Science Summary

Sanderson, B.G., C.W. Bangley, L.P. McGarry, and D.J. Hasselman. 2023a. Measuring detection efficiency of high-residency acoustic signals for estimating probability of fish-turbine encounter in a fast-flowing tidal passage. *Journal of Marine Science and Engineering* 11(6): 1172.

Motivation:

- Acoustic telemetry could provide a useful approach for estimating the probability of fish-turbine interaction in Minas Passage, but first requires an understanding of detection efficiency of acoustic signals in high flow environments.
- Some previous acoustic telemetry studies in Minas Passage used PPM (pulse position modulation; 69 kHz and 180 kHz) acoustic signals that encodes information according to the gaps between eight 10 millisecond pulses that are spaced over a few seconds. However, this technology is insufficient for estimating fish-turbine encounter in Minas Passage; particularly at fast current speeds which are of primary concern.
- HR (high residency; 170 kHz) acoustic signals encode information by abrupt phase changes within a 6 millisecond pulse that can be transmitted much more frequently before a tag is swept past the detection range of an acoustic receiver, and may provide a suitable alternative.

Methods:

- Sanderson et al. (2023a) conducted a detection range experiment to estimate how efficiently 170 kHz HR acoustic tag transmissions were detected as a function of distance and environmental conditions in Minas Passage.
- Specifically, moored acoustic receivers (Innovasea HR2) and 170 kHz HR acoustic tags were deployed at the Fundy Ocean Research Center for Energy (FORCE) tidal demonstration site.
- The data was analysed to synchronize the time signals, accurately determine the distance between receivers and tags, account for movement of moorings, remove signals reflected off the sea surface, and account for signals blocked by bathymetry (see full paper for details).

Results:

- The 170 kHz HR signals are better detected than 180 kHz PPM signals, particularly at greater distances and faster current speeds (see Figure 14 in the paper).
- The data for the 170 kHz HR signals were used to obtain detection efficiency estimates for near-seafloor acoustic signal paths as a function of range (i.e., distance between signal source and receiver; m) and tidal current speed (ms^{-1}), as shown in Figure 12; reproduced below. The detection density is high (>90%) for speeds up to 3 ms^{-1} and ranges up to 150 m, but drops off quickly with higher speeds.
- The detection density can be used to define an effective detection area, A(s) and, thus, an effective detection radius, R(s), that are both functions of speed, given by

$$A(s) = 2\pi \int_0^\infty \rho(r, s) r dr \tag{13}$$

$$R(s) = \sqrt{\frac{A(s)}{\pi}}. \tag{15}$$

- The effective detection range of 170 kHz HR signals is approximately 150 m for tidal current speeds < 3 ms^{-1} (see Figure 13; reproduced below).
- The effective detection area can be used to define an estimate of abundance (the number of tagged fish per unit area) given by:

Given tag signals from N_f tagged fish, where those signals are all detected throughout some time period T when the current is s, then an estimate of abundance $\mathcal{F}$ (number of tagged fish per unit area in the horizontal plane) can be obtained

$$\mathcal{F} = \frac{\tau N_f}{TA} \tag{14}$$

where τ is the tag transmission interval. This is the elemental concept that can be used to convert signals detected by a receiver to an estimate of fish abundance.

Conclusions:

- The 170 kHz HR tags should be used for monitoring fish in Minas Passage and for calculating the probability of fish turbine encounter at the FORCE tidal demonstration site.
- It is reasonable that probability of fish-turbine encounter can be estimated by monitoring fish that carry 170 kHz HR tags; so long as acoustic receivers are spaced < 150 m apart, and acoustic tags are programmed to transmit 170 kHz HR signals at frequently intervals (one transmission at least every 2 seconds).
- Importantly, this paper introduces the concept of effective detection area that can be calculated from detection efficiency (see equation 14; reproduced above). The effective detection area enables signals detected from tagged fish to be to be converted to an estimate of the abundance of tagged fish per unit area.

Follow up Work:

- The estimates of detection efficiency obtained by this study are compared to the detection of drifting tags in Sanderson et al. (2023b).

