Environmental Effects Monitoring Program

Quarterly Report: July 1st – September 30th, 2017

October 1st, 2017

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 an interim progress report on mid-field monitoring work at the FORCE site that has taken place up to October 1st, 2017. The 2016-2017 EEM program has completed approximately 216 hours of fish surveys, >1,000 'C-POD days' as part of FORCE's marine mammal monitoring,[1] 22 seabird surveys, bi-weekly beach surveys, and four marine noise surveys. Monitoring activity continued in Q3 2017 (July 1st – September 30th, 2017) in the absence of a deployed in-stream tidal turbine; monitoring is scheduled to continue through the calendar year. Year 1 reports on fish, marine mammals, and seabirds have undergone review by FORCE's environmental monitoring advisory committee (EMAC)[2] over the last quarter.

The document contains operational summaries from third-party researchers; however, conclusions and analysis will require longer-term data sets.

Fish monitoring: In May 2016, FORCE contracted the University of Maine to initiate 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

[1] 'C-POD days' refers to the number of days total each C-POD was deployed and collecting data since May 2016,
[2] EMAC membership is included in Appendix 6; additional information is available online at: www.fundyforce.ca/about/advisory-committees.

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 and August 2017. Data processing and analysis are led by the University of Maine. Interim reporting indicates "Monitoring of the region should continue in order to assess changes in fish distribution patterns over time".

In addition to the hydroacoustic surveys, FORCE has deployed five fish tag receivers from the Ocean Tracking Network throughout its test site.

Marine mammal monitoring: FORCE contracted the Sea Mammal Research Unit Consulting (Canada) ('SMRU Consulting') to complete equipment calibration and data analysis relating to the deployment of passive acoustic monitors ('C-PODs') in support of its marine mammal monitoring program. The goal of this program is to detect changes in the distribution of the marine mammals (predominately harbour porpoise at the FORCE site) in relation to operational in-stream turbines.

Three C-PODs and related equipment were deployed in June 2016 and recovered in August 2016. In September 2016, FORCE deployed five C-PODs to ensure data collection during/after installation of Cape Sharp Tidal Venture's first turbine. These were recovered in early 2017, re-deployed in February. In June 2017, four of the five C-PODs were successfully recovered and redeployed for summer monitoring and to ensure an near-continuous period of data collection. These four C-PODs were recovered and redeployed, along with a new fifth C-POD, in September 2017.

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. Nine shore-based surveys were completed by Envirosphere Consultants in 2016, two of which were completed after the Cape Sharp Tidal Venture turbine was installed. This work has continued in 2017 with 10 surveys completed thus far.

Marine noise monitoring: FORCE contracted Luna Ocean Consulting in 2016 to complete a study providing recommendations to FORCE regarding how to implement a marine noise monitoring program; Luna Ocean recommended using a passive acoustic program. The goal of this program is to measure both ambient (in the immediate surroundings) noise and noise generated by in-stream turbines for prediction of the potential effects of this noise on marine life.

In summer 2016, FORCE rented drifting hydrophones from JASCO Applied Sciences and Ocean Sonics to collect ambient noise measurements at and near its test site. This work consisted of an August trial and two-days of data collection in October. This work provided valuable acoustic data, as well as experience in different drifter configuration, deployment, and recovery. Drifter data was again collected in March 2017 during turbine operations. Data analysis has been completed by JASCO and Ocean Sonics, and FORCE is currently undergoing a review of these reports and recommended next steps.

Lobster monitoring: FORCE contracted NEXUS Coastal Resource Management to conduct a lobster catchability study in support of its lobster monitoring program. The goal of this study is to measure whether the presence of a turbine affects the number of lobster entering traps. Commercial lobster traps are used to compare catch volumes in different proximity to the turbine location. The planning for this work is underway; the first survey in this study is expected to occur in 2017.

