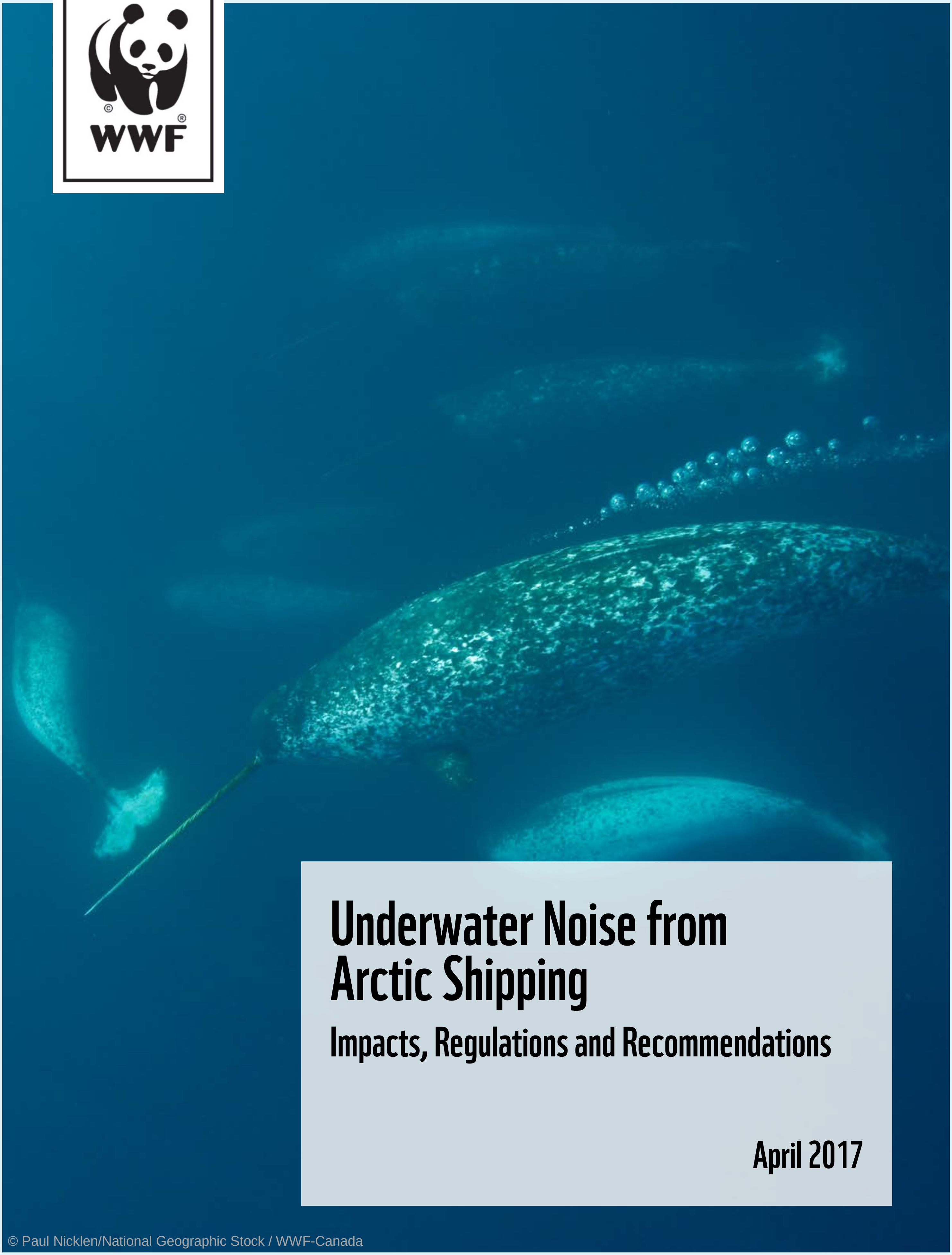

# Underwater Noise from Arctic Shipping

## Impacts, Regulations and Recommendations

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## Introduction

Marine mammals, including whales, walrus, and seals, rely heavily on sounds for survival. The Arctic soundscape has long been shaped by their clicks and calls. The rapid loss of summer sea ice that's been observed in recent years is opening this once largely inaccessible region to ship traffic. The low-frequency sounds that ships generate propagate efficiently and travel vast distances in deep water marine environments. This means that the Arctic is becoming noisier, which could have a profound impact on marine mammals.