- The result of those two studies are used to determine the probability of encounter for tagged fish that swim higher in the water column in Sanderson et al. (2023c)

Important figures from the paper:

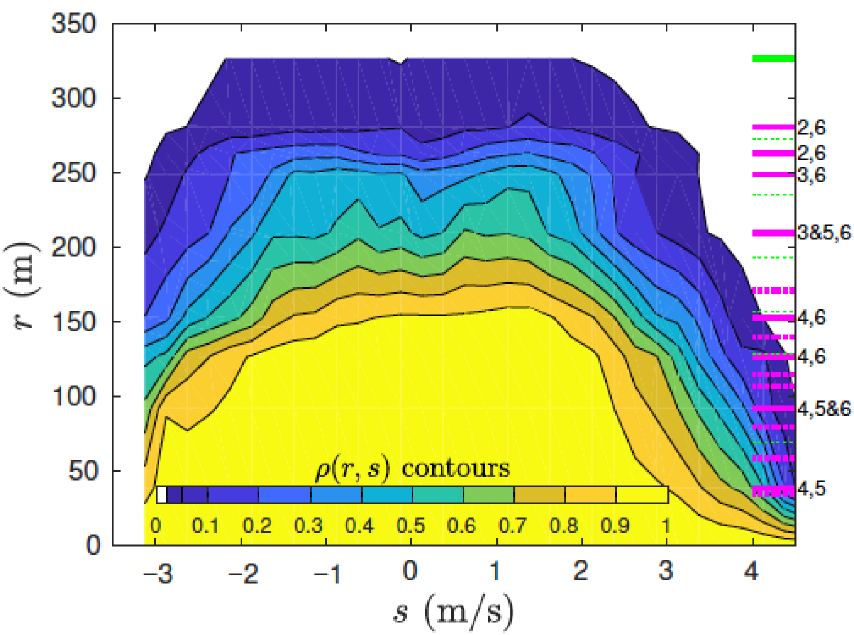

Figure 12. Contours of the detection efficiency that best applies to detecting tagged fish that swim well clear of the seafloor. This detection efficiency is obtained by selecting those HR2-HR2 propagation paths that do not appear to be blocked by variations in seafloor topography (solid magenta lines). Tag–HR2 transmissions were used to add probabilities at the greatest range (green line, top-right corner).

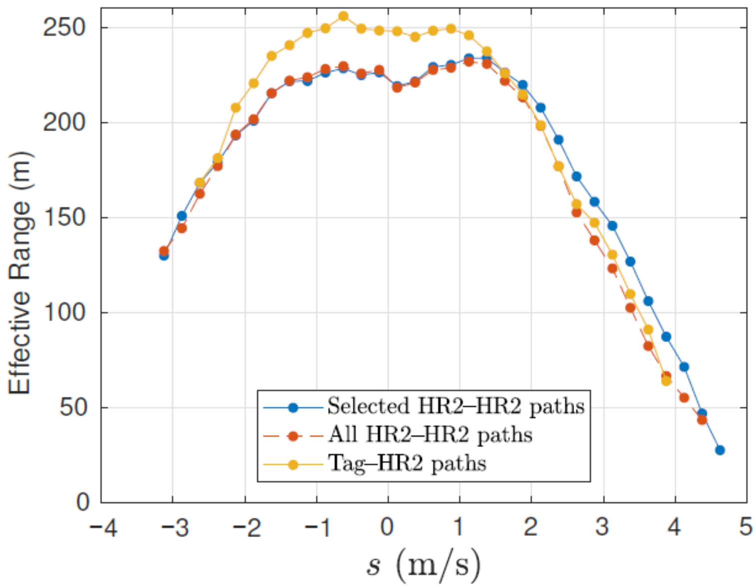

Figure 13. Effective detection range obtained by integrating the probability that a HR signal is detected. Using HR2-to-HR2 transmission paths that do not exhibit obvious blocking (blue), all of the HR2-to-HR2 transmission paths that were measured (red), and tag–HR2 transmission paths (orange).