Environmental Effects Monitoring Program

Annual Report: 2017

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Fundy Ocean Research Center for Energy

PO Box 2573, Halifax, NS B3J 3N5

(902) 406-1166

www.fundyforce.ca

Executive Summary

The Fundy Ocean Research Center for Energy (FORCE) is Canada's leading research centre for the demonstration and evaluation of tidal in-stream energy conversion (TISEC) technology. This technology (commonly known as "in-stream tidal turbines") is part of an emerging sector designed to generate electricity from the ebb and flow of the tide. It also has application in river systems and has the potential to introduce another non-carbon emitting source of electricity to the Nova Scotia electrical grid.

The first demonstration in-stream tidal energy turbine was operational at the FORCE site for a short time in 2009 and removed in 2010. There were no turbines present at FORCE until Cape Sharp Tidal Venture (CSTV) deployed a two-megawatt demonstration turbine in November 2016 and began a commissioning process. In April 2017, CSTV announced the turbine would be disconnected for temporary retrieval; on June 15th, the turbine was retrieved and moved to Saint John, New Brunswick shortly thereafter.

Environmental effects monitoring programs (EEMPs) began at FORCE 2009; to-date, over 90 tidal-related research studies have been completed or are underway with funding from FORCE and the Offshore Energy Research Association.

In 2016/2017, EEMP work is being conducted with academic and research partners, including the University of Maine, the Sea Mammal Research Unit Consulting (Canada), Envirosphere Consultants, Acadia University, Luna Ocean Consulting, JASCO Applied Scientists, Ocean Sonics, and Nexus Coastal Resource Management.

The following document is a 2017 summary of mid-field monitoring work at the FORCE site that has taken place this year. The 2017 EEM Program has completed approximately: 11 days of lobster surveys using 48 traps, ~ 130 hours of hydro-acoustic fish surveys, 334 days of C-POD data collection resulting in >1,300 'C-POD days,'[1] 16 seabird surveys, bi-weekly beach surveys, and four marine noise surveys. At the start of 2017, monitoring activities took place in relation to an operational turbine and continued throughout 2017 in the absence of a deployed in-stream tidal turbine. Monitoring is scheduled to continue into 2018. Year 1 reports on fish, marine mammals, and seabirds have undergone review by FORCE's environmental monitoring advisory committee (EMAC)[2] and are included as appendices to this report.

Lobster monitoring: FORCE's Lobster EEMP consists of a lobster catchability study in collaboration with NEXUS Coastal Resource Management. The goal of this study is to measure whether the presence of a turbine affects the number of lobsters entering traps. Commercial lobster traps are used to compare catch volumes in different proximity to the turbine location.

The first lobster catchability study took place in October-November 2017. During the survey, 48 traps were successfully deployed, with a 98% recovery rate. Trap drift was minimal during the

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[1] 'C-POD days' refers to the number of days total C-PODs were deployed times the number of C-PODs deployed.

[2] EMAC membership is available online at: www.fundyforce.ca/about/advisory-committees.

operation (~60 m on average), and a total of 351 lobsters were caught and released during the study. This amounted to an estimated total weight of 281.16 kg of lobster. Average daily catch rates ranged from 4.79-8.99 kg $trap^{-1}$ (n= 7-8 traps per day for 6 days) across both study rings.

FORCE's 2018 EEMP will include one additional lobster catchability study, to be completed during turbine operation.

Fish monitoring: FORCE and the University of Maine are conducting a fish-monitoring program using a downward facing hydro-acoustic echosounder (the University of Maine has experience conducting similar monitoring programs for a tidal energy project in Cobscook Bay, Maine). The goal of this program is to describe and quantify fish distributional changes that reflect behavioural responses to the presence of a deployed turbine.

Three 24-hour surveys were complete pre-turbine deployment (May, August, and October 2016) and well as four 24-hour surveys during the operation of the Cape Sharp Tidal turbine (November 2016, January 2017, March 2017, and May 2017), which included additional efforts to ensure data collection at the Cape Sharp Tidal turbine. Additional fish surveys were completed after the removal of the Cape Sharp Tidal turbine in July, August, and November 2017.

Surveys identified peaks in fish abundance in November and January, with a smaller peak in May. The density of fish at turbine height was highly variable across tidal stage, time of year, and location within the FORCE site. Preliminary findings suggest no significant effect of the turbine on the density of fish in the mid-field of the turbine or on fish vertical distributions, but more data collection during turbine operation is needed. Hydroacoustic surveys will continue ~1-2 times per season in 2018.

In addition to the hydroacoustic surveys, FORCE has deployed five fish tag receivers from the Ocean Tracking Network throughout its test site. Five more receivers of a new design will be deployed at the site in 2018 in collaboration with Dr. Mike Stokesbury at Acadia University.

Marine mammal monitoring: The goal of the marine mammal monitoring program is to detect changes in the distribution of marine mammals (predominately harbour porpoise at the FORCE site) in relation to operational in-stream turbines. In collaboration with the Sea Mammal Research Unit (SMRU), marine mammal presence was monitored using 3 to 5 C-PODS deployed on a near-continuous basis in the mid-field of the turbine location pre- and post-turbine installation in 2016-2017. Five C-PODS are currently collecting data at the site, and will be recovered in January for annual maintenance. Re-deployment will occur ~2 weeks after recovery in January.

In 2016 and 2017 porpoises were detected on 98.4% of days, with presence varying by time of year, current speed, tidal height, time of day, and the lunar cycle. Initial results provide no evidence of permanent avoidance in the mid-field of the turbine, but there was a temporary decline in detection rate post turbine installation (41-46%), likely due to vessel activity. Tidal height was a more important factor in driving variation in porpoise abundance, with a 12-fold greater impact on detection rate than the presence of the turbine.

In addition, FORCE has continued its a beach walks and public observation program for marine mammals.

Seabird monitoring: The main objectives of the seabird monitoring program are to obtain site-specific species abundance and behaviour data, which can be used to establish whether the presence of a turbine causes displacement of surface-visible seabirds and marine mammals from habitual waters and to identify changes in behaviour. Fifteen shore-based surveys were completed by Envirosphere Consultants in 2017, including observations during and post-turbine operation, to be compare with pre-turbine data collected in 2016.

Initial results show seasonal peaks in water-associated birds in spring and fall, consistent with known migratory patterns of species of loons, cormorants, gulls, waterfoul, and alcids. There was also a late spring and early summer occupation of the site by locally breeding Black Guillemot and Common Eider. Seabird abundances were low during summer. Initial results suggest no significant effect of turbine operations on seabird abundance, but a formal statistical analysis of the data will be performed in 2018.

Marine noise monitoring: The goal of FORCE's acoustic monitoring program is to measure both ambient (in the immediate surroundings) and noise generated by in-stream turbines for prediction of the potential effects of this noise on marine life. Acoustic monitoring is being accomplished using drifting hydrophone systems, deployed at the site in October 2016 and March 2017. Data analysis is ongoing in collaboration with JASCO, Ocean Sonics, and GeoSpectrum Technologies.

Initial results indicate that the main sources of noise in the study area included sediment movement associated with tidal flow and nearby vessel activity. Preliminary analyses indicated that drifting hydrophones were able to pick up sounds from the OpenHydro turbine in March 2017, demonstrating that drifting hydrophone systems are effective for measuring ambient and turbine-associated noise.

The 2018 marine noise monitoring program will include several more rounds of drifting data collection, timed to occur at varying points during the lunar cycle to more fully characterize the range of ambient sounds in the study area. Additional drifts will also be conducted while a turbine is in operation at the site, to gather data regarding turbine-associated noise.

FAST sensor platforms: Independent of EEM programs, FORCE is also conducting marine life effects research through its Fundy Advanced Sensor Technology (FAST) program that utilizes a series of subsea instrument platforms. While EEM addresses immediate, regulated monitoring objectives, FAST supports sensor innovation that may also yield important monitoring-related insights while advancing EEM capabilities for future regulated programs.

FAST-1 has been deployed and recovered with an acoustic zooplankton and fish profiler (to assess zooplankton and fish density and depth distribution); FAST-2 will soon be deployed with a dynamic mount with a Tritech Gemini imaging sonar; and FAST-3 has undergone multiple deployments with an acoustic zooplankton and fish profiler and an autonomous scientific echosounder.

Lessons Learned: Over the course of 2017, several lessons were learned through FORCE's EEM Program from an operational perspective. Specifically, with increased experience in collecting data, FORCE and its contractors have gained a greater understanding of the need for: managing effective and safe simultaneous operations, proper calibration and marine operation methodologies, and development of highly-qualified personnel.

In keeping with the adaptive management approach for the project, scientific lessons learned have resulted in adaptations to programming where applicable. For instance, adjustments that have been or will be made to the lobster, fish, and mammal monitoring programs in response to consultant recommendations include:

- Revisions to lobster survey design to improve efficiency of data collection;
- The addition of an 'over-the-turbine' location transect as part of the fish monitoring surveys in the survey design; and
- Shortened C-POD deployment times to reduce the risk of loss.

2018 Plan: FORCE will continue its marine mammal, fish, seabird, lobster, and acoustics monitoring programs into 2018 as committed to in the 2016 EEMP. Some modifications will be made in response to lessons learned during 2017 in keeping with the adaptive management approach. FORCE will continue to issue interim reports to summarize ongoing monitoring operations at the site. These interim reports, presented on a quarterly basis, support longer-term analysis led by academic and research partners as more data is collected through seasonal and annual cycles, and in the presence and absence of turbine operations.

Final reports prepared by EEMP contractors are published on FORCE's website, www.fundyforce.ca/environment, upon review by FORCE's independent Environmental Monitoring Advisory Committee and regulators.

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Appendix 2: 2016/2017 (Year One) Seabirds Monitoring Report

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Introduction

ABOUT FORCE

FORCE was created to lead research, demonstration, and testing for high flow, industrial-scale in-stream tidal energy devices. Located near Parrsboro, Nova Scotia, in the Minas Passage of the Bay of Fundy, FORCE is a not-for-profit facility, with funding support from the Government of Canada, the Province of Nova Scotia, Encana Corporation, and participating developers.

The FORCE project currently consists of five undersea berths for subsea turbine generators, four subsea power cables that will connect the turbines to land-based infrastructure, an onshore substation and power lines connected to the Nova Scotia power transmission system, and a visitors/operations center. The marine portion of the project is located in a leased area from the province (FORCE's Crown Lease Area, or 'CLA'), 1.6 km by 1 km in area, in the Minas Passage, and the onshore facilities are located approximately 10 km West of Parrsboro, Nova Scotia.

The FORCE demonstration project was approved on September 15th, 2009 by the Nova Scotia Minister of Environment, and the conditions of its approval[3] provide for comprehensive, ongoing, and adaptive environmental management.

FORCE has two central roles:

1) Host: providing the technical infrastructure to allow demonstration devices to connect to the transmission grid
2) Steward: research and monitoring to better understand the interaction between devices and the environment

Monitoring and reporting of any environmental effects from tidal turbines at the FORCE site is fundamental to FORCE's mandate—to assess whether in-stream tidal energy turbines can operate in the Minas Passage without causing significant adverse effects on the environment or electricity rates, and other users of the Bay. In this way, FORCE has a role to play in supporting informed, evidence-based decisions by regulators, industry, the scientific community, and the public. As deployments are expected to be phased in over the next several years, FORCE and regulators will have opportunity to adapt environmental monitoring approaches over time as lessons are learned.

BACKGROUND

Since 2009, FORCE has been conducting an environmental effects monitoring program (EEMP) to better understand the natural environment of the Minas Passage and the potential effects of turbines as related to fish, seabirds, marine mammals, lobster, marine noise, benthic habitat, and other environmental variables. All reports are available online at: www.fundyforce.ca/environment.

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[3] FORCE's Environmental Assessment Registration Document and conditions of approval are found online at: www.fundyforce.ca/environment/enviromental-assesment.

A 1-megawatt, 10-metre diameter in-stream tidal energy turbine was operational at the FORCE site for a short time in 2009. Since removal of this unit in 2010, no tidal turbines were present at the FORCE site until November 7th, 2016 when Cape Sharp Tidal Venture (CSTV) deployed a 2-megawatt, 16-metre diameter OpenHydro turbine. This turbine was recovered from the FORCE site on June 15th, 2017. Consequently, the environmental studies conducted up to 2016 have largely focused on the collection of background data.

FORCE's present EEMP was developed in consultation with SLR Consulting (Canada),[4] and strengthened by review and contributions by national and international experts and scientists, provincial and federal regulators, and FORCE's environmental monitoring advisory committee (EMAC), which includes representatives from scientific, First Nations, and fishing communities. The EEMP is designed to:

- monitor the environmental effects of operating turbines;
- focus on five subject areas: lobsters, fish, marine mammals, seabirds, and marine noise; and
- be adaptive, based on monitoring results and input from regulators and EMAC, as well as ongoing turbine operations.

MONITORING OBJECTIVES

As part of its mandate, FORCE is tasked with monitoring and evaluating the environmental effects of the activities undertaken at its site and reporting on these effects. The present FORCE EEMP is based the best available scientific advice regarding monitoring approaches and instrumentation and experience in Minas Passage. The EEMP is iterative; regulators will continue to review the program through an adaptive management approach. This means the EEMP will continue to evolve as results and research efforts suggest new approaches or different instruments, and as developments and lessons learned are ascertained, both at the FORCE site and internationally.

FORCE and the berth holders both have roles to play in monitoring environmental effects. FORCE conducts monitoring from the near-field boundary (greater than 100 m from a turbine) to the mid-field (within the FORCE site or less than 1 km from a turbine). Berth holders are responsible for monitoring environmental effects at or on the turbine and within the near-field (within 100 m from their turbine[s]).

In general, the present FORCE EEMP was designed to guide environmental monitoring activities at FORCE for the next five years, but it remains responsive to changes in turbine deployment schedules, regulatory guidance, and as data is collected and analyzed. As more devices are scheduled for deployment at the FORCE site, and as monitoring techniques are improved at the site (through FORCE's Fundy Advanced Sensor Technology (FAST) program, see below), the EEMP will be revisited, keeping with the adaptive management approach. This is nature of the adaptive management approach followed at the FORCE site since its establishment in 2009.

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[4] This document is available online at: www.fundyforce.ca/environment/monitoring.

The overarching purpose of each EEMP is to verify the accuracy of the environmental effect predictions made in the environmental assessment (see Table 1 below). Specifically, these EEMPs are aimed at post-deployment effects monitoring.

Table 1: The objectives of each of FORCE's environmental effects monitoring programs.

Environmental Effects Monitoring Program	***Objectives***
Lobster	• to determine if the presence of an in-stream tidal energy turbine affects commercial lobster catches
Fish	• to test for indirect effects of in-stream tidal energy turbines on water column fish density and fish vertical distribution • to estimate probability of fish encountering a device based on fish density proportions in the water column relative to turbine depth in the water column
Marine Mammals	• to determine if there is permanent avoidance of the mid-field study area during turbine operations • to determine if there is a change in the distribution of a portion of the population across the mid-field study area
Marine Noise (Acoustics)	• to conduct ambient noise measurements to characterize the soundscape prior to and following deployment of the in-stream turbines
Seabirds	• to understand the occurrence and movement of bird species in the vicinity of in-stream tidal energy turbines • to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to in-stream tidal energy turbines

SUMMARY OF MONITORING ACTIVITIES

FORCE’s latest monitoring program, which focuses on lobster, fish, marine mammals, seabirds, and marine noise, was initiated in 2016, has continued into 2017, and will continue into 2018 and beyond. FORCE’s EEMP, introduced in 2016, is available online at: www.fundyforce.ca/environment/monitoring.

In November 2016, CSTV deployed a two-megawatt demonstration turbine at the FORCE site. During the second quarter of 2017 (Q2: April 1st - June 30th), CSTV underwent a period of significant marine operations at the FORCE site in relation to the disconnection of the turbine from the subsea cable (reported April 21st, 2017) and turbine recovery (June 15th, 2017). Updates on the CSTV project, including its quarterly monitoring reports and 2017 annual report, are available on its website: www.capesharptidal.com.

The following sections provide a summary of the mid-field monitoring activities conducted at the FORCE site in 2017, including data collection, data analyses performed, initial results, and lessons learned. CSTV conducted near-field monitoring during the period of turbine operation at the site in 2016-2017. Near-field monitoring activities and initial results are provided in CSTV’s 2017 annual report.

Lobster

PROGRAM SUMMARY

FORCE’s lobster monitoring program consists of ‘catchability surveys,’ where commercial lobster traps are deployed on two rings increasing in distance from the turbine location (as depicted in Figure 1). The objective of this study is to determine if the presence of an in-stream tidal energy turbine affects commercial lobster catches within the Minas Passage. In 2016, FORCE contracted NEXUS Coastal Resource Management Ltd. (Halifax, NS) to conduct this work.

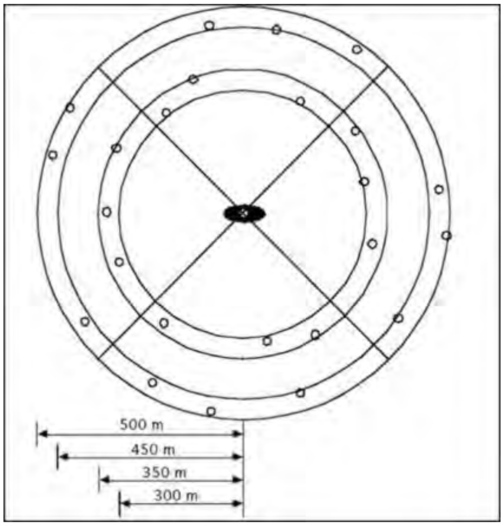

Figure 1: Double-ringed survey design proposed by Bayley (2010), with the dark centre representing the turbine and smaller circles representing lobster traps to be deployed (approximate distances shown) for the lobster monitoring program.

In January 2017, FORCE and NEXUS Coastal Resource Management met with local lobster fishers to discuss the study. In this meeting, fishers provided insight regarding how to catch lobster safely within the Minas Passage. Fishers also suggested an in-season survey would be the best time to conduct the survey given that this is the peak time for lobster movement in the area. This input helped inform the survey design—including hauling methodology, bait used, and number of traps deployed/hauled in a single day (reduced from 12 to 8).

2017 DATA COLLECTION

The first in-season lobster catchability survey was conducted in fall 2017. The survey was completed over 11 days of operations from October 23rd to November 15th, with a one-week break that suspended operations during the spring tide.

Figure 2: NEXUS team and crew of the Nova Endeavor prepare to deploy commercial lobster traps for the catchability study in October 2017.

[VIDEO]: Fall 2017 lobster survey: https://vimeo.com/243594336

During operations, three sets of eight traps were deployed on each of two concentric rings (48 total) that increased in distance from the turbine location (Figure 1). Traps were recovered after a 24-hour soaking period. Upon recovery, lobsters were retained from the traps, and measured for carapace length, shell condition, and sex. When measurements were completed, lobsters were returned to the waters from which they were caught. Water temperature and depth were also recorded at each deployment and recovery location.

DATA ANALYSIS

The primary goal of data analysis will be to determine how lobster catchability changes with distance from the turbine location, pre-and post-turbine installation. Initial analyses will examine differences in lobster catchability between treatment rings in the absence of a deployed turbine. Specifically, the effect of distance from turbine (i.e., the treatment ring), deployment set number (1-3), water depth (meters), maximum tidal height (in meters), and direction from turbine (North/South or East/West, nested within ring) on lobster catchability (average lobsters per trap) will be assessed using a generalized linear model.

Upon the completion of a survey while a turbine is in operation, the analysis will include a comparison of catchability before and after turbine deployment to identify a turbine effect. In addition, NEXUS will compare catch rates from the 2017 survey (and post-turbine survey) to catch rates in other areas of the Minas Basin to provide context to the catchability observed at the FORCE site.

INITIAL RESULTS

Trap drift was minimal during the operation (~60 m on average) and recovery rate was 98% (47/48 traps). A total of 351 lobsters were caught and released during the study. Based on a carapace length to weight conversion, this amounted an estimated total weight of ~281.16 kg. Average daily catch rates ranged from 4.79-8.99 kg trap^{-1} (n= 7-8 traps per day for 6 days) across both study rings.

LESSONS LEARNED

Some modifications to the design of this lobster catchability study are proposed based on initial findings and experiences during the 2017 survey. These include:

- Lengthening the line on some of the traps at deeper deployment locations and colouring the floats more brightly will improve trap search efficiency;
- Minor changes to the design of the survey to improve the ability to detect directional effects of turbine operation on lobster catchability. Note, any changes to study design will not compromise comparability with previous data collection efforts.

SUMMARY OF 2018 PLAN

One lobster catchability study will be planned for 2018, timed to occur in October-November to overlap seasonally with the survey completed in 2017. This will be conducted during the lobster fishing season, based on advice received from local fishers.

The main purpose of this study will be to examine effects of turbine operation on lobster catchability; therefore, this study will only be completed if a turbine is in operation at the site at that time. If a turbine is not in operation at the site in 2018, the second lobster catchability study will be postponed until a turbine is deployed at the site. This will be decided in consultation with regulators.

Fish

PROGRAM SUMMARY

The goals of the fish monitoring program are to: 1) test for indirect effects of TISEC devices on relative fish density throughout the water column, 2) test for indirect effects of TISEC devices on fish vertical distribution, and 3) estimate the probability of fish being at the same depth of the turbine based on the vertical distribution of fish relative to a deployed TISEC device. The program uses a downward-facing hydro-acoustic echosounder (sonar) mounted onto a vessel,[5] which traverses transects across the FORCE site while collecting data on fish density and vertical distribution.

The work is being completed in collaboration with the University of Maine; a recognized leader in the use of hydro-acoustics for fish monitoring purposes. The University has experience conducting similar monitoring programs for Ocean Renewable Power Corporation's turbine in Cobscook Bay, Maine.[6] Another goal of the program is to train Nova Scotians in the use of hydroacoustic techniques for tidal energy monitoring.

2017 DATA COLLECTION

In 2017, FORCE completed six surveys that followed the same protocol as surveys conducted in 2016 and consisted of transects conducted throughout the FORCE demonstration site and control areas nearer the Cape Split side of the Minas Passage. The surveys consist of a calibration period, followed by an approximate 24-hour survey to include two tidal cycles and day/night periods. Each transect is 1.8km in length and is conducted twice—with and against the tidal current. The survey design is depicted in Figure 3.

In 2017, surveys were completed during neap tides in the periods of January 20th – 22nd, March 21st – 23rd, May 4th – 5th, July 3rd – 4th, August 30th - 31st, and November 27th - 28th to target times of interest as well as to coincide with timeframes comparable to previous years' data collection. Only ~10 hours of data were collected during the November sampling due to inclement weather conditions. An additional "over the turbine" transect was sampled twice during the flood tide during the November 2016 survey to compare fish vertical distributions between transects adjacent to and over the turbine. These transects were conducted during flood tide to capture vertical distributions during the time at which water flows are likely to be at their peak.

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[5] The echosounder used is a Simrad EK80 (transducer and desktop unit). The EK80 transducer is attached onto the pole mount off the side of the vessel Nova Endeavor. This 'scientific grade' equipment uses sonar technology (split beam echosounder) to detect fish within the water column. GPS is used to verify location of the pole mount during data collection. This technology is preferred over single and multi-beam systems because it provides more detailed information on the 3D position of fish relative to a single beam sounder, and can survey over a further distance with higher resolution than a multi-beam system.

[6] This work looked at evasion and avoidance behaviours of fish and marine mammals in relation to the turbine. This work found that the probability of a fish encountering the turbine's blade would be less than 2.9% (Shen et al., 2015; Viehman and Zydlewski 2015) and that there was no difference in marine mammal behaviour in response to a turbine (ORPC 2014).

Figure 3: Transects completed for the fish hydroacoustic surveys. The green square indicates the FORCE test site whereas the white lines highlight the transects completed through the test site and control site (bottom of image) near Cape Split.

DATA ANALYSIS

Data processing and analysis of these surveys is currently underway by the University of Maine. An analysis of Year One (including 2016 surveys as well as the surveys completed in January and March 2017) is presented in Appendix 1.

Data processing is done using the software Echoview® (version 7.1.35; Myriax, Hobart, Australia). The first step is to apply a target strength threshold to removes signals from biological targets smaller than ~ 10 cm. Below this threshold length, signals from fish are difficult to distinguish from signals from other biological targets. The target strength used corresponds to what was used during previous studies at the site (Melvin and Cochrane, 2014). The second step in data processing is to apply techniques to remove signals from turbulence caused by entrained air. For details on this process, see Appendix 1.

Once data processing is complete, data are split into vertical (e.g., 1 m) or horizontal bins for analysis. A two-stage Generalized Linear Model was used to detect variation in fish density between sampling intervals, between sites (treatment and reference), and before and after turbine removal. The response variable in these analyses was volume backscatter, which is a relative metric of fish density. To describe fish vertical distributions, data were split into 1 m bins from the surface to the bottom, and the percent of fish in each depth layer was calculated.

To calculate the percentage of fish at turbine depth, transects closest to the turbine were split into 700 m distance bins. This spatial split allowed for an analysis of vertical distributions in the approach to the turbine. In each bin, the percentage of fish at turbine height was calculated.

INITIAL RESULTS

Analyses to-date include data collected through six surveys completed in 2016 (May, August, October, November) and Q1 2017 (January, March), as well as data previously collected through FORCE's baseline monitoring programs (Melvin and Cochrane, 2014) (Appendix 1). The analysis included three surveys completed during the operation of the CSTV turbine (November 2016, January and March 2017). Results show a significant effect of survey month on relative fish density, with the highest densities observed in November and January, and a small peak in May. This seasonality was consistent across sites (i.e., the control and reference sites) and year (2011-2012, 2016-2017). Fish densities did not differ widely between day/night and ebb/flood periods. Analyses did not identify a significant effect of turbine deployment on fish densities at either the reference or treatment sites, but more data is needed to evaluate this finding.

Fish vertical distributions were variable across months. In August and November, fish tended to be distributed closer to the bottom (<10 m above bottom), whereas they were more evenly distributed in the water column in other months. Preliminary analyses show that the percentage of fish at turbine depth during flood tide along the two transects adjacent to the turbine ranged from 1.77% - 97.42% (May 2017-March 2017). Initial data collection over the turbine in November 2016) indicated that the percentage of fish at turbine depth ranged from 21.0% - 78.0%. More data collection over a broader range of tidal conditions is needed to more fully characterize vertical distributions directly over the turbine.

LESSONS LEARNED

Numerous lessons learned have been realized in the fish monitoring program over the course of the surveys completed in 2017. These lessons relate to operational planning and modifications to survey design, and include:

- The methodology of the fish surveys presents a significant challenge with respect to operational planning. The data collection for the fish EEMP requires specific weather conditions, which can be challenging when operating during a limited tidal window (i.e., neap tide). Successfully planning a survey given these limitations requires planning a wide operational window around the ideal tide conditions, and maintaining flexibility in the operational team as to when the survey is completed. Challenges encountered while planning surveys also highlights the value of bottom-mounted monitoring platforms such as the FAST platforms, which are not subject to the limitations that inhibit vessel-based surveys such as visibility, seasonal constraints, weather, tides, and, most essentially, vessel availability. The utility of this platform for fish monitoring is currently being assessed;
- Conducting transects over the turbine is necessary to generate a representative strike risk model, as vertical distributions above the turbine differed from those along adjacent transects;

- Adding an additional, over-the-turbine transect can be accommodated in the survey methodology without compromising the timing of transect completion in relation to previous surveys;
- Other lessons learned include improved instrument calibration procedures and more efficient marine operations. This includes materials developed to support in knowledge transfer among FORCE staff, contractors, and additional ocean technologists for the hydroacoustic fish surveys.

SUMMARY OF 2018 PLAN

Hydroacoustic surveys of the same design will continue at a similar frequency in 2018, weather permitting. Timing of these surveys will maintain overlap with previous sampling years and cover the full seasonal cycle. FORCE will continue to explore options for physically sampling fish to document seasonal changes in species abundance in Minas Passage.

Marine Mammals

PROGRAM SUMMARY

FORCE's marine mammal monitoring program involves two main components:

1. The monitoring of the presence of click-producing mammals using CPOD receivers; and
2. An observation program that includes shoreline, stationary, and (at times) vessel-based observations to locate any marine mammals in destress in the vicinity of the FORCE site.

The first component of FORCE's marine mammal monitoring program in 2017 involves the use of passive acoustic monitoring (PAM) mammal detectors known as 'C-PODs' (Figure 4) which record the vocalizations of toothed whales, porpoises, and dolphins.[7] The goal of this program is to understand if there is a change in marine mammal presence in proximity to deployed in-stream tidal energy turbines.

In May 2016, FORCE contracted the Sea Mammal Research Unit Consulting (SMRU Consulting) to conduct the data analysis, interpretation, and reporting for its marine mammals monitoring program. SMRU Consulting, based in Vancouver, British Columbia, is a global leader in marine mammal research and has been involved in Fundy tidal energy research for marine mammals since 2009 (Tollit et al., 2011; Tollit and Redden, 2013).

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[7] The C-PODs, purchased from Chelonia Limited, are designed to passively detect marine mammal 'clicks' from toothed whales, dolphins, and porpoises. The species that C-PODS can potentially detect in the FORCE region are Killer Whale (Orca), Northern Bottlenose Whale, Dall's Porpoise, Harbour Porpoise and Pacific White-Sided Dolphin.

Figure 4: FORCE ocean technologist and crew of the Nova Endeavor (of Huntley's Sub-Aqua Construction from Kentville, NS) prepare to deploy C-PODs as part of FORCE's marine mammal monitoring program.

SMRU Blog Post: SMRU Canada wins FORCE (available online at: http://www.smruconsulting.com/smru-canada-wins-force/)

2017 DATA COLLECTION

In 2017, C-PODs (and their associated SUBS buoy packages, acoustic releases, and fish tag receivers, etc.[8]) were recovered in January 18th and redeployed for 3 periods:

- February 23rd – June 1st;
- June 2nd – September 14th; and
- redeployed on September 26th (to be recovered in early January 2018).

FORCE had targeted relatively short turnaround periods for the C-PODs to ensure close to continual coverage throughout the year. During longer 'turnaround periods,' the C-PODs underwent more substantial repairs and upgrades to ensure their continued use for another deployment(s).

Five CPODs have been deployed at the FORCE site in 2017 in the locations shown on Figure 5. CPODs are located between 200-1,710m from where the OpenHydro turbine was deployed in 2016-2017.

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[8] The C-PODs are housed in a large, yellow, and buoyant SUBS package as pictured in Figure 6. Each casing has FORCE's contact information displayed, and FORCE has had a high return rate for its instrumentation.

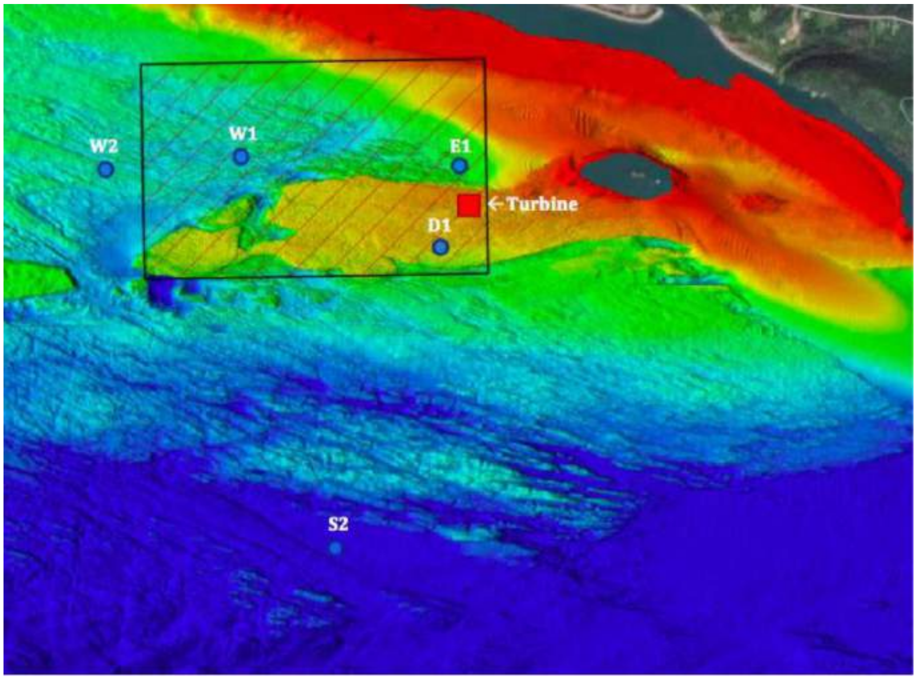

Figure 5. The five C-POD deployment locations in the mid-field of the turbine at the FORCE site.

[VIDEO]: February 2017 C-POD deployment: https://vimeo.com/210831115

A second component of FORCE's marine mammal monitoring program for 2017 is a visual observation program that includes observations through beach walks, stationary observations at the FORCE Visitor Centre, and, at times, marine-based observations during marine operations.

In 2017, FORCE developed an online tool[9] to allow staff, volunteers, and members of the public to record any observed marine mammals while conducting shoreline surveys along areas of the Cumberland shore closest to the FORCE site and beyond.[10] Throughout 2017, shoreline surveys were completed with no instances of reported strandings or fatalities; occasional sightings of seals between Black Rock and Black Rock Beach have occurred.

In November 2017, FORCE staff and community volunteers participated in the Great Canadian Shoreline Cleanup, an initiative of the Vancouver Aquarium and WWF-Canada.[11] During this clean-up activity, 5 volunteers and 2 FORCE staff removed ~43 kg of garbage from the FORCE beach.

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[9] See: https://mmo.fundyforce.ca. In the event of an observed stranding or mortality, FORCE staff and volunteers will contact the appropriate authority. The purpose of this tool is to report when an observation has been completed.

[10] FORCE-led beach walks occur on an approximate bi-weekly basis and have occurred in the areas of Black Rock Beach, West Bay, Fox River, Diligent River, and Fraserville.

[11] Learn more online at: https://shorelinecleanup.ca/

In addition, Envirosphere Consultants records any observations of marine mammals during its shore-based seabird monitoring surveys. These observations are shared with SMRU to support validation efforts of subsea-based C-POD marine mammal monitoring program and are presented in Envirosphere's reports (Year One Monitoring Report found in Appendix 2).

DATA ANALYSIS

To analyze porpoise detection data collected by CPODs deployed at the FORCE site, SMRU has developed statistical models with the objectives of: 1) evaluating environmental factors that influence porpoise detection rates, and 2) evaluating whether the presence of a turbine influences porpoise detections in the vicinity of the turbine. For the first objective, the model developed includes the time of year and day, lunar cycle, tidal height and velocity, and percent time lost as environmental factors that may influence porpoise detection rate. This model was run using all CPOD data collected at the FORCE site between 2011-2017. The second model uses only data collected when the OpenHydro turbine was present at the site in 2016 and 2017, and was designed to detect a turbine effect while accounting for the influence of environmental variables (as identified in the first statistical model). Analyses were completed using a Generalized Estimating Equation within a Generalized Linear Model framework (GEE-GLM). Analysis procedures are further described in Appendix 3.

INITIAL RESULTS

Porpoises were detected at the FORCE site on 98.4% of days monitored from 2011 to 2017 for an average of 6 minutes per day and maximum of 44. No other click-producing animals were detected at the site during that time. Statistical models indicated that porpoise detection rates were influenced by time of year, time of day, lunar cycle, and tidal current speed and tidal height. There was significant variation between years in porpoise detection rates, but seasonal peaks in detections were consistent across years, occurring in late spring (May) and fall (November). Detection rate also peaked twice per month, corresponding to the timing of the spring tides. Porpoises were most commonly detected during the night and during the first few hours after the tides turn to ebb, when water velocities are flowing at low to moderate speeds.

Preliminary analyses found no evidence that porpoise permanently avoided the site while a turbine was in operation in 2016-2017. There was a temporary reduction in porpoise detections (41-46%) following turbine installation in November 2016 at the site closest to the east of the turbine (E1) and the two sites west of the turbine (W1 and W2 in Figure 5) (200-1710 m from the turbine). The magnitude of this effect is low relative to other environmental variables, however, with the influence of tidal height being twelve-fold more important than the influence of turbine presence. No significant changes in porpoise detection were observed at the remaining two sites monitored, located 230 m and 1,690 m to the southwest of the turbine. More details on these results are available in Appendix 3.

LESSONS LEARNED

Several lessons were learned over the course of 2017, mainly related to operational planning and equipment configuration:

- The failure of one of the C-PODs' moorings highlighted that longer deployments increase the risk of instrument loss (although the C-POD was recovered by a local fisher);
- Upon recovery, two other C-PODs were not immediately found. FORCE staff currently purchasing and installing a beacon on each CPOD to aid recovery.

SUMMARY OF 2018 PLAN

CPOD data collection will continue in 2018 at the five locations monitored in 2016-2017, and further data analyses will be performed to look for a turbine effect following the re-deployment of a turbine at the FORCE site. Shoreline walks and observations will also continue at a frequency of 1-2 times per month.

Seabirds

SUMMARY OF PROGRAM

The main objectives of the seabird monitoring program are to obtain site-specific species abundance and behaviour data, which can be used to establish whether the presence of a tidal energy device causes displacement of surface-visible seabirds from habitual waters and to identify changes in behaviour. Envirosphere Consultants (Windsor, Nova Scotia) was contracted to complete data collection, analysis, and reporting activities under FORCE's seabird monitoring program in 2017. Envirosphere has been conducting seabird and marine mammal monitoring at the FORCE site since 2008 (Envirosphere Consultants Limited, 2009 – 2013).

Figure 6: Bird observers at the FORCE Visitors Centre conducting a seabird observation study.

2017 DATA COLLECTION

In 2017, sixteen shore-based observational surveys (Figure 6) were conducted monthly to cover all seasons, with additional emphasis on migratory periods. During migratory periods, two surveys per month were completed in the months of March, April, May, and November. Surveys generally took place over an approximate six-hour period with the outgoing tide, consistent with earlier surveys to help reduce statistical variability. Environmental factors expected to affect bird abundance were also recorded. The surveys used a geographic grid system to record observations in relation to various areas of the FORCE demonstration site and surrounding areas. This is depicted in Figure 7. Methods are described in more detail in the Year 1 Seabirds Monitoring Report (Appendix 2).

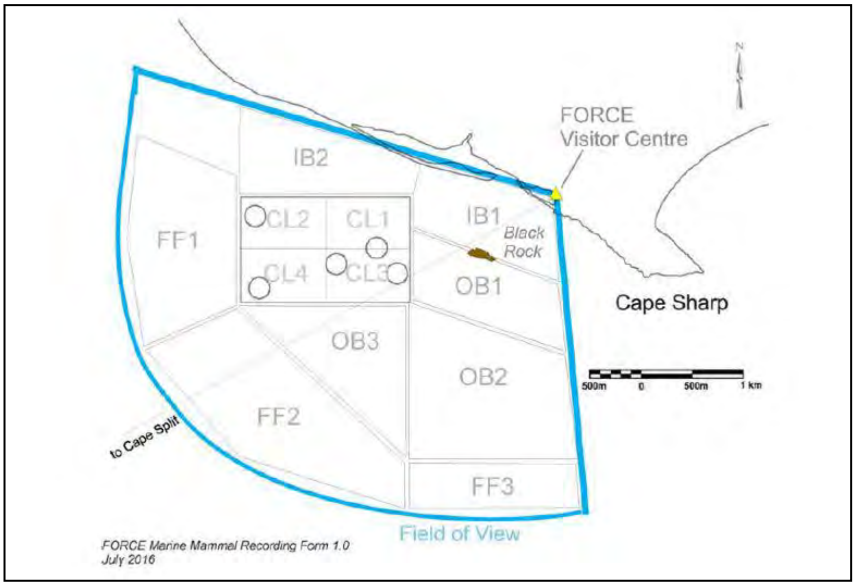

Figure 7: Subdivisions of the FORCE Crown Lease Area for the seabirds monitoring program where 'CL' indicates Crown Lease area; 'IB' indicates Inside Black Rock; 'OB' indicates Outside Black Rock; and 'FF' indicates Far-Field area.

DATA ANALYSIS

Data analyses to date have included qualitative descriptions of seasonal and inter annual changes in seabird occurrence, abundance, local distribution, and species composition at the FORCE site. For each observation period, the total and average number of species per 30-minute interval and subarea, and average abundance of birds overall and by species per 30-minute interval and subarea were calculated. Qualitative analyses to date include surveys from May 2016 – May 2017. Further data collection is needed to have sufficient power to perform a statistical analysis on the data to investigate an effect of the turbine on seabird occurrence and abundance.

INITIAL RESULTS

Thirty-two species of water-associated birds and shorebirds were observed, with the most common and abundant species being gulls, loons, eiders, guillemots, scoters, and cormorants. Least common species included shorebirds (Lesser Yellowlegs, Purple Sandpiper and Spotted

Sandpiper), as well as the Northern Gannett, Red-necked Grebe, Razorbill, Common Murre, Blue-winged Teal, Arctic Loon and Snow Goose. Abundance and behaviour showed seasonal peaks corresponding to migratory movements in spring (March-April) and fall (October-November), with Black Rock being the focal point for bird activity in the survey area. The area was occupied in late spring to early summer by locally breeding Black Guillemot and Common Eider. Abundances in summer were consistently low. Results are described in more detail in the Year 1 Seabirds Monitoring Report (Appendix 2).

LESSONS LEARNED

Several lessons have been learned over the course 2017 about how to improve survey methodologies and data analysis procedures. These include:

- Survey timing could be made more consistent in relation to tidal cycles;
- Adding observations in the early morning would capture dynamics during peak activity periods;
- An improved approach for the analysis of seabird data should include a more complete characterization of the influence of environmental variables on seabird abundance. Incorporating environmental variables will increase the ability to detect a turbine effect.

SUMMARY OF 2018 PLAN

Seabird monitoring will continue in 2018 on the schedule followed in 2017, with 1 – 2 surveys per month. Survey frequency will increase to twice per month during key migratory periods (March-April, October-November). A statistical analysis approach will be developed to describe seabird abundances in relation to key environmental variables as well as the presence of an operational turbine.

Marine Noise

SUMMARY OF PROGRAM

FORCE's marine noise program is designed to characterize the sound environment of the FORCE test site prior to and during the operation of in-stream tidal turbine(s). This information will be used to predict effects of turbine-associated noise on marine animals at the FORCE site. Over the past few years, the emphasis has been on developing the approach for FORCE's acoustics monitoring program, which has been primarily focused on evaluating the utility of drifting hydrophone systems for acoustic monitoring. FORCE has partnered with OceanSonics (Great Village, NS), JASCO (Dartmouth, NS), and GeoSpectrum Technologies (Dartmouth, NS) to complete data collection, data analysis, and program development work.

2017 DATA COLLECTION

In 2017, two ‘drifting hydrophones’ systems were tested at the site by JASCO Applied Sciences and Ocean Sonics (Figure 8). These systems measured sounds through hydrophones attached to surface buoys that drift with the tidal current. Drifters were deployed off the side of the vessel, Tidal Runner, and then traveled 1 – 2 km over the FORCE test site with the tide. The deployment vessel moved away from hydrophone systems during drifts and the engine was turned off as to avoid the introduction of vessel noise into the soundscape. Drift tests were conducted in October 2016, in the absence of a deployed turbine, and in March 2017 while a turbine was in operation at the site.

[VIDEO]: A drifting hydrophone is deployed and recovered in the Minas Passage: https://vimeo.com/210829825

Figure 8: Tyler Boucher, FORCE ocean technologist, and crew of the Tidal Runner demobilize after completing data collection using drifting hydrophones in support of the marine noise monitoring program.

DATA ANALYSIS

Data processing and analysis techniques were applied by JASCO and OceanSonics to the data collected from each system. For the data collected by JASCO, received sound levels were quantified using a 1 Hz resolution frequency domain analysis, and average sound pressure levels and pressure levels in each deci-decade band were then analyzed using standard methods (ISO 2016). Each recording was also manually reviewed to retrieve sounds associated with marine life, anthropogenic activities, and the mooring itself. Received sound levels were also retrieved from the data collected by the OceanSonics drifter, and a third octave analysis was performed. Analyses of acoustic data to identify turbine sounds during the March 2017 OceanSonics deployment are currently underway.

INITIAL RESULTS

Both analyses of drifter data collected prior to turbine deployment identified sounds associated with tides, vessels, and the movement of water and particles in the water column around the drifter system. Sound generated by tidal flow was the main source of noise detected, with sound levels increasing with tidal flow speed. The majority of this energy was in frequencies above 1kHz and was generated by sediment movement over the sea bed. Preliminary analyses indicate that drifting hydrophone systems were able to detect sounds from the operational turbine in March 2017.

LESSONS LEARNED

Following the deployment of two different drifter systems and a third party review of deployment procedures and drifter configurations, lessons have been learned regarding improvements to study design moving forward. These include:

- Following third party review of drifting hydrophone systems used by JASCO and OceanSonics, several modifications to the design of these systems have been recommended to improve data quality and ease of deployment at the FORCE site. These changes will be made to systems before deployment in 2018.
- Additional environmental data (e.g., weather, oceanographic conditions) will be collected and incorporated into future analyses to better identify natural sources of sound.
- Future drifter studies will cover a broader range of tidal conditions (e.g. spring vs. neap) to better understand natural variation in sound levels.

SUMMARY OF 2018 PLAN

Drifter data collection will continue into 2018 with the primary objective of characterizing noise while a turbine is in operation at the site. Data collection will also aim to characterize ambient sounds over a broader range of tidal and environmental conditions.

Other Activities

HYDROACOUSTIC FISH DETECTION & MODELLING WORKSHOP

In late May 2017, FORCE hosted a workshop in partnership with Acadia University's Acadia Tidal Energy Institute on methods of fish detection and population modelling in consideration of in-stream tidal energy projects. The workshop brought together researchers from the United States, Scotland, and Canada, including representatives from Fisheries and Oceans Canada, each with several years' experience in monitoring at high-flow tidal energy sites. Collectively, these researchers primarily use hydroacoustics to monitor marine animal dynamics at high flow tidal sites, and statistics and models to understand the effects of fish-turbine interactions beyond the scale of individual fish to that of fish populations.

The four-day workshop included presentations and facilitated conversations focused on international experience with tidal and wave energy sites/projects and identification of information gaps and best practices. Workshop attendees were able to discuss challenges and to identify areas to improve data collection, processing, and analysis. It is hoped that this workshop will be the catalyst to future collaborative projects amongst the researchers and help identify future methods for data collection and analysis at the FORCE demonstration site. Such information sharing and cooperation has the potential to unify approaches and work towards standardized approaches to hydroacoustic monitoring methodologies, data processing, and analysis.

A workshop report is being prepared and will be shared upon completion.

DATA MANAGEMENT

FORCE's EEM and FAST Programs collect data sets of varying types and sizes. Current protocols involve a mix of cloud based data storage, hard drive data storage and local data storage on computers. In all cases, FORCE practices as much redundancy as practical with all data storage facilities.

In spring 2017, the Offshore Energy Research Association (OERA) awarded SEG Consulting funding to define and describe a conceptual Data Management System/User Interface for use by FORCE. SEG worked closely with FORCE Staff and contractors to collect a set of requirements for data management, including reviewing future requirements for data sharing. SEG provided FORCE various options to review, and the result was two major final deliverables: one document detailing the preferred data management system infrastructure and another document providing a detailed project plan including proposed next steps and budget. This proposed plan considers the partial centralization of FORCE data, security, and data interfaces; as well as an optional advanced GIS based system for managing the data.

FORCE is now in the process of reviewing the proposed plan and recommendations, including evaluating the feasibility of the options presented, potential budget, and processes for potential implementation. In the interim, FORCE is working with students from the Nova Scotia Community College to define standard operating procedures for data management.

REPORTS OF FISH INJURIES

In response to media and social media reports of fish injuries in the south side of the Minas Basin in May 2017, FORCE engaged Envirosphere Consultants to examine the nature of these wounds in further detail. On May 19th, FORCE and Envirosphere joined a representative from Fisheries and Oceans Canada (DFO) at the Bramber-based weir in the Minas Basin to gain a better understanding of the reported injuries (Figure 9).

Figure 9: A DFO representative examines fish samples at a weir in the Minas Basin.

Personnel from Envirosphere continued to monitor incidence of injured fish through visits and discussions with fishers of the southern Minas Basin and inflowing rivers to understand what injuries, if any, they were seeing. This work was conducted throughout May until approximately two weeks after the tidal turbine operated by CSTV was removed from the FORCE demonstration site. It was found that the frequency of injuries was most intense prior to May 19th, with few injuries noted in the month of June. The cause of the injuries was not determined, nor could it be concluded that all injuries were from a single source. These findings were shared with DFO.

In addition to its investigation, DFO issued a statement that “presently, there is no evidence linking the injuries to fish found in the Minas Basin to any specific activity.”[1]

FISH TRACKING

To enhance its fish monitoring program and to expand its data collection capacity, in partnership with the Ocean Tracking Network (OTN)[12], FORCE staff attached one VEMCO fish tag receiver (a VR2 receiver) to each C-POD mooring (see ‘Marine Mammal Program’ below).

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[12] Ocean Tracking Network’s website: www.oceantrackingnetwork.org.

These receivers are used to supplement OTN's ongoing data collection program within the Minas Passage and are referred to as 'Buoys of Opportunity.' Upon retrieval of the C-PODs and receivers, instruments are shared with OTN, where data is offloaded prior to redeployment. This effort will support increased knowledge of fish movement within the Minas Passage, which has applicability beyond tidal energy demonstration. Further information about these Buoys of Opportunity can be found on OTN's website:
https://members.oceantrack.org/project?ccode=BOOFORCE

In 2018, FORCE will work in collaboration with Dr. Mike Stokesbury at Acadia University to install additional VEMCO receivers of a new design on FORCE's C-POD moorings. These new receivers are expected to be even more effective in picking up acoustic detections in high flow environments, where tag signals can be obscured by noise. This partnership will contribute additional information regarding movement patterns of Atlantic Salmon, sturgeon, striped bass, and Alewife in Minas Passage and Basin. This work is sponsored by the Offshore Energy Research Association, Natural Resources Canada, the Nova Scotia Department of Energy, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).[13]

FUNDY ADVANCED SENSOR TECHNOLOGY (FAST) PROGRAM

FORCE's Fundy Advanced Sensor Technology Program ('FAST') is designed to advance capabilities to monitor and characterize the FORCE site. Specifically, the FAST Program was designed to achieve the following objectives:

1) To advance capabilities of site characterization;
2) To develop and refine environmental monitoring standards and technologies; and
3) To develop marine operating methodologies.

FAST combines both onshore and offshore monitoring assets. Onshore assets include a meteorological (MET) station and radar system; the MET station broadcasts data live on the Ocean Networks Canada (ONC) website[14] while the radar system works to monitor surface currents. Offshore assets include three subsea data collection platforms for both autonomous and cabled data collection; cabled data collection is broadcasted live on the ONC website.

FAST's subsea platforms have a large inventory of site characterization and environmental sensors, marine operations equipment and subsea cables. In addition to marine and terrestrial sensor work, the FAST program also works closely with marine service providers. FORCE regularly works with Dominion Diving Marine Ltd. (Dartmouth, Nova Scotia) and RMI Marine Ltd. (Eastern Passage, Nova Scotia); both marine service providers contribute significantly to the advancement of FORCE's marine capabilities and methodologies.

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[13] Information about this project, and others funded through this program, is available online at: www.oera.ca/press-release-research-investments-in-nova-scotia-in-stream-tidal-technology-research/

[14] This is available online at: www.oceannetworks.ca/observatories/atlantic/bay-fundy

On April 20th, 2017, the Offshore Energy Research Association, the Nova Scotia Department of Energy, and Innovacorp awarded funding to Open Seas Instrumentation Inc. (Musquodoboit Harbour, NS) to support innovative approaches to monitoring marine life near an in-stream tidal energy turbine. This project focuses on a redesign of the cabled FAST-2 platform to enable directional sensors to collect data from a specific target, including the face of the turbine (Figure 10). FORCE is a project partner to this project as is the Nova Scotia Community College, Acadia University (Wolfville, NS), Dynamic Systems Analysis (Halifax, NS), and Ocean Moor Technical Services (Falmouth, NS). Specifically, the project consists of the development on FAST-2 of:

1) Enhanced ancillary systems to enable the capture of long-term, real-time environmental data; and
2) A dynamic mount to enable the capture of targeted environmental data.

Imaging sonar, like that to be placed on the FAST-2 platform, already plays a critical role in assessing the interaction of marine life and turbines. To-date, imaging sonars used for turbine monitoring have been mounted on the turbines (e.g., the SeaGen turbine in Strangford Lough[15] and the CSTV turbine in the FORCE region). However, this static mounting imposes a number of limitations (e.g., on the field of view), and further may have no benefit for certain turbine types (e.g., yawing turbines). The project develops technology that is able to image the turbine and surrounding sea life from the seabed, from a potentially unlimited number of perspectives made possible by the dynamic mount.

The project builds on extensive shore-side and subsea infrastructure at FORCE, and includes an incremental program for field-testing sensor technologies through three stages: low flow (intertidal zone of the FORCE beach – 2m/s), intermediate flow (between the FORCE beach and Black Rock Island – 4m/s), and high flow (in the turbine deployment region – 6m/s).

Testing continues to occur at the FORCE Site with progressive tests that include low-water near-shore testing, intertidal testing, and testing within the FORCE demonstration site. Significant marine operational challenges, technological upgrades, and the associated electromechanical work is challenging, but the result will be an advancement for environmental effects monitoring.

The FAST-3 platform holds a suite of sensors to gather data on fish presence and behaviour, including an acoustic zooplankton and fish profiler and a hydro-acoustic echosounder (the same instrument as the instrument being used in the fish environmental effects monitoring program, but mounted on the FAST-3 platform facing upwards) (Appendix 4) (Figure 11). Results from the instruments are being analyzed by Dr. Haley Viehman, a post-doctoral fellow at Acadia

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[15] The 1.2MW SeaGen unit was the world's first grid-connected commercial scale tidal device. Installed in Strangford Lough, Northern Ireland in 2008, SeaGen underwent marine mammal monitoring, bird and benthic ecology surveys. The monitoring program was managed by environmental consultancy Royal Haskoning DHV with scientific input from Queens University Belfast and the Sea Mammal Research Unit (SMRU) based at St Andrews University in Scotland. (Final report: https://tethys.pnnl.gov/sites/default/files/publications/Final_EMP_report_SeaGen.pdf)

University,[16] and will help to identify the best sensor settings and operating schedule for future data collection at the FORCE demonstration site.

[VIDEO]: FAST-3 is recovered from the Minas Passage, data download begins: https://vimeo.com/210830655

Figure 10: FORCE personnel work on the FAST-2 sensor platform in mid-June, connecting a multibeam imaging sonar camera to a multiplexer, which collects and transmits data to shore via optical fibres.

In 2017, FORCE deployed 'FAST-3' between the FORCE beach area and Black Rock near the demonstration site in February 2017 and recovered approximately one month later. It was deployed in the FORCE demonstration area on June 23rd, 2017 for approximately 1.5 months, and redeployed on September 14th and recovered on October 13th. It was deployed again on December 12th and will be recovered in early 2018.

[VIDEO]: Dr. Viehman explains how the data is acquired and used: https://vimeo.com/210831742

Dr. Viehman is continuing to develop data analysis techniques for the data collected by FAST-3.

TETHYS STORY: Remote Sensor Platforms for Environmental Monitoring at FORCE, Canada (available online at: https://tethys.pnnl.gov/tethys-stories/remote-sensor-platforms-environmental-monitoring-force-canada)

Figure 11: The FAST-3 platform prior to deployment on the deck of the Nova Endeavor

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[16] Dr. Viehman's work is supported by Mitacs through the Mitacs Accelerate Program.

EUROPEAN WAVE & TIDAL ENERGY CONFERENCE

In August 2017, FORCE participated in the European Wave & Tidal Energy Conference, one of the largest tidal energy research conferences. In addition to presentations on site characterization and cable monitoring at the FORCE site, two papers were presented on environmental monitoring projects at the FORCE site and are presented in Appendix 5.

ENVIRONMENTAL MONITORING ADVISORY COMMITTEE (EMAC)

The purpose of FORCE's Environmental Monitoring Advisory Committee (EMAC) is to provide advice on monitoring programs, and to review and advise on monitoring results. Membership includes representatives from scientific, First Nations, and fishing communities. EMAC continued to meet in 2017, and provided advice to FORCE on the Year 1 reports on FORCE's fish, marine mammal, and seabird programs and interim reports provided by the third-party consultants leading EEMP activities.

More information on EMAC, including objectives, terms of reference, membership, and summary minutes from these meetings are available on the FORCE website: http://fundyforce.ca/about/advisory-committees/

RESEARCH NETWORKS

It is also important to note that additional research projects are occurring within the Bay of Fundy, particularly the Minas Passage and the Minas Basin outside of the jurisdiction of FORCE. FORCE works closely with many research partners, such as the Acadia Tidal Energy Institute,[17] Dalhousie University, Nova Scotia Community College, and others to keep up-to-date on these activities and how they may contribute to the growing understanding of the monitoring turbine effects.

In addition, FORCE also participates in research forums to understanding the growing local and international knowledge of tidal energy effects monitoring. This includes the Fundy Energy Research Network (FERN), a research forum designed to "coordinate and foster research collaborations, capacity building and information exchange […] associated with tidal energy development in the Bay of Fundy,"[18] and Annex IV, an international body connects those actively involved in marine renewable energy projects to share information and discuss progress in environmental monitoring efforts.[19] These groups provide FORCE with the opportunity to learn from international experts and other marine energy projects as well as communicate its research and monitoring activities.

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[17] The Acadia Tidal Energy Institute is the lead organization behind the Nova Scotia Tidal Energy Atlas (http://tidalenergyatlas.acadiau.ca/). FORCE is a project partner to the Atlas.

[18] Source: http://fern.acadiau.ca/about.html. FORCE participates in the Natural Sciences, Engineering, and Socio-Economic Committees of FERN.

[19] Annex IV is an initiative of the International Energy Agency's Ocean Energy Systems. Information about Annex IV is available online at https://tethys.pnnl.gov/about-annex-iv

Moving Forward: 2018+

As outlined above, FORCE has continued, and will continue, to conduct data collection and facilitate data analysis through both the EEM and FAST Programs. FORCE's mid-field EEMP has been in place since 2016, with data collection being led by Cape Sharp Tidal Venture in the near-field of the OpenHydro turbine in 2016 and 2017. In the coming year, the data collected by these two monitoring programs will be integrated to provide a more complete picture of environmental effects associated with the turbine deployment in 2016-2017. These integration efforts will help support future data integration when Cape Sharp Tidal Venture reinstalls its turbine at the FORCE site. As turbines are deployed in additional berths at the FORCE site, data collection, analyses, and interpretations will be coordinated and integrated further between the near and mid-field, to the extent to which this is possible. This integrated approach will help to verify the environmental effect predictions made in the original FORCE EA (2009).

FORCE's EEMP has been designed to cover the mid-field area within ~1000 m of each berth at the FORCE site. This plan includes adaptations to accommodate multiple turbine deployments at the site by different 'berth holders'. These accommodations include:

1. Additional deployments of C-PODs in the vicinity of occupied berths at the FORCE site.
2. Modifications to the positioning of fish survey transects, including the addition of transects "over the turbine" in the case that a bottom-resting device does not fall under an existing transect line, or adjustments to accommodate a safe distance from turbines to avoid encounter, where applicable.
3. An additional lobster catchability survey in a second occupied berth (assuming a survey has been completed during turbine deployment at Berth D), provided that the occupied berth is at least 1000 m from Berth D. In the event that three or more turbines are deployed, or that several nearby berths are occupied, the size of treatment rings will be expanded (see 2016 plan for details).
4. Acoustic surveys using drifting hydrophones with additional turbine deployments. This will be done to track acoustic signals that may differ between device types, as well as cumulative effects of multiple devices. Survey paths may be adjusted to accommodate a safe distance from turbines to avoid entanglement, where applicable.

Reports highlighting marine operations, lessons learned, and interim findings will be provided on a quarterly basis with a more comprehensive report provided annually. Reports highlighting analysis prepared by contractors will be provided upon completion and review by EMAC and regulators. All reports prepared by FORCE will be shared online at www.fundyforce.ca/environment/monitoring.

All berth holders at the FORCE site conducting environmental effects monitoring will also provide reports on a similar schedule. These monitoring programs are reviewed by EMAC and regulators (Nova Scotia Department of Environment and Fisheries and Oceans Canada) prior to the installation of turbines at the FORCE site.

In November 2017, the Offshore Energy Research Association, Natural Resources Canada, and the Nova Scotia Department of Energy announced a funding contribution to FORCE and its partners Acadia University, Kongsberg Marine (Dartmouth, NS), University of Maine (Orono, Maine, USA), and ASL Environmental (Victoria, British Columbia) for a project that will integrate hydroacoustic datasets. This program will begin in January 2018 and will focus on joint analysis of datasets collected through FORCE's EEM and FAST Programs with the goals of understanding fish distributions/densities in relation to deployed turbine(s) as well as understanding the scientific and operational utility of each method. A description of this project can be found in Appendix 6.

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Appendix 1: 2016/2017 (Year One) Fish Monitoring Report

This report presents the results of the first year of fish monitoring of FORCE's 2016 – 2021 Environmental Effects Monitoring Program as completed by the University of Maine.

Final report

Marine Fish Monitoring Program Tidal Energy Demonstration Site – Minas Passage

Submitted to the Fundy Ocean Research Center for Energy (FORCE)

Prepared by: Aurélie Daroux and Gayle Zydlewski

University of Maine
School of Marine Sciences

Contact information:
gayle.zydlewski@maine.edu
207-581-4365

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This is the final report submitted = to the Fundy Ocean Research Center on Energy (FORCE) for the *Marine Fish Monitoring Program Tidal Energy Demonstration Site – Minas Passage*. It includes a description of the survey design, the methodology used to process and analyze the data, the results and their interpretation for 2016 and 2017.

Summary: Six 24-hour hydroacoustic surveys were run successfully, three before the turbine deployment (May, August and October 2016) and three after (November 2016, January and March 2017). Data processing methods were implemented to export relative fish density while removing noise created by entrained air. Historical (2011-2012) data supplied by Gary Melvin, Canadian Department of Fisheries and Oceans, was re-processed and relative fish density was combined with the 2016-2017 data to complete the dataset.

Mean relative fish densities were variable, with higher relative densities observed in the Crown Lease Area site (turbine site) where the turbine berths are located compared to the reference site (across the channel). The highest relative density was observed in May 2016 and may have been associated with the alewife and striped bass spring spawning migrations as well as the presence of Atlantic herring. During winter surveys (November and January, all years), relative fish density was also high compared to other months, possibly reflecting different fish behavior in different parts of the channel during that time of year.

Fish vertical distribution, from bottom to surface, varied greatly within and among surveys. We estimate that the percentage of fish at the depth of the OpenHydro turbine (based on data collected adjacent to the turbine) also varied greatly and ranged between 2 and 51% depending on the time of year.

Our results did not show a significant effect of the turbine (during the three surveys it was present) in the mid-field on overall relative fish density or any obvious change in vertical distribution in the water column. However, statistical comparisons were limited because the turbine was only present in the site for restricted periods of time. As such, monitoring of the region should continue to assess changes in fish distribution over time.

In summary, a valid approach to monitoring the regional responses to changes in the CLA has been developed and should be used moving forward. We recommend that similar monitoring continue in order to assess changes in fish distribution patterns as the site is further developed; ideally, physical sampling of fish be conducted to verify the presence of species seasonally; and a complete probability of encounter model would require concentrated transects over-the-turbine.

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Glossary

Area backscatter (Sa or sa): Total area backscatter (Sa in dB or sa in $m^2 \cdot m^{-2}$) is volume backscatter integrated over depth, and therefore scales to 1 m^2. Sa from different depth layers can be used to estimate the **vertical distribution** of fish.

Bin**:** analysis cell used for echo integration, with horizontal units in distance or time and vertical (depth) units in distance.

CLA: Crown lease area at FORCE site in Minas Passage, where Tidal In-Stream Energy Conversion (TISEC) devices can be connected to one of five berths.

Contemporary data: dataset collected by FORCE and the University of Maine in 2016 and 2017.

Echosounder: a device which uses the sound properties in water for the measurement of underwater biological components.

Echo integration**:** Echo integration is a widely-adopted and well-established technique for estimatingacoustic target density and hence biomass from hydroacoustic data. Echo integration can be run using vertical (depth) and/or horizontal (time or distance) bins.

FORCE: Fundy Ocean Research Center for Energy.

GLM: generalized linear model, the application of regression models to explain the relationships between a response variable (e.g., sv) as a function of other parameters/features (e.g., tide).

GR1_N0A (transect naming convention): this naming convention was used to identify the grid (GR1 to GR4), transect (N0 to N5 for CLA transects, S1 to S3 for reference site transects), and the direction the vessel was moving relative to the tide (W = with, A = against). Example: GR1_N0A is for grid 1 (first grid of the survey), transect N0, run against the tide.

Grid: The series of transects carried out at the CLA and reference sites over the course of one tidal stage (e.g., ebb or flood).

Historical data: dataset collected by Gary Melvin in 2011 and 2012 and described in (Melvin and Cochrane 2014).

Mid-field*:* approximately 100 m distance from a turbine.

Near-field: within 100 m of a turbine.

ORPC: Ocean Renewable Power Company.

Outliers: data values that differ greatly from the majority of a set of data. These values fall outside of an overall trend that is present in the data.

Site: A physical location where data are collected. The CLA site was on the north side of the Minas Passage, and the reference site defined for these surveys was on the south side of the passage.

Survey: a 24-hour period of time during which acoustic data are collected at the CLA and reference sites. Each survey includes four complete grids (one during each tidal stage at each the CLA and reference sites). Six surveys were carried out in 2011-2012 (historical data) and six in 2016-2017 (contemporary data).

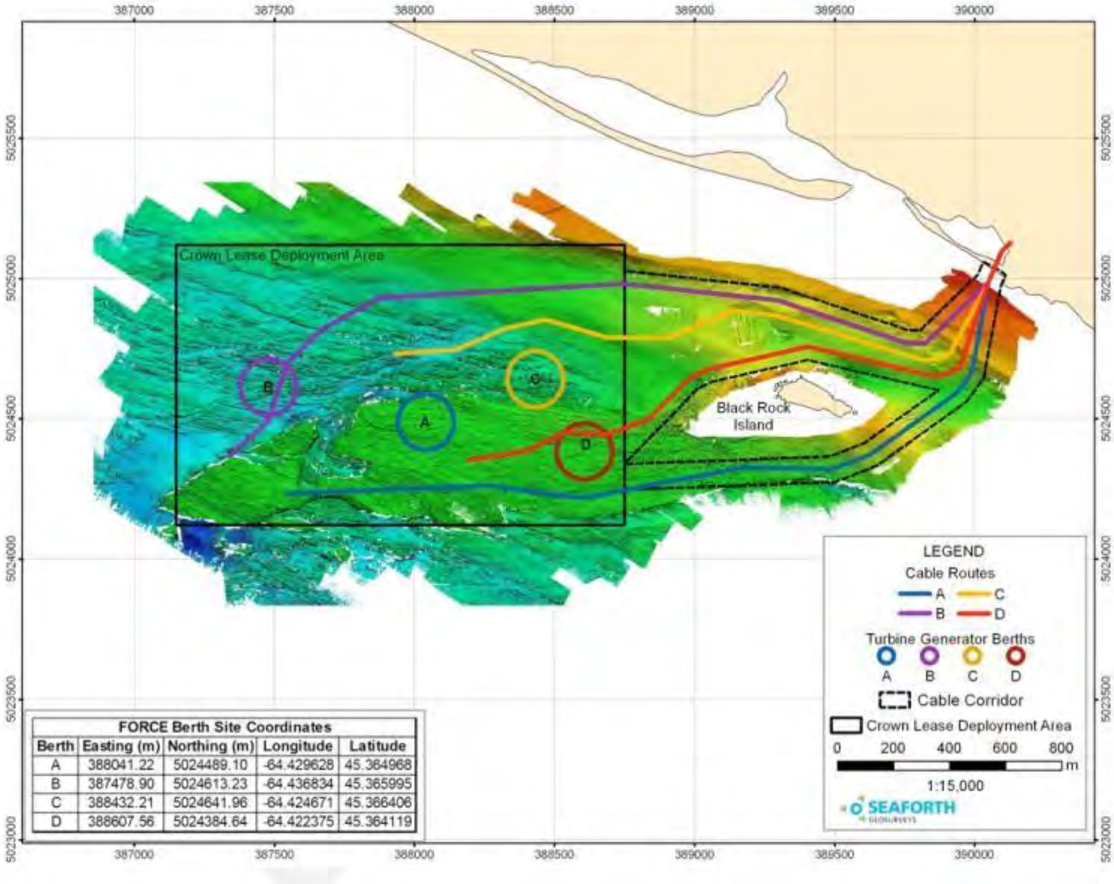
Transect: The individual lines traversed by the vessel across the CLA and reference sites, with and against the current. During contemporary surveys six transects were carried out at the CLA (named N0 to N5), and three were carried out at the reference site (named S1 to S3). In the historical dataset there were 9 transects in the CLA and 1 in the reference site.

TISEC: Tidal In-Stream Energy Conversion

Volume backscatter, water column relative fish density (Sv, and sv): Volume backscatter (Sv in dB or sv in $m^2 \cdot m^{-3}$) is the summation of the acoustic energy reflected by all targets within a sampling volume, scaled to 1 m^3. Alone, volume backscatter is a relative measure of the density of acoustic targets. When combined with species composition (if known), volume backscatter can be used to estimate absolute fish density and abundance (McLennan and Simmonds, 2013). In this report, volume backscatter is used as Sv (dB value) and sv (linear value) in plots and as relative fish density in the main text.

Introduction

The Bay of Fundy has the largest tides in the world. The Fundy Ocean Research Center for Energy (FORCE) has created a facility in Minas Passage to allow industry to demonstrate and evaluate tidal in-stream energy conversion (TISEC) technology. FORCE is required to establish an Environmental Effects Monitoring Program (EEMP) covering device mid-field effects on fish, lobsters, marine birds, marine mammals, and marine noise. This document specifically addresses the EEMP for fish in the area that includes the FORCE Crown Lease Area (CLA). On November 8, 2016, a turbine was deployed in berth D of the FORCE CLA (Fig 1).



FORCE Berth Site Coordinates				
Berth	Easting (m)	Northing (m)	Longitude	Latitude
A	388041.22	5024489.10	-64.429628	45.364968
B	387478.90	5024613.23	-64.436834	45.365995
C	388432.21	5024641.96	-64.424671	45.366406
D	388607.56	5024384.64	-64.422375	45.364119

Figure 1: Crown Lease turbines deployment Area map. The turbine was deployed in berth D.

This project was designed to assess indirect effects of deployed TISEC devices in the FORCE CLA by quantifying fish behavior changes, measured as changes in spatial distribution in the mid-field (i.e., 100-1000 m from the turbine). Indirect effects are changes in the mid-field of the turbine that are associated with turbine presence and do not include direct interaction with the turbine in its near-field. Specific objectives included: (1) testing for indirect effects of TISEC devices on relative fish density throughout the entire water column; (2) testing for indirect effects of TISEC devices on fish vertical distributions; and (3) estimating the probability of fish being at the same depth of the turbine based on the vertical distribution of fish relative to a deployed TISEC device depth.

