An analysis of marine anthropogenic noise in New Zealand: sources, policies, and implications for cetaceans.

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Abstract

In recent decades, anthropogenic noise has become recognised as a major pollutant worldwide and the study of its impacts has increased due to the potential for adverse consequences on wildlife. For marine environments, where sound is transmitted very efficiently through water, underwater noise has increased, mainly, at low and medium frequencies. Of all marine organisms, cetaceans may be the most affected, as they depend primarily on sound to communicate, navigate and find food. Accordingly, the general aims of this thesis are to identify the types of anthropogenic noise facing New Zealand's cetaceans, the potential impacts, review current legislation, and to propose improvements to enhance current mitigation measures of impacts.

My systematic review showed that 90% of the information about impacts of noise pollution on cetacean comes from peer-review journals and, although available from 1975, studies of marine noise pollution substantially increased after 1997. In addition, I identified the limited information on this topic in important areas such as Latin America, Africa and Southeast Asia, as well as regions in the Arctic and Southern Ocean. I also found that most effort has been focused on the impact of vessels, and bottlenose dolphin and harbour porpoise are, by far, the most studied species, showing a disparity in research coverage of both sources of noise and species. For New Zealand, there is a striking lack of knowledge of the range of sources of noise on cetaceans (excluding vessels). The information I compiled on New Zealand's cetacean distributions showed that three main groups are well represented: baleen whales, delphinids and beaked whales. Nonetheless, the information available for these species varies greatly. While there are some species very well studied, for others New Zealand species, the available information is scarce, as in the case of beaked whale.

Current mitigation measures can only be effective if comprehensive data are used to inform them. For example, planning surveys at different spatiotemporal scales are crucial to increase the effectiveness of mitigation measures. In particular, spatial modelling techniques can support mitigation measures by helping managers to identify areas of conflicts between marine mammal conservation and the development of activities such as dredging, drilling and seismic surveys. I used opportunistic sighting

data collected from different platforms, and several environmental variables biologically important for cetaceans and/or their prey, to create maps of habitat suitability for seven species of cetaceans in New Zealand. These maps were created using maximun entropy modelling (MaxEnt), a model system that does not require absence data and performs well with small sample size. Models validations were done using the Receiver Operating Characteristic curve (ROC) and the Area Under the Curve (AUC) values. The models for all seven species had excellent discriminatory power (AUC > 0.9). The environmental variables depth and sediment had the most explanatory power for the distribution of these species. Comparisons of the areas of current and designated areas for exploration activities with the marine mammal distributions generated using MaxEnt show significant and wide-ranging conflicts. Of particular concern is the designated area for exploration in the northern part of the North Island, this area overlaps with the distribution of the highly endangered Maui's dolphin, and will add new pressures on this already diminished population. Expanding noise related research in this region (as elsewhere) will help stakeholders to support future decisions for planning when human activities enter into conflict with cetaceans.

Finally, the development of effective laws that adequately regulate the anthropogenic noise impacts on marine mammals has been a task that has taken many years to advance. To assess the effectiveness of New Zealand's legislation to mitigate impacts from seismic surveys and whale-watching activities, I described and compared methods prescribed by international associations. Strengths of The Code of New Zealand are that it presents a set of comprehensive guidelines with specific mention of biologically important aspects such as mother/calve pair priority. Nonetheless, improvements could be made regarding the enforcement of these guidelines. In addition, I suggest that New Zealand's whale-watching guidelines, could be improved through the inclusion and implementation of an Impact Assessment, the creation of separate guidelines to protect specific species and/or areas and, as with seismic activities, ongoing enforcement of guidelines.

Table of Contents

List of Figures

List of Tables

Glossary[1]

- **Attenuation:** Decrease of sound pressure levels/acoustic energy.

- **Audiogram:** Graph showing the absolute auditory threshold versus frequency

- **Auditory threshold (hearing threshold):** Minimum sound level that can be perceived by an animal in the absence of background noise.

- **Bandwidth:** Range of frequencies of a given sound.

- **Critical band:** Frequency band within which ambient/background noise has strong effects on detection of a sound at a particular frequency.

- **Critical ratio:** Is the difference in level between a tone at the threshold of aural detection and the spectrum level of masking noise at the same frequency (Cato et al., 2004)[2].

- **Decibel (dB):** Unit of sound level measured by comparing a sound pressure (P) to a reference pressure (1μPa for underwater sound reference and 20 μPa in air). Decibels are on a logarithmic scale (usually sound level (dB) = 20 log(P/Pref)) (Lusseau, 2008)[3].

- **Duty cycle:** Percent of a time a given event occurs. A 1 s long tone with silent intervals of 1 s has a duty cycle of 50%.

- **Evoked potential:** Electrical signal that is emitted in the nervous system in response to a stimulus such as a sound (Lusseau 2008)[3].

- **Masking:** Obscuring of sounds of interest by interfering sounds at similar frequencies.

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[1] Glossary after Thomsen, F., Lüdemann, K., Kafemann, R., & Piper, W. (2006). Effects of offshore wind farm noise on marine mammals and fish. *Biola, Hamburg, Germany on behalf of COWRIE Ltd*, 62.

[2] Cato, D. H., McCauley, R. D., & Noad, M. (2004, November). Potential effects of noise from human activities on marine animals. In *Annual Conference of the Australian Acoustical Society* (pp. 369-374).

[3] Lusseau, D. (2008). Understanding the impacts of noise on marine mammals. In J. Higham & M. Lück (Eds.), *Marine wildlife and tourism management* (pp. 206-218). UK.

- **Octave band:** Interval between two discrete frequencies having a frequency ratio of two.

- **One-third-octave-band:** Interval of 1/3 of an octave. Three adjacent 1/3 octave bands span one octave.

- **Peak-to-peak (p-p):** Is the difference of pressure between the maximum positive pressure and the maximum negative pressure in a sound wave.

- **Permanent threshold shift (PTS):** A permanent elevation of the hearing threshold due to physical damage to the sensory hair cells of the ear.

- **Propagation loss (transmission loss):** Loss of sound power with increasing distance.

- **Pulse:** A transient sound having a finite duration.

- **Source level (SL):** Acoustic pressure at a standard reference distance of 1 m. Unit in dB re 1 μPa at 1 m (sometimes given as: @ 1m).

- **Sound pressure level (SPL):** Expression of the sound pressure in decibel (dB).

- **Temporary threshold shift (TTS):** Temporal and reversible elevation of the auditory threshold.