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: FORCE's environmental effects program continues to evolve based on operational experience and input. This includes:

- a greater understanding of the impacts of biofouling on equipment, equipment calibration and set-up, efficiency in data collection efforts, data processing techniques and in general marine operations;
- growing skills development, including two graduates from Nova Scotia Community College's Oceans Technology program now working at FORCE;
- growing experience planning simultaneous operations during periods of extensive marine operational activity;
- identifying the limitations of planning for scientific operations during limited tidal and weather conditions;
- an adjustment in the timing of the lobster monitoring program in response to advice received from local lobster fishers and in consideration of other operations; and
- identifying methodologies that limit risk regarding instrument recovery.

Moving Forward: FORCE will continue to publish interim reports to summarize ongoing monitoring operations at the site. These interim reports, presented on a quarterly basis, support longer-term analysis by academic and research partners as more data is collected through seasonal and annual cycles. The final report for 2017 will be an annual report, submitted on December 31st, 2017.

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

Contents

Appendices

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 had 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.

In March 2016, the Offshore Energy Research Association (OERA) announced its and the Province of Nova Scotia's, funding support FORCE's fish and marine mammal EEMPs for 2016 and into 2017 at a cost of $250,000.

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,

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

and other environmental variables. All reports are available online at: www.fundyforce.ca/environment.

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. 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 of environmental parameters 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.

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 specifically at post-deployment effects monitoring.

---

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

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 and observed marine mammals 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

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

Summary of Monitoring Activities

FORCE's latest monitoring program, which focuses on lobster, fish, marine mammals, seabirds, and marine noise, was initiated in 2016 and has continued into 2017. 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 first quarter of 2017 (Q1: January 1st – March 31st), FORCE disconnected onshore power cables for safety and technical reasons during a planned upgrade to electrical equipment at the FORCE substation. 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, are available on its website: www.capesharptidal.com.

The following sections provide a summary of the monitoring activities conducted at the FORCE site up to and including the third quarter (Q3) of 2017.

Lobster

2016 Lobster Program

FORCE contracted NEXUS Coastal Resource Management Ltd. (Halifax, NS) to conduct its lobster monitoring program. NEXUS has previous experience in fisheries and marine resource management as well as environmental monitoring of lobster in Atlantic Canada. This program will consist of catchability surveys of commercial lobster traps deployed in locations within two rings around the deployed CSTV turbine (see Figure 1). Lobsters will be caught, carapace length and other physical features will be recorded by technicians, and released.

Due to the design of this program, given its experimental/control 'rings' that compares catch rates closer and farther from a turbine, the survey was required to be delayed until after turbine installation. In 2016, FORCE did conduct initial program planning and gear acquisition.

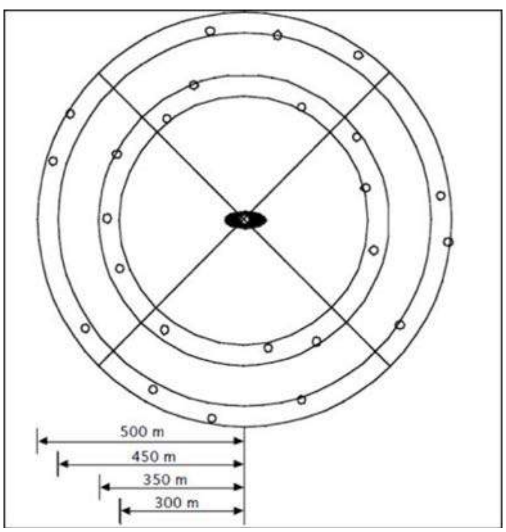


Figure 1: Double-ringed survey design proposed by Bayley (2010), with the dark centre representing the turbine and smaller circles representing lobster traps to be deployed (approximate distances shown) for the lobster monitoring program.

2017 Q1 Lobster Program

In January, FORCE and NEXUS Coastal Resource Management met with local lobster fishers to discuss the lobster catchability study. In this meeting, the 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 that is the peak time for lobster movement in the area. This input was incorporated into the program and FORCE and NEXUS will continue to engage this group and report back on progress throughout the study period.

NEXUS is in the process of defining its operational safety plan for the study and finalizing details such as bait acquisition.

