Pilot Boat Contributions to Underwater Noise in Cockburn Sound

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ABSTRACT
Underwater noise from marine vessels is a significant contributor to the underwater soundscape. The state government of Western Australia (WA) is developing a new port in Kwinana, which is expected to increase shipping activity in Cockburn Sound, a sheltered marine embayment off the west coast of WA. The acoustic characteristics of the pilot boat *Genesis*, a small vessel that frequently operates in Cockburn Sound, were extracted from a one-year soundscape study originally conducted for the Western Australian Marine Science Institution. Of the nine recorders deployed around Cockburn Sound in the original study, *Genesis* frequently operated near the recorder that was situated near the Kwinana Grain Terminal. Pattern-of-life analysis revealed that in the vicinity of the recorder, *Genesis* was primarily either stationary or operating at high speeds (10.0–12.5 m/s [20-25 kn]), with limited activity at intermediate speeds. After correcting for source-receiver range at the closest point of approach (CPA), the measured median broadband source level was 170 dB re 1 μPa·m. One-third octave spectral analysis revealed that at speeds above 7.5 m/s (15 kn), the frequency bands below 200 Hz produce the highest source levels. Variability was high, particularly at the lowest and highest frequencies, with a weak negative correlation between noise levels and speed. The variability in received noise levels was attributed to environmental factors and the semi-displacement characteristics of the monohull vessel. This study developed a repeatable methodology that could be applied to other vessels that recur repeatedly in the same dataset (e.g., the four tugs that regularly operate in Cockburn Sound), expanding the current understanding of noise generation by small vessels and quantifying their contributions to the local soundscape.

1 INTRODUCTION
The proposed establishment of the Westport container port in Cockburn Sound, WA will result in an increase in ship traffic, which will increase underwater noise. To understand the potential impact of an increase in noise levels from shipping and port activities, a comprehensive study of underwater noise in Cockburn Sound was undertaken by the Centre for Marine Science and Technology (CMST) at Curtin University, as part of the larger WAMSI Westport Marine Science Program (WWMSP) scientific program (Parnum et al. 2025). One of the activities undertaken by CMST was to quantify the baseline marine soundscape over a 12-month period at nine sites, seven within Cockburn Sound and two just outside of Cockburn Sound to the North (Parnum et al. 2025). Seasonal variability, diurnal variability, and spatial and temporal correlations among sites were quantified using statistical methods, and observed noise was grouped into three categories: geophony, anthropophony, and biophony.

The raw noise recordings obtained starting in July 2022 and ending in January 2024 provide a valuable record of recurring activities at various locations in Cockburn Sound, in addition to the arrival and departure of larger ships such as bulk carriers, tankers, and container ships. In particular, several smaller vessels with daily presence in Cockburn Sound were identified, including the pilot boat *Genesis* operated by Fremantle Ports, and four tugs operated by Svitzer: *Svitzer Eagle*, *Svitzer Falcon*, *Svitzer Harrier*, *and Svitzer Albatross*.

Underwater radiated noise (URN) from vessels is usually characterised as having three main origins: machinery noise, flow noise, and propeller noise (Smith and Rigby 2022). Machinery noise originates from onboard machinery vibrations which couple directly to hull plating or openings to the sea (Smith and Rigby 2022). Flow noise is the noise generated by the vessel hull, appendages, and openings moving through the water, and increases with vessel speed (Smith and Rigby 2022). Propeller noise is by far the most complex noise to study and model. At lower speeds, non-cavitating propeller noise arises from vortices that are generated by the tip and blades of the propeller moving through the water (Smith and Rigby 2022). Low-frequency tonal noise that be either non-cavitating or cavitating arises from the propeller moving through the spatially varying wake field. When the vessel's speed exceeds its "cavitation inception speed", cavitation noise can arise in various forms including vortex, sheet, bubble, and cloud cavitation, each arising from different aspects of the fluid flow around the propeller that combine to produce cavitation (Smith and Rigby 2022).

Previous measurements of acoustic source level from small boats were often studies with small sample sizes, for example, only a few passes from one or several small boats (e.g., Erbe et al. (2016)). Parsons et al. (2021) performed a meta-analysis of such studies and determined that speed and closest point of approach (CPA) were the two variables with the greatest effect on measured source level. The yearlong WAMSI soundscape dataset with the daily presence of the pilot boat *Genesis* therefore provided an ideal opportunity to measure noise arising from operation of a single boat at a variety of speeds, without introducing confounding factors such as different vessels or recording conditions.

