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# Passive acoustic telemetry detection of Striped Bass at the FORCE TISEC test site in Minas Passage, Nova Scotia, Canada.

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## INTRODUCTION

Canada's inner Bay of Fundy (FIGURE 1) features the world's largest recorded tidal range (17 m) and is home to one of the preeminent tidal energy sites in the world [1,2]. In 2009, the Fundy Ocean Research Centre for Energy (FORCE) was established in Minas Passage as a test centre for large, commercial-scale tidal in-stream energy conversion (TISEC) devices [3]. One of the main environmental concerns at this site is the potential effect of TISEC devices on migratory fishes.

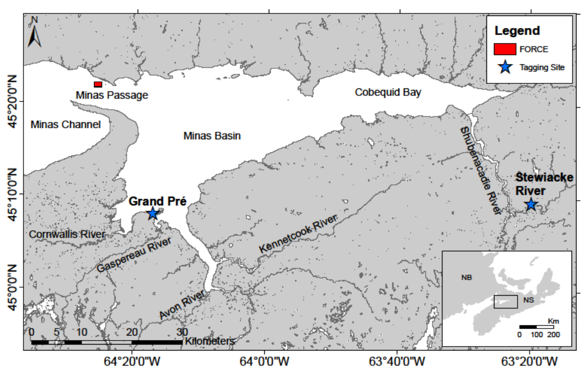


**FIGURE 1. SOUTHERN PORTION OF THE INNER BAY OF FUNDY. MINAS PASSAGE IS THE 6 KM WIDE PASSAGE BETWEEN MINAS CHANNEL AND MINAS BASIN. THE FORCE TISEC TEST SITE IS INDICATED BY A RED RECTANGLE. STRIPED BASS TAGGING LOCATIONS ARE INDICATED BY BLUE STARS.**

The inner Bay of Fundy supports a diverse assemblage of fish of both economic and ecological importance, including transboundary migratory species [4,5] and several species of high conservation significance [6], including Striped Bass, Atlantic Sturgeon, Atlantic Salmon, and American Eel. Installation and testing of TISEC devices at the FORCE site presents uncertain risk of fish-facility interactions. While many fish species are known to move through Minas Passage on a seasonal basis, their spatial and temporal use of Minas Passage has not been well studied and therefore remains poorly resolved. Lack of directed commercial and recreational fisheries within Minas Passage limit the usefulness of traditional mark-recapture tagging techniques. Extreme tidal currents also limit survey methods such as mid-water trawling, gill netting and active acoustic surveys [3,6].

Advances in bio-telemetry technology have given rise to tools that offer the potential to collect information regarding fish presence/absence, movement/migration, activity, behavior, and habitat use that is not easily acquired via traditional methods [7,8].

During 2010-2013, multi-species acoustic telemetry studies [9,10] were conducted to assess the potential for fish interactions with TISEC devices installed within the FORCE test site in Minas Passage. Acoustic telemetry was employed to document the presence and depth preferences of several species, including Striped Bass (*Morone saxatilis*). This species is represented by the local Bay of Fundy Striped Bass population that spawns within the extreme inner portions of Minas Basin during late May-June and disperses throughout the inner Bay of Fundy for summer-fall feeding. The local population is currently recommended for Endangered status [11]. In addition, transboundary migrants from US populations north of Cape Hatteras, NC may overlap in habitat range with the local population [12,13].

The main objectives of the initial Striped Bass acoustic telemetry study were to: 1) assess the timing and duration of occupancy within Minas Passage and the FORCE test site, and 2) determine swimming depth preferences of sub-adults and adults, and their depth patterns relative to day/night and ebb/flood tidal stages in Minas

Passage, a high flow environment. This information is currently being used to model detection probability that will help address questions related to the potential for interaction between Striped Bass and TISEC infrastructure at FORCE.

## METHODS

*Study Site*

Minas Passage is a 6 km wide constriction that separates Minas Channel from Minas Basin (FIGURE 1), where a hyper-tidal range (7-13m) [14] generates flow which can reach 106$m^3$/s, with sustained depth-averaged tidal currents of up to 3.3m/s [2]. Surface currents can reach velocities of 6m/s during spring tides [15]. The bathymetry of Minas Passage is highly variable, and greatest (>100m) in the central and southern regions of the passage.

