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USE OF ANIMAL TRACKING TECHNOLOGY TO ASSESS POTENTIAL RISKS OF TIDAL TURBINE INTERACTIONS WITH FISH

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ABSTRACT

Fish utilization of high flow environments and the associated risks of fish-turbine interactions at tidal energy development sites are little understood. The Fundy Ocean Research Centre for Energy (FORCE) in the upper Bay of Fundy is a tidal energy test facility that has been the focus of a multi-year fish tracking study (2010-2013) to address questions related to the potential risks of turbine operation to migratory species "at risk" – Atlantic salmon, Atlantic sturgeon, American eel and striped bass. Tagged fish of all 4 species were detected on receiver "listening gates" in the Minas Passage and FORCE test area. Travel speeds through the Minas Passage often exceeding 3 m/s. Swimming depth in Minas Passage was variable for eels, sturgeon and striped bass and largely within the top 40 m in and near the FORCE test area. Of the four species, striped bass was most commonly detected in the Minas Passage, with many being detected during summer, fall and winter. The ability of striped bass (and other fish species) to detect and avoid tidal turbines when travelling at very high speed (>3m/s) remains unknown. The main challenge faced in detecting acoustically tagged fish in Minas Passage is poor receiver efficiency due to excessive noise interference when current speeds exceed 2 m/s.

INTRODUCTION

To date, there have been no comprehensive field studies to assess the effects on fish of large tidal in-stream tidal energy converters (TISEC) deployed in very high flow environments (>2 m/s). The issue is especially pertinent in areas where migratory fish, including transboundary species of special concern, are present. Direct contact with turbine blades and subsequent injury or mortality, and indirect effects on behaviour and use of natural migratory pathways, continue to be the primary concerns of regulators and many other stakeholders.

The Fundy Ocean Research Centre for Energy (FORCE), Canada's leading tidal energy test and research facility in Minas Passage (Fig 1), is one of the world's most physically challenging marine renewable energy demonstration sites. It features a 13 m tidal range (spring tide max), extreme currents (up to 6 m/sec), and short slack water periods (5-15 min). Cumulative frequencies of average water column speed in Minas Passage show that speeds >1.5 m/s occur nearly 50% of the time (Fig 2).

The Minas Passage is also characterised by large masses of sediment-laden ice in winter, and diverse and abundant fish species, some of which are nationally designated as "at risk". At this extreme high flow site, the use of conventional methods of assessing the temporal and spatial patterns in the presence and abundance of fish (e.g. via mid-water trawls) have not been successful. Consequently, little is known about the degree to which migratory fish use the Minas Passage and FORCE site.

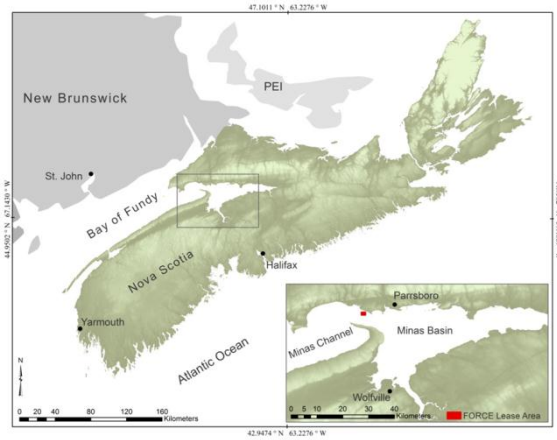

Figure 1. Map of Nova Scotia, the Bay of Fundy and FORCE site in Minas Passage.

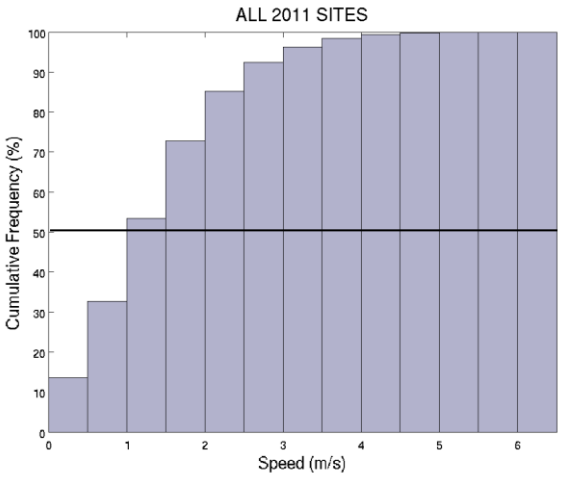

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Figure 2. Cumulative frequency distribution of depth averaged current speed (m/s).

