Science Summary

Sanderson, B.G., R.H. Karsten, C.C. Solda, D.C. Hardie, and D.J. Hasselman. 2023c. Probability of Atlantic salmon post-smolts encountering a tidal turbine installation in Minas Passage, Bay of Fundy. Journal of Marine Science and Engineering 11(5): 1095.

Motivation:

- Previous work quantified the detection efficiency of HR acoustic tags as a function of current speed and range from a moored acoustic receiver (Sanderson et al. 2023a) and demonstrated that drifters carrying HR tags will be effectively detected when the drifter track crosses an array of receivers in Minas Passage (Sanderson et al. 2023b)
- Inner Bay of Fundy (IBoF) Atlantic salmon are a federally endangered species and is protected by Canada's *Species at Rick* Act; the species is known to occupy the upper water column during various life history stages and there is concern about harm from encounters with near-surface deployed tidal energy devices at the FORCE tidal demonstration site in Minas Passage.
- This paper develops and applies a method by which acoustic tag detections by the HR2 acoustic receiver array in Minas Passage can be used to estimate the expected number of times a IBoF salmon post-smolt would encounter a single near-surface tidal energy device at the FORCE site during its seaward migration
- For this paper, probability of encounter is defined as the probability that a tagged fish passes within a turbine width of a receiver location.

Methods:

- This study used detections of tagged IBof Atlantic salmon post-smolts (Gaspereau River and Stewiacke River) as they passed by an array of acoustic receivers in Minas Passage to develop a method to convert that information into a probability of encounter in Minas Passage and at the FORCE tidal demonstration site.
- The method builds upon the approach that was previously used by Sanderson et al. (2021) to calculate the probability that drifters would encounter a turbine installed in Minas Passage.
- It assumes fish are swimming at same height as turbines blades, the tidal device used here was 38m wide and centred at receiver location
- The method calculates the probability of encounter from an ensemble averaged estimate of detection efficiency, that was calculated based on fixed and drifting tags (see Sanderson et al 2023 a,b).
- The paper analyses data from two experiments:

- In 2019, 87 smolts were tagged in the Gaspereau River and 57 smolts in Stewiacke River; these passed an array of 4 receivers, two of which were in the TED area
- In 2022, 25 smolts were tagged in the Gaspereau River; these passed an array of 11 receivers, four of which were in the TED area

Results:

- In 2019, 43 of 87 Gaspereau River smolts and 29 of 57 Stewiacke River smolts were detected in Minas Passage; in 2022, 23 of 25 Gaspereau River smolts were detected in Minas Passage.
- Acoustic detections of IBoF Atlantic salmon post-smolts by moored and drifter-based HR2 receivers indicate that they are substantially displaced by tidal currents, and can be swept through Minas Passage multiple times during their seaward migration (up to 8 passing events over a 6-day period for a Gaspereau River smolt tagged in 2022)
- The expected number of encounters between IBoF Atlantic salmon post-smolts and a near-surface tidal device installed in the FORCE tidal demonstration site is relatively low, (Figure 8; reproduced below)
- The number of encounters is higher for post-smolts from the Stewiacke River, indicating that they are more likely to migrate through the northern part of Minas Passage
- The expected number of encounters at the FORCE site is also low across current speeds, and consistently lower than if a device was installed in the middle of Minas Passage (Table 3; reproduced below).
- The estimated uncertainty of the number of encounters is relatively low, suggesting that the tagging method can accurately predict fish encounters with turbines.

Conclusions:

- An array of appropriately spaced (<150m) receivers in Minas Passage can detect fish migrating through Minas Passage, allowing for an accurate estimate of the probability of encounters with tidal turbines.
- The calculated probability encounter at speeds > 1m/s is 0.9% and 3% for the Gaspereau and Stewiacke River IBoF Atlantic salmon post-smolts, respectively.
- These values represent an upper limit on mortality, as they do not consider avoidance/evasion behavior or that fish can pass through a turbine swept area unharmed.
- Putting this into broader context, the average at-sea mortality of immature Atlantic salmon was 97% for the period 1990-2003 period (DFO, 2008), so outmigration losses caused by near-surface tidal turbine operations at FORCE would only add, at most, 0.027% and 0.09% to the 97% marine mortality.

Important figures and tables from the paper:

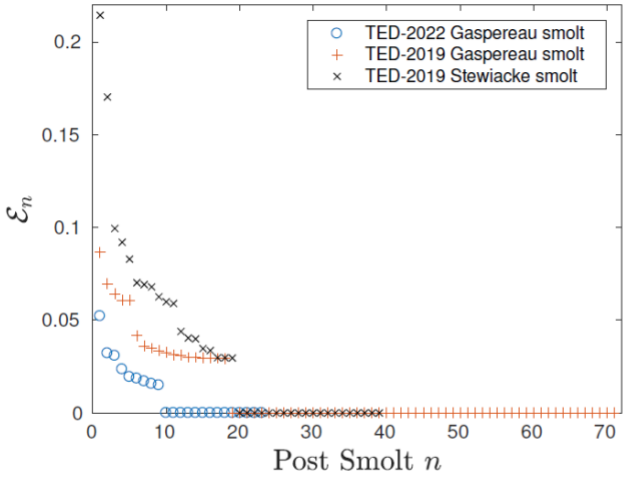

Figure 8. Expected number of encounters that each post-smolt would make with a single turbine installation at the TED area.

Table 3. Expected number of times that a smolt would encounter a single turbine installation during its seaward migration from the Gaspereau and Stewiacke Rivers.

2022 Gaspereau River		2019 Gaspereau River		2019 Stewiacke River		$\lvert s_d \rvert$
$\overline{\mathcal{E}}_{\text{TED}}$	$\overline{\mathcal{E}}_{\text{mid-passage}}$	$\overline{\mathcal{E}}_{\text{TED}}$	$\overline{\mathcal{E}}_{\text{S2}}$	$\overline{\mathcal{E}}_{\text{TED}}$	$\overline{\mathcal{E}}_{\text{S2}}$	(ms^{-1})
0.0098 ± 0.0030	0.075 ± 0.031	0.0110 ± 0.0024	0.014 ± 0.004	0.034 ± 0.0078	0.075 ± 0.017	≥ 0
0.0091 ± 0.0028	0.073 ± 0.031	0.0087 ± 0.0022	0.014 ± 0.004	0.032 ± 0.0078	0.072 ± 0.017	≥ 1
0.0091 ± 0.0028	0.072 ± 0.031	0.0082 ± 0.0022	0.013 ± 0.004	0.03 ± 0.0079	0.063 ± 0.016	≥ 1.5
0.0085 ± 0.0029	0.069 ± 0.032	0.0074 ± 0.0021	0.011 ± 0.004	0.026 ± 0.0071	0.058 ± 0.015	≥ 2
0.0078 ± 0.0029	0.067 ± 0.031	0.0070 ± 0.0020	0.008 ± 0.004	0.024 ± 0.0064	0.044 ± 0.013	≥ 2.5