Probability of Atlantic salmon post-smolts encountering a tidal turbine installation in Minas Passage, Bay of Fundy

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force

Introduction

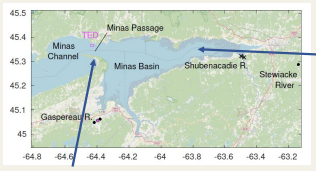
Quantifying whatever harm a Marine Hydrokinetic (MHK) turbine may or may not do to a fish population begins with the probability of an individual encountering the turbine. A definition for probability of a fish encountering a MHK turbine is a precondition for unambiguous calculation from practicable measurements:

- Definition: Probability of encounter is the probability that — at some location, during some time interval — a fish that belongs to a distinguishable population will pass through the area that would be swept by the blades of a MHK turbine without the turbine actually being deployed at that position at that time

Secondly, any measurement of fish behaviour must recognize the affect of the environment:

- Tidal currents are the predominant environmental factor effecting movement of tagged fish and the detection of the acoustic signals that they transmit.

Location: Minas Passage

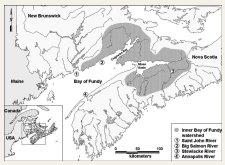


16m tidal range in Minas Basin

Minas Passage
- 5 km wide, 15km long
- Flow speeds: Ebb 3m/s, Flood 5 m/s
- Depths: 30m to 150m
- High levels of turbulence
- 2500 WM potential for Tidal Energy
- Tidal Energy Demonstration (TED) region shown in pink.

Inner Bay of Fundy Atlantic Salmon

- Inner Bay of Fundy Salmon is a unique species of Salmon that spawns in the watershed surrounding the upper Bay of Fundy
- Listed as endangered in 2010 in Schedule 1 of SARA
- prohibition against killing, harming, harassing, capturing or taking **an individual** of that species;
- prohibition against damaging or destroying the residence of **one or more individuals** of that species.

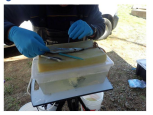


Tags and Receivers

- Tags are surgical inserted into each fish
- Each tag transmits a unique signal
- Receivers are deployed on floats near the sea bottom

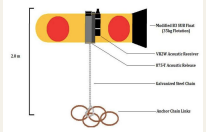
Tags

Tag inserted into Salmon Smolt



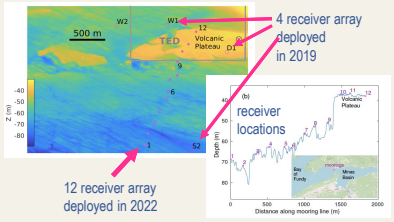
Receiver

Receiver deployed on a SUBS float



Calibration with Tags on Receivers

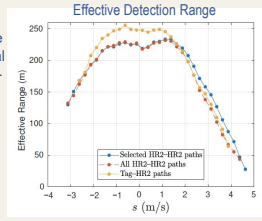
Mooring layout in Minas Passage. moorings 1 through 12 from 2022 and the 4 moorings from 2019 and the TED area (gray box). Depth profile along the mooring line.



4 receiver array deployed in 2019

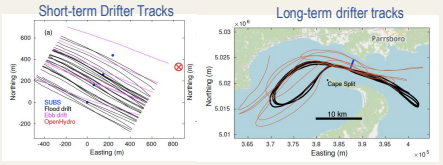
12 receiver array deployed in 2022

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).



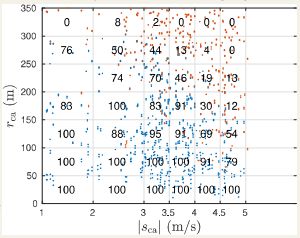
Calibration with Drifters

Drifters with multiple tags and GPS were deployed on Short Term Drifts (STD) just in the TED region and Long Term Drifts (LTD) over several tidal cycles. The drifters mimic fish passing receiver array, map out the potential fish paths and also measure of velocity of the tidal currents.



