Underwater noise studies to support environmental impact assessment in Cockburn Sound, Western Australia

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Abstract - A coordinated program of underwater noise studies in Cockburn Sound, Western Australia, was carried out between September 2022 and December 2023. These studies were part of the Western Australian Marine Science Institution's Westport Marine Science Program, which is designed to improve the capacity to avoid, mitigate, and offset environmental impacts of new developments in Cockburn Sound. This project included measurements to help improve knowledge of the baseline underwater soundscapes, sound propagation, source levels of vessels and port activities, and hearing sensitivity of key marine fauna of Cockburn Sound. The underwater soundscape of Cockburn Sound was found to contain geophony (e.g., wind), anthropophony (vessels and machinery), and biophony (dolphins, fish, and snapping shrimp) sources. Hearing sensitivity of Little Penguins and Australian Sea Lions was modelled based on anatomical information from stranded and deceased specimens. Sound propagation, in particular from the port and ships, was measured and modelled, and the susceptibility of key species to the range of frequencies emitted by vessels and port operations investigated. The findings will be used to develop mitigation methods for the potential effects of underwater noise on marine species.

1 INTRODUCTION

The WAMSI Westport Marine Science Program (WWMSP) is designed to improve the capacity to avoid, mitigate, and offset environmental impacts of the proposed Westport container port development and increase the WA Government's ability to manage other pressures acting on Cockburn Sound into the future. The establishment of a container port in Cockburn Sound will result in an increase in ship traffic, which will increase underwater noise (WAMSI, 2022). To understand the potential impact an increase in noise levels from shipping and port activities, requires knowledge of the source levels, sound propagation, ambient noise levels and hearing sensitivity of potential receptors in Cockburn Sound (Figure 1).

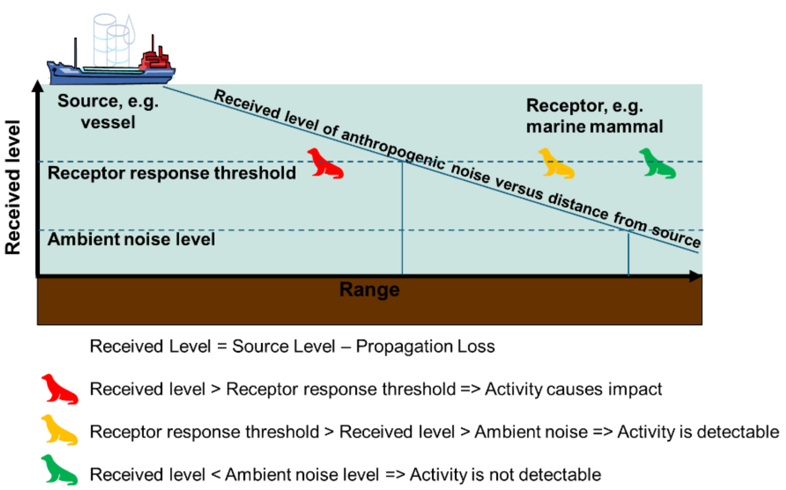

Figure 1 – A schematic representation of the relationship between an underwater noise source, sound propagation, ambient noise and receptors.

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To address knowledge gaps identified in WAMSI (2022), a comprehensive study of underwater noise in Cockburn Sound was undertaken with the main objectives to:

1. Record and quantify the baseline marine soundscape over a 12-month period at multiple sites,
2. Develop validated models for sound propagation in Cockburn Sound,
3. Fill the gap in noise data for port operations and ships under specific conditions, and
4. Fill the gap in hearing sensitivity of key fauna found in Cockburn Sound, such as Australian Sea Lions and Little Penguins.

The paper presents a summary of this program of study.

2. METHODS

2.1 Underwater soundscape

The baseline marine soundscape was measured over a 12-month period at nine sites, seven within Cockburn Sound and two just outside of Cockburn Sound to the north. Soundscape analysis followed a similar methodology to the one set out by Erbe et al., (2015). In summary, at each site, noise percentiles across a frequency range of 20-48000 Hz were calculated for narrowband, broadband, and one-third octave band levels. Seasonal variability, diurnal variability, and spatial and temporal correlations among sites were quantified using statistical methods including correlation analysis and principal component analysis. Observed noise was grouped into three categories: geophony, anthropophony, and biophony.