To address the potential risk of environmental effects on fish that utilize the FORCE test area as a migratory route and for other movements (e.g. foraging), we focused on assessing the movements of four species of concern (Table 1) that display broad characteristics of movement and depth preferences, and which may provide insight on potential impacts on species with similar natural history characteristics. The main objectives of the study [1] were to:

1. Determine temporal (seasonal, diel) movements of tagged fishes (Atlantic sturgeon, Atlantic salmon, American eel and striped bass) within the Minas Passage and FORCE test area;
2. Identify broad distribution patterns in the Minas Passage (north to south regions, east to west);
3. Determine depth preferences and movements in relation to tidal stage (ebb/flood) and current speed;
4. Estimate travel speeds through the passage, based on detections by multiple receiver lines; and
5. Assess potential risks of fish-turbine interactions at the FORCE site.

Table 1. Selected at-risk fish species in the Bay of Fundy, COSEWIC status designations and numbers tagged during 2010-2012.

Species	COSEWIC Status	# Fish Tagged
Striped bass	Endangered	165
Atlantic salmon*	Endangered	62
American eel	Threatened	45
Atlantic sturgeon	Threatened	114

* smolts

METHODOLOGY

VEMCO animal tracking technology was used to detect near year-round animal movements (path, velocity and depth) and behaviour of 386 tagged fish in Minas Passage during 2010-2013. VEMCO VR2w hydro-acoustic receivers are passive, single channel, omnidirectional, and function to autonomously detect coded acoustic transmitters which enter the detection radius of the receiver. Receivers were placed in lines ("listening gates") at 300-400 m intervals across both the Minas Passage (5 km wide) and the FORCE test site (1 km wide) (Fig 3). The arrays were designed to detect the presence of transmitters surgically implanted in fish as they moved within the Minas Passage during migrations into and out of the Minas Basin. Custom modified A2 Model SUB streamlined instrument floats were used to house a receiver and an acoustic release. All instrumentation was moored 2-3 m above the seafloor for periods up to 1 year.

Depending on the fish size, fish were implanted with V9, V13 or V16 electronic transmitters; most included pressure sensors. Salmon were tagged in the Stewiacke and Gaspereau Rivers; eels were tagged in the Gaspereau River; striped bass were tagged in the Stewiacke River and Minas Basin nearshore areas; and Atlantic sturgeon were tagged following Minas Basin weir and otter trawl captures.

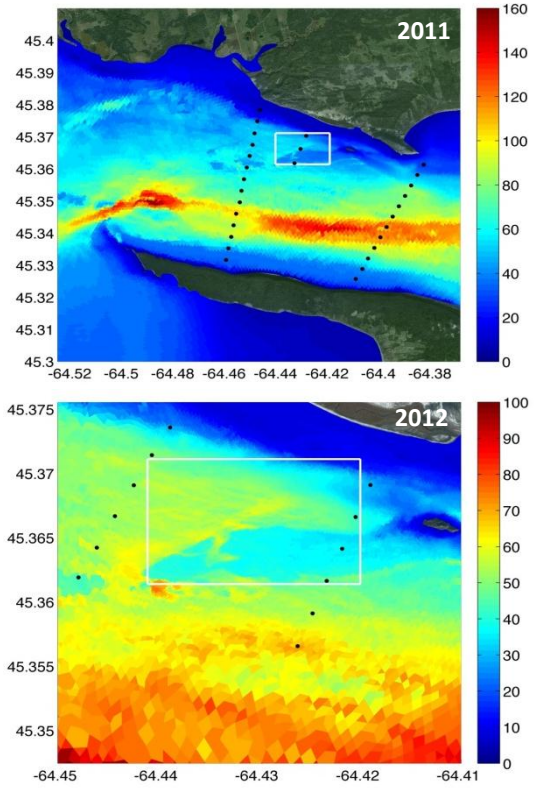

Figure 3. Receiver locations and mean water depths (m) in Minas Passage (top, 2011) and in/near the FORCE site (bottom, 2012-2013).

OBSERVATIONS

Results show that the FORCE test area represents an important migratory corridor for all fish species examined. Atlantic salmon post-smolts traversed the passage in late May to mid-June *en route* to the Bay of Fundy and beyond, occasionally making multiple passes. Of those smolts detected leaving the river mouths (N=20), nine were detected in Minas Passage; of these, five were detected by receivers at the FORCE test site.