The FORCE test site is located in the northern region of Minas Passage (FIGURE 2). It is a 1.6 x 1.0 km area, with depths of approximately 30-55m at mean water level (MWL) [16,17]. On November 12$^{th}$, 2009, an OpenHydro TISEC turbine (ducted, open hub, 10m diameter, 12 blades) was deployed on a 400 tonne tripod gravity base within the FORCE test site. The turbine remained in place for over a year, but was operational (i.e. blades turning) for only the first three weeks of its deployment [3]; the operational period did not overlap with this study.

*Telemetry Range Testing*

During fall 2009, prior to initiation of Striped Bass tracking, a 47 day range test was conducted to examine the effect of physical environmental conditions at FORCE on detection range and efficiency of VEMCO acoustic telemetry technology [18,19]. Seven VR2W acoustic receivers were moored in the FORCE test site in an east-west orientation covering a distance of approximately 800m. Four range testing transmitters (models V7, V9, V13, V16), with fixed delays of 480sec and manually offset by 120sec to avoid signal collision, were co-located on receiver mooring assemblies [18].

*Array Deployment*

Twenty-two (22) VEMCO VR2W acoustic receivers, attached directly to Teledyne Benthos 875-TD acoustic releases, were mounted inside custom modified Open Seas Instrumentation streamlined subsurface buoys (1.4m x 0.37m x 0.39m, drag coefficient: 0.6, floatation: 35kg) [18]. Instrument packages were moored 2m above the seabed with 200kg surplus steel anchors and riser cable. Independent mooring stations were deployed in two array groupings in Minas Passage. A clustered array of ten (10) stations, 200m spacing, was deployed June 22, 2010 in close proximity (<500m) to the OpenHydro TISEC device (FORCE Array) (FIGURE 2). A linear array of twelve (12) stations, 400m spacing, was deployed in collaboration with the Ocean Tracking Network (OTN) on July 14, 2010 (Minas Passage Line Array). The Minas Passage Line was positioned approximately 2.5km east of the FORCE site and bisected Minas Passage north to south (FIGURE 2). Twenty of twenty-two (20/22) receivers were recovered during November 23-29, 2010.

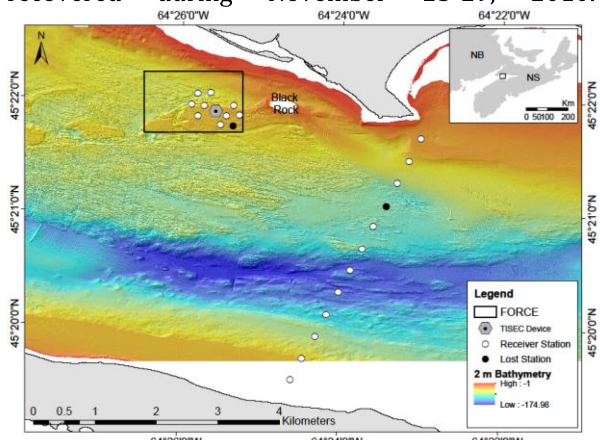


**FIGURE 2. ACOUSTIC TELEMETRY RECEIVER STATIONS DEPLOYED IN MINAS PASSAGE. STATIONS OF THE FORCE ARRAY ARE INDICATED WITHIN THE FORCE TEST SITE (BLACK BOX). THE MINAS PASSAGE LINE ARRAY BISECTS MINAS PASSAGE EAST OF THE FORCE SITE.**

*Striped Bass Tagging*

Adult Striped Bass were collected by angling near spawning grounds of the Stewiacke River, NS (FIGURE 1) during May 10-13, 2010 (n= 43, Mean TL (±SD)= 0.71 ± 0.06m). Sub-adult Striped Bass were collected by angling from Minas Basin, near Grand Pre, NS during August 4-16, 2010 (n= 37, Mean TL(±SD)= 0.43 ± 0.06m). Striped Bass were anesthetized, and surgically implanted with VEMCO V13P-1H (69kHz, 153dB re 1pa @ 1m, 36mm x 11mm) pressure sensing acoustic transmitters following methods of Douglas et al. [20].