2.2 Sound propagation models

Details of the methods used to derive sound propagation models can be found in Duncan *et al.* (2024). In summary, sound propagation input model parameters, in particular, parameters describing propagation in the sediments, were explored by using a combination of airgun measurements and modelling. The accuracy of an “equivalent fluid layer” model for bottom parameters was compared with a more conventional two or three-layer structure and with *in situ* propagation measurements.

2.3 Ship and port operation noise signatures

Vessel noise was estimated for four vessel classes: tanker, bulk carrier, tug, and pilot boat, as well as for the combined noise arising from routine port operations near the Kwinana Grain Terminal. Ships were identified for analysis by filtering AIS data for ships passing northward or southward through the main shipping channel into Cockburn Sound. AIS data was also used to identify underwater noise from activity surrounding the Kwinana Grain Terminal jetty.

2.4 Hearing sensitivity of marine fauna

Hearing sensitivity of Little Penguins and an Australian Sea Lion were derived using the methodology set out by Wei et al. (2024). In summary, naturally deceased Little Penguins and an Australian sea lion were collected for medical CT and microCT (just Little Penguin ears) scans. The scans were used for 3D reconstruction of the ears and head. Finite element sound reception models were then built to simulate sound (e.g., noise) reception process.

3. RESULTS

3.1 Underwater soundscape

The geophony was dominated by wind-generated noise. Anthropophony was dominated by vessel noise, with industrial noise contributing at the south end of Cockburn Sound and an unknown but strong 50-Hz noise source contributing to the noise measured on the Kwinana Shelf. Biophony was dominated by dolphins, fish, and snapping shrimp, which varied also by location, season, and time of day.

3.2 Sound propagation models

Models were able to qualitatively reproduce the higher propagation losses observed at frequencies of 100-300 Hz, but the detailed pattern of high-loss and low-loss frequencies depends strongly on the assumed layer properties. In practice, the layering between any source and receiver will vary in a range-dependent manner and the high- and low-loss bands will be smoothed out across multiple frequencies, resulting in a high-loss "notch" in which sound propagates more efficiently through the bottom than via the water column. More details and suggested model parameters derived from a combination of airgun experiments and modelling can be found in Duncan *et al.* (2024).

3.3 Ship and port operation noise signatures

Due to the peculiarities of underwater acoustic propagation in Cockburn Sound, broadband ship noise at close range was higher from the bow aspect of the ship, dominated by frequencies higher than 1000 Hz, and varied considerably between ships of the same classes. Source signatures for a pilot boat and several tugs were measured at the southern end of the Sound. Broadband noise levels varied up to ±15 dB for both boat classes and did not show a significant dependence on vessel speed over the limited number of observations available. The combined noise from port operations was measured for ships arriving, loading, and departing the Kwinana Grain Terminal at the southern end of Cockburn Sound. Pilot boats and tugs were involved in the arrival and departure, contributing to higher noise levels for a short time, while the loading phase was quieter.

3.4 Hearing sensitivity of Little Penguins and Australian Sea Lions

Audiograms were successfully derived for Little Penguins and an Australian Sea Lion. The results compared well with other studies of comparable species.

4. CONCLUSIONS AND FUTURE WORK

A comprehensive study of underwater noise was undertaken that will support future environmental impact assessments of port construction and other developments in Cockburn Sound, Western Australia. Future work was identified that could be explored with the existing datasets. Additional finer-scale temporal analysis of biophony could include exploration of the behavioural and ecological implications of presence and absence of various species, and examination of the potential impact of masking by anthropophony sources. Sound exposure levels from geophysical surveys and other types of sonar noise could be measured in a relatively straightforward way by combining AIS tracks during known geophysical surveys with existing measurements of underwater noise. Analysis of port operations noise and noise from individual ships and boats could be expanded from the few dozens of occasions described in this document to the several hundred occasions theoretically available by exploiting the entire dataset, in order to increase the statistical validity of the conclusions.

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