The Effects of Anthropogenic Noise on Canadian Marine Mammals

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Introduction

Canada is very rich in marine mammal diversity including various species of whales, porpoises, dolphins, seals, sea lions, the polar bear and the sea otter. Unfortunately, the population status of many of these is "at risk": The Committee of the Status of Endangered Wildlife in Canada (COSEWIC) of the Canadian Wildlife Service, Environment Canada, currently lists the bowhead whale, the right whale and some populations of beluga whales as endangered; the N Pacific humpback whale, the N Atlantic harbour porpoise, resident BC killer whales and the sea otter as threatened; and the blue whale, fin whale and polar bear as vulnerable.

Threats to these marine mammals include accidental or intended takings (killings); entanglement in debris or fishing gear; habitat destruction; water contamination due to industrial pollution, oil spills, toxic chemicals, waste and sewage; changes in water temperature and salinity; physical alteration of habitat during offshore construction; overfishing of prey; and underwater noise exposure. Since the beginning of the industrial revolution, the world's oceans have become increasingly noise. Ship traffic, hydrocarbon and mineral exploration, offshore construction, all contribute to the noise pollution of marine mammal habitat.

Noise can have a variety of effects on marine mammals: 1) Behavioural disturbance. Particularly if important behaviour such as mating, nursing or feeding is disrupted or if animals are scared away from critical habitat, the impact will be biologically significant (i.e. affecting the long-term survival of the species). 2) Masking. Marine mammals rely primarily on their acoustic sense for communication and orientation. Noise thus has the potential to interfere with the animals' communication sounds, echolocation (odontocete active sonar) signals, environmental sounds (e.g. surf) animals might listen to for orientation, the sound of prey, and the sound of predators. 3) Hearing loss. Sudden bursts of noise or prolonged exposure to loud noise can cause temporary or permanent threshold shifts. 4) Physiological damage to other organs and tissues (brain, heart, lungs, vestibular system etc.).

Canada currently has no regulations for industrial noise emission in marine mammal habitat. In an effort to establish regulations, we need to understand both the propagation of broadband and often intermittent noise through the ocean and the relationship between received sound spectrum levels and impact thresholds.

Impact assessment package

A software package has been developed that combines a sound propagation model and impact threshold models. As input parameters, this software package requires the source level and spectrum of the noise of interest; physical oceanography data about the local ocean environment such as bathymetry, bottom and surface loss data and sound speed profiles; and bioacoustical information about the target species in form of an audiogram (hearing thresholds for single frequencies), critical auditory bands (the width of the ear's auditory filter), spectra of typical animal vocalizations, reported sound levels of disturbance, and criteria for hearing damage. As output, the software produces plots of the zone of audibility, the zone of disturbance, the zone of masking and the zone of hearing damage around a noise source as a function of depth and range.

The sound propagation model is based on ray theory and calculates received noise levels as a function of depth, range and frequency. It is based on Bowlin's RAY code [1] with modifications for eigenray searching, an inclusion of surface loss and frequency-dependent absorption by ocean water.

The audibility model takes the received noise spectra as a function of depth and range from the sound propagation model and compares them to the animal's audiogram and typical natural ambient noise spectra for the receiver location. If at least at some frequencies, the received noise spectrum exceeds both the audiogram and the ambient noise, the noise source is considered audible.

The disturbance model is based on observed disturbance reactions to anthropogenic noise in the wild. For some species, received noise levels causing behavioural disturbance can be found in the literature. This is often around 120 dB re 1mPa [2].

The masking model calculates received noise levels in the critical auditory bandwidths of the animal's ear and compares them to bandlevels of typical vocalizations of the target species. If the noise is louder than the signal in all bands, masking occurs. Alternatively, the masking model can be linked to more complex software simulations of masking involving neural networks [3] which are based on masking experiments with captive marine mammals [4].

The hearing damage model is based on threshold criteria for human workplace noise exposure. If continuous noise exceeds the audiogram by 80dB repeatedly over a couple of hours, a threshold shift might occur at the corresponding frequencies [2].