## Background

Commercial shipping is one of the main contributors to anthropogenic underwater noise and is mainly generated by propeller cavitation and onboard machinery. At high latitudes, noise from a ship is particularly efficient at propagating over large distances because the SOFAR channel (short for Sound Fixing and Ranging channel), which is created by the ocean's thermocline[1] and facilitates sound travel. In addition, icebreakers generate higher and more variable noise levels from propeller cavitation compared to other vessels due to the episodic nature of breaking ice, which often involves maneuvers such as backing-and-ramming into the ice.[2] Table 1 compares the noise frequency produced by various vessel types. Some icebreakers are equipped with bubbler systems that blow high-pressure air into the water to push floating ice away from the ship, creating an additional noise source over short ranges.

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[1] Region of rapid change in temperature with water depth.

[2] Roth, E.H., Schmidt, V., Hildebrand, J.A., Wiggins, S.M., (2013), Underwater radiated noise levels of a research icebreaker in the central Arctic Ocean, J Acoust Soc Am. 133(4):1971-80. doi: 10.1121/1.4790356.

**Table 1** Comparison of anthropogenic underwater sound from different vessel types.[3] [4] [5]

| Vessel classification | Frequency (Hz) |
|---|---|
| Fishing vessel (12 m long – 7 knots) | 300 |
| Cargo vessel (173 m length, 16 knots) | 10 to 50 |
| Supertankers (337 m length, 18 knots) | 23 |
| Small- to medium-sized vessel (< 50 m for pleasure craft; 50-100 m for other vessels) | 300 to 1000 |

Underwater noise from shipping is increasingly recognized as a pollutant[6] [7] and is considered a high-risk anthropogenic threat for species at risk protected under the *Species at Risk Act* (SARA). Marine mammals use sound to communicate, locate mates, search for prey, avoid predators and hazards, maintain social bonds, and for short- and long-range orientation and navigation. Anthropogenic sound introduced into a marine environment can potentially affect marine mammals in numerous ways. Since the frequency of noise produced by vessels can overlap with the hearing frequency of marine mammals, biologically relevant signals (used for communication and echolocation) can be masked. Table 2 shows the general hearing and vocalizing ranges of marine mammals. Marine mammals have been observed to compensate for masking by emitting calls at higher frequencies. However, higher frequency calls travel shorter distances and require more energy to produce.[8] In addition, the risk that competitors, predators, or parasites may detect these calls is greater.[9] Therefore, masking can cause decreased foraging efficiency, higher energetic demands, less group cohesion, and higher predation.

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[3] Cluster Maritime Français, (2014), Underwater Noise: Economic and Environmental Challenges in the Marine Environment, Cluster Maritime Français.

[4] Hildebrand, J.A. (2005), Impact of anthropogenic sound, in. Reynolds, J.E. et al. (ed.) Marine mammal research: Conservation beyond crisis. The Johns Hopkins University Press, Baltimore, Maryland, pp. 101-124.

[5] McDonald, M.A., J.A. Hildebrand and S.M. Wiggins (2006) Increases in Deep Ocean Ambient Noise in the Northeast Pacific West of San Nicolas Island, California. J. Acoust. Soc. Am. 120:711-718

[6] Williams, R., Wright, A.J., Ashe, E., Blight, L.K., Bruintjes, R., Canessa, R., Clark, C.W., Cullis-Suziki, S., Dakin, D.T., Erbe, C., Hammond, P.S., Merchant, N.D., O'Hara, P.D., Purser, J., Radford, A.N., Simpson, S.D., Thomas, L., Wale, M.A., (2015), Impacts of anthropogenic noise on marine life: Publication patterns, new discoveries, and future directions in research and management, Ocean and Coastal Management, 115;17-24.

[7] Clark, C.W., Ellison, T.W., Southall, B.L., Hatch, L., Van Parijs, S.M., Franckel, A. and Ponirakis, D., (2009), Acoustic Masking in Marine Ecosystems: Intuitions, Analysis, and Implication. Mar. Ecol. Prog. Ser. 395, 201-222.

[8] Moore, S.E., Reeves, R.R., Southall, B.L., Ragen, T.J., Suydam, R.S., and Clark, C.W. 2012. A New Framework for Assessing the Effects of Anthropogenic Sound on Marine Mammals in a Rapidly Changing Arctic. BioScience 62: 289-295.

[9] Tyack, P. 2008 Implications for marine mammals of large-scale changes in the marine acoustic environment. J. Mammal. 89: 549-558.