Logistical difficulties and safety considerations in tidally dynamic regions can be barriers to performing quantitative fisheries surveys using physical capture of fish. As such, project objectives were accomplished using mobile surveys with a down-looking hydroacoustics echosounder (EK80) mounted to a medium-sized boat (the *Nova Endeavor*) using field methods, data processing, analysis techniques, and interpretation that were applied at the successful ORPC Cobscook Bay Tidal Energy Project (CBTEP) site in Maine, USA. These techniques have proven acceptable to local regulators, the US Department of Energy, the US Federal Energy Regulatory Commission, and the scientific community (Viehman *et al.* 2015). We have incorporated multiple and diverse approaches used in Cobscook Bay to design the mobile survey approach to meet the physical demands of the Minas Passage and the global fish assessment at the site of the turbine. Near-field effects at the device were not the purview of this research.

Material and methods

1. Historical data: 2011-2012

In 2011 and 2012, 6 hydroacoustics mobile surveys (Table 1) were conducted using a split beam echosounder (SIMRAD EK60) operating at 120 kHz using the charter vessel *FUNDY SPRAY* (Melvin and Cochrane 2014). No turbine was present during these surveys. Transmitting power was set at 500W, pulse duration was 1.024 and ping rate at 1/s (to reduce interference with other devices).

Table 1: Summary of the historical dataset surveys conducted in Minas Passage between August 22, 2011 and May 31, 2012.

Survey	Start date	Start time	End date	End time	Day/ Night	Tidal cycle	Number of grids	Water Temperature (°C)	Turbine presence
1	2011-08-22	11:45:18	2011-08-22	21:28:30	D	1	2	15.41	No
2	2011-09-19	10:55:27	2011-09-19	20:22:39	D	1	4	15.7	No
3	2011-11-22	14:22:38	2011-11-22	22:35:59	D/N	1	3	10.3	No
4	2012-01-25	18:32:58	2012-01-25	16:15:18	D/N	2	9	3.57	No
5	2012-03-19	14:23:30	2012-04-19	13:33:06	D/N	2	12	2.5	No
6	2012-05-31	12:09:40	2012-05-31	23:12:16	D/N	1	5	9.51	No

The duration of each survey was either 1 or 2 tidal cycles, as the vessel could only return to port near high tide. The grid for each survey started at the western end of what was the CLA area, and each of the 9 CLA transects was sampled in numerical order, alternating direction (with or against the current) on each successive 900m transect until arriving at the eastern end of last transect (Figure 1). A transect on the opposite side of the channel (called X1, Figure 2) was then run as the reference transect. An east-to-west transect was sample (Y1) and then a return transect (Y2) ended at the west end of the first transect to finish the first grid (T0; Table 2 and Figure 2).

The EK60 system was calibrated in September 2010 with a 38.1 mm tungsten carbide sphere and calibration settings were applied to all survey data during data processing.

Table 2: Latitude and longitude in decimal degrees used by Melvin and Cochrane (2014) as Minas Channel transects for historic surveys in 2011 and 2012.

Along-Channel	**North-West End**		**South-East End**	
CLA Transect	N	W	N	W
T0	45 22.229	64 26.057	45 22.067	64 25.326
T1	45 22.175	64 26.081	45 22.018	64 25.349
T2	45 22.130	64 26.100	45 21.971	64 25.365
T3	45 22.093	64 26.117	45 21.939	64 25.381
T4	45 22.021	64 26.151	45 21.862	64 25.414
T5	45 21.969	64 26.173	45 21.812	64 25.434
T6	45 21.918	64 26.194	45 21.761	64 25.458
T7	45 21.864	64 26.219	45 21.702	64 25.484
T8	45 21.809	64 26.242	45 21.647	64 25.507
Reference transect	N	W	N	W
X1	45 19.970	64 26.995	45 19.950	64 26.178
Cross- channel transects	N	W	N	W
Y1	45 21.647	64 25.507	45 19.950	64 26.178
Y2	45 22.229	64 26.057	45 19.970	64 26.995

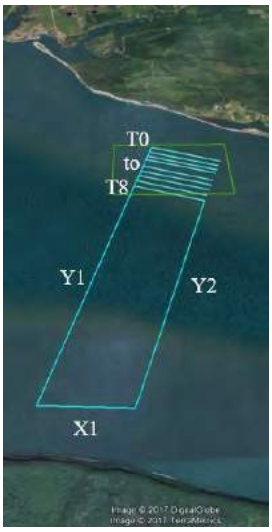


Figure 2: Historic mobile survey design. Collectively, the blue lines show one grid, with transect names indicated by the text. The green square represents the CLA.

Raw data and calibration settings from these 6 historical surveys were provided by Gary Melvin and re-processed using our own data processing methods (see part 4 of Materials and Methods: Data processing).

2. Contemporary data: 2016-2017

The survey design and the echocounder system settings used for historical data collection were used to collect a comparable contemporary dataset. Data were collected with a Simrad EK80 scientific echosounder, mounted over the side of a medium sized boat, the *Nova Endeavor* (Figure 3).

The EK80 is Simrad's newest scientific echosounder system which replaced the previous EK60 system. It has the capability to collect wideband data (spanning a range of frequencies) when operating in frequency modulated (FM) mode. It can also operate at only one frequency, like other scientific echosounders and the EK60, in continuous wave (CW) mode. For the sake of comparison with historical data, the majority of the data collected in 2016 and 2017 were sampled in CW mode at 120 kHz. Only CW data were used in analyses.


Figure 2: The Nova Endeavor at Parrsboro harbor (left) and the mounted echosounder and GPS on the side of the boat (right).

The transducer settings were: pulse duration of 1.024 ms (consistent with historical settings), power of 250W (recommended by Simrad), and ping interval of 250ms (lower than the historical dataset collection settings, which was fixed at 1s to minimize interference with other devices).

Six surveys were performed in 2016 and 2017 (Table 3), with 3 surveys before the turbine deployment (May, August and October 2016) and 3 after turbine deployment (November 2016, January and March 2017).

Table 3: Summary of contemporary surveys conducted in Minas Passage between May 28, 2016 and March 08, 2017. A tidal cycle lasts approximately 12 hours and is composed of two stages: ebb tide and flood tide. A grid consists of one full time through all transects. Generally, two were conducted during the day and two at night.

Survey	Start date	Start time	End date	End time	Day/ Night	# of Tidal cycle	# of grids	Water Tempera-ture (°C)	Turbine presence
1	2016-05-28	06:01	2016-05-29	05:35	D/N	2	4	7	No
2	2016-08-13	09:09	2016-08-14	07:40	D/N	2	4	15	No
3	2016-10-07	05:45	2016-10-08	04:21	D/N	2	4	15	No
4	2016-11-24	08:38	2016-11-25	09:07	D/N	2	4	8.0	Yes
5	2017-01-21	06:55	2017-01-22	05:55	D/N	2	4	1.5	Yes
6	2017-03-21	08:24	2017-03-22	06:04	D/N	2	4	4	Yes

Two calibrations (one for the CW mode and one for the FM mode) were performed before each survey. To calibrate the echosounder, we used the calibration program of the Simrad EK80 echosounder software. One person adjusted the location of the 23mm diameter copper calibration sphere attached to a monofilament fishing line suspended from a fishing rod in the echosounder beam, while one or two other people looked at the monitor to follow the position of the calibration sphere in the software and communicate to the other person its location in the beam. When the software indicated that adequate beam coverage had been achieved, the RMS Error was automatically calculated and the calibration was considered good if this value was less than 0.2.

The survey design was composed of four grids traversed over 24 hours, which included two tidal cycles (one grid per tidal stage). Every 1.8km transect was performed twice, with and against the tidal current. A grid began at transect N0 (always beginning the first transect with the ebbing tide and conducting it with the current), and each successive transect was traversed in numerical order (N0 to N5). Then a southward across-channel transect (South_CW) terminated near the Passage's southern coastline and was followed by 3 reference transects (S1 to S3), with and against the current. To finish the grid, a northward return transect (North_FM) returned the vessel to N0 and was the only transect performed in frequency modulated mode (Table 4 and Figure 4). A grid consisted of one full time through all transects. Generally, two grids were conducted during the day and two at night.

Table 4: Latitude and longitude in decimal degrees used as Minas Channel transects for contemporary surveys in 2016 and 2017.

	West End		**East End**	
CLA transects:	**Lat**	**Lon**	**Lat**	**Lon**
N0	45.3717	-64.4414	45.3666	-64.4188
N1	45.3701	-64.4424	45. 3648	-64. 4197
N2	45.3684	-64.4435	45.3631	-64.4207
N3	45.3667	-64.4445	45.3613	-64.4216
N4	45.3649	-64.4455	45.3595	-64.4226
N5	45.3717	-64.4414	45.3666	-64.4188
Cross-channel transects:	**Lat**	**Lon**	**Lat**	**Lon**
South_CW	45.3717	-64.4414	45.3352	-64.4605
North_FM	45.3276	-64.4388	45.3717	-64.4414
Reference transects:	**Lat**	**Lon**	**Lat**	**Lon**
S1	45.3352	-64.4605	45.3313	-64.4372
S2	45.3334	-64.4615	45.3296	-64.4380
S3	45.3317	-64.4623	45.3276	-64.4388

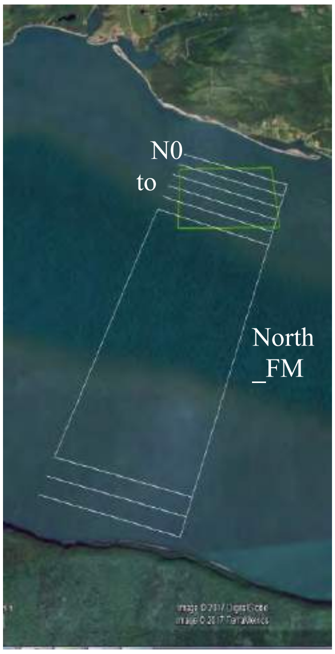


Figure 4: Contemporary survey grid. Thegreen square represents the CLA. White lines show one complete grid, with transects at the- CLA (N0-N5) and reference (S1-S3) sites connected by cross-channel transects (South_CW and North_FM).

3. Data processing

Data processing was performed using the software Echoview® (version 7.1.35; Myriax, Hobart, Australia), which is specialized for the analysis of hydroacoustic data. The data were cleaned (threshold applied and entrained air removed), split into analysis bins, and echo integrated.

A. Threshold

To detect only fish, we used a Target strength (TS) threshold of -60dB and an Sv threshold of -66dB, according the methods from Higginbottom *et al.* (2008). This method allowed us to detect only fish greater than 10cm in length.

B. Entrained air removal

The presence of turbulence and eddies caused large quantities of air to become entrained in the water column, which intermittently contaminated the acoustic data from the surface down to 50 m depth (Figure 5). This impacted the quality of the data on some transects in both the historical and contemporary datasets. During data processing, this entrained air had to be removed so that it would not be echo integrated with the fish.

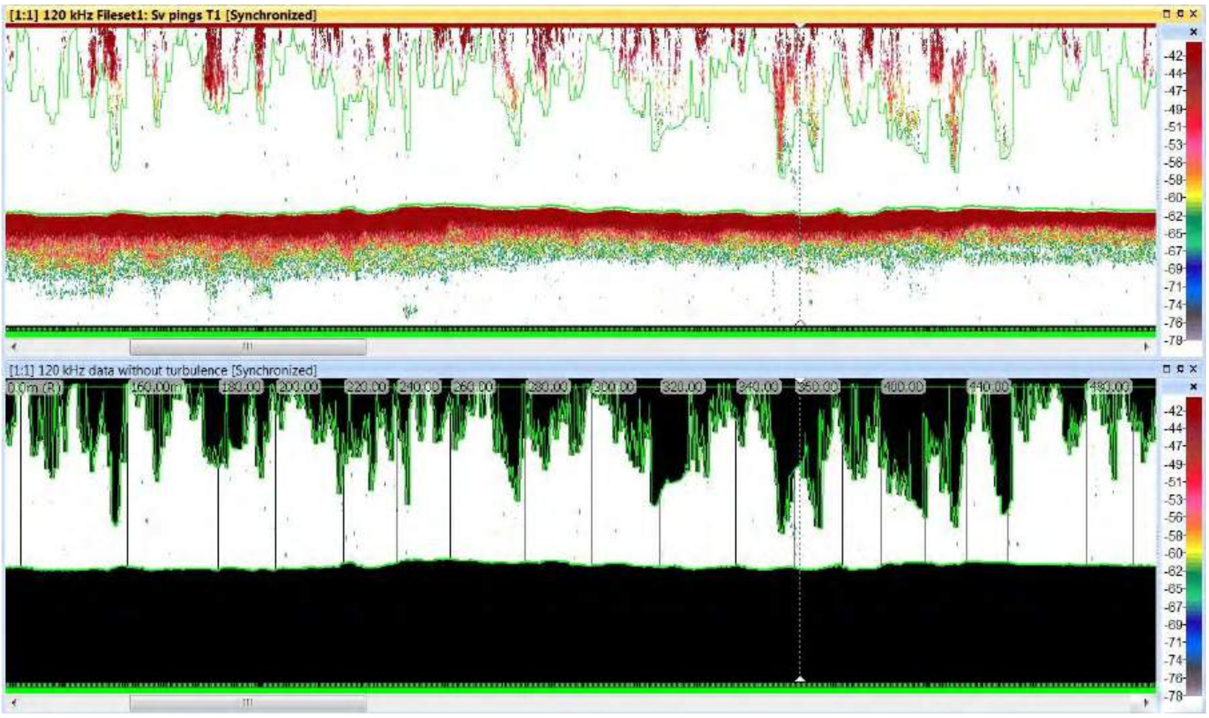
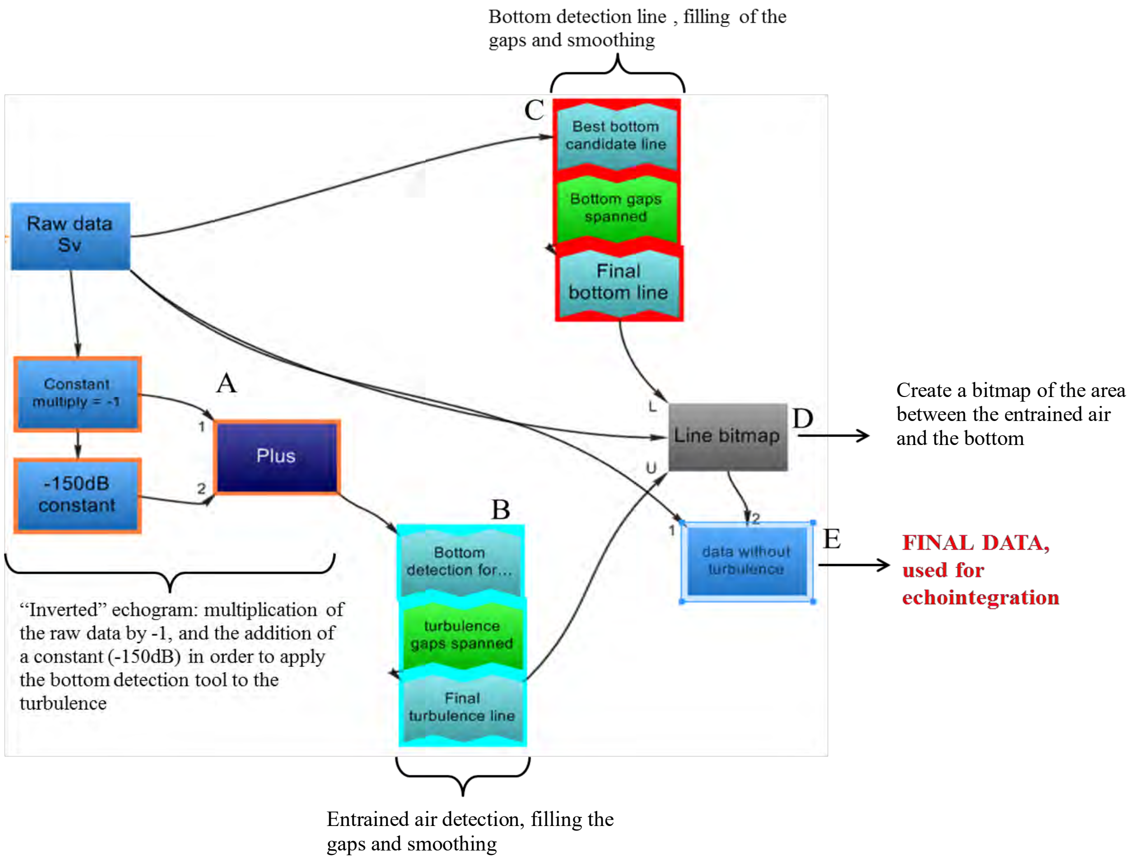


Figure 5: Snapshot of an echogram from October 2016. Top: raw volume backscatter data with target strength threshold of -60dB applied, showing entrained air extending from surface. Bottom: data with entrained air removed, showing turbulence and bottom lines. Data excluded from echo integration indicated by black areas. Vertical lines show 20 m data analysis bins.

To remove entrained air, the raw volume backscatter data were multiplied by -1.0 and a constant was added so Echoview interpreted the surface boundary as the bottom of the water column (Figure 6A). Then, a bottom detection algorithm was applied to the transformed data to identify and smooth the turbulence line—the boundary between entrained air and empty water (Figure 6B). A traditional bottom detection algorithm was applied to untransformed data to detect the actual sea floor (Figure 6C). The data outside the turbulence line and the bottom line were then discarded (Figure 6D), and the data between those two lines were used for echo integration (Figure 6E and Figure 5, bottom).



Bottom detection line , filling of the gaps and smoothing

Create a bitmap of the area between the entrained air and the bottom

FINAL DATA, used for echointegration

"Inverted" echogram: multiplication of the raw data by -1, and the addition of a constant (-150dB) in order to apply the bottom detection tool to the turbulence

Entrained air detection, filling the gaps and smoothing

Figure 6: Echoview algorithm for processing data prior to echo integration.

C. Analysis bins: space and time

To assess changes in fish density over time, data were divided into analysis bins spanning the entire water column to provide statistically independent samples. To choose the appropriate bin size to use in echo integration, we performed autocorrelation tests using a range of bin sizes. Bins could either be defined by distance (in meters traveled) or duration (in minutes). We performed autocorrelation tests on 4 randomly chosen transects by grid (GR1_N0A, GR2_N3A, GR3_N5W and GR4_S1W) for each survey. Distance bins were chosen over time bins in order to separate the transects made with or against the tide (since time length differed greatly) in a comparable number of bins based on the distance of a transect. The cleaned acoustic data from each of these transects were partitioned into 5-m distance bins. Each bin was echo integrated, and the resulting volume backscatter values were exported from Echoview and tested for autocorrelation (Figure 7). For the 4 tested transects from all surveys, data became uncorrelated (with a 5% significance level) at 20-m distance bins. As such, all data were split into 20-m distance bins and echo integrated over the entire water column for each transect of each survey (Figure 8, right).

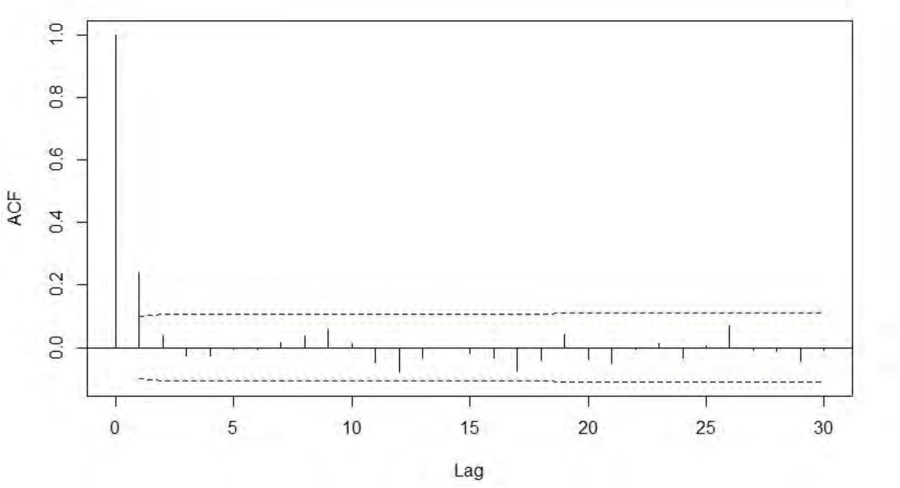


Figure 7: Example of an autocorrelation function (for GR4_S1W). ACF is the autocorrelation function for a given lag, with lag of 1 equivalent to 5 m (the bin size). The dashed blue lines indicate the 95% confidence interval. At lags in which the ACF is within this interval, samples are no longer correlated (e.g., are independent). In this example, samples become independent at lag = 2, or 10 m.

To study fish vertical distribution, the data from each transect were split into depth bins 1 m deep, measured upward from the sea floor (Figure 8, left).

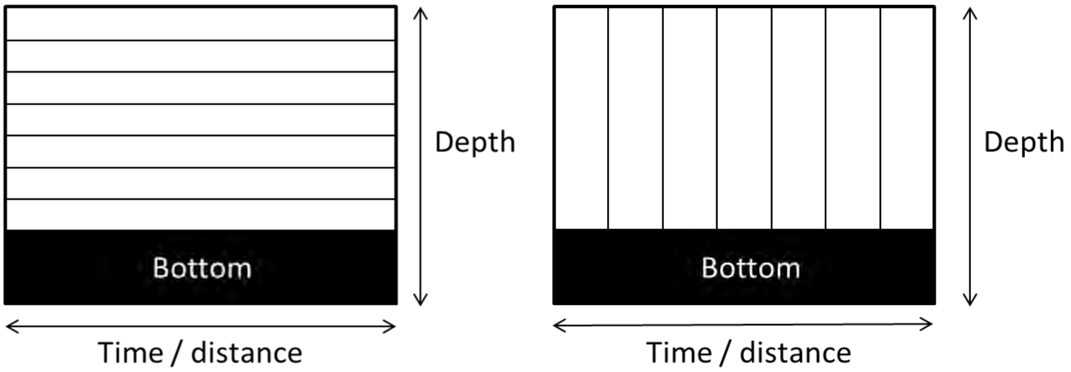


Figure 8: Representation of the data export by 1m depth bins (left) and by 20m vertical distance bins (right).

4. Data Analysis

Data analysis was conducted with the software R (version 1.0.136, R Core Team, Vienna, Austria). We examined changes in water column fish density, the vertical distribution of fish, and the proportion of fish at turbine depth.

A. Water column fish density

To test for indirect effects of the single deployed TISEC device on fish density (throughout the water column), we used the data exported for 20-m distance bins. The data distribution was not normal, with 60.4% of values equal to zero (empty water column). A zero-inflated two-stage generalized linear model (GLM) was created for sv values (volume backscatter in the linear domain, or relative fish density) on the full dataset (historical data and contemporary data combined) to statistically test the effect of site (CLA or reference) and turbine (presence or absence) .

The first stage modeled relative fish density (sv) as a function of fish presence (presence = 0 if sv = 0, or 1 if sv > 0).

***1st stage** = GLM (sv ~ fish presence)*

We then applied the prediction from the first stage to the second stage model and added the variables of interest (site and turbine).

***2nd stage A** = GLM (sv ~ 1st stage + site + turbine)*

To also test for an effect of time of year, we performed another two-stage GLM that incorporated survey month:

***2nd stage B** = GLM (sv ~ 1st stage + site + month)*

B. Fish vertical distribution

To test for indirect effects of a single TISEC device on fish vertical distribution, we worked with the data exported by 1 m depth bins for each individual transect. We calculated the proportion of area backscatter, sa, contributed by each layer (sa for each layer divided by the sa summed for all layers). Depth varied over the course of each transect, between transects, and with the tidal stage (from 40 to 65 meters). As such, we analyzed only the first 50 meters above the bottom.

C. Proportion of fish at turbine depth

To test the probability of fish being at the same depth of the recently deployed bottom-mounted OpenHydro turbine, we used data from the N2 and N3 transects (the two transects closest to the turbine location). We only used data from when the tide was flooding (n=2 for each survey). The turbine was located on the east side of the CLA, so during flood tide, the survey vessel was approaching the turbine. Transect data were echo integrated in three 700 m distance bins (the length of the transect divided by 3), numbered 1 to 3 (1 farthest from the turbine and 3 closest; Figure 9). This allowed us to examine changes in fish density as the boat approached the location of the turbine. Only two transects were conducted directly over the turbine (called 'over-the-turbine transect') when the tide was flooding during the November 2016 survey (Figure 9, left). This over-the-turbine transect was not run again during other surveys because it delayed the timing to complete the surveys planned to quantify indirect mid-field effects.

For each survey, the proportion of fish in the bottom 23 m above the sea floor (turbine height) was calculated for each distance bin at flood tide in N2 and N3 transects.

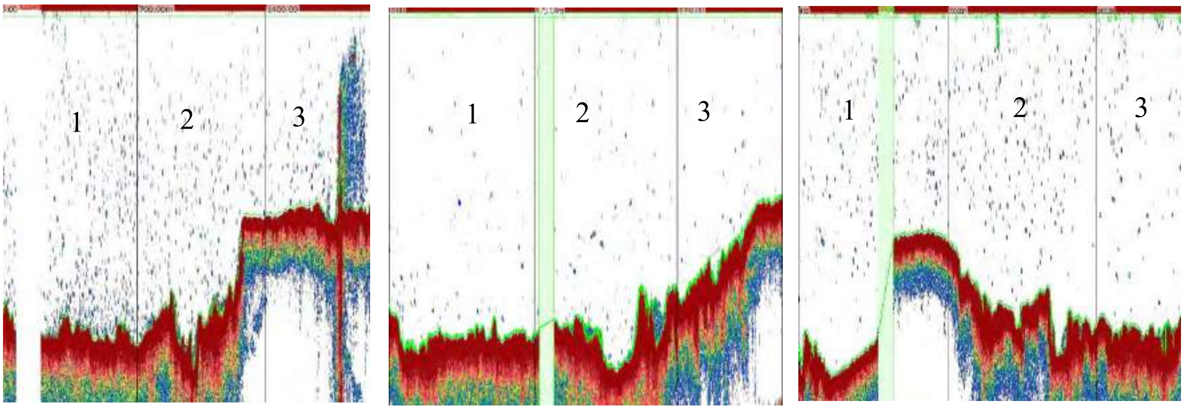


Figure 9: Condensed echograms of flood-tide transects during the November 2016 survey over-the-turbine (left), during the N2 transect (middle), and during the January 2017 survey in N3 transect (right) after entrained air and bottom detection.

The results of these two turbine transects were compared to the results from all N2 and N3 transects conducted in other surveys to determine if N2 and N3 transects (which are 50 m either side of the turbine) reflected the fish distributions at the location of the turbine.

D. Cross-channel distribution

The cross-channel transects were processed to examine the variability in fish distribution across the channel, between the CLA and reference site. Condensed echograms, Sv mean variation and sv boxlot by bins (transect length divided by 3 to obtain one south, one middle and one north bin) were created.

Results and discussion

1. Water column fish density

Changes in fish density were explored as a function of several factors (turbine, survey, month, diel and tide). Boxplots were used to visualize relative fish density (sv) data. All following boxplots show the median fish density (thick horizontal line), interquartile range (colored box), and 10th and 90th percentiles of fish density (whiskers). A large number of 0's (empty water column) resulted in heavily skewed distributions, so non-zero variation is best visualized by the extent of the box and whiskers. The mean or average fish density value is shown by the empty circle in some figures (e.g., Fig. 13), as an indicator of the influence of extreme values (outliers). In all plots, the red color is associated with the CLA site and the blue color with the reference site.

A. Model results

The 2-stage generalized linear model showed a statistically significant effect of survey (month, Pr = 0.037) on fish density, but no significant effect of site or turbine presence (Tables 5 and 6).

Table 5: Results of the two-stage GLM B (factors: fish presence, site and survey month). Df = degrees of freedom, Resid. Df = Residual degrees of freedom, Resid. Dev = Residual Deviance, Pr = probability of observing a Chi square statistic. ** = statistical significance at the p < 0.05 level, * = statistical significance at the p < 0.001 level.**

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
Null model			77371	1.9E-07	
Fish presence	1	2.97E-11	77370	1.9E-07	0.0005 ***
Month	5	3.35E-11	77362	1.9E-07	0.037*
Site	1	5.25E-12	77368	1.9E-07	0.34

Table 6: Results of the two-stage GLM A (factors: fish presence, site and turbine).

	Df	Deviance	Resid. Df	Resid. Dev	Pr (>Chi)
Null model			77371	1.9E-07	
Fish presence	1	2.97E-11	77370	1.9E-07	0.0005 ***
Site	1	5.25E-12	77368	1.9E-07	0.34
Turbine	1	7.21E-11	77367	1.9E-07	0.09

The two stage GLM results revealed no significant effect of turbine presence on fish density. However, data are limited and monitoring of the region should continue in order to assess changes in fish distribution patterns over time since seasonal shifts in fish distributions have also been reported in other similar environments (Wilson *et al.*, 2006; Copping *et al.*, 2016; Viehman, 2016). The two stage GLM revealed a statistically significant month effect, where relative densities of fish varied greatly among months in this region, reflecting significant seasonal variability.

B. Fish density before and after turbine deployment

For the full dataset (historic and contemporary data combined), relative fish density (sv) was not statistically significantly different at either site before or after the period when the turbine was present. This is likely based on similar variation in relative fish densities between the sites. However, within sites, fish density upper whisker boxplot was higher at both the CLA and reference sites after the turbine was present (Figure 10). The importance of the reference site is demonstrated by the similarity in changes in fish density at both sites (Figure 10), relative fish density increased ***at both sites*** post deployment. These similarities enable us to not falsely associate these changes with the deployment of the turbine.

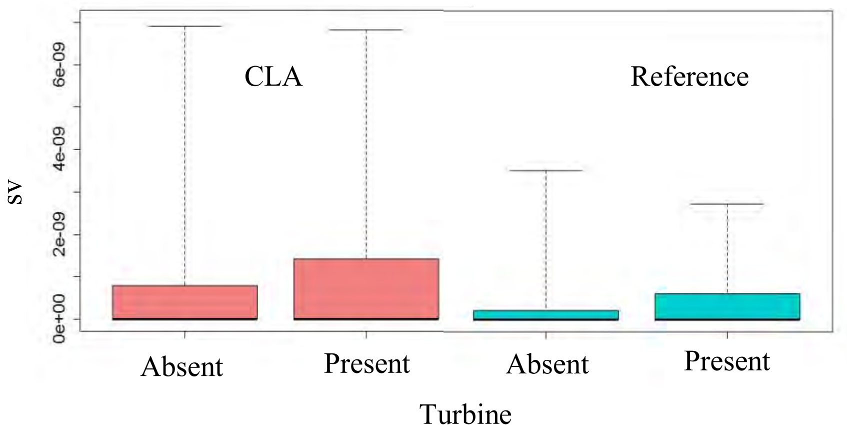


Figure 10: Boxplot of sv (relative fish density) by site before and after turbine deployment (turbine absent or present). Before-deployment data include the historical dataset (2011-2012) and part of the contemporary dataset (May, August, and October 2016); after-deployment data include November 2016 and January and March 2017 of the contemporary dataset.

C. Fish density over time

Fish density was similar among sites but varied by survey timing (Figures 11 and 12). The seasonal variation was similar between historical (2011-2012) and contemporary (2016-2017) data, with consistently higher densities in November and January surveys. This seasonal variation is consistent with the GLM modeling results.

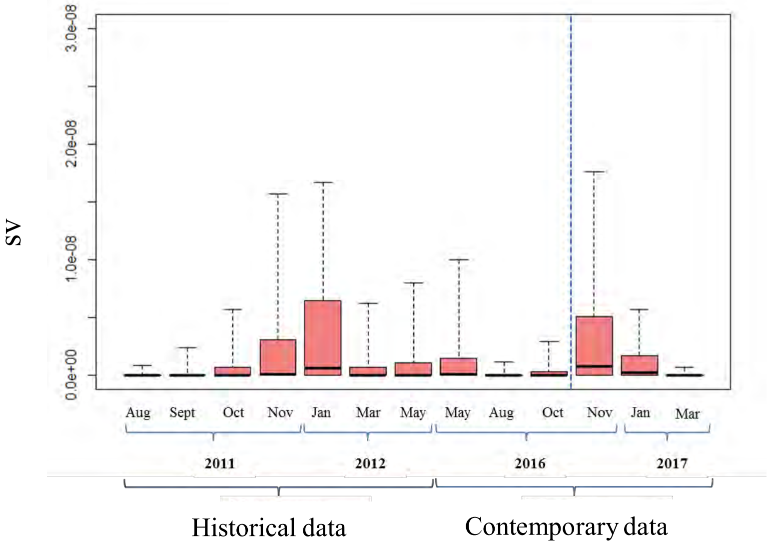


Figure 11: Boxplot of sv (relative fish density) by survey for the CLA site. The dotted blue vertical line indicates turbine deployment.

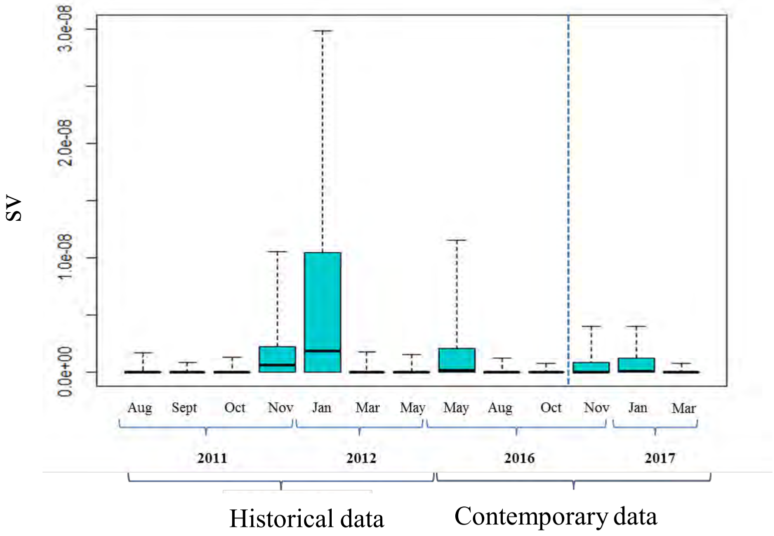


Figure 12: Boxplot of sv (relative fish density) by survey for the reference site. The dotted blue vertical line indicates turbine deployment.

Complementary months of historical and contemporary data showed similar seasonal variation with highest densities in November and January surveys, likely related to specific winter behavior and a higher occupation of the channel in winter. This type of difference was also reported by Keyser *et al.* (2016) for striped bass in Minas Passage.

D. Fish density by month

The contemporary data (Figure 14) had similar interannual relative fish densities as the historical data (Figure 13). Density was high in November and January in both dataset, especially in January 2012 (Figure 13).

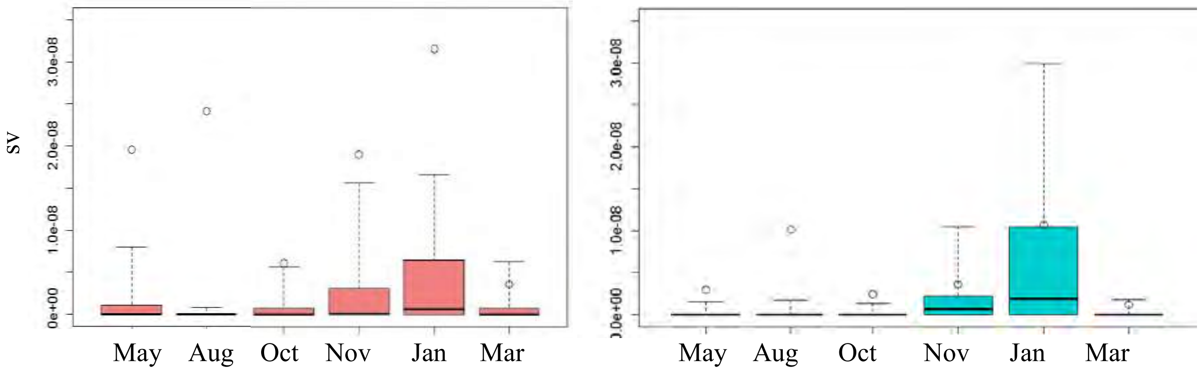


Figure 13: Boxplot of sv (relative fish density) by survey month for historical dataset (2011 and 2012) for CLA site (left, red) and reference site (right, blue).

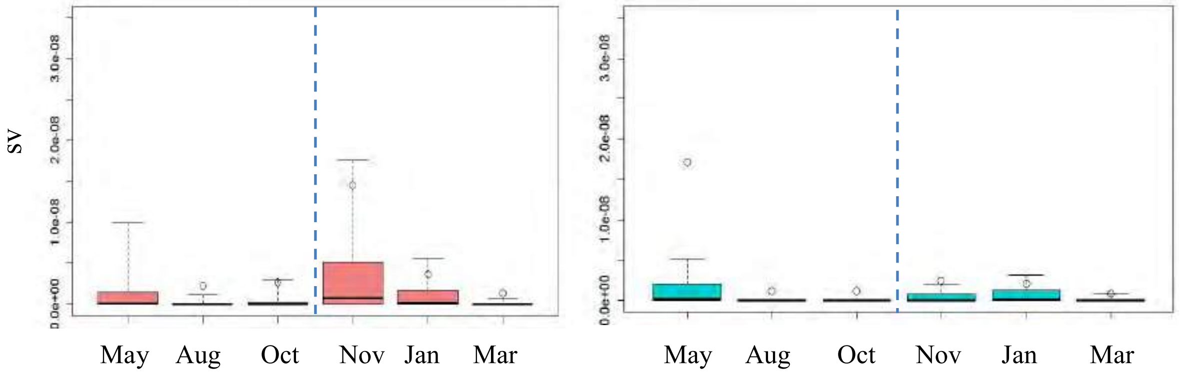


Figure 14: Boxplot of sv (relative fish density) by survey month for contemporary dataset (2016 and 2017) for CLA site (left, red) and reference site (right, blue). The vertical blue line indicates turbine deployment. There is no mean associated with May, CLA site because it was so high that it could not fit into the plot.

High densities in November could be related to emigration of juvenile clupeids. By late fall, young- of- the -year river herring (*Alosa aestivalus*), alewife (*Alosa pseudoharengus*) and Atlantic herring (*Clupea harengus*) are the abundant clupeid species remaining along the northern coast (Ames and Litcher, 2013; Dadswell, 2013). After that period, they are thought to move to deeper, warmer depths through the winter (Townsend *et al.*, 1989), and return to coastal nurseries in the spring.

Higher fish density in May (especially in 2016) was observed. This may have been associated with adult alewife spring spawning migrations and the presence of Atlantic herring and striped bass (*Morone saxatilus*) (Baker et *al.*, 2014). Striped bass are common in the Minas Passage along the shoreline and they spawn in the head of the tide in May-June (Rulifson and Dadswell, 1995). Spring variation may also be linked to other species migrating into the Basin for the summer, e.g. Atlantic sturgeon (*Acipenser oxyrhynchus*), American shad (*Alosa sapidissima*), American mackerel *(Scomber scombrus*), and rainbow smelt (*Osmerus mordax*) (Dadswell 2010).

E. Fish density by tide and by diel stage

Overall (historical data and contemporary data combined), relative fish density (sv) was similar during ebb and flood tides. However, mean fish density (the unfilled circles on Figure 15) was higher during ebb tides than during flood tides, reflecting a higher number of extreme values (outliers), perhaps indicating movement of big fish or aggregations of fish into the basin with the ebb tide (Figure 15).

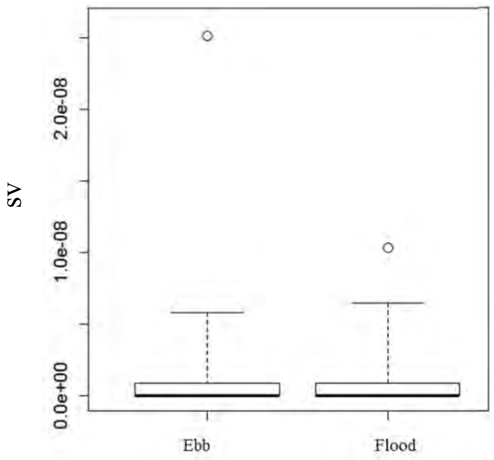


Figure 15: Boxplot of sv (relative fish density) by tidal stage for historical and contemporary data combined.

For all data examined, fish density was similar day and night with higher variability at night than during the day (Figure 16, left). Mean relative fish density during the day was higher than during the night for historical data (2011-2012) while the opposite was observed in the contemporary data (2016 -2017; Figure 16, right).

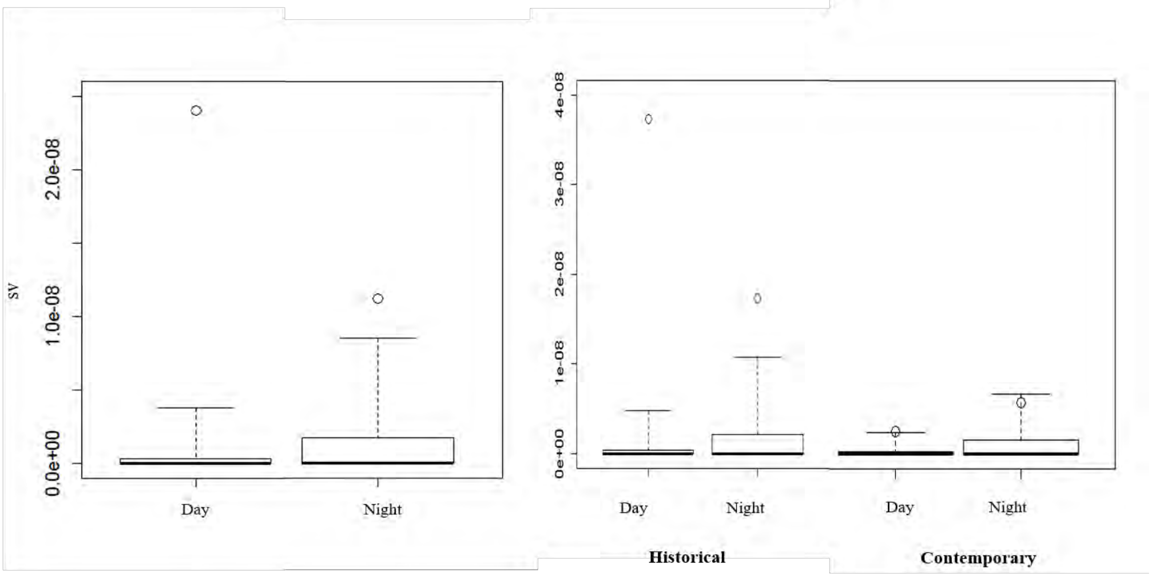


Figure 16: Boxplot of sv (relative fish density) by diel stage for all the data (left), historical (2011-2012) and contemporary data (2016-2017) separated (right). Mean data are shown by the unfilled circles.

In the historical dataset, the higher mean relative fish densities observed during the day may be explained by the numerous outliers, particularly since the highest probability of observing fish aggregations occurs during the day and more samples were collected during the day during the historical surveys. Also, some fish aggregate during the day and tend to spread out more at night (Viehman, 2016), perhaps this diel dynamic can be explained by these changing behaviors.

It is well known that fish densities are generally higher at night at similar tidal energy sites (e.g., Cobscook Bay, ME; Viehman *et al.* 2015; Viehman and Zydlewski, 2017) and with up-looking stationary hydroacoustic surveys in the FORCE site (Viehman, personal communication). Furthermore, ebb tide sampling showed higher relative fish densities. Thus, fish behavior has been inferred to result in different densities being observed during different tidal and diel stages (Helfman, 1993; Viehman and Zydlewski, 2017).

G. Cross-channel distribution

Cross-channel transects were explored to visualize the distribution of fish across Minas Passage (from the CLA to the reference site). We selected the May 2016 and January 2017 surveys to demonstrate the variation in fish density across the channel (Figure 16). Visualizations of other cross-channel surveys can be found in Appendix I.

Fish density varied along the channel cross-section (Appendix I) and tended to increase south toward the reference site in Figure 16. In these examples, fish density on the CLA side was more variable than on the reference site (south) side of the Minas Passage. The middle part of the Passage, despite its deeper depth (120 meters), did not have higher fish density. Nevertheless, there was high variability in cross-channel distribution (Appendix I) and patterns across the channel cannot be generalized using this dataset.

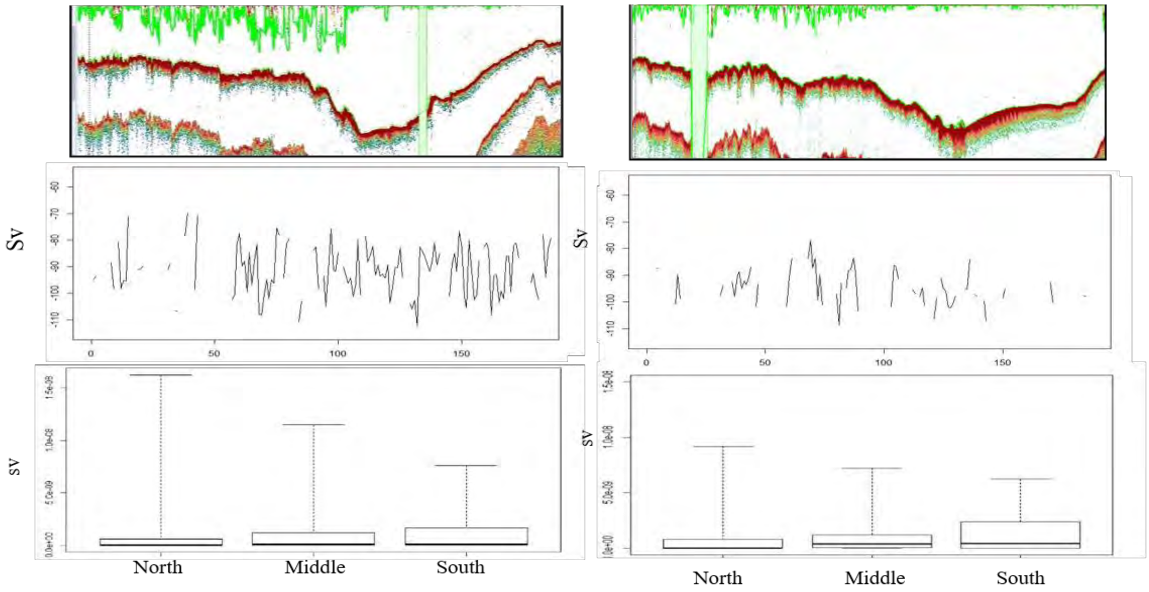


Figure 16: January 2017 survey, flood tide (left) and May 2016 survey, flood tide (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). In the condensed echograms, the beginning (left side) is the CLA and the end (right side) is the arrival at the reference site. There is a double bottom and the green vertical bars are passive data that have not been echo-integrated. In the mean relative fish density (Sv) plot, the x-axis is distance in 20m bins. In the relative fish density boxplot (sv), the relative fish density is plotted in 3 bins (North, Middle and South) to separate the cross-channel into 3 equal distance bins.

2. Fish Vertical Distribution

Relative fish densities in vertical bins of the water column varied among month and between CLA and reference sites (Figure 17).

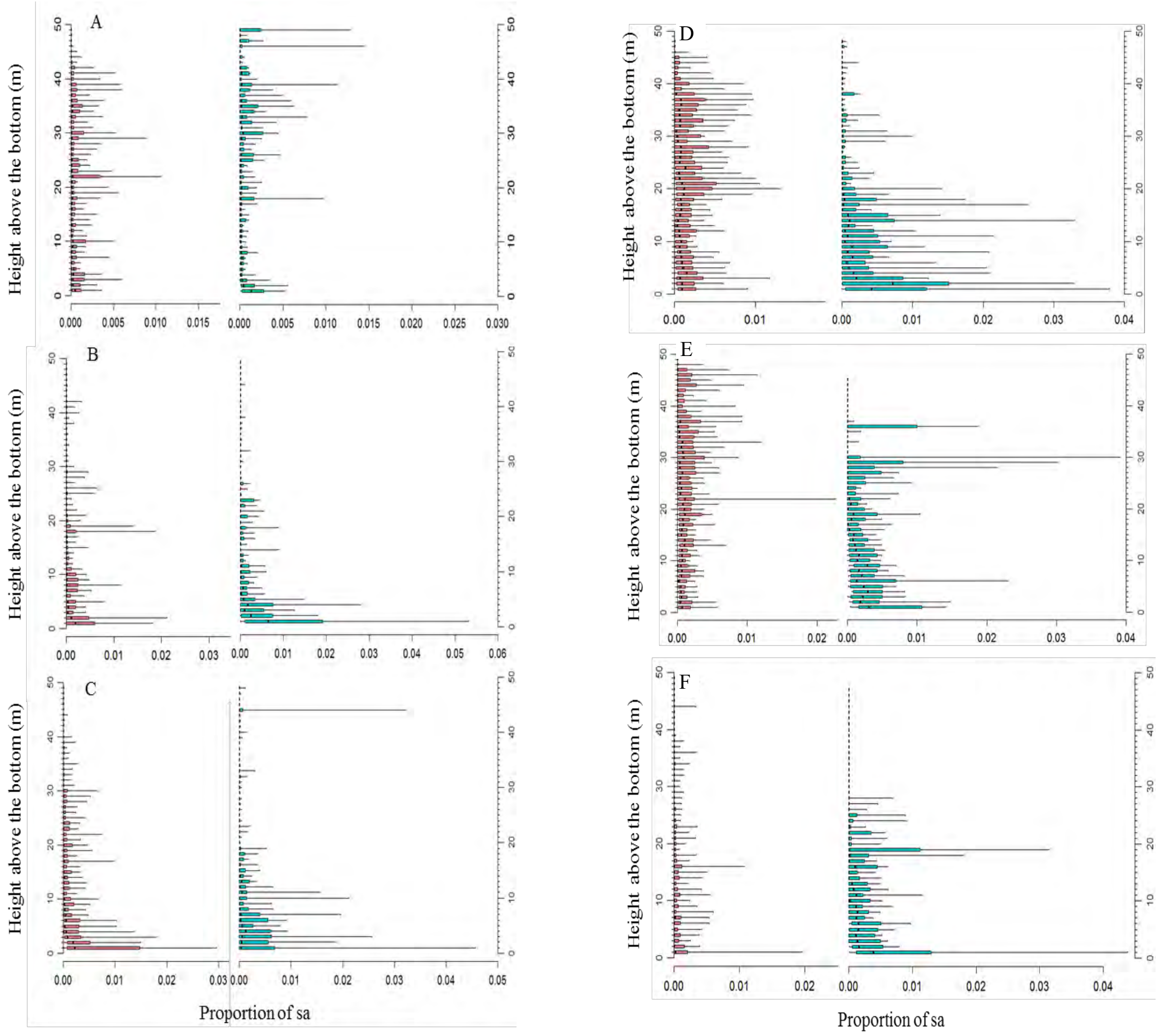


Figure 17: Boxplot of proportion of backscatter (sa, relative fish density) before the turbine deployment by layer for May (A), August (B), October (C), November (D) 2016, January (E) and March (F) 2017, by site (CLA in red, left and reference in blue, right). The proportion of sa (x axis) is very small because numerous outliers have not been plotted so that trends in vertical distributions can be observed.

Fish vertical distributions were highly variable within month and sites. Nevertheless, in August and November, the fish were more concentrated in the first 10 meters above the bottom. These densities could be related to benthic-oriented fish presence. Numerous demersal species occupy the channel, e.g., Atlantic sturgeon (*Acipenser oxyrinchus*), brook trout (*Salvelinus fontinalis*), wolffish (*Anarhichas lupus*), sea raven (*Hemitripterus americanus*), grubby (*Myoxocephalus aeneus*), etc and can contribute to this higher bottom density concentration (Dadswell, 2013). In most other months fish were more evenly distributed throughout the water column and could be various pelagic species mentioned previously, including clupeids.

3. Proportion of fish at turbine depth

The proportion of fish at the depth of the turbine in the spatial bin associated with the turbine (23 m above the sea floor), at a location adjacent to the turbine, was overall lower than the proportion of fish at the same depths in the spatial bins away from the turbine location; distance bins 1 and 2 in Figure 9; Table 7). The proportion of fish at the depth of the turbine in the distance bin nearest the turbine varied among surveys, with a minimum of 1.77% in August 2016 and a maximum of 51.35% in November 2016.

Figure 18 shows the proportion of fish at the depth of the turbine for adjacent N2 and N3 transects with a global lower proportion in the interval 3 where the turbine is/will be located. Figure 19 showed an increasing proportion of fish while we approached the turbine during the Over-the-turbine transect. Taken together, the proportion of fish at the depth of the turbine (Figure 19) during the transect Over-the-turbine was drastically different from the proportions observed in the adjacent N2 and N3 transects (Figure 18).

Table 7: Summary of the percentage of sv (relative fish density) at the turbine depth for each survey and distance bin. Bin 1 is farthest from the turbine location, while bin 3 (in red) is closest. The depth of each interval is also given with the transect depth range. Percent of sv in each bin is also shown for the transect conducted over-the-turbine in November 2016.

Survey	Transect depth range	Interval	Proportion of fish at the depth of the turbine at adjacent transects (see Figure 18)	Proportion of fish at the depth of the tubine in the over-the-turbine transect (see Figure 19)
May-16	45m	1	93.23	
May-16	40m	2	44.81	
May-16	30m	3	**20.48**	
Aug-16	45m	1	23.68	
Aug-16	40m	2	67.09	
Aug-16	30m	3	**1.77**	
Oct-16	45m	1	97.42	
Oct-16	40m	2	29.63	
Oct-16	30m	3	**38.73**	
Nov-16	45m	1	57.11	**21.60299**
Nov-16	40m	2	52.24	**46.50778**
Nov-16	30m	3	**51.35**	**78.07587**
Jan-17	45m	1	71.17	
Jan-17	40m	2	80.39	
Jan-17	30m	3	**3.3**	
Mar-17	45m	1	54.79	
Mar-17	40m	2	32.69	
Mar-17	30m	3	**32.24**	

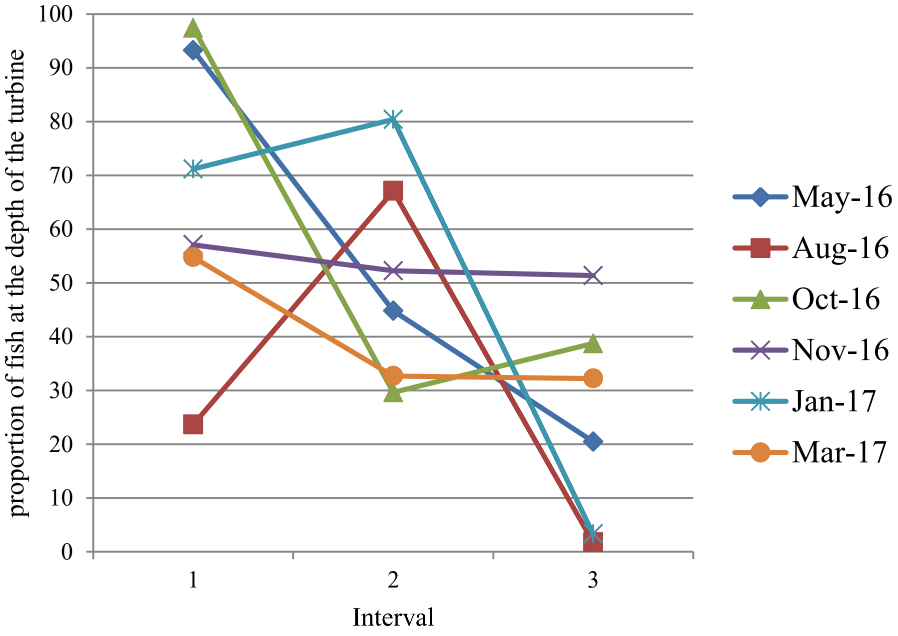


Figure 18: Percent of backscatter (relative fish density, sv) at the depth of the turbine by interval and survey. This plot only includes data from the two transects adjacent to the turbine (N2 and N3).

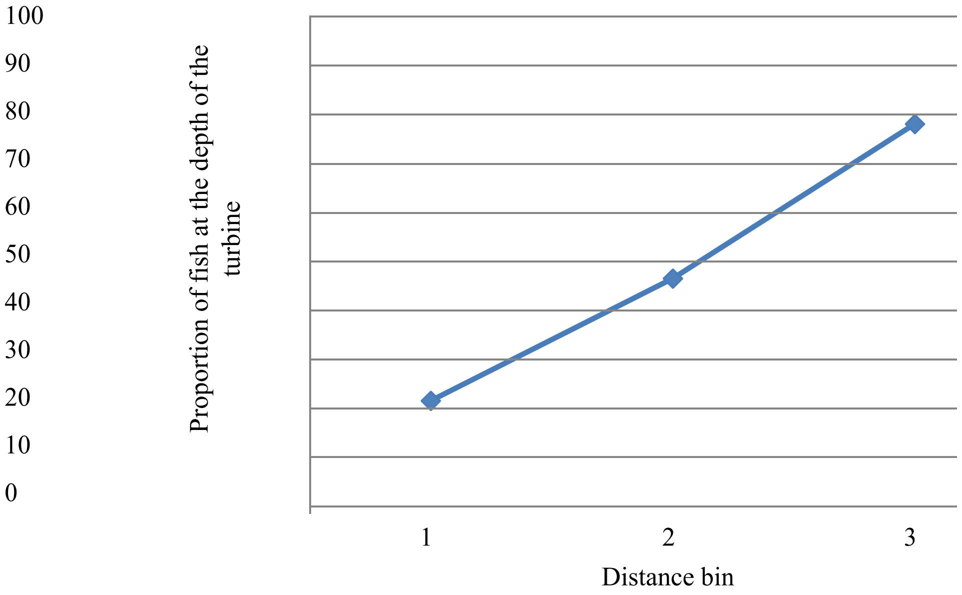


Figure 19: Percent of backscatter (relative fish density, sv) at the depth of the turbine by interval for the transect conducted over-the-turbine in November 2016.

The proportion of fish observed at the same depth of the turbine for the adjacent transects in November were not similar to the over-the-turbine transect. As such, the adjacent transects do not offer a good representation of the fish vertical distribution over a turbine. Therefore, conducting additional surveys repeatedly over-the-turbine would be necessary to assess near-field fish behavioral avoidance (or evasion) when approaching the turbine and developing a full probability of encounter model as in Shen *et al* (2016).

Summary and Conclusions

Six fish surveys were successfully conducted by UMaine and FORCE staff in 2016 and 2017. During these surveys, the FORCE staff was trained to conduct mobile surveys to collect quality data for comparative processing and analysis. The data collected were fully calibrated, making it reliable and comparable among samples. The data were good quality, despite the presence of entrained air at the surface since the entrained air was not integrated into the dataset. Data processing was efficient and allowed the removal of entrained air, export of relative fish density metrics, and comparisons within and between contemporary and historic surveys. Statistical analyses were limited to a two stage GLM because of the non-normality of the data. Additional analyses could focus on the use of an index or way to "normalize" the data but that is beyond the scope of this report.

Conclusions related to the originally stated study objectives:

Objectives 1 and 2: *testing for indirect effects of TISEC devices on (1) relative fish density throughout the entire water column*; and (2) *fish vertical distributions*

- While statistical tests revealed no significant effect of turbine presence on fish density, data are limited to 9 surveys before the deployment and 3 after the deployment. As such, monitoring should continue in order to assess changes in fish distribution patterns as the site is further developed.
- High variability was observed within surveys and among surveys for fish density and vertical distribution. This supports the conclusion that assessment of fish distribution should continue. Trends detected included higher fish densities at night and during ebb tides with seasonal variation being high but fish densities generally highest in May, November and January. Because these patterns are consistent with fish distribution patterns reported in the literature, this type of data collection and analysis suggests the approach can be used to document such patterns.

Objective (3) *estimating the probability of fish being at the same depth of the turbine based on the vertical distribution of fish relative to a deployed TISEC device depth.*

- The proportion of fish at the turbine depth varied greatly.
- As such, a full probability of encounter model could not be developed with the data as collected.

Recommendations

- A valid approach to monitoring the regional responses to changes in the CLA has been developed and should be used moving forward.
- Monitoring should continue in order to assess changes in fish distribution patterns as the site is further developed.
- To keep the data quality high, continue to choose the day of the survey by using the tide calendar, choose a less than 9m difference between high tide level and low tide level and keep the boat running at 5-6knots, no more (unless in the transect is going with the tide when the current is too fast).
- Ideally, physical sampling of fish should be conducted to verify the presence of species seasonally.
- To develop a complete probability of encounter model additional transects over-the-turbine should be conducted.

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Appendix I

Condensed echogram from cross channel transects (from the CLA to the reference site) are presented for all surveys (top of the plots). They are associated to mean relative fish density, Sv plots echo integrated by 20m distance bins (middle of the plots) and boxplot of fish relative density, sv (bottom of the plots) to assess the fish density variation along the channel (separated into 3 interval: North, middle, south).

A double bottom echo can be present in the condensed echogram and the green vertical bar is passive data that we collected but which are not echo-integrated.

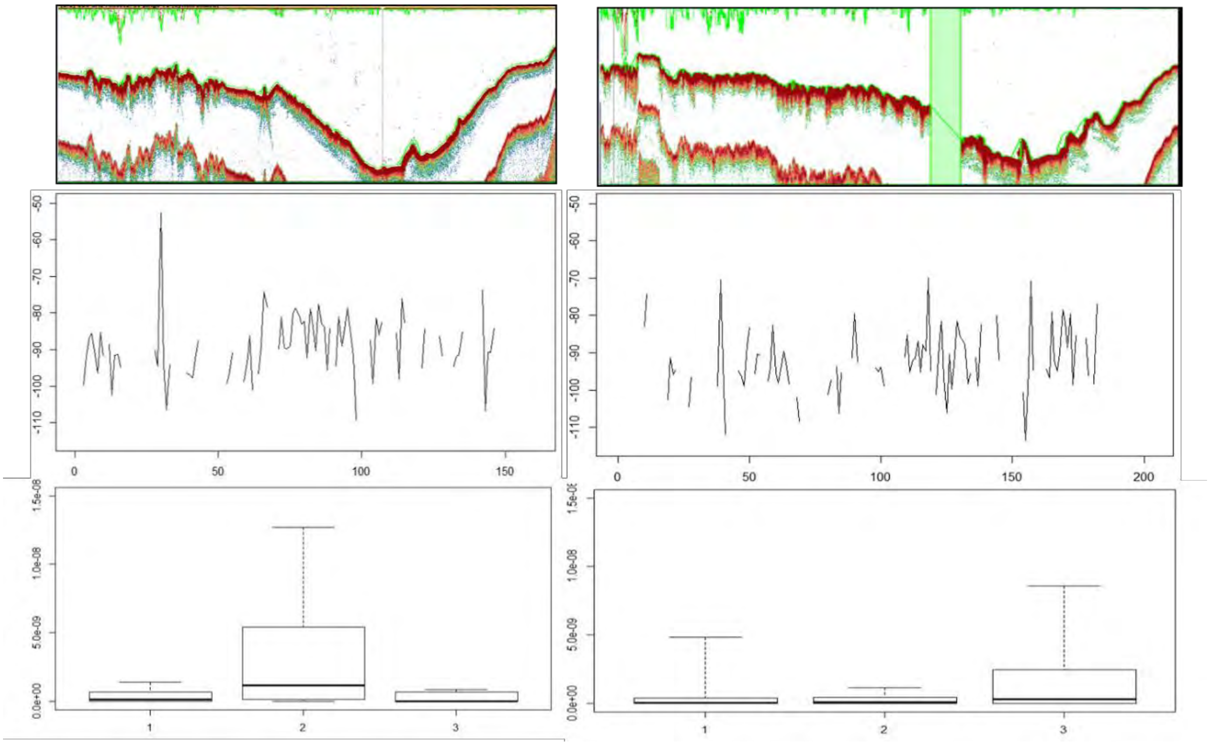

Figure A1: May survey, ebb tide grid 1 (left) and ebb tide grid 3 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom).

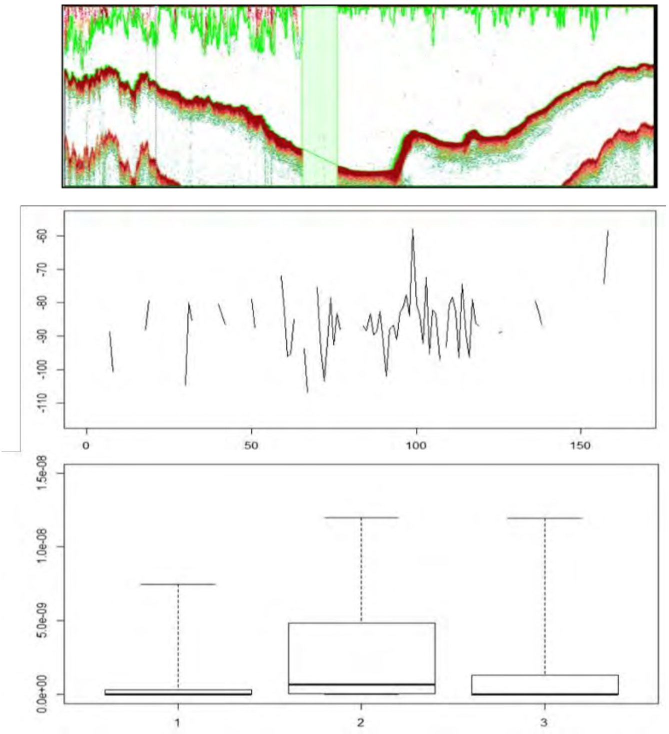

Figure A2: May survey, flood tide grid 4. Condensed echogram of cross-channel transect (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The May flood tide grid 2 is presented in Figure 16 (right).

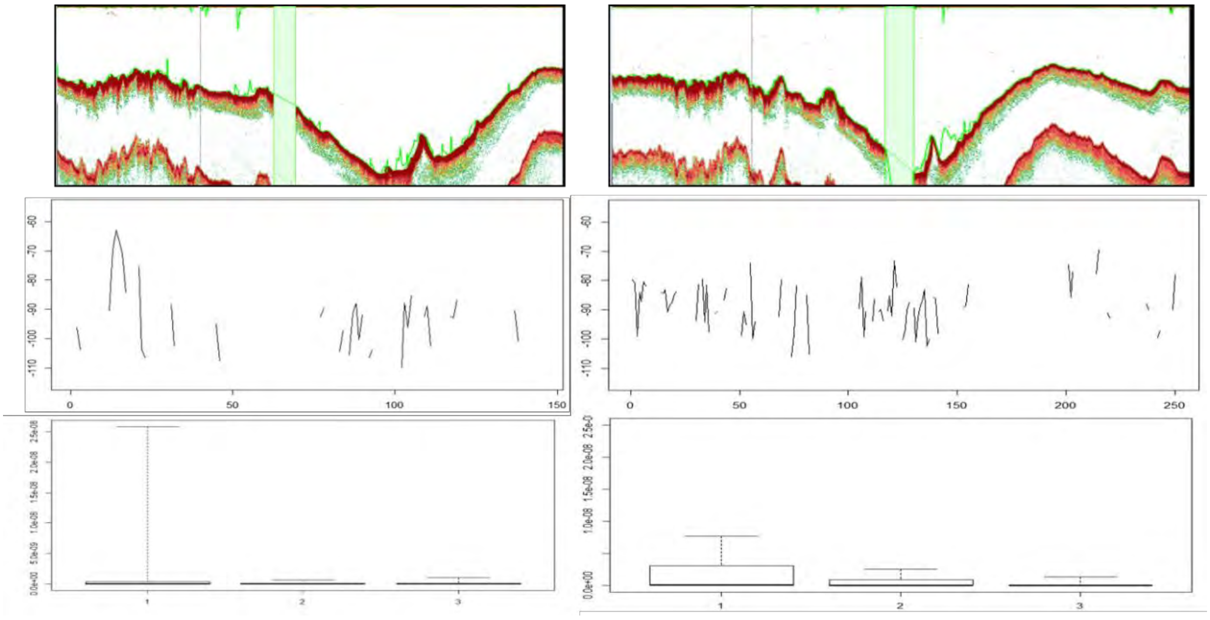

Figure A3: August survey, ebb tide grid 1 (left) and ebb tide grid 3 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom).

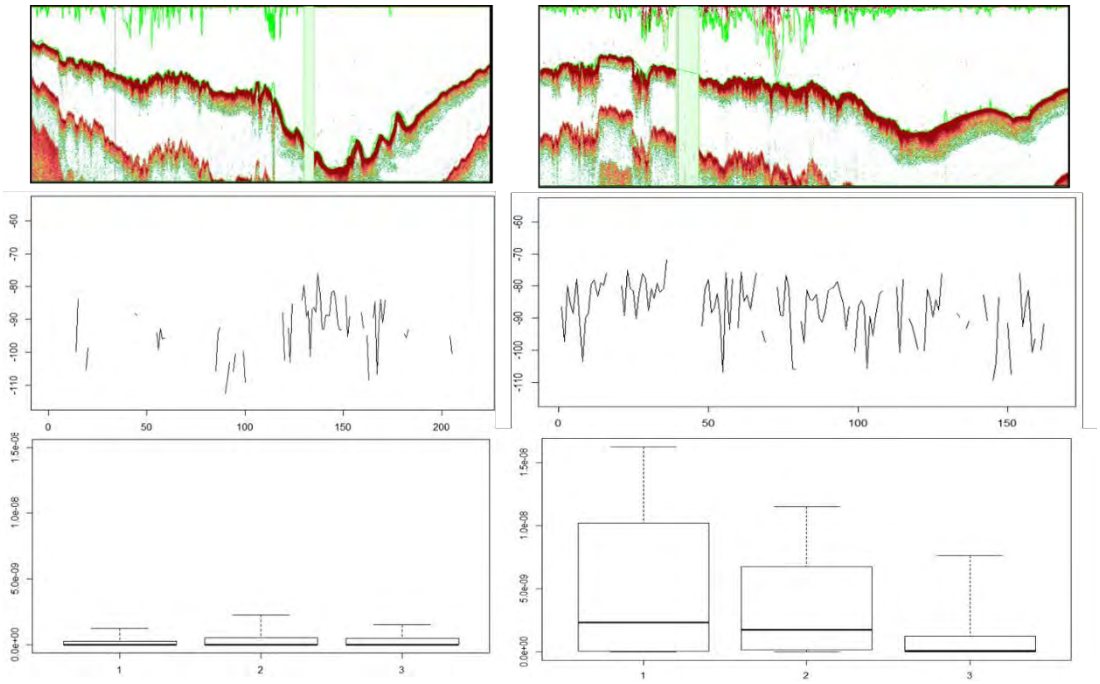

Figure A4: August survey, flood tide grid 2 (left) and flood tide grid 4 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom).