Tagged American eels exited the Minas Basin via the Minas Passage during mid-September to mid-November, with passage occurring at speeds up to 3m/s and over short time periods (1-6 days), mostly at night during ebb tide. About 90% of the detections at FORCE were during ebb flow periods, with movements largely in the top 30 m of the water column.

Atlantic sturgeon entered Minas Basin (summer feeding grounds) via Minas Passage in the spring, and exited in the fall, with sporadic use of Minas Passage throughout the summer. Sturgeon detections in the passage were more concentrated in the southern region. Although sturgeon were detected at

all water depths, their movements in and near the FORCE site showed a preference for depths ranging from 15 to 35 m. The highest estimated travel speed (current assisted) between receiver lines was 3.2 m/s.

Striped bass, especially large bass (>60 cm), spent more time in the Minas Passage and near the FORCE test area than any of the other fish species examined. Residency spanned summer, fall and winter. Of the 165 tagged striped bass, 52 swam through the FORCE tidal turbine test site in the Minas Passage, and many at depths of proposed turbine hub height. Striped bass were detected mostly in the top 40 m of the water column, and were located closer to the surface during the night. Their estimated travel rates across the Minas Passage (1.2 - 3.9 m/s) often exceeded critical swimming speeds. Near year-round use of the region, including the FORCE test area, makes this species highly vulnerable to interactions with turbines.

Poor detection efficiency during periods of high current velocity [2] may account for low numbers of detections at velocities greater than 2 m/s (Fig. 4). Tag transmission datasets for Minas Passage are likely to represent 40% or less of the actual transmissions within the general listening range of the receivers, in large part because of these factors:

1. High flow effects (i.e. elevated ambient noise levels) on detection range. This may result in tagged fish being able to pass through Minas Passage undetected during high flow periods, especially during spring tides.
2. Incomplete tag transmissions, especially during high flows. Full transmission sequences generally consist of 8-10 consecutive pings separated by unique spacing intervals. If the receiver does not detect a complete ping sequence, then the transmission is not logged.

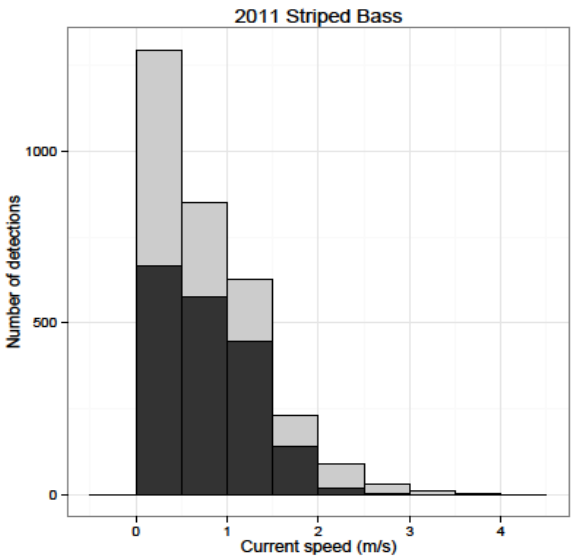

Figure 4. Striped bass detections in relation to depth averaged current speed (m/s) and both flood tide (dark bars) and ebb tide (light bars).

The main challenge faced in detecting tagged fish in order to assess the potential risk of fish-turbine interactions was reduced receiver efficiency and effects on detection range due to noise interference (e.g. bedload transport) when current speeds exceed 2 m/s. Additional noise induced by tethered mooring components (2-3 m above bottom) may also be a factor.

CONCLUSIONS

The FORCE site represents a relatively small area within the Minas Passage (<20% of the passage width), with a single turbine of about 100 m^2 occupying only 0.02% of the cross sectional area of Minas Passage. The probability of fish-turbine encounters is dependent on the size of the fish, swimming depth, and duration of occupancy at the site. The results of this study provided evidence of frequent use of the passage rather than use for just in- and out-migration. Unlike the other species examined, striped bass were within the detection range of acoustic receivers for surprisingly long periods of time (up to 10 months) and thus are at significant risk of interaction with TISEC devices.

It is unknown how well migratory fish can control their movements and avoid structures within the passage when travelling at peak current speeds (>5 m/s). The hypothesis that they avoid extreme flow conditions remains untested due to detection efficiency limitations of acoustic receivers operating in a tidal race.

ACKNOWLEDGEMENTS

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