2017 Q2 Lobster Program

The first lobster catchability study under the 2016 FORCE EEMP was expected to be completed in spring 2017; however, the study work was delayed due to turbine recovery operations (see 'Other Activities & Lessons Learned' below). In order to proceed with safe data collection, this work could not begin until after the recovery of the CSTV turbine.

2017 Q3 Lobster Program

With no turbine currently on-site, the study's design objective is currently delayed. However, FORCE anticipates NEXUS will conduct one study in the absence of a deployed turbine. Additional preparations, as well as optimal timing for a catchability study, have moved the schedule of the survey towards later in 2017.

Future surveys will be conducted when in-stream tidal turbine(s) are deployed at the FORCE demonstration site.

Fish

2016 Fish Program

FORCE contracted the University of Maine (Orono, Maine) to conduct its fish monitoring program. Internationally, the University of Maine is recognized as a leader in the use of hydro-acoustics for fish monitoring purposes. The University is the only non-governmental group in North America with experience conducting similar monitoring programs, its in-stream tidal energy hydro-acoustic fish monitoring project of Ocean Renewable Power Corporation's turbine in Cobscook Bay, Maine.[5]

The goal of this program is to describe and quantify fish distributional changes that reflect behavioural responses to the presence of a deployed in-stream tidal energy turbine. The program uses a downward-facing hydro-acoustic echosounder (sonar) mounted onto a vessel,[6] which traverses transects across the FORCE site while collecting data on fish density and vertical distribution.

[5] 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).

[6] 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.

Four 24-hour surveys were completed in 2016 (May, August, October, November) and were conducted by FORCE and University of Maine staff. During the November survey (the first post-deployment survey), additional efforts were made to ensure data was collected above the Cape Sharp Tidal turbine.

The final component to this program has been the transfer of knowledge to Nova Scotians, where University of Maine staff have trained FORCE staff to conduct the data collection.

2017 Q1 Fish Program

A second post-deployment hydro-acoustic survey in support of FORCE's fish EEMP was conducted from January 20th – 22nd, and a third survey was conducted March 21st – 23rd. Both surveys 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. Data collection efforts were led by the University of Maine and FORCE staff.

To enhance its fish monitoring program and to expand its data collection capacity, in partnership with the Ocean Tracking Network (OTN)[7], FORCE staff attached one VEMCO fish tag receiver (a VR2 receiver) to each C-POD mooring (see 'Marine Mammal Program' below). 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

2017 Q2 Fish Program

Additional data was collected by the FORCE team during the early neap tide in May 2017. Data will continue to be analyzed by the University of Maine. Note: due to weather conditions, and managing simultaneous operations, a planned fish survey for the second neap tide in June 2017 did not occur.

2017 Q3 Fish Program

FORCE completed two fish surveys during Q3 – early July and late August 2017. Data analysis of these surveys, along with the survey completed in May 2017, is currently underway by the University of Maine. A Year One report completed by the University of Maine for the surveys completed in 2016 and Q1 2017, which compares data collected at the FORCE demonstration site as well as a control site on the other side of the Minas Passage to data previously collected through FORCE's monitoring programs (Melvin and Cochrane, 2014)[8], has undergone EMAC review and is now being finalized by the University of Maine. This report will be made public upon its completion.

Additional surveys for 2017 are planned for the fall migration period to enable year-to-year comparisons.

---

[7] Ocean Tracking Network's website: www.oceantrackingnetwork.org.
[8] Melving and Cochrane, 2014. Available online at: www.oera.ca/wp-content/uploads/2014/12/Final_Report_03Dec2014_Melvin_and_Cochrane.pdf.

Marine Mammals

2016 Marine Mammals Program

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. SMRU completed initial equipment calibration (while providing training to FORCE ocean technologists) and data analysis on the data retrieved by FORCE relating to the deployed (and recovered) passive acoustic monitoring (PAM) mammal detectors known as 'C-PODs' (as well as supporting equipment such as streamlined underwater buoyancy systems known as 'SUBS', acoustic releases, and anchors).[9] 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.