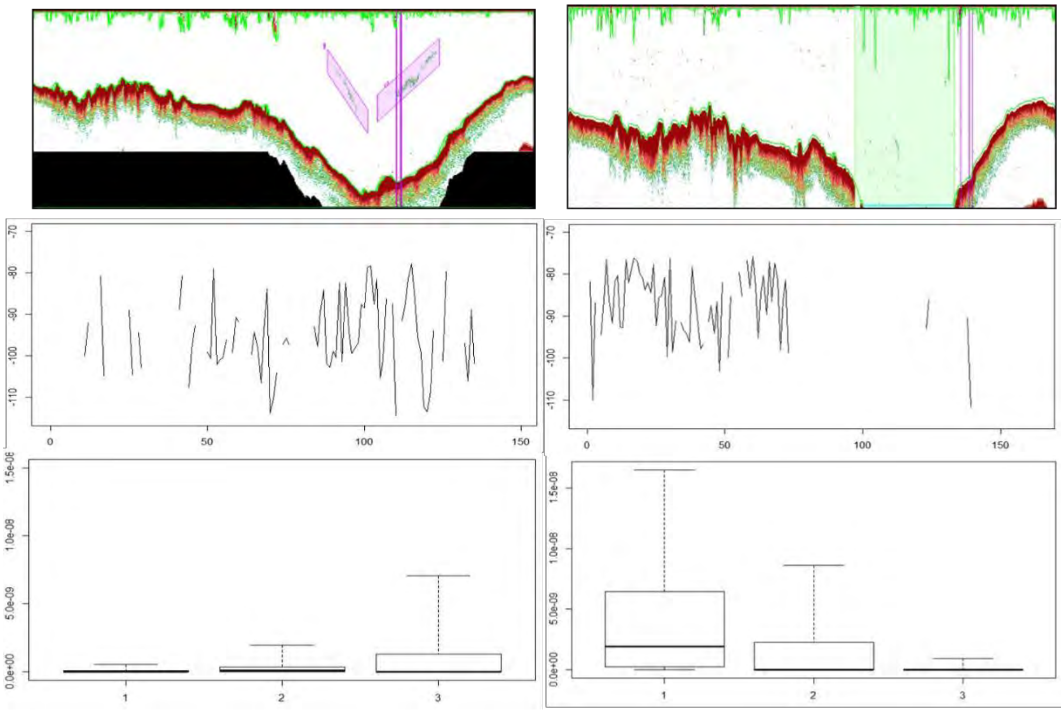

Figure A5: October survey, ebb tide grid 1 (left) and ebb tide grid 3 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

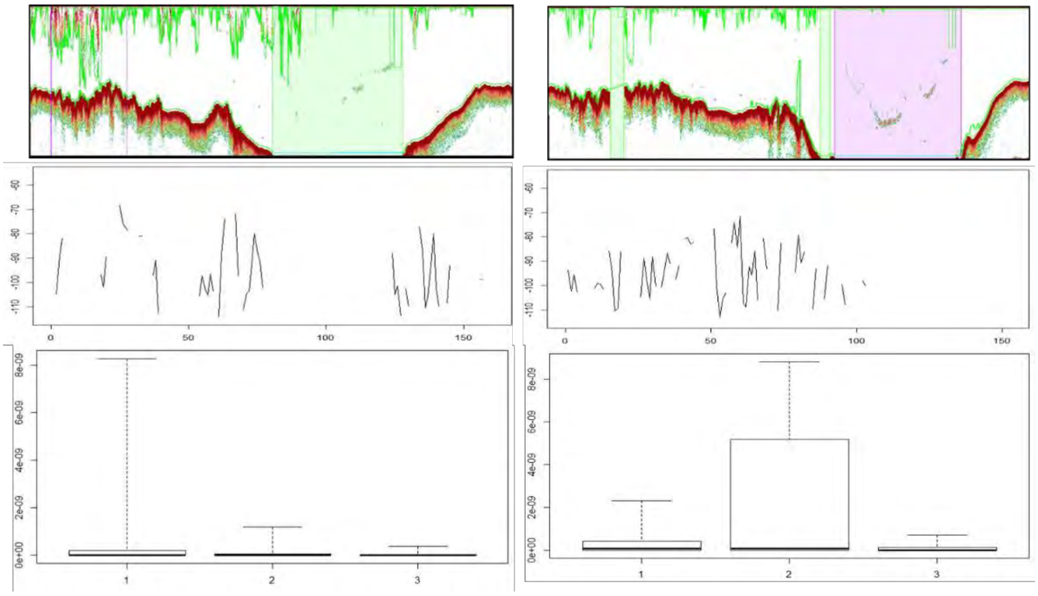

Figure A6: October survey, flood tide grid 2 (left) and food tide grid 4 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

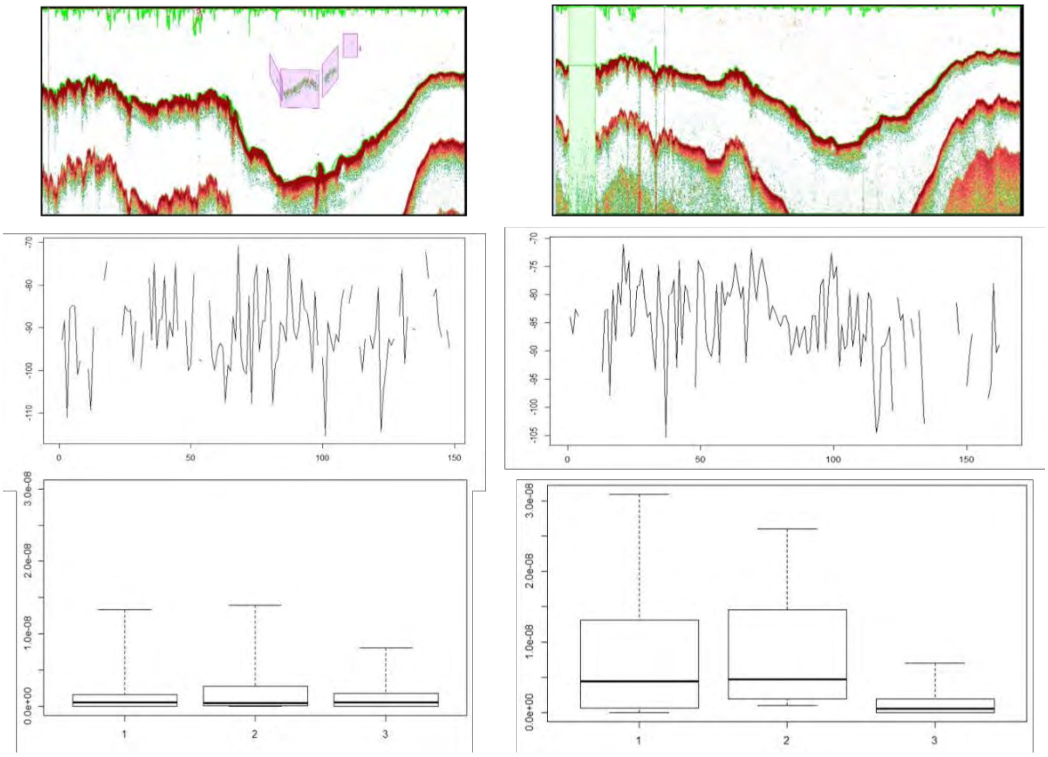

Figure A7: November survey, ebb tide grid 1 (left) and ebb tide grid 3 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

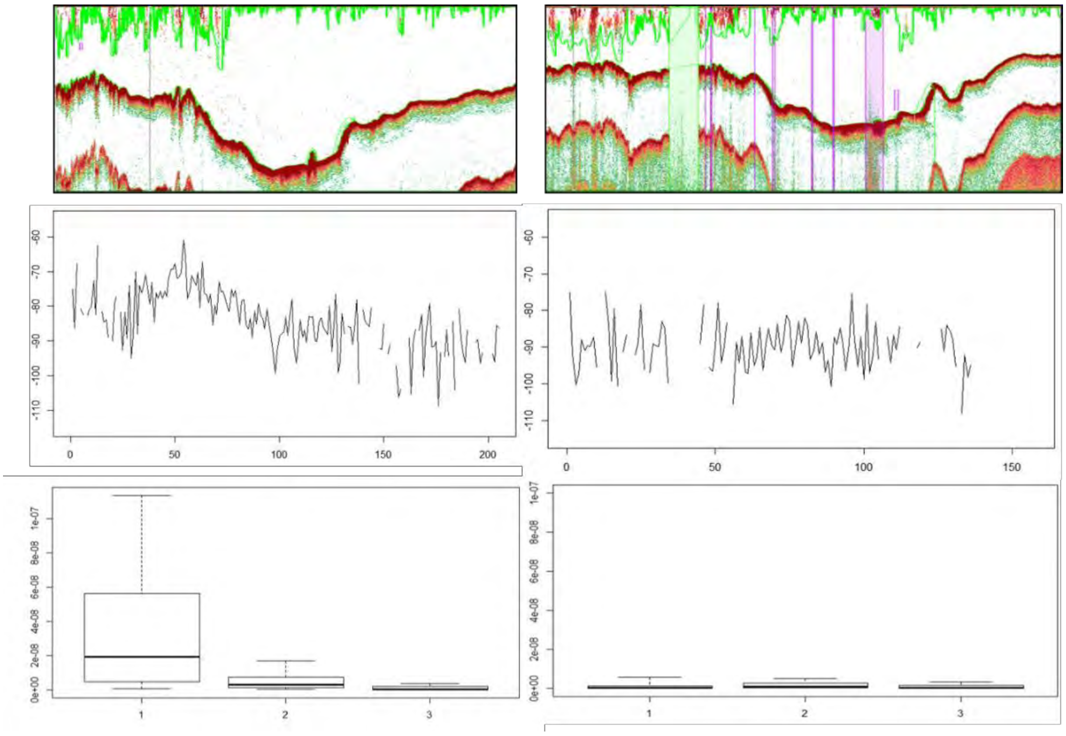

Figure A8: November survey, food tide grid 2 (left) and flood tide grid 4 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

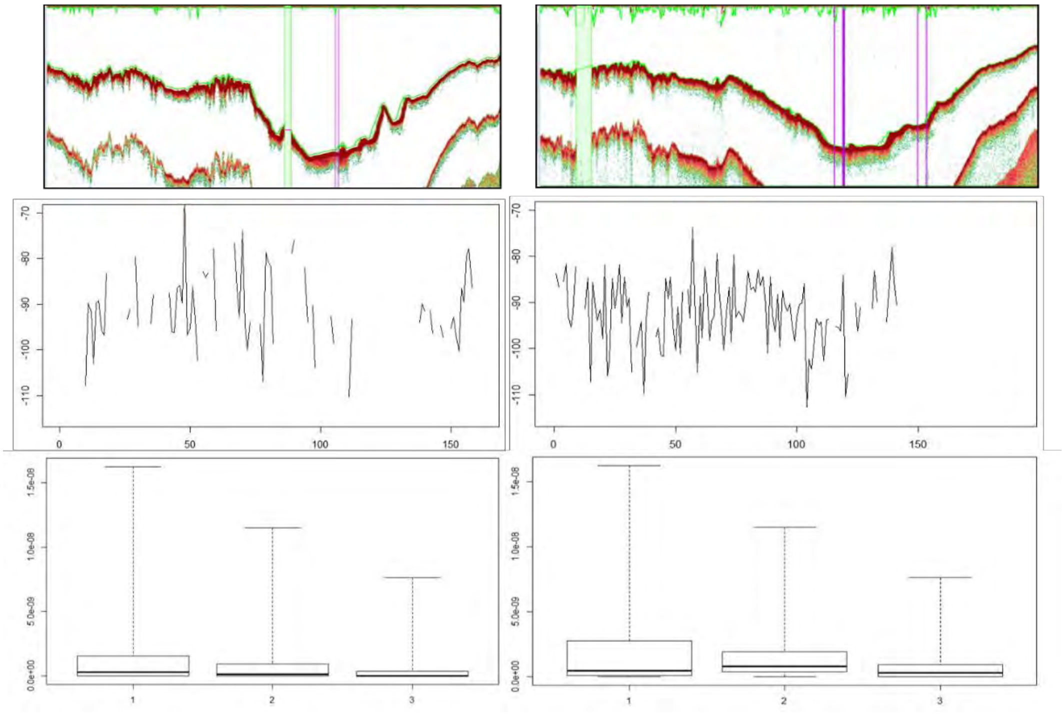

Figure A9: January survey, ebb tide grid 1 (left) and ebb tide grid 3 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

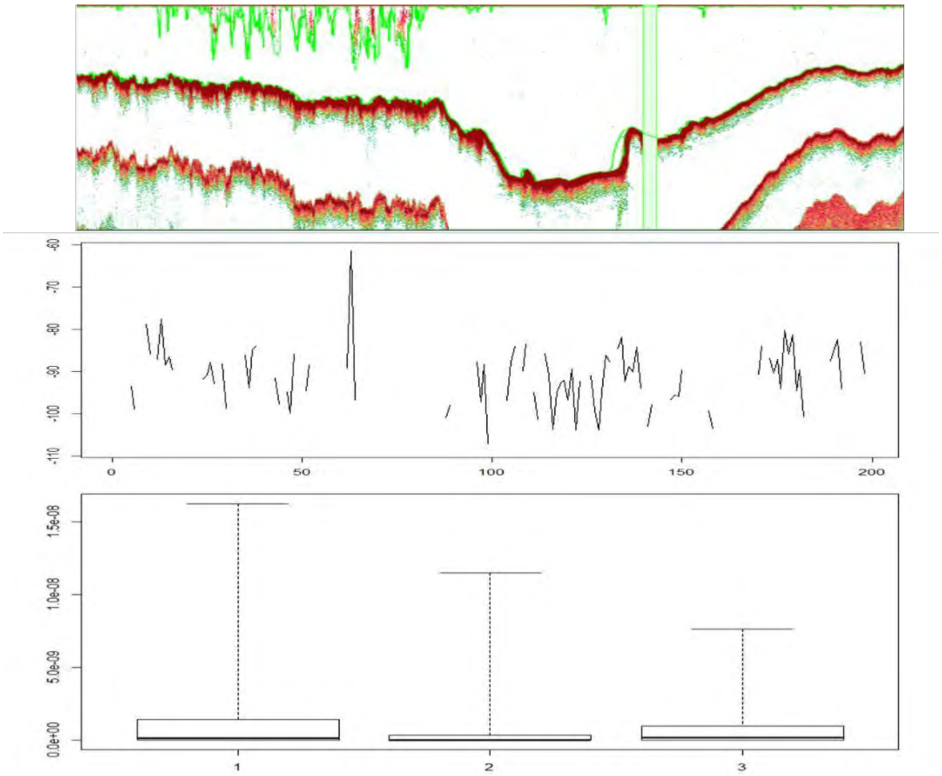

Figure A10: January survey, food tide grid 4. Condensed echogram of cross-channel transect (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The January flood tide grid 2 is represented in Figure 16 (left).

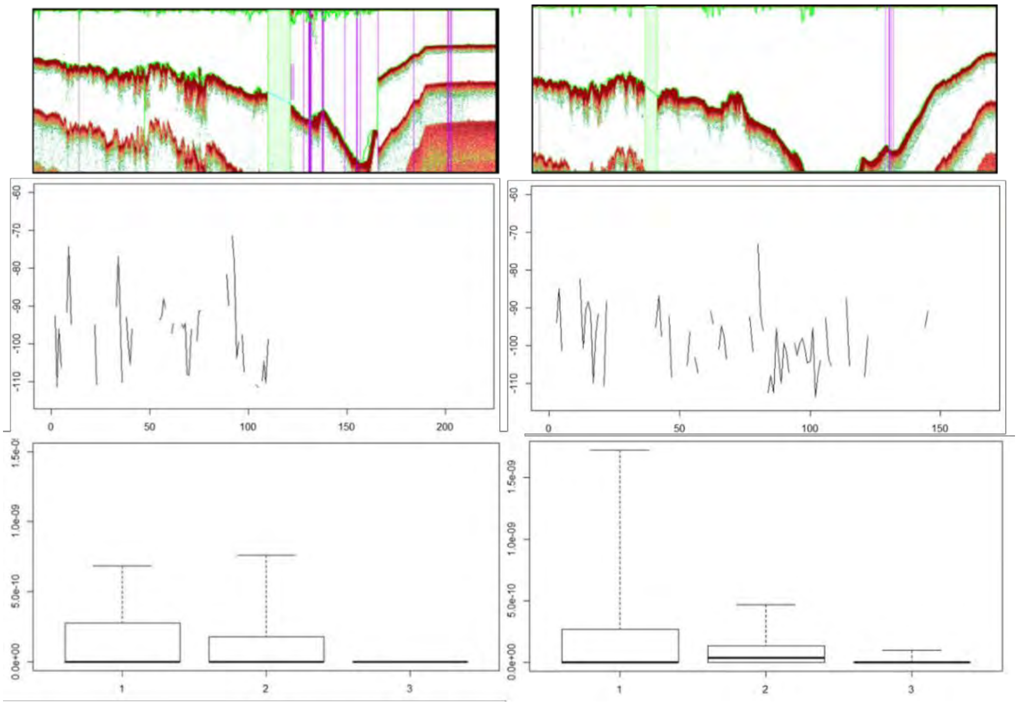

Figure A11: March survey, ebb tide grid 1 (left) and ebb tide grid 3 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

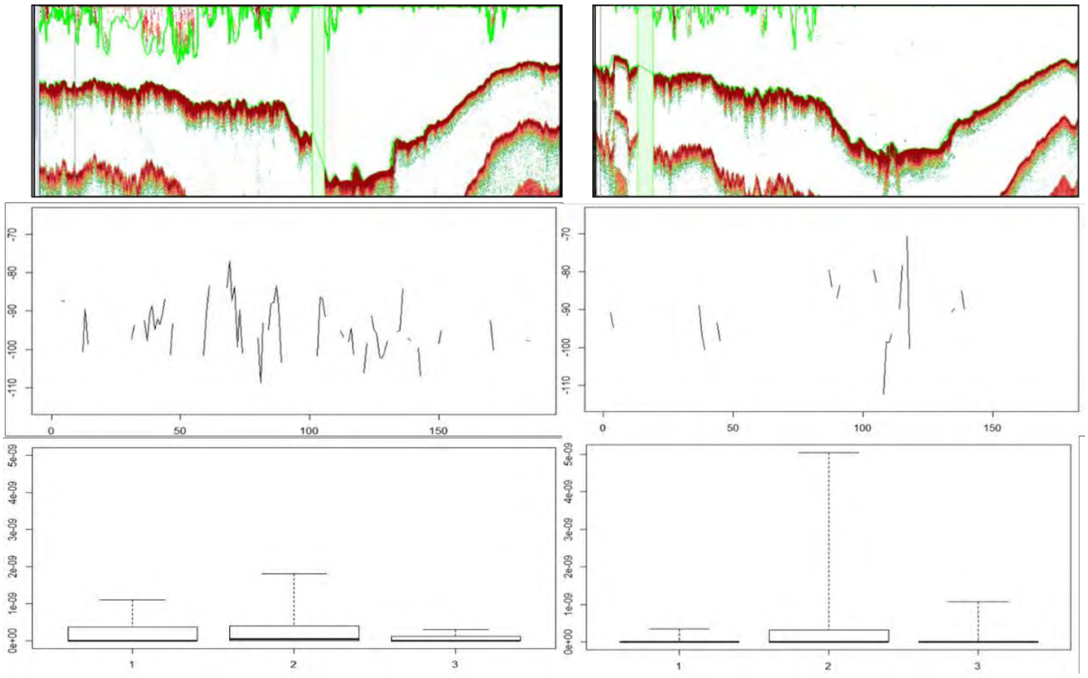

Figure A12: March survey, flood tide grid 2 (left) and flood tide grid 4 (right). Condensed echogram of cross-channel transects (top), mean relative fish density (middle) and boxplot of fish relative density (bottom). The purple vertical bars and area correspond to bad data and have not been echointegrated.

Appendix 2: 2016/2017 (Year One) Seabirds Monitoring Report

This report presents the results of the first year of seabird monitoring of FORCE's 2016 – 2021 Environmental Effects Monitoring Program as completed by Envirosphere Consultants.

Marine Seabirds Monitoring Program

Tidal Energy Demonstration Site –
Minas Passage, 2016-2017

July 2017

Submitted to:

Fundy Ocean Research Center for Energy (FORCE)
Halifax, Nova Scotia

Submitted by:

Envirosphere Consultants Limited
Windsor, Nova Scotia

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Fundy Ocean Research Center for Energy (FORCE)
PO Box 2573
Halifax, Nova Scotia B3J 2N5

Envirosphere Consultants Limited
P.O. 2906, Unit 5 – 120 Morison Drive
Windsor, Nova Scotia B0N 2T0
Tel: (902) 798-4022
Fax: (902) 798-2614
www.envirosphere.ca

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Executive Summary

The Fundy Ocean Research Center for Energy (FORCE) developed and operates a tidal energy demonstration site and support facility along the north shore of Minas Passage in Nova Scotia's Bay of Fundy. As a condition of its regulatory approvals to operate at the site, FORCE has been required to carry out an environmental effects monitoring program (EEMP) to provide information on the marine ecosystem, including seabirds and marine mammals, before and after installation of tidal energy devices, to verify predictions that these organisms are not likely to be impacted by tidal energy development activities. FORCE conducted vessel- and shore-based observational surveys for seabirds and marine mammals beginning in 2009 and extending until 2012 as part of ongoing Environmental Effects Monitoring Program (EEMP) activities at the site.

The latest phase of the EEMP extends from 2016-2021 and includes year-round shore-based monitoring of marine seabirds. The first year of shore-based surveys under the present EEMP covers the period from May 6, 2016 to May 1, 2017, conducted from the FORCE Visitor Center on the north shore of Minas Passage, near Parrsboro, Nova Scotia, and covering a period both before and during the operation of a grid-connected tidal turbine which was installed in early November, 2016, and which operated through the end of the survey period.

Surveys targeted the occurrence, abundance, local distribution, and annual pattern of composition and abundance of seabirds and water-associated birds (loons, cormorants, waterfowl, gulls, alcids), in coastal waters of Minas Passage, which included the zone designated for deployment of tidal energy devices (the 'Crown Lease' area) and adjacent waters both inshore and offshore and on Black Rock, an island at the site. Thirty-two (32) species of water-associated birds and shorebirds, and three marine mammal species (Harbour Porpoise, Harbour Seal and Harp Seal) seen incidentally at the site, were observed during the year. The most common and abundant bird species included gulls (Great Black-backed Gull and Herring Gull, present in 88 and 100% of surveys respectively), Common and Red-throated Loon, Common Eider, Black Guillemot, Black Scoter, Double-crested Cormorant and Great Cormorant. Least common species included shorebirds (Lesser Yellowlegs, Purple Sandpiper and Spotted Sandpiper), as well as Northern Gannet, Red-necked Grebe, Razorbill, Common Murre, Blue-winged Teal, Arctic Loon and Snow Goose, which were each observed on single surveys. An estimated four pairs of Black Guillemot and several Great Black-backed Gull were nesting on Black Rock, but there was no indication of nesting by Herring Gull, Double-crested Cormorant, or Great Cormorant on the island during the year.

Abundance of water-associated birds (loons, cormorants, waterfowl, gulls, alcids) at the Minas Passage site showed seasonal peaks corresponding to migratory movements (March-April and October-November); a late spring to early summer occupation of the area by local resident breeders such as Black Guillemot and Common Eider; and a low summer abundance when migrants are not present and individuals of local breeding species such as gulls and cormorants move out of the area. Number of species observed per survey ranged from a low of five species in early September and early December 2016; to a high of 17 species per survey in mid-April 2017. Abundance ranged from a low of 1.8 birds per half-hour on October 17, 2016 to a high of 267.8 birds per 30-minute period on April 17, 2017.

Fewer species of seabirds and water-associated birds visited the site than in the surveys conducted at the site in 2010-2012, both in total numbers observed (32 versus 45) and average number per survey. Common and abundant species in 2016-2017 were the same ones as in the earlier surveys, with the exception of Northern Gannet which was nearly absent this year, occurring in only one survey. Abundance was similar to earlier surveys but the peak abundance during the spring 2017 migration

(April 17, 2017) was the highest of any observed at the site, when high numbers of Red-throated Loon and Black Scoter, concurrently with high numbers of Double-crested Cormorant, visited the area.

Birds showed moderate and about equal utilization of survey subareas including the 'Crown Lease' and areas east of it around Black Rock. Black Rock was a focal point for bird activity, with birds typically roosting on and otherwise using it as a stopover for longer flights; for nesting (e.g. Black Guillemot); or as a base for local feeding in the adjacent waters at various times. During migration peaks, however, birds moving through the area over the water dominated numbers using Black Rock.

Since environmental monitoring at the Minas Passage site began in 2009, 50 species of water-associated birds and shorebirds have been seen in the vicinity of the Tidal Energy Demonstration Site (Minas Basin, Minas Passage & Minas Channel), the majority in Minas Passage specifically at the demonstration site, as the result of shore-based surveys.

Three species of marine mammal, the Harbour Porpoise (*Phocoena phocoena),* Harbour Seal (*Phoca vitulina*) and Harp Seal (*Pagophilus groenlandicus)* were observed during the year. Seal sightings were rare with three Harbour Seal noted on two surveys and a single Harp Seal on the January 2017 survey. Harbour Porpoise (*Phocoena phocoena)* occurred occasionally. Twenty-one Harbour Porpoise were seen at the site, principally from early summer to early fall, with highest numbers detected in September-October, and individuals most commonly observed in the tidal stream outside Black Rock and the Crown Lease area, south and southwest of Black Rock. Porpoise typically moved with the tidal current, westerly with the ebb tide (out-going) and easterly with the incoming tide, typically in the tidal stream outside Black Rock and extending through the Crown Lease and inshore areas in the direction of the tidal stream.

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1 Introduction

The Fundy Ocean Research Center for Energy (FORCE) operates a marine tidal energy demonstration site and testing facility in Minas Passage, near Parrsboro, Nova Scotia. The site is important both for the high energy potential of the tidal currents which occur there, and as a biologically significant part of the Bay of Fundy—supporting a unique marine ecosystem and habitat for many important marine species, as well as providing a migration route through the Bay of Fundy and a gateway into Minas Basin, the biologically productive bay located at its eastern end.

As a condition of its regulatory approvals to operate the Minas Passage tidal energy demonstration site, FORCE has, from the inception of the project, been required by the Province of Nova Scotia to carry out environmental effects monitoring (EEM) to provide information to verify impact predictions made in the environmental impact assessment for the project. FORCE undertook various studies as part of its initial Environmental Effects Monitoring Program (EEMP) activities (FORCE 2011, 2014), which included a three-year project to determine the occurrence, abundance, species composition and seasonality of seabirds and marine mammals which were important components of the marine ecosystem at the site (Envirosphere Consultants Limited 2011; 2012; 2013; FORCE 2011; 2014). The studies provided information to verify predictions that these groups were not likely to be impacted by tidal energy development activities. The shore- and vessel-based surveys in 2010-2012 as part of the EEMP, added basic knowledge concerning these species at the site—an essential component of any environmental monitoring program—against which changes potentially arising from the project could be assessed.

Seabirds and other water-associated birds are among the most important organisms in the marine ecosystem of the Bay of Fundy, Minas Passage and Minas Basin. They are generally less numerous than other organisms in the ecosystem; have protected status and are managed under Canadian and international law; are often of higher importance and concern to the general public; and in the context of tidal power development, are among the organisms which have the potential to interact physically as well as indirectly (e.g. through the food chain), with tidal energy devices and activities. Studies of seabirds and incidental occurrence of marine mammals from shore- and vessel-based observations from carried out in FORCE's EEMP from 2009-2012, revealed some 45 species of seabirds and water-associated birds as well as several marine mammal species, including Harbour Porpoise, Grey Seal and Harbour Seal which occur occasionally at the Minas Passage site (Envirosphere Consultants Limited, 2010-2012).

Potential for impacts of tidal energy activities and equipment on seabirds and other water-associated birds is a major concern and has been assessed at various stages of the development of the FORCE site, including reviews conducted as part of the environmental assessment process (JWEL 2008; AECOM 2009); and evaluation of information arising from baseline and environmental studies carried out through the course of the development of the site (e.g. FORCE 2011, DFO (2016)). FORCE has been allowed to proceed by regulatory agencies with various conditions, including a requirement to conduct environmental monitoring, most recently to conduct an operational phase Environmental Effects Monitoring Program (EEMP) in 2016-2021 to gather information on key environmental features as activity and use of the site by tidal energy developers increases[1] (FORCE 2016).

This latest phase of Environmental Effects Monitoring (EEM) extends from 2016-2021 and includes shore-based monitoring of seabirds (FORCE 2016). Since early May 2016, observations of seabirds and harbour porpoise, have been made as part of this monitoring program through a series of half day,

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[1] The Cape Sharp Tidal Development Inc. installed an Open Hydro turbine on November 7, 2016.

monthly to semi-monthly surveys conducted from the FORCE Visitor Center facility, located on West Bay Road, Black Rock, Nova Scotia. The monitoring study focused on determining local distribution, abundance and seasonality of seabirds in subareas of the nearshore marine environment at the FORCE test site, including areas designated for deployment of tidal turbines and Black Rock—a prominent island at the site. The results of the monitoring study, extending from May 2016 to May 2017 are presented in this report.

2 Methods

2.1 Study Area

The Fundy Ocean Research Center for Energy (FORCE) tidal energy demonstration site is located on the northern shore of Minas Passage, a narrow (5 km) strait which connects the Bay of Fundy and the Atlantic Ocean to Minas Basin, a shallow estuarine and macrotidal bay at its eastern end. The site consists of an area of seabed and waters above it allocated by the Province of Nova Scotia (a 1 x 1.5 km box ("Crown Lease") located approximately 1 km from the northern shore of Minas Passage (Figure 1)); submarine electricity transmission cables for present and future tidal installations; instrumentation platforms and supporting power and data cabling; and onshore infrastructure, including an operations and interpretive center (FORCE Visitor Center), a high-voltage transformer substation, and a high voltage transmission line connecting the offshore tidal energy devices to the Nova Scotia electricity grid. Observations were made from the deck of the FORCE Visitor Center, an onshore operations center (45° 22.21' N 64° 24.22' W, 22 m above mean high water) used in baseline monitoring surveys in 2011 & 2012. The site has an unobstructed view of about 5 km across Minas Passage and a panoramic view of Minas Channel including nearby Cape Split from due south to west (coastal features obstruct views to the southeast) (Figures 2-4). Vantage points from both indoors and outdoors were available; the front windows of the Visitor Center are positioned about 10 m landward of the outer edge of the deck, and the indoor and outdoor fields of view are nearly identical. Surveys in winter and in inclement weather were done indoors.

Sixteen shore-based surveys were carried out at the site between May 6, 2016 and May 1, 2017 (Table 1). Field activities were arranged to take place on days when high tide occurred near mid-day, and to continue during the approximately 6-hour period of the outgoing tide. This approach was consistent with the earlier 2010-2012 surveys, and also allowed us to monitor a consistent time of day and tidal phase to help reduce statistical variability inherent in seabird observations. Dominant environmental factors expected to affect bird abundance, include tide phase; time of day; day length, weather, etc. The observer team typically arrived on site at approximately high tide and observations were made from that time until low tide. On several occasions in 2016-2017, however, weather and scheduling resulted in the observations being conducted on the rising tide, although the time of day was preserved for all surveys.

The first survey included an orientation in which the entire field team participated, during which the data recording methods were finalized and standardized among observers and field assistants. Two visits were made by one member of the team (Stewart) for obtaining 'landscape' photographs of the waters at the site to provide a visual reference for the locations of the study sub-areas, which included, coordination of a support vessel to occupy the four corners of the Crown Lease to record the positions on photographs to be used in subsequent surveys.

Surveys used a geographic grid system to locate the observations in space and in relation to the Crown Lease area, following standard practice in monitoring of seabirds in general, and in particular in monitoring studies used in monitoring tidal energy development sites in the United Kingdom (e.g. Jackson and Whitfield 2011; Robbins 2012). The subareas in the grid were assigned to be relevant to analysis in terms of a statistical design for environmental effects monitoring, in particular Before-After Control Impact (Green 1979). The areas included the 'Crown Lease' (CL), the 1.5 x 1 km box assigned for deployment of tidal energy devices; two areas inshore of the CL, "Inside Black Rock 1" (IB1) and "Inside Black Rock 2" (IB2) (Figure 2); three areas outside the CL, "Outside Black Rock 1-3" (OB1-OB3); and three sites ("Farfield 1-3 'Reference' sites). Because of low numbers of birds at the "Farfield" sites, counts were grouped under the "FF" category in data analysis and interpretation. Positions of grid areas on the water as they appear from the FORCE Visitor Center are shown in Figure 4.

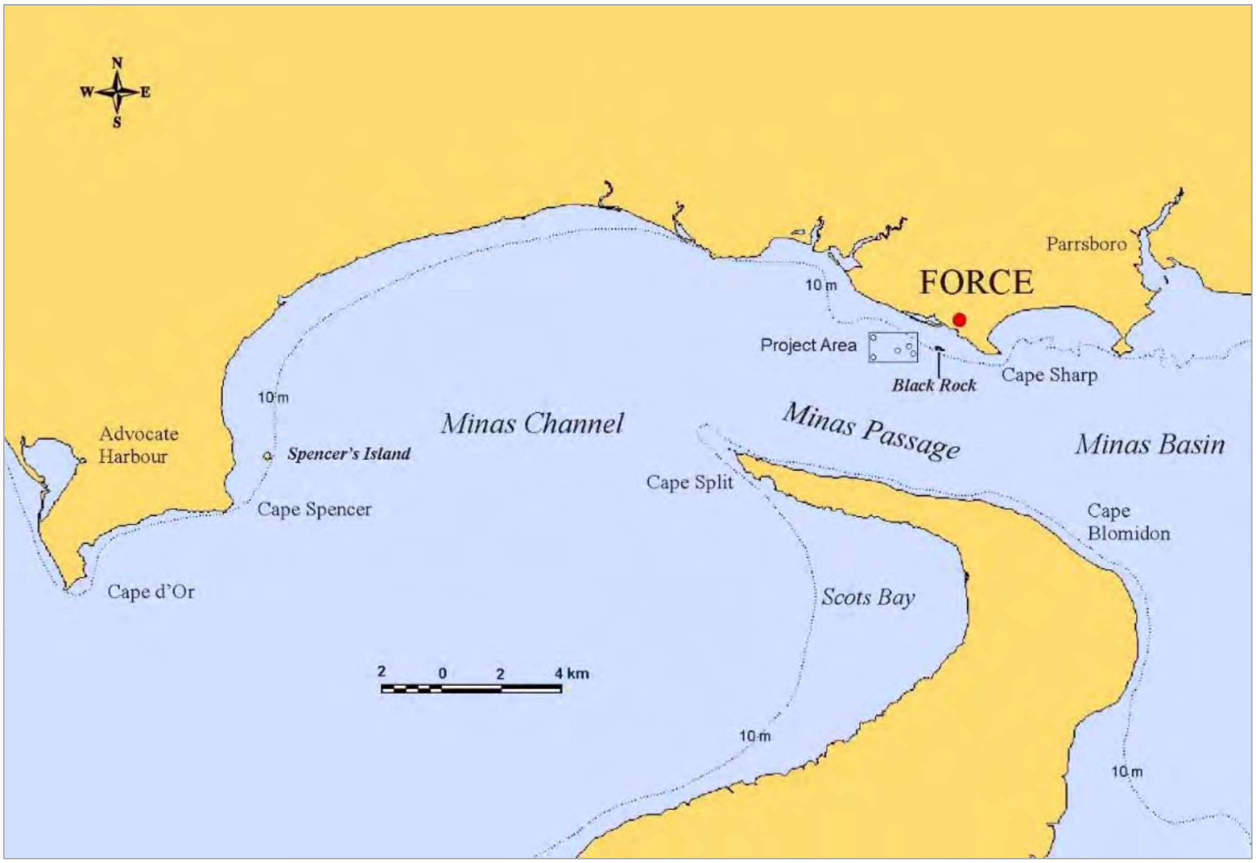

Figure 1. Study area for vessel surveys, showing project location and major subdivisions.

Information from the seabird reporting form was entered directly into a MicroSoft Excel spreadsheet with columns corresponding to those on the form, and all the surveys were compiled as they were completed. At the completion of the Year-One activities, the annual data was transferred into a MicroSoft Access database where it was combined with the data from the earlier (2010-2012) shore-based surveys. Statistics compiled included: total and average number of species per survey and subarea; and average abundance of birds overall and by species per survey and subarea.

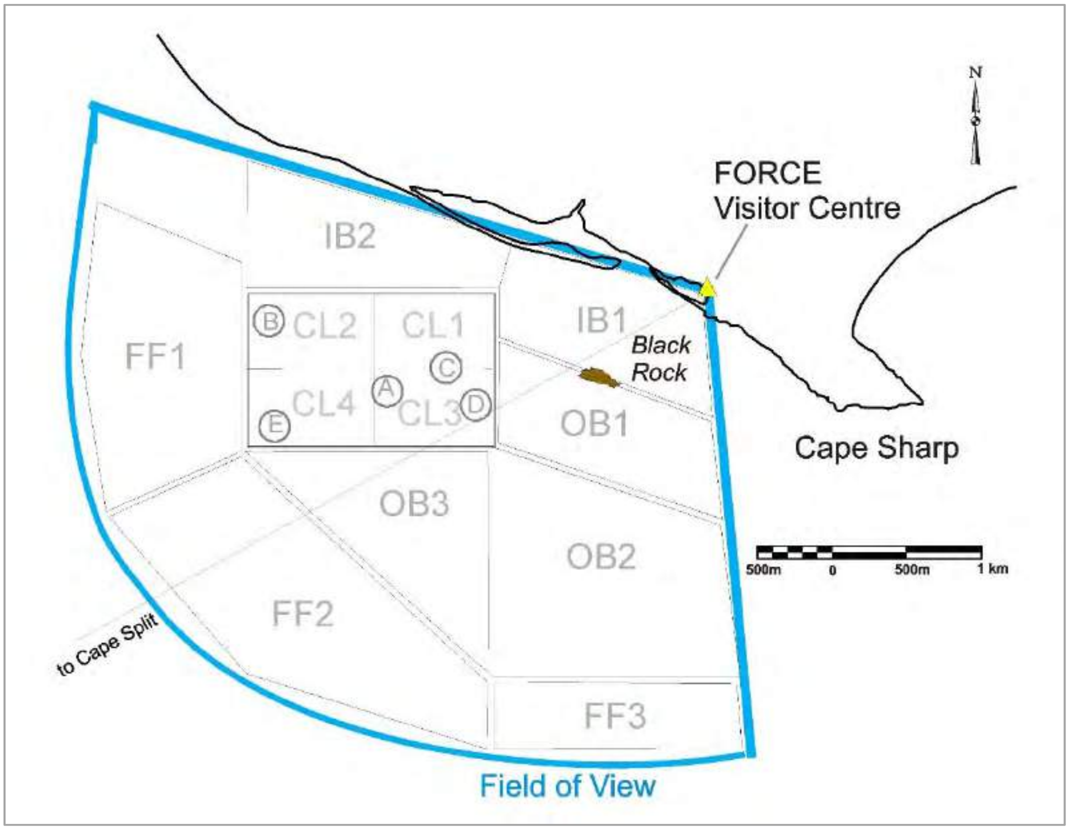

Figure 2. Spatial grid showing subareas used in seabird survey. Berths currently assigned to FORCE berth holders are shown as circles in Crown Lease (CL) area.

Figure 3. Bird Observer, Fulton Lavender, counting bird occurrences using a 22x Bushnell spotting scope. June 2, 2016.

Figure 4. Photograph of the view from the observation point at the FORCE Visitor Center, showing subareas used in survey, including Black Rock. Red lines show reference directions to assist in locating subareas.

3 Results and Discussion

3.1 Seabirds and Other Water-Associated Birds

A wide variety of seabirds and other water-associated birds utilize the waters of Minas Passage off the FORCE site throughout the year. These include seabirds—oceanic species such as shearwaters and petrels, which spend their lives wholly at sea, except for breeding on land; and species such as some gulls, cormorants, and other species whose life cycle spans a spectrum of oceanic and coastal environments—waterfowl such as ducks, geese, and loons, which may occupy the full range of marine, freshwater and estuarine environments during their life cycle; shorebirds which are often found seasonally in intertidal areas; and other species which from time to time occur.

The FORCE marine seabirds monitoring program includes the waters of Minas Passage and locations where tidal energy devices will typically be installed. Dynamics of birds there are influenced by various factors, in particular proximity to shore, exposure to spatially- and temporarily-varying tidal currents, presence of Black Rock, the small coastal island at the site etc., and also by the presence in the general vicinity of coastal features including a major nearby point of land (Cape Sharp), a coastal salt marsh, a sand spit and lagoon system, and nearby shoreline and tidal flats—all of which may attract seabirds and other water-associated birds of many different kinds to the area. Black Rock in particular, is an exceedingly important feature of the site, influencing occurrences and abundance seabirds and other water-associated birds in the adjacent waters by attracting birds to the site from throughout the region for roosting, resting, and nesting, and as a base for active feeding in the adjacent waters.

Table 1. Tide times and heights for seabird surveys at the Fundy Tidal Power Demonstration Site (FORCE Visitor Center) during 2016 - 2017.

SURVEY DATE	START/ END TIME	TIME & HEIGHT FOR HIGH & LOW TIDE		NUMBER OF PERIODS
		Time	**Meters (above MLW)**	
May 6, 2016	12:38 – 18:12 (ADT)	13:03	13.3	11
		19:13	0.2	
June 2, 2016	12:00 – 18:15	10:56	12.5	12
		17:08	0.9	
July 2, 2016	11:50 – 17:20	11:29	12.5	12
		17:40	0.9	
August 2, 2016	13:00 – 19:00	12:56	12.7	12
		19:09	0.9	
September 1, 2016	13:15 – 19:15	13:23	12.6	12
		19:38	0.9	
October 1, 2016	11:30 – 17:35	13:41	12.5	12
		19:56	1.1	
October 17, 2016	11:45 – 17:45	14:10	13.8	12
		20:23	0.2	
November 3, 2016	12:15 – 18:15	09:37	2.1	12
		15:48	11.8	
November 17, 2016	12:00 – 17:30 (AST)	08:13	0.3	11
		14:25	13.6	
December 1, 2016	12:30 – 17:00	13:41	12.1	9
		19:55	1.5	
January 16, 2017	12:15 – 16:45	09:16	1	10
		15:25	12.8	
February 21, 2017	12:00 – 18:00	08:23	10.6	12
		14:43	3.1	
March 13, 2017	12:15 – 18:15 (ADT)	14:09	13	12
		20:24	0.6	
April 3, 2017	12:15 – 18:15	12:33	1	12
		18:50	12.1	
April 17, 2017	11:50 – 18:20	11:43	2.5	13
		17:59	10.7	
May 1, 2017	12:00 – 18:00	11:17	0.5	12
		17:32	12.6	

3.1.1 Seabird Community – Species Diversity

Thirty-two (32) species of water-associated birds and shorebirds were observed at the FORCE site during year (Tables 2 and 3; Figure 5). Table 2 contains a list of all bird species that were observed during the year-long survey. Seasonal occurrence of the number of observed species by survey date is displayed in Table 3.

The most common and abundant species included Herring and Great Black-backed Gull, Red-throated Loon, Common Loon, Common Eider, Black Scoter and both Double-crested and Great Cormorant, all of which occurred on at least 50 % of the 16 surveys. Various species were observed on single surveys only, including three shorebird species (Lesser Yellowlegs, Purple Sandpiper and Spotted Sandpiper), as well as Northern Gannet, Red-necked Grebe, Common Merganser, Blue-winged Teal, Wilson's Storm Petrel and Snow Goose (Table 3). A vagrant or accidental Arctic Loon, a species with a range encompassing Arctic and east and northern Pacific waters, was a significant sighting on November 17, 2016 (Table 3). Frequency of species sightings, defined as the percentage of surveys a bird species was observed, are displayed in Figure 6.

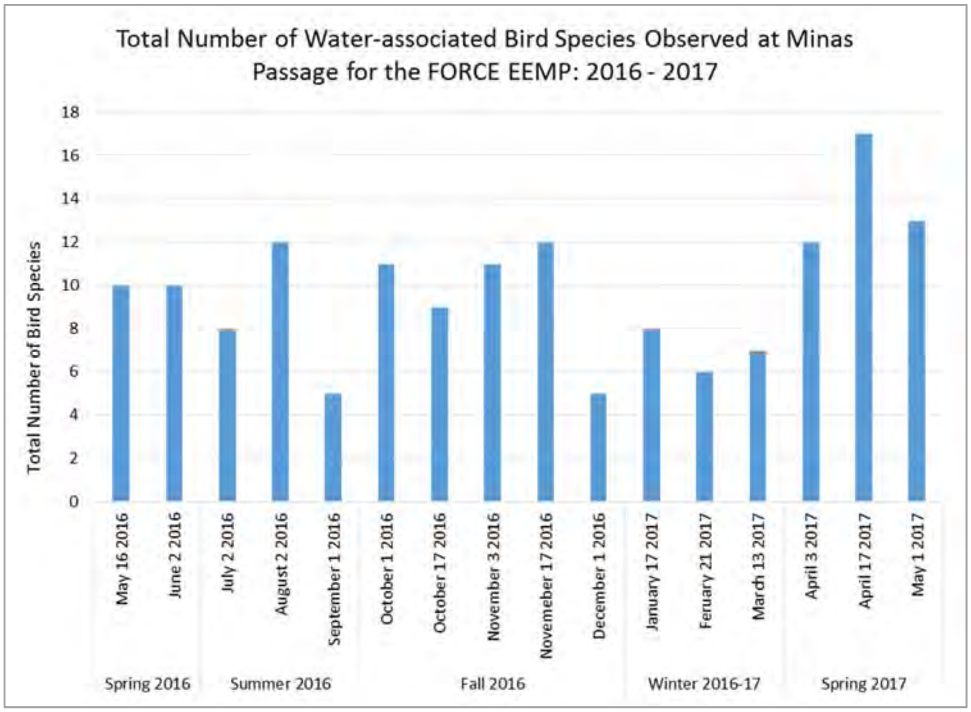

Figure 5. Total number of water-associated bird species observed during Year-One (May 2016 – May 2017) of the Shore-Based Seabird Survey – Tidal Energy Demonstration Site, Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia.

Number of species observed per survey (an indicator of the overall diversity of birds at the site) was higher during the spring-early summer nesting and migration season seasons (April to June) (10 – 17 species); and the fall migration period (October to November)(9 – 12 species). Species richness ranged from a low of five species in early September and early December 2016; to a high of 17 species per survey in mid-April 2017 (Figure 8). The number of species present was made up of several resident and locally breeding species, which were usually present; and the remainder by migrants of various types, as well as seasonal visitors (e.g. Atlantic Puffin, Razorbill, Red-throated Loon). Species composition and relative abundance in survey subareas is presented in Figures 7-9 and 14-25.

The majority of seabirds and other water-associated birds seen at the site were common and not of particular conservation concern, with the exception of Harlequin Duck and Red-Necked Phalarope[2]. Conservation status of other birds occurring at the site are shown in Appendix C, Tables C1 & C2).

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[2] Harlequin Duck is a species of *Special Concern* under both the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the federal *Species at Risk Act* (SARA) and *Endangered* under the Nova Scotia *Species at Risk Act.* Red-Necked Phalarope is rated *Special Concern* by COSEWIC.

Table 2. Seabirds and other water-associated bird species observed at the Fundy Tidal Power Demonstration Site (FORCE Visitor Center) during the 2016 - 2017 shore-based survey year. A total of 32 species were observed and documented.

Species Code	***Common Name***	***Scientific Name***
WATERFOWL, LOONS, GREBES		
COLO	Common Loon	*Gavia immer*
RTLO	Red-throated Loon	*Gavia stellata*
ARLO	Arctic Loon	*Gavia arctica*
RNGR	Red-necked Grebe	*Podiceps grisegena*
ABDU	American Black Duck	*Anas rubripes*
SNGO	Snow Goose	*Chen canagica*
CAGO	Canada Goose	*Branta canadensis*
COGO	Common Goldeneye	*Bucephala clangula*
RBME	Red-breasted Merganser	*Mergus serrator*
COME	Common Merganser	*Mergus merganser*
BWTE	Blue-winged Teal	*Anas cyanoptera*
SEABIRDS & SEA DUCKS		
ATPU	Atlantic Puffin	*Fratercula arctica*
BLGU	Black Guillemot	*Cepphus grylle*
COMU	Common Murre	*Uria aalge*
RAZO	Razorbill	*Alca torda*
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*
GRCO	Great Cormorant	*Phalacrocorax carbo*
GBBG	Great Black-backed Gull	*Larus marinus*
HEGU	Herring Gull	*Larus argentatus*
ICGU	Iceland Gull	*Larus glaucoides*
LBBG	Lesser Black-backed Gull	*Larus fuscus*
RBGU	Ring-billed Gull	*Larus delawarensis*
NOGA	Northern Gannet	*Morus bassanus*
WISP	Wilson's Storm Petrel	*Oceanites oceanicus*
COEI	Common Eider	*Somateria mollissima*
LTDU	Long-tailed Duck	*Clangula hyemalis*
BLSC	Black Scoter	*Melanitta americana*
SUSC	Surf Scoter	*Melanitta perspicillata*
WWSC	White-winged Scoter	*Melanitta deglandi*
SHOREBIRDS		
LEYE	Lesser Yellowlegs	*Tringa flavipes*
PUSA	Purple Sandpiper	*Calidris maritima*
SPSA	Spotted Sandpiper	*Actitis macularius*

Table 3. Water-associated bird species presence (p) for each survey conducted for the Shore-Based Seabird Survey – Tidal Energy Demonstration Site, Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia.

DATE	Spring		Summer			Fall					Winter			Spring			Total # of Surveys Observed	% of surveys
	06-May-16	02-Jun-16	02-Jul-16	02-Aug-16	01-Sep-16	01-Oct-16	17-Oct-16	03-Nov-16	17-Nov-16	01-Dec-16	16-Jan-17	21-Feb-17	13-Mar-17	03-Apr-17	17-Apr-17	01-May-17		
LOONS (GAVIIDAE)																		
COLO	p	p	p	p		p	p	p	p		p	p	p		p		12	75.0
RTLO	p	p	p			p		p	p			p	p	p	p	p	11	68.8
ARLO									p								1	6.3
WATERFOWL (ANATIDAE)																		
ABDU						p				p	p		p	p			5	31.3
SNGO														p			1	6.3
CAGO						p								p			2	12.5
COEI	p	p	p	p			p	p	p		p		p	p	p	p	12	75.0
COGO											p	p		p			3	18.8
RBME						p								p	p	p	4	25.0
COME										p							1	6.3
LTDU								p	p					p	p	p	5	31.3
BLSC	p			p		p	p	p	p					p	p	p	9	56.3
SUSC								p							p	p	3	18.8
WWSC							p								p		2	12.5
BWTE																p	1	6.3
AUKS, MURRES & PUFFINS (ALCIDAE)																		
ATPU								p	p						p		3	18.8
BLGU	p	p	p	p										p	p	p	7	43.8
COMU									p		p						2	12.5
RAZO								p	p								2	12.5
CORMORANTS (PHALACROCORACIDAE)																		
DCCO	p	p	p	p	p	p	p								p	p	9	56.3
GRCO	p	p	p	p	p	p	p					p	p		p	p	11	68.8
GULLS (LARIDAE)																		
GBBG	p	p	p	p		p	p	p		p	p	p	p	p	p	p	14	87.5
HEGU	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	16	100.0
ICGU								p			p				p		3	18.8
LBBG	p	p		p												p	4	25.0
RBGU		p		p	p	p	p		p	p					p		8	50.0
NORTHERN GANNET (SULIDAE)																		
NOGA															p		1	6.3
RED-NECKED GREBE (PODICIPEDIDAE)																		
RNGR									p								1	6.3
WILSON'S STORM PETREL (PROCELLARIIDAE)																		
WISP					p												1	6.3
SHOREBIRDS (SCOLOPACIDAE)																		
LEYE				p													1	6.3
PUSA														p			1	6.3
SPSA				p													1	6.3

Resident species at the site, including gulls (Great Black-backed Gull, Herring Gull, and Ring-billed Gull), Double-crested Cormorant and Great Cormorant, Black Guillemot, and Common Eider, frequently occupy Black Rock, either for resting or nesting (Black Guillemot), often in large numbers. Birds on Black Rock formed the largest proportion of total birds on most surveys, occurring prominently in late spring, early summer, summer and winter. Birds typically seen over water were often those species moving to and from Black Rock, but the most abundant were mainly migrants, in particular Red-throated Loon, sea ducks including Black Scoter, Surf Scoter and White-winged Scoter, Long-tailed Duck, Red-breasted Merganser and Common Merganser. During peak migration, numbers of birds were often exceedingly high in the water areas of the site.

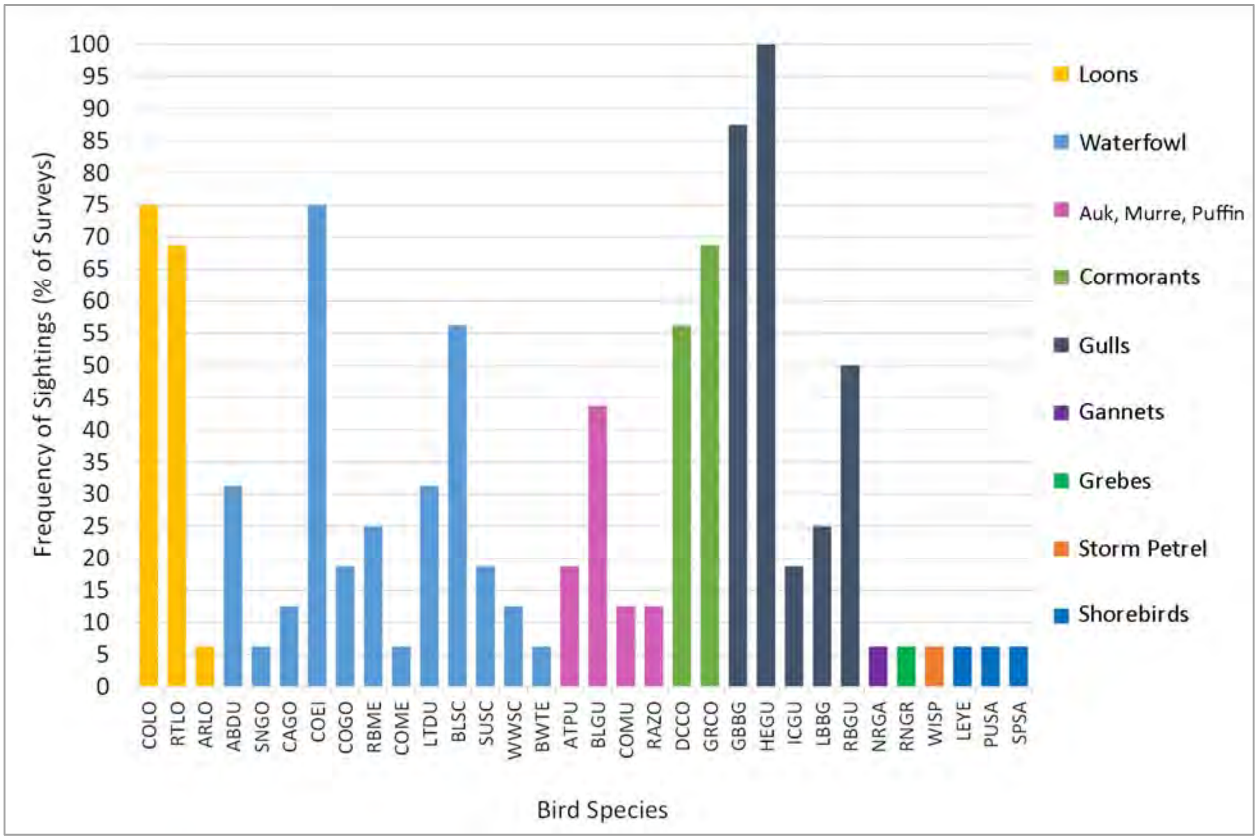

Figure 6. Frequency of surveys (%) in which a species occurred out of 16 surveys conducted for the Shore-Based Seabird Survey – Tidal Energy Demonstration Site, Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia.

3.1.2 Abundance of Seabirds and Other Water-Associated Birds

Overall, the abundance of seabirds and water-associated birds at the FORCE site is low compared with other coastal areas of the Bay of Fundy and Atlantic Canada (Envirosphere Consultants Limited 2012). This conclusion was based on a comparison of the abundances determined in vessel-based surveys for the site, which used a methodology comparable to the ECSAS surveys (Gjerdrum et al 2012). The present survey approach does not make absolute or quantitative assessments of bird abundance which can be related to other areas; and there are no similar studies (i.e. a full annual study of bird abundances in Atlantic Canada) to which the abundances can be compared. The present approach allows, however, comparisons within the site, as in looking at differences before and after activities, such as the installation of tidal energy devices, which is the objective of monitoring at the site.

Black Rock

The relative abundance of birds on Black Rock (Table 4, Figure 10) is an important indicator of activity for species such as Black Guillemot, which nest on the island, since it reflects breeding activity and success, as well as use of adjacent waters for feeding. Abundance of other birds on Black Rock including Herring Gull, Double-crested Cormorant and Great Cormorant, and Common Eider, are not breeding on the island and their occurrence and abundance there reflects the local population abundance (i.e. in the system encompassing the outer Minas Basin, Minas Passage, and Minas Channel) of these species. Great Black-backed Gull are thought to have nested on Black Rock this year. Number of birds occurring over water at the site reflects overall abundance and also preferences for particular sub-areas, and in the context of monitoring for interactions with tidal installations, are most important direct indicators of the potential for tidal interactions.

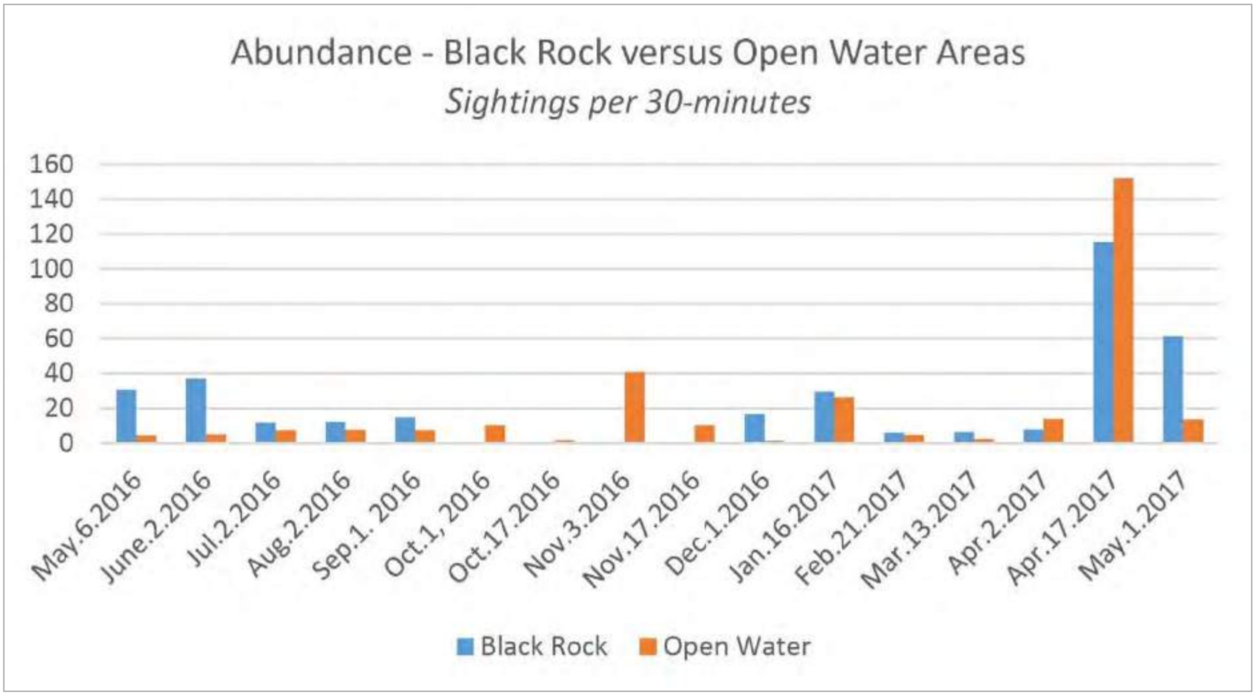

Figure 7. Average abundance of seabirds and water-associated birds (Black Rock versus open water) during the Shore-Based Seabird Survey – Tidal Energy Demonstration Site, Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia.

Peak abundance of birds on Black Rock occurred in the late spring to early-summer (with a peak in mid-April 2017), and winter to early spring. Peak abundances for the survey of 115.5 and 61.4 individuals per 30 minutes were observed on April 17th 2017 and May 1st 2017 respectively. This peak was dominated by Double-crested Cormorant, which made up about 50% of numbers; and Great Black-backed Gull and Herring Gull most of the remainder (Figure 11). These two gulls were also important in the early summer from mid-May to early June 2016; and were the most abundant birds on Black Rock over the winter to early spring. Summer abundance of gulls on Black Rock was low, indicating a general absence from the area, and low importance on Black Rock in summer. Ring-billed Gull which had been relatively abundant in the earlier (2010-2012) baseline surveys occurred occasionally and in small numbers in the summer and in the December survey (Figure 9). Common Eider was present in moderate numbers in the late spring through the summer, and was most abundant in the early summer (June and July, 2016) surveys, when 3.4 and 2.3 birds per 30 minutes were observed, and in the April 3rd and April 17th 2017 surveys (6.3 and 4.7 sightings per 30 minutes respectively). Double-crested Cormorant were present in moderate numbers chiefly from late spring to early October with highest numbers observed on Black Rock on April 17th and May 1st 2017 (61.2 and 28.1 birds per 30-minute period respectively). Black Guillemot is an important species which nests on the island, but which was observed in less than 50% of surveys. Surveys confirmed Black Guillemot, possibly four pairs, nest on Black Rock but were seen most frequently on the water adjacent to it during individual surveys, and their low abundance reflects the short period during which they land on Black Rock to access nesting crevices.

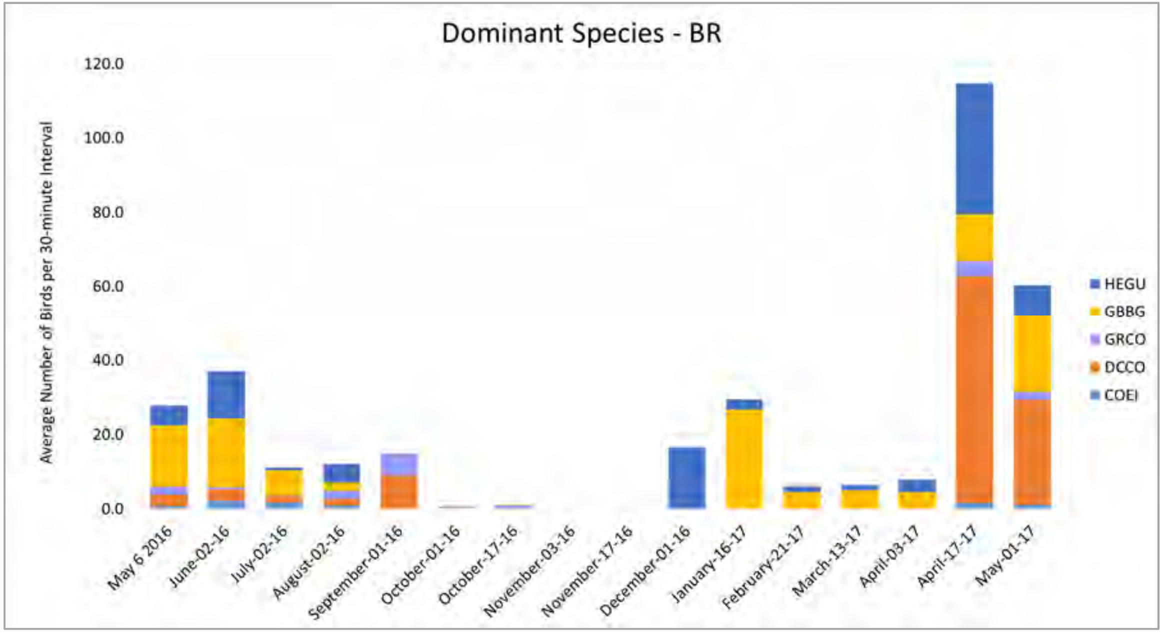

Figure 8. Average abundance of dominant bird species per 30-minute interval on subarea BR (Black Rock).

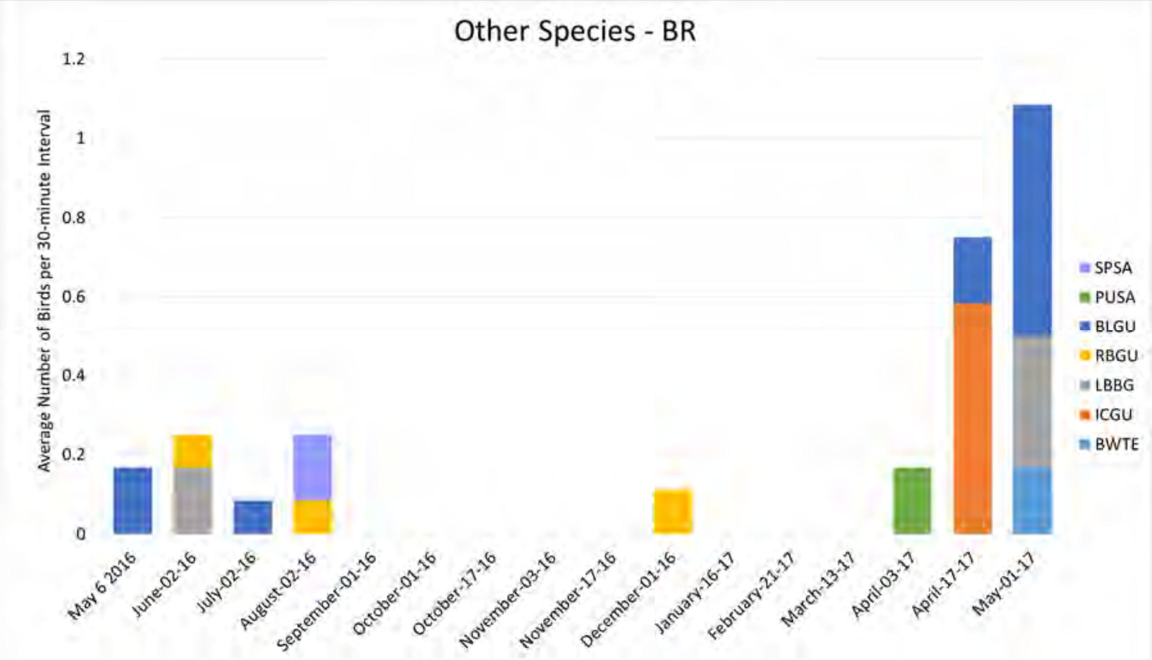

Figure 9. Average abundance of other bird species per 30-minute interval on subarea BR (Black Rock).

Various bird species were observed landing on or flying over Black Rock which are not typically aquatic, including terrestrial and coastal species such as American Crow, American Bald Eagle, Peregrine Falcon, and various songbirds, as well as shorebirds, the latter which are considered aquatic and are included in the analysis. Bald Eagle occurred at the site during several surveys, flying through the area close to shore or landing on the island. Bald Eagles landing on the Black Rock can drive normal resident species away temporarily. Presence of a Bald Eagle on April 17th 2017 appeared to drive gulls and cormorants off Black Rock, as flocks of more than 100 Double-crested Cormorant and Herrings Gull abruptly flew off the island and landed on the water in OB1 when the eagle arrived. An individual male Peregrine Falcon was seen flying parallel to shore in IB1 during the October 1st 2016 survey. This threatened species nests on cliffs in the area, in particular at Cape Sharp located east of the site (AECOM 2009) and commonly feeds on small birds such as shorebirds. The species has been seen on other occasions in the vicinity of the FORCE Visitor Center although not during our surveys and occurrences were not documented.

Purple Sandpiper, a shorebird, landed on Black Rock in early April 2017; and a Spotted Sandpiper was recorded in early August 2016, coincident with the expected southerly shorebird migration through the area. Several individual Iceland Gull and Lesser Black-backed Gull, as well as a Blue-winged Teal, were observed on Black Rock in early May 2017 (Figure 9).

Abundance in Open Water Areas

Use of open water (i.e. areas other than coastal features, flats and islands) by seabirds and other water-associated birds at the FORCE site provides background information useful in assessing trends in distribution and abundance of birds, particularly in areas primarily occupied by tidal energy devices, but also in assessing patterns useful in interpreting observations in later, operational phases of the tidal energy demonstration site. Various factors can influence local distribution of birds overall including closeness to food sources and food abundance, availability of islands and other protection from predators, presence of geographic features such as passages and points which can direct a bird's movements and lead to concentrations, and proximity to colonies and breeding areas, among others.

For the year as a whole, highest average numbers of birds were observed in open water subareas IB1, OB1, and CL (Figure 10). Black Rock is in the middle of areas IB1 and OB1 and the numbers in these areas in part reflect birds landing on or flying from Black Rock. Flocks of scoters and other migratory species, such as Red-throated Loon also travel through these sub areas en route to West Bay and other areas in Minas Basin and outer parts of the Bay of Fundy beyond Minas Passage. For most of the year except during migration, most birds in open water areas at the FORCE site were detected in the IB1 (Inside Black Rock) sub-area (Figures 11-13)[3]. Birds seen here included those which were coming and going from Black Rock but many birds also used the IB1 area in their coastal movements through the area. IB1 had the highest number of birds through the summer and early fall (Figure 11) (from July 2nd to October 1st 2016); and through the winter (Figure 13). IB1 also supported significant numbers of birds during the migration periods of November and April-early May, when overall numbers of birds were seasonally highest; numbers in the nearby CL (Crown Lease) area were also high, and comparable to those in IB1.

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[3] Survey subareas are shown in Figure 2.

Abundance of birds in the CL ("Crown Lease") area was usually a close second to IB1 in the late spring to fall period (beginning May 6, 2016 and extending to October 17th, 2016 (Figure 14) and also figured prominently although at low numbers during the winter (Figure 12)). Numbers in the CL area were highest of all areas in surveys during migration in the November 2016 and April 2017 (Figure 13) when large numbers of scoters moved through the FORCE site. The CL area is immediately 'upstream' or 'downstream' in the tidal currents passing Black Rock depending on tidal stage, and birds on the water in either area frequently drift with the current, before flying upstream to maintain an overall position relative to Black Rock. Most of our surveys were conducted on the ebb tide, with currents flowing from Black rock to the CL area.

The remaining survey areas supported lower numbers of birds than the IB1, OB1 and CL subareas, in particular with lowest abundances in the more removed sites (i.e. the "Farfield" (FF) sites FF1, FF2 & FF3) (which have been grouped together in the analysis). Significant, though low, numbers of birds at the FF sites were observed only in the summer (May 6, 2016) and during migration (November 3, 2016) surveys. This finding suggests that the inner parts of the study area such as IB1, CL and the OB1 to OB3 sites are more attractive to birds than the distant sites, and in particular the complexity of the local environment—which includes the presence of Black Rock as well as other features at the site, such as proximity to the coast, a point of land, a coastal marsh, a sand spit system, and nearby shoreline and tidal flats—may attract seabirds to the area. We don't think that this observation of is due to 'distance effects' (i.e. that some observations in the furthest sites will be missed, due to increasing difficulty in accounting for all birds with distance from the observation site)(Buckland et al 2001; Gjerdrum et. al. 2012); although some birds at the furthest locations are most certainly missed in our survey protocol, the contribution of this effect is thought to be small, although the assumption wasn't evaluated in the current study. The IB2 site, situated west along the coast from Black Rock, and the OB ("Outside Black Rock") sites OB2 and OB3 usually supported lower numbers of birds than IB1, OB1 and CL, although both subareas had higher numbers in the May 6, 2016 survey. The OB3 site, which is near the CL site and is also close to Black Rock, also supported comparable numbers of birds to the other sites on occasion. OB1 had the highest number of birds on the April 17, 2017 survey when all the sub-areas around Black Rock and the CL area, and including OB3 supported significant numbers of migrating birds (Figure 13). Species occurring in these subareas, and their relative abundance, are summarized in Figures 17-28 and Table 4.

Table 4. Average abundance of seabirds and water-associated birds (number per 30-minutes) at the FORCE Tidal Energy Demonstration Site, Black Rock, Nova Scotia, 2016-2017. Number in brackets is standard deviation.