## RESULTS

Range testing indicated variable daily detection efficiency within the FORCE site (FIGURE 3). Transmitters with high output power (V16, V13) were detected with greater efficiency and at greater range than lower power models (V9, V7). Tag output power, tag-to-receiver distance, tidal stage, and current speed were all significant predictors of detection efficiency [18, 19]. Range testing results informed the subsequent fish tracking array design (receiver spacing), and identified the V13 as the most appropriate transmitter model for study of multiple Striped Bass life stages.

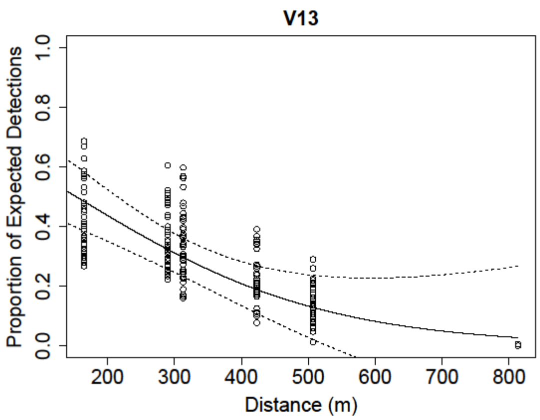


**FIGURE 3. DAILY PROPORTION OF EXPECTED V13 TRANSMISSIONS LOGGED BY RECEIVERS AT INCREASING TAG-TO-RECEIVER DISTANCE. THE NUMBER OF EXPECTED TRANSMISSIONS/DAY = 180.**

Detection of tagged Striped Bass occurred throughout the receiver deployment period. Striped Bass were detected on the Minas Passage Line array on 102/139 (70%) of deployment days (July 14-November 23, 2010). Striped Bass were detected on the FORCE array on 49/156 (31%) of deployment days (June 22 – November 23, 2010). In total, 40 adult (>0.55m TL) and 12 sub-adult (<0.55m TL) bass were detected by the Minas Passage Line array (TABLE 1). The FORCE array logged detections of 21 adults and 4 sub-adults within 500m of the non-operational OpenHydro TISEC device (TABLE 1).

**TABLE 1. SUMMARY OF STRIPED BASS TAGGING LOCATIONS AND NUMBER OF INDIVIDUALS DETECTED BY ACOUSTIC RECEIVER ARRAYS IN MINAS PASSAGE (MP) AND FORCE.**

| Tagging Location | Fish Tagged | Mean TL (SD) (m) | Detected in MP | Detected at FORCE |
|---|---|---|---|---|
| Stewiacke River | 43 adults | 0.71 (0.06) | 40 (93%) | 21 (49%) |
| Grand Pré | 37 sub-adults | 0.43 (0.06) | 12 (32%) | 4 (11%) |

Individual tagged Striped Bass were detected in Minas Passage on up to 17% of available detection days (Mean ± SD= 4 ± 3%, n= 52). Periods of continuous detection of an individual bass, with no gap between successive detections >60 minutes, were considered unique detection interactions. As many as 24 unique detection interactions were observed for individual tagged Striped Bass within Minas Passage (Mean ± SD= 6 ± 5.1, n= 52).

Each of the 20 recovered receiver stations logged detections of tagged Striped Bass. Individual bass were detected, on average, by 7 receiver stations throughout the deployment (Range: 1-20). There was little evidence to suggest use of specific movement pathways or corridors through Minas Passage. The average number of bass detected per receiver station along the Minas Passage Line was greater in both the southern (29 individuals) and central (24 individuals) portions compared to the northern stations which logged an average of 15 individuals per receiver. Adult bass (>0.55m TL) were detected more frequently than sub-adults by both the Minas Passage Line and FORCE receiver arrays. Sub-adult bass showed limited overall presence in Minas Passage during the study period.

