Ship-Source Noise Modeling from 2015-2018 in the Kitikmeot Region and Lancaster Sound (Northwest Passage), Nunavut



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NOTICES

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Dr. Jackie Dawson, Associate Professor, University of Ottawa – project PI, advised on analysis area, edited and contributed to report.

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EXECUTIVE SUMMARY

Ship traffic has been increasing in the Canadian Arctic, and with it, underwater noise. Underwater noise from ships is known to cause a number of impacts on marine animals, and is therefore an important concern in the Arctic. This report is part of a larger study funded by the Nunavut General Monitoring Plan. In the report, we examine ship traffic in the Kitikmeot Region and Lancaster Sound, Nunavut (Northwest Passage – southern route), and model the noise levels caused by all of the ship traffic between 2015 and 2018. Ship noise peaks in August and September of every year analysed. Modeled ship noise was highest within Eclipse Sound due to the large volume of traffic within that area, but was also high south of Victoria Island in Dease Strait where ships are spatially constricted to following a relatively narrow route. Future work should be carried out to validate these modeling results with acoustic measurements in different parts of this region. Future work should also examine the overlap between ship noise and various marine animals, such as narwhal and beluga, to estimate the exposure of these animals to ship noise.

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1.0 INTRODUCTION

Nunavut waters attract the highest intensity of ship traffic compared to any other Canadian Arctic regions (Dawson et al. 2018; Kochanowicz et al. 2020). Traffic volume in Nunavut doubled over the past decade and further increases are expected given changes in climate, the allure of trade through the Northwest Passage, the abundant fish and mining resources, and the growing popularity of Arctic cruise tourism. The on-going and expected increases in shipping traffic in Nunavut will create risks to the environment and to people and it has become increasingly urgent to engage in monitoring activities that inform effective risk-mitigation decision-making for shipping traffic risks in Nunavut. Underwater noise from ships is an important indicator of shipping risk to monitor considering the potential impact of ship-source noise for marine mammals and the cascading implications for subsistence hunting and ecosystem health. Compared to other ocean regions globally, the Arctic has historically had low levels of ship traffic (Arctic Council, 2009; Dawson et al., 2018; Smith and Stephenson, 2013), and therefore lower levels of underwater noise from ships (PAME, 2019). In fact, the Arctic has some of the lowest ambient noise levels in the world under solid sea ice (Insley et al., 2017; PAME, 2019), making it prone to proportionately large impacts caused by underwater noise from ships (Halliday et al., 2020).

Change is opening up the Arctic to increased ship traffic through the loss of summer sea ice (Pizzolato et al., 2016) and it is vital that the associated increases in underwater water noise from this increased ship traffic be quantified. However, there have been limited studies conducting analysis of ship-source underwater noise in Arctic Canada or on the impact increased noise may have for marine mammals, particularly in Nunavut. This three-year Nunavut General Monitoring Plan project was established in direct response to the need to monitor shipping risks. The project involves three major objectives including: 1) monitoring and analyzing risks to ships that are changing because of altered sea and iceberg conditions as a result of climate change, 2) monitoring and analyzing the risks from ships to marine mammals and to safe and sustainable subsistence hunting activities, and 3) facilitation of Inuit and northern youth training workshops to be held in communities where some of the greatest increases in ship traffic is occurring.

This report is related to objective 2 of the overall project by focusing specifically on understanding the risk for ships to marine mammals from underwater noise. For this project, we modeled monthly underwater noise from ship traffic in the Kitikmeot Region and Lancaster Sound (Tallurutiup Imanga National Marine Conservation Area) between 2015 and 2018. The main goal of this modeling work was to expand our understanding of the spatial and temporal extent of underwater noise from ship traffic in these areas of Nunavut, providing information on hotspots for underwater noise that deserve more focused attention.

2.0 METHODS

Here, we briefly describe the procedures for ship noise modeling. Full technical methodological details can be viewed in the Appendix. The modeling methods involved three steps: 1) estimating how sound propagates or travels through the water in different regions of the study area; 2) modeling the "noise footprint" of individual vessels as they transited through the region; and 3) compiling the noise footprints for every ship in each month and counting the number of times that the behavioural disturbance threshold was surpassed.