Figure 2: FORCE ocean technologist and crew of the Nova Endeavor (of Huntley's Sub-Aqua Construction from Kentville, Nova Scotia) prepare to deploy C-PODs as part of FORCE's marine mammal monitoring program.

For the second deployment in 2016, in response to regulators, FORCE deployed five C-PODs, which were recovered in early 2017. The timing of that deployment was planned to ensure data collection during/after installation of the CSTV turbine.

[9] 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.

FORCE had also added to the scope of work for the visual seabird surveys to also note any observed marine mammals.

In addition, FORCE began a beach walks and associated observation program for marine mammals. No mammals were observed as part of this program in 2016.

2017 Q1 Marine Mammals Program

The five C-PODs deployed in September 2016 were recovered on January 18th, 2017. Following the January recovery, the C-PODs were cleaned and prepared for redeployment by FORCE ocean technologists. The C-PODs were redeployed February 23rd.

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

In addition, FORCE continued to conduct its observation program while conducting beach walks along areas of the Cumberland shore closest to the FORCE site and beyond, and is developing a system for the public to record any observed marine mammals.[10]

During their shore-based observation program, Envirosphere Consultants reported: "Individual harbour porpoises were observed during the November 17th, 2016 and January 16th, 2017 surveys. As well, a harbour seal was observed resting on Black Rock during the January 16th, 2017 survey". These observations are shared with SMRU to support validation efforts of subsea-based C-POD marine mammal monitoring program.

2017 Q2 Marine Mammals Program

FORCE has contracted SMRU Consulting (Canada) to complete the data analysis for all C-POD deployments in 2017, beginning with 5 C-PODs deployed in February 2017.

Prior to scheduled recovery, one C-POD was discovered by a fisher in Diligent River on May 16th, 2017. The C-POD and SUBS package (which houses the instrument) was returned to FORCE shortly after.[11] Upon inspection, FORCE staff found that the chain links connecting the instrumentation to the anchor had considerable abrasion, which caused the package to surface prematurely.

During recovery on June 1st, 2017, FORCE had difficulty with the recovery of two of the four remaining C-PODs. Though FORCE ocean technologists were able to communicate with the acoustic releases, and were able to confirm the acoustic releases were activated, two of the four still deployed C-PODs were not found. Additional search efforts were made but were not successful.

The two recovered C-PODs, along with the one recovered in Diligent River, were redeployed on June 2nd, 2017 to ensure minimal gaps in the dataset. After consultation with SMRU, it was decided that a quicker redeployment of instruments was preferred over a staggered approach—this allows the same C-PODs to be redeployed in the same location, minimizing variability among data sets. However, only two of these three C-PODs were re-deployed at their original location. The third, which was originally deployed westward of the FORCE test site, was re-

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

[11] The C-PODs are housed in a large, yellow, and buoyant SUBS package (which have FORCE's contact information on them) that have a high return rate.

deployed nearer the Cape Sharp Tidal Venture turbine to ensure a continued dataset in proximity to the turbine.

Figure 3: C-POD deployment from Nova Endeavor (retrieved Q2 2017).

One of the two 'lost' C-PODs was recovered on June 20th, 2017 after it was found by a fisher in Advocate Harbour. Upon inspection, the SUBS package suffered damage (see Figure 4) and the fish tag receiver supplied by the OTN was lost. FORCE was, however, able to redeploy the C-POD using one of its spare SUBS package on June 22nd, 2017 while the original SUBS package (pictured below) underwent repairs.

Figure 4: A SUBS package, which housed a C-POD and fish tag receiver, recovered in Diligent River lost its rudder.

In addition, FORCE staff and volunteers have completed beach walks at Black Rock Beach, West Bay, Fox River, Fraserville, and Diligent River Harbour as part of its marine mammal monitoring program throughout 2017. Beach walks occur on a bi-weekly basis.

In order to promote community participation in program, FORCE has prepared a poster for distribution online and in communities around the Bay of Fundy (see Appendix 8). In addition, FORCE has developed a web-based app to enable beach walkers to report their walks and findings: mmo.fundyforce.ca. During this reporting period, two observations of an active seal moving near Black Rock Beach were reported via the app—one on the evening of May 4th, the other during the day of turbine recovery, June 15th.