Total Bird Abundance								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016	0.33 (0.78)	0.33 (0.89)	0.92 (1.24)	0.67 (0.98)	1.17 (1.47)	0.17 (0.39)	1.42 (2.31)	28.75 (11.29)
June.2.2016	1.83 (2.55)	2 (2.37)	0.33 (0.89)	0.75 (0.97)	0.33 (0.89)			37.25 (10.14)
Jul.2.2016	1.58 (2.35)	3.83 (2.17)		0.5 (0.67)		0.25 (0.45)	0.08 (0.29)	11.67 (2.53)
Aug.2.2016	1.75 (1.71)	3.75 (2.42)		1 (1.35)		0.42 (1)	0.17 (0.58)	12.33 (6.47)
Sep.1. 2016	3.33 (5.35)	3.58 (2.75)		0.17 (0.39)		0.08 (0.29)		14.75 (5.89)
Oct.1, 2016	0.67 (0.78)	5.17 (6.62)		0.58 (1.24)		0.92 (2.11)	0.58 (0.9)	0.67 (0.98)
Oct.17.2016	0.33 (0.49)	1.83 (2.21)		0.58 (1)		0.25 (0.45)		1.08 (1)
Nov.3.2016	25.83 (57.24)	1.42 (2.87)		3.17 (6.39)		1.83 (4.88)	6.25 (21.65)	
Nov.17.2016	6 (10.48)	1 (1.6)		0.25 (0.45)		0.5 (1.45)	0.25 (0.62)	
Dec.1.2016	0.08 (0.29)	0.83 (1.53)						12.5 (43.3)
Jan.16.2017	0.5 (1.17)	20.58 (59.78)		0.75 (2.6)			0.08 (0.29)	24.58 (41.45)
Feb.21.2017	0.42 (0.9)	2.5 (2.47)		0.17 (0.58)				6.08 (15.44)
Mar.13.2017	0.33 (0.49)	0.92 (1.44)		0.17 (0.39)				6.5 (5.99)
Apr.2.2017	1.75 (4.52)	7.83 (22.77)	0.58 (2.02)	1.92 (5.73)		0.92 (2.61)		7.92 (11.1)
Apr.17.2017	46.83 (62.76)	26.25 (51)	0.5 (1.73)	60.75 (58.35)	0.58 (2.02)	16.67 (57.74)		115.5 (63.43)
May.1.2017	5.67 (8.82)	3.5 (2.84)		4.33 (6.51)	0.5 (1.73)			61.42 (15.31)
Black Guillemot								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016			0.09 (0.3)	0.27 (0.65)				0.18 (0.4)
June.2.2016	0.08 (0.29)	0.5 (1)		0.25 (0.45)				
Jul.2.2016	0.08 (0.29)	1.08 (1)			0.17 (0.39)			0.17 (0.39)
Aug.2.2016	0.42 (0.67)	0.58 (1.44)				0.17 (0.58)		
Apr.2.2017	0.08 (0.29)	0.08 (0.29)				0.08 (0.29)		
Apr.17.2017				0.08 (0.29)				0.17 (0.58)
May.1.2017		0.75 (1.14)		0.08 (0.29)				0.58 (0.79)
Black Scoter								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016	0.18 (0.6)		0.09 (0.3)					
Aug.2.2016				0.08 (0.29)				
Oct.1, 2016				0.17 (0.58)	0.75 (2.6)			
Oct.17.2016		0.5 (1.73)						
Nov.3.2016	21.42 (56.72)			2.58 (6.47)	1 (3.46)	1.42 (4.91)	6.25 (21.65)	
Apr.2.2017	0.42 (1.44)	0.33 (1.15)						
Apr.17.2017	10.17 (17.72)	8.58 (27.31)		32.33 (37.4)				
May.1.2017				0.92 (1.78)				

Table 4. Average abundance of seabirds and water-associated birds (number per 30-minutes) at the FORCE Tidal Energy Demonstration Site, Black Rock, Nova Scotia, 2016-2017. Number in brackets is standard deviation.

Common Loon								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016			0.09 (0.3)					
June.2.2016	0.25 (0.45)	0.08 (0.29)		0.08 (0.29)				
Aug.2.2016				0.08 (0.29)				
Oct.1, 2016	0.08 (0.29)	0.92 (0.29)						
Oct.17.2016				0.08 (0.29)				
Nov.3.2016		0.08 (0.29)						
Nov.17.2016	0.09 (0.3)							
Jan.16.2017	0.2 (0.42)	0.1 (0.32)						
Mar.13.2017		0.08 (0.29)						
Apr.17.2017	0.08 (0.29)			1.92 (3.12)				
Common Eider								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016			0.64 (1.21)					0.82 (0.98)
June.2.2016	1.17 (1.75)	0.25 (0.45)						2.17 (2.66)
Jul.2.2016	1.08 (2.02)	0.50 (1.17)						1.25 (1.29)
Aug.2.2016		0.58 (1.00)						0.83 (0.83)
Oct.17.2016		0.75 (0.97)						
Nov.3.2016		0.08 (0.29)						
Nov.17.2016		0.64 (1.57)						
Jan.16.2017	0.40 (1.26)							
Mar.13.2017		0.42 (1.44)						
Apr.2.2017		6.25 (21.65)						
Apr.17.2017		0.33 (0.65)		2.42 (5.65)				1.58 (1.44)
May.1.2017	1.17 (2.76)							1.17 (1.64)
American Black Duck								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
Oct.1, 2016		0.33 (1.15)						
Dec.1.2016		0.22 (0.67)						
Jan.16.2017		0.30 (0.95)						
Mar.13.2017		0.42 (1.44)						
Apr.2.2017		0.08 (0.29)	0.58 (2.02)					
White-winged Scoter								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
Oct.17.2016		0.08 (0.29)						

Table 4. Average abundance of seabirds and water-associated birds (number per 30-minutes) at the FORCE Tidal Energy Demonstration Site, Black Rock, Nova Scotia, 2016-2017. Number in brackets is standard deviation.

Apr.17.2017				0.58 (1.08)				
Surf Scoter								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
Nov.3.2016					1 (3.46)			
Apr.17.2017	11.83 (40.37)	0.42 (1.44)		15.42 (48.78)				
May.1.2017	0.5 (1.73)			2.42 (6.11)				
Red-throated Loon								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016		0.09 (0.3)				0.09 (0.3)	0.73 (1.56)	
June.2.2016	0.08 (0.29)	0.08 (0.29)						
Jul.2.2016							0.08 (0.29)	
Oct.1, 2016	0.08 (0.29)							
Nov.3.2016	0.17 (0.39)			0.17 (0.58)	0.25 (0.45)	0.42 (1)		
Nov.17.2016	4 (11.05)	0.18 (0.4)		0.09 (0.3)	1.27 (2.65)	0.45 (1.21)	0.09 (0.3)	
Feb.21.2017	0.08 (0.29)				0.08 (0.29)			
Mar.13.2017	0.17 (0.39)							
Apr.2.2017	0.33 (1.15)							
Apr.17.2017	4.83 (6.06)	1 (2.66)		1.67 (3.58)	0.25 (0.87)	8.33 (28.87)		
May.1.2017	0.17 (0.39)	0.33 (1.15)		0.42 (0.67)	0.08 (0.29)			
Common Merganser								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
Nov.17.2016		0.56 (1.67)						
Red-breasted Merganser								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
Oct.1, 2016	0.08 (0.29)							
Apr.2.2017		0.08 (0.29)						
Apr.17.2017		0.58 (1.24)						
May.1.2017	0.08 (0.29)			0.17 (0.58)				
Ring-billed Gull								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
June.2.2016								0.08 (0.29)
Aug.2.2016	0.67 (1.37)	0.92 (1.16)		0.75 (1.22)	0.5 (0.67)		0.08 (0.29)	0.08 (0.29)
Sep.1. 2016	1.5 (3.32)	0.5 (0.8)		0.08 (0.29)	0.08 (0.29)			
Oct.1, 2016	0.25 (0.62)	0.17 (0.39)		0.08 (0.29)			0.17 (0.39)	
Oct.17.2016					0.08 (0.29)			
Nov.17.2016		0.09 (0.3)		0.18 (0.4)	0.18 (0.6)			

Table 4. Average abundance of seabirds and water-associated birds (number per 30-minutes) at the FORCE Tidal Energy Demonstration Site, Black Rock, Nova Scotia, 2016-2017. Number in brackets is standard deviation.

Dec.1.2016								0.11 (0.33)
Apr.17.2017		0.33 (1.15)						
Double-crested Cormorant								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016		0.18 (0.6)	0.27 (0.9)	0.18 (0.4)				3.27 (1.85)
June.2.2016	0.33 (0.78)	0.58 (1.24)	0.25 (0.87)					3.08 (2.23)
Jul.2.2016		0.08 (0.29)			0.08 (0.29)			2 (1.21)
Aug.2.2016	0.08 (0.29)	0.33 (0.49)						1.83 (1.19)
Sep.1. 2016	0.08 (0.29)	1.58 (1.93)		0.08 (0.29)				8.92 (2.5)
Oct.1, 2016	2.67 (7.7)	0.58 (0.79)						0.25 (0.62)
Oct.17.2016								0.08 (0.29)
Apr.17.2017		10.67 (23.89)		1.17 (3.01)	0.5 (1.73)			61.17 (38.61)
May.1.2017		0.83 (1.19)		0.17 (0.39)	0 (0)			28.08 (10.15)
Great Cormorant								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016								2.36 (2.66)
June.2.2016	0.08 (0.29)	0.17 (0.39)						0.5 (0.67)
Jul.2.2016								0.17 (0.58)
Aug.2.2016	0.08 (0.29)			0.08 (0.29)				2.17 (1.03)
Sep.1. 2016	0.17 (0.39)							5.75 (6.48)
Oct.1, 2016		0.42 (0.67)		0.17 (0.58)				0.42 (0.51)
Oct.17.2016				0.08 (0.29)				1 (0.95)
Feb.21.2017	0.25 (0.87)							
Mar.13.2017				0.08 (0.29)				0.08 (0.29)
Apr.17.2017								4.17 (3.83)
May.1.2017								2.25 (1.76)
Great Black-backed Gull								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016	0.09 (0.3)	0.09 (0.3)		0.27 (0.9)		0.09 (0.3)	0.09 (0.3)	18.91 (3.88)
June.2.2016		0.17 (0.39)		0.58 (0.79)	0.08 (0.29)			18.5 (4.83)
Jul.2.2016	0.08 (0.29)	0.5 (0.67)		0.5 (0.67)				7.08 (1.44)
Aug.2.2016		0.08 (0.29)						2.25 (0.87)
Oct.1, 2016		0.08 (0.29)						
Oct.17.2016	0.08 (0.29)							0.08 (0.29)
Nov.3.2016								0.08 (0.29)
Dec.1.2016	0.11 (0.33)							0.11 (0.33)
Jan.16.2017		0.6 (1.58)		0.2 (0.63)				26.7 (39.1)

Table 4. Average abundance of seabirds and water-associated birds (number per 30-minutes) at the FORCE Tidal Energy Demonstration Site, Black Rock, Nova Scotia, 2016-2017. Number in brackets is standard deviation.

Feb.21.2017					0.25 (0.87)			4.58 (12.03)
Mar.13.2017								4.92 (2.19)
Apr.2.2017		0.08 (0.29)	0.08 (0.29)			0.33 (1.15)		4.5 (4.7)
Apr.17.2017			0.08 (0.29)		0.08 (0.29)	4.17 (14.43)		12.67 (6.18)
May.1.2017		0.25 (0.45)		0.25 (0.62)				20.42 (8.12)
Herring Gull								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
May.6.2016	0.09 (0.3)				0.09 (0.3)		0.45 (0.82)	5.82 (2.93)
June.2.2016		0.17 (0.39)	0.08 (0.29)					12.75 (6.97)
Jul.2.2016	0.33 (0.65)	1.67 (2.1)			1 (1.41)	0.25 (0.45)		1 (1.04)
Aug.2.2016	0.33 (0.78)	1.25 (1.86)		0.08 (0.29)	0.17 (0.39)		0.08 (0.29)	5 (5.98)
Sep.1. 2016	1.25 (2.01)	1.5 (1.57)			0.17 (0.39)	0.08 (0.29)		0.08 (0.29)
Oct.1, 2016	0.17 (0.39)	2.67 (6.85)		0.08 (0.29)	0.17 (0.39)	0.92 (2.11)	0.42 (0.9)	
Oct.17.2016	0.25 (0.45)	0.5 (1.24)		0.42 (1)	0.33 (1.15)	0.25 (0.45)		
Nov.3.2016	3.58 (11.5)	1.25 (2.9)		0.42 (0.51)	0.08 (0.29)			
Nov.17.2016	0.64 (0.67)	0.27 (0.9)			0.09 (0.3)		0.18 (0.4)	
Dec.1.2016		0.33 (0.71)						16.44 (49.33)
Jan.16.2017	0.1 (0.32)	21.5 (66.24)		0.7 (2.21)			0.1 (0.32)	2.8 (5.9)
Feb.21.2017		0.33 (0.65)		0.17 (0.58)	1.42 (4.91)			1.5 (3.45)
Mar.13.2017	0.17 (0.39)	0.92 (1.44)		0.08 (0.29)				1.5 (4.3)
Apr.2.2017	0.08 (0.29)	0.33 (0.65)		0.25 (0.62)	0.75 (2.6)	0.5 (1.24)		3.25 (6.88)
Apr.17.2017	4.17 (14.43)	0.25 (0.45)	0.42 (1.44)	0.08 (0.29)	0.25 (0.87)	4.17 (14.43)		35.17 (41.56)
May.1.2017	0.58 (1)	1 (1.13)						8.42 (4.14)
Long-tailed Duck								
SUBAREA	CL	IB1	IB2	OB1	OB2	OB3	FF	BR
Nov.3.2016	0.42 (1.44)							
Nov.17.2016	0.27 (0.9)							
Apr.17.2017	15.25 (40.02)	3.33 (11.55)		4.92 (13.66)				
May.1.2017	0.5 (1.45)							

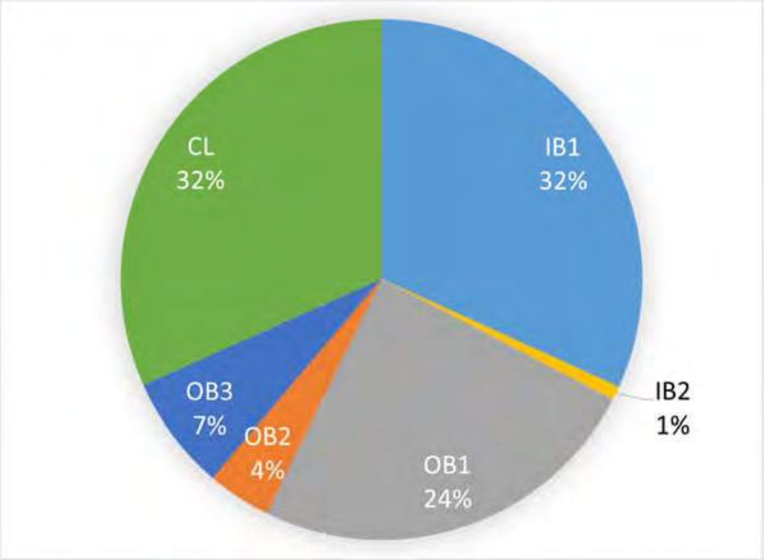

Figure 10. Average abundance of birds by subarea, as a proportion of the total for Year-One of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017). Total includes birds flying or on the water; and sitting on or in the water immediately adjacent to Black Rock (BR).

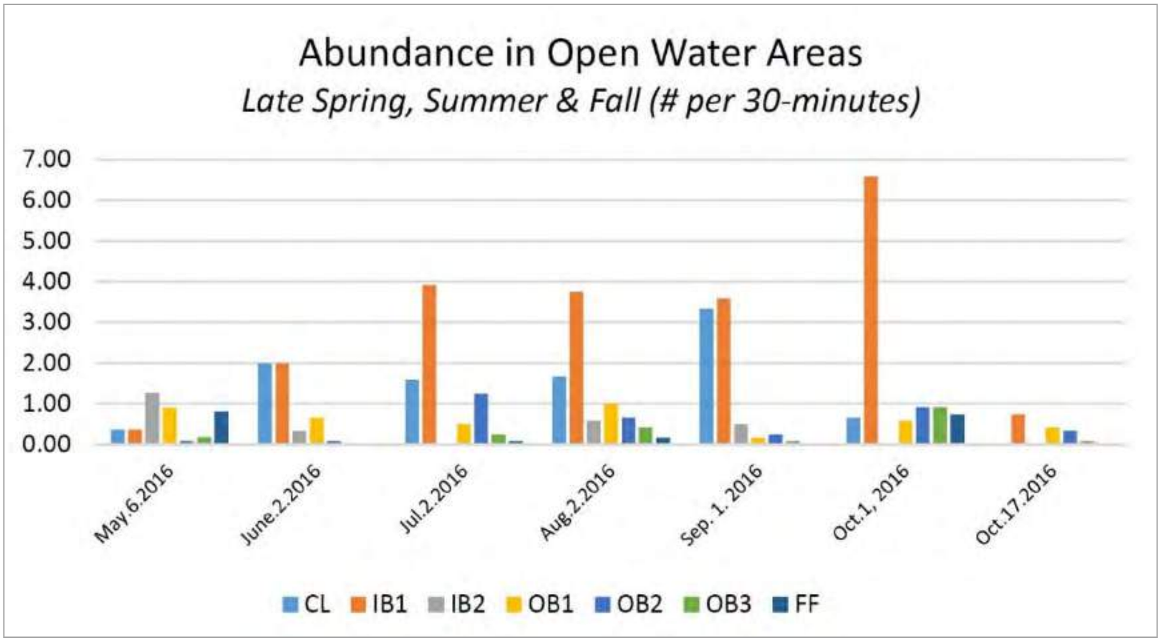

Figure 11. Utilization by seabirds of sub-areas of the FORCE site in late spring, summer and fall.

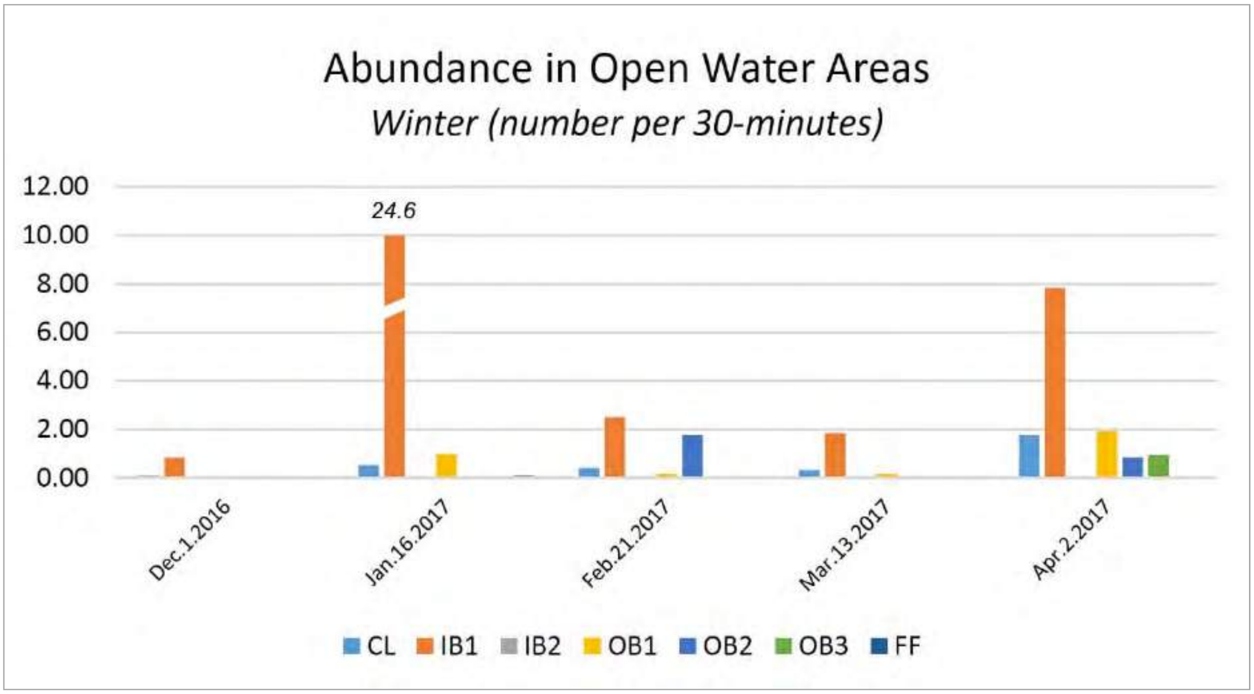

Figure 12. Utilization by seabirds of sub-areas of the FORCE site in winter to early spring.

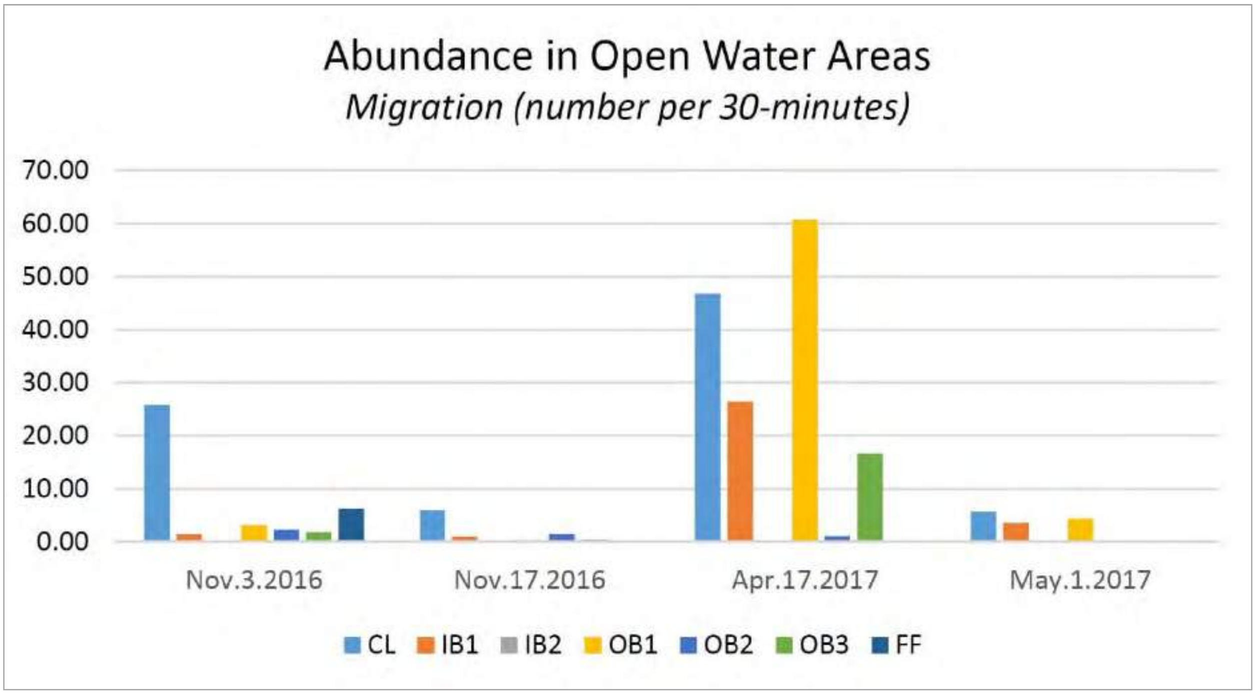

Figure 13. Utilization by seabirds of sub-areas of the FORCE site in migration periods.

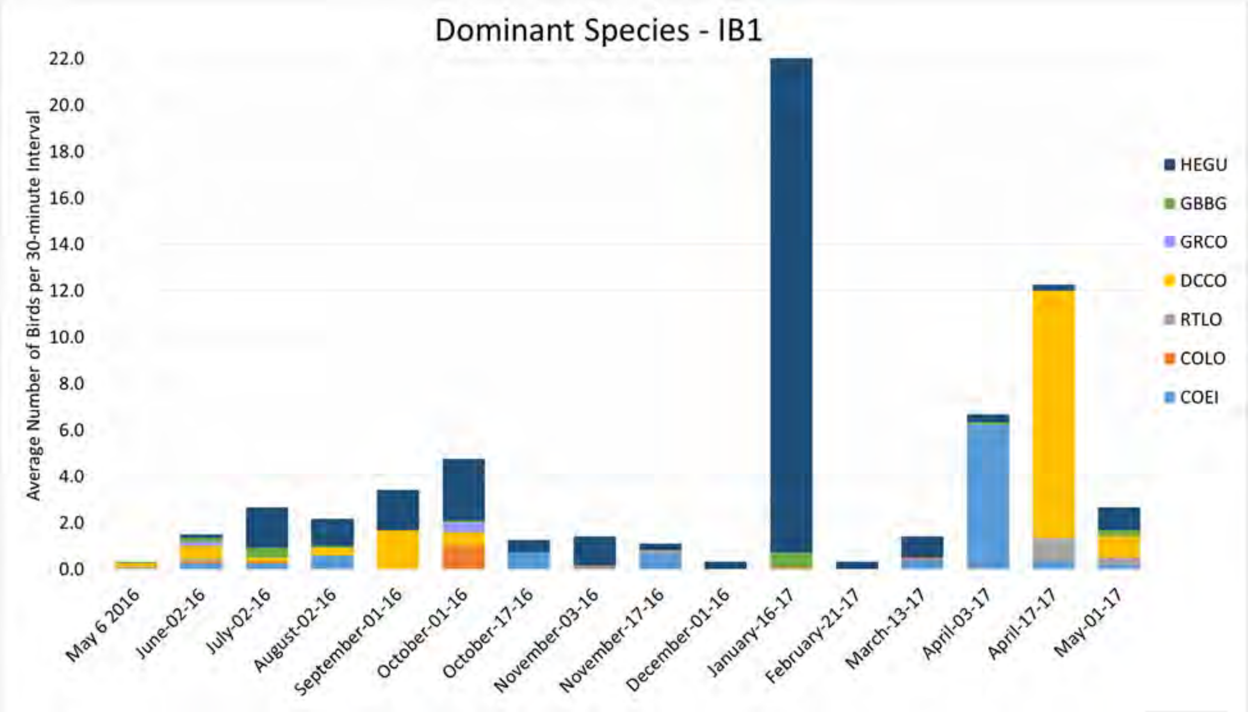

Figure 14. Average abundance of dominant birds per 30-minute interval in subarea IB1.

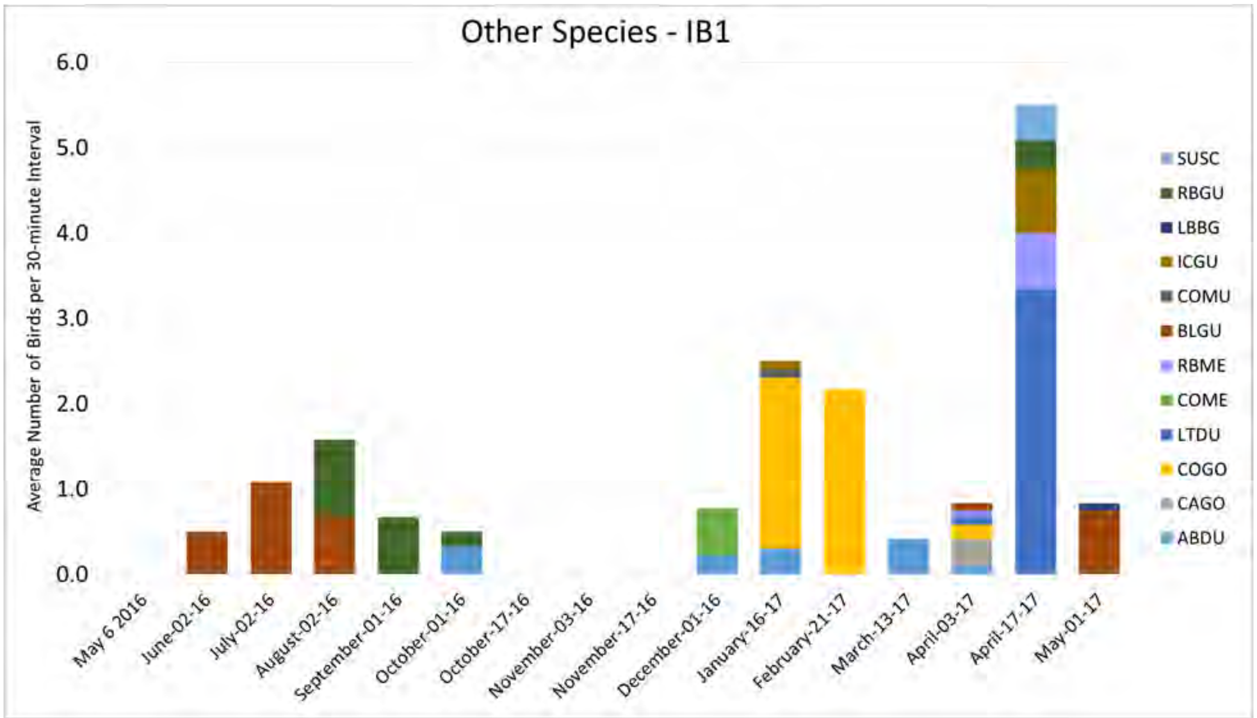

Figure 15. Average abundance of other birds per 30-minute interval in subarea IB1.

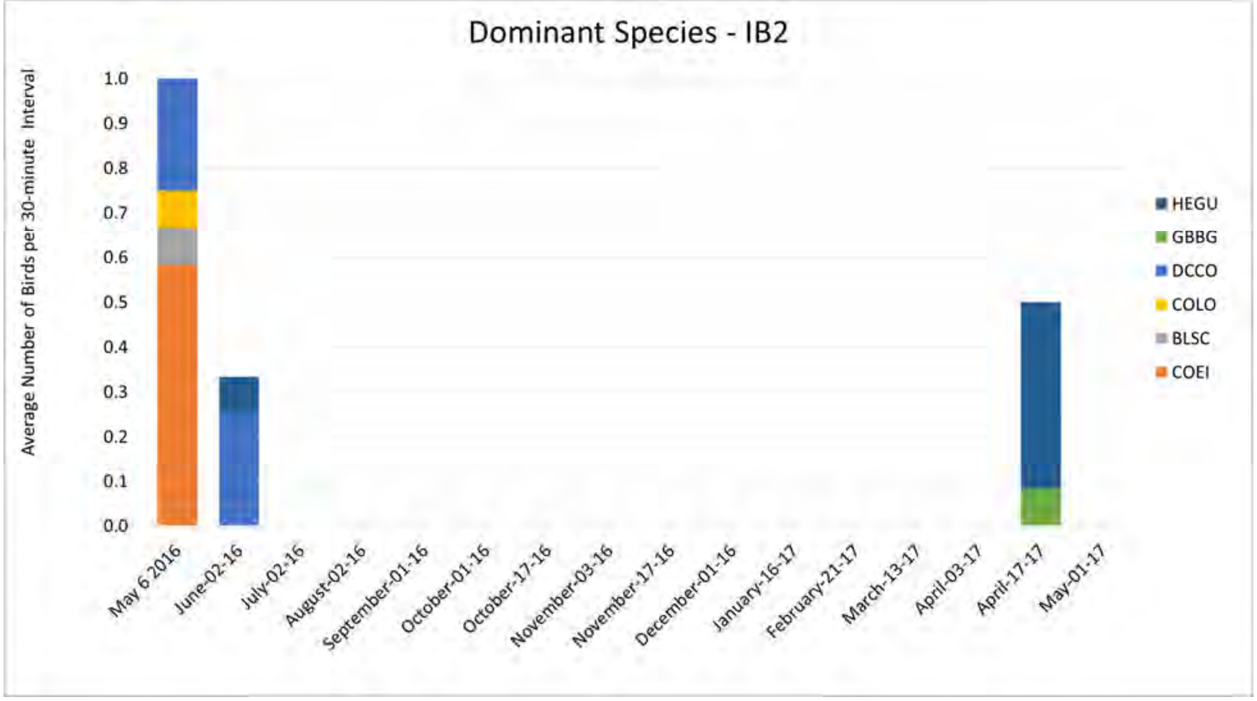

Figure 16. Average abundance of dominant birds per 30-minute interval in subarea IB2.

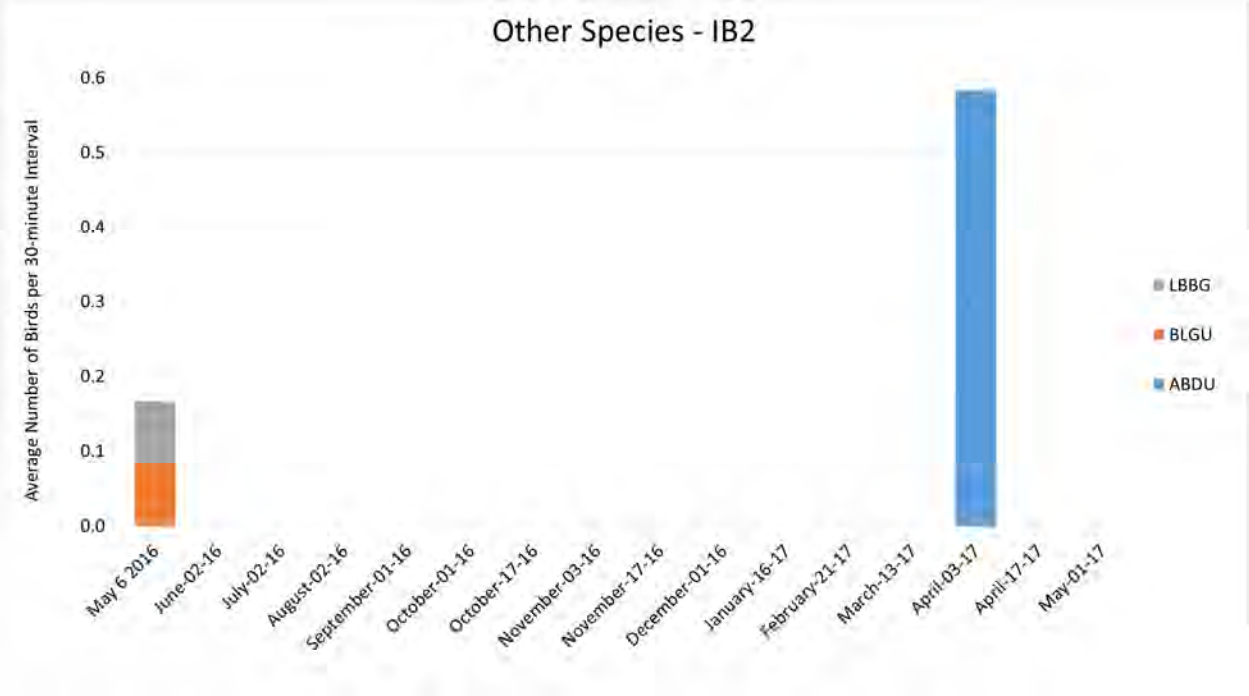

Figure 17. Average abundance of other birds per 30-minute interval in subarea IB2.

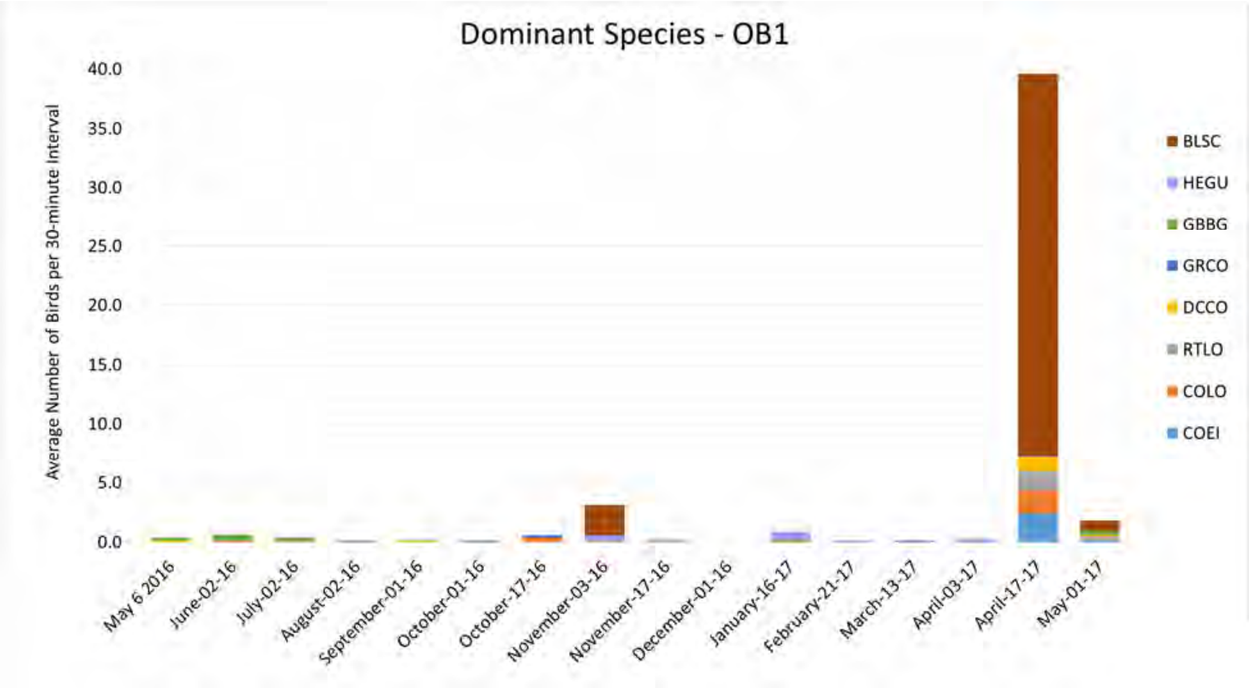

Figure 18. Average abundance of dominant birds per 30-minute interval in subarea OB1.

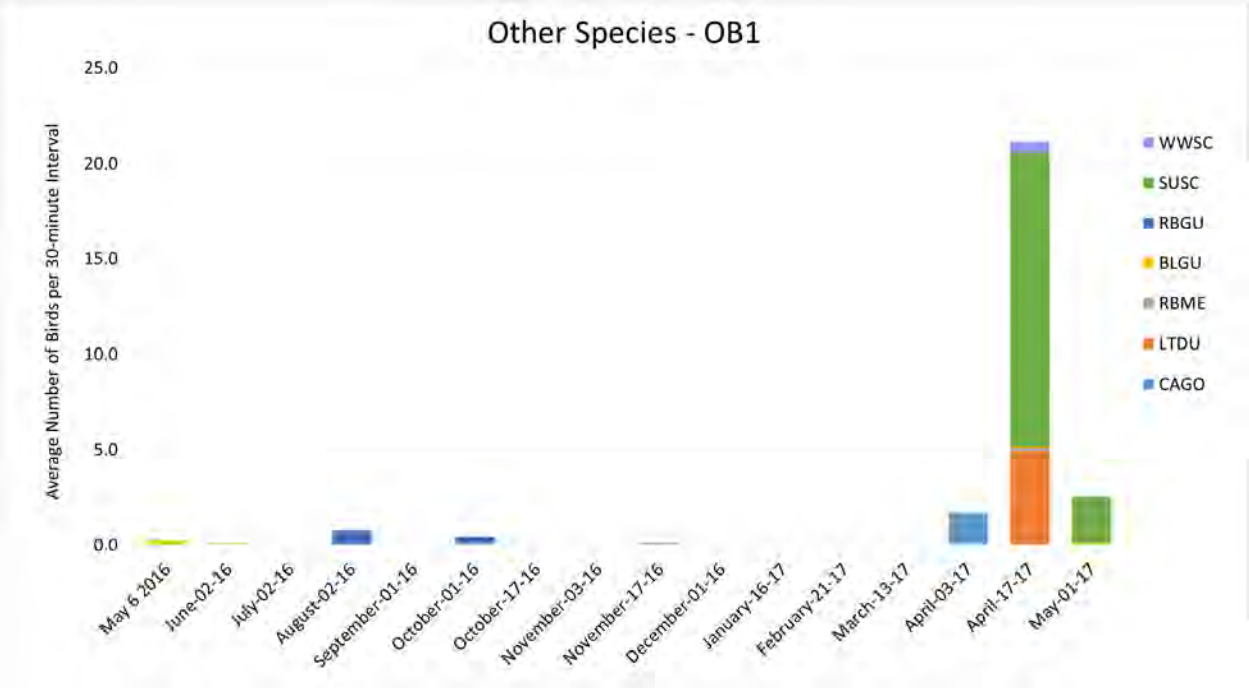

Figure 19. Average abundance of other birds per 30-minute interval in subarea OB1.

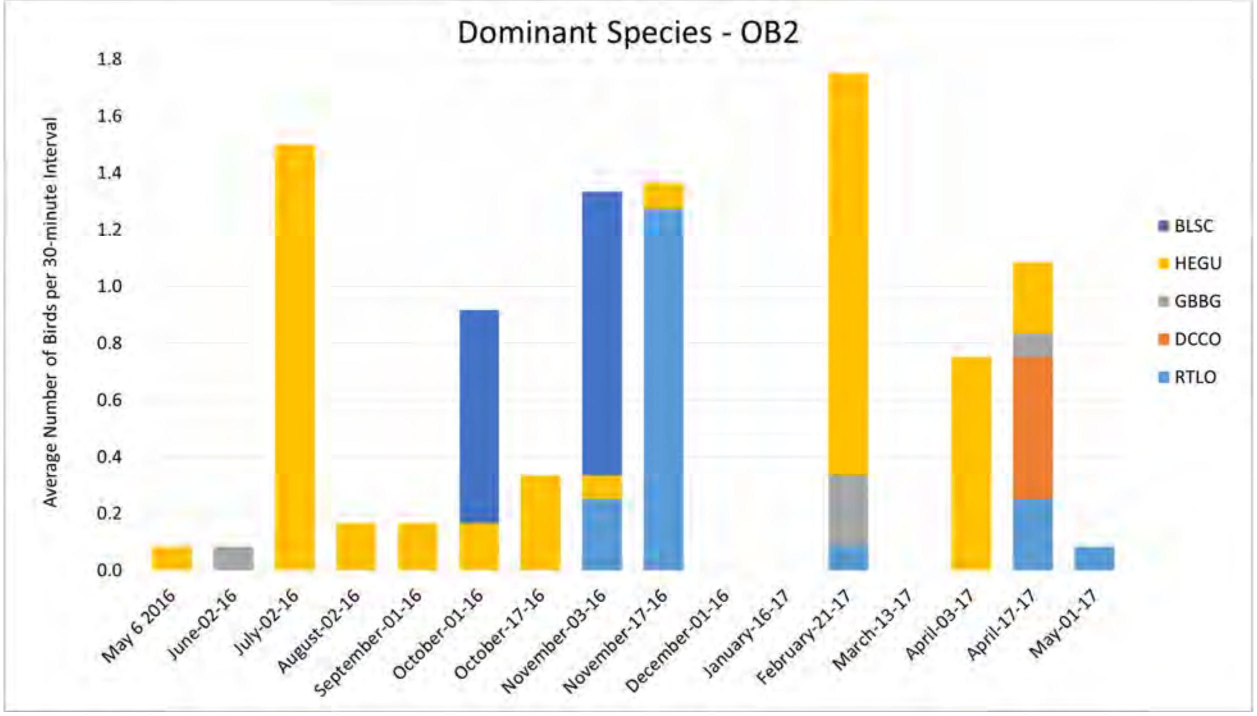

Figure 20. Average abundance of dominant birds per 30-minute interval in subarea OB2.

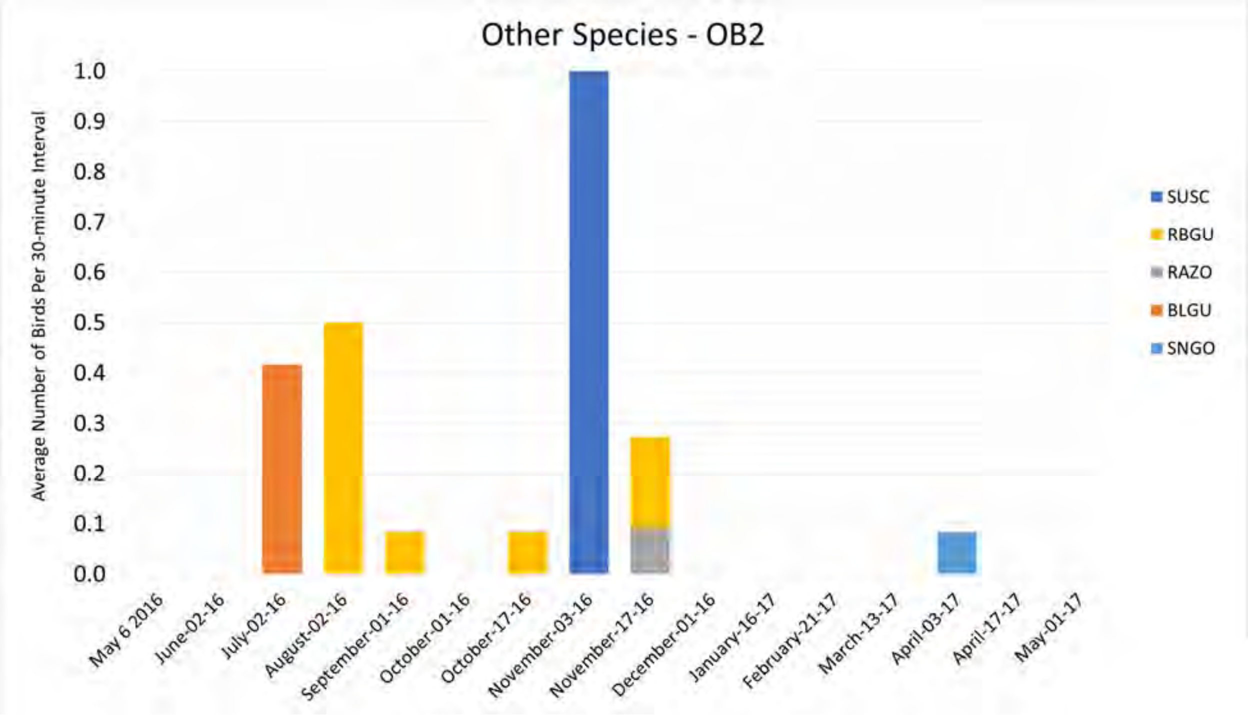

Figure 21. Average abundance of other birds per 30-minute interval in subarea OB2.

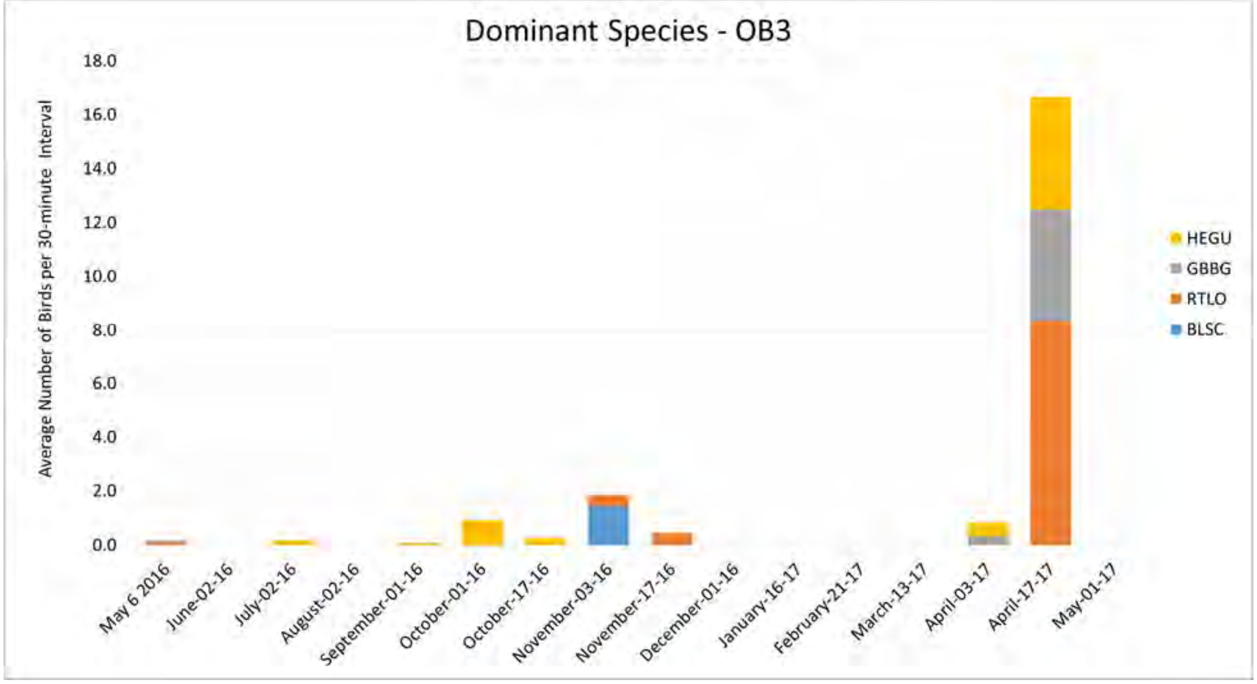

Figure 22. Average abundance of dominant birds per 30-minute interval in subarea OB3.

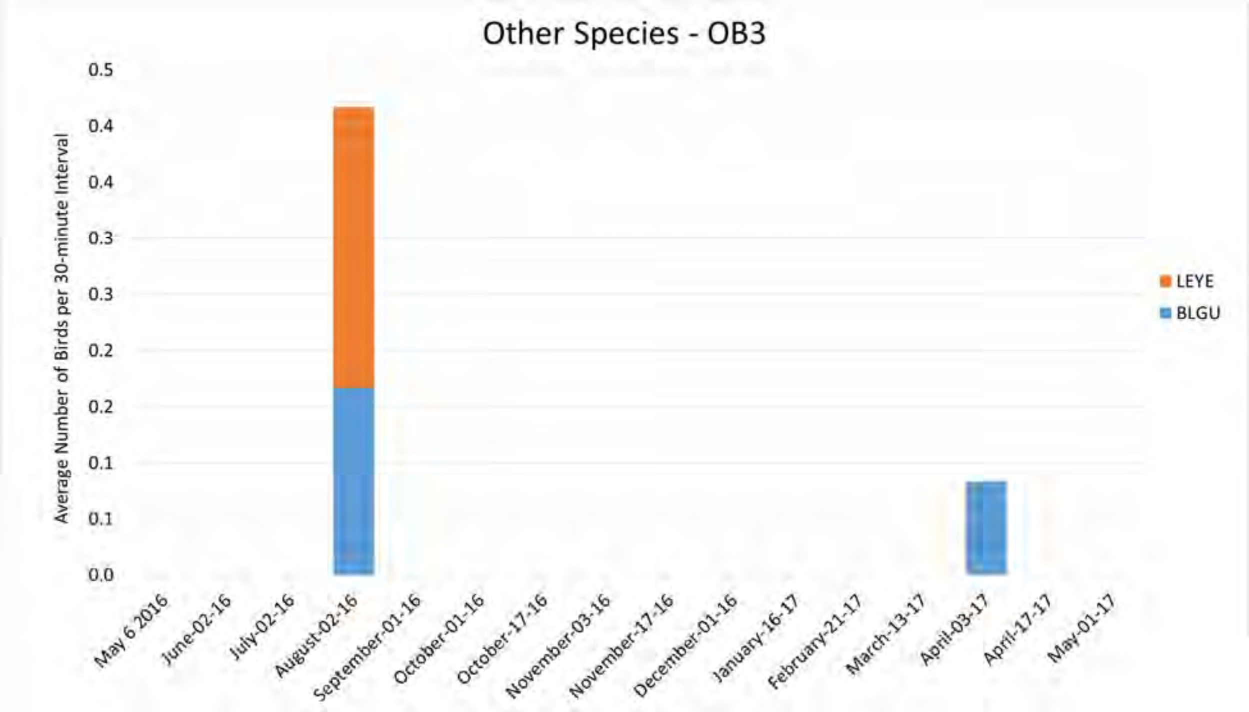

Figure 23. Average abundance of other birds per 30-minute interval in subarea OB3.

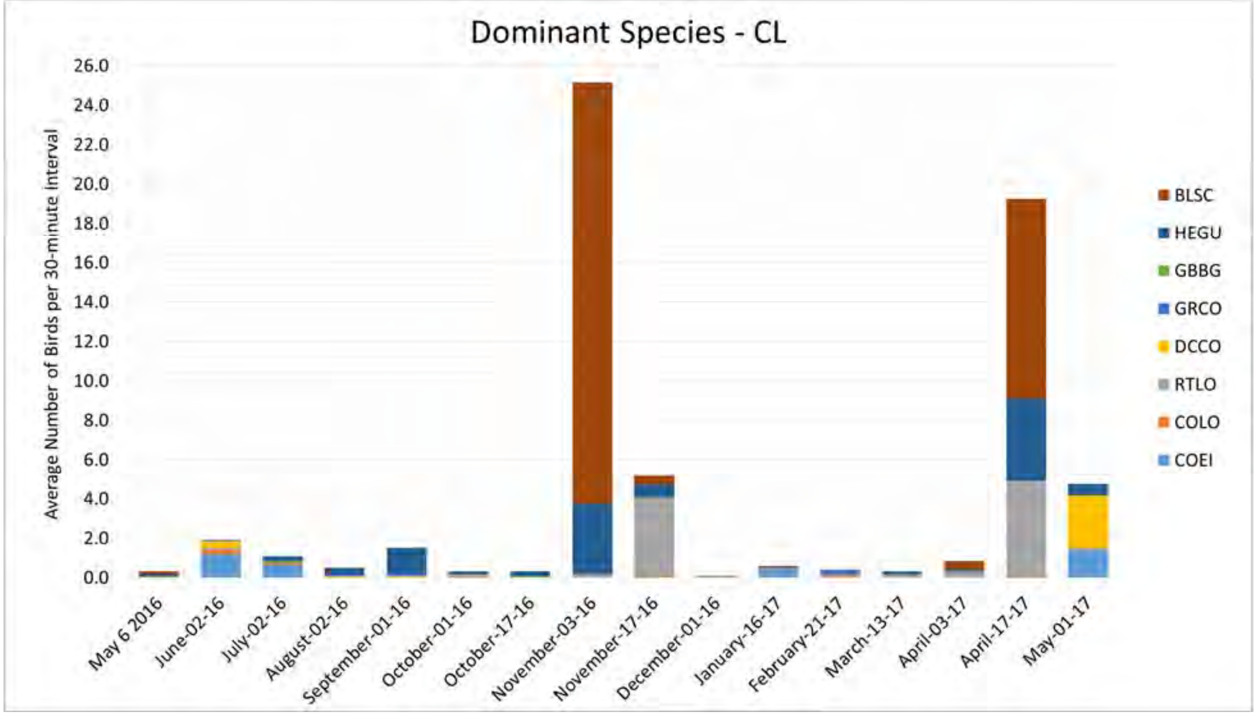

Figure 24. Average abundance of dominant birds per 30-minute interval in subarea CL.

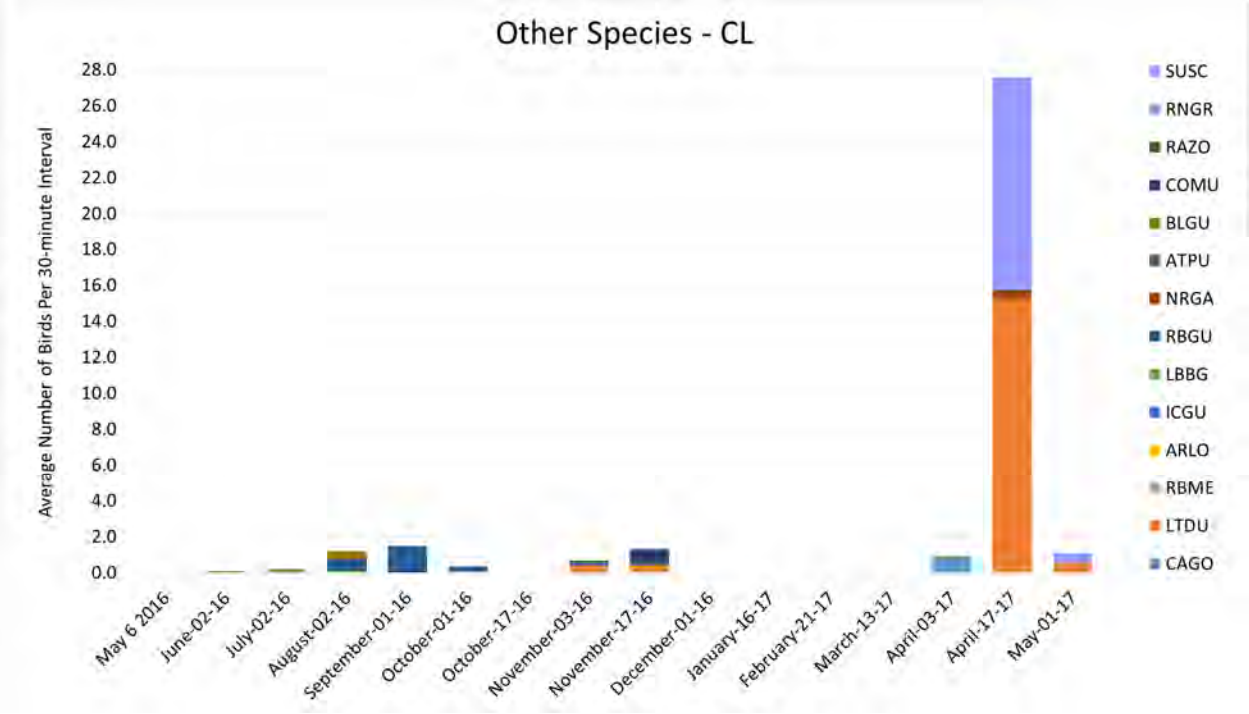

Figure 25. Average abundance of other birds per 30-minute interval in subarea CL.

3.1.3 Species Composition Based on Seasonality

3.1.3.1 Dominant Species

Dominant bird species [4] included Black Scoter, Common Eider, Common and Red-throated Loon, Double-crested Cormorant and Great Cormorant, as well as Herring Gull and Great Black-backed Gull (Figures 26 and 27). Common Eider, both cormorants, and both dominant gulls, are common seasonal residents and breeders in Atlantic Canada and the Bay of Fundy. Common Loon breed on lakes and are commonly seen in Atlantic coastal waters in summer, and overwinter in coastal areas. Black Scoter and Red-throated Loon are migratory species which pass through the Bay of Fundy at certain times of year, although individuals can often be found year-round.

Common Eider – Common Eider is a diving duck species and a common breeder on islands and shorelines of the Bay of Fundy. The species feeds in shallow water and occasionally deeper to reach shellfish and other aquatic organisms. Common Eider was observed on consecutive surveys during the breeding season (May 6 – August 2, 2016; March 13 – May 1, 2017) and intermittently during the fall and early winter (Figure 26). Overall, densities were low with small numbers including both males and females, observed on the water in IB1, close to and on Black Rock or near shore. Average abundance was highest on April 3rd 2017 (6.3 birds per 30-minute interval) and lowest on November 3rd 2016 (0.1 birds per 30-minute interval) (Figure 27).

Double-crested and Great Cormorant –Double-crested and Great Cormorant are colonial resident species in the area, nesting and breeding in the inner Bay of Fundy and migrating through the study site during spring and fall, but also found at other times of year. Cormorants feed primarily on fish which they catch through diving. Great Cormorant is the least abundant of the two and is known to dive deeper and feed farther offshore than other cormorant species.

Both species were observed at the site through the year, when they were commonly seen resting on Black Rock. Overall, Double-crested Cormorant was the most abundant cormorant observed. Abundances were relatively low for both species during the 2016 spring and early fall surveys, (May 6th to October 17th 2016) (Figure 26), with highest abundance for both species recorded on September 1st 2016 (Double-crested Cormorant – 10.5 birds per 30-minute interval; Great Cormorant – 5.9 birds per 30-minute interval) (Figure 30). Peak abundances for the year for Double-crested Cormorant were recorded on April 17th and May 1st 2017. (79.8 and 31.8 birds per 30-minute interval, respectively); while Great Cormorant abundances on those surveys were similar to those in the other surveys (4.2 and 2.3 birds per 30-minute interval, respectively) (Figure 27). Both species occurred through the winter, and, in particular, a group of three Great Cormorants were observed on February 21st flying east through CL. Groups of Double-crested Cormorants were occasionally observed taking flight from Black Rock and landing on the water upstream in relation to the tide, in particular in CL on the incoming tide, to feed while drifting eastward towards and then returning to Black Rock.

Common Loon and Red-throated Loon – Common Loon and Red-throated Loon were observed occasionally throughout the survey (Figure 26). Individual Common Loon were most commonly seen flying eastward through CL and IB1, and occasionally through OB1. Individuals were also frequently seen on the water, feeding and/or drifting in IB1. Highest average abundance for Common Loon occurred on

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[4] Dominant species are defined as those which were observed on at least 50% of the surveys.

April 17th, 2017 (2.0 birds per 30-minute interval) (Figure 27). Common Loon is a year-round resident, frequently found in coastal areas, but habitat also includes freshwater lakes, in particular during its spring and summer breeding season.

Red-throated Loon was the most abundant loon, occurring throughout the year, but peaking in abundance in the spring and during fall during migration (October 1st, November 3rd and 17th 2017) (Figures 29 and 30), during which the species returns from Arctic breeding sites to US northeast Atlantic coastal areas to overwinter. Peak abundance was observed during the spring migration on April 17th, 2017 when large flocks of Red-throated Loon were observed at the site, and birds were frequently seen on the water, feeding and drifting with the tidal stream, generally in CL and OB1.

Black Scoter – Black Scoter are large sea ducks which feed by diving in shallow waters where they feed on shellfish and other bottom-dwelling organisms. The species is a regular migrant, passing through the Bay of Fundy in spring and fall, commonly accompanied by Surf Scoters and White-winged Scoters, with individuals also seen occasionally throughout the year. Black Scoter were observed on consecutive surveys, typically in large flocks, during the fall and spring migration (Figures 26 & 27). Peak abundances of Black Scoter occurred during two surveys; November 3rd, 2016 and April 17th, 2017. An average of 33 birds per 30-minute interval were observed on November 3rd, including a flock of over 100 birds. Black Scoter were typically seen flying east into West Bay, or on the water drifting. A peak of 51 birds per 30-minute interval occurred on April 17th, including flocks of over 100 birds (Figure 30) seen on the water in CL. Like the cormorants, many scoters used the tidal current, drifting with the tide until close to Black Rock, and then flew back to the outer boundary of CL, landed, and drifted east again. As the tide shifted to ebb stage, during the last hour of the survey, the birds drifted west with the current before returning to the water near Black Rock.

3.1.3.2 Gulls (Lariidae)

Herring and Great Black-backed Gull are both common, annual breeders, nesting on islands and seacliffs year-round in the Bay of Fundy region, and both species were dominant sat the site. Herring Gull were observed year-round, during all surveys; and Great Black-backed Gull on all but two surveys late in the year (September 1st and November 17th 2016). Other gulls—Iceland Gull, Ring-billed Gull, and Lesser Black-backed Gull—also occurred at the site, but less frequently and in lower abundances. Gulls in coastal areas feed mainly by scavenging along shores and at the water surface, and as well can prey on juveniles of other bird species.

Herring Gull – Herring Gull was the most common gull species, observed during all surveys, often sitting on Black Rock, flying in and out of the study area, and circling above the subareas searching for food. During several surveys, Herring Gull abundance dramatically increased during the last hour or less of observations, nearing dusk, as the gulls flew in from the south and southwest and landed on Black Rock presumably to roost (i.e. December 1st 2016; January 16th 2017; April 17th 2017). Abundance was generally consistent throughout the year, with peak abundances on January 16th (25.3 birds per 30-minute interval—attributed to birds flying to Black Rock to roost), and April 17th 2017 (44.5 birds per 30-minute interval) (Table 4, Figures 28 and 29).

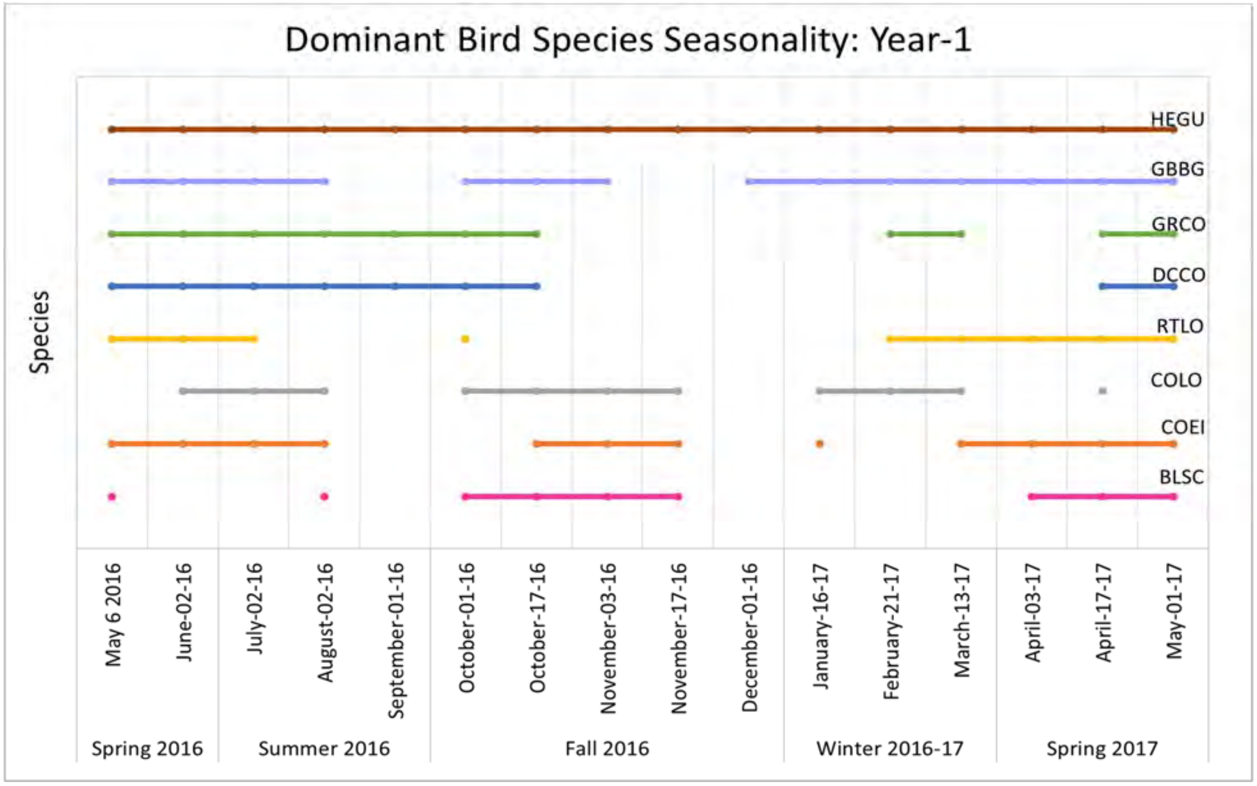

Figure 26. Seasonal occurrence of dominant bird species based on season for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

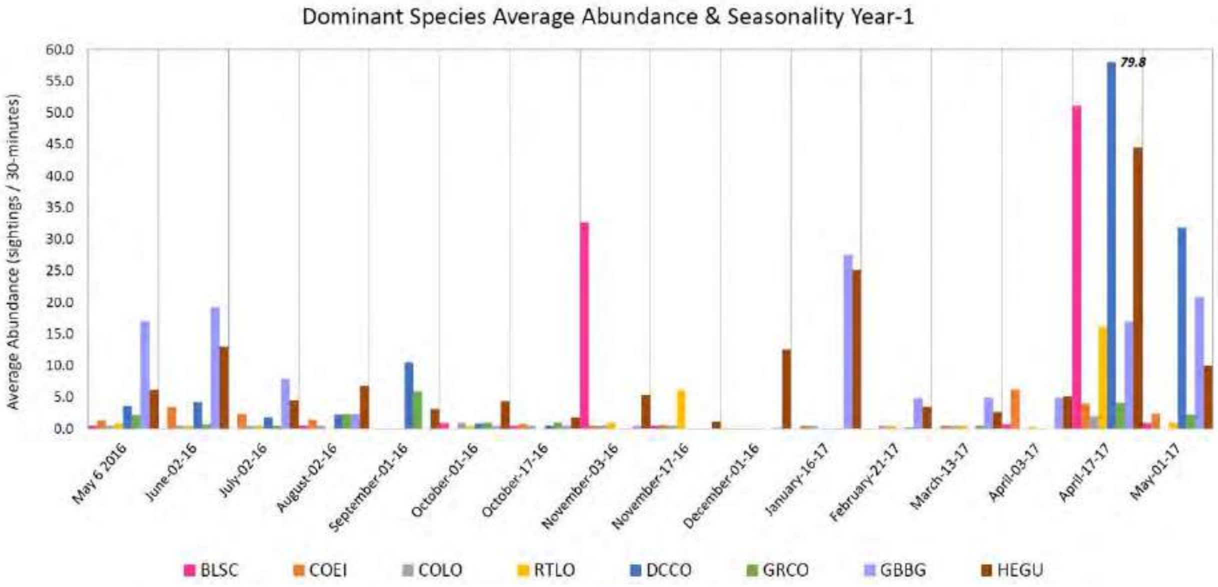

Figure 27. Average abundance and seasonal occurrence of dominant bird species for Year-One (16 surveys) of FORCE tidal energy demonstration site, 2016-2017.

Great Black-Backed Gull – Great Black-Backed Gull was the second most frequently occurring bird species at the site. It was usually observed sitting on Black Rock, but also was seen flying through and circling above searching for food in all subareas. Based on our observations of 4-5 juveniles, 2-3 pairs of Great Black-backed gull probably nested on Black Rock in 2016. Average abundance fluctuated from survey to survey and peaked during late spring and early summer, but the highest abundance occurred on January 16th, 2017 with an average of 27.5 birds per 30-minute interval, the highest abundance for all surveys, a similar pattern to Herring Gull with the movement of large flocks to Black Rock to roost. Abundances were lowest on October 1st and November 3rd 2016, with 0.1 birds per 30-minute interval on both days (Figures 28 and 29).

Ring-Billed Gull – Ring-Billed Gull is a common annual late summer migrant and occasional summer resident of the area but individuals can frequently found year-round. The species breeds inland near freshwater in central North America including the Great Lakes region, and moves to Atlantic coastal areas post-breeding in late summer. They feed on insects, crustaceans, molluscs and other invertebrates along the shore, as well as in agricultural and urban areas, and sometimes pirate food from other species. Ring-billed Gulls were observed on 50% of the surveys, in low abundance, during spring 2016 and 2017, and summer and fall surveys in 2016, generally seen flying through subareas OB1, IB1 and CL. Highest abundance was observed on August 2nd 2016 (3.0 birds per 30-minute interval)(Figures 28 and 29).

Iceland Gull – Iceland Gull overwinters in Nova Scotian coastal areas, including the Bay of Fundy region. Low numbers were observed on three occasions from fall 2016 to early spring 2017 (November 3rd 2016, January 16th and April 17th, 2017). Although two of the sightings were of a single bird flying or circling over water, a group of 12 gulls were seen sitting on Black Rock on April 17th (Figures 28 and 29).

Lesser Black-backed Gull – Lesser Black-backed Gull shares a similar habitat preference as Herring Gull, and was seen on four occasions in the spring and summer (May 6th, June 2nd August 2nd, 2016; and May 1st, 2017) all recorded on Black Rock. Highest average abundance for Lesser Black-backed Gull occurred on May 1st 2017 (0.4 birds per 30-minute interval) (Figures 28 and 29).