To estimate propagation loss, we used the software dBSea 2.0 to measure how sound travels through the water in different areas of the study region. Effectively, areas with deep, open water had further sound propagation compared to areas with shallower water or narrow channels. We then split the study area into zones with different levels of propagation loss.

Following the estimation of propagation loss, vessel noise footprints were produced for each vessel track for each ship within each month of each year from 2015 to 2018. Ships were only active between mid July and mid October, so we focused on the four months between July and October. We used satellite Automatic Identification System (AIS) data to derive ship tracks, and used a standard geometric spreading equation, accounting for the propagation loss within different regions, to estimate the spread of noise around each ship track for each ship within a month. We then extracted the area of each noise footprint that surpassed the behavioural disturbance threshold for marine mammals as defined by NOAA (National Marine Fisheries Service, 2016), which is 120 dB re 1 μ Pa. We combined all noise footprints for all ships within a month, and counted the number of times that the behavioural disturbance threshold would be surpassed.

3.0 RESULTS AND DISCUSSION

3.1 Trends in Ship Traffic

Ship traffic is limited in the region in July, except for a few cargo ships, government vessels and icebreakers, pleasure craft, tankers, and tugs that were variable between years (Figures 1-5). All ships combined traveling in July traveled a maximum of 3,770 km in a given year, compared with all other months in this study, where all ships combined traveled greater than 15,000 km per month (Figure 5). August and September have much higher levels of traffic in all years, with September being the peak month for every year except 2017, when it was in August. The unusual increase in traffic observed in August 2017 seems to be driven by cruise ships and pleasure craft, which both had higher distance traveled in August compared with September, as well as by cargo ship traffic within Eclipse Sound. For the Kitikmeot Region in general, and Dease Strait specifically, September is the peak month in every year, whereas for Eclipse Sound, August is the peak month (Figure 6). Traffic then decreases in October, although not as low as in July, with ship tracks still running mostly from east to west across the study area.



Figure 1. Ship tracks (satellite automatic identification system) in the Kitikmeot Region and Lancaster Sound between July and October 2015, colour-coded by vessel category.



Figure 2. Ship tracks (satellite automatic identification system) in the Kitikmeot Region and Lancaster Sound between July and October 2016, colour-coded by vessel category.



Figure 3. Ship tracks (satellite automatic identification system) in the Kitikmeot Region and Lancaster Sound between July and October 2017, colour-coded by vessel category.



Figure 4. Ship tracks (satellite automatic identification system) in the Kitikmeot Region and Lancaster Sound between July and October 2018, colour-coded by vessel category.



Figure 5. Total distance traveled by different vessel categories in the Kitikmeot Region and Lancaster Sound between July and October 2015-2018.



Figure 6. Total distance traveled by each vessel class within each month between July and October In 2015-2018 within Dease Strait (top) and Eclipse Sound (bottom).

3.2 Modeled Underwater Noise

Underwater noise modeling outputs (Figures 7-12) showed a great deal of variability in ship noise through time. In all four years, July only had a handful of vessel tracks, with the highest underwater noise levels in 2018 when Baffinland expanded their shipping season more into July (Figures 7-12). August and September have the highest underwater noise levels, and October is intermediate (Figure 11). The majority of the study area has either no noise above 120 dB or noise from a single ship track within a month. However, a few hotspots for vessel traffic existed in August and September of every year: Eclipse Sound and Milne Inlet, the corridor south of Victoria Island near Cambridge Bay and leading south of Prince of Wales and Somerset Islands, and generally through the middle of the Parry Passage between Devon Island and northern Baffin Island (Figures 7-10). Eclipse Sound and Milne Inlet have by far the most ship traffic and ship noise, and are the only areas exceeding 20 noise disturbance events within a 500 m cell in a month (Figure 12). South of Victoria Island near Cambridge Bay (Dease Strait) is the next highest hotspot for ship noise, simply because the safe shipping corridor is quite narrow, so more ships are restricted in where they can travel (Figure 12).

