Science Summary

Sanderson, B.G., R.H. Karsten, and D.J. Hasselman. *2023b.* Using drifters equipped with acoustic tags to verify the efficacy of an array of acoustic receivers for estimating probability of fish-turbine encounter. *Journal of Marine Science and Engineering 11(8): 1592.*

Motivation:

- Using acoustically tagged fish to determine probability of fish-turbine encounter at the FORCE tidal demonstration site requires knowledge of how reliably a tag can be detected as it passes by an acoustic receiver array.
- Prior estimates of acoustic tag detection efficiency in Minas Passage (Sanderson et al. 2023a) were obtained using tags and receivers deployed at fixed locations near the seafloor. Those measurements gave detection efficiency as a function of range and tidal current speed.
- However, the detection of tagged fish differs in three ways from that (Sanderson et al. 2023a):
    - First, many tagged fish swim well clear of the seafloor, so signal-to-receiver paths are less likely to be blocked by variable bathymetry.
    - Second, tagged fish move relative to the fixed receivers so signal paths differ with respect to both time and space.
    - Third, the detection efficiency is an average over a given time period whereas the tagged fish is detected at a different instant in time.
- Given the fast tidal currents in Minas Passage, tagged fish that swim well clear off the seafloor are expected to pass moored receivers in a way that is very similar to drifters that move passively with tidal currents.
- As such, the detection efficacy of tags carried by passing fish can be accurately measured using acoustic tags on GPS-tracked drifters.
- Therefore, a tagged-drifter experiment can be used to quantify how the fixed measurements of detection efficiency are related to the detection of tagged fish.

Methods:

- Sanderson et al. (2023) suspended one 69 kHz PPM (pulse position modulation; transmits every 10 seconds) and multiple 170 kHz HR (high residency; transmits every 2 seconds) acoustic tags at differing depths (surrogate for fish swimming at varying depths) beneath multiple GPS-tracked drifters
- The drifters passed by an array of acoustic receivers (12 stations) in the northern half of Minas Passage.
- Two experiments were conducted:

- short-term drifters (STD) that were released upstream of the FORCE CLA and recovered downstream (see Figure 2; reproduced below); a total of 62 STD tracks were analysed
- long-term drifters (LTD) that were allowed to passively drift back and forth through Minas Passage over many tidal cycles (see Figure 8; reproduced below); 138 LTD tracks with at least one tag detected were analyzed (89 LTD tracks passed south of the receiver line and were not detected) (see Figure 9; reproduced below).

- Analyses considered downward signal transmissions from tags on drifters to moored receivers, upward signal transmissions from moored receivers to receivers on drifters, and interference from signal reflections with the sea surface.

Results:

Short-Term Drifters

- For passing events at high flow speeds (>3.5 m/s), the number of tag detections was significantly lower than that expected based on the fixed tag experiment of Sanderson et al. (2023a); (see Figure 6; reproduced below, and Table 4 in original paper):
  - Total tag detections were 63% of expected
  - Passes with at least one detection were 82% of expected
- Almost all tags within a distance of 100 m of a receiver were detected, most multiple times.
- The number of detections dropped rapidly as the distance exceeds 150 m from a receiver.

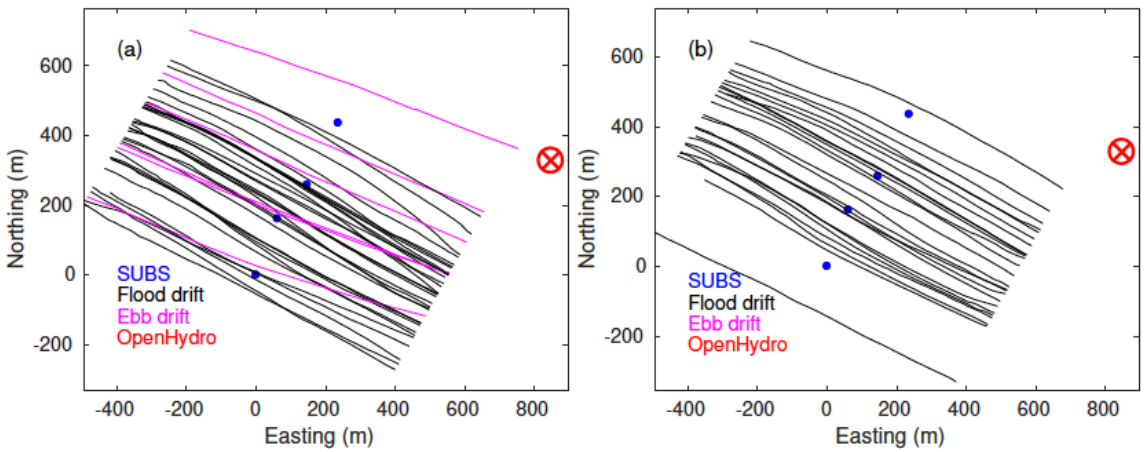

Figure 2. STD tracks. Positions of moorings 9-12 are marked with blue dots. Black lines show flood tracks. Ebb tracks are magenta. Tracks were measured on: (a) 13, 15 and 16 June 2022 (n=37). (b) 17 and 18 July 2022 (n=25).

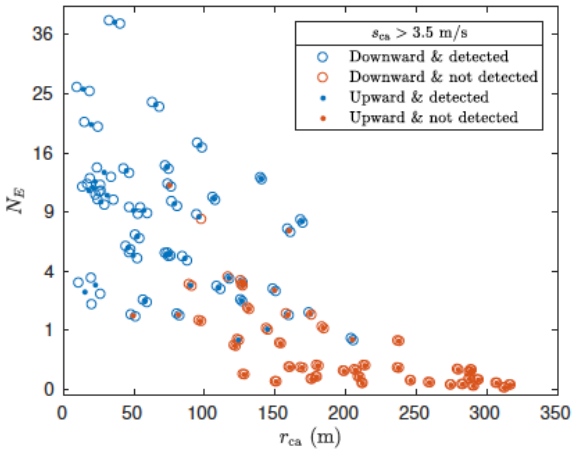

Figure 6. The expected number of detected signals N_E declines with increasing slant range of closest approach r_{ca}. Only the 44 STD tracks with $s_{ca} > 3.5$ ms^{-1} are included.