2017 Q3 Marine Mammals Program

In July 2017, FORCE ocean technologists calibrated FORCE's two spare C-PODs at Ocean Sonics tank facility in Great Village, NS. The four deployed C-PODs were recovered on September 14th, 2017. After undergoing repairs, the four C-PODs, along with one of the newly calibrated spares, were deployed on September 26th, 2017. Data is currently with SMRU for analysis.

The Year One marine mammals report prepared by SMRU has been reviewed by EMAC (see Appendix 9). This report provides data analysis associated with two C-POD (i.e., marine mammal detector) deployments:

- May 2016 – August 2016: 3 C-PODs
- September 2016 – January 2017: 5 C-PODs

Shoreline surveys were completed during Q3 with no instances of reported strandings or fatalities. FORCE staff completed a vessel-based marine mammal survey during the recovery of the FAST-3 platform in July 2017. A single Harbour Porpoise was observed during this operation.

Seabirds

2016 Seabirds Program

FORCE contracted Envirosphere Consultants (Windsor, Nova Scotia) to continue with its seabird monitoring program in 2016. Envirosphere has been conducting seabird and marine mammal monitoring at the FORCE site since 2008, contributing to the baseline knowledge at the site. 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 and marine mammals from habitual waters and to identify changes in behaviour.

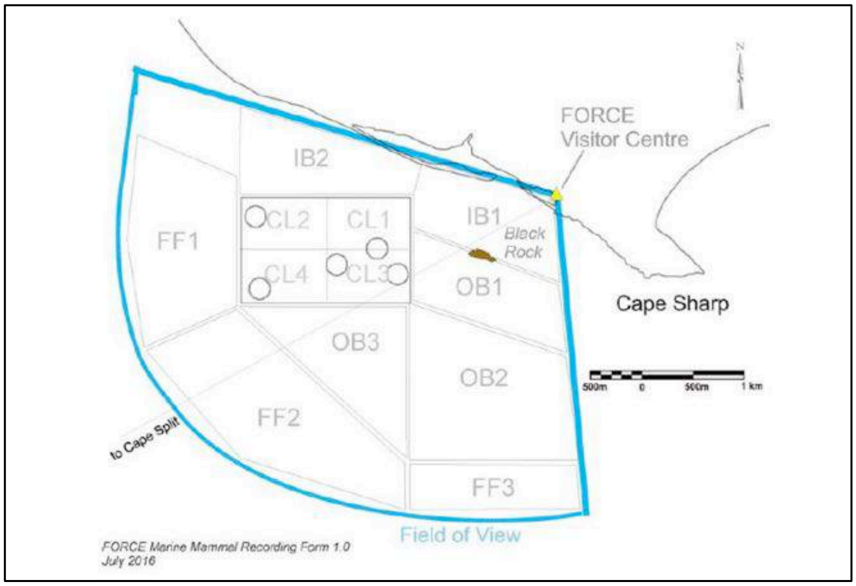


Figure 5: Subdivisions of the FORCE Crown Lease Area for the seabirds monitoring program where 'CL' indicates Crown Lease area; 'IB' indicates Inside Black Rock; 'OB' indicates Outside Black Rock; and 'FF' indicates Far-Field area.

Nine shore-based surveys were completed by Envirosphere Consultants[12] in 2016, two of which were completed after the CSTV turbine was installed. For the first three months of observations (May through July), 10 species were observed (lowest in July, highest in June); the following four months (August through November pre-turbine deployment), 22 species were observed (lowest in August and October, highest in September and November) (see Appendices 3-4). The results from the two surveys conducted post-turbine deployment are reported below in the 2017 seabirds section.

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

[12] These are completed using 8x and 10x binoculars and a spotting spot (22x magnification Bushnell spotting scope) from a position on the FORCE Visitors Centre deck.

2017 Q1 Seabirds Program

Three seabird surveys were completed during 2017 Q1: January 17th, February 21st, and March 13th.