2 METHODS

Figure 1(a) is a map locating Cockburn Sound and surrounding features, and Figure 1(b) shows a navigational chart of Cockburn Sound, with yellow labels (1 – 9) indicating soundscape deployment locations. The green labels (M1 – M5) indicate temporary deployment locations for large vessel noise. The analysis presented here will be based on Deployment 2 (07/02/2023 to 20/07/2023) at location 6 (South Basin). The underwater recorder at that location was set to sample at 96 kHz, for 4 minutes out of every 5 (80% duty cycle). To speed up subsequent processing, the recordings for this analysis were downsampled to 24 kHz.

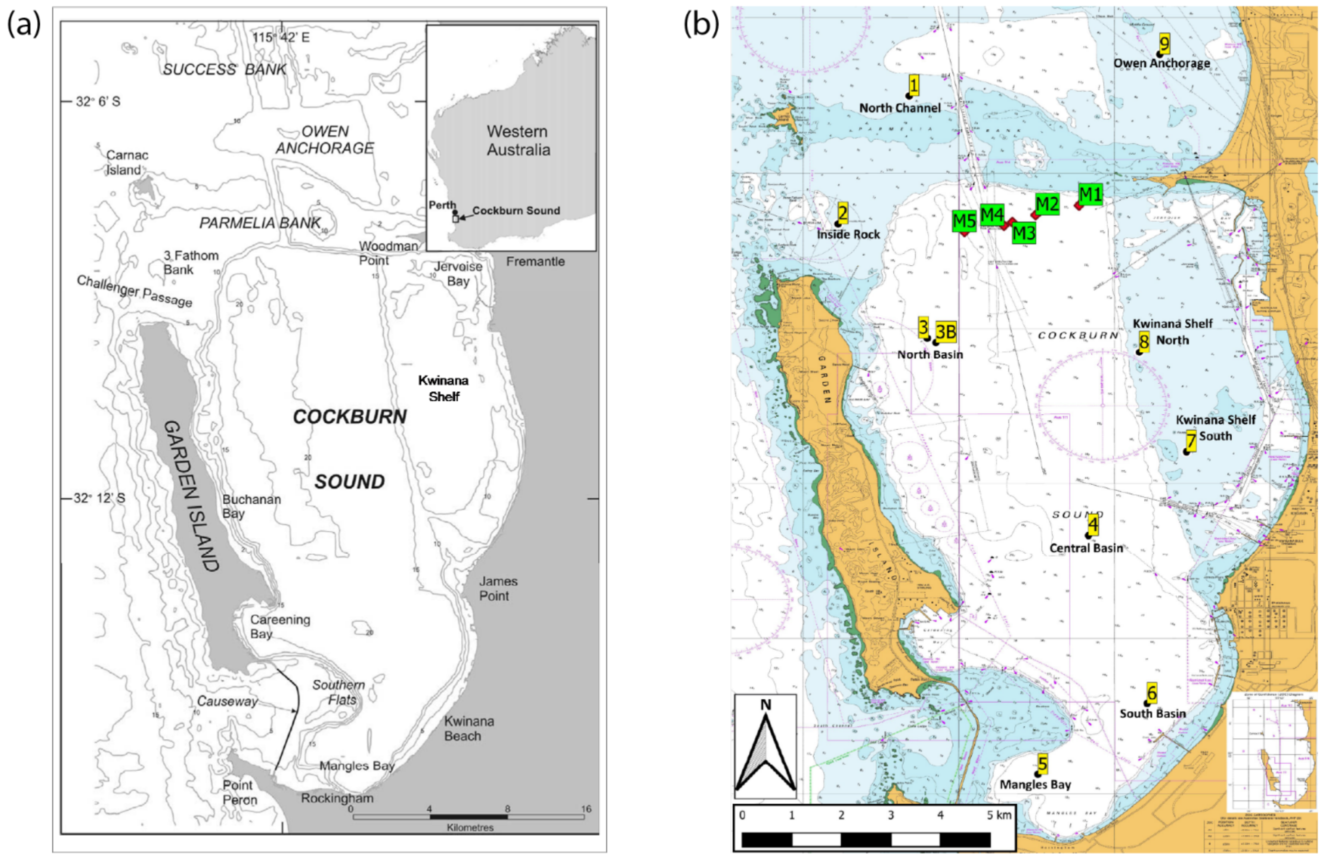

Figure 1: (a) Map of Cockburn Sound, WA with soundscape recorder locations marked in yellow and ship noise recorders marked in green. The data for the analysis presented in this paper originated from location 6, South Basin.