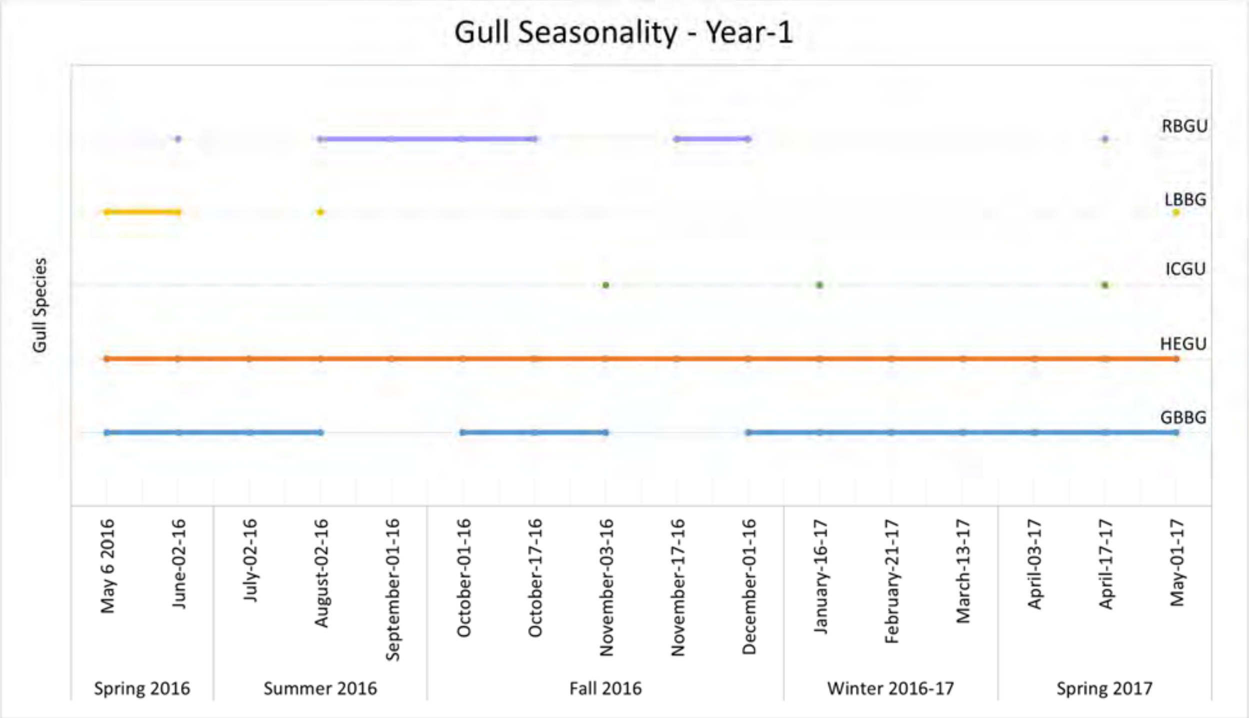

Figure 28. Presence of gull species based on season for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

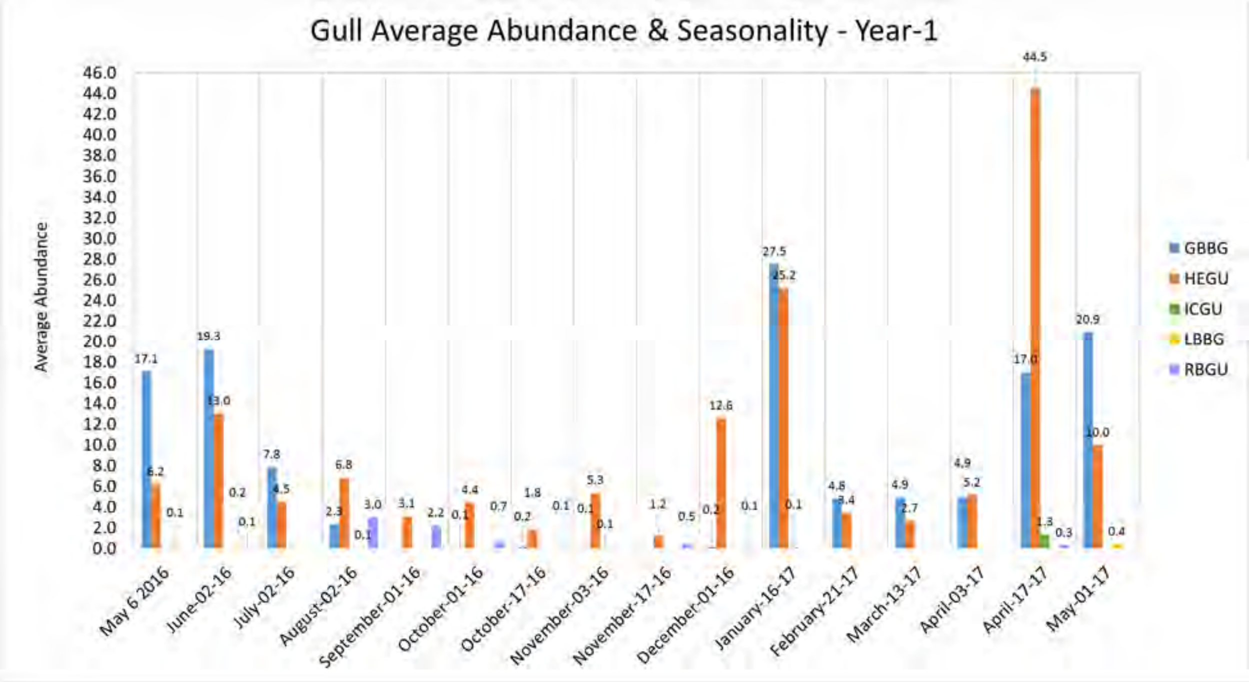

Figure 29. Average abundance and seasonal presence of gull species for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

3.1.3.3 Occasional Seabirds and Sea Ducks

Several seabirds and sea ducks were observed regularly during the survey, although less frequently and generally at lower abundance than dominant species. These included four alcid species (Atlantic Puffin, Common Murre, Razorbill, and Black Guillemot), sea ducks including Long-tailed Duck, Surf Scoter and White-winged Scoter, Northern Gannet, and Wilson's Storm Petrel.

Alcids – Alcids (Family Alcidae) are a family of stocky, diving and predominantly fish-eating birds, which nest in colonies on cliffs and islands in cold northern waters, including the Bay of Fundy for some species. Black Guillemot is a resident species of alcid in the area, and occurred regularly during the breeding season and occasionally at other times of year. The species nests on Black Rock and breeding pairs were observed in the waters around the island during spring and summer 2016, and spring 2017. Birds could be seen moving between nests in rock crevices and the water, diving and feeding. Between one and four pairs of birds were documented during spring and summer 2016 surveys (May 6th to August 2, 2016). During spring 2017 surveys (April 3rd, April 17th, and May 1, 2017) up to two pairs were observed. Highest average abundance of Black Guillemot occurred on July 2, 2016 (1.8 birds per 30-minute interval) (Figures 30 and 31).

Individual Atlantic Puffin were seen on three occasions –November 3rd and 17th 2016, and April 17th 2017, all flying west through CL. The species is commonly seen in coastal waters year-round. Summer distribution is along the eastern Canadian coastlines and Greenland where it nests in colonies along the coast (Figures 30 and 31).

Common Murre were seen in two surveys in late-fall, early-winter, eight on November 17th 2016 and an individual on January 16th 2017. The species nests on coastal cliffs and ledges of eastern Canada from Newfoundland to the eastern Arctic and Greenland (Figures 30 and 31) and disperses along the Canadian East Coast post-breeding.

A single Razorbill was observed on the water in CL on November 3rd 2016 and again on November 17th 2016 flying west and landing on the water in OB2, with an average abundance of 0.1 birds per 30-minute interval each day. Razorbill nests on rocky offshore islands and disperses to coastal waters along eastern Canada and the United States (Figures 30 and 31). Occurrences of Razorbill and Atlantic Puffin are consistent with use of the outer Bay of Fundy, Gulf of Maine and offshore areas by overwintering birds from East Coast colonies and for other alcids from winter offshore dispersal from coastal and generally more northerly nesting areas.

Long-tailed Duck – Long-tailed Duck was observed on four surveys during fall 2016 and spring 2017 migration (Figure 30). Fall sightings included five individuals seen on November 3rd on the water in CL, and three on November 17th flying east through CL. Highest numbers were observed on April 17th 2017 during a migratory movement. Birds were typically observed in flocks, the largest with 90 birds and others consisting of 20-50 individuals, as well as scattered birds either flying through the site or drifting with the tide in IB1, OB1 and CL. Average abundance on April 17th 2017 was 23.5 birds per 30-minute interval (Figure 31).

Northern Gannet—Two Northern Gannet were observed during one survey on April 17th 2017 (Figure 30) flying southwest through CL towards the outer bay (0.4 birds per 30-minute interval) (Figure 31). This species normally migrates through the area to colonies on the Gulf of St. Lawrence at this time of year, but the Inner Bay of Fundy also support immatures and late migrants at other times. The species feeds by diving from great heights for fish.

Wilson's Storm Petrel – Storm Petrels are primarily pelagic, spending most of their lives at sea feeding on plankton, crustaceans, and small fish, except when nesting in colonies on coastal islands and sea coasts. They are a highly migratory species, but are seen regularly in Atlantic Coastal waters and can be occasionally seen from shore. Two Wilson's Storm Petrel were observed on September 1st 2016 feeding in CL during one survey interval (15:15 – 15:45) (Figures 30 and 31).

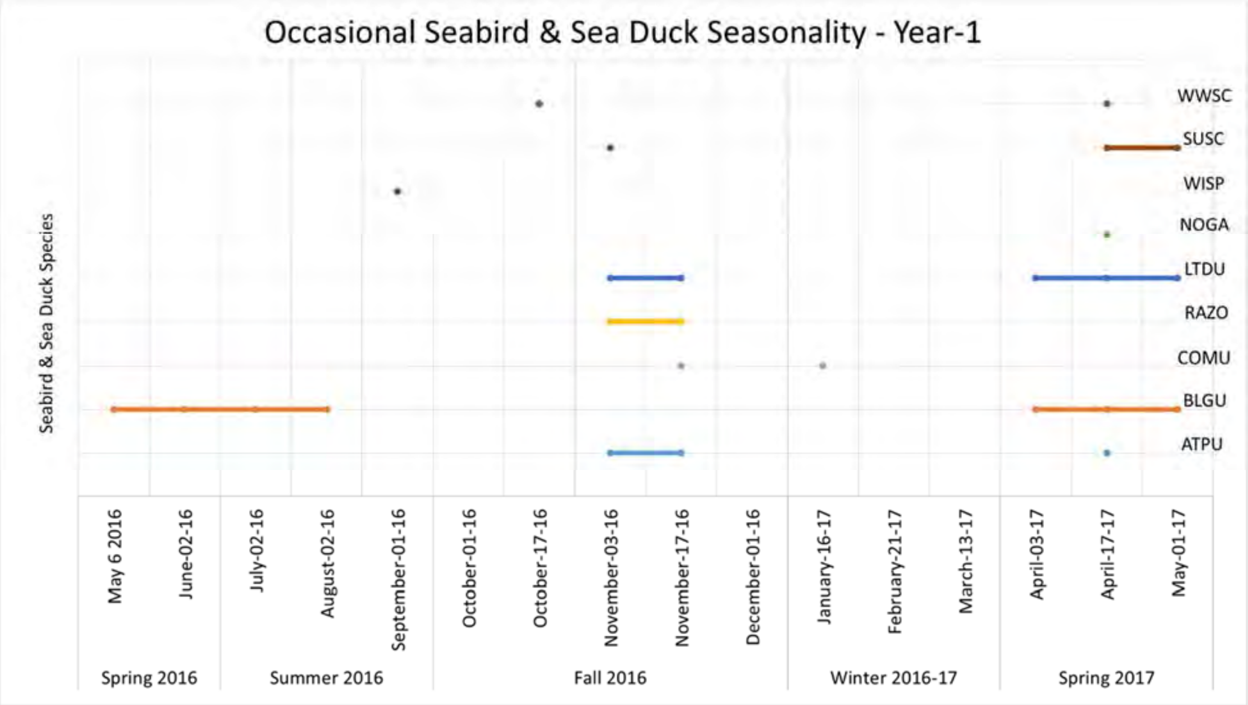

Figure 30. Presence of occasional seabird and sea duck species based on season for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

Surf Scoter and White-winged Scoter – Surf Scoter and White-winged Scoter are large sea ducks, having similar biology and behaviour to Black Scoters (one of the dominants bird species at the site, discussed in Section 3.2.4.1). These species are regular migrants through Nova Scotian coastal waters including the Bay of Fundy in spring and fall, frequently migrating together, and individuals may occur casually year-round. Both Surf Scoter and White-winged Scoter were less common and abundant than Black Scoter at the FORCE site. White-winged Scoter was least abundant, observed in fall (a single individual flying easterly through IB1 on October 17th 2016); and seven White-winged Scoters were observed in spring on April 17th 2017 (0.58 birds per 30-minutes) during a major passage of birds at the site (Figures 30 and 31, Table 4). Surf Scoters also occurred infrequently— observed on three surveys—but in higher abundance compared to White-winged Scoters. Twelve were observed November 3rd 2016, drifting on the water in OB2. During spring 2017 surveys, Surf Scoters were observed on April 17th and May 1st. Large flocks were observed during the April 17th survey, the largest consisting of140 Surf Scoters on the water drifting from

CL to OB1, but other groups or flocks of from 2 to 120 Surf Scoters also occurred, leading to an average for that survey of 27.7 birds per 30-minute interval, among the highest of any species in the monitoring program Generally, the birds were on the water, drifting with the tidal stream between OB1 and CL. Smaller numbers observed on May 1, 2017 included a flock of approximately 20 birds flying through the site and a daily average of 2.9 birds per 30-minutes (Figure 31, Table 4). Observations of both Scoter species in the fall and spring correspond to migratory periods as the birds move through Minas Passage.

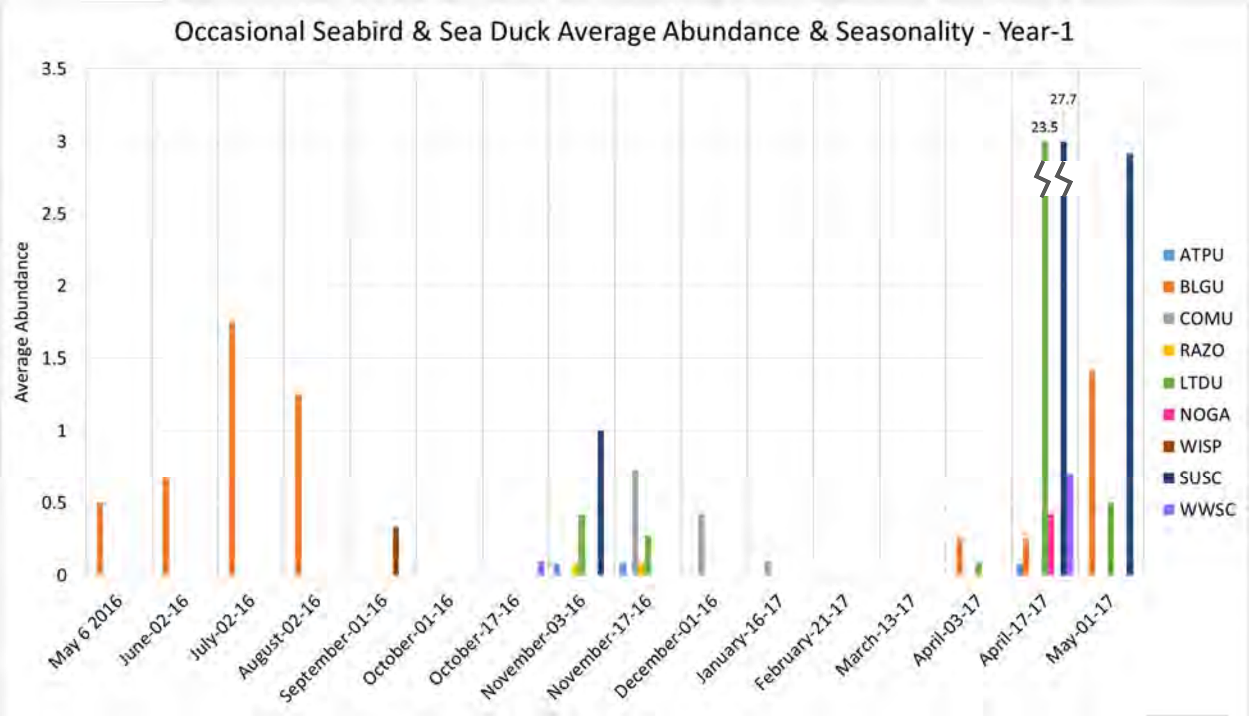

Figure 31. Average abundance and seasonal presence of occasional seabird and sea duck species for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

3.1.3.4 Other Waterfowl

In addition to Red-throated Loon and Common Loon which were dominants at the site (see Section 3.2.4.1), waterfowl species recorded at the site included nine species which occurred in lower frequency and abundance overall. These included two species of Merganser (Red-breasted and Common Merganser), two species of geese (Canada Goose and Snow Goose), American Black Duck, Blue-winged Teal, Common Goldeneye, Red-necked Grebe and a single occurrence of a vagrant or accidental Arctic Loon.

Red-breasted and Common Merganser – Mergansers migrate regularly through the inner Bay of Fundy in spring and fall and Red-breasted Merganser can overwinter in the area. They feed by diving for fish in shallow water. A single Red-Breasted Merganser was present during one survey in the fall (October 1st 2016) observed on the water in CL. The species was present during all three spring 2017 surveys, in similar abundance, with highest abundance on April 17th 2017 of 0.8 birds per 30-minute interval. Common

Merganser were observed during the December 1st 2016 survey only, when a small group of five birds (average abundance of 0.4 birds per 30-minute interval) were seen flying east through IB1 (Figures 32 and 33, Table 4).

Canada Goose and Snow Goose – Although more typically found in terrestrial and freshwater settings, both species can be found in marine coastal waters, saltmarshes and eelgrass beds feeding on grasses, seeds, aquatic plants and shellfish. Canada Goose were observed on October 1st 2016 and April 3rd 2017, during fall and spring migration periods, but the species is a year-round resident in Nova Scotia, found in both coastal and inland areas. The single Canada Goose observed on October 1st was on the water in OB1, while flocks of 10 and 20 birds were observed on April 3rd (2.8 birds per 30-minute interval), generally on the water and in the outer areas of the study site (OB1, IB1 and CL) (Figures 32 and 33).

Sightings of Snow Geese are an uncommon but regular occurrence in the Bay of Fundy region. A single Snow Goose was seen flying west in OB2 on April 3rd 2017 (Figures 32 and 33). Snow Geese overwinter in western, midcontinent, and eastern regions of the United States and migrate to northern Canada during the summer breeding season. Migratory patterns of the species are roughly parallel to the lines of longitude for wintering grounds, and they typically congregate and migrate in large flocks. The eastern population of Snow Goose overwinters along the Atlantic Coast from New Jersey to North Carolina.

American Black Duck – American Black Duck is a common duck species in the Atlantic Region, found in a range of habitats including freshwater lakes, ponds and marshes, as well as bays and estuaries. The species is present year-round in Nova Scotia, often found in large concentrations in marine coastal areas including the Bay of Fundy in winter. The species feeds on aquatic plants, seeds, insects and other aquatic invertebrates. Low abundances of birds, typically in small (i.e. IB1 & IB2) groups near shore, were observed during five surveys between fall 2016 and spring 2017 (October 1st, December 1st 2016; January 16th, March 13th and April 3rd 2017) (Figures 32 & 33, Table 4). Two pairs were observed on October 1st 2016 flying through IB1; one pair on December 1st 2016; and a group of three on January 16th 2017 seen flying through IB1. A group of five birds was seen flying northwest in IB1 on March 13th and a group of seven were observed flying into IB2 on April 3rd (0.7 individuals per 30-minutes) and landing on the water nearshore.

Blue-winged Teal – A single occurrence of Blue-winged Teal in the study site occurred on May 1st 2017 (Figures 32 and 33). A male/female pair were observed on Black Rock during the first half hour of the survey, and then flew from the front of the rock to the opposite side and out of view. Blue-winged Teal are a dabbling duck species usually found in freshwater habitats as well as mudflats.

Common Goldeneye – Common Goldeneye is a duck species typically found in lakes and coastal bays and estuaries during winter, and forested lakes during the reminder of the year. It feeds by diving for aquatic plants and animals as well as marine invertebrates in shallow coastal areas. Common Goldeneye were observed on three occasions, January 16th, February 21st, and April 3rd 2017 (Figure 32), when they were relatively abundant, averaging two per 30-minutes on January 16th and 2.2 per 30-minutes on February 21st (Figure 33), usually observed in small groups of eight or less on the water near the shoreline in IB1. On April 3rd a pair were observed flying east through IB1.

Red-necked Grebe – A single Red-necked Grebe was observed flying west in CL on November 17th 2016 (Figures 32 and 33). Grebes feed by diving for small fish and other aquatic life. Red-necked Grebe are found in freshwater habitat year-round, and also in coastal areas during winter.

Arctic Loon – Arctic Loon are extremely rare on the Atlantic Coast and the sighting of a single Arctic Loon on November 17th was the first for the FORCE site. The bird, briefly landed on the water in CL and then flew off in a westerly direction (Figures 32 and 33). Arctic Loon is a migratory species found during winter on the coasts of the northeast Atlantic and eastern and western Pacific, as far south as the Mediterranean, Black Sea, Caspian Sea, China, Japan and southern Alaska. During the breeding season, Arctic Loon is found on large, inland, freshwater lakes in Russia, Scandinavia, and Alaska.

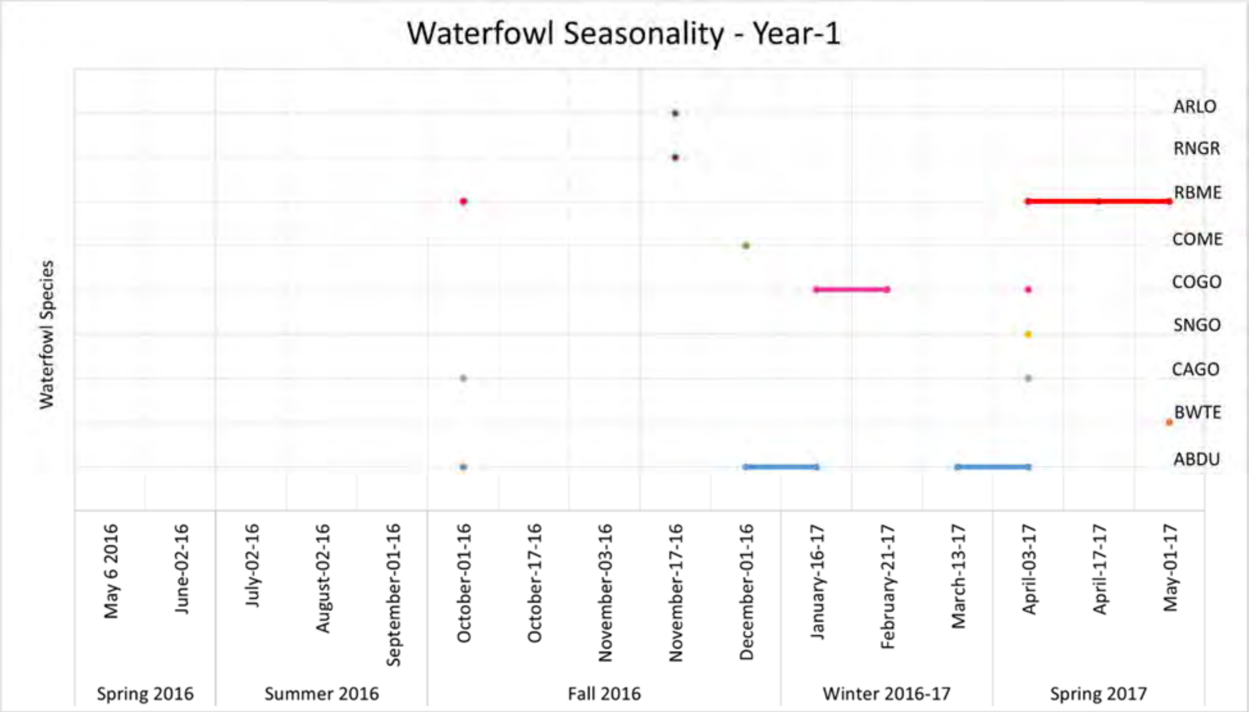

Figure 32. Presence of waterfowl species based on season for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

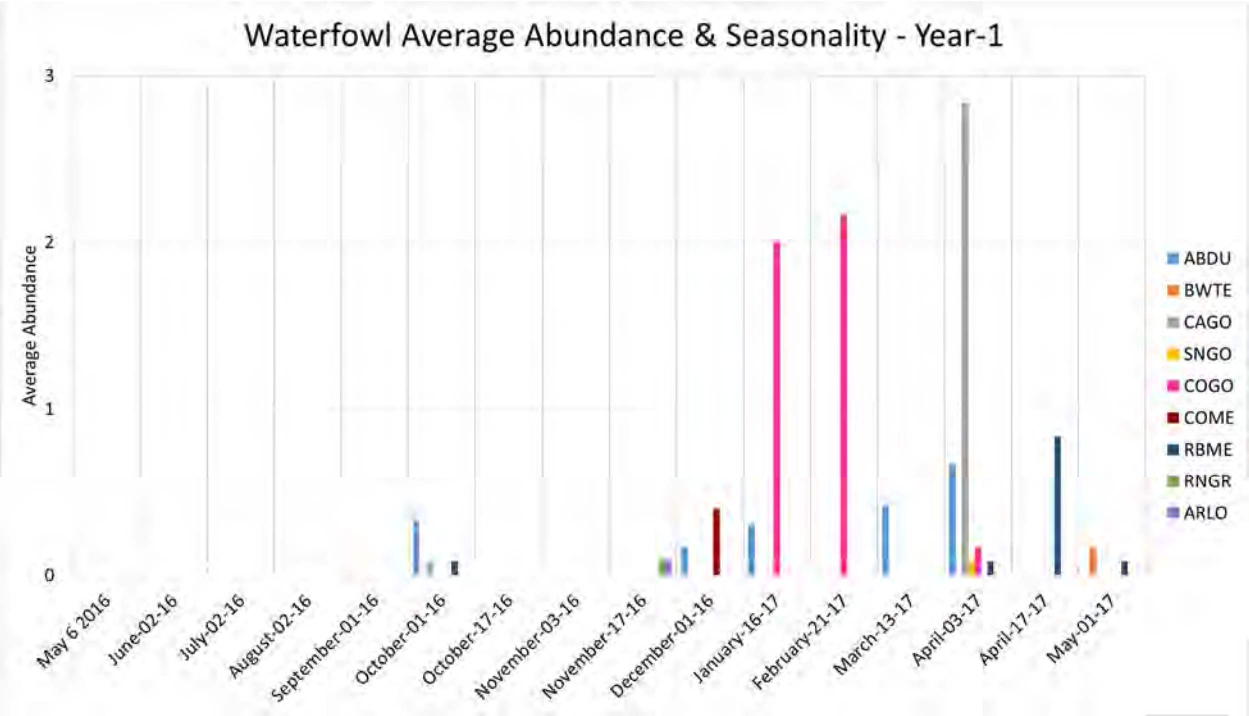

Figure 33. Average abundance and seasonal presence of seabird and sea duck species for Year-One (16 surveys) of FORCE shore-based seabird survey. FORCE Visitor Center, Parrsboro, Nova Scotia. (May 2016 – May 2017).

3.1.4 Comparison with Earlier Surveys

3.1.4.1 Species Composition

Fewer species were observed overall at the site in the 2016-2017 survey compared to the number seen in the first surveys (2010 – 2012) (Figure 34, Table 5). The difference on an annual basis was statistically significant (Kruskal-Wallace One-Way Analysis of Variance, p<0.001, n=14) [5]. The overall lower number of species in 2016-2017 versus the earlier surveys (32 versus 45) was largely due to the absence of oceanic species such as shearwaters and some rare and casual species. All of the common and abundant resident species were present this year including Great Black-backed Gull, Herring Gull, Double-crested Cormorant, Great Cormorant, Common Eider, and Common Loon, and Black Guillemot, as well as common migrants (Red-throated Loon, Ring-billed Gull, Northern Gannet, Black Scoter, Surf Scoter, White-winged Scoter and Long-tailed Duck) and seasonally important species (American Black Duck, Red-breasted Merganser and Common Merganser).

Several new species were recorded this year, including birds occurring well outside their normal range, such as Snow Goose and Arctic Loon and oceanic/coastal species (Wilson's Storm Petrel) (this species had previously been recorded in vessel-based surveys at the FORCE site). Species from earlier surveys not seen this year included Pacific Loon, King Eider, Horned Grebe and Red-necked Grebe, Thick-billed Murre, gulls (Laughing Gull, Mew Gull, and Black-legged Kittiwake), shearwaters (Cory's Shearwater, Greater Shearwater, and Sooty Shearwater), Black Tern, ducks (Northern Shoveler, Mallard and

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[5] Number of species and total abundance were compared for fourteen surveys on corresponding dates from the baseline (2010-2012) surveys and Year-One surveys (2016-2017)(Table 5).

Harlequin Duck), and several shorebirds (Red Phalarope, Red-necked Phalarope, Ruddy Turnstone, Sanderling, and Semipalmated Sandpiper).

3.1.4.2 Species Diversity & Seasonality

Diversity of species as expressed by number of species (species richness) at the site in 2016-2017 was uniform throughout the year with a small peak in spring migration in April to early May 2017. Earlier baseline surveys had shown peaks in both fall and spring (Figure 34, Table 5). The 2016-2017 survey had the lowest number of species per survey (5) of all surveys done at the FORCE site—observed during two surveys on September 1 and December 1, 2016 (Figure 34, Table 5). In surveys through the spring and summer completed in 2016, number of species per survey was comparable to that observed during the baseline surveys; the later surveys in the Year-One program (October 2016 to May 2017) showed numbers of species which were typically lower than or equal to baseline levels (Figure 34, Table 5). The fall migration period in 2016 had approximately half the number of species as 2010)(Figure 37, Table 5). Number of species at the site during spring migration, 2017, however, were comparable to those in the earlier baseline surveys.

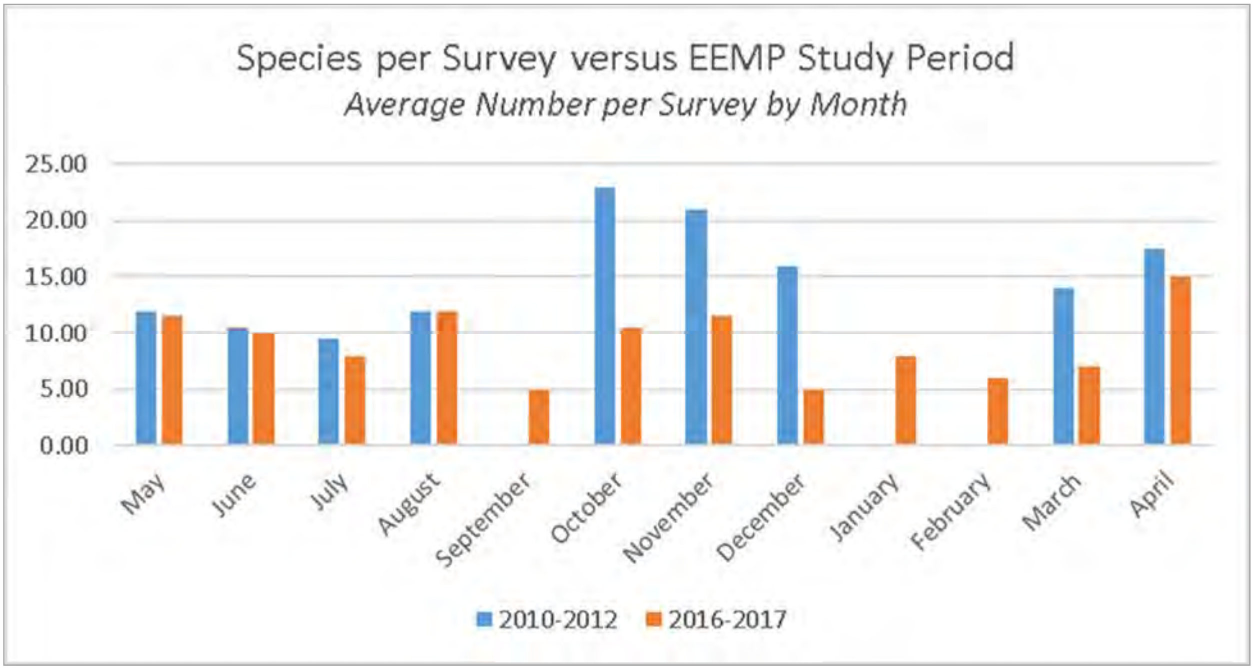

Figure 34. Comparison of diversity of species (number of species per survey) of seabirds and water-associated birds at the FORCE tidal energy demonstration site in 2016-2017 with EEMP studies conducted in 2010-2012.

3.1.4.3 Abundance

Abundance of birds at the FORCE site in 2016-2017 overall was comparable to that observed in the baseline surveys (2010-2012) and followed similar seasonal cycles, although abundances in the fall migration season were lower than in baseline surveys, and abundances during spring migration were

Table 5. Comparison of average abundance (sightings per 30 minutes) and total species per survey, in the survey period (May 1 to April 30), 2016-2017 versus 2010-2012. Surveys arranged by days from January 1. (T) denotes presence of turbine.

SURVEY	ABUNDANCE		SPECIES	
	2010-2012	2016-2017	2010-2012	2016-2017
May.1.2010 (T)	47.70	--	12	--
May.1.2017 (T)	--	75.00	--	13
May.6.2016	--	35.09	--	10
May.13.2010 (T)	40.49	----	12	--
May.27.2010 (T)	56.58		12	--
June.2.2016	--	42.33	--	10
June.12.2010 (T)	69.83	--	12	--
June.21.2012	25.40	--	9	--
Jul.2.2016 (T)	--	19.17	--	8
Jul.4.2012	20.30	--	11	--
Jul.18.2012	7.20	--	8	--
Aug.2.2012	12.40	--	14	--
Aug.2.2016	--	20.00	--	12
Aug.15.2012	13.40	--	8	--
Aug.29.2012	11.10	--	14	--
Sep.1. 2016	--	22.17	--	5
Oct.1, 2016	--	11.08	--	12
Oct.17.2016	--	1.75	--	9
Oct.23.2010 (T)	16.25	--	23	--
Nov.3.2016	--	40.92	--	11
Nov.13.2010 (T)	57.33	--	25	--
Nov.17.2016 (T)	--	10.27	--	12
Nov.22.2010	18.67	--	17	--
Dec.1.2016	--	17.89	--	5
Dec.2.2011 (T)	8.60	--	15	--
Dec.13.2011	6.50	--	17	--
Jan.16.2017 (T)	--	55.80	--	8
Feb.21.2017 (T)	--	10.92	--	6
Mar.13.2017 (T)	--	8.83	--	7
Mar.16.2011	14.70	--	12	--
Mar.31.2011	16.00	--	16	--
Apr.2.2017 (T)	--	21.83	--	13
Apr.15.2011	41.50	--	16	--
Apr.17.2017 (T)	--	267.75	--	17
Apr.30.2011	39.20	--	19	--

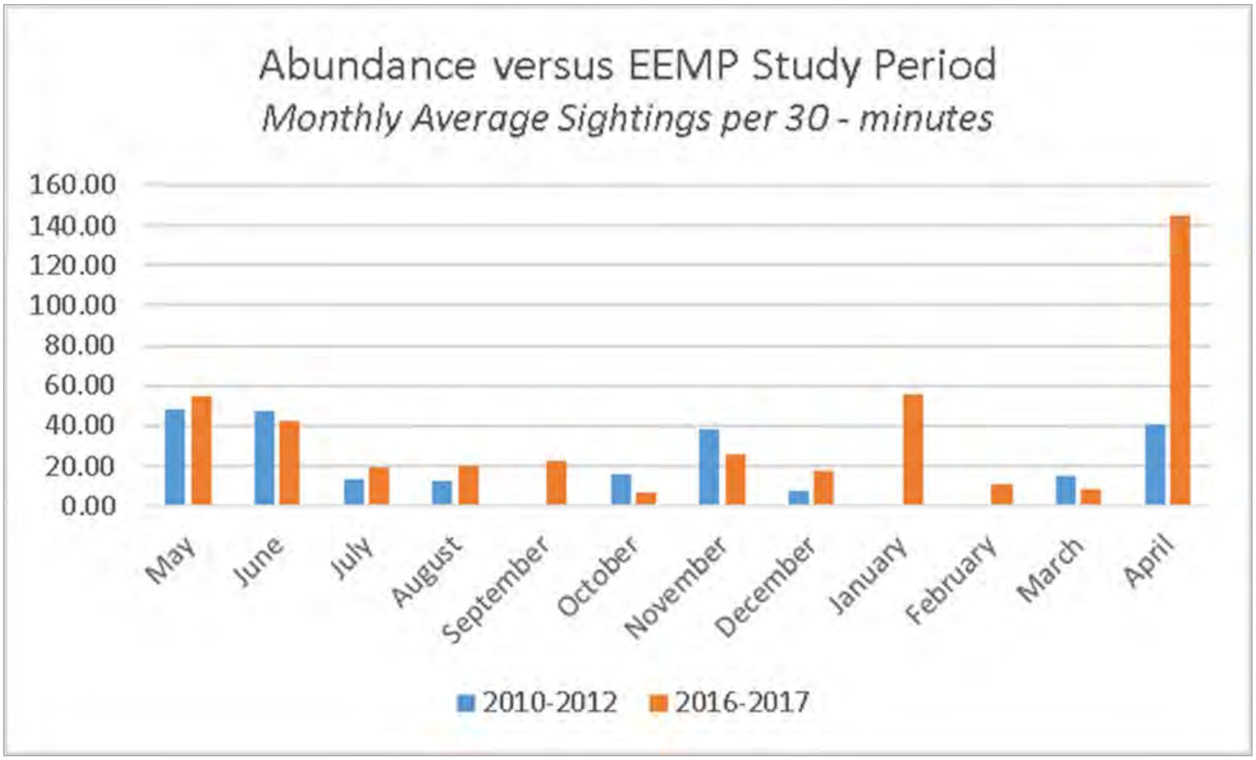

Figure 35. Monthly comparison of abundance of seabirds and water-associated birds (number per 30-minute survey) at the FORCE tidal energy demonstration site in 2016-2017 with EEMP studies conducted in 2010-2012.

higher than baseline years (Figure 35, Table 5). Overall the differences were not significantly different statistically (Kruskal-Wallace One-Way Analysis of Variance, p=0.44, n=14)[1]. On comparable dates between the baseline and Year-One surveys, abundances in surveys in 2016-2017 were similar to or greater than the baseline approximately 75% of the time (12 out of 16 surveys). Surveys in which abundances were greater in the baseline survey were in early June and November 2010 (Figure 35, Table 5).

3.1.5 Use of Open Water Areas

Seabirds and water-associated birds over open water at the FORCE site were recorded as either flying or sitting on the water, a feature which reflects their utilization of the area and is relevant to assessing risk for interactions with tidal energy devices. Birds may fly through the area while moving between distant areas, or pass through open water areas to access or leave from Black Rock and other coastal areas. More seabirds and water-associated birds occupying open water areas throughout most of the year were flying, typically in a ratio of 2:1 (Table 6, Figure 36) although relatively more birds were seen on water than were flying during peak migration periods (e.g. November 3, 2016 and April 17, 2017). Number of seabirds flying were equal to or larger than numbers on the water in 12 surveys (75%), but the differences were not significantly different statistically (Kruskal-Wallace One-Way Analysis of Variance, p=0.19, n=16).

Table 6. Average abundance (sightings / 30-minute survey) of seabirds seen flying or on water in open water areas of the FORCE tidal demonstration site, 2016-2017. n= number of observations.

SURVEY	FLYING		ON WATER	
	Average (SD)	n	Average (SD)	n
May.6.2016	2.73 (0.64)	19	1.55 (0.36)	11
June.2.2016	2.17 (0.43)	20	2.83 (0.57)	19
Jul.2.2016	5.5 (0.69)	40	2.42 (0.31)	15
Aug.2.2016	4.75 (0.65)	40	2.58 (0.35)	23
Sep.1. 2016	4.83 (0.71)	43	2 (0.29)	14
Oct.1, 2016	4.83 (0.53)	25	4.25 (0.47)	30
Oct.17.2016	2 (0.75)	14	0.67 (0.25)	5
Nov.3.2016	6.25 (0.29)	19	15 (0.71)	14
Nov.17.2016	9.64 (0.95)	35	0.55 (0.05)	6
Dec.1.2016	1.22 (1)	7	0 (0)	0
Jan.16.2017	1.8 (0.5)	11	1.8 (0.5)	4
Feb.21.2017	0.83 (0.17)	7	4.17 (0.83)	10
Mar.13.2017	1.75 (0.75)	12	0.58 (0.25)	3
Apr.2.2017	10 (0.69)	22	4.5 (0.31)	9
Apr.17.2017	52.83 (0.35)	51	98.33 (0.65)	47
May.1.2017	8.17 (0.56)	46	6.33 (0.44)	19

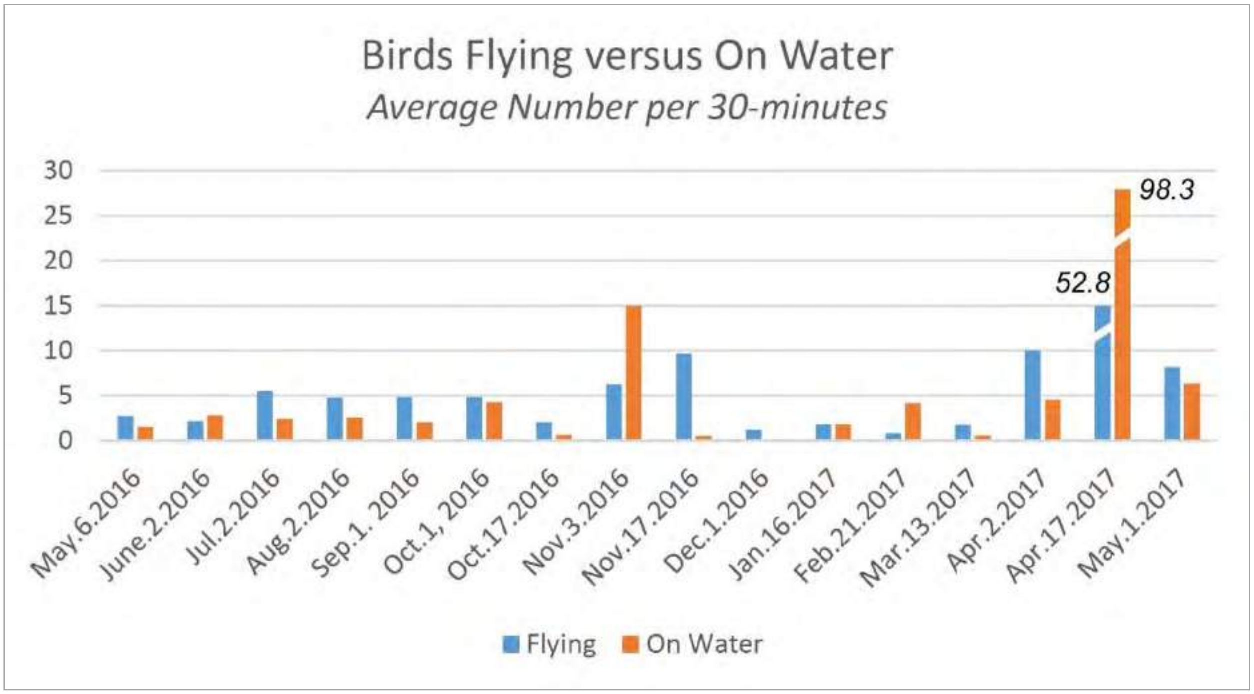

Figure 36. Abundance of seabirds and water-associated birds which were seen flying or on water in shore-based surveys at the Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia.

3.1.6 Assessment of Impacts

The principal objective of the FORCE EEMP is to verify predictions that the placement of tidal energy devices will not negatively impact seabirds at the site, including both at the population level, and for individual interactions of birds with tidal devices. At times during both survey periods (i.e. 2010 – 2012 & 2016-2017), OpenHydro turbines were installed at Site D of the Crown Lease Area (see Figure 2 for location of berths at the FORCE site). The first was in place from November 2009 to December 2010, and the most recent, a grid-connected turbine[6], from November 2016 to mid-June, 2017, and thus operated through the end of the most recent survey period. In addition to the presence of the turbines, activities related to turbine deployment, principally vessel traffic and use for activities such as equipment installation and removal, have the potential to interact with, and potentially affect seabirds, although not negatively and typically at a negligible level of effect. The FORCE site is also used for personnel transport from shore at the FORCE site to West Bay, and principally for vessels used in turbine deployment and support vessels; however no negative impacts of these activities are predicted.

Verifying the prediction of no effect of tidal-energy-related activities, requires a statistical analysis of information collected in the FORCE EEMP against a backdrop of high natural variability in bird populations which occur at the site and generally in coastal areas. Statistical analyses will be done to formally test impacts of turbine presence and/or vessel operations on seabird presence after the second year of observations, when more information has accumulated to fully document bird populations occurring at the site and seasonal patterns of abundance, both when tidal devices are operating and when they are absent.

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[6] Cape Sharp Tidal Development Inc., installed November 7, 2016 and removed June 15, 2017.

Anecdotal observations of lack of effect have been made, however, during this year's surveys, and also when information is examined from earlier surveys in the EEMP (i.e. from 2010 to 2012 and 2016-2017) when tidal energy devices were or were not present at various times, or related activities were taking place. Some of our surveys this year coincided with various types of on-water activities. Observations suggested that overall, seabird activity was not correlated with project activity. For example, on several occasions when vessels were present during surveys, birds on Black Rock were not disturbed and birds were not attracted to vessels. Birds including Double-crested Cormorants and dominant gulls, which frequently rested on Black Rock for long periods of time, did not move when vessels were passing by. The assessment was not systematic, however, and a survey protocol which includes these activities should be developed to allow for collecting information on bird reactions to nearby vessels.

Patterns of overall abundance and species diversity were comparable throughout the surveys (from 2010 to 2017)(Figures 35 & 36; Table 6) during periods when turbines were both operating and absent from the site. There also appeared to be no particular correlation with timing of deployment of the tidal turbine at the site when surveys were separated specifically on the basis of the presence of tidal turbines (Table 7; Figures 37 & 38). Overall, other differences compared with earlier surveys (e.g. the low number of species this year through absence of oceanic and other migrant species) are extremely unlikely to be related to activities at the FORCE site.

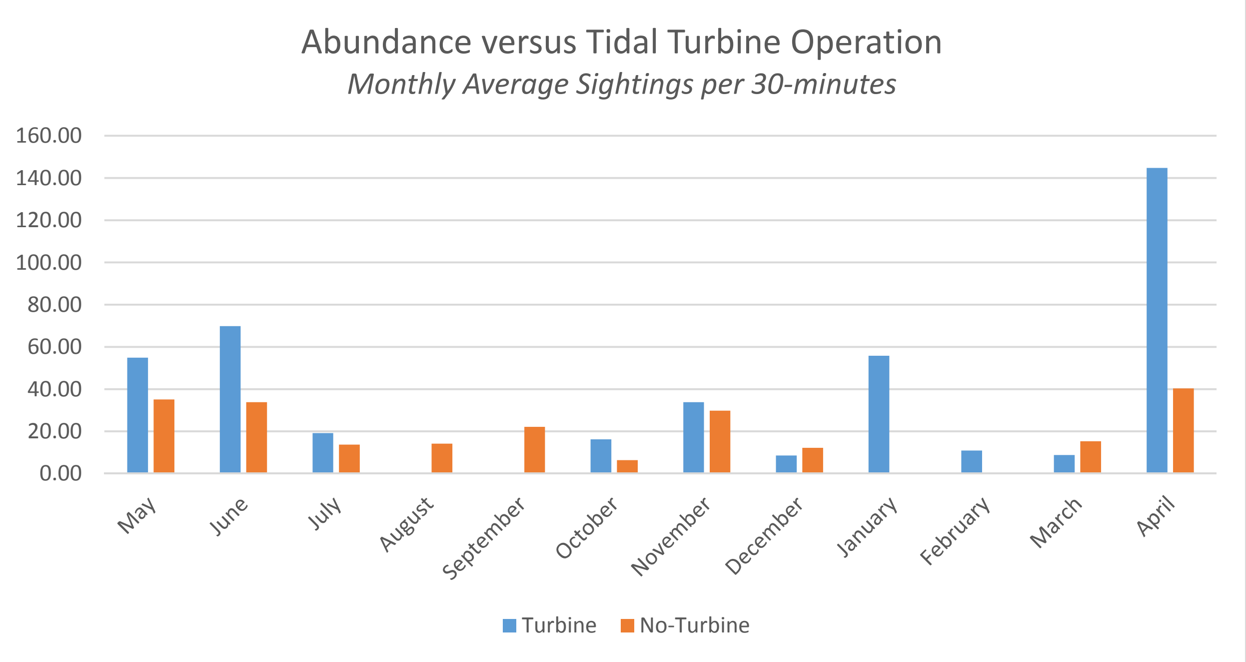

Figure 37. Abundance of seabirds and water-associated birds versus periods of turbine operation in shore-based surveys at the Fundy Ocean Research Center for Energy, Parrsboro, Nova Scotia.

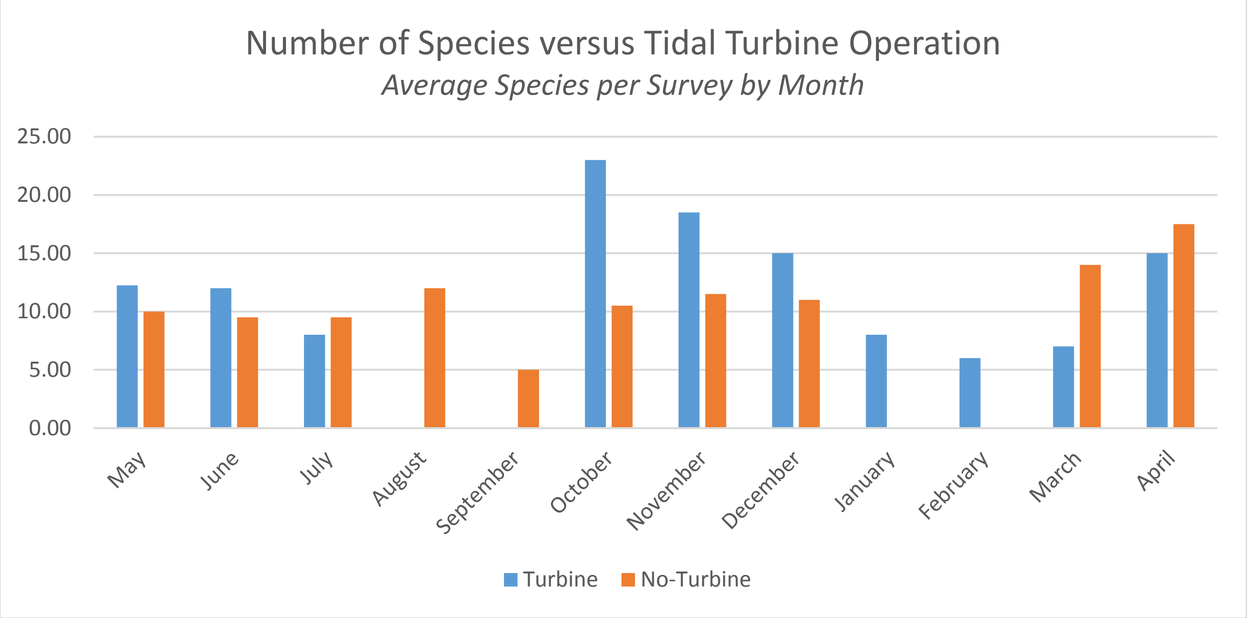

Figure 38. Diversity (number of species per survey) of seabirds and water-associated birds versus periods of turbine operation in shore-based surveys at the Fundy Ocean Research Center for Energy, Parrsboro, Nova Scotia.

Table 7. Comparison of average monthly abundance of seabirds (sightings per 30 minutes) and monthly average species per survey for surveys when turbines were and were not present, over the monitoring period (2010 to 2012 and 2016-2017. For a breakdown of surveys with and without turbines, see Table 5.

MONTH	ABUNDANCE		SPECIES	
	Turbine	No-Turbine	Turbine	No-Turbine
May	54.94 (14.9)	35.09 (-)	12.25 (0.5)	10.00 (-)
June	69.83 (-)	33.87 (12.0)	12.00 (-)	9.50 (0.7)
July	19.17 (-)	13.75 (9.3)	8.00 (-)	9.50 (2.1)
August		14.23 (4.0)		12.00 (2.8)
September		22.17 (-)		5.00 (-)
October	16.25 (-)	6.42 (6.6)	23.00 (-)	10.50 (2.1)
November	33.80 (33.3)	29.80 (15.7)	18.50 (9.2)	11.50 (0.7)
December	8.60 -()	12.20 (8.1)	15.00 (-)	11.00 (8.5)
January	55.80 (-)		8.00 (-)	
February	10.92 (-)		6.00 (-)	
March	8.83 (-)	15.35 (0.9)	7.00 (-)	14.00 (2.8)
April	144.79 (173.9)	40.35 (1.6)	15.00 (2.8)	17.50 (2.1)
Standard Deviations in brackets.				

3.2 Marine Mammals

Three species of marine mammal, the Harbour Porpoise (*Phocoena phocoena),* Harbour Seal (*Phoca vitulina*) and Harp Seal (*Pagophilus groenlandicus)* were observed during the year (May 2016 – May 2017). Harbour Porpoise were observed on eight of the sixteen surveys; Harbour Seal on two surveys; and Harp Seal on one survey. Abundance for each occurrence were low – single seals, and typically a single or pair of porpoise, and only occasionally groups of four to five porpoises (Table 8, Figures 39 & 40).

In total, twenty-one Harbour Porpoise were seen at the site during the survey (Table 1). Harbour Porpoise occurred mainly in the late Spring to Fall (May 1 to October 1) with highest daily sightings and largest group sizes in September and October surveys (Table 8; Figure 39). Single occurrences were in late Fall (November 1) and mid-January 2017. Overall, occurrence and abundance of Harbour Porpoise in the study area is lower than recorded in shore-based surveys from June to August in 2012, although the general location of sightings are similar (Envirosphere Consultants, 2012). The seasonal observations suggest that Harbour Porpoise are less common and abundant in summer. Harbour Porpoise were most commonly observed in the tidal stream outside Black Rock and the Crown Lease area, south and southwest of Black Rock—generally moving in a westerly direction towards the Bay of Fundy with the ebb (out-going) tide (Figure 40; Appendix B). On two occasions (November 17th, 2016 and January 16th, 2017), sightings were made of a single porpoise during the flood tide heading east; however the November 17th sighting was less than an hour before peak high tide and the animal was seen surfacing only once in OB1. The January 16th sighting was about two hours before peak high tide when water levels were relatively high; the porpoise was moving eastward with the incoming tide (Table 8; Appendix B).

The pattern of Harbour Porpoise occurrences is suggested to follow the local pattern of fish distribution and availability, as herring and other runs of migratory species usually take place in late spring to early summer. Seasonal movements of Harbour Porpoise observed at the site have been thought to follow the movements of herring into Minas Basin in the spring, while being largely absent other times of the year (Baker et al 2014).

Prior to the monitoring undertaken by FORCE in 2009, Harbour Porpoise, Harbour Seal, Grey Seal were expected to occur in the study area, but their relative abundance and seasonal occurrence was unknown, as there were few previous recorded sightings for the area. The 2010-2011 shore-based monitoring showed that these species were present, with Harbour Porpoise relatively common in the spring as early as March, and late fall, but not early winter. The 2012 study extended the seasonal occurrence of Harbour Porpoise through the summer (late June to late August) with significant numbers (some of the highest abundances observed at the site) occurring in mid-July and mid-August (Envirosphere Consultants, 2012).

Table 8. Summary of marine mammal observations made during shore-based marine seabird surveys, Fundy Tidal Power Demonstration Site. 2016 – 2017.

DATE	TIME (ADT)	LOCATION & DIRECTION OF SIGHTING	TIDE DIRECTION AT TIME OF SIGHTING	SPECIES	NUMBER OBSERVED
May 6, 2016	15:12 – 15:42	CL into FF	Ebb tide	Harbour Porpoise	2
June 2, 2016	17:00 – 17:30	IB1 into IB2	"	"	1
July 2, 2016	12:08 – 12:10	OB1/OB2 into CL	"	"	2
	12:20 – 12:50	OB2	"	"	1
August 2, 2016	14:00	CL	"	"	1
September 1, 2016	14:50	CL towards FF1	"	"	4
October 1, 2016	14:07 —14:11	IB1 into OB1 through CL into IB2	"	"	2
	14:10 – 14:11	OB3	"	"	1
	14:28 – 14:31; 14:32 – 14:39	IB1 near northeast corner of CL, into IB2; West through IB2	"	"	5
November 17, 2016	13:40	OB1	Flood tide	"	1
January 16, 2017	13:09 – 13:13	CL into OB1, east of BR	"	"	1
	13:00 – 14:30	BR	"	Harp Seal	1
April 3, 2017	12:15	BR	Ebb tide	Harbour Seal	1
April 17, 2017	13:20; 17:50	IB1 close to BR; IB1 close to shore.	Flood tide	"	2
IB: Inside Black Rock. CL: Crown Lease (Turbine Area). OB: Outside Black Rock. FF: Far Field. BR: Black Rock					

The Northwest Atlantic population of the Harbour Porpoise (*Phocoena phocoena)* is listed as a Species of Concern by Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the status is *threatened* under the Federal *Species at Risk Act*. Harbour Seal (*Phoca vitulina*) is a small species widely distributed along the east coast of North America north of Cape Cod. The species is often associated with bays and inlets from which habit its name is derived. Harbour Seal population trends in the Bay of Fundy are unknown, with trends in adjacent areas ranging from increasing (Maine) to decreasing (Sable Island)(Baird 2001). Harp Seal (*Pagophilus groenlandicus*) is commonly found in more northerly waters including the eastern Scotian Shelf, Gulf of St. Lawrence, Newfoundland and Labrador where it is typically found around ice edges in winters, but individuals often disperse into Nova Scotia coastal waters.

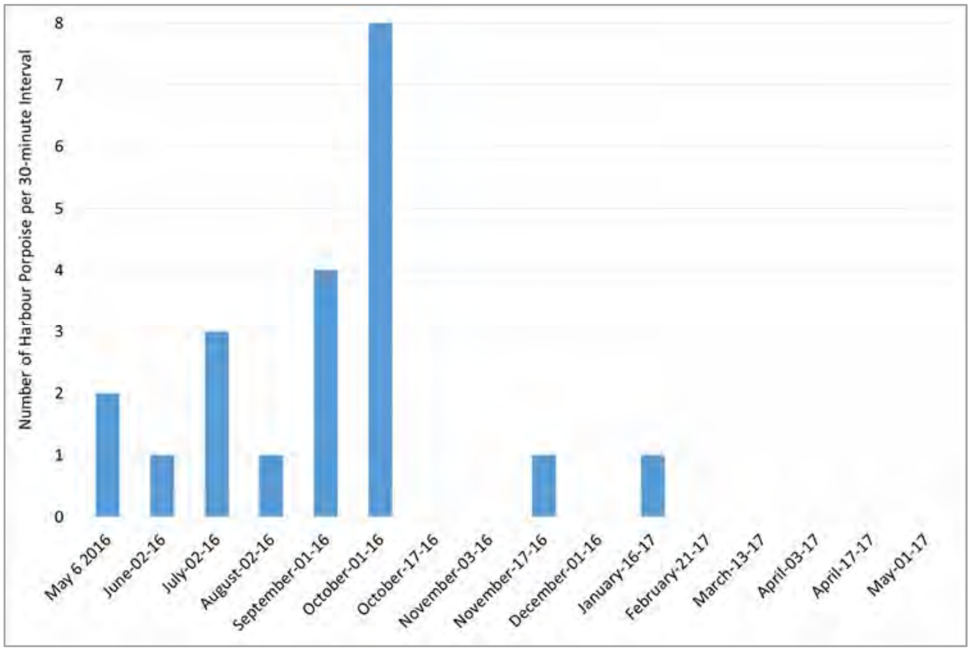

Figure 39. Number of Harbour Porpoise observed during the year-one survey in the study area for the Shore-Based Seabird Survey – Tidal Energy Demonstration Site, Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia.

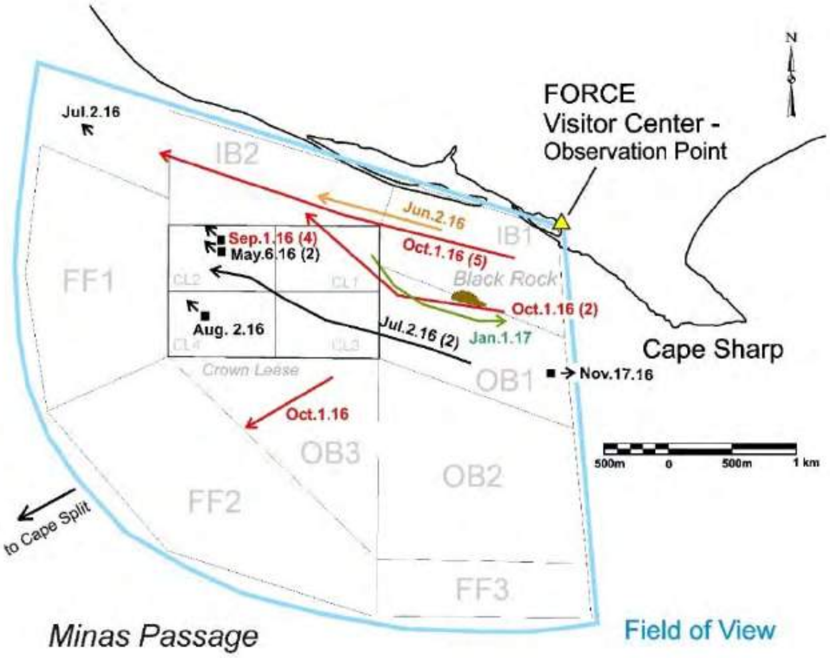

Figure 40. Summary of approximate locations of Harbour Porpoise sightings during the survey year, made from the FORCE Visitor Center during the Shore-Based Seabird Survey – Tidal Energy Demonstration Site, Fundy Ocean Research Center for Energy. Parrsboro, Nova Scotia. May 6, 2016 – May 1, 2017. Harbour Porpoise numbers are in parentheses after the date; all others show single individuals.

4 Conclusions and Recommendations

The series of surveys for seabirds conducted at the FORCE demonstration site from 2016-2017 has provided information relevant to assessing the potential for interactions and impacts of installations of in-stream tidal energy devices and associated activities, as well as increasing the database of information on seabirds and water-associated birds as well as Harbour Porpoise and seals, at the Minas Passage site. The information generated so far (i.e. from 2010-2017) consists of more than two years of observations, with coverage from all seasons, providing a series of snapshots of occurrences and abundance of seabirds and marine mammals at the FORCE site on particular days through the annual cycle.

4.1 Seabirds and Water-Associated Birds

Observations have estimated both the population of resident birds (i.e. birds which occupy, feed, and breed) in the immediate vicinity (i.e. in the outer Minas Basin, Minas Passage, and Minas Channel system of the Inner Bay of Fundy); as well as migrants which occur in the area, and can at times be most numerous; wanderers such as oceanic seabirds (e.g. shearwaters); and casual or occasional species which may occur by chance at the site. Residents are species including Great Black-backed Gull and Herring Gull, Double-crested Cormorant and Great Cormorant, Common Eider, Black Guillemot, and Common Loon; migrants include shorebirds, Red-throated Loon, sea ducks including Black Scoter, Surf Scoter and White-winged Scoter, and Long-tailed Duck, as well as waterfowl such as Red-Breasted Merganser; and casuals such as Snow Goose as well as other seasonally-occurring species such as American Black Duck, alcids (e.g. Atlantic Puffin, Common Murre, Razorbill) which occur at the site at certain seasons.

The present surveys follow the methodologies outlined in the FORCE 2016-2021 Environmental Effects Monitoring Program (EEMP), which reflects survey approaches used in other areas of the world for monitoring seabirds and other water-associated birds in the vicinity of tidal energy installations. Observations were focused on subareas of the site which reflect potential areas of concern (e.g. the zone for turbine deployment—'Crown Lease') as well as nearby 'control' or reference areas, as is standard in Environmental Effects Monitoring designs (Robbins 2012; Jackson and Whitfield 2011). Observation height (~22 m) has been suitable and consistent throughout the survey, and has proven to be effective for our purposes. Observation distances are consistent with other studies (e.g. Robbins 2012; Jackson and Whitfield 2011) (the furthest corner of the Crown Lease area is approximately 3 km from the observation site) and our bird observer can confidently identify the presence of birds at and beyond that distance.

Throughout the monitoring program, surveys have focused consistently on a single time of day and point in the tidal cycle covering the ebb tide from high tide and beginning at mid-day. This was initially both to ensure consistency in two of the major environmental variables (tide and time of day) and also to be logistically achievable in a one-day surveys. This year's surveys followed the recommended monitoring protocol from the FORCE 2016-2021 EEMP (SLR 2015) which mirrored the approach used in the baseline surveys; however some of the surveys could not be completed following this protocol exactly for various logistical reasons, resulting chiefly in having observations overlap the low tide and flood tide period. These surveys, however, provided new and useful information on conditions at the site, such as demonstrating Harbour Porpoise moving through the site with the tidal current on the incoming tide, something that had not been observed before, in previous shore-based surveys. We have also recognized that the focus on noon for observations does not provide information on other times of day (e.g. morning), all of which could be relevant to assessing impacts of tidal developments. In Year-2, we recommend including a number of additional half-hour periods which include the morning for comparison with the normal survey period.

The Year-One Environmental Effects Monitoring survey at the FORCE site provides the first year-round survey of seabirds and water-associated birds at the FORCE site, using methods which were consistent with those in the baseline monitoring. The earlier surveys differed in having been conducted over three years, and therefore included inter-annual variability, but also omitted the winter and late-summer to early-fall (September to mid-October) period.

Overall, the present survey has shown similar abundance although lower diversity than in the earlier surveys. Abundance of some species of birds at the site, however, by all measures (including species comparisons between periods of time from earlier surveys) is reduced compared with the earlier observations over three years. For example, Northern Gannet were virtually absent this year. However locally nesting species (Black Guillemot and Common Eider) and dominant species are not notably different in abundance and seasonal pattern. Seabirds and water-associated birds using the site were represented mostly by coastal species which use inshore waters on a regular basis or during migration. Also notably absent this year, compared to earlier surveys, were oceanic seabirds such as shearwaters, storm-petrels, and Northern Gannet, which have occurred in past, but the variety of coastal species was also lower. Pacific Loon, for example, which was seen on over half of the earliest surveys, was not observed this year.

Several factors which are potentially important in influencing overall bird abundance at the site include: food availability; changes in atmospheric and oceanographic conditions; direct and indirect effects of presence of the demonstration site (i.e. activity associated with tidal energy development and tidal energy devices--much more activity at present than in earlier surveys); long term trends in abundance of migrants due to conditions in northern breeding areas and overwintering areas; and even fishing activity, in particular activity seiner fisheries for Atlantic Herring in the area, are all potential factors. In particular, an increased understanding of food availability at the site may help to explain some of the observations from the survey.

Comparisons of abundance and diversity in the current versus earlier surveys, have not shown changes related to work at the site, or installation of the tidal turbines, both this year and in the earliest survey period, when a test turbine was installed from November 2009 to December 2010. Although a lower diversity of birds was demonstrated this year, compared to earlier baseline surveys, much of the difference was due to the absence of incidental species such as oceanic seabirds and also to northern nesting species which occur only occasionally at the site often in winter, the occurrence of which are not likely to be impacted by conditions at the site. The main species component (i.e. the dominants) with the exception of Northern Gannet, continue to occupy the site, with approximately the same seasonality and abundance as in earlier years.

The observation protocol used in the survey has been suitable for long-term monitoring. Data recording methods have been the same through the overall program, with minor refinements. Data recording forms and the analysis approach were developed during the first year (2010) and have been used largely unchanged to the present. After the early surveys, the on-site weather station at the FORCE Visitor Centre has provided more-detailed information on atmospheric conditions at the site, and in the present survey, we routinely record sea state information and other information, compiled in the database.

4.2 Marine Mammals

FORCE's activities in environmental effects monitoring for seabirds has continued to provide insight, in addition, into marine mammal and particularly Harbour Porpoise activity in Minas Passage. Fewer sightings of Harbour Porpoise were made overall this past year than in the earlier baseline surveys. Abundance estimates are more qualitative than those for birds as Harbour Porpoise are not the primary objective of observations, which focus on birds and bird abundance, and are incidental to the recording of bird occurrences. Additional information determined this year, for the first time shows movements of Harbour Porpoise through the study area with the incoming tide. Previous shore-based monitoring studies in the FORCE Baseline monitoring did not include flood tides and therefore excluded this type of observation. Observations of Harbour Porpoise obtained in the FORCE monitoring program have provided important information on the occurrence and some of the activities and behavioural traits of the species, which was not known before the monitoring associated with the FORCE project took place. Based on the shore-based surveys, Harbour Porpoise is a common visitor from early spring to fall, with its abundance likely linked to movements of prey species, such as Atlantic Herring.

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APPENDIX A –SEABIRD ABUNDANCE BY SPECIES AND SURVEY

Table A1. Seabird and waterfowl abundance, shore-based observations – May 6, 2016 Survey.

Species	Date: May 6, 2016			Time: 12:30 – 6:30				Observer: Fulton Lavender					
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
BLGU	0	0	1	1	1	2	0	0	0	1	0	0	0.5
BLSC	0	0	0	0	0	2	0	0	0	1	0	0	0.25
COEI	0	0	2	2	5	5	1	0	1	0	0	0	1.3
COLO	0	0	1	0	0	0	0	0	0	0	0	0	0.08
DCCO	4	5	5	4	4	2	4	5	4	0	6	0	3.2
GBBG	21	20	21	23	23	20	20	20	20	16	1	0	17.1
GRCO	2	0	2	3	0	3	3	5	4	4	0	0	2.2
HEGU	4	5	3	8	7	8	11	5	4	12	7	0	6.2
LBBG	0	0	0	0	1	0	0	0	0	0	0	0	0.08
RTLO	1	6	1	0	0	0	0	0	0	2	0	0	0.8

Table A2. Seabird and waterfowl abundance, shore-based observations – June 2, 2016 Survey.

Species	Date: June 2, 2016			Time: 12:00 – 18:15				Observer: Fulton Lavender					
	Location: FORCE Visitor Center observation deck facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
BLGU	2	1	0	1	3	0	0	0	0	1	0	0	0.7
COEI	2	0	1	8	6	3	0	6	3	4	4	4	3.4
COLO	0	0	0	0	0	0	1	0	0	0	1	1	0.3
DCCO	6	2	2	2	3	0	2	7	4	9	9	5	4.3
GBBG	34	21	17	24	18	13	22	18	16	15	17	16	19
GRCO	0	0	0	0	1	1	1	1	2	1	1	1	0.8
HEGU	14	20	23	20	21	14	13	5	1	9	7	9	13
LBBG	0	0	0	0	0	1	0	0	0	0	0	1	0.2
RBGU	0	0	0	0	0	0	0	0	0	0	0	1	0.1
RTLO	0	0	0	0	0	1	0	0	0	0	0	1	0.2

Table A3. Seabird and waterfowl abundance, shore-based observations – July 2, 2016 Survey.

