated Identification System (AIS) vessel data collected via exactEarth's (Ontario, Canada) satellite network to determine which vessels were within 100 km of our hydrophone, and then manually examined spectrograms of the acoustic data to determine when we could detect vessels based on characteristic horizontal banding (continuous energy at specific frequencies). We expanded this radius beyond 100 km when vessels were still being detected at the 100 km radius. While eight vessels passed within the 100 km radius when we had hydrophones deployed, we only detected signals from two of these vessels, which spent much more time close to our hydrophone than the other vessels. These two vessels were the CCGS Amundsen (Canadian Coast Guard icebreaker and research vessel, detected between 30 August and 18 September 2015) and the HMCS Saskatoon (Royal Canadian Navy Kingston-class maritime coastal defence vessel, detected between 22 and 25 August 2015). The other vessels noted within the AIS dataset that were within the 100 km radius but were not acoustically detected were four tug boats, an icebreaker, and a pleasure craft. For each vessel, we obtained a time series of GPS coordinates, distance to our hydrophone, and speed of travel over ground.

We processed all recordings in Matlab to quantify the underwater acoustic signals. We measured power spectral densities (PSD) between 10 Hz and 24 kHz, computed from fast Fourier transforms (FFTs) of 1 s of data in 1 Hz bins overlapped by 0.5 s (120 averages/min) using a Hanning window. From these PSDs, we calculated sound pressure level (SPL) in 1/3-octave bands between 63 Hz and 20 kHz, and broadband SPL over this same range. For the two vessels that we acoustically detected, we extracted the spectra which corresponded to the vessel's closest point of approach (5 min recording). We calculated source level for the spectrum based on transmission loss with a mix of spherical and cylindrical spreading, while factoring in frequency-dependent attenuation and loss due to depth (adapted from Pine et al., 2014):

$$SL = RL + 15log_{10}RO + 10log_{10}\frac{R}{RO} + 0.04 + 10log_{10}\frac{d}{dO} + \propto \quad (1)$$

where *SL* is source level, *RL* is received level, *R* is the range of the vessel, *RO* is the range at which geometric spreading switches from spherical to cylindrical, *d* is depth of the recorder, *dO* is depth of the source, and *α* is frequency-dependent attenuation. The subsequent noise