In order to obtain positional information on vessels in Cockburn Sound for the deployment period, a ship automatic identification system (AIS) receiver (GME, model AISR 120) and data logging computer were installed 30 km NE of Cockburn Sound on Rottnest Island from 24/01/2023 to 02/01/2024. The AIS logging station provided position reports approximately every 10 s for AIS-equipped vessels, including *Genesis*, operating throughout Cockburn Sound. The position reports for *Genesis* were grouped into tracks, and the time and range at CPA for each track was identified. To obtain a sufficient number of ship tracks for analysis, all tracks within 500 m of the recorder were included. Corrections for propagation loss (PL) between the receiver and range at CPA were applied using measured PL from an airgun propagation experiment, as described in Parnum et al. (2025).

Narrowband spectra were derived by first subtracting the mean DC offset in each 4-minute audio file, applying the known hydrophone calibration for the recorder, and then using the “spectrogram” function in Matlab, with 30-s Hamming windows and 50% overlap. One-third octave (OTO) spectra were also calculated for each 30-s sample by summing the narrowband components in each OTO band. The time of each window was corrected for recorder clock drift and matched up with the corresponding AIS data to determine the CPA distance between the boat and the recorder.

3 RESULTS

Histograms of vessel speed were created from the AIS data for *Genesis* for each month of the deployment. Figure 2(a) from March 2023 shows the typical pattern: *Genesis* spent most of its time either stationary, or at speeds of 10.0–13 m/s (20–26 kn).

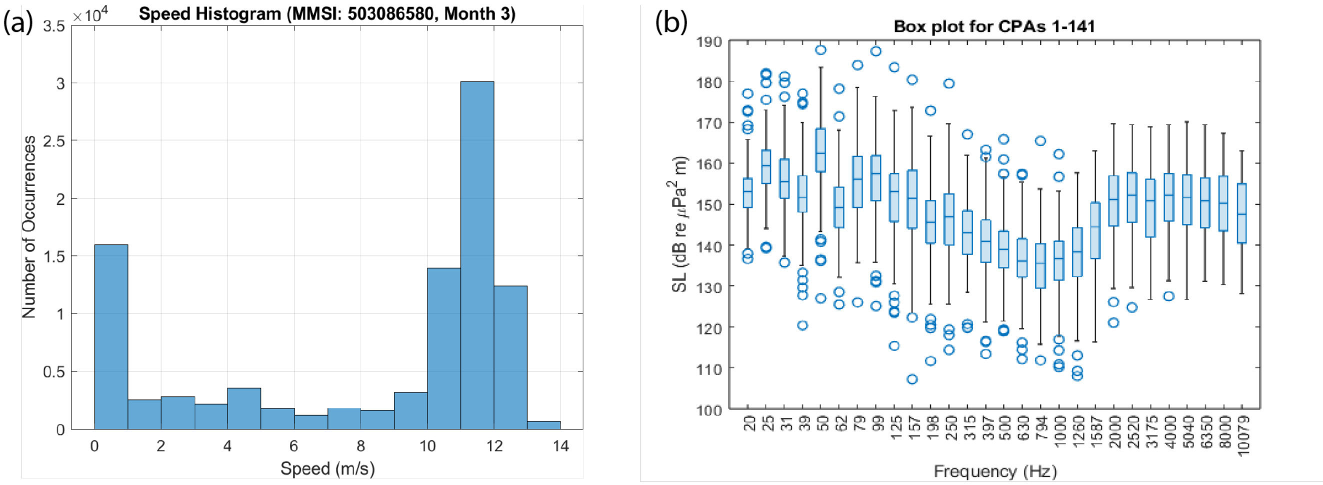

Figure 2: (a) Histogram of speed (m/s) for the vessel *Genesis* for the month of March 2023. (b) Box plot of one-third octave source levels (dB re 1 μPa·m) for 141 approaches of *Genesis* measured at the South Basin and corrected for range at CPA.