2017 Q2 Seabirds Program

Additional seabird surveys were conducted by Envirosphere Consultants Limited (Windsor, Nova Scotia) in April (two surveys), mid-May, and again in mid-June.

2017 Q3 Seabirds Program

Seabird surveys have continued once a month in July, August, and September.

A final report prepared by Envirosphere Consultants has been reviewed by EMAC and is currently being finalized by Envirosphere.

Marine Noise

2016 Marine Noise Program

In early 2016, FORCE contracted Luna Ocean Consulting (Freeport and Shad Bay, Nova Scotia) to provide recommendations to FORCE regarding the best passive acoustic monitoring (PAM) program moving forward as a way to understand underwater soundscapes before/after turbine operations.

Luna Ocean recommended target areas for data collection (to measure spatial and temporal variation in soundscape around deployment areas), equipment and necessary vessel specifications, and methodology to complete a "drifter" hydroacoustic survey program. Accordingly, in summer 2016, FORCE rented drifting hydrophones[13] from JASCO Applied Sciences (Halifax, Nova Scotia) and Ocean Sonics (Great Village, Nova Scotia) to collect ambient noise measurements at and near its test site with two different drifter configurations. Based on the one day trial in the summer, FORCE then conducted two-days of data collection in October with both drifter configurations. Data analysis will be forthcoming from both JASCO and Ocean Sonics.

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

[13] A 'drifting hydrophone' consists of (at a minimum) a buoy and a hydrophone, which is designed to record marine noise. This configuration allows the instrument to travel in the water while limiting flow-related noise (in comparison to a static instrument).

Figure 7: 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.

2017 Q1 Marine Noise Program

On March 27th, 2017, FORCE completed the first noise data collection post deployment of the CSTV turbine. The purpose of this work is to collect a noise profile using drifting hydrophone systems provided by Ocean Sonics in proximity to the deployed CSTV turbine and to understand the distance that turbine-generated noise can travel. Data analysis is currently underway by Ocean Sonics.

2017 Q2 Marine Noise Program

FORCE staff have been working on defining marine operational methodologies that can reduce risk associated with longer drifts. Longer drifts will provide larger data sets, but pose a risk that drifter system may run ashore or be lost.


Figure 8: Hydrophone deployment where drifters travel 1 – 2 km, collecting sound data in the Minas Passage.

2017 Q3 Marine Noise Program

FORCE staff have received preliminary analysis from Ocean Sonics and Jasco based on the datasets collected in 2016 and Q1 2017. FORCE is currently reviewing the reports and recommendations in order to determine next steps for its acoustics EEMP. This work may include a third-party assessment of the data and recommendations for next steps.

Other Research & Monitoring Activities – Q1

Wetland Monitoring

In addition to EEMP-related activities, FORCE has also undertaken a wetlands monitoring program since 2014 in the wetland where trenching and cable laying took place onshore. This monitoring, completed by Envirosphere Consultants, included periodic walkovers by a biologist and a botany survey in the disturbed area, repeating baseline work done in 2014 and monitoring work completed in 2015. This work consisted of an assessment of plant communities in areas approximately 1m square at locations representing areas in the wetland, and in adjacent areas that were undisturbed by the activity. The survey showed that—as predicted—the wetland is well-vegetated and has largely recovered from the trenching operations associated with the cable installation.

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.

In 2016, FORCE also initiated several operations under its FAST Program. The FAST-1 platform (an autonomous, battery-powered platform that is designed to support short-term site characterization) underwent a pilot deployment in January and was redeployed from June 17th to July 13th near the CSTV berth to obtain pre-installation site data.

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

Figure 9: The FAST-1 platform fixed to the stern of the Dominion Victory.

A second cabled subsea sensor platform, known as 'FAST-2', was deployed for eight months (January to September 2016) between the shore and Black Rock in close proximity to the FORCE site, which provided real-time oceanographic and environment monitoring data to the FORCE Visitors Center and ONC via an undersea cable. FAST-2 operated successfully from January 29th to July 12th, 2016 at which time data transmission ceased and a recovery operation was initiated. Delays to avoid lobster fishing season, and due to coordinating other marine operations and weather/tide windows, saw recovery completed on September 9th, 2016.