Results Long-Term Drifters:

- 'Long-term drifters' deployed for extended periods of time (i.e., weeks) become 'caught' in quasi-stable trajectories by tidal currents and typically pass through the center of Minas Passage to the south of the FORCE tidal demonstration site (see Figure 8; reproduced below).
- 69 kHz PPM signals were poorly detected by the receiver array, particularly during fast current speeds (> 3.5 ms^{-1}), due in part to the extended period of time required to transmit the entire signal; current PPM technology is inadequate for estimating the probability of fish-turbine encounter in fast-flowing tidal channels.
- 170 kHz HR signals were usually detected by the receiver array (see Figure 9; reproduced below), even in fast currents (> 3.5 ms^{-1}) during spring tides, but frequent signal transmission (i.e., every 2 seconds) is needed
- For all current speeds there is a high likelihood that frequently transmitted HR signals will be detected if receivers are spaced 150 m apart (Figure 12; reproduced below)

Conclusions:

- Reliable detection of acoustically tagged fish moving through the FORCE tidal demonstration site at current speeds ≥ 3.5 ms^{-1} requires the use of HR acoustic tags with transmission intervals ≤ 2 seconds
- Given that the movements of drifters and some fish species are similar, it is reasonable to expect that the majority of individual fish tracks also pass through the center of Minas Passage
- Acoustic receivers should be spaced approximately 150 m apart to ensure detection of tagged fish passing through the array

- To the extent that fish movements in Minas Basin/Channel/Passage mimic drifter quasi-stable trajectories, the majority of passes through Minas Passage are expected to the south of FORCE tidal demonstration site

Important figures from the paper:

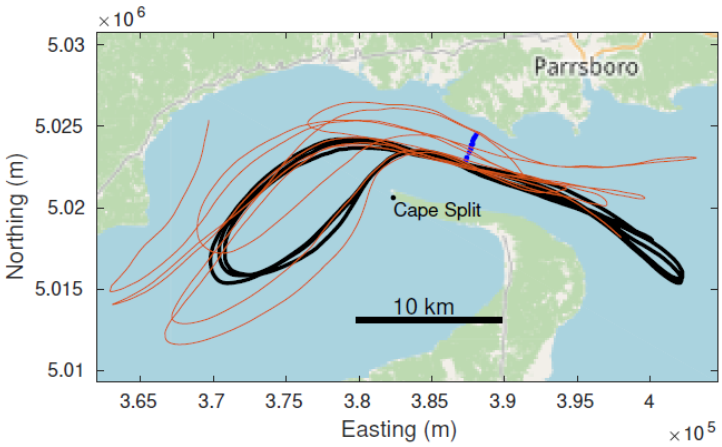

Figure 8. Two LTD tracks. A quasi-steady track (black) frequently passes near the southern end of the line of moored receivers (blue). A highly variable track (orange) sometimes passes through the northern end of the receiver line.

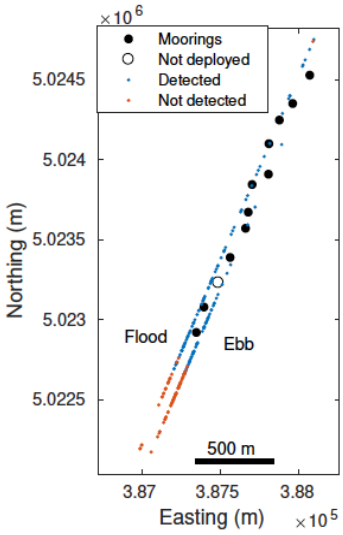

Figure 9. Dots indicate where LTD tracks crossed the mooring line, with flood crossings displaced to the left and ebb crossings displaced to the right. Blue dots indicate passing events that were detected by the array of HR2 receivers and orange dots indicate passing events that were not detected.

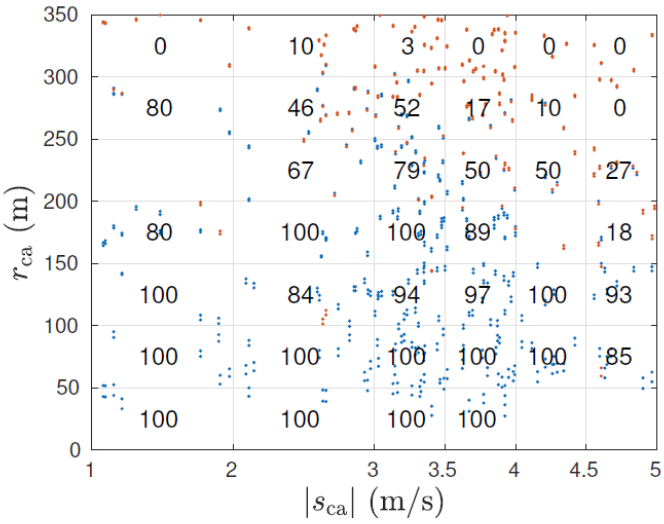

Figure 12. Percentage of tag passing events that are detected by a moored HR2 receiver as a function of speed $|s_{\mathrm{ca}}|$ and range r_{ca} at closest approach. Here we consider LTD of the two deepest HR tags (19 m and 28 m). Each tag transmitted every $\tau = 2$ s.