Species	Date: July 2, 2016			Time: 11:20 – 17:20				Observer: Fulton Lavender					
	Location: FORCE Visitor Center observation deck facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per 30-minute Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
BLGU	5	2	4	2	1	2	0	0	1	1	0	3	1.8
COEI	0	0	1	3	0	3	4	2	2	3	4	6	2.3
COLO	0	0	1	0	0	1	0	0	0	0	0	0	0.2
DCCO	1	3	1	1	0	1	0	2	3	4	3	3	1.8
GBBG	11	13	3	7	6	9	8	7	5	9	8	8	7.8
GRCO	0	0	0	0	0	0	0	0	2	0	0	0	0.2
HEGU	5	4	5	6	5	4	2	10	4	3	2	4	4.5
RTLO	1	0	0	0	0	0	0	0	0	0	0	0	0.1

Table A 4. Seabird and waterfowl abundance, shore-based observations – August 2, 2016 Survey.

Species	Date: August 2, 2016				Time: 13:00 – 18:30				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
BLGU	1	2	8	2	0	0	1	0	0	0	0	1	1.3
BLSC	0	0	0	0	0	0	0	0	1	0	0	0	0.1
COEI	1	1	2	1	1	1	1	2	2	2	3	0	1.4
COLO	0	0	0	0	1	0	0	0	0	0	0	0	0.1
DCCO	0	1	3	3	3	4	2	1	3	1	2	4	2.3
GBBG	3	4	3	3	2	2	2	2	3	1	1	2	2.3
GRCO	3	1	3	3	3	3	2	2	2	1	2	3	2.3
HEGU	20	13	10	15	5	4	1	1	4	3	2	4	6.8
LBBG	0	0	0	0	0	1	0	0	0	0	0	0	0.1
LEYE	0	0	0	0	0	0	0	0	0	0	0	3	0.3
RBGU	0	0	0	0	4	4	3	3	3	7	6	6	3.0
SPSA	2	0	0	0	0	0	0	0	0	0	0	0	0.2

Table A 5. Seabird and waterfowl abundance, shore-based observations – September 1, 2016 Survey.

Species	Date: September 1, 2016				Time: 13:15 – 18:45				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
DCCO	8	8	14	17	11	12	14	11	8	5	10	8	10.5
GRCO	3	4	4	0	2	1	1	4	5	12	14	21	5.9
HEGU	6	9	3	1	6	2	0	5	3	1	0	1	3.1
RBGU	1	1	0	0	6	12	3	1	2	0	0	0	2.2
WISP	0	0	0	0	4	0	0	0	0	0	0	0	0.3

Table A 6. Seabird and waterfowl abundance, shore-based observations – October 1, 2016 Survey.

Species	Date: October 1, 2016				Time: 11:30 – 17:05				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
BLDU	0	0	0	0	0	0	4	0	0	0	0	0	0.3
BLSC	0	2	9	0	0	0	0	0	0	0	0	0	0.9
CAGO	0	0	1	0	0	0	0	0	0	0	0	0	0.1
COLO	0	2	1	1	1	1	1	1	1	1	1	1	1.0
DCCO	1	2	0	1	0	0	1	2	0	0	2	1	0.8
GBBG	0	0	0	0	0	0	0	0	0	0	0	1	0.1
GRCO	1	1	2	0	1	0	0	1	2	2	1	1	1.0
HEGU	1	3	2	7	0	0	3	0	31	0	1	5	4.4
RBGU	1	2	0	0	0	0	0	0	1	1	3	0	0.7
RBME	0	0	0	0	0	0	0	0	0	1	0	0	0.1
RTLO	1	0	0	0	0	0	0	0	0	0	0	0	0.1

Table A 7. Seabird and waterfowl abundance, shore-based observations – October 17, 2016 Survey.

Species	Date: October 17, 2016				Time: 11:45 – 17:15				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
BLSC	6	0	0	0	0	0	0	0	0	0	0	0	0.5
COEI	0	0	0	0	0	0	1	0	2	2	2	2	0.8
COLO	0	0	0	0	0	0	0	1	0	0	0	0	0.1
DCCO	0	0	0	0	0	0	0	0	0	0	0	1	0.1
GBBG	0	1	0	0	0	0	0	0	0	0	0	1	0.2
GRCO	0	0	1	0	1	2	2	2	2	2	0	0	1.0
HEGU	0	1	2	1	0	0	0	3	0	0	7	7	1.8
RBGU	0	1	0	0	0	0	0	0	0	0	0	0	0.1
WWSC	0	0	0	0	0	0	0	1	0	0	0	0	0.1

Table A 8. Seabird and waterfowl abundance, shore-based observations – November 3, 2016 Survey.

Species	Date: November 3, 2016				Time: 12:15 – 17:45				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
BLSC	20	0	0	7	15	0	15	0	97	17	0	221	32.7
COEI	0	0	0	0	0	0	0	1	0	0	0	0	0.1
COLO	0	0	0	0	0	0	0	1	0	0	0	0	0.1
GBBG	0	0	0	0	0	0	0	0	0	0	0	1	0.1
HEGU	2	0	0	0	2	0	0	0	2	4	41	13	5.3
ICGU	0	0	0	0	0	0	0	0	0	0	1	0	0.1
LTDU	0	0	0	0	0	0	5	0	0	0	0	0	0.4
ATPU	0	0	0	0	0	0	0	0	0	0	1	0	0.1
RAZO	0	0	0	0	0	0	0	1	0	0	0	0	0.1
RTLO	0	3	3	2	0	1	0	0	1	1	1	0	1.0
SUSC	0	0	0	0	0	0	0	0	0	12	0	0	1.0

Table A 9. Seabird and waterfowl abundance, shore-based observations – November 17, 2016 Survey.

Species	Date: November 17, 2016					Time: 12:00 – 17:00				Observer: Fulton Lavender		
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.											
	Number of Individuals Sighted per Observation Period											
	1	2	3	4	5	6	7	8	9	10	11	Average
ARLO	0	0	0	0	0	1	0	0	0	0	0	0.1
ATPU	0	0	0	0	0	1	0	0	0	0	0	0.1
BLSC	2	0	0	3	0	0	0	0	0	0	0	0.5
COEI	0	2	0	0	0	0	0	0	0	5	0	0.6
COLO	0	1	0	0	0	0	0	0	0	0	0	0.1
COMU	8	0	0	0	0	0	0	0	0	0	0	0.7
HEGU	2	1	2	0	0	0	1	1	0	1	5	1.2
LTDU	0	0	0	0	0	3	0	0	0	0	0	0.3
RAZO	0	0	0	0	0	1	0	0	0	0	0	0.1
RBGU	0	0	2	0	1	0	0	0	2	0	0	0.5
RNGR	0	0	0	0	0	0	0	1	0	0	0	0.1
RTLO	1	1	1	0	50	8	4	2	0	0	0	6.1

Table A 10. Seabird and waterfowl abundance, shore-based observations – December 1, 2016 Survey.

Species	Date: December 1, 2016				Time: 12:30 – 16:30			Observer: Fulton Lavender		
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.									
	Number of Individuals Sighted per Observation Period									
	1	2	3	4	5	6	7	8	9	Average
ABDU	0	2	0	0	0	0	0	0	0	0.2
COME	0	0	0	0	0	0	0	0	5	0.4
GBBG	0	0	1	0	0	0	0	0	1	0.2
HEGU	0	0	1	0	0	0	0	2	148	12.6

RBGU	0	0	0	0	0	0	0	0	1	0.1

Table A 11. Seabird and waterfowl abundance, shore-based observations – January 16, 2017 Survey.

Species	Date: January 16, 2017				Time: 12:15 – 16:45			Observer: Fulton Lavender			
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.										
	Number of Individuals Sighted per Observation Period										
	1	2	3	4	5	6	7	8	9	10	Average
ABDU	3	0	0	0	0	0	0	0	0	0	0.3
COEI	0	0	4	0	0	0	0	0	0	0	0.4
COGO	6	6	8	0	0	0	0	0	0	0	2
COLO	0	1	0	0	0	1	0	0	0	0	0.2
COMU	0	0	1	0	0	0	0	0	0	0	0.1
GBBG	0	0	0	0	0	0	31	63	71	110	27.5
HEGU	4	0	0	0	0	0	1	2	14	231	25.2
ICGU	0	0	0	0	0	0	0	1	0	0	0.1

Table A 12. Seabird and waterfowl abundance, shore-based observations – February 21, 2017 Survey.

Species	Date: February 21, 2017					Time: 12:00 – 17:30				Observer: Fulton Lavender			
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
COLO	0	0	0	1	0	0	0	0	0	0	0	0	0.1
GBBG	0	0	0	0	0	0	0	0	1	7	8	42	4.8
COGO	5	5	5	5	5	0	0	0	0	1	0	0	2.2
GRCO	0	0	0	0	0	0	0	3	0	0	0	0	0.3
HEGU	1	0	0	0	0	0	1	1	2	22	2	12	3.4
RTLO	0	0	0	0	1	0	0	0	0	1	0	0	0.2

Table A 13. Seabird and waterfowl abundance, shore-based observations – March 13, 2017 Survey.

Species	Date: March 13, 2017				Time: 12:15 – 17:45					Observer: Fulton Lavender			
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
ABDU	5	0	0	0	0	0	0	0	0	0	0	0	0.4
COEI	5	0	0	0	0	0	0	0	0	0	0	0	0.4
COLO	0	0	0	0	0	0	0	0	1	0	0	0	0.1
GBBG	1	2	3	4	5	5	4	6	7	7	7	8	4.9
GRCO	0	0	0	0	0	0	0	0	0	0	0	2	0.2
HEGU	1	1	0	1	1	2	0	0	0	4	2	20	2.7
RTLO	0	0	0	0	0	0	0	1	0	0	1	0	0.2

Table A 14. Seabird and waterfowl abundance, shore-based observations – April 3, 2017 Survey.

Species	Date: April 3, 2017				Time: 12:15 – 17:45				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
ABDU	0	1	0	0	0	0	7	0	0	0	0	0	0.7
BLGU	0	0	1	1	1	0	0	0	0	0	0	0	0.3
BLSC	0	0	9	0	0	0	0	0	0	0	0	0	0.8
CAGO	0	2	0	10	0	20	2	0	0	0	0	0	2.8
COEI	0	75	0	0	0	0	0	0	0	0	0	0	6.3
COGO	0	2	0	0	0	0	0	0	0	0	0	0	0.2
GBBG	1	1	2	5	1	1	3	2	9	11	11	12	4.9
HEGU	0	0	0	14	2	1	1	5	2	6	7	24	5.2
LTDU	0	0	0	0	0	0	0	0	0	1	0	0	0.1
PUSA	0	0	0	0	0	0	0	0	0	0	1	1	0.2
RBME	1	0	0	0	0	0	0	0	0	0	0	0	0.1
RTLO	0	0	0	4	0	0	0	0	0	0	0	0	0.3
SNGO	0	0	0	0	0	0	1	0	0	0	0	0	0.1

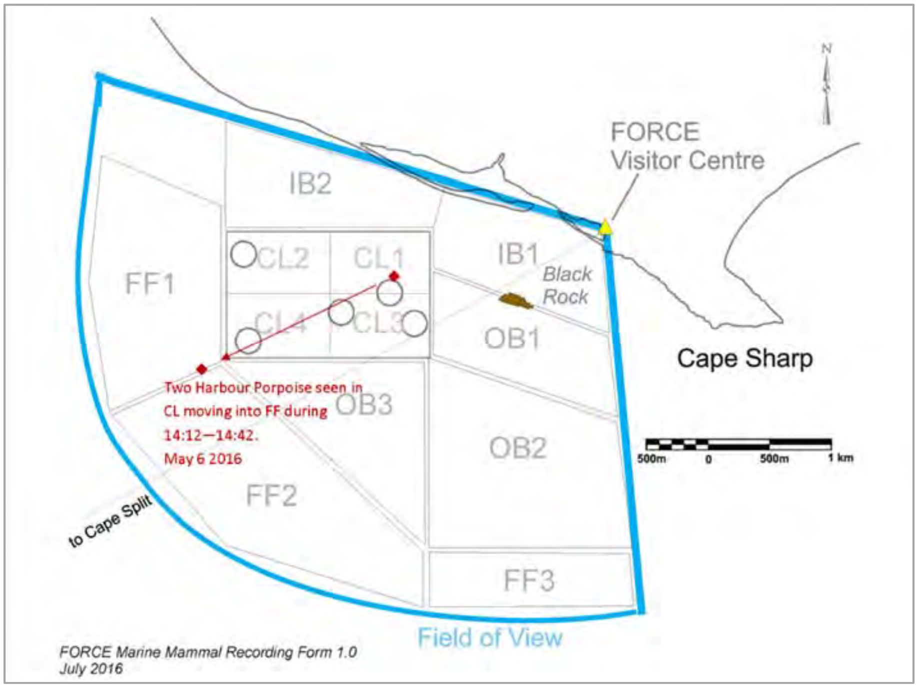
Table A 15. Seabird and waterfowl abundance, shore-based observations – April 17, 2017 Survey.

Species	Date: April 17, 2017				Time: 11:50 – 17:20				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
ATPU	0	0	0	0	0	0	0	0	1	0	0	0	0.1
BLGU	0	0	0	0	0	0	1	0	0	2	0	0	0.3
BLSC	67	116	60	115	30	25	32	95	18	30	0	25	51.1
COEI	0	15	1	2	2	2	2	17	0	2	2	4	4.1
COLO	1	2	0	0	0	9	0	4	0	0	8	0	2.0
DCCO	56	54	14	81	81	81	124	90	80	83	85	128	79.8
GBBG	9	5	61	9	10	7	7	15	18	21	22	20	17.0
GRCO	15	7	3	4	4	1	4	3	3	4	0	2	4.2
HEGU	22	2	70	11	7	7	7	61	41	100	105	101	44.5
ICGU	1	0	0	0	3	12	0	0	0	0	0	0	1.3
LTDU	0	2	63	0	48	5	1	2	140	1	20	0	23.5
NOGA	0	0	2	1	0	0	0	0	1	0	1	0	0.4
RBGU	0	0	0	0	0	0	4	0	0	0	0	0	0.3
RBME	0	3	4	0	0	0	0	3	0	0	0	0	0.8
RTLO	1	8	123	3	12	4	11	6	20	0	2	3	16.1
SUSC	2	0	0	0	140	10	170	5	5	0	0	0	27.7
WWSC	0	2	0	0	2	1	0	0	0	0	0	3	0.7

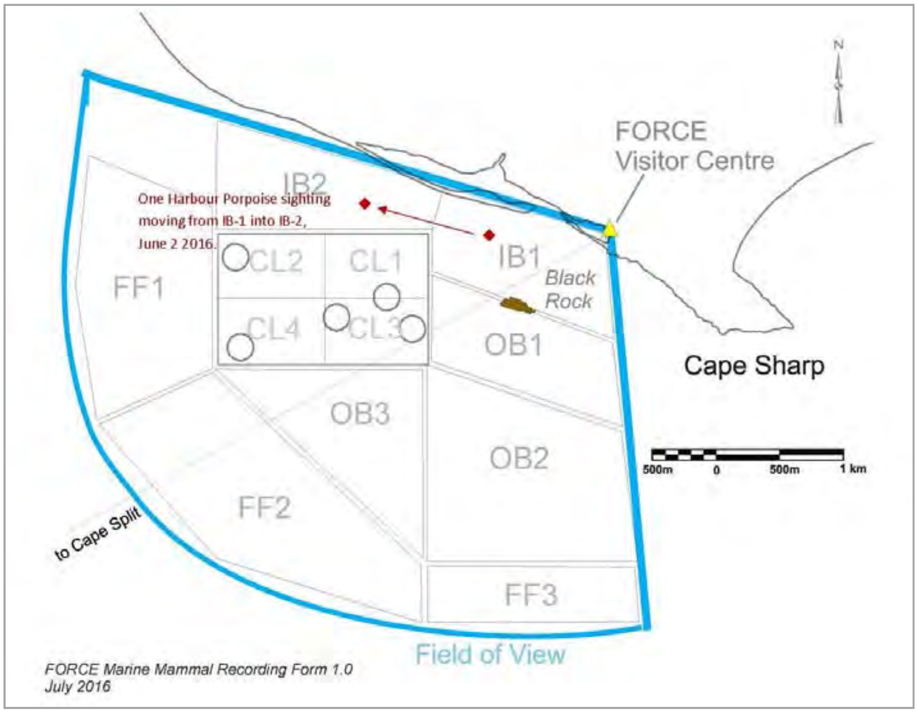
Table A 16. Seabird and waterfowl abundance, shore-based observations – May 1, 2017 Survey.

Species	Date: May 1, 2017				Time: 12:00 – 17:00				Observer: Fulton Lavender				
	Location: FORCE Visitor Center main lobby facing water, Parrsboro Nova Scotia.												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
BLGU	2	2	2	3	2	2	0	1	1	2	0	0	1.4
BLSC	0	0	5	0	0	0	0	0	2	0	4	0	0.9
BWTE	2	0	0	0	0	0	0	0	0	0	0	0	0.2
COEI	1	10	3	9	0	0	0	1	0	1	1	3	2.4
DCCO	42	37	17	24	37	32	29	33	33	29	38	31	31.8
GBBG	16	23	19	25	18	15	1	23	30	29	26	26	20.9
GRCO	6	4	1	1	0	4	3	3	2	1	1	1	2.3
HEGU	15	11	13	5	5	13	5	7	8	9	14	15	10.0
LBBG	0	0	0	0	0	0	0	0	1	2	1	1	0.4
LTDU	5	0	1	0	0	0	0	0	0	0	0	0	0.5
RBMR	0	0	0	0	0	0	0	0	0	1	0	0	0.1
RTLO	0	1	2	1	0	0	0	0	0	1	3	4	1.0
SUSC	6	0	0	21	0	0	0	6	2	0	0	0	2.9

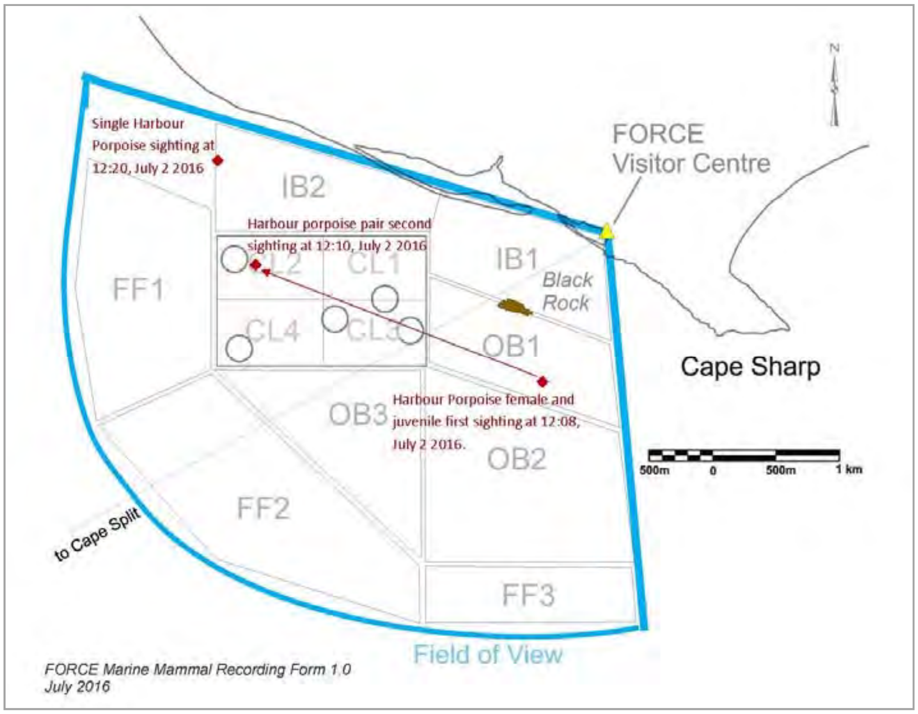
APPENDIX B – SUMMARY OF HARBOUR PORPOISE SIGHTINGS



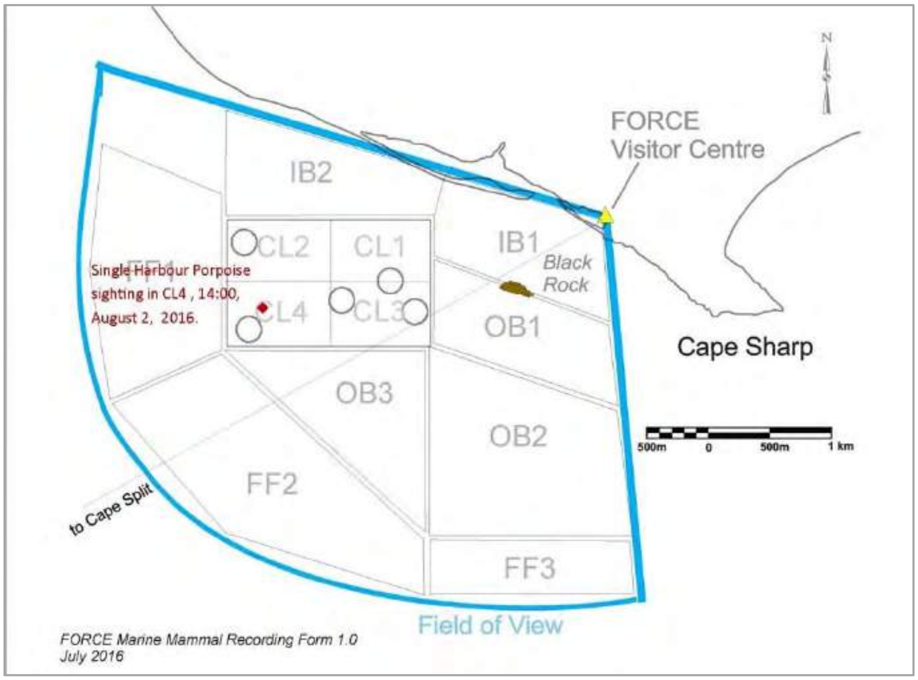
Depiction of a single Harbour Porpoise sighting on May 6 2016 from the FORCE Visitor Center outdoor observation deck.



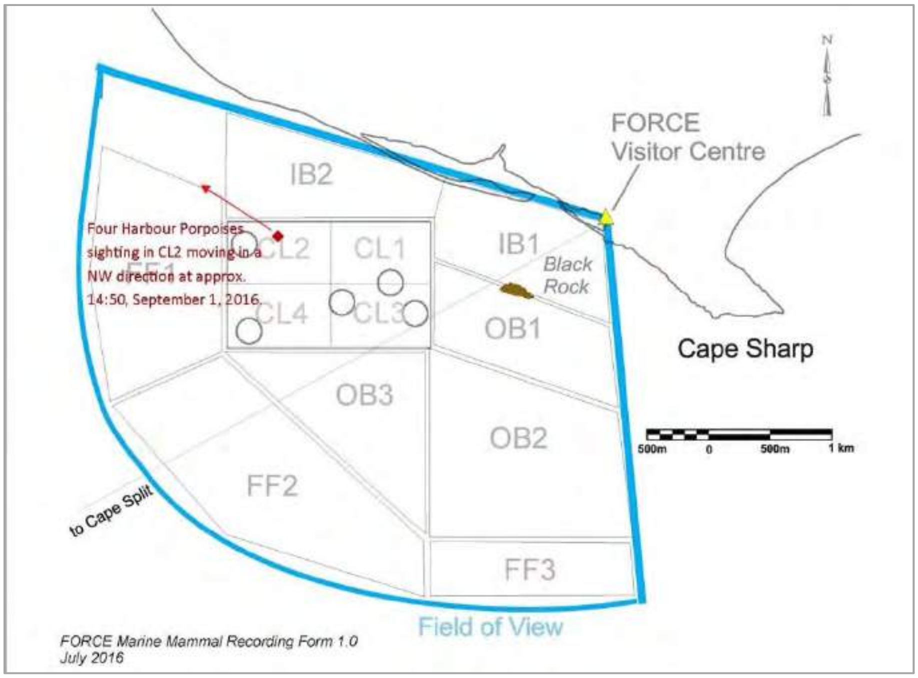
Depiction of a single Harbour Porpoise sighting on June 2 2016 from the FORCE Visitor Center outdoor observation deck.



Depiction of Harbour Porpoise sighting on July 2 2016 from the FORCE Visitor Center outdoor observation deck.

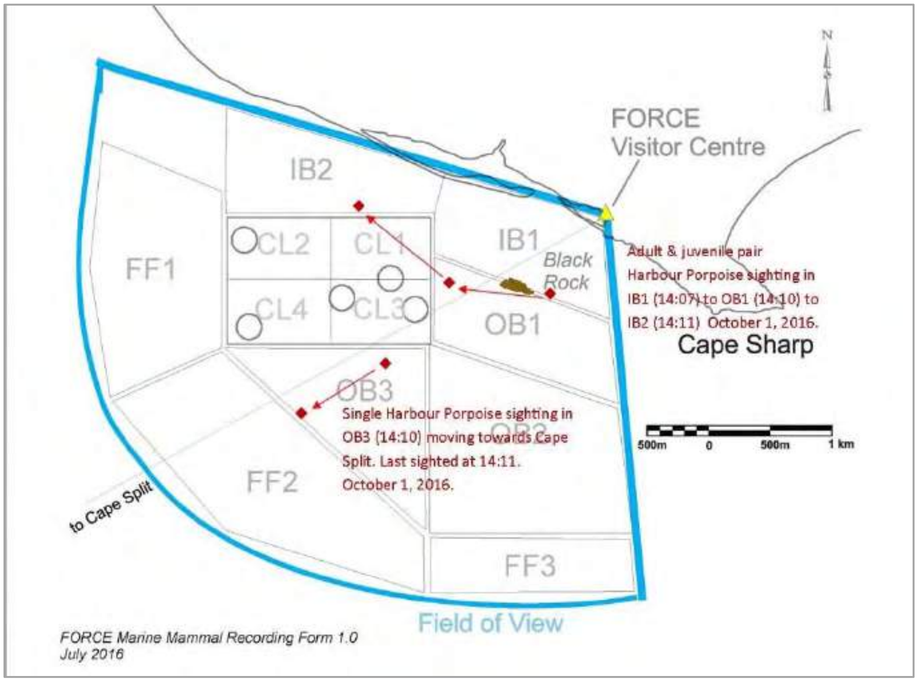


Depiction of a single Harbour Porpoise sighting on August 2, 2016 from the FORCE Visitor Center outdoor observation deck.



Four Harbour Porpoises sighting in CL2 moving in a NW direction at approx. 14:50, September 1, 2016.

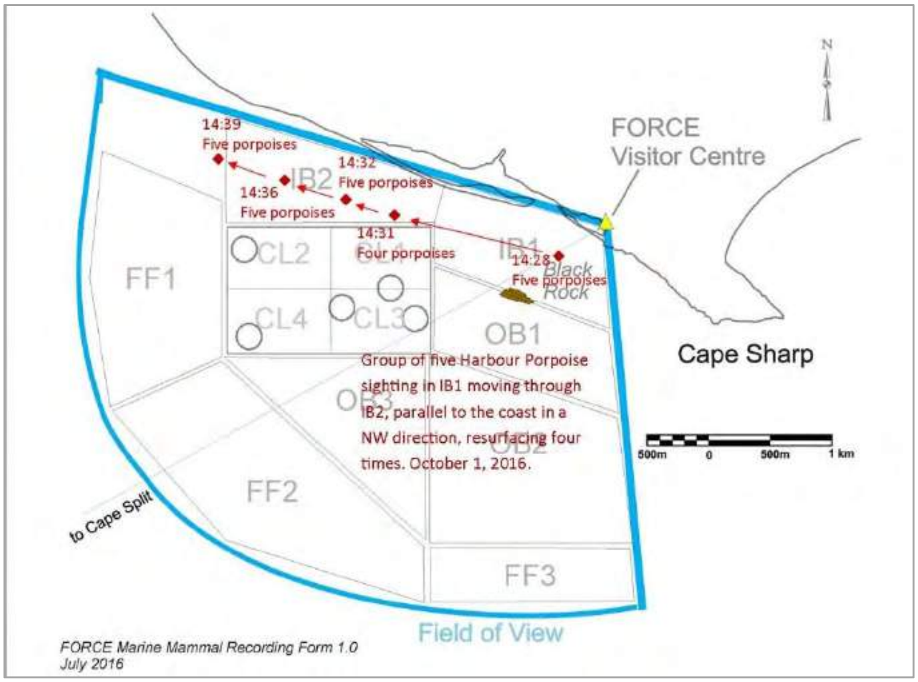
Depiction of Harbour Porpoise sighting on September 1, 2016 from the FORCE Visitor Center outdoor observation deck.



Adult & juvenile pair Harbour Porpoise sighting in IB1 (14:07) to OB1 (14:10) to IB2 (14:11) October 1, 2016.

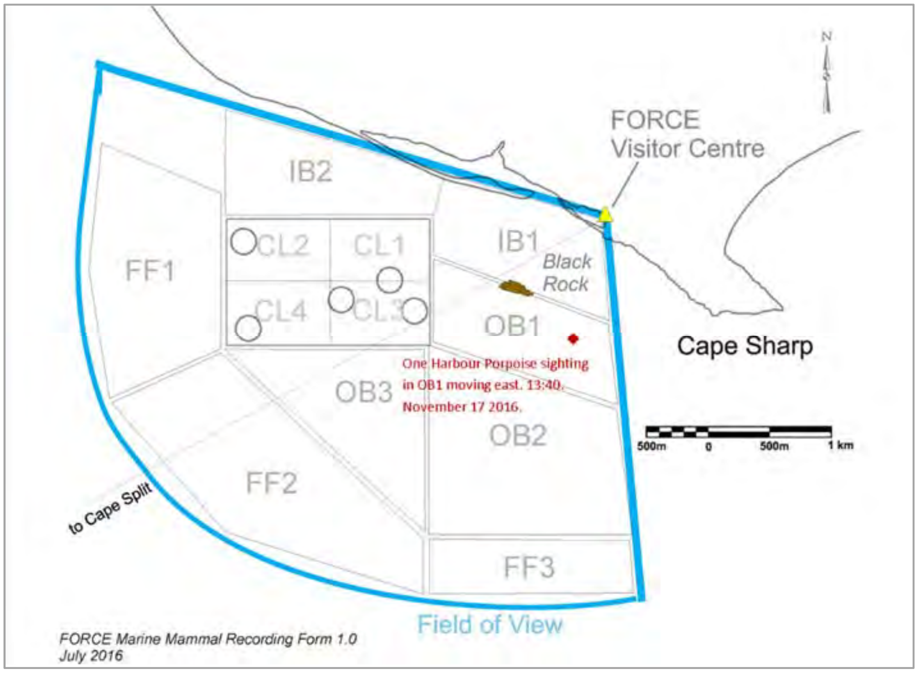
Single Harbour Porpoise sighting in OB3 (14:10) moving towards Cape Split. Last sighted at 14:11. October 1, 2016.

Depiction of first Harbour Porpoise sighting on October 1, 2016 from the FORCE Visitor Center outdoor observation deck.



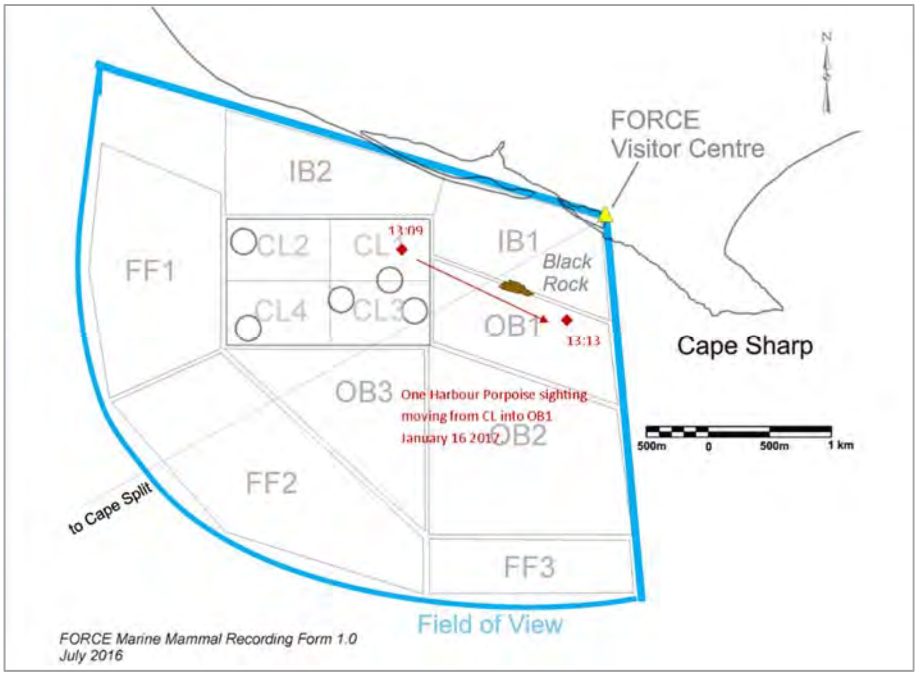
Group of five Harbour Porpoise sighting in IB1 moving through IB2, parallel to the coast in a NW direction, resurfacing four times. October 1, 2016.

Depiction of second Harbour Porpoise sighting on October 1, 2016 from the FORCE Visitor Center outdoor observation deck.



One Harbour Porpoise sighting in OB1 moving east. 13:40. November 17 2016.

Depiction of Harbour Porpoise sighting on November 17, 2016 from the FORCE Visitor Center outdoor observation deck.



Depiction of Harbour Porpoise sighting on January 16, 2017 from the FORCE Visitor Center outdoor observation deck.

APPENDIX C – CONSERVATION STATUS OF SEABIRDS, OTHER WATER-ASSOCIATED BIRDS, AND COASTAL RAPTORS AT THE FORCE SITE, 2010-2017

Table C1. Conservation status of seabirds and other water-associated birds and coastal raptors at the FORCE Tidal Energy Demonstration Site, 2010-2017.

Common Name	**Scientific Name**	**Conservation Status/Rank**					
		COSEWIC	SARA	NS Endangered Status	Provincial Rarity Rank	Provincial General Status Rank (NR=not rated)	Other Comments
American Black Duck	*Anas rubripes*				S5	4 Secure	
Arctic Loon	*Gavia arctica*					NR	Accidental
Atlantic Puffin	*Fratercula arctica*				S3B, S5N	3 Sensitive	
Bald Eagle	*Haliaeetus leucocephalus*	Not at Risk			S5	4 Secure	Terrestrial
Black-Bellied Plover	*Pluvialis squatarola*				S3M	4 Secure	
Black Guillemot	*Cepphus grylle*				S4	4 Secure	
Black-Legged Kittiwake	*Rissa tridactyla*				S3B, S5N	3 Sensitive	
Black Scoter	*Melanitta nigra*				S4N	4 Secure	
Black Tern	*Chlidonias niger*	Not at Risk			S1B	2 May Be At Risk	
Blue-Winged Teal	*Anas discors*				S3S4B	2 May Be At Risk	
Canada Goose	*Branta canadensis*				SNAB, S4N	4 Secure	
Common Eider	*Somateria mollissima*				S3S4	4 Secure	
Common Goldeneye	*Bucephala clangula*				S2B, S5W	4 Secure	
Common Loon	*Gavia immer*	Not at Risk			S3B, S4N	2 May Be At Risk	
Common Merganser	*Mergus merganser*				S5	4 Secure	
Common Murre	*Uria aalge*				S1?B, S5N	4 Secure	
Cory’s Shearwater	*Calonectris diomedea*				SNA	8 Accidental	
Double-Crested Cormorant	*Phalacrocorax auritus*	Not at Risk			S4B	4 Secure	
Great Black-Backed Gull	*Larus marinus*				S4S5	4 Secure	
Great Cormorant	*Phalacrocorax carbo*				S2S3	3 Sensitive	

Table C1. Conservation status of seabirds and other water-associated birds and coastal raptors at the FORCE Tidal Energy Demonstration Site, 2010-2017.

Common Name	**Scientific Name**	**Conservation Status/Rank**					
		COSEWIC	SARA	NS Endangered Status	Provincial Rarity Rank	Provincial General Status Rank (NR=not rated)	Other Comments
Great Shearwater	*Puffinus gravis*				S5N	4 Secure	
Greater Yellowlegs	*Tringa melanoleuca*				S3B, S3S4M	3 Sensitive	
Harlequin Duck	*Histrionicus histrionicus*	Special Concern	Special Concern	Endangered	S2N	1 At Risk	
Herring Gull	*Larus argentatus*				S5	4 Secure	
Horned Grebe	*Podiceps auritus*				S4W	4 Secure	
Iceland Gull	*Larus glaucoides*				S4N	4 Secure	
King Eider	*Somateria spectabilis*				SNA	4 Secure	
Laughing Gull	*Larus atricilla*				SHB	2 May Be At Risk	
Lesser Black-Backed Gull	*Larus fuscus*				SNA	8 Accidental	
Least Sandpiper	*Calidris minutilla*				S1B, S3M	4 Secure	
Lesser Yellowlegs	*Tringa flavipes*				S3M	4 Secure	
Long-Tailed Duck	*Clangula hyemalis*				S5N	4 Secure	
Mallard	*Anas platyrhynchos*				S5	4 Secure	
Mew Gull	*Larus canus*				SNA	8 Accidental	
Northern Gannet	*Morus bassanus*				SHB, S5M	4 Secure	
Northern Harrier	*Circus cyaneus*	Not at Risk			S3S4B	4 Secure	Terrestrial
Northern Shoveler	*Anas clypeata*				S2B	2 May Be At Risk	
Pacific Loon	*Gavia pacifica*				SNA	8 Accidental	
Peregrine Falcon	*Falco peregrinus*	Not at Risk	Special Concern	Vulnerable	S1B, SNAM	3 Sensitive	Terrestrial
Purple Sandpiper	*Calildris maritima*				S3?N	3 Sensitive	

Table C1. Conservation status of seabirds and other water-associated birds and coastal raptors at the FORCE Tidal Energy Demonstration Site, 2010-2017.

Common Name	**Scientific Name**	**Conservation Status/Rank**					
		COSEWIC	SARA	NS Endangered Status	Provincial Rarity Rank	Provincial General Status Rank (NR=not rated)	Other Comments
Razorbill	*Alca torda*				S2B, S4N	3 Sensitive	
Ring-Billed Gull	*Larus delawarensis*				SUB, S5N	4 Secure	
Red-Breasted Merganser	*Mergus serrator*				S3S4B, S5N	4 Secure	
Red Phalarope	*Phalaropus fulicarius*				S2S3M	3 Sensitive	
Red-Necked Grebe	*Podiceps grisigena*				S4N	4 Secure	
Red-Necked Phalarope	*Phalaropus lobatus*	Special Concern	No Status		S2S3M	3 Sensitive	
Red-Throated Loon	*Gavia stellata*				S4N	4 Secure	
Ruddy Turnstone	*Arenaria interpres*				S3M	4 Secure	
Sanderling	*Calidris alba*				S3M, S2N	4 Secure	
Semipalmated Plover	*Charadrius semipalmatus*				S1B, S3S4M	4 Secure	
Semipalmated Sandpiper	*Calidris pusilla*				S3M	3 Sensitive	
Sooty Shearwater	*Puffinus griseus*				S5N	4 Secure	
Snow Goose	*Anser caerulescens*				SNA	4 Secure	
Spotted Sandpiper	*Actitis macularius*				S3S4B	3 Sensitive	
Surf Scoter	*Melanitta perspicillata*				S4N	4 Secure	
Thick-Billed Murre	*Uria lomvia*				SNA	4 Secure	
Wilson's Storm-Petrel	*Oceanites oceanicus*				S5N	4 Secure	
White-Winged Scoter	*Melanitta fusca*				S4N	4 Secure	

Table C2. Conservation status codes used in Table C1. Source: Atlantic Canada Conservation Data Centre, http://www.accdc.com/en/rank-definitions.html

Provincial) Rarity Rank

S1	**Critically Imperiled-** Extremely rare throughout its range in the province (typically 5 or fewer occurrences or very few remaining individuals). May be especially vulnerable to extirpation.
S2	**Imperiled-**Rare throughout its range in the province (6 to 20 occurrences or few remaining individuals). May be vulnerable to extirpation due to rarity or other factors.
S3	**Vulnerable-**Uncommon throughout its range in the province, or found only in a restricted range, even if abundant in at some locations (21 to 100 occurrences).
S4	**Apparently Secure**-Usually widespread, fairly common throughout its range in the province, and apparently secure with many occurrences, but the Element is of long-term concern (e.g. watch list). (100+ occurrences).
S5	**Secure**-Demonstrably widespread, abundant, and secure throughout its range in the province, and essentially ineradicable under present conditions.
SU	**Unrankable -** Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
SNA	**Not Applicable –** A conservation status rank is not applicable because the species is not a suitable target for conservation activities.

Codes Attached to Provincial Rarity Rank

B	**Breeding-** Conservation status refers to the breeding population of the province.
NB	**Nonbreeding-**Conservation status refers to the non-breeding population of the province.
M	**Migrant-**Migrant species occurring regularly on migration at particular concentration spots where the species might warrant conservation attention; status refers to the agtregatin transient population of the species in the area.
?	**Inexact or Uncertain-**Denotes inexact or uncertain numeric rank (The ? qualifies the character immediately preceding it in the S-rank.)

Provincial General Status of Wild Species Rank listed for Nova Scotia

0.2=Extinct (Blue);
0.1=Extirpated (Purple);
1=At Risk (Red);
2=May be at Risk (Orange);
3=Sensitive (Yellow);
4=Secure (Green);
5=Undetermined (light grey);
6=Not Assessed (dark grey);
7=Exotic (Black);
8=Accidental (Aqua).

Appendix 3: 2016/2017 (Year One) Marine Mammals Monitoring Report

This report presents the results of the first year of marine mammal monitoring of FORCE's 2016 – 2021 Environmental Effects Monitoring Program as prepared by Sea Mammal Research Unit (Consulting).

FORCE Marine Mammal EEMP 1st Year Monitoring Report

Prepared for FORCE

[May 2017]

SMRU Consulting North America

PO Box 764
Friday Harbor, WA 98250
USA

1529 West 6th Ave., Suite 510
Vancouver, BC V6J 1R1
Canada

FORCE Marine Mammal EEMP
1st Year (2017) Monitoring Report

2 May 2017

Prepared by SMRU Consulting

Canada Office
1529 West 6th Ave., Suite 510
Vancouver, BC
V6J 2C1

Authors:

Ruth Joy, PhD
Senior Research Scientist, SMRU Consulting

Jason Wood, PhD
Senior Research Scientist, SMRU Consulting

Frances Robertson, PhD
Research Scientist, SMRU Consulting

Dominic Tollit, PhD
Senior Research Scientist, SMRU Consulting

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Executive Summary

Tidal inlets such as the FORCE demonstration area are dynamic regions that provide important habitat for h arbor porpoise (*Phocoena phocoena*). Harbor porpoise use echolocation to hunt and communicate (Kastelein et al. 2002), and they are known to be very susceptible to noise disturbance (Tougaard et al. 2009). Few studies to date have focused on exposure to continuous low frequency noise sources such as that emitted by tidal turbines. The tidal dynamics inform the presence of porpoises in these areas in complex ways. Hence, long-term and ongoing monitoring of this variability has been an important component of understanding the impacts of installing tidal turbines at this site. FORCE contracted SMRU Consulting (Canada) to complete equipment calibration and click detection data analysis relating to the deployment of passive acoustic monitors (C-PODs) in support of its marine mammal environmental effects monitoring program (EEMP). The most recent EEMP-specific monitoring began on 7 June 2016 and concluded on 18 January 2017, encompassing two C-POD deployment periods with monitoring periods of 84 and 118 days respectively. The installation of the Cape Sharp Tidal Venture's (CSTV) tidal turbine occurred on 7 November 2016, with associated vessel activity also occurring the next day.

This report firstly summarizes the dynamic temporal patterns in porpoise presence in Minas Passage 2011-2017 related to key environmental covariates, notably annual, seasonal, tidal and day vs night variability. It is important to note that temporal coverage was intermittent over this period, with only one winter-early spring period of baseline. Spring through fall data was better represented with two or three years of data collection. We then use this information to provide a statistical analysis of the distribution and activity of harbor porpoise around the FORCE demonstration area in response to the installation and operation of the turbine during the 2nd of the 2016/2017 C-POD deployments, for which data from 5 C-PODs was available.

From May 2011 through to January 2017, there have been 805 monitoring days and 2847 C-POD days, spread across 8 locations within and immediately outside the FORCE area. Overall, harbor porpoises have been detected on 98.4% of days at a median of 6 detection positive minutes per day and maximum of 44 minutes. No dolphins were detected during any of the C-POD deployments at any of the 8 C-POD locations. A statistical model using all C-POD monitoring days confirmed porpoise presence varied significantly by time of year (peak period May/June and lower secondary peak October/November), by current speed and tidal height (preference for 0-2.5 m/s ebb tides), by time of day (higher activity at night) and across the lunar cycle (affected by the position in the spring-neap tide cycle). C-POD performance (termed % time lost) also varied due to noise effects, notably due to non-biological clicks associated with sediment transfer during periods of relatively high current velocity.

During the 2nd of the 2016/2017 C-POD deployments, porpoises were detected at all five monitoring locations on each of the 45 pre-installation days (median 4 detection positive minutes per day) and on 71 of 73 (97.3%) days post-installation of the turbine (median 3 detection positive minutes per day). Consequently, there was no evidence of porpoise exclusion of the mid-range (210 – 1710 m) study area post-installation, noting that changes in the overall distribution of porpoise within the vicinity of the turbine is considered of higher importance.

A statistical model of this period tested for changes in the distribution of harbor porpoise in relation to the installation and operation of the turbine. East1, a site 210 m north of the turbine at 41 m depth, showed statistically fewer porpoise detections post installation of the turbine, whereas D1, a site 230 m northwest of the turbine at 33 m depth, on the rock shelf on which the turbine was also installed, showed no significant effect on porpoise detection rates. Both these sites had overall lower activity levels pre- and post-turbine installation, whereas the sites > 1 km west and south of the turbine had overall higher activity levels. West1, located inside the FORCE demonstration area (1,140 m from the turbine), and West2 (1,710 m away just outside of the FORCE demonstration area), both statistically declined in porpoise detections post installation, while South2 (1,690 m away, south of the FORCE demonstration area) and the deepest site at 68 m depth, had similar detections rates pre and post installation (i.e., no turbine effects). Declines in post installation detection rates were between 41-46%. The obvious and immediate drop in detections observed at East1, West1 and West2 likely represent disturbance from vessel activity, while subsequent dips observed after this period may reflect continued lunar-scale fluctuations related to lower detection performance of C-PODs during all spring tides (higher % lost time). These observations coupled with high levels of inter-annual and site variability and the very short post-installation period so far analyzed, result in the overall conclusion that further C-POD data collection is required before robust inferences can be drawn and preliminary statistical results of mid-range turbine effects at some sites can be substantiated. In particular, continued C-POD monitoring will allow for a better comparison with previous baseline data collected.

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List of Acronyms

ACF: autocorrelation function

AR-1: First order Auto-regressive, used to describe the form of the autocorrelation function

BinDPM: Binomial (0 or ≥1) Detection Positive Minute

BinDPM=0: No porpoise detected within a consecutive 10-minute period

BinDPM=1: At least one porpoise detected within a consecutive 10-minute period

P(BinDPM=1): Probability of there being at least 1 detection positive minute of 10 consecutive minute period.

CSTV: Cape Sharp Tidal Venture

CV: Coefficient of Variation

DPM: Detection Positive Minutes (a count of the number of minutes a porpoise is detected in a fixed period of time

E1: C-POD location East 1

D1: C-POD location specific to berth D.

EEMP: Environmental Effects Monitoring Program

FORCE: Fundy Ocean Research Center for Energy

GEE-GLM: Generalized Estimating Equation with a General Linear Model

IQR: Interquartile Range

OERA: Offshore Energy Research Association

QIC: Quasi Information Criteria

S2: C-POD location South 2

SPL: Sound Pressure Levels in units of Pascal

W1: C-POD location West 1

W2: C-POD location West 2

1. Introduction and EEMP Objectives

Tidal energy is a largely untapped renewable energy source. Worldwide, only a small number of in-stream tidal turbines have been deployed to date. The Fundy Ocean Research Center for Energy (FORCE) is a Canadian non-profit institute that owns and operates a facility in the Bay of Fundy, Nova Scotia (Figure 1), where grid connected tidal energy turbines can be tested and demonstrated. It enables developers, regulators and scientists to study the performance and interaction of tidal energy turbines with the environment. The FORCE test site is in the Minas Passage area of the Bay of Fundy, near Cape Sharp and roughly 10 km west of the town of Parrsboro (Figure 1).

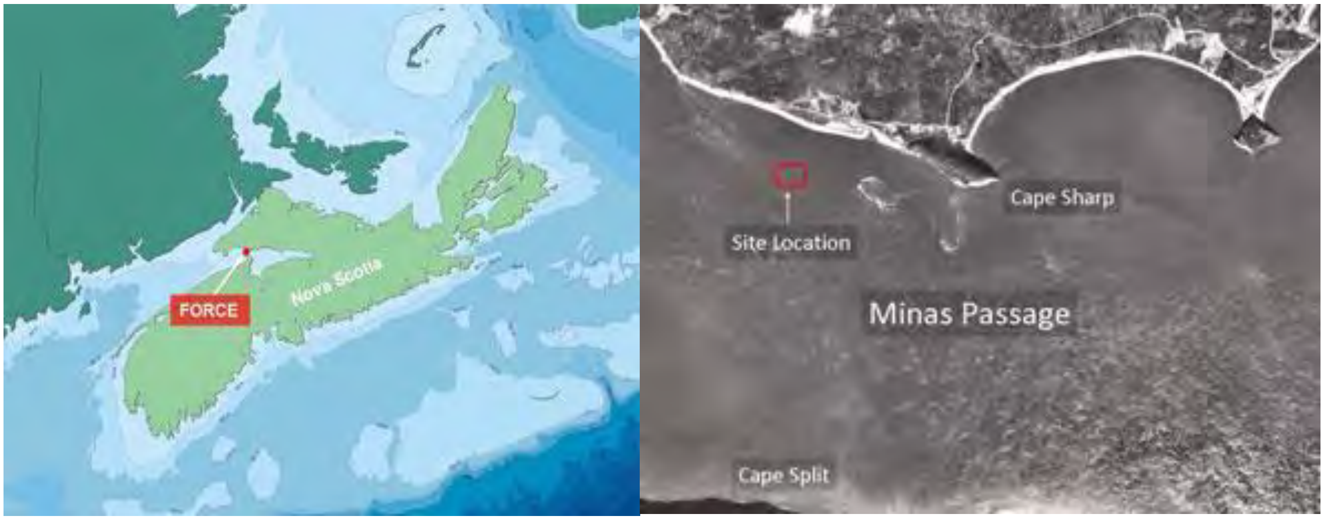

Figure 1. Reginal location of FORCE test site (Left Panel) and the location of the test site in Minas Passage (Right Panel).

Harbor porpoise (*Phocoena phocoena*), the key marine mammal species in Minas Passage, use high frequency echolocation clicks to hunt and communicate (Kastelein et al. 2002) and are known to be very susceptible to pulsed noise disturbance (Tougaard et al. 2009). FORCE contracted SMRU Consulting (Canada) to complete equipment calibration and data analysis relating to the deployment of passive acoustic monitors (C-PODs) in support of its marine mammal environmental effects monitoring program (EEMP). The goal of this program is to detect changes in the distribution and activity of echolocating cetaceans (predominately harbor porpoise) at the FORCE tidal demonstration site in relation to operational in-stream turbines. This 2017 Marine Mammal EEMP Report describes the results of the first nearly eight months of the C-POD monitoring program as part of FORCE's 2016-2021 EEMP at its marine demonstration and testing facility in Minas Passage. The report aims to describe the current program's objectives, methodology, problems encountered, and a statistical analysis of porpoise activity and site use, including an assessment of turbine installation and operational effects.

The main objectives of the larger multi-year FORCE marine mammal EEMP are to assess medium-term effects of direct and indirect stressors on harbor porpoise by monitoring porpoise activity and site use, with the primary objectives to assess (SLR 2015): 1) Permanent avoidance of the mid field (considered

100-1000m) study area during turbine installation and operation; 2) Large magnitude (~50%) change in the distribution (echolocation activity levels) of a portion of the population in the study mid field area. While the marine mammal EEMP was designed to have sufficient power to detect large magnitude changes in distribution (SLR 2015), smaller scale change should not be considered insignificant.

SMRU Consulting previously undertook the design, analysis and interpretation of marine mammal acoustic monitoring studies to collect 2011-2014 baseline information in the FORCE tidal demonstration site (e.g. Tollit et al. 2011). These baseline studies were completed in collaboration with Dr. Anna Redden at Acadia University and funded by FORCE and the Offshore Energy Research Association (OERA) of Nova Scotia. Following a pilot effects assessment study associated with the Open Hydro deployment in 2009-2010 (Tollit et al. 2011), a gradient passive acoustic monitoring design was developed deploying up to 7 C-PODs to collect long-term baseline data and to assess reliability of methodologies (Wood et al. 2013, Porskamp et al. 2015). Beginning in June 2016, the EEMP added an additional C-POD monitoring location next to Berth D, and collected a further 4 months of C-POD marine mammal detection data at five sites in total (including four sites previously monitored) to contrast with the 2011-2014 baseline data. This additional baseline data was collected to improve the turbine effects analysis, not least in capturing the scale of inter-annual variability in porpoise presence in Minas Passage, but also in exploring the consistency of key seasonal, tidal and diurnal trends detected in previous (2011-2014) analyses (e.g., spring and fall peaks in presence, variability linked to tidal phases, and higher night-time activity). A statistical model was used to describe changes in harbor porpoise presence in response to the variability in the environmental effects observed across the monitoring stations in the Minas Passage area of the Bay of Fundy. It is important to note that temporal coverage was intermittent over this period, with only one winter-early spring period of baseline. Spring through fall data was better represented with two or three years of data collection.

On 7 November 2016, a single 2 MW Open Hydro turbine was installed at Berth D by Cape Sharp Tidal Venture (CSTV). Passive acoustic monitoring using five C-PODs originally deployed on 23 September continued throughout the turbine installation period and for up to 73 days post-installation until 18 January 2017. Two C-POD sites were located within 230 m of the turbine, while the remaining three C-POD sites varied between 1,140-1,710 m from the turbine site. These locations represented safe deployment and retrieval distances from Berth D, as well as previously used baseline monitoring locations within and outside the FORCE site, which were selected to represent a gradient design in monitoring turbine noise effects (i.e., locations close to the turbine berths as well as locations at increasing distances away from the turbine berths). A part of the wider FORCE EEMP, monitoring of distances nearer the turbine (<100m) were considered the responsibility of the berth holder.

A statistical model was fit to the time series of porpoise echo-location data detected at these 5 C-POD locations during the September to January deployment focusing on an assessment of turbine installation and operational effects.

2. Methods

2.1 C-POD Calibration

As recommended for the FORCE Marine Mammal EEMP, SMRU Consulting and FORCE staff conducted an echolocation click[1] sensitivity calibration of all 5 available C-POD units to determine reliability and consistency, and to make recommendations for the first deployment. The C-PODs were configured with settings to match Wood et al. (2013) and the hydrophone elements soaked overnight in water. The calibration trials were conducted at the Ocean Sonics Ltd tank facility in Great Village, Nova Scotia. We played back sequences of 5 successively louder 130 kHz clicks from an Ocean Sonics *icTalk* projector (an all-in-one projector that produces a complex range of tones and sweeps) located at the center of the test tank (Figure 2), and recorded >100 clicks at each amplitude on each unit. C-PODs were mounted around the periphery of the tank (Figure 2). This was undertaken twice to test all 5 C-PODs, with one unit tested twice, to ensure between test compatibility.

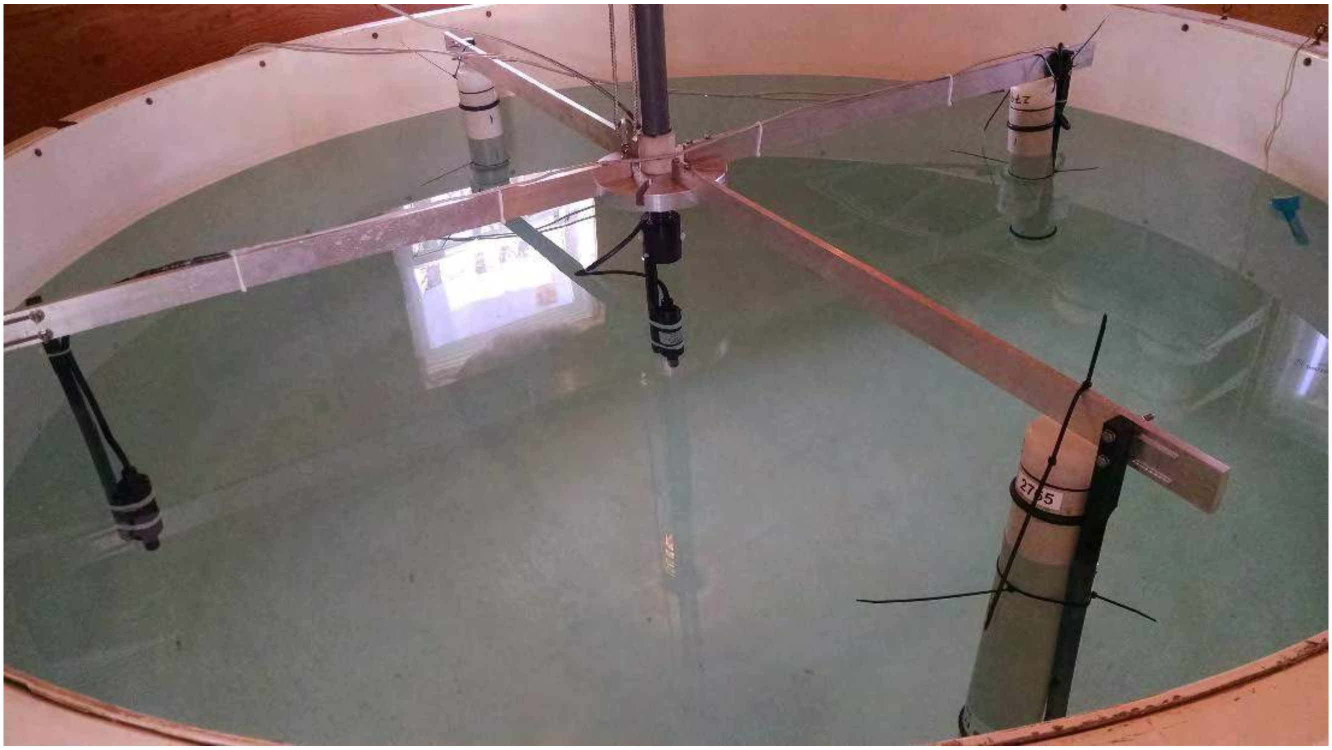

Figure 2. Experimental setup with the Ocean Sonics *icTalk* projector in the center of the tank, 3 C-PODs around the periphery and an Ocean Sonics *icListen* reference hydrophone, also at the periphery.

All five C-PODs operated and detected clicks as expected. The time and amplitude of each detected click was exported from the C-POD software for further analysis in R (version 3.3.2, R Core Team 2016). Figure 3 shows the distribution of click Sound Pressure Levels (SPL) in units of Pascal for each C-POD unit and round (C-POD 2973 was tested in both round 1 and 3), for each of the 5 amplitude clicks (left to right on

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[1] C-PODs have been designed to record the echolocation clicks produced by toothed cetaceans. Echolocation, or bio-sonar is used by animals that have evolved to listen for the echoes of their returning calls to learn about their environment (e.g. navigate, detect, and catch prey). Harbor porpoise have evolved to produce narrow band high frequency (NBHF) clicks in series, commonly referred to as a click train.

the X-axis). Mean SPL were calculated and then converted to dB re 1µPa. Some clicks were not detected by the C-POD unit and this is reported as % clicks missed. The coefficient of variation (CV) is reported for each click amplitude and averaged across all amplitude levels.

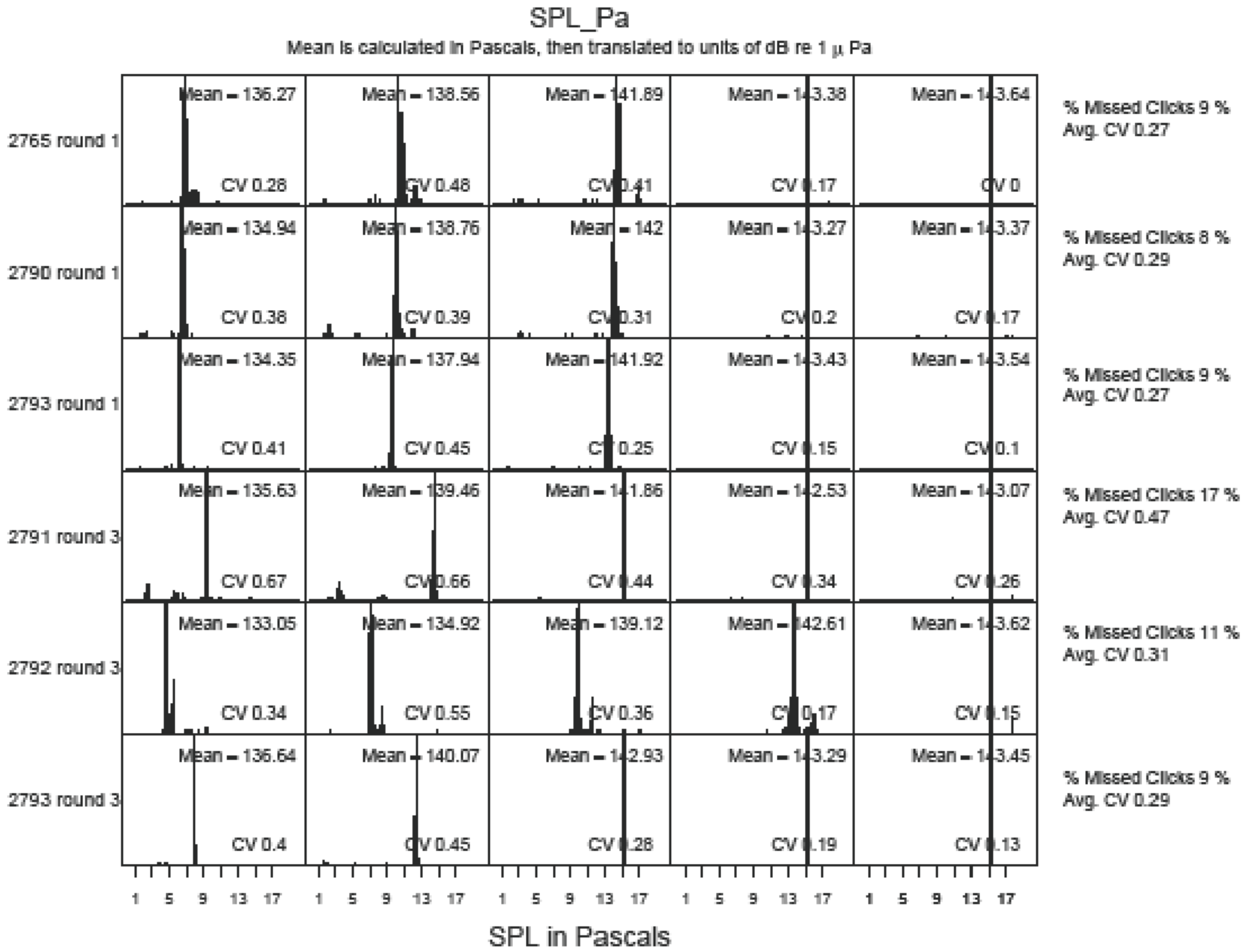

Figure 3. Distribution of click received levels (Sound Pressure Level reported in Pascals). Each column corresponds to each of the 5 amplitude levels of clicks generated by the *icTalk*. The loudest 2 sets of clicks exceeded the input level of the C-PODs and were thus recorded at the maximum SPL of the system. Each row corresponds to a C-POD number and the round of testing. Round 2 data were ignored as the *icListen* did not record during that period.

C-PODs 2765, 2790 and 2793 consistently report similar SPL levels, and have the lowest CV and % missed clicks. These C-PODs were recommended for use in period one and for sites within the FORCE demonstration area. The sensitivity of C-POD 2791 was clearly lower than all other C-PODs with % clicks missed at 17% compared to 8-11% for the remaining C-PODs. C-POD 2791 was deployed at location South2 and this scale of differences was noted in comparison to environmental levels and other C-PODs.

2.2. Deployment and Recovery Information

C-PODS and associated moorings and buoys were loaded onto the modified lobster fishing boat *Nova Endeavor* in Parrsboro, Nova Scotia on 6 June 2016 (period #1) and 21 September 2016 (period #2). The deployments took place in a single tide over roughly 3 hours on the following day. Each cylindrical shaped C-POD is approximately 1.21 m (4 ft.) long and approximately 40 cm (16") in diameter. The C-PODs are assembled into a "subs package" containing the acoustic release mechanism and recovery buoy. This is connected by a 2.5 m long chain to an anchor made of several lengths of chain (Figure 4).

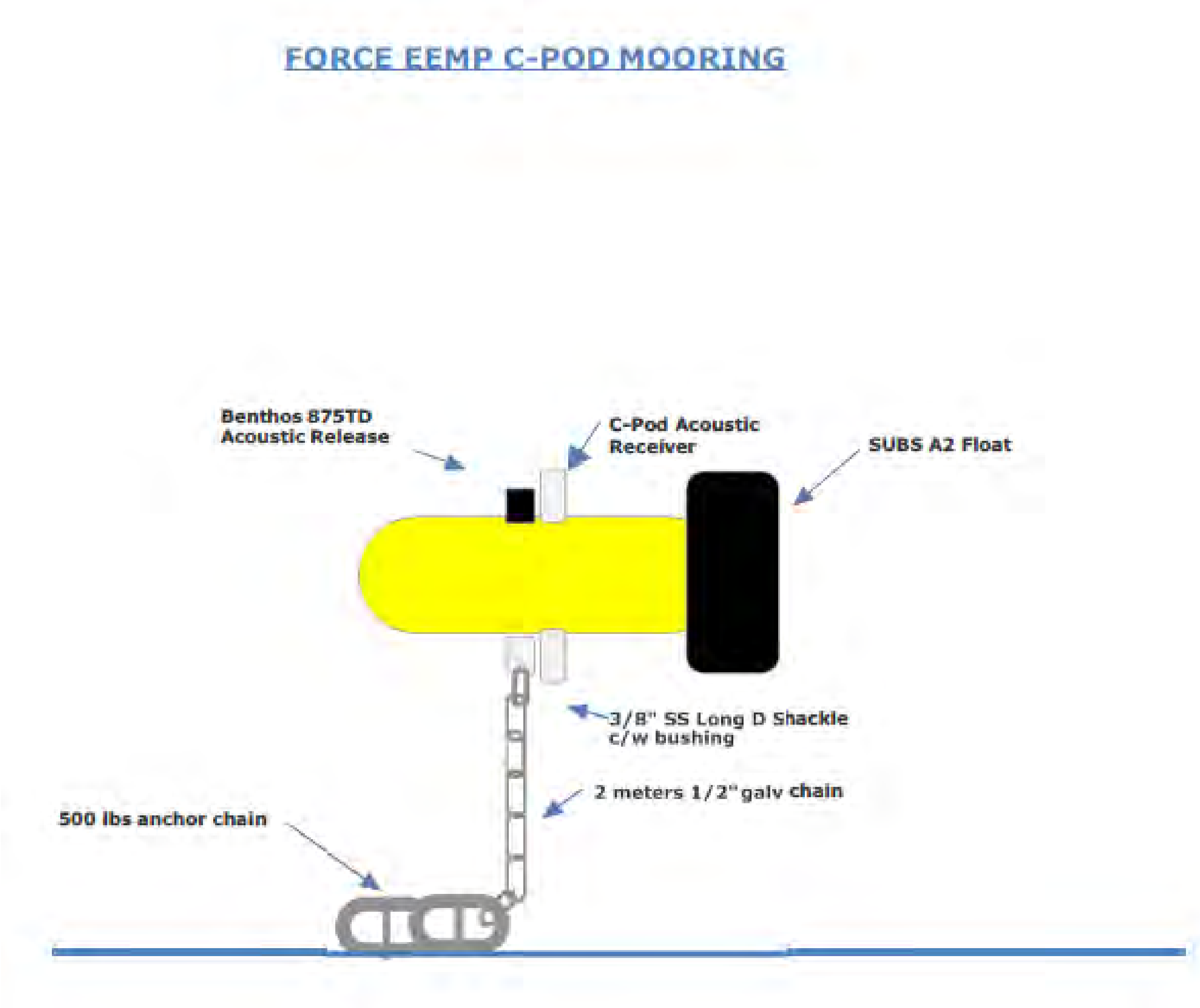

Figure 4. Diagram of FORCE C-POD mooring.

The 2016/2017 deployment locations and related information are provided in Table 1 with deployment times and locations relative to previous deployments depicted in Figure 5. The spatial location of C-PODs and turbine are depicted in Figure 6.

Table 1. C-POD deployment and retrieval information for 2016/2017 deployment #1 (top 3 rows) and #2 (bottom 5 rows). Depth is standardised to tidal height at deployment. Times are in UTC.

Site	C-POD ID	Depth (m)	Distance to turbine (m)	Deployment (date, time)	Retrieval (date, time)	Longitude (ºW)	Latitude (ºN)
D1	2790	31	230	7 June 2016 18:08	30 Aug 2016 13:58	-64 25.388	45 21.766
East1	2765	40	200	7 June 2016 17:59	30 Aug 2016 13:50	-64 25.333	45 21.973
West1	2793	53	1090	7 June 2016 17:52	30 Aug 2016 14:09	-64 26.125	45 21.944
D1	2790	33	230	22 Sept 2016 13:59	18 Jan 2017 14:54	-64 25.366	45 21.759
East1	2765	41	210	22 Sept 2016 14:07	18 Jan 2017 14:48	-64 25.360	45 21.975
West1	2793	46	1140	22 Sept 2016 14:12	18 Jan 2017 14:02	-64 26.163	45 21.947
West2	2792	44	1710	22 Sept 2016 14:17	18 Jan 2017 13:50	-64 26.601	45.21.963
South2	2791	68	1690	22 Sept 2016 13:49	18 Jan 2017 13:38	-64 25.835	45 21.039

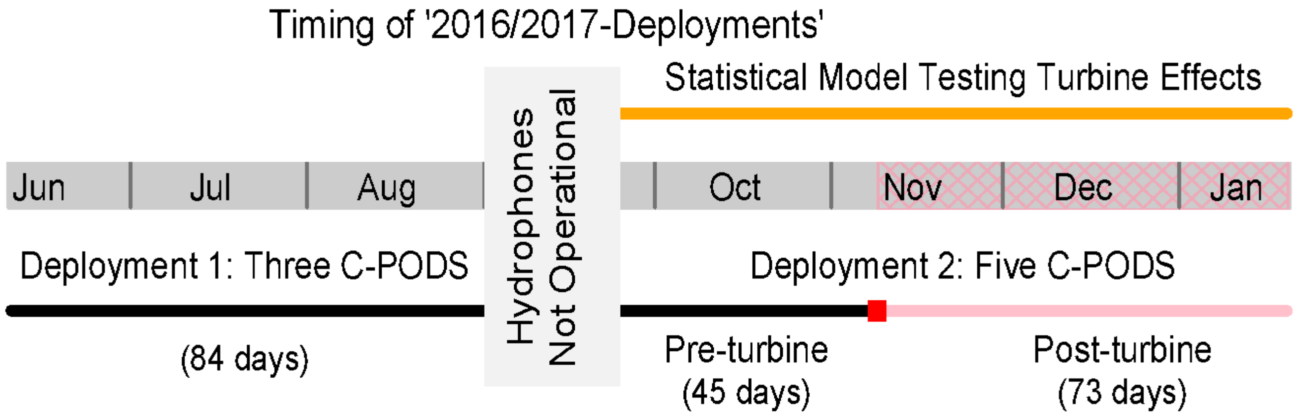

Figure 5. Timing of 2016/2017 deployments in which there were two periods of C-POD deployment to allow for retrieving acoustic data and for changing batteries. Deployment 1 included three C-PODS at D1, East1 and West1. Deployment 2 included an additional 2 C-PODS added to locations West2 and South2 (Figure 6), for a total of five C-PODS (Table 1).