**Table 2** General hearing and vocalizing ranges of marine mammal.[10]

| Marine mammal | Hearing sensitivity (Hz) | Peak frequency (Hz) |
|---|---|---|
| Mysticete | 20 to 20,000-30,000 | 10 to 2,000 |
| Odontocete | ~100 to 160,000 | |
| - click | 5,000 to 150,000 | |
| - whistle | 1,000 to 25,000 | |
| Pinniped | 1,000 to 20,000 | <1,000 to 4,000 |

Exposure to anthropogenic sound can also lead to a variety of behavioural reactions, increase stress hormones, decrease reproduction, cause temporary and permanent hearing loss, and change the ecosystems as a result in a reduction of prey availability – all of which can negatively affect a population. [11] [12] It should be noted that the response of each marine mammal to noise may differ because of the species, individual characteristics, age, gender, prior experience with noise, behavioural states, as well as other possible factors.

Many marine mammals tend to exhibit a flee response when an icebreaker is heard. This can occur over very large distances, for example, beluga whales can hear ships transiting through sea ice 35-78 km away and flee the area as soon as they are heard.[13] Belugas tend to avoid the area where icebreaking was heard for 1-2 days.[14] The displacement of animals from preferred areas could results in negative consequences. The changes in food availability to marine mammals would likely affect their energy budget and thus their fitness.[15] The possible increase in animal density caused by the displacement could subsequently result in increased competition and predation.[16] Alternatively, marine mammals have also been observed to display

[10] Hildebrand, J.A. (2005), Impact of anthropogenic sound, in. Reynolds, J.E. et al. (ed.) Marine mammal research: Conservation beyond crisis. The Johns Hopkins University Press, Baltimore, Maryland, pp. 101-124.
[11] Weilgart, L.S. (2007). The Impacts of Anthropogenic Ocean Noise on Cetaceans and Implications for Management. Canadian Journal of Zoology, 85(11), 1091-1116.
[12] Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. Int. J. Comp. Psychol. 20(2):159-168.
[13] Erbe, C. and M. Farmer. 2000. Zone of impact around icebreakers affecting beluga whales in the Beaufort Sea. J. Acoust. Soc. Am. 108(3), Pt. 1.
[14] Cosens, S.E. and L.P. Dueck. 1993. Icebreaker noise in Lancaster Sound, NWT, Canada: Implications for marine mammal behavior. Mar Mam Sci. 9(3):285-300.
[15] Canadian Science Advisory Secretariat, and Canada Department of Fisheries and Oceans, Central and Arctic Region. 2014. Science review of the final environmental impact statement addendum for the early revenue phase of Baffinsland's Mary River project. http://publications.gc.ca/collections/collection_2014/mpo-dfo/Fs70-7-2013-24-eng.pdf.
[16] Stewart, R.E.A., V. Lesage, J.W. Lawson, H. Cleator and K.A. Martin. 2012. Science Technical Review of the draft Environmental Impact Statement (EIS) for Baffinland's Mary River Project. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/086. vi + 62 p.

a freeze response when in the presence of icebreakers.[17] This can allow ships to get close enough for potentially harmful effects to occur, including damage to their auditory system.

# Mitigation Measures

Mitigation measures to reduce noise radiated by commercial vessels can be split into two categories: 1) ship design; and, 2) operation and maintenance. However, to reduce overall noise, it may be essential to combine different mitigation measures from both categories.

## Ship Design Considerations

Since vessel noise is mainly produced by cavitation and onboard machinery, the largest opportunities to reduce underwater noise is with a ship's initial design.

### Propellers

Propellers should be designed and selected to reduce cavitation, which includes optimizing the propeller load, ensuring as uniform a water flow as possible into the propellers, and the careful selection of the propeller characteristics (diameter, blade number, pitch, skew and sections). Cavitation is the dominant radiated noise source and may increase underwater noise significantly.

### Hull design

Uneven or non-homogeneous wake fields are known to increase cavitation. Therefore, the ship hull form with its appendages should be designed such that the wake field is as homogeneous as possible. This will reduce cavitation as the propeller operates in the wake field generated by the ship hull.

### Onboard machinery

Machinery, particularly main diesel engines as well as auxiliary diesel engines, is a significant source of noise because of its potential to induce structure-borne vibrations that radiate via the hull. Consideration should be given to the selection of onboard machinery, along with appropriate vibration control measures, the proper location of equipment in the hull, and optimization of foundational structures that may contribute to reducing underwater radiated and onboard noise. Diesel-electric propulsion has been identified as an effective option to reduce noise and may even facilitate the effective vibration isolation of diesel generators.