In 2017, FAST-2 is undergoing enhancements to significantly advance the ability to provide long-term, real-time, targeted imaging of the interaction between marine mammals, fish, and turbines. Specifically, in partnership with Open Seas Instrumentation Inc., 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.

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).

Imaging sonar 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

[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. The program detected no major environmental impacts.

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.

In February 2017, FORCE deployed 'FAST-3', the third subsea sensor platform built as part of the FAST Program. FAST-3 was deployed between the FORCE beach area and Black Rock near the demonstration site. The platform, which was recovered approximately one month later, was deployed with 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). Results from the deployment are being analyzed by Dr. Haley Viehman, a post-doctoral fellow at Acadia University, [16] and will help to identify the best sensor settings and operating schedule for future data collection at the FORCE demonstration site.

Figure 10: The FAST-3 platform prior to deployment on the deck of the Nova Endeavour

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

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

Data Management

The Offshore Energy Research Association (OERA) released a request for proposals relating to data management, which closed in March 2017. Further updates are below.

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

Lessons Learned – Q1

Fish Surveys

Numerous lessons learned have been realized in the fish monitoring program:

- A component of the University of Maine's tasks in delivering the fish environmental monitoring program was to provide training to FORCE ocean technologists to take over the data collection portion of the program. This training has enabled Nova Scotia to gain more trained and knowledgeable persons in this highly novel and technical field.
- Due to this work, the University of Maine was able to collaborate with Dr. Haley Viehman of Acadia University to enhance their data processing method and remove turbulence and eddy data.
- Additional learnings for the fish monitoring program include improved instrument calibration and more efficient marine operations.

Marine Noise

Due to the rapidly evolving nature of marine noise monitoring techniques, inherent within the marine noise monitoring program is learning. In order to ensure better data collection, FORCE conducted a trial of two different drifting hydrophone systems, which provided experience for vessel crew and FORCE ocean technologists. The objective of this trial was to familiarize themselves with two types of equipment (Jasco and Ocean Sonics drifting hydrophone systems) and operations of safely deploying and recovering the equipment.

Marine Mammals

In addition to SMRU providing training to FORCE ocean technologists regarding how to calibrate C-PODs correctly (in preparation for deployment), FORCE also was able to lengthen its C-POD deployments due to longer than anticipated battery life.

FAST

Historically, many instruments that were deployed in the harsh undersea environment of the Minas Passage were never seen again. The initial purpose of developing the FAST platforms was to enable secure deployment and retrieval of instrumentation in the Minas Passage. Learnings continue with each deployment of the FAST platforms.

Significant lessons were learned in the recovery of the FAST-2 platform in early September 2016. When recovery was first attempted, the pop-up buoy failed to surface after interrogation and prompting of the acoustic release. As a result, the recovery operation required a diver to attach a lifting line from the platform to the recovery vessel. Upon recovery and inspection, the failure of the pop-up buoy was due to the presence of marine fouling and sediment, which became lodged in the release mechanism preventing the release of the shackle holding the pop-up buoy. Analysis is underway to address biofouling prior to the next deployment. FORCE is also working in collaboration with the European Marine Energy Centre on related research, comparing the performance of marine coatings in both tidal tests.

Other Research & Monitoring Activities – Q2

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, with experience in fish detection 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. 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.

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

Data Management

In spring 2017, the OERA awarded SEG Consulting funding to define and describe data management system for use by FORCE. Since that time, SEG, FORCE, and the OERA have examined representative data sets in order to prepare a 'current and future state analysis' and options for a data management system/user interface (DMS). FORCE is currently evaluating these options and will move forward with building the chosen DMS option.

Reports of Fish Injuries

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

Figure 11: A DFO representative examines fish samples at a weir in the Minas Basin.