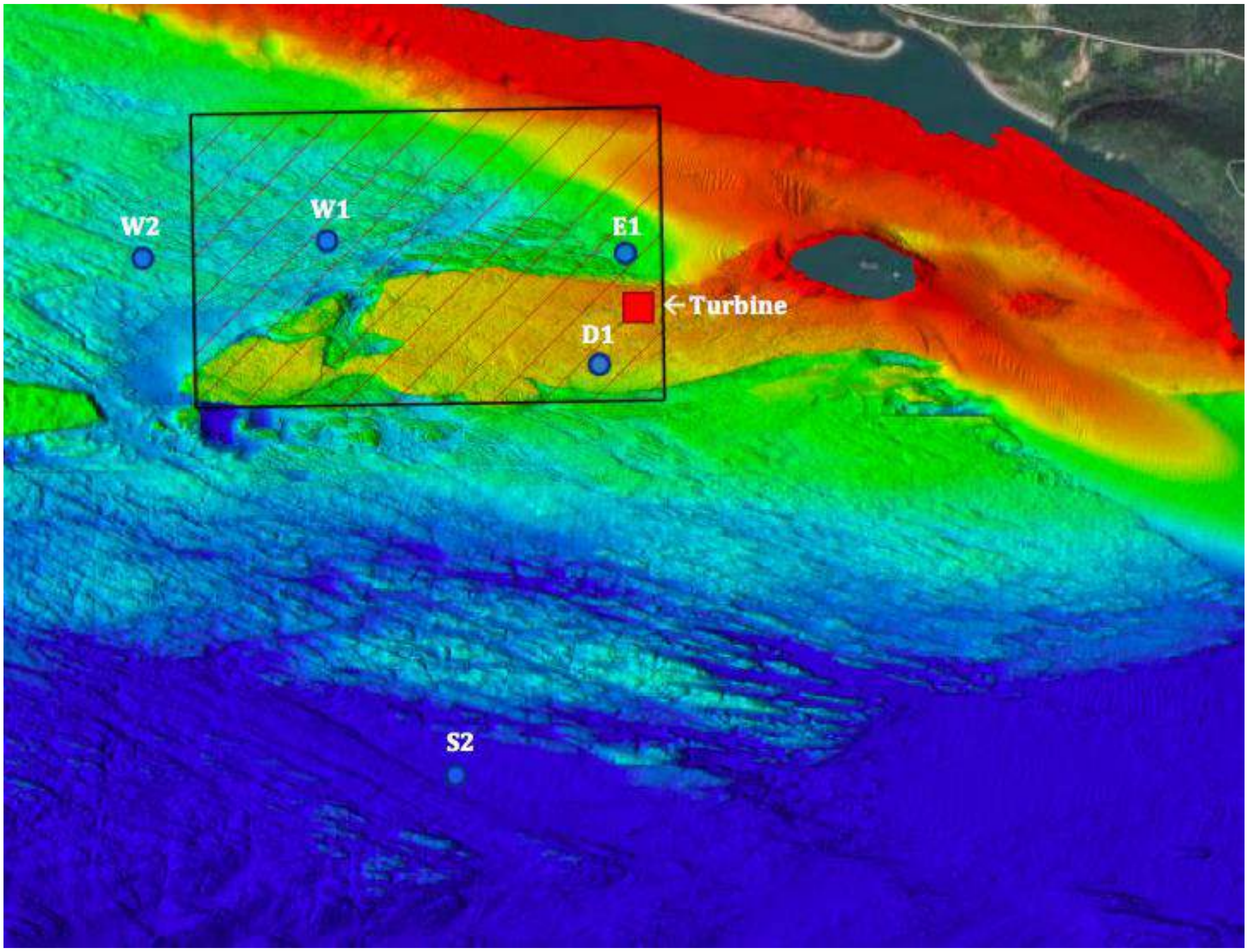

Figure 6. Locations of five monitoring C-PODs and CSTV turbine installed at Berth D. The hatched box denotes the FORCE demonstration area. Shallow water is depicted by warmer colours.

Site selection was based on continuing to monitor the two core long-term baseline sites within the FORCE demonstration area (Sites West1 and East1, Figure 6). These sites represent the best baseline coverage for comparable C-POD studies undertaken 2011-2014 with 535 and 470 days of coverage, noting that coverage was poor across winter months. The third site selected was D1, in the vicinity and on the rock shelf of Berth D (Figure 6) – where CSTV planned to install an Open Hydro turbine in fall 2016. A vertical cone of safety plan developed by Joel Culina (*cf.* Tollit et al. 2017) was used to determine how far a C-POD should be deployed in relation to a turbine and the ability to safely recover a C-POD. These precautionary calculations were undertaken by FORCE staff and are fully described in the process to receive a Marine Access Permit. Two extra sites outside the FORCE demonstration area (West2 and South2) were selected to provide additional area coverage in the 2nd deployment. Both these sites had previously been used to collect baseline C-POD data during the 2011-2014 deployments. Site East1 was closest to the turbine (200-210 m) at a depth of 40-41 m, with D1 slightly further away (230 m) and shallower (31-33m). West1 was 1,090-1,140 m away at a depth of 46-53 m, West2 was 1,710 m away at a depth of 44 m and South2 was 1,690 m from the turbine and the deepest deployment at 68 m (Table 1).

2.3 Data Quality Assessment

C-POD software V2.044 was used to process the data and custom Matlab (R2016a) and R (version 3.3.2, R Core Team 2016) scripts were used to calculate statistical outputs and create data plots using presence/absence of porpoise detections per 10-minute period. We refer to this as BinDPM (as in binary detection positive minutes). The data quality assessment specifically assesses 1) if non-biological interference has occurred, 2) determines whether the porpoise click detector is operational, 3) ensures no clock drift occurred, and 4) assesses the scale of % time lost due to internal memory restrictions. Non-target noise from sediment movement and moorings can result in periods of lost recording time in each minute, due to exceeding the C-PODs click maximum buffer.

To allow for the hydrophone elements to reach their typical underwater sensitivity, data from the first 2016 deployment resulted in 82 days, 19 hours and 30 minutes of data at each location spread across 84 calendar days (Julian days 159-243). Data were collected throughout this period on each of the three C-PODs. C-PODs were time synced when started and checked for clock drift after retrieval. Clock drift was estimated at less than 1 minute during this deployment cycle. There was no evidence of data corruption in either of the 2016/2017 deployment periods. During the 2nd of the 2016/2017 deployments, the batteries at two locations ran out before the scheduled end of the monitoring period (South2: 32 days lost, D1: 1 day lost). The remaining C-PODs monitored for 118 calendar days. No clock drift greater than 1 minute was observed in the units that monitored the entire deployment.

2.4 Statistical Analysis

To fulfill the goals of this current study, we fit two different statistical models. The first was a statistical model of all C-POD data dating back to 5 May 2011, noting that temporal coverage is incomplete across years and seasons (Figure 7). This was to understand the variability in porpoise activity across years, and within years across the seasons. It was not used to test the impacts of the turbine deployment, but was used to identify important environmental covariates. The second statistical model was specifically tailored to testing the effects of the installation of the turbine using only the 2nd of the 2016/2017 deployments, while controlling for larger scale environmental variability identified using all C-POD data in the first model. These variables were time of year and day, lunar cycle, tidal height and velocity as well as percent lost time (a proxy for environmental noise). Both models used the same general statistical approach, which we discuss next. While only the 2nd deployment has been currently used to directly assess turbine effects, as more post-installation data is collected for time periods where C-POD baseline coverage overlaps, then the ability to incorporate this C-POD baseline data in the analysis is justified.

Figure 7. C-POD deployment history at 8 locations between 5 May 2011 and 18 January 2017. For descriptive purposes, this report describes four deployment periods denoted by the labels on the bottom x-axis. The 2nd of the 2016/2017 deployments includes the turbine installation on 7 November 2016 and covers the far right (most recent) 73 days of post-turbine monitoring from 7 November 2016 to 18 January 2017, denoted in this figure (and following figures) by pink hatching (also see Figure 7). The grey shading denotes when at least one C-POD was operating.

Porpoise were generally detected for just a few minutes per day, and often logged in consecutive minutes. The number of DPM within a 10-minute window was therefore not a measure of independent observations (i.e., it was autocorrelated). As well, the distributional form was zero-heavy with a right-skewed tail for consecutive detections. We have therefore reported median and inter-quartile ranges (Zar 1999) for DPM per day. We analysed the presence or absence of porpoise detections per 10-minute period (BinDPM) as a binary response variable (i.e., when porpoise detected, BinDPM=1; when porpoise not detected or absent, BinDPM=0) in the comparative statistical models. These are described in detail below.

2.4.1 Logistic Regression with Correlated Time Series

We used statistical models for comparing the BinDPM C-POD data using a logit link function to accommodate the Binomial distribution of the BinDPM 0 or 1 data. The BinDPM data is continuously collected at each C-POD deployment location (Table 1). This kind of time-series data is highly correlated across time, and this data structure requires modeling methods that accommodate the autocorrelation. Correlated data can be incorporated using models with correlation structures built directly into them, or by using high-rank smoothers such as splines to help remove correlation across continuous covariates in a model. We used both approaches.

2.4.2 Fitting GEE Models with AR-1 Correlation Structure

We used a Generalized Estimating Equation within a Generalized Linear Model framework (GEE-GLM) approach as it allows both a logit link function to accommodate the Binomial distribution of the BinDPM data, and allows for the inclusion of autocorrelation[2] functions (ACFs) to accommodate the correlation structure in the data. A model with an ACF assumes a parameterized correlation matrix to down-weight adjacent time points to avoid pseudo-replication and artificial inflation of p-values. We examined the autocorrelation at lags between 1 and 50 time steps to ensure that sequential dependence declined across time (Figure 8), and a first order auto-regressive (AR-1) form to the autocorrelation function (ACF) was appropriate. The AR-1 ACF has a sparse structure with a single parameter to estimate that allows the function to decay exponentially towards 0 as the time lag increases.

The GEE-GLM models with an assumed AR-1 correlation structure were fit to clusters of 10-minute data. The time interval length for each cluster is based on examining the auto-correlation in residuals that originates from a model fit without accommodating the auto-correlation. In this dataset, the autocorrelation fell to negligible levels after 3 hours as depicted in Figure 9, therefore the limit at which data could be assumed independent was 3 hours, and the grouping structure of our model is thus based around 3-hour windows of data.

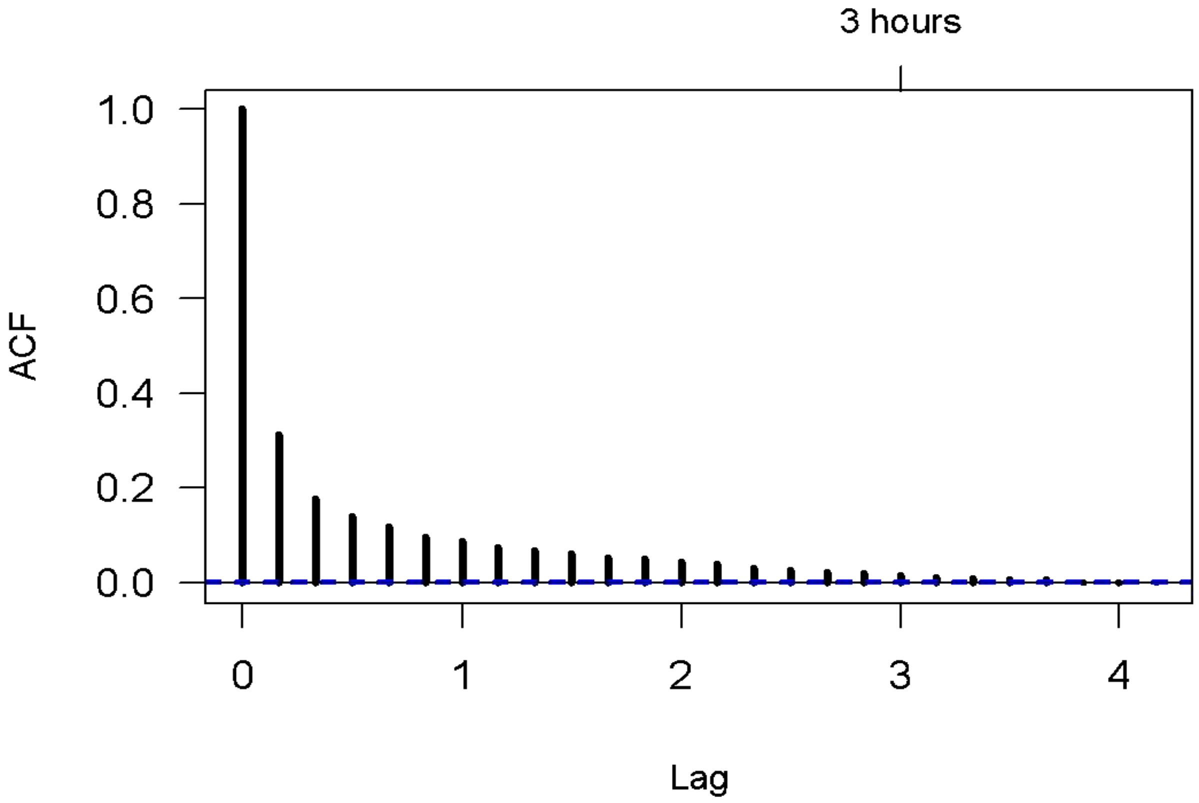

Figure 8. ACF of the model residuals without considering autocorrelation. This was used to set the autocorrelation structure of the GEE-GLM model, in which independence was assumed after a lag of 3 hours (after 18 time windows ACF=0.01).

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[2] Autocorrelation in relation to time quantifies the extent of the linear relation between values at time points that are a fixed interval apart (e.g., behavior for a one minute sample is likely related to behavior in the next minute sample).

Using the full dataset back to 2011, there were 407,592 10-minute intervals (rows of data in the dataset), and timely convergence of candidate models was an important consideration. With non-linear functional relationships between environmental covariates and the response variable, this meant not only solving the regression coefficients, but also optimizing the number and placement of smoothing knots, a task which can easily become intractable when there are multiple non-linear relationships between environmental covariates and the response variable.

Therefore, the smoothing spline describing the relationship between porpoise response variable and each environmental covariate was optimized separately outside of the GEE-GLM model using the "*bs*", and "*gam*" function in the R-package "*mgcv*". The number and location of knots in each smoothing spline is optimized via a penalty term that has the effect of penalizing steep slopes by reducing the degrees or freedom (or wiggliness) in the smoothing function. The advantage of using this regression spline approach is that the analysis stays within the linear model framework, with the same linear model theory and computational methods as any other linear model. This additionally ensures that data from outside of the target analysis period could be included to describe porpoise response to normal stochastic changes in the regional environment.

These smoothed basis functions were then adopted as the covariate data into the design matrix of the GEE-GLM models. From a modeling perspective, fitting the smoothing splines external to the optimization of the AR-1 ACF ensures identifiability in parameters as both autocorrelation terms and the degrees of freedom of a spline compete to describe the complexity of the data series as correlation between observations increases.

We fit the smoothing functions to the following environmental covariates: annual cycle, the lunar cycle, the day/night cycle, as well to two components of the tidal cycles: the tidal height, and current speed, and examined the relationship to the amount of time lost at the C-POD hydrophone due to internal memory restrictions.

The GEE-GLM fit to all the data from 2011 through 2017 was undertaken to assess the influence of changes in porpoise habitat in the FORCE demonstration tidal area due to environment variability over time. Until more data is collected (especially in winter for which only one year is represented), the main results of this first model were thus to determine the environmental covariates important in describing porpoise detection across the seasons, and control where possible for this natural source of variability in our key GEE-GLM model that covers the 118 monitoring days of the 2nd of the 2016/2017 C-POD deployments.

It is important to bear in mind that only 73 days of C-POD data were collected after a delayed turbine installation and that the current EEMP aims to assess turbine effects over multiple years. Nevertheless, the objective of this report (as per SLR 2015) was to make a preliminary assessment of, 1) Permanent avoidance by harbor porpoise of the mid field study area during turbine installation and operation, and 2) Large magnitude (~50%) change in the distribution (echolocation activity levels) of a portion of the porpoise population in the study mid field area. To achieve these objectives, we fit a GEE-GLM with focused significance testing on data collected in deployment 2. This modeling approach removes confounding effects such as differences between C-PODs, while accounting for natural (baseline) environmental variability, thus allowing the model to compare the 'population-averaged' effect of the turbine on porpoise presence before and after its installation. Optimally, this approach should be undertaken with an extended post-installation period that includes a long enough time series to distinguish seasonal variability from turbine effects.

3. Results

3.1 Annual Porpoise Detection Rates (2011-2017)

Across all years of the Minas Passage C-POD monitoring study, there have been a total of 2,847 C-POD days across 805 calendar days. Porpoise were detected on 98% of days and detected for 6 minutes per day on average (Table 2). Similar to previous C-POD deployments (e.g., Wood et al. 2013), there were no acoustic-operator confirmed dolphin detections during the more recent 2016/2017 EEMP deployments (i.e., a scientist analyzed all periods that each C-POD had recorded as a 'possible' dolphin and found that on all occasions these were false positives). C-PODs do not detect non-echolocating whales (e.g., Right whales or minke whales).

Harbor porpoise were present in Minas Passage on 83 of the 84 calendar days (98.8%) during deployment 1 of 2016, and 116 of 118 calendar days (98.3%) during deployment 2. These 2016/2017 rates and other descriptive statistic are provided in Table 2, and can be compared to previous 2011-2014 baseline deployments here. The lowest daily presence was observed during the 2012 deployment (95.6%), and the highest rate during the 2011 deployment (99.2%), however, porpoises were observed for the fewest minutes per day during both pre- and post-turbine periods of the 2016/2017 deployment period compared to all other deployments. Porpoise were present for 7 minutes of the day during deployment 1, and for 4 and 3 minutes during the pre-turbine and post-turbine deployment periods respectively for deployment 2 in 2016/2017. Porpoises were present 97.3% of days post installation, highlighting no evidence of permanent avoidance of the mid field study area by porpoise. Clearly, caution is required when interpreting this simple raw data synthesis, especially as it does not incorporate different timing of deployments within a year and lunar cycle, as well as the specific site locations available in each year and the level of associated percent time lost metrics. This is of particular note given baseline studies have identified strong seasonal variations, with lower activity noted during one previous baseline winter period, which is coincident with the timing of this recent turbine installation.

As part of the EEMP to specifically monitor the turbine in Berth D, D1 was added for the 2016/2017 deployments. C-POD locations East1 and West1 were consistently used in the 2011-2014 baseline monitoring program and both are located within the FORCE demonstration area. These 2 sites were therefore selected for monitoring in both the 1st and 2nd periods of the 2016/2017 C-POD deployments (noting West2 and South2 were selected for the 2nd deployment period only), and allow for direct comparison of daily porpoise detections to previous deployments.

Table 2. Percent of calendar days with at least one porpoise present at one or more monitoring locations, and the number of minutes per day porpoise were there, when present. Monitoring effort is reported in three ways; the number of calendar days reported for each monitoring period, the number of pod days in which each location considered a "Day" (number of days multiplied by the number of locations), and the number of 10 minute monitoring periods.

Deployment	% Days Porpoise Present	Median (IQR) of DPM if Present/Day	Number of Calendar Days	Number of POD-Days	Number of 10 Min. Intervals
2011 Deployment	99.2	7 (2, 17)	258	958	136,446
2012 Deployment	95.6	5 (1, 13)	137	391	56,795
2014 Deployment	99.0	9 (3, 16)	208	689	99,108
2016/2017:					
1st Deployment	98.8	7 (3.75, 14)	84	252	35,775
2nd Deployment:					
Pre Turbine	100.0	4 (1, 10)	45	225	32,065
Post Turbine	97.3	3 (0, 7)	73	332	47,403
All Data	**98.4**	**6 (2, 15)**	**805**	**2847**	**407,592**

We provide a direct comparison of daily porpoise detection rates at these two key sites, comparing 2011-2014 baseline with the recent 2016/2017 deployments, noting that C-POD units used across these two studies vary. In terms of seasonal timing of previous C-POD deployments at East1 and West1 compared to 2016/2017, there was good temporal overlap with the 2011 and 2012 deployments, but poor temporal overlap with the 2014 deployment (Figure 9). Direct comparison of previously collected data with the 73-day turbine installation period was notably low, one of the reasons for focusing on data from the 2nd deployment only to assess potential turbine effects. Variability within years and across years can be observed at both sites (Figure 9), with detection rates visibly lower in 2016/2017. The environmental factors driving these effects were investigated further using GEE-GLM modelling.

As part of the seabird EEMP, Envirosphere Consultants Limited made concurrent observations of marine mammals from a shore-based observation site above Minas Passage. Recorded sightings of porpoise on four days in which C-POD deployments were concurrent were 2 August 2016, 1 October 2016, 17 November 2016 and 16 January 2017). On each day, C-PODs also detected porpoise, though none of the four visual sightings were concurrent to the hour of detection by C-PODs.

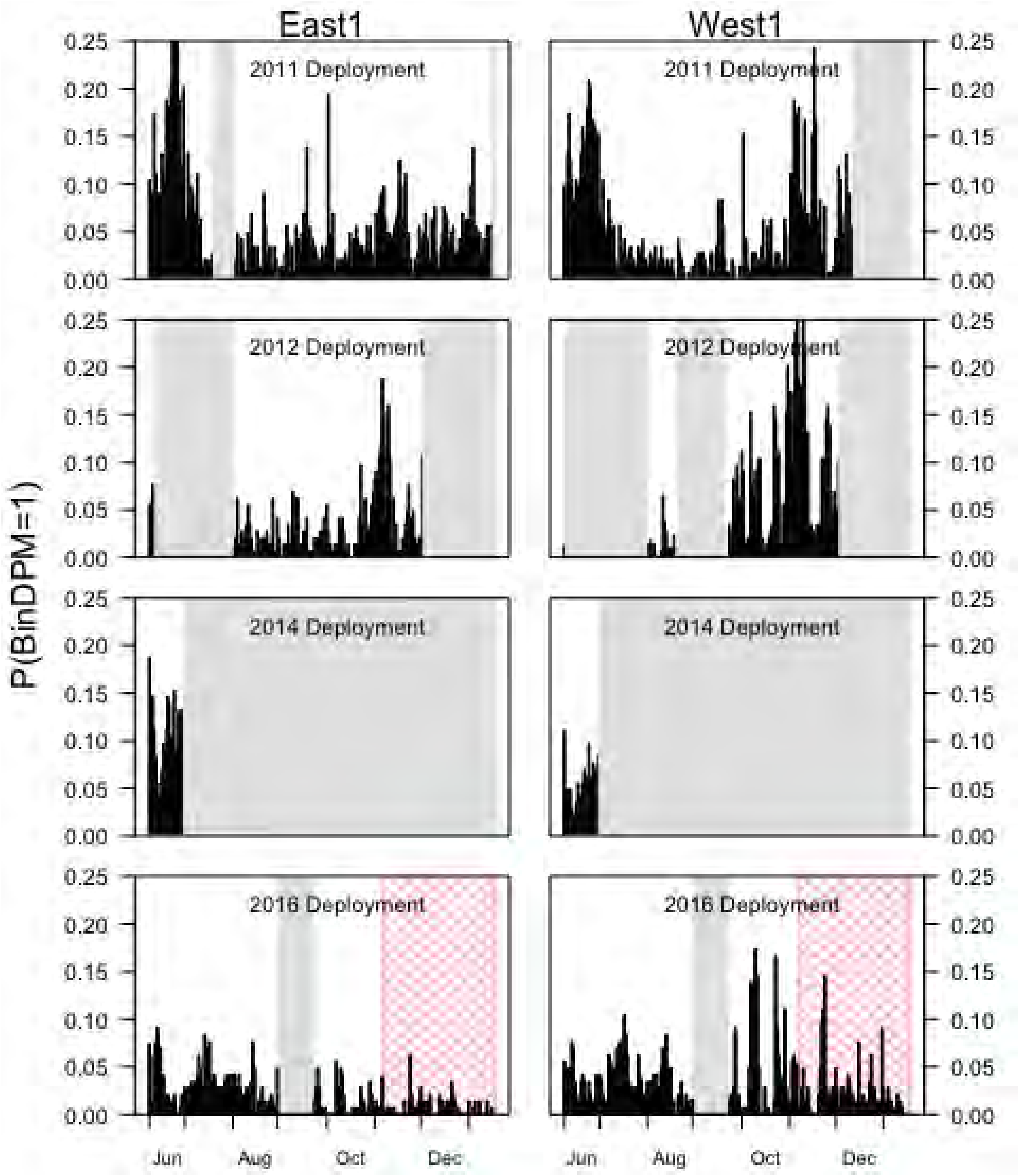

Figure 9. Comparing daily porpoise detections (P(BinDPM=1)) between 8 June and 18 January across 4 years of deployment. Grey periods denote when the hydrophones were not operational. The pink hatching on the bottom 2 panels denote the period when the turbine was installed.

3.2. GEE-GLM Models

We fit a comprehensive GEE-GLM model to all the C-POD data from 2011 to 2017 (Figure 10) to compare the observed patterns in porpoise detections in this region between and within years. It is important to note that temporal coverage is intermittent over this period, with only one winter-early spring period of baseline. Spring through fall data is better represented with two or three years of data collection. As illustrated for West1 and East1 in Figure 9, there was considerable variability both between year and within year in porpoise detections, but consistency in seasonal peaks: one in the May/June and one in October/November. The model predictions for the post turbine installation period does not support any permanent avoidance of the mid field study area by porpoise. However, we are cautious about making further inferences about turbine effects using this model due to the lack of consistency across C-POD deployment locations and time (Figure 7). For example, in the 2011 deployment, there was only one C-POD operational during 37 of the 73 day post-turbine installation period. In the 2012 deployment, there is C-POD coverage for only the first 28 of 73 days, and in the 2014 deployment there is C-POD coverage for the last 45 days of the 73 days (but no overlap with that of the 2012 deployments). This complex deployment history combined with the inter-annual variability introduces unintended bias to those sites and time periods where the majority of data were collected, and until more data is collected in 2017 for direct comparison renders this model's predictions unreliable for testing turbine-related effects for the same period in 2016/2017.

These previous deployments (2011-2014) and the 2016/2017 deployments allowed us to better understand the variability in porpoise detections explained by the natural cycles in the Minas Passage environment. There is clearly a complex interaction between tidal cycles and current speed that can influence the presence of porpoise (e.g., Tollit et al. 2011, Porskamp et al. 2015), as well as processes happening at both larger annual scales and smaller local processes (Figure 10). The impact of time lost due to internal memory limitations also needs to be quantified. These relationships are best understood and described through smoothing functions, which we describe in the following sections. The model also ranks the importance of these factors in describing variability in porpoise detections.

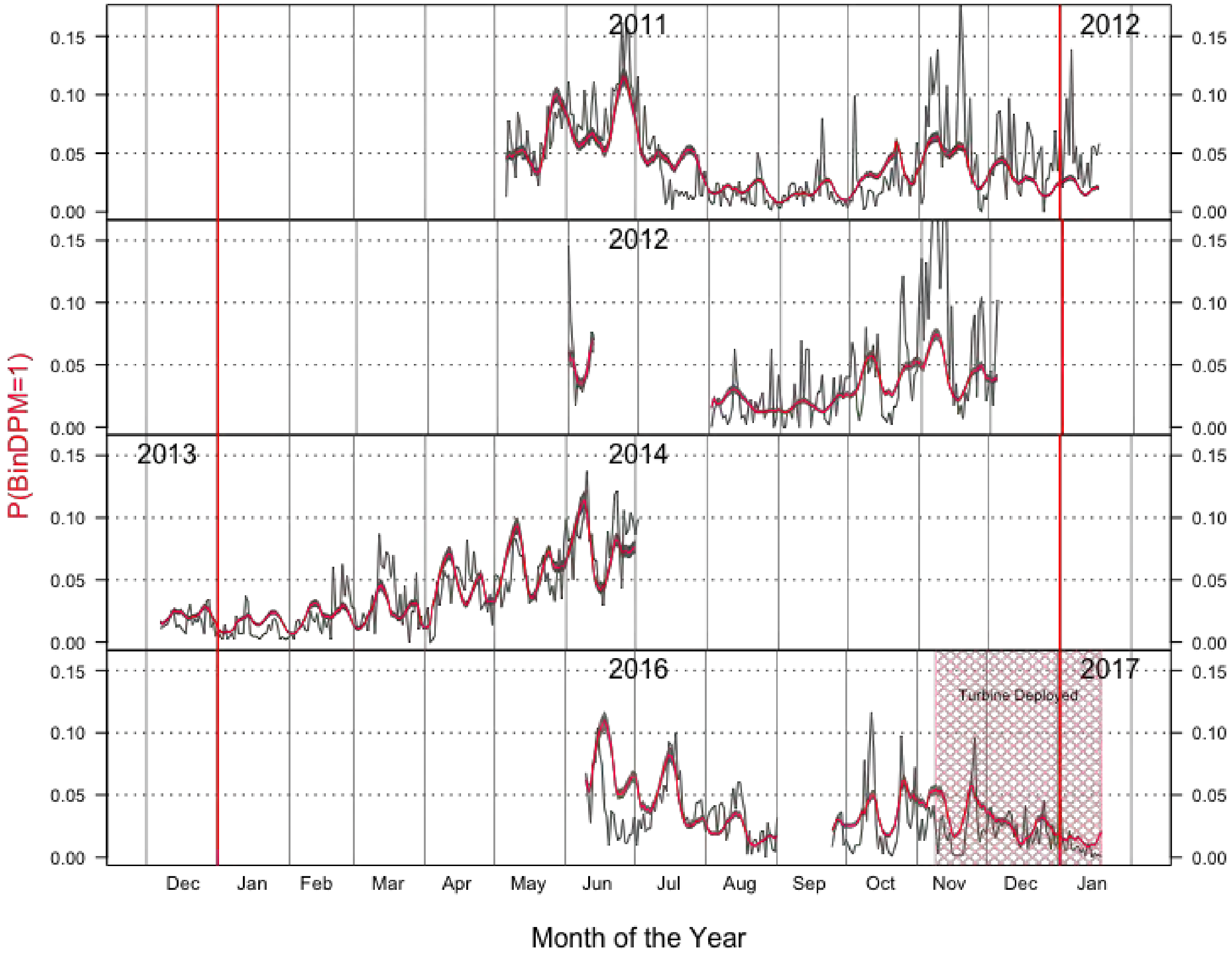

Figure 10. FORCE baseline data 2011-2017. Raw data BinDPM per day (grey lines) versus GEE-GLM model predictions of the overall mean probability of porpoise detection per time bin (PBinDPM) over time (red line).

3.2.1. Porpoise Detection Rates in Response to Environmental Variables

We included a set of environmental variables that have profound biological influence in the marine environment and, in our models statistical power to describe the variability in our porpoise activity response variable (BinDPM). We assumed all processes had a fixed (and known) periodicity and acted independently from other cyclic processes and therefore were well described by additive components in the GEE. We considered a 365-day annual cycle (366 for leap years), a 29.6-day lunar cycle (IQR: 29.1, 30.2; www.timeanddate.com/moon/phases/canada/halifax), a 24-hour day-night cycle, and an approximately twice-daily (M2) tidal cycle. Each of these processes was described either by a cyclic or by a non-cyclic cubic regression spline smooth (Figure 11), such that the environmental predictor variables are considered random smooth functions.

The shape of these functional relationships, the rationale for including them, and the relative importance of each in the GEE models are explained in the following sections.

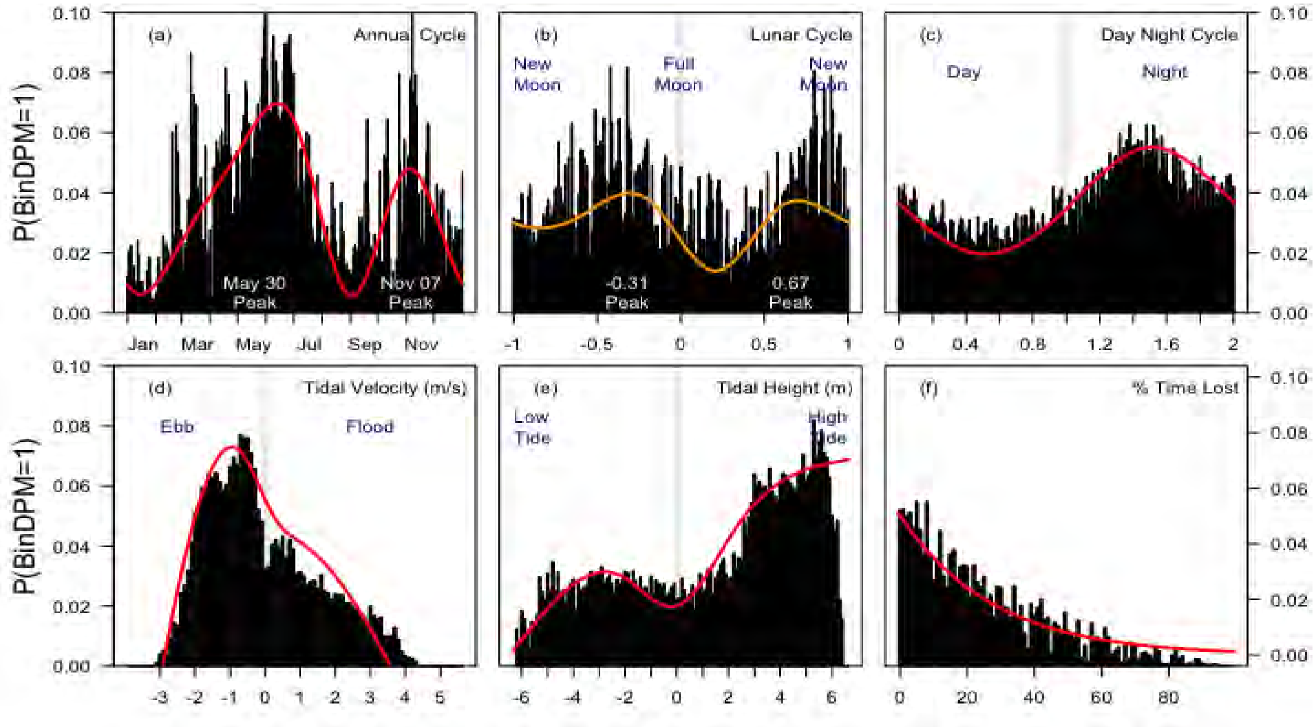

Figure 11. Shape of smoothing functions overlaid over the domain of a set of environmental variables. Black bars are P(BinDPM=1) frequency bars of raw data provided as a way to check the performance of the smoothing splines. Coloured lines are the cyclic (a, b, c) and non-cyclic (d, e) cubic regression smoothing splines. In all panels, the y-axis denotes the probability of detecting at least one porpoise in a 10-minute window, i.e., P(BinDPM=1), and how this varies over the range of the environmental variable denoted on the x-axis. Data includes all data collected during 2011-2017 from 8 hydrophone locations over all deployment dates. In Panel (a), the x-axis is Julian Day starting with January 1st, and ending on December 31st. In Panel (b), the x-axis denotes the phase of the moon with new moons at both ends of the axis (at '-1' and '1'), and full moon in the middle (at '0'). In Panel (c), sunrise is set to occur at the beginning and end of the x-axis (at '0' and '2'), with sunset occurring at '1'. In Panel (d), the x-axis is simply the tidal velocity measured in m/s, while the x-axis of Panel (e) is the height of the tide in m. Panel (f) represents the (logit) linear relation of porpoise presence to % time-lost due to C-POD internal memory space limitations.

3.2.1.1. Annual Cycle over 365 Julian Day (Figure 11; Panel a)

The annual cycle has two peaks in porpoise detections, a late spring cycle that peaks around 30 May, and another lower peak in the fall around 7 November. November 7th is also notable as this is the date that the turbine was deployed at the FORCE demonstration site in 2016.

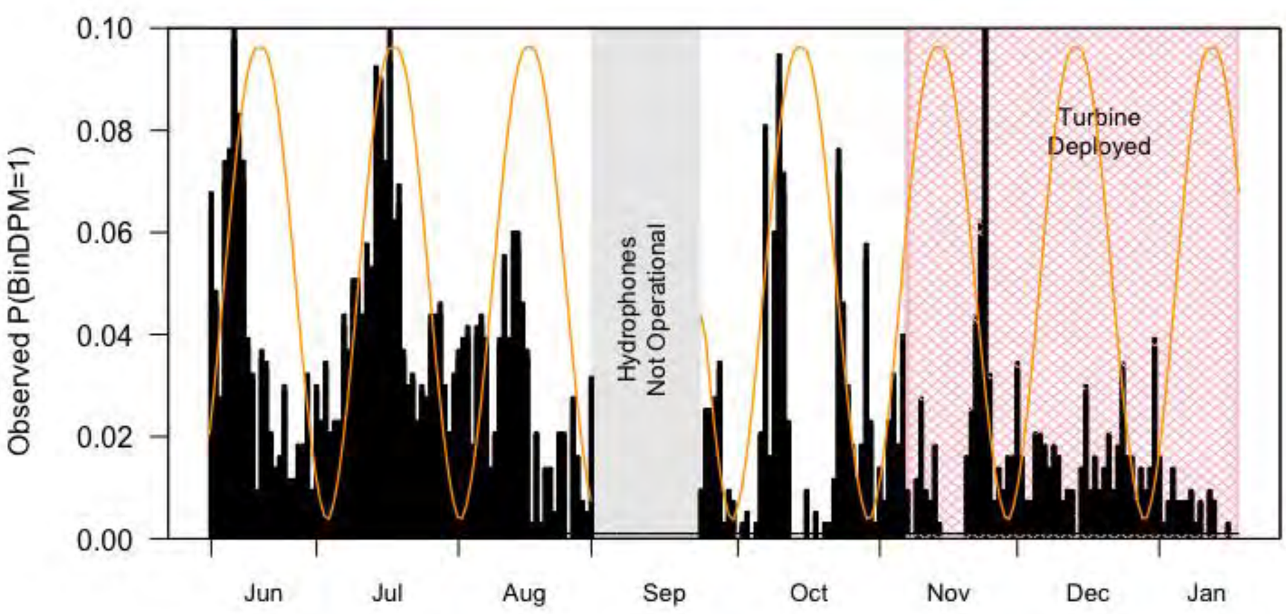

Figure 12. Raw Data from both time periods of 2016/2017 deployments: Lunar Cycle is overlaid in orange with spring tides at both the maximum and minimum of the cyclic function. Porpoise detections are maximized at just before (~70% along) the spring tide cycle.

3.2.1.2. Lunar Cycle and Spring Neap Tides (Figure 11; Panel b)

There was a strong signal observed in porpoise detections in response to the lunar cycle with two peaks per lunar cycle. This dual cycle reflects the spring tides that occur every full and new moon. Peaks occurred when the tidal amplitude was 70% that of a full spring tide on both the full moon, and the new moon. These trends are also seen in a time series plot of the raw data plotted for the full 2016/2017 C-POD deployments (Figure 12).

3.2.1.3. Diurnal Patterns (Figure 11; Panel c)

Porpoise were most often detected at night, peaking in the middle of the night, with the least number detected during the middle of the day.

3.2.1.4. Tidal Current Speed and Tidal Height (Figure 11; Panels d and e)

Porpoise detections changed with the tidal conditions of the M2 tidal cycle observed in the Bay of Fundy. Porpoise are more likely to be detected during the ebb tide compared to the flood tide, with most detections during moderate ebb current speeds (between 0 and -2.5 m/s). Porpoise are most likely present when the tidal heights are moderately high (>2.5 m). To summarize, porpoise in the Minas Channel therefore prefer the first few hours after tides have turned to ebb when water velocities are flowing at low to moderate speeds.

3.2.1.5. Percent Time Lost (Figure 11; Panel f)

The amount of data recording time lost on the C-POD is a function of the internal memory restrictions coupled with the amount of non-target clicks recorded at each site. These lost recording times happen when the allowable memory fills up prior to the completion of a 60 second time window and the remaining detection time within that minute is lost due to the turning off the C-POD recorder to conserve memory (that is otherwise assumed to be taken up by non-target noise from sediment movement and mooring). Percent time lost due to sediment interference varied by site and was also included in the GEE-GLM as an explanatory variable. There is a simple linear relation on the logit scale between % time lost and detection of porpoises, with the greater the time lost, the fewer detections of porpoises. This makes intuitive sense as the less time the C-POD is actively recording data, the lower the probability a porpoise would be detected.

Summaries of differences in % time lost for each C-POD location are presented in Table 3, and each location's distribution of % time lost is plotted in Figure 13. West2 had the least amount of time lost (highest percentage of data with 0% time lost, and lowest with >95% time lost), and therefore was the best at listening for porpoise detections. The most time lost was observed at South2 with only 51.83% of the data with 0% time lost, and the greatest amount of data with >95% time lost. This is also the location that ran out of battery 32 days before the retrieval of the C-POD unit, highlighting the limitations of monitoring certain sites that are subject to large amount of sediment noise (more echo-location clicks also require more battery power). In previous monitoring periods (prior to 2016), there were far higher rates of time lost reported for South1 and East2 and as a consequence these sites were omitted for C-POD deployment in this EEMP. As found in previous C-POD studies (Tollit et al. 2011), periods of spring tides (especially around the full moon) were associated with higher relative levels of non-porpoise sediment-related clicks. This leads to a decreased performance in porpoise detection ability. Percent time lost was included in addition to other environmental variables to assess the potential effects of the turbine installation.

Table 3. Proportion of % Time Lost by C-POD location (averaged across time). At West 2, we observed the highest % of data with '0 % time lost', whereas at South we observed the least amount of observed '0 % time lost'.

Location Site	Time Lost= 0 %	Time Lost>50 %	Time Lost>75 %	Time Lost>95 %
D1	62.34	26.25	21.17	7.37
East1	55.66	28.11	22.98	10.36
West1	58.23	24.91	18.51	5.20
West2	75.52	15.94	12.80	4.50
South2	51.83	36.79	31.86	18.81

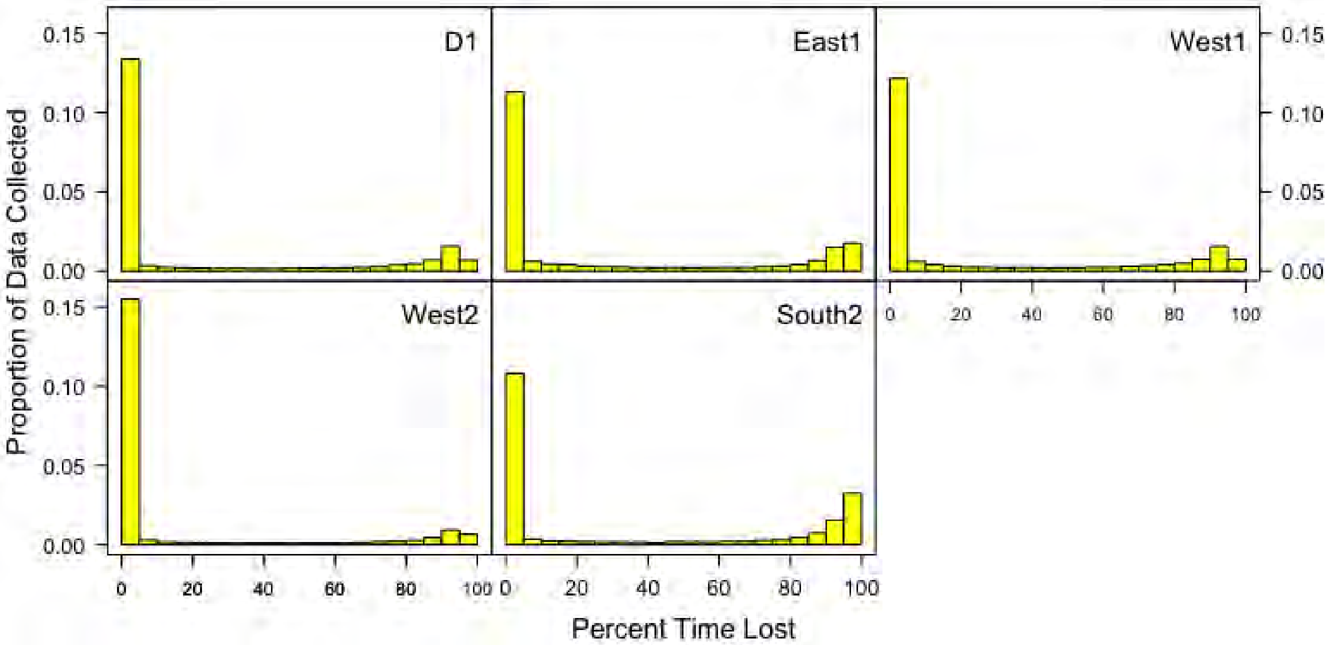

Figure 13. Distribution of % time-lost data from 5 hydrophone locations in the 2016/2017 deployments. For comparing between sites, both the X- and Y- axes are standardized to have the same limits.

3.3 Assessing the Effect of the Turbine Installation on Porpoise Detection Rates

Observed probabilities (from raw data) of porpoise presence in the 2nd of 2016/2017 deployments varied by location and are presented as percentages in Table 4. The highest porpoise presence was found at West2, the same location with the least % time lost. Despite a somewhat lower click sensitivity of the C-POD located at South2, detection rates at the shallower sites at D1 and East1 were lowest. As the same C-PODS were used in the same locations both pre-and post-turbine installation (i.e., a balanced design); these rates are comparable between locations, but because the season is advancing through time, the reduction post turbine installation in the observed probabilities are confounded with the expected lower presence in the area due to seasonal winter lows. Subsequent GEE-GLM modelling of on-going data collections covering seasonal variability will aim to take this into account. The raw data reductions (41-46%) in porpoise activity after turbine installation can be observed for the three sites (East1, West1 and West2) out of five. In all three cases, the 95% Confidence Intervals of porpoise presence during pre and post turbine installation do not overlap. The activity at site D1 increases by 10% with overlapping 95% confidence intervals, while site South2 activity levels are within 1%. Statistical data analyses using a GEE-GLM model (Table 5) accounts for seasonal variability, % time lost and early battery power loss at D1, and South2 (not accounted for in these raw observed probabilities).

Table 4. Percent probability (95% C.I.'s) of porpoise presence from the 2nd period of the 2016/2017 C-POD deployments. Observed probabilities are the sum of BinDPM=1 divided by the total number of 10-minute intervals then multiplied by 100 to translate to % probability.

Location Site	% Probability **Before** Turbine	Number of 10-Minute Intervals	% Probability **After** Turbine	Number of 10-Minute Intervals
D1	1.29 (1.04, 1.61)	6413	1.42 (1.21, 1.67)	10273
East1	1.20 (0.95, 1.51)	6413	0.67 (0.53, 0.85)	10419
West1	4.01 (3.55, 4.52)	6413	2.17 (1.9, 2.47)	10419
West2	5.11 (4.59, 5.69)	6413	3.02 (2.71, 3.37)	10419
South2	3.31 (2.89, 3.78)	6413	3.27 (2.84, 3.76)	5873

In order to compare porpoise activity pre-turbine to the post-turbine installation, only the second period of the 2016/2017 deployment was selected. This period provided the most balanced design in which there was approximately equal effort at the 5 locations, with the same C-POD units deployed at each location across the 45 days pre-installation, and for the 73 days post turbine installation. Selecting this restricted 118 day subset of data therefore provided the optimal design for comparing any immediate effects of the turbine installation at local sites in the mid field area of the turbine (Figure 11). Currently the model includes the two day installation and connection period during which project vessels were operating in the area. Full use of baseline data is recommended as further data is collected.

We compared candidate models using a model selection criteria (quasi information criteria: QIC), and the model with the lowest QIC was selected. The final model included smoothed terms to remove confounding effects of environmental variability associated with time of year, the spring-neap tidal cycle, the tidal height and current velocity, as well as the time of day. Finally, the model included a linear term to control for the recording time lost at the hydrophone due to internal memory restrictions (% Time Lost). C-POD location was treated as a categorical variable, and the model coded 'D1' as the reference group (forms the model's intercept) against which the other four locations are compared. The GEE model found significant differences between C-POD locations, as well as a significant effect of the turbine on porpoise detection (Table 5).

In terms of the relative importance of the predictive value of the covariates used within the model, tidal velocity was the most important, followed by time of day, location, lunar cycle, Julian day, % time lost and lastly turbine presence. In fact, tidal velocity was twelve fold more important in predicting porpoise detection than turbine presence.

Table 5. GEE Model statistical results on 2nd deployment porpoise detection rates pre and post turbine installation. Location effects have higher statistical significance than turbine effects.

Model Covariate	Degrees of Freedom	Chi-Square Statistic	P-value
Location	4	190.15	<0.01**
Turbine	1	18.83	<0.01**
Location*Turbine Interaction	4	11.58	0.02*

Table 6. GEE regression coefficients at each of the 5 hydrophone locations for the 2nd of the 2016/2017 deployments. Significance at $\alpha < 0.05$ is denoted by '*', and at <0.01 by '**'. The model predicts, 1) more porpoise detections at West1, West2 and South2 than D1 (all p-values < 0.01) and 2) fewer porpoise detections at East1, West1, and West2 after the turbine installation (all p-values 0.01), but no significant differences in porpoise detections between pre- and post-turbine installation at D1 (p-value = 0.55), or South2 (p-value = 0.35).

Model Term	Estimate	Standard Error	Wald Chi-Square Statistic	P-value
D1:Locaton	13.62	27.23	0.25	0.62
East1:Location	-0.11	0.21	0.29	0.59
West1:Location	1.11	0.21	28.29	<0.01**
West2:Location	1.28	0.18	50.9	<0.01**
South2:Location	1.03	0.17	36.07	<0.01**
D1:Turbine	-0.16	0.27	0.35	0.55
East1:Turbine	-0.68	0.28	5.96	0.01*
West1:Turbine	-0.67	0.26	6.56	0.01*
West2:Turbine	-0.58	0.23	6.42	0.01*
South2:Turbine	-0.22	0.23	0.89	0.35

The significant interaction between location and turbine in Table 5, indicates that turbine effects were not equal across locations. In Table 6, we present the location-by-turbine regression coefficients for each C-POD location with the Chi-square tests. This model fit to the 2nd of the 2016/2017 deployments, found that there were significantly more porpoise detections at West1, West2, and South2 (p-values<0.01) compared to D1 and East1 (Top 5 rows of Table 6). The model predicts significantly fewer porpoise detections post-turbine installation at East1, West1, and West2 (p-values=0.01), but with no significant differences in porpoise detections on account of the turbine at D1 (p-value=0.55) or South2 (p-value=0.35). Therefore, the lower porpoise detections at locations East1, West1, and West2 post-installation of the turbine are driving the overall significant result of the turbine installation as presented in Table 5.

Figure 14 compares raw detection rate data (left panels) against the GEE-GLM model predictions (right panels). This figure highlights firstly, an immediate decline in model predicted porpoise detection post turbine deployment at these three locations. FORCE representatives documented that vessel activity occurred around installation on 7 November as well as the following day. Thus, significant effects include the short-term effects likely caused by vessel presence during this period. Secondly, across all sites, there was a period of very low porpoise presence a week after turbine installation, similar to that observed a month prior (pre-turbine). Both these dips appear related to full moon spring tides (Figure 12), a period known to exhibit high levels of sediment transfer and decreased detection performance (Tollit et al. 2011, Porskamp et al. 2015). Notably, FORCE representatives reported no vessel activity associated with the significant operation of deployment/interconnection at the site during this mid-November dip. Lastly, there looks to be a longer term drop in porpoise presence at the time limit of the data series in mid-January. This may be because of natural seasonal variability, another spring tide dip or may be due to the turbine's presence. More data are needed to determine if this trend persists, or was just part of the natural variability in the Minas Passage environment.

In summary, the data highlights that porpoise were not excluded from the mid field study area either during the period of turbine installation nor from the subsequent days the tidal turbine was in operation. A model of these data identified a significant decrease in porpoise activity at three of the five C-POD monitoring sites. These decreases were all less than a 50% reduction and occurred at ranges of 200 – 1710 m. The site at D1, which is on the same shelf and within 230 m of the turbine, did not show a significant turbine effect, nor did a more (1690 m) distant, and deeper water site at South2.

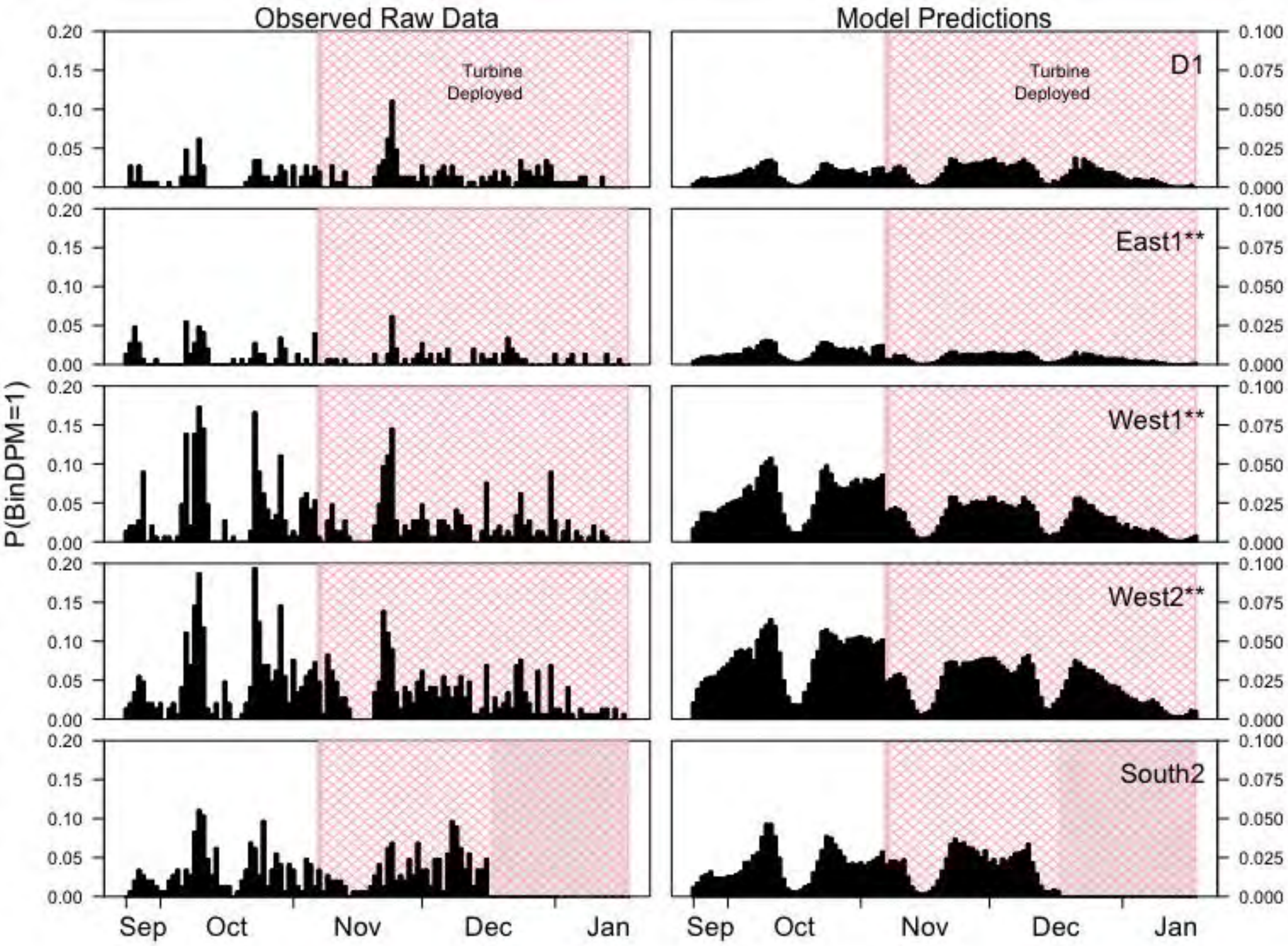

Figure 14. Probability of Porpoise detections, P(BinDPM=1) during the 2nd period of the 2016/2017 deployment. The left panels depict the raw data, the right panels depict the GEE model predictions for the same period. Locations with significantly lower probability in DPM post turbine installation are noted by '**'. The cross hatching denotes when the turbine was installed and working. The grey shading in the bottom panels shows when the C-POD at South2 was not collecting data for the last 32 days of the deployment (dead batteries).

4. Discussion

Harbor porpoise use echolocation to hunt and communicate (Kastelein et al. 2002), and they are known to be very susceptible to noise disturbance (Tougaard et al. 2009). Tidal turbines have the potential to cause acoustic effects on porpoise from continuous low-frequency noise, noting that emitted noise levels and range of effects will likely vary with current speed (Ellison et al. 2012, Polagye et al. 2011). In Minas Passage, baseline acoustic C-POD monitoring of harbor porpoise echolocation clicks occurred for 732 calendar days spread across four years between 5 May 2011 and 6 November 2016, and occurred at 8 different locations. C-PODs were deployed in a similar manner, used identical detection settings and analytical methodology and were therefore considered comparable. A single CSTV turbine was installed on 7 November 2016, and this report summarizes the factors that affect porpoise detection rates in the Minas Passage area and provides the preliminary effects analysis of the first 73 days of post turbine installation monitoring.

4.1 Annual Variability

Porpoise were detected on >95% of days across all monitoring deployments. However, in the 2016/2017 2nd deployment, porpoises were in the region for fewer minutes per day than in previous years (median 3.5 minutes compared to overall median of 7 minutes), noting importantly this period coincides with a previously recorded seasonal decrease in detection rates. However, baseline data was available for only one winter for comparison and additional data collection in this time period is recommended. Significant between-year variability has been previously reported in this region (Porskamp et al. 2015), and despite extensive baseline data, incomplete annual coverage combined with some inconsistency in monitoring locations, there remains uncertainty in applying the past to interpreting the patterns observed in the 2016/2017 dataset. It is clear that longer than 73 days of post-turbine installation monitoring is required to determine if these lower detection rates persist into the following seasons. C-POD monitoring at five sites is currently ongoing.

4.2 Time of Year Variability

In addition to between year variability, we observed strong within year (Julian day) cycles that influenced the presence of porpoise in the study area (as previously reported in Wood et al. 2013, Porskamp et al. 2015). This result is consistent with studies in other locations that have shown as much as three-fold changes in harbor porpoise abundance across the year (e.g., Hall 2011). Long-term satellite-tag monitoring of harbor porpoises have shown large habitat ranges in this species (7,738-11,289 km^2; Johnston et al. 2005), but the size of monthly focal areas were typically far smaller (122-415 km^2). This suggests that the within year variability in porpoise detections is a result of seasonal movements to favoured habitat (Wood et al. 2013). In our study region, porpoise presence peaked during May and June coinciding with the movement of spawning herring into the area, and was lowest during the late summer, presumably during the summer movement of the harbor porpoise population out into the more open waters of the Bay of Fundy. There was a secondary peak in porpoise occurring in late October/November, followed by low levels through the remainder of the winter period. The turbine was installed during this secondary peak. Although we might expect timing of these peaks to vary annually, a consistency across previous monitoring periods suggests that local porpoise density declines naturally over this post-installation period of 7 November to 18 January, even without any disturbance in the area.

4.3 Lunar and Flood/Ebb Tidal Variability

The tides are an alternating pattern of rising and falling sea level whose amplitude is influenced by both the moon and the sun. When the sun lines up with the moon and the earth, as during a new moon or full moon, we observe spring tides, thus there are two spring tides for each lunar cycle. The lunar cycle has been associated with harbor porpoise numbers in the Salish Sea with statistically more harbor porpoise associated with new moons (Hall 2011). Porpoise detection rates in our study region were clearly affected by lunar-related tidal patterns. Porpoise detection rates were highest in the transition period between neaps and springs. This result has been observed in Scotland where harbor porpoise detections were dependent on the position in the spring-neap tide, with highest detections when approaching peak spring tides (Embling et al. 2010). In Minas Passage, peak tidal exchanges and high current velocities associated with spring tides have been linked to C-POD % time lost and lower detection performance of C-PODS (e.g., Tollit et al. 2011, Section 3.2.1.5 in Porskamp et al. 2015).

On a shorter scale, the daily tidal cycle has long been associated with harbor porpoise habitat selection, with tidal variables such as tidal state (ebb/flood), tidal speed and tide height having an important influence on both the distribution (Marubini et al., 2009), and behaviour (Calderan, 2003, Johnston et al. 2005) of harbor porpoises. These dynamic spatio-temporal patterns in porpoise presence in Minas Passage related to tidal variables were likely because prey are known to also respond to these variables (e.g. Embling et al. 2010, Benjamins et al. 2016) by changing their distribution in the water column and/or by inducing schooling behaviour that could make them more accessible to predators (Embling et al. 2013). Notably, over the second deployment, tidal speed was the most important covariate in predicting porpoise detection (note that the analysis period covers 118 days, and therefore the seasonality described in 'JulianDay' has less of an effect than in the models with longer time series, e.g. Porskamp et al. 2015). Overall, we found porpoise were more likely to be detected during the ebb tide compared to the flood tide, with most detections during moderate ebb tidal flows between 0 and -2.5 m/s. Thus, porpoise in the Minas Passage were detected at highest rates in the first few hours after tides had turned to ebb when water velocities were flowing at low to moderate speeds.

4.4 Diel Patterns

In addition to annual, seasonal, and tidal variability, there are smaller daily processes that affect porpoise detection. We similarly found that porpoise detections were highest during the night, as shown in previous studies (Porskamp et al. 2015). Elsewhere, harbor porpoises have been shown to change their vocalisation behaviour with time of day (Carlström 2005), and the observed nocturnal pattern in Minas Passage may be a consequence of changes in behaviour, animal orientation and vocalisation rates rather than a change in porpoise presence (Williamson et al. 2017).

Alternatively, strong increases in after-midnight feeding has been reported across the range of this species (e.g., Carlström 2005, Todd et al. 2009, Linnenschmidt et al. 2013, Mikkelsen et al. 2013 and Brandt et al. 2014). The harbor porpoise is a highly mobile and a wide-ranging species that can move up to 50 km per day based on satellite tracking data (e.g., Johnston et al. 2005). Porpoise in the Baltic Sea have been shown to adapt their foraging strategy to prey behaviour, with daily movement patterns in a certain area depending on temporal changes in food availability. In Scotland, daily cycles of porpoise detection changed according to substrate type and water depth (Williamson et al. 2017). For this study, there was no prey field data to match to porpoise movements. However, it is reasonable to suppose that changes in prey distribution and abundance linked to darkness may cause important prey aggregations for porpoise in Minas Passage or that darkness makes hunting easier as porpoise are less visible. Either way, the distribution of prey and the ease with which it can be captured at different locations likely help explain the diel patterns in porpoise detections.

4.5 Location and Turbine Effects

The C-POD deployments were aligned according to a gradient design, with mid-field monitoring at the turbine site ranging outward from 200 to 1,710 m, with distances based mainly on predictive noise modelling undertaken by Polagye et al. (2011). However, depth varies over the FORCE demonstration area, with a steep drop-off to the south of the FORCE demonstration area. As a result, there were differences in the C-POD deployment depths. The two West locations were selected to ensure coverage of shallow waters west of the turbine, and the South location was included to monitor the deeper water where certain prey may concentrate (Wood et al. 2013). Depth and slope has been shown to be significant predictors of harbor porpoise distributions (Watts and Gaskin, 1985; Read and Westgate, 1997, Raum-Suryan and Harvey 1998) with porpoises generally found in the deeper water of their range. In Minas Passage, we observed the fewest detections in the shallow waters adjacent to the turbine at sites D1 and East1, with higher detection rates at the deeper depths of West1, West2, and South2. D1 and East1 were located not only in the shallowest water but also closest to the turbine with detection rates at less than half that of the other deeper sites during the 2nd of the 2016/2017 deployments. These potential differences in porpoise distribution due to differences in depth highlight the importance of good experimental design with balance in locations and redundancy at distances from the turbine at different depths to ensure the effects of the turbine are not confounded with C-POD location or depth.

Few studies to date have focused on exposure to continuous low frequency noise sources such as that emitted by tidal turbines, but one of the key goals of this study was to determine if the presence of the single operating turbine could cause porpoises to be displaced or excluded from their preferred habitat. Harbor porpoise were detected at all monitoring stations both before and after the turbine installation, thus it is clear that harbor porpoises were not excluded post-installation from the mid-range area monitored in this study. However, in our statistical GEE-GLM model fit to the 118 days of the 2016/2017 2nd deployment, we found the turbine (installation period and operational period) was a significant (p-value = 0.01) factor in the detection of porpoises at three of the five monitored sites, with reductions in detection probability of 41-46%. These sites included the closest C-POD site to the turbine (East1, 210 m away), as well as West1 and West2 (1,140 and 1,710 m from the turbine respectively) The site at D1 was located south of the turbine at Berth D, but at similar depth and distance from the turbine as East1, yet showed a small increase in observed (raw) detection probability (Table 4) but a non-significant turbine effect in the GEE-GLM model (Table 6). South2 detected no change in detection rates pre and post turbine installation. Noise propagation effects may explain observed differences across sites. However, to put the magnitude of the turbine related turbine effects into context, this effect was the least important in predicting changes in porpoise detection rates in our GEE-GLM model, with its influence 12 times less than that of tidal speed, the most important covariate.

5. Conclusions and Recommendations

Harbor porpoise use of the study area varies on both long (seasonal peaks, lunar cycles) and short (nocturnal preference, state of tide) timescales, as well as spatially (preference for deeper water). C-POD performance also varies temporally and spatially, requiring sophisticated modeling techniques to assess residual effects, while also noting that temporal coverage across years is intermittent and limited in winter. On average, porpoise clicks are detected in the Minas Passage study area almost every day (98.5% of days) for 0 to 44 minutes (median 7 minutes). Porpoise were detected at all five C-POD monitoring stations both immediately before (100% of days, median 4 minutes) and after (97.3%, median 3 minutes) the single CSTV turbine was installed. Overall, there was clearly no porpoise exclusion of the mid-range study area post-installation of the turbine. However, a significant (41-46%) drop in porpoise presence was found at three of the five monitoring sites, including the site at East1, 210 m south from the turbine, as well as the two sites 1140 and 1,710 m to the west. Currently this analysis includes the two day period of installation (with associated vessel activity) as well as 71 days of turbine operation. Interestingly, the site at D1, a site located close to the turbine (230 m to the northwest) on the rock shelf on which the turbine was also installed, showed no significant effect in porpoise detections post-installation of the turbine. The deeper-water site at South2 also showed no significant reduction in porpoise detections. Noise propagation effects may explain observed differences across sites. It is important to bear in mind the very short post-installation period analyzed to date, resulting in the overarching conclusion that further C-POD data collection is required before robust conclusions can be drawn and preliminary GEE-GLM model findings of potential mid-range turbine effects substantiated. This additional EEMP data will allow for a better comparison with previous baseline data collected.

Acknowledgements

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Appendix 4: FAST-3 Platform Program Description

Acoustic detection of fish presence and depth distribution at the FORCE tidal energy test site in the Bay of Fundy: assessing risk of interaction with tidal turbines

FORCE has developed marine sensor platforms as part of the Fundy Advanced Sensor Technology (FAST) program to monitor physical and biological characteristics of the test site.

This acoustic detection project uses the FAST-3 platform, which houses two different fisheries sonars (a narrowband single beam and broadband split beam). Specifically, the platform includes an Acoustic Doppler Current Profiler (ADCP) and two echosounders: the ASL Acoustic Zooplankton and Fish Profiler (AZFP) and the Simrad Wideband Autonomous Transceiver (WBAT).

The platform will be deployed for one month at a time, several times per year. The general objectives of this two-year program are to:

- To assess the temporal patterns in fish presence and risk of fish-turbine interactions at the FORCE tidal energy site; and
- To evaluate different acoustic technologies for monitoring fish at the FORCE test site.

Data analysis will be completed by Dr. Haley Viehman, a post-doctoral researcher at Acadia Centre for Estuarine Research at Acadia University. Results from this work will provide a better understanding of the temporal variation in fish presence at the tidal energy site, the potential effects of tidal energy turbines on fish, and the development of best practices for effects monitoring of fish with active acoustics. This research will directly address the regulatory needs of this emerging renewable energy industry.

FAST-3 was deployed for the first time in February 2017 at a test location near the FORCE site. Results from this deployment helped identify the best sensor settings and operating schedule for future data collection at the FORCE demonstration site. The platform was redeployed within the FORCE test site in June 2017.

[VIDEO] Dr. Viehman explains the project: https://vimeo.com/210831742

Appendix 5: European Wave & Tidal Energy Conference

Two research papers presented at the European Wave & Tidal Energy Conference regarding projects at the FORCE site.

Winter and summer differences in probability of fish encounter (spatial overlap) with MHK devices

Haley Viehman#1, Tyler Boucher*2, Anna Redden#3

#Acadia Centre for Estuarine Research, Acadia University
23 Westwood Ave., Wolfville, Nova Scotia B4P 2R6, Canada
[1]haley.viehman@acadiau.ca
[3]anna.redden@acadiau.ca

****Fundy Ocean Research Center for Energy***
PO Box 2573, Halifax, Nova Scotia B3J 1V7, Canada
[2]tyler.boucher@fundyforce.ca

***Abstract*—The likelihood of fish encountering an MHK device, and therefore the risk posed to fish, depends largely on the natural distribution of fish at tidal energy development sites. In temperate locations, such as the Bay of Fundy, seasonal changes in the environment and fish assemblage may alter the likelihood of fish encounters with MHK devices. We examined two one-month hydroacoustic datasets collected in winter 2015 and summer 2016 by an upward-facing echosounder deployed at the Fundy Ocean Research Center for Energy test site in the Minas Passage. Fish density was higher and less variable in winter than in summer, likely due to the presence of migratory vs. overwintering fish. The vertical distribution of fish varied with sample period, diel stage, and tidal stage. The proportion of fish at MHK device depth was greater, but more variable, in summer than in winter. Encounter probability, or potential for spatial overlap of fish with an MHK device, was < 0.002 for winter and summer vertical distributions. More information on the distribution of fish (horizontal and vertical), species present, fish sensory and locomotory abilities, and nearfield behaviours in response to MHK devices is needed to improve our understanding of likely device effects on fish.**

***Keywords*—Fish, encounter risk, MHK, hydroacoustics, Bay of Fundy, FORCE**

I. INTRODUCTION

The effects of marine hydrokinetic (MHK) devices on fish are generally unknown, but of high concern to industry, regulators, the scientific community, fishers and other stakeholders. To address this knowledge gap, the Fundy Ocean Research Center for Energy (FORCE) developed a series of marine sensor platforms to monitor physical and biological characteristics of the test site, where multiple MHK technologies will be deployed in coming years.