Probability of Detection of Drifting Tags

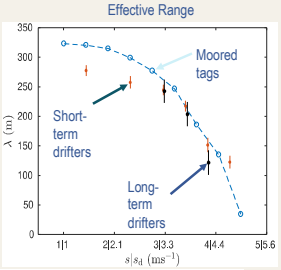
Each dot on the figure represents a drifter passing the receiver array. If the drifter was detected, the dot id blue; if it was not, the dot is red. The detection probability is then calculated for each current speed/distance from receiver box. The probability drops off rapidly when the distance exceeds 150m or the current speed exceeds 3m/s

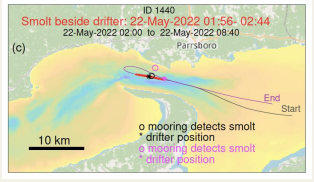


The drifter results can be used to calculate an effective range of the tags/receivers.

This figure compares the half cross-current width scale for tag detection as a function of current speed.

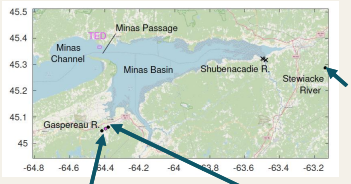
Effective Range





The black line shows a portion of the track of a drifter; red shows where the drifter was when its HR2 detected HR signals from a tagged post-smolt that was nearby.

Probability of Encounter for Salmon Smolts



2019, 57 smolts tagged; as many as 39 expected to have reached Minas Passage.

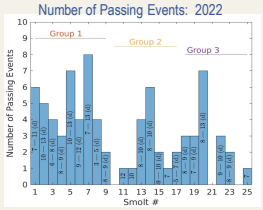
2022: 25 smolts tagged in three groups; at least 23 reach Minas Passage.

2019: 87 smolts tagged, 71 smolts were detected at the mouth of river

All groups were detected doing multiple passes of the receiver array, consistent with the fish drifting with the tidal currents.

- 2022 Gaspereau: 7.8 passing events.
- 2019 Gaspereau: 3.0 passing events
- 2019 Stewiacke: 7.8 passing events.

Number of Passing Events: 2022



The probability encounter is calculated as the ratio of the integrated probability of detection to half cross-current width. The expected number of encounters is then calculated as the sum of probabilities.

$$\mathcal{P}(z,s,s_d) = \frac{\int_0^{W/2} p(y|z,s,s_d)dy}{\lambda}$$

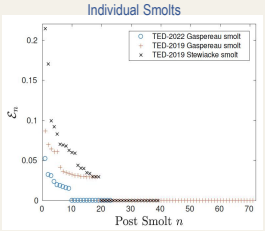
$$\lambda(z,s,s_d) = \int_0^{L} p(y|z,s,s_d)dy,$$

$$\mathcal{E}_{n,\mathrm{TED}} = \frac{1}{4}\sum_{k=1}^{K} \mathcal{P}_{n,9\le j\le 12,k}$$

$$\overline{\mathcal{E}}_{\mathrm{TED}} = \frac{1}{23}\sum_{n=1}^{23} \mathcal{E}_{n,\mathrm{TED}}.$$

- Expected number of encounters with a 40m-wide, surface turbine within TED
- Assume fish swim at same depths as turbine
- Average of all TED locations

Individual Smolts



Averages for each group

Post Smolts	N_{MP}	N_{TED}	$\bar{\iota}_{TED}$	$\bar{\mathcal{E}}_{TED}(\mathcal{E}_{n,TED} > 0)$	$\bar{\mathcal{E}}_{TED}$
2022 Gaspereau	23	9	11	0.025 ± 0.004	0.010 ± 0.003
2019 Gaspereau	71	18	22	0.042 ± 0.004	0.011 ± 0.002
2019 Stewiacke	39	19	38	0.070 ± 0.011	0.034 ± 0.008

The expected number encounters varies is small values, 0.01 to 0.034, these values are consistent with the proportion of flow passing through the turbine area.

Conclusion

- Careful calibration of tags/receivers is required in high-energy flow environments
- Drifters with tags provides excellent calibration data
- Smolts pass through passage multiple times
- Smolts move similar to drifters – limited swimming in strong flow
- Probability of individual smolt encountering a turbine is low

Bibliography

•Sanderson, B. G., Bangley, C. W., McGarry, L. P., & Hasselman, D. J. (2023). 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.

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