## Operation and Maintenance

Operational modifications and maintenance measures should be considered as ways of reducing noise for both new and existing ships.

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[17] Finley, K. J., Miller, G. W., Davis, R. A., & Greene, C. R. (1990). Reactions of belugas, Delphinapterus leucas, and narwhals, Monodon monoceros, to ice-breaking ships in the Canadian high arctic. Can. B. Fish. Aquat. Sci. 224, 97-117.

### Propeller and underwater hull surface cleaning

Marine fouling and the roughness of surfaces are known to increase cavitation by creating a non-homogeneous wake field. Cleaning and polishing blade propellers and maintaining a smooth underwater hull surface help to reduce cavitation and simultaneously improve ship efficiency by reducing the ship's resistance and propeller load.

### Speed Reduction

In general, for ships equipped with fixed pitch propellers, reducing ship speed can be a very effective operational measure for reducing underwater noise, especially when it becomes lower than the cavitation inception speed.

### Rerouting

The effect of noise on the animal depends to a large degree on the proximity of the animal to the noise source and the animal's received level of the signal. Routing to avoid sensitive marine areas including well-known habitats or migratory pathways when in transit will help to reduce adverse impacts on marine life. behavioral responses

## Additional technologies for existing ships

In addition to their use for new ships, the following technologies are known to contribute to noise reduction for existing ships: design and installation of new state-of-the-art propellers; installation of wake conditioning devices; and installation of air injection to propeller (e.g. in ballast condition).

# Challenges

## Regulations

The issue of underwater noise and its effects on marine biodiversity has received increasing attention at the international level with recognition by a number of international and regional agencies, commissions and organizations including the Convention of Migratory Species (CMS), the International Whaling Commission (IWC), the United Nations (U.N. General Assembly (UNGA) and U.N. Convention on the Law of the Sea (UNCLOS)), the European Parliament and European Union, the International Union for Conservation of Nature (IUCN), the International Maritime organization (IMO), the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic and the Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM). To date, there are no specific national regulatory requirements in Canada.

In 2014, the IMO produced voluntary guidelines for commercial ships on ways to reduce underwater noise because of concerns about the short- and long-term negative impacts on marine life.[18] The guidelines relate to features of ship design, on-board machinery, and various operational and maintenance recommendations, which are discussed in the '*Mitigation Measures*' section of this paper.

Through the Particularly Sensitive Sea Areas (PSSAs) that the IMO can designate, if areas are considered vulnerable to international shipping, ships from IMO member states must follow measures that protect the environment.

Within the MSFD, member states must ensure that any introduction of energy into the water, such as underwater noise, is at levels that do not adversely affect the marine environment. However, the challenge is that we face an ignorance concerning the characteristics and levels of sound exposures that may pose risks to marine animals. Because injuries to marine species from shipping noise are generally indirect, the identification of the acoustic threshold represents a real challenge.

# Recommendations

1. Establish long-term ocean noise monitoring programs in specific areas of high biological importance in the Arctic where shipping activities occur.
2. Improve the current understanding about the possible causal relationships between anthropogenic noise from shipping and the short- and long-term effects on marine life.
3. More work should be done to translate the science of underwater noise into policy and regulations to guide management decisions to improve underwater noise management.
4. Marine plans should specify noise objectives, and set cumulative noise caps regionally. They should in part do this by engaging the local community.
5. Encourage industry to address underwater noise and implement best practices.
6. Education programs and tools should be developed for public and industry about the impacts of underwater noise on marine life, and possible mitigation measures.
7. A new DFO policy on underwater noise, addressing projects' full acoustical footprints and incorporating cumulative impacts of multiple developments, should be developed to guide project proponents and regulatory decision makers.
8. Existing industry and port environmental incentive programs should be expanded to include underwater noise criteria.
9. Industry should follow the following mitigation measures:
    a. Operate below cavitation inception speed and avoid rapid acceleration.
    b. Clean hull and maintain propeller.
    c. Insulate ship engine and use resilient mountings for onboard machinery. Modify propeller to minimize cavitation.
    d. Incorporate vessel quieting considerations during re-fits and new vessel construction.
    e. Modify route to avoid whales in immediate vicinity and known sensitive marine areas.

[18] International Maritime Organization (IMO), (2014), Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life CIRC/MEPC/01/833.doc