Estimated travel speeds, along an assumed straight line path between the Minas Passage Line and FORCE receiver arrays, ranged from 1.8-2.9m/sec (Mean ± SD= 2.3 ± 0.3m/sec, N=15). Maximum calculated travel speed was 4.9 body lengths/sec.

Striped Bass were detected over a wide range of depths across both the Minas Passage Line array (surface to >95m) and the FORCE array (max depth 55m). Adult bass (>0.55m TL) were detected at deeper depths than sub-adults (<0.55m TL) at both the Minas Passage Line array (Wilcoxon Test, W= 44540, p= <0.001), and FORCE array (Wilcoxon Test, W= 2095, p= <0.001). At the FORCE array, Striped Bass detection depths were negatively correlated (r = 0.419, p < 0.001) with depth-averaged current speed (FIGURE 4).

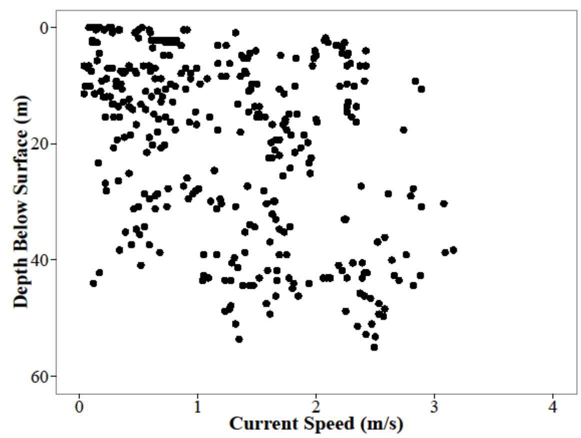


**FIGURE 4. ASSOCIATION BETWEEN STRIPED BASS DETECTION DEPTH (M, BELOW SURFACE) AND DEPTH-AVERAGED CURRENT SPEED (M/S) AT THE FORCE ARRAY.**

Striped Bass were detected deeper in the water column during flooding tide than ebbing tide at both the Minas Passage Line array (Wilcoxon Test, W= 197089.5, p= <0.001) and FORCE array (W= 8412.5, p= <0.001). At FORCE, sub-adults (<0.55m TL) were detected only during ebbing tide (FIGURE 5). Striped Bass also showed a diel depth distribution pattern, with bass detected deeper during daylight hours at both the Minas Passage Line Array (Wilcoxon Test, W= 405556.5, p = <0.001) and FORCE array (W= 15609.5, p = 0.004) (FIGURE 6).

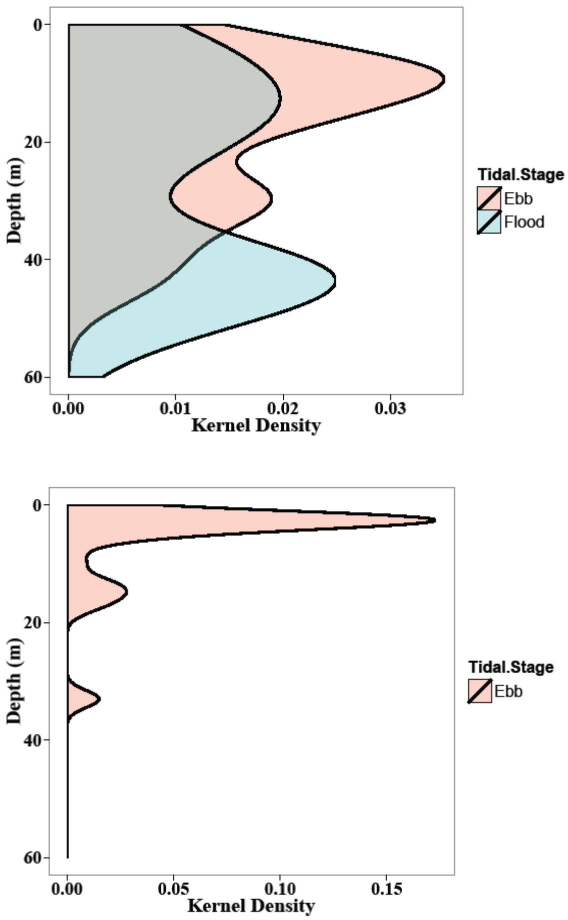


**FIGURE 5. KERNEL DENSITY DISTRIBUTION OF STRIPED BASS DETECTION DEPTHS RECORDED BY ACOUSTIC RECEIVERS IN THE FORCE ARRAY. TOP AND BOTTOM PANELS INDICATE DEPTHS OF ADULT (>0.55M TL, n= 21) AND SUB-ADULT (<0.55M TL, n= 4) BASS, RESPECTIVELY. PINK AND BLUE SHADING DENOTE THE DEPTH DISTRIBUTIONS DURING EBB AND FLOOD TIDES, RESPECTIVELY.**