The year 2018 has lower noise levels than expected compared to other years, particularly in Dease Strait (Figures 10, 12). This is because 2018 was a heavy sea ice year, which caused many cruise ships and passenger vessels to change or cancel their trips, and these vessels completely avoided the Kitikmeot Region.



Figure 7. Counts of the number of times that each 500 m cell in the study region exceeded 120 dB in each month from July to October of 2015.



Figure 8. Counts of the number of times that each 500 m cell in the study region exceeded 120 dB in each month from July to October of 2016.



Figure 9. Counts of the number of times that each 500 m cell in the study region exceeded 120 dB in each month from July to October of 2017.



Figure 10. Counts of the number of times that each 500 m cell in the study region exceeded 120 dB in each month from July to October of 2018.

Figure 11. Total number of times per cell that the marine mammal behavioural disturbance threshold was surpassed in the Kitikmeot Region and Lancaster Sound between July and October 2015-2018.



Figure 12. The total number of times per cell that the marine mammal behavioural disturbance threshold was surpassed in each month between July and October of 2015-2018 in Dease Strait and Eclipse Sound.

4.0 DISCUSSION

As ship traffic in Kitikmeot and Lancaster Sound regions increases, concurrent ship-source noise risk will also increase. Compared to other global Arctic regions ship traffic is low in Inuit Nunangat, but it is the highest, and is growing the most rapidly, in Nunavut waters. It is expected that climate change will facilitate increased shipping opportunities in the southern route of the Northwest Passage over the medium to long term and that the northern route will remain choked with ice at least until the end of the century (Laliberté et al. 2016; Howell and Brady 2019). These observed and expected increases in shipping traffic is likely to intersect with key marine mammal habitat regions that have been previously identified in scientific studies (Doniol-Valcroze et al., 2020b, 2020a; Yurkowski et al., 2019) and through Inuit Knowledge (Dawson et al. 2020a; 2020b). It is thus important to both model potential ship-source underwater noise risks for marine mammals, such as has been conducted in this study, and to verify modelled impacts through hydrophone data and Inuit knowledge. Benchmarking historic and current noise impacts before the expected increases in shipping traffic through the Northwest Passage will be very important in identifying policy measures to mitigate underwater noise impacts for marine mammals in the future.

5.0 FUTURE WORK

This study has highlighted a number of future priorities for research on underwater noise in Nunavut. These include: 1) examining the overlap between important areas for marine mammals

and fish and underwater noise from ships to estimate the potential exposure of these species to noise; 2) forecast future shipping levels and estimate underwater noise levels in the future; 3) obtain better estimates of ship source levels for ships traveling in the Canadian Arctic; and 4) validate model results using passive acoustic data collected at key hotspots, such as in Eclipse Sound and Dease Strait.



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APPENDIX - DETAILED METHODOLOGY

Estimating Propagation Loss

The propagation loss of sounds moving away from a source ship were modeling throughout the Kitikmeot region and Lancaster Sound to identify how sound travels differently across this study area. Of particular importance were sites differing in bathymetry or proximity to land. Propagation loss of different classes of ships was calculated using the software dBSea 2.0 (Irwin Carr Consulting, Northern Ireland). Propagation loss typically depends on four main factors: the source level of the noise, the sound speed profile of the region, bottom sediment type, and bathymetry. We accounted for all four of these variables when modeling (see below)

Median vessel source levels in 1/3 octave bands were obtained from the Port of Vancouver's listening station (ECHO Program) for the following ship categories: bulk carrier, cruise ship, government research vessel, tanker, and tug (see Table 1). Average broadband source levels for military, recreational, and fishing vessels were obtained from Veirs et al. (2016) (Table 1Error! Reference source not found.), but were not used for the detailed acoustic propagation modeling because they were not available as 1/3 octave levels.