Figure 2(b) is a box plot of the median, interquartile range (IQR), and outliers for OTO source levels calculated for 141 approaches of *Genesis* measured at the South Basin recorder, as described in Section 2. There is less scatter (fewer outliers) for frequencies above 1500 Hz than there are at lower frequencies. The median source levels are between 150 and 160 dB re 1 μPa·m for frequencies less than 198 Hz, except for a slight peak of 163 dB re 1 μPa·m at 50 Hz, which could be due to the boat’s electrical generator. The source levels fall off steadily up to 794 Hz, where they begin to rise and then level off at approximately 150 dB re 1 μPa·m above 2000 Hz.

Due to the bimodal speed distribution of *Genesis*, a limited analysis of the dependence of broadband source levels on vessel speed was possible. Figure 3 is a scatter plot of broadband source level as a function of vessel speed. There are very few measurements for vessel speeds less than 7.5 m/s (15 kn) although the values of 171–174 dB re 1 μPa·m show very little scatter. However, at speeds greater than 7.5 m/s there is considerable scatter, with broadband source levels ranging from 145 to 185 dB re 1 μPa·m. A linear fit was used for speeds greater than 7.5 m/s, and the trend line, with correlation coefficient of -0.15 indicating a weak negative relationship, is plotted in red in Figure 3. The median broadband source level ± IQR over all speeds was 170.2 ± 8.0 dB re 1 μPa·m.

4 DISCUSSION

The observed variability in source level is not surprising when compared to similar studies with monohull vessels (e.g., Parsons et al. (2021)) that also show a wide range of variability in source level as a function of speed. The weak negative correlation in Parsons et al. (2021) was attributed to the semi-displacement hull of the vessel in question, which can result in a decrease in noise levels when transitioning from displacement to planing mode. As the hull rises out of the water in planing mode, there is less propeller loading and therefore a lower acoustic outputs. The paucity of data at lower speeds does not allow for further analysis of this possible effect.

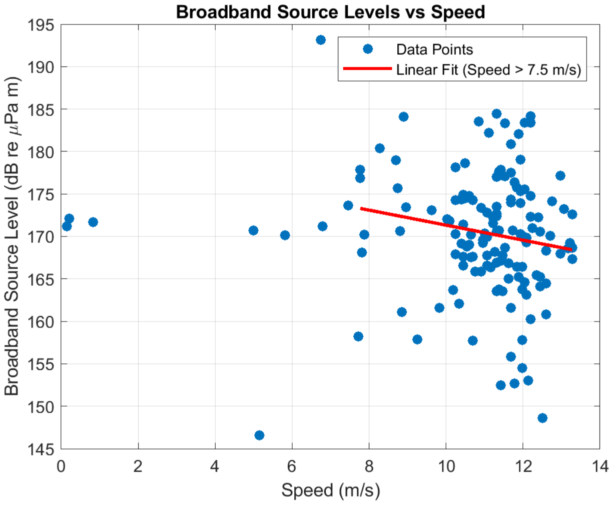

Figure 3: Broadband source level (dB re 1 µPa·m) as a function of vessel speed (blue dots). The polynomial fit (red line) was restricted to speeds greater than 7.5 m/s (15 kn).

Furthermore, any directional properties of the vessel's radiated noise were not taken into account in this above analysis. All CPAs within 500 m of the South Basin recorder were used regardless of the bearing to the boat. Variation in bottom properties within 500 m of the recorder would have also affect the received levels.

5 CONCLUSIONS

The variability and speed dependence of source level of the pilot boat *Genesis* was measured for approaches within 500 m of a bottom-mounted recorder in Cockburn Sound from January to July 2023. At speeds above 7.5 m/s (15 kn), there was a weak negative correlation between source level and speed, possibly due to the semi-displacement hull transition from displacement to planing mode. The median broadband source level ± IQR over all speeds was 170.2 ± 8.0 dB re 1 µPa·m, in reasonable agreement with values from literature for similar vessels.

ACKNOWLEDGEMENTS

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