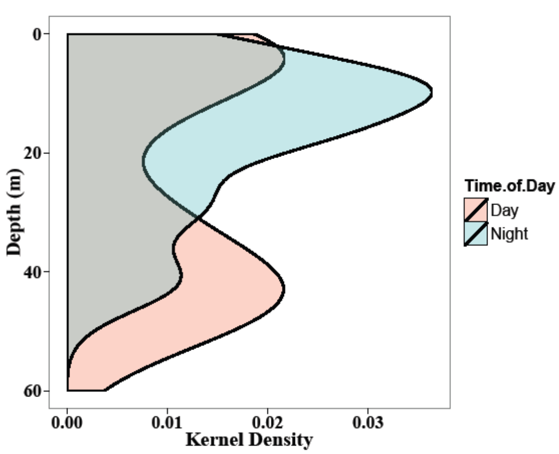


**FIGURE 6. KERNEL DENSITY DISTRIBUTION OF ADULT STRIPED BASS (>0.55M TL, n= 21) DETECTION DEPTHS RECORDED BY ACOUSTIC RECEIVERS IN THE FORCE ARRAY. PINK AND BLUE SHADING DENOTE THE DEPTH DISTRIBUTIONS DURING DAY AND NIGHT, RESPECTIVELY.**

## DISCUSSION

The use of acoustic telemetry has advanced the understanding of Striped Bass use of Minas Passage and the FORCE TISEC test site. This study also provides the first examination of Striped Bass activity at a high flow site, and is one of the first fishery-independent descriptions of Striped Bass depth distribution in marine waters.

This study was unable to fully characterize Striped Bass presence in Minas Passage and the FORCE site when depth-averaged current speed exceeded 2 m/s. Limited detections during peak flows may be a result of reduced efficiency/range of the acoustic telemetry system, reduced presence of tagged fish, and/or undetected high speed travel of fish through acoustic receiver arrays. The detection data presented here are thus likely to underestimate Striped Bass presence in the monitored areas.

VEMCO acoustic telemetry was effective in detecting the mid- to far-field presence of Striped Bass, and this study serves as a proof-of-concept for future use of acoustic telemetry in environmental monitoring programs in Minas Passage and other high flow sites globally. However, the technology employed is not the ideal tool to resolve near-field activity (including behaviour near turbines) of fish at TISEC sites. Future studies should incorporate monitoring at near-field spatial scales (<100m) using integrated passive and active acoustic instruments. Advances in sensor development (including protection), deployment methods and multi-sensor integration will be required for long-term monitoring of turbine impacts on marine life.

## CONCLUSIONS

This study documents the presence and depth distribution of Striped Bass in Minas Passage and the FORCE test site and highlights the potential for interaction with TISEC devices deployed at FORCE.

Tagged Striped Bass were detected by both the Minas Passage Line and FORCE receiver arrays throughout the monitored period (June 22-November 23, 2010). Striped Bass were distributed broadly throughout Minas Passage, with little evidence of specific movement pathways or corridors. A significant portion (49%) of the tagged adult Striped Bass were detected by receivers at FORCE, with many detected on numerous occasions (multiple passes) and at depths that correspond to hub height for a range of turbine designs and device mooring configurations.

Given that sub-adults were rarely detected at FORCE, they may be at lower overall risk for interaction with TISEC devices in Minas Passage than adult Striped Bass.

Future research should focus on examining near-field behaviour of fish near tidal turbines, with attention to detection of avoidance, evasion of, or collision with, TISEC devices.


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