Characterisation of an underwater acoustic seal deterrent system in the Tamar River

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ABSTRACT

Underwater acoustic seal deterrent systems are increasingly used internationally to mitigate interactions between seals and marine fish farming operations, however none have been utilised in Australian waters or with Australian fur seals. The OTAQ SealFence™ system was examined at a site on the Tamar River, Tasmania via a detailed modelling and field characterisation study. The modelling study considered a source spectra derived from measurements, along with different sea states and applied a statistically justifiable representation of multiple operational devices. The measurement study was conducted using fixed and mobile recorders during different sea states, and re-modelling was undertaken to allow comparison between similar scenarios. Understanding the propagation of signals from individual and multiple devices in a specific location is essential when estimating effects. Confidence in the predicted ranges to effect thresholds for seals and other marine fauna (e.g., cetaceans and fish), is an important part of an impact assessment required prior to further system use. The characterisation results have provided the basis for understanding potential effects of the SealFence™ on marine fauna, and the representation will be used to underpin the feasibility of the next project phase; a long-term behavioural response study to examine the system efficacy on Australian fur seals.

1 INTRODUCTION

Since the inception of non-native salmon farming in Tasmanian waters over 25 years ago, fur seals have interacted with salmon farming activities (MMIC 2002, Cummings et al. 2019)(Robinson et al. 2008). Currently legislation allows marine salmonid farms in Tasmania to manage seals when negative interactions occur (DPIPWE Wildlife Management Branch 2019). One avenue to deter the seals from the immediate area (but not necessarily from the general vicinity) is the use of underwater acoustic seal deterrent systems. The SealFence™ made by OTAQ is a short range underwater physiological deterrent system designed to deter seals at close range from entering salmon farm pens. The SealFence™ system typically comprises several individual underwater acoustic projectors (units) and associated controllers, installed principally on the nets around the perimeter of a fish farm. Each unit emits sound into the underwater environment, and the number of units in any installation varies depending on the size and layout of the farm itself. To support the University of Tasmania (UTAS) Animal Ethics Committee (AEC) approval process, acoustic modelling was conducted and monitoring programs were committed to and implemented: a baseline program and a sound source verification study.

2 ACOUSTIC MODELLING

Acoustic modelling was used to inform an impact assessment predicting the potential effects on relevant marine fauna, and develop mitigation strategies so that the risk that any marine mammal could be exposed to signals from the device which could lead to injury, impairment or behavioural disturbance is minimised. Each unit in the SealFence™ system operates with a specific pattern: an on period of three seconds, during which the device is emitting an acoustic signal, and an off period of any whole number between 3 and 9 seconds, during which no signal is emitted. The acoustic signal produced during the on period consists of a repeated pattern of 10 kHz tone bursts which lasts 1.8 ms and is repeated every 45 ms for the duration of the on period. This on-off cycle is repeated throughout the entire period of operation. Acoustic source levels for each operating mode were provided by OTAQ, as determined by the UK National Physical Laboratory (NPL 2020a, 2020b, 2020c). Sound Pressure Level (SPL) source spectral levels were provided in decidecade bands for a single steady-state tone burst, and these were converted to an equivalent Sound Exposure Level (SEL) source level (in dB re 1 $\mu Pa^2 \cdot m$) for a single tone burst by accounting for the on time; the broadband SEL source level is 162.7 dB re 1 $\mu Pa^2 \cdot m$. Directivity patterns were applied in the horizontal and vertical plane according to the results of testing by NPL (NPL 2017).

The project site is located in the Tamar River, and the river exhibits a relatively uniform width of 1 km in the section containing the fish farm, with sharp bends upstream and downstream from the site. The modelling study used geoacoustic and sound speed profile data from work previously conducted in the river (McCauley and Kent 2008). Propagation loss was modelled around each individual source using a gaussian beam acoustic ray-trace model (BELLHOP; Porter and Liu 1994), accounting for the variability of the sound level of the emitted pulse with both azimuth and depression angles according to the 3-D beam pattern of the source. Propagation loss was calculated in decidecade bands between 1 and 63 kHz with a horizontal separation of 1 m between receiver points along the 2.5° spaced modelled radials, and had receiver depths which spanned the entire water column. All scenarios were modelled under sea state 0 and 3 conditions, a wind speed of 0 and 9 knots respectively, to give a plausible range of results under different sea surface roughness conditions.

The signals emitted by the SealFence™ units are categorised as non-impulsive sounds, and maximum-over-depth sound level contours were calculated based on the predicted sound fields. The outputs of the modelling included the distance to frequency-weighted sound exposure level (SEL; L_E) thresholds for marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) (Southall et al. 2019), and behavioural response (NOAA 2019). Thus the metrics considered were SPL and the 24h SEL. The SEL_{24h} output for each unit was calculated from the SEL source level per for a single tone burst using Equation 1, where N is the number of tone bursts output by a single unit within 24 hours, accounting for the variability in the off time period.

$$\text{SEL}_{24\text{h}} = \text{SL}_{\text{SEL}} + 10\log_{10}(N) \quad (1)$$

The SPL output for a single unit was calculated using Equation 2 where τ is the integration time window in seconds (0.125 ms) and N_τ is the number of tone bursts occurring within the integration time window (3).

$$\text{SPL} = \text{SL}_{\text{SEL}} + 10\log_{10}(N_\tau) - 10\log_{10}(\tau) \quad (2)$$

As SPL is an instantaneous rather than accumulated metric, consideration was additionally given to the number of units likely to be operating at any given time. Unit operation has a random self-deterministic nature, and a simulation was conducted which determined that for 14 units operating, the average number of units operating simultaneously within in 0.125 s integration window is 5.