Icebreaker Noise affecting Beluga Whales in the Beaufort Sea

The impact assessment package is applied to the case of propeller cavitation noise emitted by an actively icebreaking

icebreaker in beluga habitat in the Beaufort Sea. The noise is broadband consisting of sharp pulses occurring 11 times per second and has a source level of 203 dB re 1mPa @ 1m [4].

This noise is audible to belugas at all depths out to ranges of 35km. Closer to the surface, the low-frequency part of the noise spectrum is audible within 70km.

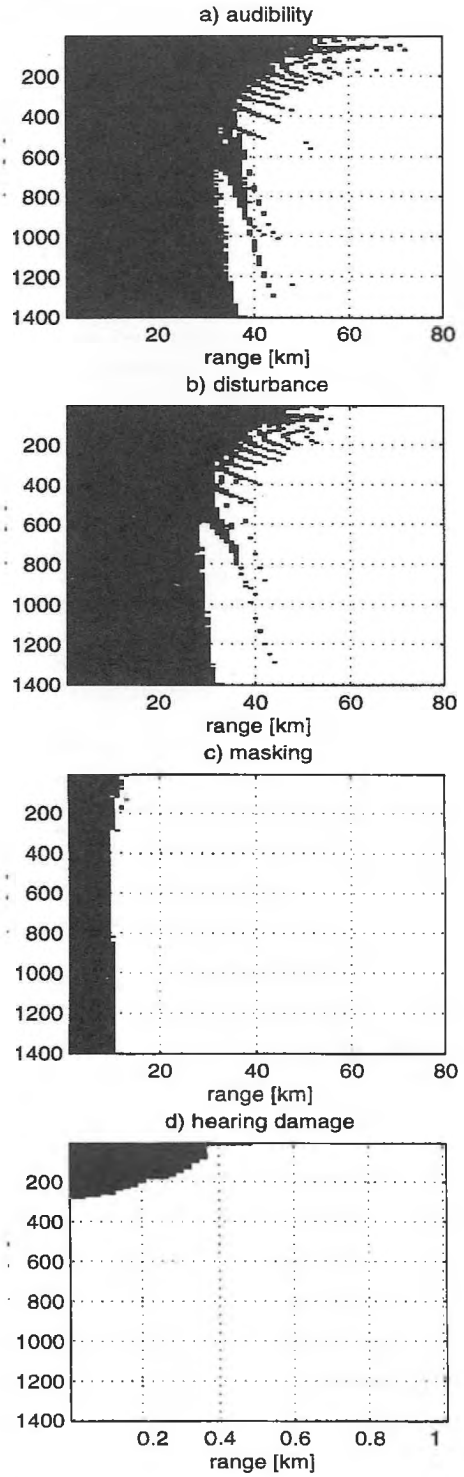

Fig.1: Zones of impact on beluga whales around an icebreaker located in the top left corner at (0,0).

Disturbance thresholds are based on field experiments [5]. The zone of behavioural disturbance is only slightly smaller than the zone of audibility.

Masking of beluga communication signals to the point of non-detectability occurs at all depths out to a range of about 10km. Hearing damage could occur if animals stayed within 300m depth and 500m range repeatedly for many hours.

Conclusion

Icebreaker cavitation noise is audible to beluga whales over long ranges. The animals tend to avoid icebreakers almost as soon as they detect them. Therefore, belugas do not get close enough for potentially harmful effects to occur such as masking or even auditory damage. However, problems can arise in heavily industrialized areas where underwater noise emitted by various sources adds up and is omnipresent for long durations. Here, animals might either be permanently scared away from critical habitat or be adversely affected because they have nowhere to flee to.

Case studies for threatened Canadian marine mammal species and industrialized areas are currently being undertaken. In summary, this software package finds its application in environmental assessments of man-made noise with respect to its impact on marine mammals. Noise sources of concern to the Department of Fisheries and Oceans Canada include offshore hydrocarbon exploration (drill ships, oil rigs, tankers, trenchers, pipeline lay barges), seismic exploration, mineral mining, ocean dredging, fishing vessels, cargo vessels, ocean acoustic research, military activities, ocean liners, ferries, pleasure boats, private boats and the whale watching fleet.

References

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