The FORCE test site is in the Minas Passage of the Bay of Fundy, where tidal range reaches 13 m and current speeds can exceed 5 $m \cdot s^{-1}$ [1]. The fish assemblage of this region changes seasonally [2]. Differences in fish assemblage and species behaviour with temperature means the risk MHK devices pose to fish will also vary seasonally. Depth preferences and vertical migration patterns vary with species and life stage of fish, so the likelihood of physical overlap with a fixed-depth MHK device will change with the fish assemblage. Additionally, temperature-related changes in physiology and behaviour alter the likelihood of fish interacting with an MHK device. For example, striped bass were recently found to be present in the passage near year-round, but with reduced diel vertical migration during periods of very low temperatures [3].

The goal of this project was to compare the pre-device density and vertical distribution of fish at the FORCE site in winter 2015 and summer 2016 and consider the implications for the likelihood of fish interactions with a Cape Sharp Tidal MHK device (OpenHydro). This device spans 0-20 m above the sea floor and was installed in November 2016. We analysed hydroacoustic data collected at the FORCE site in winter and summer months to examine natural differences in (1) overall fish density, (2) fish vertical distribution, and (3) the proportion of fish at device depth, with respect to tide, diel stage, and time of year. This information was used to calculate the likelihood of spatial overlap of fish with an MHK device, a basic probability of encounter model.

II. METHODS

A. Data Collection

Hydroacoustic data were collected with an upward-facing ASL Environmental Sciences Acoustic Zooplankton and Fish Profiler (AZFP), mounted approximately 1.5 m above the sea floor on the FAST-1 bottom platform (Fig. 1).

Fig. 1 FAST-1 sensor platform developed by FORCE and deployed at the FORCE test site. White arrow indicates location of AZFP transducer. Photo credit: Tyler Boucher.

The AZFP utilized a 125 kHz, 8° (half-power beam angle) circular transducer, which operated at a 300 µs pulse duration and ping rate of 1 Hz. Current speed and water temperature were recorded for 10 minutes every half hour by a Nortek

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Signature 500 Acoustic Doppler Current Profiler (ADCP), also mounted on the platform. The platform was deployed at the FORCE test site for approximately one-month intervals. The first deployment spanned 8 December 2015 to 5 January 2016 (the "winter" dataset) and the second deployment was from 17 June to 13 July 2016 (the "summer" dataset).

The platform was deployed at the south-western corner of the FORCE test area in winter, and in summer, at a site nearer to the Cape Sharp Tidal MHK device location (site D, Fig. 2). Both sites are on a volcanic plateau formation that extends into Minas Passage, the 5.5-km-wide connection between Minas Basin and Minas Channel. The sites were approximately 1 km apart and experienced similar environmental conditions, including current velocity (mid-water-column current speed exceeding 4 m·s^{-1} at peak flood tide and 3 m·s^{-1} at peak ebb tide) and depth range (spring tide depths of 33 to 45 m at the winter site, 30 to 43 m at the summer site). Temperatures ranged from 5.4°C to 8.4°C during the winter deployment, and from 9.9°C to 13.6°C during the summer deployment.

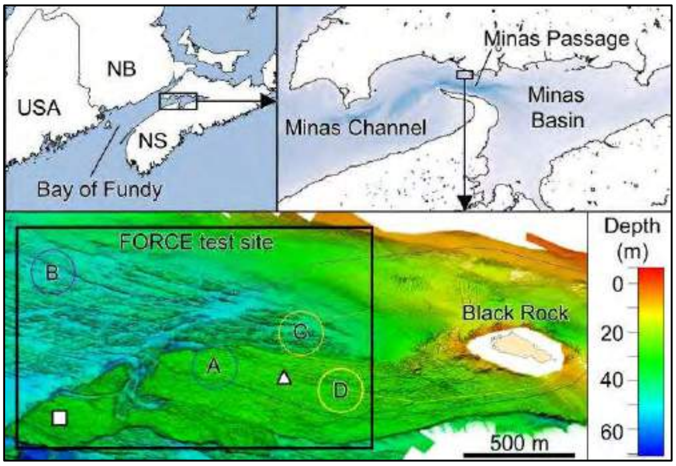

Fig. 2 Study site with deployment locations. Lower panel shows site bathymetry and proposed MHK device sites (A-D) at the FORCE test site. Location of the FAST-1 platform in winter 2015 indicated by □, summer by △. Upper panel maps made in QGIS with data obtained from GeoGratis Canada and bathymetry data from [4]. Lower panel map produced by Seaforth Geosurveys, Inc.

B. Data Processing

Hydroacoustic data were processed in Echoview® software (8.0, Myriax, Hobart, Australia). Steps included applying calibration constants, setting a -60 dB target strength threshold to remove most non-fish targets and fish under a few cm in length [5-11], excluding data that has acoustic interference from the ADCP, and removing acoustic signal from the acoustic nearfield and from entrained air (Fig. 3).

Calibration of the echosounder was carried out by the manufacturer prior to the December 2015 deployment. A second calibration conducted in January 2017 revealed the echosounder had drifted by several dB over that time. The majority of this drift appears to have occurred after the June 2016 deployment: examination of surface backscatter from the December 2015 and June 2016 deployments showed a drop of approximately 2 dB from December to June, which was within the error range of the manufacturer's calibration. The December and June datasets are therefore comparable using the factory calibration settings, but this difference should be kept in mind when interpreting results.

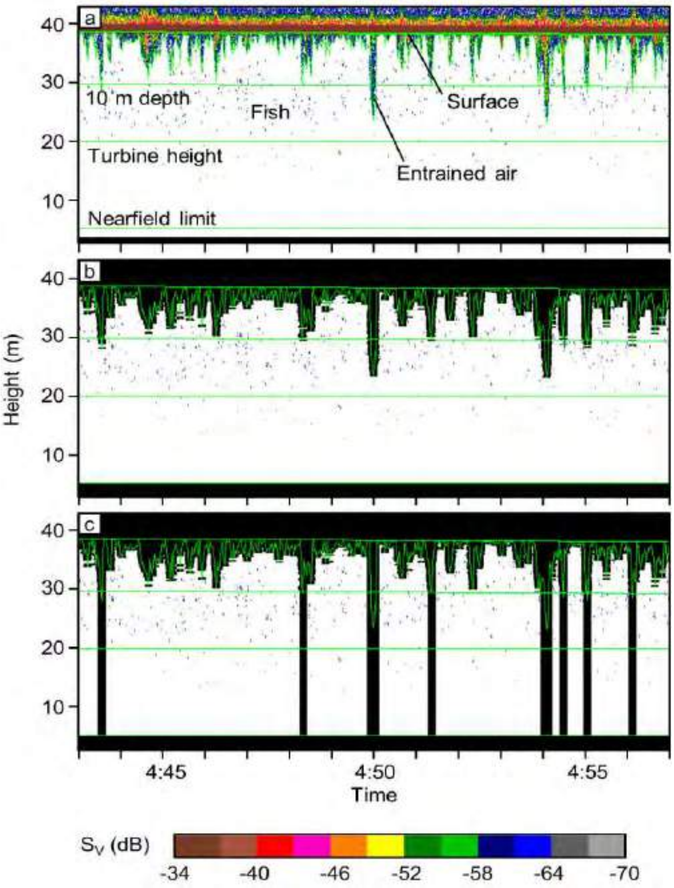

Fig. 3 Example of volume backscatter (S$_V$) data collected from 4:43 to 4:57 UTC on 9 December 2015. (a) Raw data, showing entrained air and lines in data processing. (b) Processed data, with entrained air removed. (c) Processed data with pings removed where depth of entrained air surpassed 10 m. Height is measured from the sea floor.

A layer of entrained air was almost always present near the surface, and at peak flows, turbulence frequently drew air to depths near the seafloor. Entrained air is a common issue at tidal energy sites [12-14]. Because air is a strong acoustic target, any fish that may have been within the entrained air layer were not detectable. Entrained air was removed from the data with a series of steps in Echoview® that used a modified bottom-detection algorithm to isolate the air layer (Fig. 3a), then expanded its boundaries slightly to remove any fringe signal that was not encompassed by the line (Fig. 3b).

Due to the high prevalence of entrained air at 0-10 m depth, the subsequent analyses were limited to depths greater than 10 m. Additionally, any pings in which entrained air surpassed 10 m depth were entirely excluded from the dataset (Fig. 3c). This resulted in more pings lost during periods of high flow (i.e., mid-tide; Fig. 4a), particularly during the flood tide, which was more turbulent. However, excluding entire pings improved comparability of values obtained from throughout the water column.

C. Data Analysis

Analysis was divided into three parts: (1) analysis of fish backscatter from the whole water column (Fig. 4b), (2) inspection of the vertical distribution of backscatter (Fig. 4c), and (3) comparison of backscatter from the depths spanned by the proposed MHK device to that from the water column (Fig. 4d).

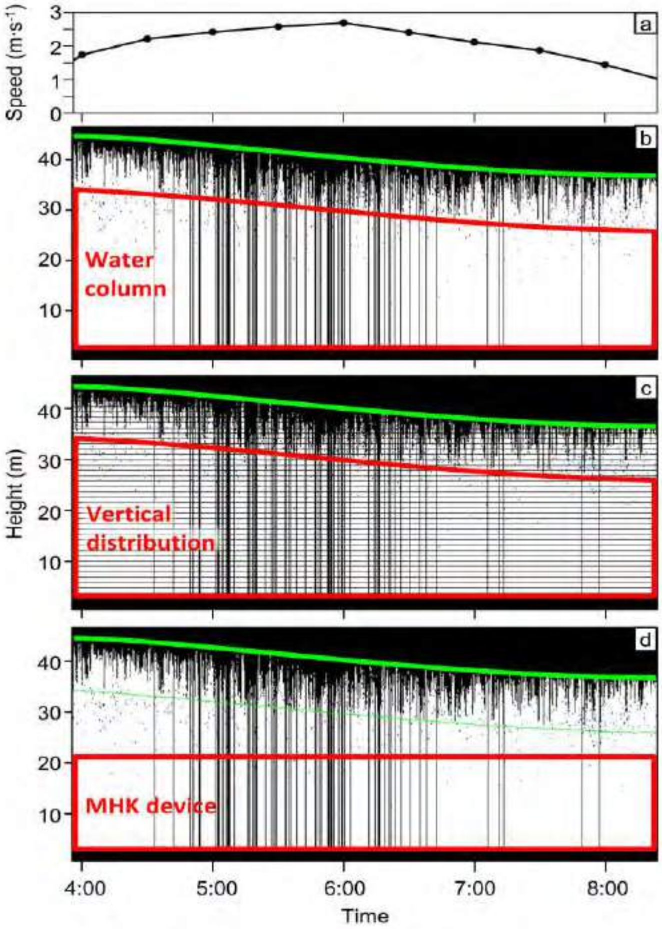

Fig. 4 Data from one ebb tide from 3:56 to 8:23 UTC on 9 December 2015. (a) Current speed from 16-17 m above the sea floor. (b-d) The three water column partitions used in analysis: (b) entire water column, defined as the acoustic nearfield to the 10-m depth line; (c) 1-m layers for vertical distribution analysis; (d) layer that encompasses depths spanned by the MHK device installed in 2016. Height is measured upward from the sea floor. Vertical black lines are pings omitted due to entrained air (Fig. 3c).

Hydroacoustic data were first split into segments according to tidal (ebb or flood) and diel (day or night) stages. Slack tides were defined as periods when mid-water-column current speed was less than 1 $\mathrm{m \cdot s^{-1}}$. The rise and fall in current speed was slightly asymmetrical (Fig. 4a). Low slack tide averaged 70 min (9.4 min standard deviation) in length while high slack tide averaged 44 min (7.1 min standard deviation). Slack tides were then omitted from analyses in order to focus on ebb and flood tides, when an MHK turbine would be rotating (depending on cut-in speed) and thus a potentially greater risk to fish. Periods of dusk and dawn were then defined as the hours centred at sunrise and sunset, and were also excluded in order to avoid likely periods of vertical fish migration that could confound analysis of vertical distribution. The remaining data segments were classified by tidal stage and diel stage, and were treated as separate samples. Any of these samples missing more than half of their data points due to entrained air were omitted from analyses.

Further analysis required partitioning the water column in three different ways (Fig. 4). The water column used in analyses was limited to the portion between the acoustic nearfield (3.2 m height above the sea floor) and the 10-m depth line (Fig. 4b). Assessing the vertical distribution of backscatter required splitting this analysis region into 1-m-deep layers measured upward from the face of the transducer (Fig. 4c). To compare MHK device depth to the rest of the water column, the analysis region was split at proposed device height (20 m above the seafloor; Fig. 4d). From here onward, “water column” refers to the portion of the true water column which we were able to analyse.

The acoustic metrics exported from these portions of the water column for each time segment were mean volume backscatter and the area backscattering coefficient. Volume backscatter, S_V, is the amount of acoustic energy scattered by a unit volume of water and is a rough proxy for fish density [15, 16]. S_V is expressed logarithmically in units of decibels (dB re 1 $\mathrm{m^{-1}}$) or in the linear domain as s_v, with units of $\mathrm{m^2 \cdot m^{-3}}$. Mean S_V was calculated for the entire (analysed) water column to examine general differences in fish density with respect to tidal stage, diel stage, and sampling period. The area backscattering coefficient, s_a, is s_v integrated over a given layer of the water column (units of $\mathrm{m^2 \cdot m^{-2}}$), and so is also a proxy of fish density. s_a was used to calculate the proportion of acoustic backscatter contributed by each 1-m layer of water and from the depths spanned by the proposed MHK device.

Statistical analyses were carried out in R (3.3.1, R Core Team, Vienna, Austria). Differences in water column S_V and the proportion of backscatter from the MHK device depths related to tidal stage (ebb or flood), diel stage (day or night), and sampling period (winter or summer) were examined using analysis of variance (ANOVA) tests with a significance level of 0.05. Comparisons between factor groups found to have significant effects were carried out with Tukey-type multiple comparisons. Nonparametric versions of these tests (permutation ANOVA, nonparametric Tukey-type comparisons) were used for water column S_V data, which did not meet the assumptions of normality. The linear form of S_V ($s_v = 10^{Sv/10}$) was used in significance testing and to calculate summary statistics.

The probability that fish might encounter an MHK device was estimated as the probability of spatial overlap with the device under three fish distribution scenarios: (1) uniform vertical distribution; (2) winter vertical distribution; and (3) summer vertical distribution. For this exploratory exercise, fish horizontal distribution (across the breadth of the passage) was assumed uniform, and the proportion of backscatter at turbine depth was assumed equivalent to the proportion of fish at that depth range (i.e., acoustic properties were assumed the same for all fish). Under scenario 1, the probability of encounter was simply the cross-sectional area of the turbine divided by that of the passage. For scenarios 2 and 3, the probability was the proportion of passage cross-section spanned by the turbine's width multiplied by the proportion of fish at turbine depth in winter and summer (the median proportion of backscatter at turbine depth). The passage cross-sectional area at site D (Fig. 2) was estimated as 338,814 m^2 at mean tidal height, using bathymetry data in [4] and Quantum GIS open source software package (2.18.7, QGIS Development Team). The area of a single Cape Sharp Tidal device was approximated as 320 m^2 (16 m width x 20 m height), and the area of the vertical slice of the passage spanned by the turbine was 592 m^2 (16 m width x 37 m depth).

III. RESULTS

After data processing, 51 flood tides and 64 ebb tides remained for analysis in the winter dataset, and 66 flood tides and 71 ebb tides remained in the summer dataset (Fig. 5, full page display). In the winter dataset, fish were almost always present, mainly as individuals spread out in the water column, though small, compact aggregations were also present during the day. In the summer dataset, there were long spans of empty water column or water column interspersed with a few individual traces, punctuated occasionally during the day by loose or compact aggregations of fish. Aggregations of fish were not observed at night in either dataset. During calm periods with little entrained air, fish could often be seen in the upper 10 m of water that were excluded from analyses (Fig. 3, Fig. 4), which should be kept in mind while interpreting results.

A. Water column fish density

The water column mean S_V (index of fish density) was significantly higher in the winter dataset than in the summer one, by approximately 8 dB (Fig. 6a). The median (IQR) S_V in winter was -84.2 dB (-85.6, -83.1) and in summer was -92.7 dB (-94.9, -88.7). Tidal and diel stage were not found to significantly affect water column mean S_V, but it is worth noting that in the summer, mean S_V was noticeably lower at night than during the day (Fig 6b).

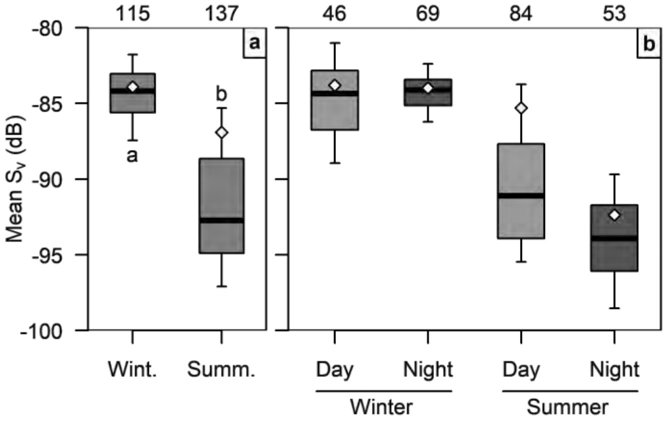

Fig. 6 Water column mean volume backscatter, S_V (proportional to fish density). (a) Winter vs. summer. (b) Day vs. night in winter and summer. Sample sizes are shown at top. Letters indicate groups with significantly different means (a highest, b lowest), where tested. White diamonds are means, horizontal bars are medians, boxes span 25th to 75th percentiles, and whiskers span 10th to 90th percentiles.

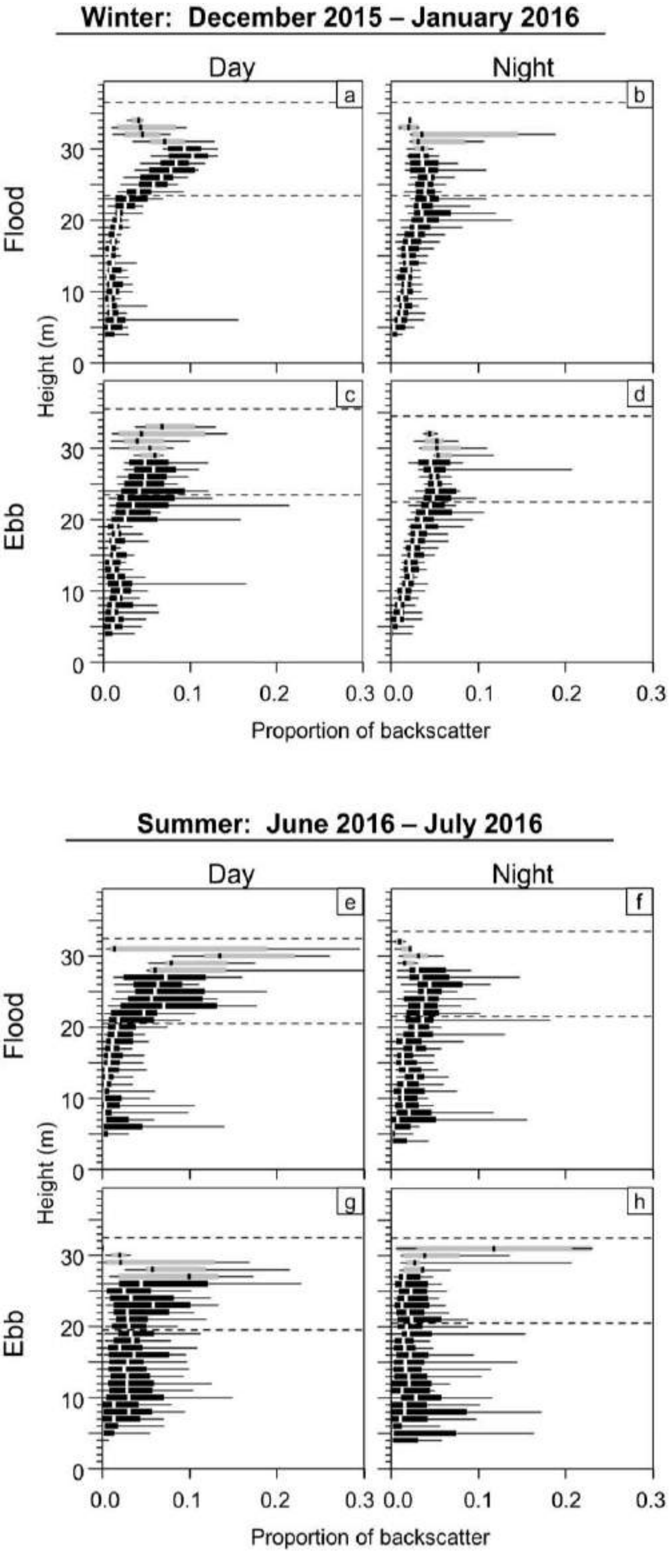

Fig. 7 Vertical distribution of area backscatter during time periods of interest, from the winter (a-d) and summer (e-h) datasets. Thick vertical lines indicate median, boxes encompass the interquartile range, and whiskers span the 10th to 90th percentiles of each 1-m layer of the water column. Grey boxes indicate sample sizes less than 10. Horizontal dashed lines are the minimum and maximum height of the analysed water column (which extended upward to 10 m below the true surface) for the duration of each time period. Height is measured upward from the sea floor.

B. Vertical distribution

Vertical distributions were generally 'top-heavy' regardless of sample period, tidal stage, or diel stage. Backscatter was typically strongest in the upper layers that were analysed, though a secondary increase was present at times in the lowest layers (Fig. 7). Differences in vertical distribution related to tidal stage, diel stage, and sampling period were also apparent. Diel differences were particularly noticeable in the winter dataset: during the day (Fig. 7a,c), backscatter was strongest in the upper layers of the water column, with a minimum centred at approximately 15 m above the sea floor. At night (Fig. 7b,d), backscatter was distributed more evenly across depths, increasing from the lowest layers to approximately 20 m height above the sea floor, and remaining similar or decreasing slightly in higher layers. In the summer dataset (Fig. 7e-h), higher variability in the backscatter within each layer made vertical distributions less distinct than in winter, and indicated vertical distribution was less consistent over time. In the summer, a diel difference in vertical distribution similar to that of winter was apparent for flood tide (Fig. 7e,f) but not for ebb tide (Fig. 7g,h). During the ebb tide, backscatter was more uniformly spread across layers during the day and slightly higher in the uppermost layers (though variability was high; Fig. 7g); at night, most of the backscatter was contributed by the upper- and lower-most layers (Fig. 7h).

C. Fish at MHK device depth

The proportion of fish backscatter from the depths spanned by the MHK device (0-20 m height) was significantly higher in summer than in winter (median and IQR for winter: 0.365, 0.232-0.476; summer: 0.566, 0.297-0.848; Fig. 8a). The interaction of sample time with tidal stage was also significant: in winter, flood and ebb tide had similar proportions of backscatter at device depth (flood: 0.325, 0.202-0.451; ebb: 0.401, 0.288-0.504), while in summer ebb-tide proportions were higher than flood (flood: 0.393, 0.201-0.710; ebb: 0.714, 0.481-0.895; Fig. 8b). Diel stage did not significantly affect the proportion of backscatter within the device layer, despite visual differences in vertical distribution (Fig. 7). However, the proportion at device depth in summer was noticeably more variable than in winter, which agrees with water column mean S_V and fish vertical distribution.

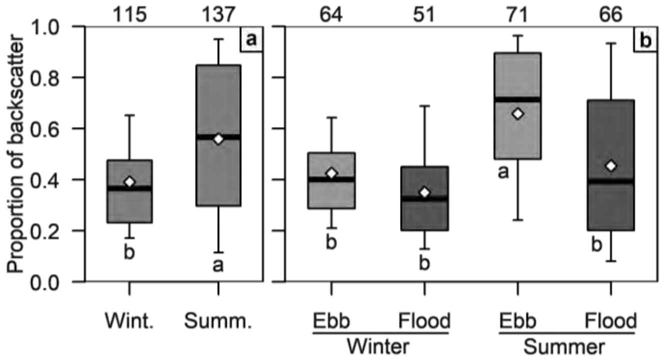

Fig. 8 Proportion of water column area backscatter, s_a, from depths spanned by the proposed MHK device (0-20 m above sea floor). (a) Winter vs. summer; (b) flood tide vs. ebb tide in winter and summer. Sample sizes shown at top. Letters indicate groups with significantly different means (a highest, b lowest). White diamonds are means, horizontal bars are medians, boxes span 25th to 75th percentiles, and whiskers span 10th to 90th percentiles.

D. Probability of encounter

The probability that fish would encounter the MHK device based on spatial overlap alone (assuming uniform horizontal distribution) was 0.00175 with uniform vertical distribution. The probability of encounter was 0.00064 with the winter vertical distribution of fish (median proportion of fish at turbine depth = 0.365), and 0.00099 with the summer vertical distribution (median proportion of fish at turbine depth = 0.566).

IV. DISCUSSION

Fish density and vertical distribution in the analysed water column (3.2 m above the bottom to 10 m depth) were found to differ between winter and summer and with tidal and/or diel stage. Potential MHK device effects therefore also differ in winter and summer and on shorter time scales. Overall, fish density was found to be higher and less variable in winter than in the summer, though the proportion of fish backscatter within depths spanned by the device was higher in the summer than in the winter. Smaller-scale temporal patterns in water column fish density and vertical distribution were also evident, including tidal and diel differences, which encourage a closer look with greater temporal resolution. Studies of other tidal energy sites have found patterns in nekton density and distribution (vertical and horizontal) occurring over a wide range of temporal and spatial scales [17-20]. In this study, we took a broad approach, limiting temporal resolution to entire tidal stages and omitting slack tides, dawn, and dusk. Movements and density changes were likely occurring within each tidal stage (e.g., in response to current speed) that would not be apparent with this approach. Additionally, slack tides, dawn, and dusk are likely associated with different fish behaviours (e.g., vertical migration [17-20]) than the periods of day, night, and running tides which were examined here. Changes in fish density and distribution occurring on these finer time scales can alter the likelihood of MHK device interaction and should be examined in future assessments.

The proportion of fish backscatter at device depth was found to differ between winter and summer and with tidal stage, though not with the diel stage, despite diel differences in vertical distribution (in winter) and in density (in summer). Unfortunately, backscatter cannot be easily changed to an absolute number or density of fish in a mixed fish assemblage without knowledge of the species of each individual fish or aggregation [16]. This is because the acoustic reflectivity of fish is largely determined by their anatomy (species, life stage, and size) and orientation within the acoustic beam [16]. If all fish are assumed to be the same, the proportion of backscatter at device depth can be a direct estimate of the proportion of fish. In reality, this proportion must be scaled depending on the acoustic properties of the fish detected, but from this rough starting point it is clear that a large proportion of fish within the region analysed was at device depth. The proportion would decrease if the uppermost 10 m of water could be included in analysis. Near low slack water, an additional 10 m would more than double the amount of water above the MHK device. A better method for dealing with surface turbulence should be investigated to avoid complete omission of the upper 10 m of water.

The decrease in water column backscatter, and therefore fish density, from winter to summer was not expected. More fish were expected in summer than in winter because many migratory fish species use Minas Basin and Minas Channel from spring through fall for spawning and feeding purposes [2, 21]. This apparent contradiction by water column backscatter may reflect differing uses of Minas Passage by fish in the winter and summer. Fish present in the passage in summer are likely to be using it to reach the habitats of Minas Basin or the outer Bay of Fundy (or beyond). Based on sampling in Minas Basin and other parts of the Bay of Fundy, some species known to be in the area from spring through fall that are also likely to be detected mid-water-column include anadromous species, e.g. alewife (***Alosa pseudoharengus***), blueback herring (***Alosa aestivalis***), American shad (***Alosa sapidissima***), Atlantic salmon (***Salmo salar***), striped bass (***Morone saxatilis***), rainbow smelt (***Osmerus mordax***), sea lamprey (***Petromyzon marinus***), and Atlantic sturgeon (***Acipenser oxyrhynchus***); the catadromous American eel (***Anguilla rostrata***); seasonally present species such as Atlantic mackerel (***Scomber scombrus***), pollock (***Pollachius virens***), and blackspotted stickleback (***Gasterosteus wheatlandi***); and species present year-round in various life stages, including Atlantic herring (***Clupea harengus***) and threespine stickleback (***Gasterosteus aculeatus***) [2, 3, 21, 22]. Various shark species may also be present in the summer, the most common being porbeagles (***Lamna nasus***) and spiny dogfish (***Squalus acanthias***), which likely follow their migrating fish prey [21]. The summer dataset was likely collected between the major inward and outward migration periods in the spring and fall. Additionally, any fish using the passage to travel to or from Minas Basin would be unlikely to pass through it many times. Fish density in Minas Passage could therefore be low and variable even when fish abundance in nearby, lower-flow areas is known to be high.

In contrast to summer, water column fish density in the winter was higher and much less variable. The majority of fish in the passage at that time was likely to be herring, whose presence was supported by frequent trails of bubbles seen rising from schools or individuals in the echogram (herring and other clupeids are known to release swim bladder gas through the anal duct [23, 24]). Rainbow smelt and sticklebacks were also potentially present in the area based on what is generally known of their life histories [21], and acoustically tagged striped bass have been recorded repeatedly passing through Minas Passage in the winter [3]. The repeated movement of striped bass through Minas Passage indicated they were overwintering rather than migrating, moving more or less with the tidal currents, and it is possible this would be the case for other overwintering species. Fish moving back and forth through the passage with the currents would result in stronger and more consistent backscatter over time in the winter, as opposed to the intermittent acoustic signal of species passing quickly through in the summer. The somewhat counterintuitive relationship between fish density and season within Minas Passage highlights the need for more information on fish use of these unique, fast-paced environments—observations from low-flow areas nearby may simply not be applicable within.

The density difference between winter and summer could have been partially due to the vertical extent of the water column we were able to use in analyses. The decrease in fish density in the summer, for instance, could have been caused by increased use of the upper- and lower-most layers of the water column. These layers were omitted from analyses, but it would not be surprising to find migratory fish within them, especially considering the extreme current speeds of the passage. Many species have been found to use selective tidal stream transport (STST) to facilitate migration through areas with fast tidal currents. This involves timing movements between shelter (e.g., slow-moving bottom water) and fast-moving surface water to utilise the currents moving in the desired direction of travel. STST has been observed for American eel [25], American shad [26], Atlantic cod (***Gadus morhua***) [27], sockeye salmon (***Oncorhynchus nerka***) [28], sea trout (***Salmo trutta***) [29], and plaice (***Pleuronectes platessa***) [30, 31]. Migrating Atlantic mackerel [32] and Atlantic herring [33] have also been observed to alter their behaviour to oppose unfavourable tidal flows, though not necessarily via vertical migrations. STST has not been observed for many of the species present in Minas Passage, but fine-scale fish distribution in fast-paced tidal environments has not been of particular interest until recent years. Movements in such environments may not adhere to what is ‘typical’ for species in other locations; for example, Atlantic sturgeon, which are classified as demersal fish, were recently found to pass through Minas Passage pelagically [22]. Differences between ebb and flood tides were not evident in the vertical distributions presented here, but the omission of the upper 10 m of the water column makes it difficult to rule out STST and other vertical movements, or to assess their effects on results. Assessing these data on a finer time scale (sub-tidal-stage) and including more of the upper 10 m of water, where possible, may allow better assessment of flow-related behaviours such as STST.

Diel vertical migration could have also influenced some of the observed differences between winter and summer. Though typical fish movements may be altered in these areas of fast flow [22], many of the fish species present in Minas Passage in the summer have exhibited nightly migrations upward into the water column in other locations. These species include alewife [34], American shad and blueback herring [35], Atlantic herring [36], and striped bass [3]. Any fish moving into the upper 10 m of water at night would be outside the portion of the analysis region, which would be recorded as lower density. There was not a distinct difference in vertical distribution between night and day in the summer sample, but again, without information from the upper 10 m, fish cannot be assumed absent there.

In winter, a diel change in vertical distribution was clear. Fish were more evenly spread out in the water column at night, but because water column backscatter did not decrease, this diel difference was unlikely to be related to fish moving vertically out of the portion of water column analysed. Instead, the diel redistribution of fish was more likely related to the dissolution of schools at night, as schooling fish rely heavily on vision to remain aggregated [37, 38]. Numerous aggregations of fish were visible in the middle and upper water column during the day that were not seen at night, and the majority of these were likely Atlantic herring [13, 21]. Herring is a schooling species, and their daily school dispersion and re-formation would generate a much more obvious diel change in vertical distribution than vertical movements of less abundant species. Striped bass, for example, were likely migrating upward at night [3], but this pattern was not strongly evident.

The locations of the summer and winter deployments were different, and could also have contributed to the differences we observed. The sites were nearly 1 km apart, and while current speed and direction and water depth were similar at both locations, it is possible the winter sampling location was in a part of the passage more frequented by fish [3, 22]. Fish and other marine animals have been found to associate with fine-scale hydrodynamic features at other locations (e.g., eddies and fronts) [13, 39], and turbulence could influence their vertical distribution, particularly for small animals [40]. If this is the case in Minas Passage, fine-scale hydrodynamics at even nearby sites could affect how fish use those locations. Further study of the relationship between fish and the hydrodynamic features of tidal energy sites would help determine how fish densities are likely to differ spatially. Eddies, fronts, and regions of high turbulence are often indicated in hydroacoustic data by the plumes of entrained air [12], which have thus far been omitted from analyses. These may prove to be valuable environmental data points to consider in future assessments. Examining the association of fish with any of these features will require more advanced techniques for separating fish signal from entrained air, and potentially the operation of more than one hydroacoustic tool simultaneously (e.g., multibeam and split beam systems of one or more frequencies) [12, 13]. Assessment of the spatial representativeness of one point in the FORCE test site would also aid in determining whether data from one location can be extrapolated to others [19].

Given the lack of echosounder calibration immediately before and after the summer deployment, we were concerned that echosounder performance could have affected our results. We explored the potential effect of transducer drift by applying gain offsets ranging from 0 to 5 dB to the acoustic data, which should more than compensate for the ~2 dB drift observed in surface backscatter. We found that even a correction of 5 dB did not alter results noticeably, so findings are likely independent of echosounder drift. However, this uncertainty highlights the importance of calibrating echosounders before and after every deployment (e.g., as described in [41]). This is particularly true at tidal energy sites, where gear is subjected to constant motion, wear by sediment-laden currents, and increased rates of corrosion, all of which can lead to earlier equipment failure than may generally be expected.

In the future, the ability to separate species, or even groups of them, will be essential to understanding fish use of tidal energy development sites. Using multiple acoustic frequencies simultaneously could help separate anatomically distinct groups of fish [42]. Emerging broadband echosounders have the potential to further improve species identification in acoustic data [43]. There is also a need to physically sample fish in these areas to ground-truth any acoustic information collected. Much of our knowledge of fish use of Minas Passage is based on samples taken from weirs within Minas Basin (predominantly spring through fall) [2], or from studies carried out long ago (see references in [2, 21]). Physical sampling within the passage, e.g. with midwater trawls, is likely to be incredibly difficult, if not impossible. However, sampling at either end of the passage near slack tide could potentially provide insight into what fish were moving through the passage just prior, and may be more logistically feasible. Such sampling cannot provide the spatial and temporal resolution of hydroacoustic methods, but it is essential for our understanding of the local ecosystem and for interpretation of hydroacoustic data.

More information on the species present would also allow us to better predict the likelihood of fish interaction with MHK devices at the species level. This would be helpful in the cases of commercially important or threatened/endangered species. Knowing what part of the water column is preferred by these species would aid in evaluating their potential for interacting with an MHK device at a known depth, and therefore the potential for impacts on fish populations. Knowledge of species composition would also improve our ability to convert hydroacoustic backscatter into more useful values for effects modelling, such as fish biomass or numbers of individuals. In a mixed-species assemblage, converting between backscatter and biomass is difficult, particularly with no way to estimate which backscatter comes from which species [15, 16]. In previous studies, echograms from multiple acoustic frequencies have been combined with prior knowledge of species present and their behaviours, such as depth preference, to estimate biomass [42, 43]. This is not yet possible in the Minas Passage and most other mixed-species tidal energy sites, where little fine-scale information is available on species presence and their behaviours in very fast tidal flows.

The winter and summer vertical distributions presented allowed the estimation of the probability that fish may encounter an MHK device at this site. The use of the water column by fish, many of which vertically migrate, affected their likelihood of being within the depths occupied by the MHK device. In winter, this probability was substantially lower than in summer due to a greater presence of fish in the upper water column, above depths spanned by the device. Additionally, in both months sampled, the probability of fish being at device depth was lower than if fish had been uniformly distributed in the water column. The opposite would be true if the MHK device under consideration were surface-oriented rather than bottom-mounted. Device depth must be taken into account along with fish use of the water column when estimating encounter probability.

The horizontal distribution of fish at a tidal energy site is also an important consideration, albeit more difficult to assess in a wide channel. The encounter probabilities estimated above assumed a uniform horizontal distribution of fish across the channel. However, as with vertical distribution, the horizontal distribution of fish is likely to be non-uniform and dependent on the species present. For example, Atlantic sturgeon utilized the southern side of Minas Passage more than the northern [22], whereas striped bass were more often detected mid-passage [3]. Sturgeon may therefore be less likely to overlap with MHK devices at the FORCE site than if they were evenly distributed across the passage, whereas striped bass may be more likely. More information on fish distribution at the species level would be necessary to adjust the above probabilities for each species present. Data on the horizontal distribution of fish in general would be best acquired via mobile hydroacoustic transects across the passage [44], and FORCE is currently working with University of Maine researchers to carry out such transects [45]. In the future, results from these mobile surveys can be combined with results presented here to build a better understanding of the likelihood that fish may encounter MHK devices. This information will be increasingly useful as tidal energy deployments expand from individual devices to arrays.

It is important to recall that estimates of encounter probability based on spatial overlap of fish with devices do not take into account the behavioural responses of fish to MHK devices. Though the distribution of different fish species and life stages will influence their likelihood of encountering tidal energy devices, fish sensory and locomotory abilities will influence if and how they physically interact. We have little reason to believe fish are passive particles in this environment, despite the strong currents. There is evidence of fish responding to MHK devices at a variety of spatial scales, from potential avoidance beginning as far as 140 m upstream [46] to evasion by even small fish (~ 10 cm) occurring within the nearest few meters [47, 48]. The sensory abilities of fish will affect at what distance they detect an MHK device, and subsequently their likelihood for avoidance or evasion. Fish have a wide variety of senses to inform them of their environment, including vision, hearing, and the lateral line system [49-51], all of which are likely to be of use in avoiding MHK devices [47]. The sensitivity of each sensory system varies with species and life stage [52] and can be modified by the environment—for example, striped bass may be less responsive to environmental cues at very low temperatures [3]. Assuming a fish detects an MHK device, swimming power then becomes important for avoidance or evasion. Swimming power is proportional to fish length [52], and larger fish may be less likely to enter a turbine than smaller ones [47]. More observations of fish behaviour near MHK devices, as well as information on the perception and locomotion thresholds of different species and life stages of fish in loud, turbulent, high-speed environments, is necessary to better predict if fish will avoid or enter MHK devices.

If a fish does not avoid an MHK device and instead enters an operational turbine, it then risks contact with turbine blades. Quantifying strike in the field is likely to be incredibly difficult, if not impossible. This is primarily due to resolution limitations of acoustic equipment [47] and the difficulty of seeing in dark, turbid water by other means (e.g. video [54]). However, laboratory simulations have found it difficult to make fish enter MHK turbines even in confined spaces, and have measured survival rates greater than 90% for those fish that do pass through [55, 56]. These studies have not examined survival rates in the dark, which may be an important factor in turbine avoidance and evasion [47]. Also, conditions in laboratory flumes differ substantially from those in the field, e.g. with much slower current speeds, less turbulent flow, and different acoustic environments. There is a need for laboratory testing under more realistic conditions to better describe which MHK device cues elicit responses in which species and life stages of fish, in addition to estimating survival rates. By combining such information with knowledge of the species present at tidal energy sites and their natural distribution and behaviours on various time scales, we can build a more complete picture of fish interactions with MHK devices and better predict their effects on fish from individual to population levels.

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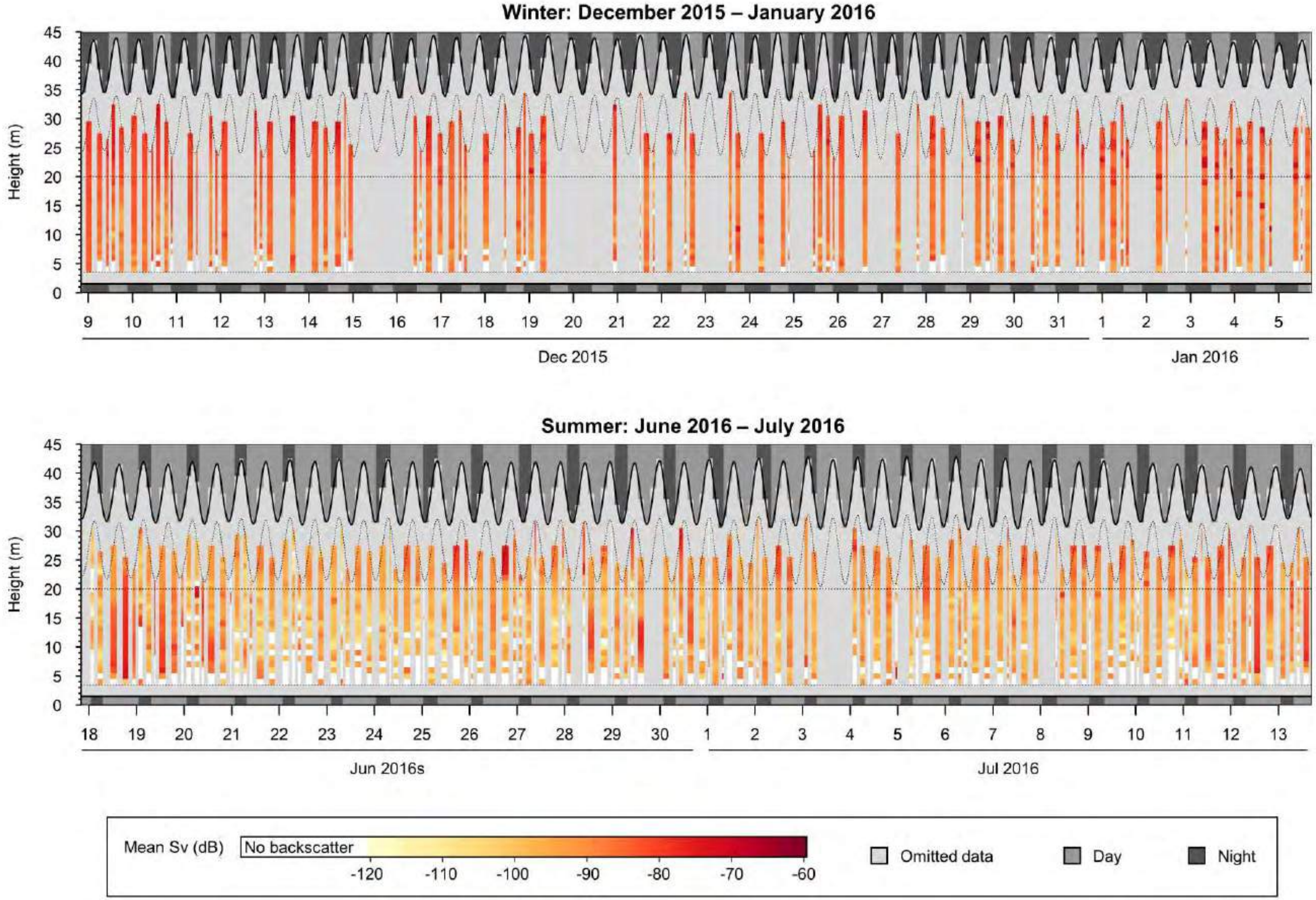

Fig. 5 Mean volume backscatter, S_V (proportional to fish density), from 1-m layers of the water column in each time increment used in analyses of hydroacoustic datasets collected in winter (top) and summer (bottom). Color reflects mean S_V, with white indicating no backscatter and darker, redder colors indicating higher S_V. Data omitted from analyses (because of entrained air or being within periods of slack tide, dawn, or dusk) are in light gray. Day and night are indicated in the background of each image plot, as medium and dark gray, respectively. Height of surface and transducer face indicated by solid black lines. Dotted lines indicate the acoustic nearfield, height of the turbine, and 10-m depth limit. Height is measured upward from the sea floor.

Fish Monitoring to Assess Effects of a Turbine in a Tidal Energy Development Site

Aurélie Daroux[#1], Gayle Zydlewski[#2]

[#]*University of Maine, School of Marine Sciences*
Orono, 04469 ME, USA
[1]aurelie.daroux@gmail.com
[2]gayle.zydlewski@maine.edu

***Abstract* — The effect of tidal in-stream energy conversion (TISEC) devices on fish remains largely unknown and long-term fish monitoring is essential to assess such effects. The goal of this project was to quantify relative fish distribution changes associated with the presence of a deployed TISEC device in Nova Scotia, Canada. Mobile active acoustic surveys (n=6) were performed before (n=3) and after (n=3) the turbine deployment and included a reference site for comparison. Relative fish densities differed in each month of the survey but there was no statistically significant effect of the site (impact or reference) or turbine presence. May and November surveys had the highest density of fish, probably associated with seasonal migrations of certain species. In August and October, fish were more concentrated in the 10 m layer above the seafloor. The proportion of fish at the depth of the turbine, based on data collected adjacent to the turbine varied greatly, ranging from 2 and 51%, depending on the time of year. This survey is preliminary and the site will continue to be monitored to examine longer-term influences of turbine presence.**

Keywords — Fish distribution, survey design, tidal turbine, active hydroacoustics, Bay of Fundy

I. INTRODUCTION

The Bay of Fundy (Canada) has the largest tides in the world. The Fundy Ocean Research Center for Energy (FORCE) has taken advantage of these tides near Minas Passage (Nova Scotia, Canada) and created a facility to allow industry to demonstrate and evaluate tidal in-stream energy conversion (TISEC) technology. The effect of TISEC devices on fish behaviour, density, and distribution remains largely unknown. Tidal sites are an unavoidable ecosystem for passage of migratory fish between fresh and saltwater while also being important nursery and spawning habitats for many marine species (e.g. [6], [16]). This study is part of a monitoring program that aims to understand potential effects and interactions of fish with TISEC devices.

Our study objectives are threefold, all testing indirect effects of a turbine on fish distribution. We examined: (i) total water column relative fish density by comparing survey month and sites, (ii) vertical distribution in the water column, comparing the distribution between sites for each survey month and (iii) proportion of fish at the depth of the turbine.

II. MATERIALS AND METHODS

In 2016 and 2017, during the lowest neap tides, six 24h mobile surveys were conducted using downlooking hydroacoustics with a SIMRAD EK80 echosounder. The transducer was operated at 120 KHz discrete frequency (CW mode) and settings were: pulse duration of 1.024ms, power of 250W and ping interval of 250ms. The EK80 was calibrated before each survey following the methods from [4].

Data were collected during two flood tides and two ebb tides, during day and night (e.g. [16]). Each survey was comprised of nine parallel transects 1.8 km long and 100 meters apart: (1) six transects in the crown lease area (CLA where several turbines will ultimately be installed), and (2) three transects in the reference site, which was on the opposite side of the passage channel (Fig. 1). Each transect was made twice in a row, once with and once against the tide. The vessel speed was maintained between 5 and 8 knots, depending on the tidal stage and the direction of the boat.

Fig. 1 Mobile survey design. The green square represents the CLA. White lines show one complete grid, with transects at the CLA (6 transects) and reference (3 transects) sites connected by cross-channel transects. The turbine is located at berth D.

Six surveys were conducted: May, August, October 2016 (before the turbine deployment, which occurred on the 6th of November 2016), November 2016, January and March 2017 (after the turbine deployment).The turbine, located at berth D in the CLA, was operational and connected to the electric grid during the three post-deployment surveys (Figure 2).

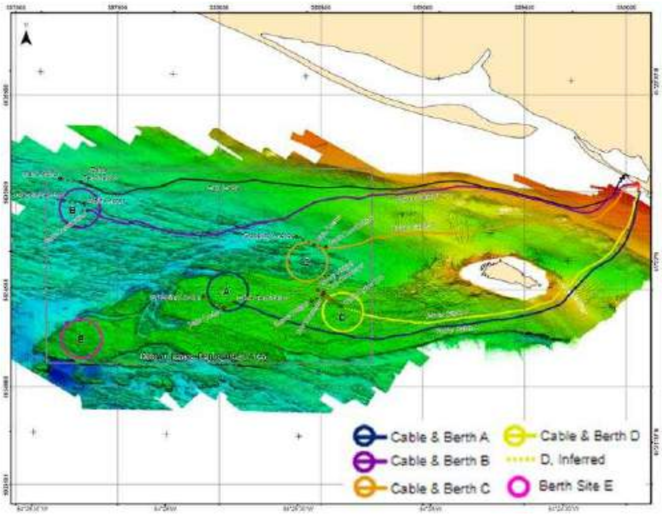

Fig. 2 Survey site CLA turbine deployment map (source: Environmental Effects Monitoring Program Fundy Ocean Research Center for Energy - March 2016)

The turbulence-generated backscatter in the data caused by entrained air affected most of the top 10 meters (and frequently deeper) of the water column most of the time. This entrained air obscured biological targets and had to be removed from the dataset (e.g [16]).

Data processing was performed with Myriax Echoview processing software (v7.1). Using Echoview algorithms, the bottom (seafloor) was detected as well as the entrained air using a reverse bottom detection technique (Fig. 3). Then, the bottom and entrained air lines were manually corrected to ensure algorithm reliability.

Data between the entrained air and bottom lines were echo-integrated as in [5]. We applied a target strength, TS (Table I) threshold of -60dB (to only detect fish, e.g. [7]) to the data and a volume backscattering strength, S_v threshold of -66dB.

Fish relative densities (S_v, s_v and s_a as in [9], see Table I) were exported at two different scales: (1) the entire water column for 20 meters distance bins over each transect; and (2) by 1 meter vertical layer bins above the bottom, again for each transect.

A. Relative Fish Density

To test for indirect effects of TISEC devices on water column relative fish density, we used the data exported for 20 m distance bins. The data distribution was not normal, with 56% being zeros. To test the effect of site (CLA or reference) and turbine (presence or absence) a two-stage GLM (zero-inflated) was performed on s_v using R software (v1.0.136) and the following equations:

$$1^{st}\ stage = GLM\ (s_v \sim fish\ presence)$$

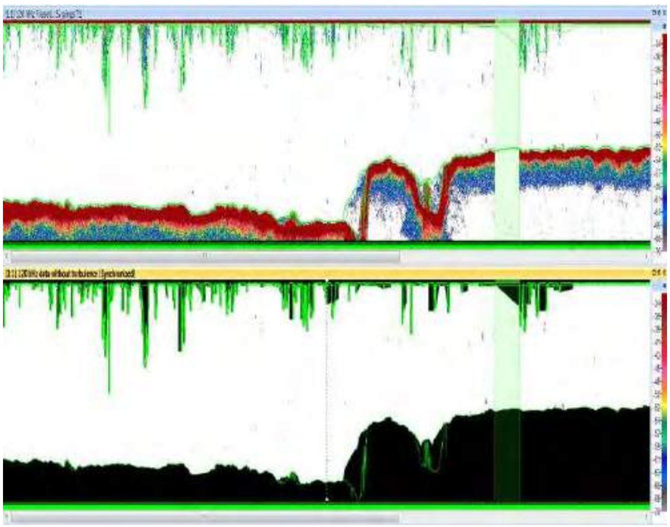

Fig. 3 Snapshot of an echogram from the August survey, first ebb tide, transect N1 against the tide (raw data, top and data corrected without turbulence, bottom) where the reverse bottom detection processing method has been performed. The analysed portion of the echogram corresponds to the white part of the echogram between the two black sections in the bottom echogram shown

The first stage calculated the regression as a function of fish presence.

$$2^{nd}\ stage\ A = GLM\ (s_v \sim 1^{st}\ stage + site + turbine)$$

We applied the prediction of the first stage to the second stage model and added the variables of interest (site and turbine).

To also test for a month effect, we performed another two-stage GLM:

$$2^{nd}\ stage\ B = GLM\ (s_v \sim 1^{st}\ stage + site + month)$$

B. Fish Vertical Distributions

To test for indirect effects of TISEC devices on fish relative vertical distribution, we worked with the data exported by 1 meter depth bins by transect and calculated s_a proportion by layer (s_a by layers divided by the s_a sum for all

TABLE I: DEFINITIONS OF FREQUENTLY USED TERMS (e.g. [10])

Area backscatter (s_a in m2•m-2): area backscattering coefficient integrated over depth, scaled to 1 m2. s_a from different depth layers are used to estimate the **vertical distribution** of fish	
Bin: analysis cell used for echo integration, with horizontal units in distance or time and vertical (depth) units in distance	
Grid: The series of transects carried out at the CLA and reference sites over the course of one tidal stage (e.g., ebb or flood)	
Site: A physical location where data are collected. The CLA site was on the north side of the passage, and the reference site was on the south side of the passage	
Target strength (TS): The ratio of the intensity of the reflected wave by a target at a distance of 1 yard to the incident sound wave (in decibels).	
Volume backscatter, S_v, and s_v: Volume backscattering strength (S_v in dB) and volume backscattering coefficient (s_v in m2•m-3) are the summation of the acoustic energy reflected by all targets within a sampling volume, scaled to 1 m3. In this paper, volume backscatter is used as S_v (dB value) and s_v (linear value) in plots and as **relative fish density** in the main text	

layers for each transect). Transect depths were different and varied with the tide stage (from 40 to 65 m). As such, we analyzed only the first 50 meters above the bottom.

C. Proportion of fish at turbine depth

To examine whether or not fish used the same depth layers of the turbine, we used data from the two transects adjacent to the turbine location. We only used data from when the tide was flooding (n=2 for each survey). The turbine was located on the east side of the CLA, so during flood tide, the vessel was approaching the turbine. Transect data were echo integrated in three 700 m distance bins (the length of the transect divided by 3), numbered 1 to 3 (1 farthest from the turbine and 3, closest). This allowed us to examine changes in fish density as the boat approached the location of the turbine. Only two transects were conducted directly over the turbine (called over the turbine transect) when the tide was flooding during the November 2016 survey. This over-the-turbine transect was not run again during other surveys because it delayed the timing to complete the surveys planned to quantify indirect mid-field effects.

The proportion of fish in the bottom 23 meters (turbine height) above the sea floor was calculated for each distance bin in each survey's flood tide, turbine-adjacent transects.

III. PRIMARY RESULTS

Data were successfully collected for 24 hours in each survey month (May, August, October, and November in 2016, January and March in 2017). Entrained air was removed and data were exported by transect and survey.

A. Relative Fish Density

Relative fish densities varied significantly with the presence of fish and month of data collection (Table II).

TABLE II: RESULTS OF THE TWO-STAGE GLM A (FISH PRESENCE, SITE AND TURBINE) AND GLM B ((FISH PRESENCE, SITE AND MONTH)

	Df	**Dev**	**Resid. Df**	**Resid. Dev**	**Pr (>Chi)**
Null model (A)			39701	1.81E-07	
Fish presence (A)	1	2.31E-11	39700	1.80E-07	0.024 *
Site (A)	1	3.74E-12	39699	1.80E-07	0.36
Turbine (A)	1	1.29E-11	39698	1.80E-07	0.09
Null model (B)			39701	1.81E-07	
Fish presence (B)	1	2.31E-11	39700	1.81E-07	0.024 *
Month (B)	5	5.39E-11	39695	1.80E-07	0.037*
Site (B)	1	3.20E-12	39694	1.80E-07	0.401

The highest relative fish densities were in May (before the turbine deployment) and November (after the turbine deployment; Fig. 4). Difference in relative fish densities between the CLA and reference sites varied among surveys, with a similar trend of higher relative fish density in the CLA than in the reference site (Fig. 5). The turbine factor was not significant (Table II), which is consistent with the trend of relative fish density in the CLA and reference site before and after turbine deployment.

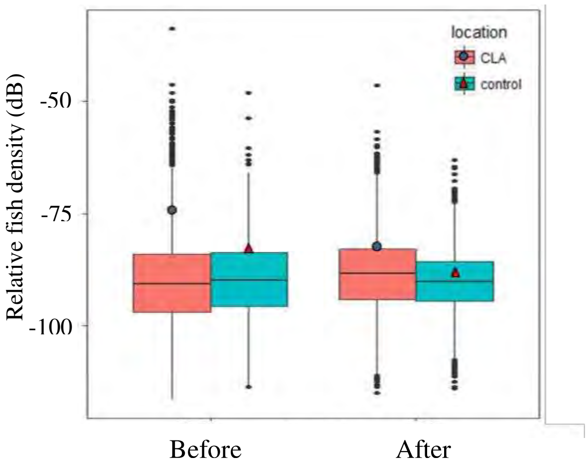

Fig. 4 Boxplot of the relative fish density (S_v in dB) for each survey (May, August, October before turbine deployment; November, January and March (after turbine deployment) and by site (CLA and reference). The blue circle (for CLA) and red triangle (for reference site) represent the mean S_v (calculated via mean s_v)

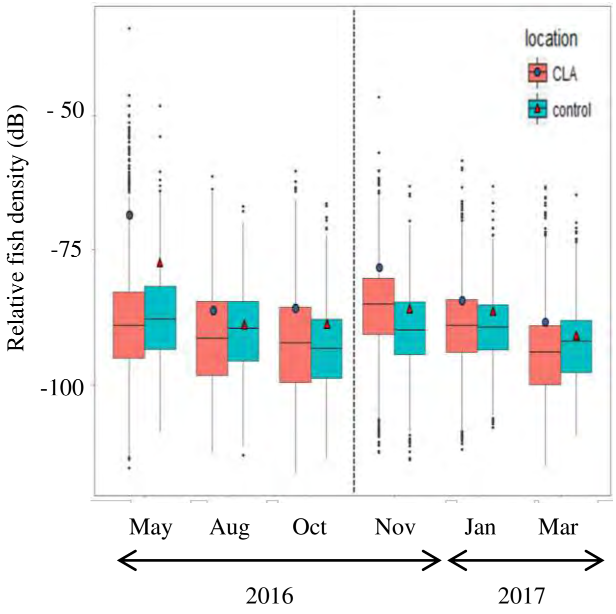

Fig. 5 Boxplot of the relative fish density (S_v) before and after the turbine deployment and by site (CLA and reference). The blue circle (for CLA) and red triangle (for reference site) represent the mean S_v (calculated via mean s_v). The dotted vertical line represents the relative turbine deployment time

B. Vertical Distributions:

Fish vertical distributions differed from month to month with the distributions being variable. Vertical distributions in August and October were mainly concentrated in the first 10 meters above the bottom (Fig. 6 and 7). Proportions by layers in the CLA were smaller than those in the reference site (Fig.

6 and 7), because of the influence of more variable outliers (data values that differed greatly from the majority of the dataset, in this case large fish or aggregations of fish) in the CLA. Variability may be related to more data collected in the CLA (six transects) than in the reference site (three transects).

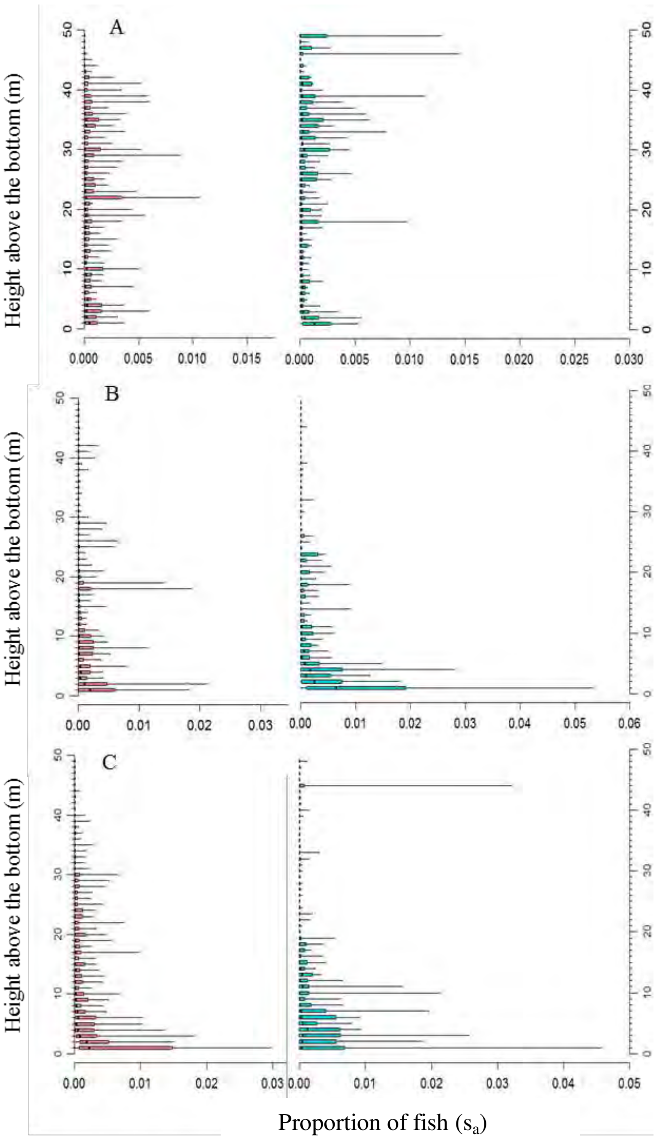

Fig. 6 Boxplot of proportion of the relative fish density (s_a) by 1meter depth layer for May (A), August (B) and November (C) 2016 before the turbine deployment and by site (CLA in red, left and reference in blue, right). The proportion of s_a (x axis) is very small reflecting the high variability and the fact that outliers (big fish or fish aggregations which can represent a high percentage of the total fish density) have not been plotted to be able to see trends in vertical distributions

C. Proportion of fish at turbine depth

The proportion of fish at the depth of the turbine in the spatial bin associated with the turbine (distance bin 3, at a location adjacent to the turbine) was overall lower than the proportion of fish at the same spatial bins (distance bins 1 and 2, away from the turbine location, Figure 8).

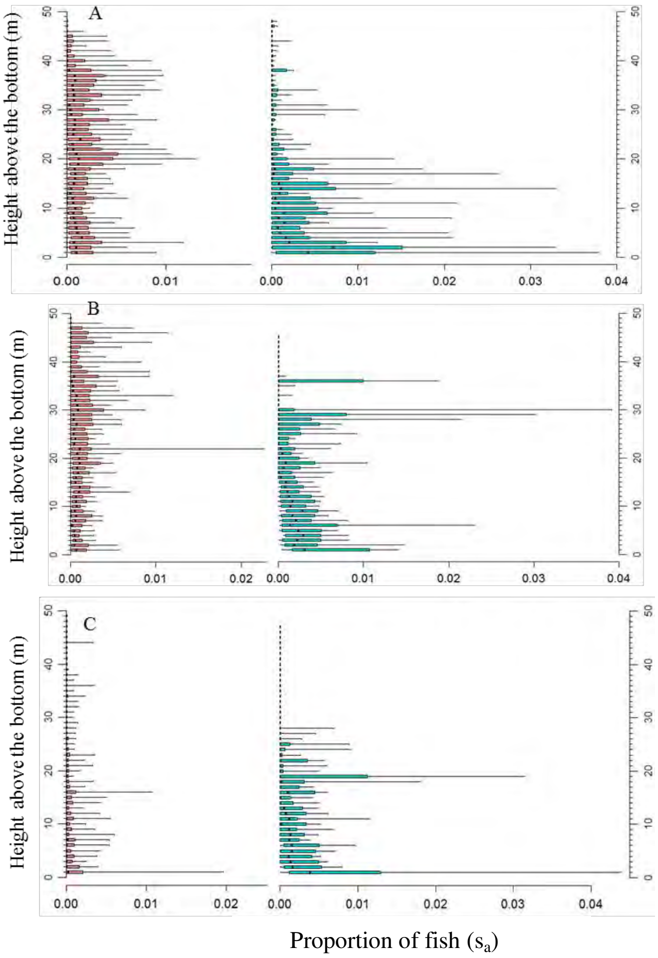

Fig. 7 Boxplot of proportion of the relative fish density (s_a) by 1m depth layer for November 2016 (A), January (B) and March (C) 2017 after the turbine deployment and by site (CLA in red, left and reference in blue, right). The proportion of s_a (x axis) is very small reflecting the high variability and the fact that outliers (big fish or fish aggregations which can represent a high percentage of the total fish density) have not been plotted to be able to see trends in vertical distributions

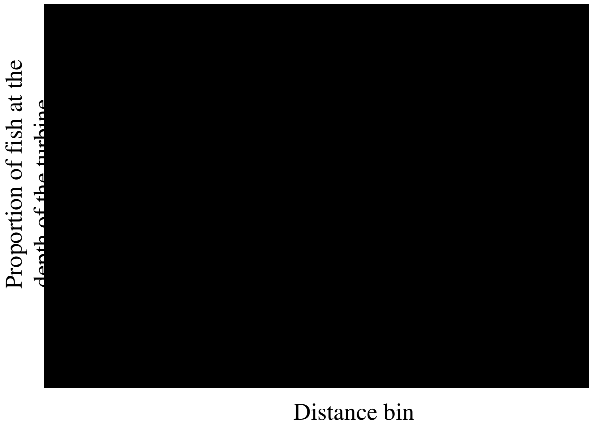

Figure 8: Boxplot of percent of backscatter (relative fish density, s_v) at the depth of the turbine by distance bin. This plot includes data from the two transects adjacent to the turbine for the six analysed surveys.

The proportion of fish at the depth of the turbine in the distance bin nearest the turbine varied among surveys, with a minimum of 1.77 % in August 2016 and a maximum of 51.35% in November 2016 (Figure 9).

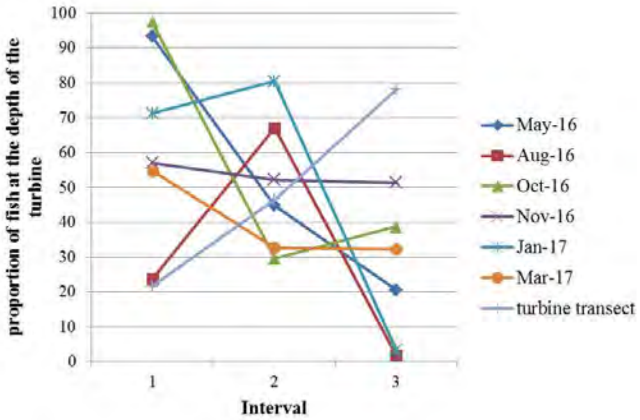

Figure 9: Percent of backscatter (relative fish density, s_v) at the depth of the turbine by distance bin and survey. This plot includes data from the two transects adjacent to the turbine for all surveys and for the turbine transect in November 2016

The proportion of fish at the depth of the turbine during the actual transect over the turbine was drastically different from the proportions observed in the adjacent transects (Figure 9, turbine transect).

IV. DISCUSSION

According to the GLM, there was no significant effect of the turbine on fish densities in this area during the few months of monitoring post-deployment. The pattern of water column integrated relative fish densities was consistent between the CLA and reference site for all six surveys. This suggests that, after the turbine deployment, fish relative densities did not change compared to surveys conducted prior to deployment. Nevertheless, there was high variability likely related to seasonal differences, which might be better discerned if sampling were to occur over multiple years in similar seasons. As such, continued monitoring is essential to assess the effect of the turbine on fish distributions.

This study is preliminary and the monitoring will continue in 2017. In addition, another baseline acoustic dataset (e.g. [12]) collected in 2011 and 2012 has been reprocessed for comparability to the 2016 data collection. These comparisons will complete our pre-turbine deployment dataset and confirm the GLM results reported here, a significant effect of month but no effect of site or turbine deployment

The effect of the month of the survey was significant, reflecting seasonal variation in fish density. The highest relative fish density in May was predictable and may be associated with alewife spring spawning migrations and the presence of Atlantic herring (e.g. [2]). High densities in November could be related to emigration of juvenile alewife. By late fall, young of the year river herring (alewives) and Atlantic herring are the only abundant clupeid species remaining along the northern coast (e.g. [1]). After that period, they move to deeper, warmer depths though the winter (e.g. [15]), and return to coastal nurseries in the spring.

Vertical distributions of fish were significantly different in the CLA and the reference site, preventing us from highlighting any similar or different patterns before and after turbine deployment. Nevertheless, in August and November, the fish were more concentrated in the first 10 meters above the bottom. These could be benthic-oriented fishes. For example, this region is known for the presence of Atlantic sturgeon, which has been shown to be bottom-dwellers as well as water column swimmers (e.g. [11], [13], [3]).

Fish presence at the turbine depth varied greatly. Considering the differences observed between the adjacent transects and the one conducted directly over the turbine, the best way to assess changes in fish distribution, linked to near-field interaction (within 100 m of a turbine.), would be to conduct additional transects over the turbine as in [14].

To fully examine the effects the deployed turbine may have on fish, more data must be collected to compare complementary months of data collection before and after turbine deployment. This will enable separation of seasonal effects from the potential turbine effects. Others have found significant shifts in seasonal fish presence in tidal sites [e.g., 16] that should be considered when monitoring variation in fish densities in these ecosystems. The surveys reported here always occurred at the lowest neap tide in order to maintain comparability among surveys and due to the site's strong tidal constraints. As such, we did not collect data during spring tides, which may present different patterns of fish presence and distribution.

Monitoring for several years post-deployment is then advised since, without long-term monitoring programs, population evaluations may incorrectly indicate adverse effects where none exist or no effect where one is likely to occur (e.g. [8]). Population density variation can be high and many environmental parameters can have an effect on this variation. Long-term monitoring studies are essential to determine if TISEC devices effect fish populations.

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Appendix 6: Integrated Hydroacoustics Project Description

Integrating Hydroacoustic Approaches to Predict Fish Interactions With In-Stream Tidal Turbines

A key challenge facing the global marine renewable energy sector is the ability to effectively answer the critical question of the safety of in-steam tidal energy turbines. To-date, traditional sampling technologies have limited application in high-flow environments; novel approaches are required to provide the environmental data necessary to achieve public, regulatory, and industry confidence. This project is designed to build this confidence, delivering a better understanding of the potential for fish interaction with in-stream tidal energy turbines. Specifically, this program will:

- Support data collection and analysis from multiple hydroacoustic surveys at the FORCE test site;
- Evaluate the scientific and operational utility of individual and integrated hydroacoustic survey methods; and
- Develop a program for skills development in Nova Scotia.

FORCE and its partners are collecting data on fish use of the Minas Passage in two ways: downward-looking, mobile and upward-looking, stationary hydroacoustic surveys. The first method provides spatial coverage but only spans 24 hours at a time. Conversely, the upward-looking approach lacks spatial coverage but spans long periods of time through month-long deployments of a bottom-mounted platform. Combining these complementary approaches will provide a more complete understanding of fish use of the site, and therefore allow better predictions of potential fish/turbine interaction. This dual approach has yet to be implemented in environmental monitoring at other tidal energy sites.

This project will help to increase public and regulatory confidence regarding the potential impacts of tidal energy turbines. Supporting integrated methods of data collection and analysis will fill critical information gaps and support the creation of best practices for environmental monitoring. Further, the project will provide benefits to Nova Scotia by developing local capacity for environmental monitoring and innovation.

Press release from the OERA: http://www.oera.ca/press-release-research-investments-in-nova-scotia-in-stream-tidal-technology-research/