3 MONITORING

Two monitoring programs were conducted as part of the process, a baseline program and a sound source verification study. The objectives of the baseline program were to characterise the ambient environment, contributions to the soundscape from natural and anthropogenic sources, and the presence of marine mammals. The baseline monitoring was conducted at two locations (stations), close to the Petuna Rowella salmon farm lease (~17 m water depth) and downstream of the Tamar Valley Power Station close to Bell Bay (28 m water depth). The monitoring was conducted with JASCO's Autonomous Multichannel Acoustic Recorders (AMARs) configured to record continuously at 64 and 512 kilosamples per second for a recording bandwidth of 10 Hz to 32 (or 256) kHz, storing data on 2.5TB of internal solid-state flash memory. Two three-month periods were sampled.

We used a specialised computing platform (PAMlab; JASCO) capable of processing acoustic data hundreds of times faster than real time to process the data. The monitoring program determined that substantial contributors to ambient sound levels at all location and deployments is tidally-drive flow noise below approximately 100 Hz and vessel traffic below approximately 2 kHz. Port operations at Bell Bay and small vessel traffic near the fish farm being dominant contributors to the soundscape. Close to the salmon farm sound level increases at most frequencies occurred in relation to various fish farm activities. Specifically, net cleaning equipment causes sound level increases in the frequency range above 300 Hz (and up to 100 kHz). The daily and weekly median SPL close to the salmon farm increase during typical daytime, weekday working hours, and decrease at night and on weekends. No fish vocalisations or chorusing events were apparent in the data, but snapping shrimp were omnipresent, and significant contributors to the soundscape above 2 kHz, with minimal dusk/dawn increases in level. Cetacean acoustic presence was very rare with only limited signals detected. During the initial three-month deployment (March to May), acoustic signals resembling a dolphin click train were observed on the station closest to the salmon farm on 4 May 2021. During the second three-month deployment, again on the station closest to the salmon farm, five dolphin identifications were made on separate days, one click train and four instances of faint/infrequent whistles (only 1 – 2 in a 14 min file). Australian fur seal vocalisations were present across the data from all stations. It is thought that they are primarily calling with their mouth out of the water but their body in the water while swimming or drifting near the recorder, however this warrants further investigation. No detector was created for these calls, and no systematic analysis was conducted, however there appeared to be a higher rate of occurrence at the stations closest to the salmon farm.

The objectives of the sound source verification study were to compare *in-situ* measurement results from an operating SealFence™ system (single and multiple units) with the modelling, and validate predicted ranges to thresholds in marine mammals. During the study exclusion zones were implemented to mitigate potential effects on marine fauna. Measurement stations included one AMAR close to the salmon farm, one deployed downstream of the power station (~3 km from the farm), and an JASCO OSM-2 completing drifts. The measurements captured a single node in calm weather and up to four nodes in increasing sea states before severe weather caused field work to be suspended. All data was processed with an 8 kHz high-pass filter to minimise noise influence on the results. Due to the semi-random timing of the Sealfence units, a k-means clustering algorithm implemented in R (R Core Team 2020) was used to extract only the highest levels that are assumed to correspond to times when one (or more) units were active and associate with a range from the units. The algorithm takes in the requested number of clusters, K, (5) and the number of iterations (10) to minimise the Euclidean distance from the data to the updated cluster centres at each iteration. The measurements results for a single node were compared against the modelling results and the ambient noise environment for the 1-s SPL and frequency weighted SEL_{24h}. The modelling results are significantly higher than the measurement results at close range. In part, this is because the maximum-over-depth modelling results are considered, rather than the modelling results at the same depth as the recorders. At long range, the influence of the snapping shrimp in the recordings biases the 1-s SPL results, and thus also the SEL_{24h} results particularly for mid-frequency cetacean weighted results particularly beyond 2 km, where the received SealFence™ signals are quieter, and the snapping shrimp are more present. The influence of increased sea state is significant at ranges over 2 km, however there is minimal influence on the measurement results within 1 km, which aligns with the predictions. The inclusion of the ambient data, both SPL and SEL, provides context for the measurement results. The SealFence™ signals are above the 75th percentile ambient level at all ranges, however any effects on fauna hearing the signals would be range and context specific.

4 CONCLUSIONS

The measurement study demonstrates that the modelling conducted was a reasonable representation of the received levels within the Tamar River and that modelled results for PTS and TTS in marine mammals considering a stationary animal for 24 h are representative. The mid-water column measurements at ~70 m and centred at 200 m show close alignment with the modelling results. The alignment between the measurement and modelling results means that a representation of the sound field around a variable number of active SealFence™ units can be created with confidence. This representation can be used to support future work understanding the potential responses of seals, marine mammals and seabirds to the SealFence™ units.

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