Source of data	Vessel category	N	Source level
			(dB re 1 µPa @ 1 m)
ECHO Program	Bulk carriers	1728	188.3
ECHO Program	Cruise ships	81	179.5
ECHO Program	Government and icebreakers	12	192.6
ECHO Program	Tankers	292	187.4
ECHO Program	Tugs	582	180.8
Veirs et al. 2016	Fishing	65	164
Veirs et al. 2016	Military	113	161
Veirs et al. 2016	Recreational	41	159

Table 1. Median broadband vessel source levels from the Port of Vancouver's ECHO program and for additional vessel classes from Veirs et al. (2016).

The average sound speed profile for the study region was calculated based on conductivitytemperature-depth (CTD) measurements taken by the research vessel CCGS Amundsen. The mean CTD and sound speed values at each metre of depth were calculated from the data from 22 different CTD casts aboard the Amundsen in 2014.

For the bottom sediment type, one single sediment value was used for the entire region. Letaïef et al. took sediment samples across the Canadian Arctic Archipelago, aboard the Amundsen in 2014.

The samples were collected at specific spatial points and further interpolated; the average sediment type for this region was identified as silt (Letaïef, 2019; Letaïef et al., 2018).

Bathymetric data was obtained from the International Bathymetric Chart of the Arctic Ocean at a 500 m spatial resolution (Jakobsson et al., 2012). These data are the most recent and most accurate data currently available for the Arctic Ocean at a broad spatial scale.

Using the four inputs mentioned above, sound propagation was modelled using vessel positions along major routes in the region, identified using satellite AIS data. Vessels positions were placed between 20 and 50 km apart while also ensuring that the bathymetric characteristics were included. The model estimates received levels every 500 m away from the source of noise along eight radial slices (45° separation) and 10 metre depth increments. The modeling accounted for frequency-dependent attenuation and propagation of sound by modelling each 1/3 octave band, and used two different models to calculate propagation: normal modes for low frequency noise sources (12.5 Hz to 1.2 kHz) and ray tracing for high frequencies (1.6 kHz to 32 kHz). Propagation loss values were estimated by examining broadband received level by distance out to a maximum distance of 25 km across all radial slices, fitting a logarithmic line of best fit to the data, and estimating the slope coefficient of the logarithmic line as the propagation loss value (see Table 3). This was done for four different vessel classes: bulk carriers, cruise ships, government vessels, and tug boats; the propagation loss were used for fishing vessels, recreational vessels, and military vessels. The different regions of propagation loss are shown in Figure 12.

Monthly Ship Noise Footprints

Following the estimation of each zone's propagation loss, vessel noise footprints were produced for each vessel track for each ship within each month of each year from 2015 to 2018 using ArcMap 10.4 software (ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute); ship tracks were built from satellite AIS data (exactEarth, Cambridge, ON). First, a grid of distance values was calculated around each vessel track using 500 m cell size out to a 10 km radius from the ship track, and each cell was assigned a specific propagation loss value depending on its location and the class of the vessel. The cell containing the ship track was assigned a distance value of 1 m. The received level (dB re 1 μ Pa) in each cell was then calculated using the standard received level equation:

RL = SL - PL * Distance

where *RL* is received level, *SL* is the broadband source level for a given vessel class, *PL* is the propagation loss calculated for different areas in the study region, and *Distance* is the distance grid.

The received level grid was then converted into a binary raster variable, with a one assigned to any cell where received level was ≥ 120 dB re 1 µPa, and a zero assigned to all cells with received level < 120 dB. 120 dB is the behavioural disturbance threshold for marine mammals as defined by NOAA (National Marine Fisheries Service, 2016; Southall et al., 2007). Binary rasters were

then summed for all vessels within a month to estimate the number of times that each 500 m cell exceeded the 120 dB noise threshold within each month of each year. This count represents the number of times within a month that a marine mammal in any given cell could have been exposed to ship noise that exceeds the 120 dB behavioural disturbance threshold.



Figure 13. Zones of propagation loss in the Kitikmeot Region and Lancaster Sound of Nunavut. The propagation loss values are specific to bulk carriers. Different values were used for other vessel classes, but the relative difference and delineation of the zones remains the same for all vessel classes.