Envirosphere Consultants personnel continued to monitor incidence of injured fish in fisheries of southern Minas Basin and inflowing rivers for approximately two weeks after the tidal turbine operated by CSTV was removed from the FORCE demonstration site. DFO issued a statement that “presently, there is no evidence linking the injuries to fish found in the Minas Basin to any specific activity.”

Fundy Advanced Sensor Technology Program

On April 20th, 2017, the Offshore Energy Research Association, the Nova Scotia Department of Energy, and Innovacorp awarded $135,000 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 FAST-2 platform to enable directional sensors to collect data from a specific target, including the face of the turbine. FORCE is a project partner to this project as is the Nova Scotia Community College, Acadia University, Dynamic Systems Analysis, and Ocean Moor Technical Services.

Testing will occur at the FORCE Site with a series of progressive tests that will 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.

Figure 12: 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.

FAST-3 was deployed in the FORCE demonstration area on June 23rd, 2017. This was the first full-length deployment in the FORCE demonstration area with the finalized testing arrangement for Dr. Haley Viehman's (Acadia University) study. The platform was deployed for approximately 1.5 months, gathering fish and environmental data

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)

Lessons Learned – Q2

Simultaneous Operations

During this reporting period, CSTV announced that it would be removing its turbine from the FORCE site.[17] After this announcement in April 2017, CSTV undertook significant marine operations at the FORCE site in relation to the cable disconnection and attempted recovery of the turbine. The turbine was successfully recovered from the site on June 15th, 2017 and transported to Saint John, New Brunswick the following day.

This work has required FORCE to manage simultaneous operations—turbine-related communications, operational support and safety, FAST, and EEMP operations. The management of simultaneous operations presented a two-fold issue—extensive marine operational activity has the potential to compromise EEMP data collection, particularly for fish surveys, and has also restricted the availability of the vessels used in EEMP operations.

EEM Program Lessons Learned

Additional lessons were learned over the course of the second quarter of 2017. In particular, it was identified that the methodology of the fish surveys presents a significant challenge with respect to operational planning. For instance, the data collection for the fish EEMP requires specific weather conditions, which can be challenging when operating during a limited tidal window (neap tide). Successfully planning a survey given the tidal window and weather limitations is challenging. This work highlights the value of bottom-mounted monitoring platforms. The FAST platforms are not subject to the limitations that inhibit vessel-based surveys such as visibility, seasonal constraints, weather, tides, and, most essentially, vessel availability.

The latest C-POD deployment and recovery provided two important lessons learned:

- 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). FORCE staff are currently review the mooring design.
- Upon recovery, two other C-PODs were not immediately found. FORCE staff are investigating options that can help with instrument recovery.

With increased marine operations at the site, FORCE has required additional support in data collection and FAST-related operations. In May 2017, FORCE hired an ocean technologist intern to support in these efforts as well as interns based at the visitors/operations center to assist in some monitoring activities, including the public observation/beach walks program.

[17] See announcement: www.capesharptidal.com/commissioning.

Other Research & Monitoring Activities – Q3

FORCE continued to conduct research and monitoring activities during Q3, during which there were no turbines deployed at its test site.

Fundy Advanced Sensor Technology Program

During Q3, the FAST-3 platform was deployed for two periods: June 23rd – July 27th and was redeployed on September 14th (ongoing). Dr. Viehman is continuing to conduct data analysis from the sensors on the platform.

The FAST-2 platform is undergoing continued testing both onshore and through short-term deployments near Black Rock Beach.

Data Management

SEG Consulting completed its contract with scope of work, providing FORCE with two major final deliverables: one document detailing the preferred data management system based on extensive consultation with FORCE personnel and one 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.

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 10.

Lessons Learned – Q3

Marine Operations

Iridium Go!, supplied by MetOcean Telematics, in being used in support of a marine operations to enhance communication capabilities in and around the FORCE test site.

EEM Program Lessons Learned

FORCE has contracted with additional ocean technologists to support with various EEM program activities. In addition, FORCE staff have developed materials to support in knowledge transfer among FORCE staff, contractors, and these additional ocean technologists for the hydroacoustic fish surveys.

In response to the loss of C-PODs during the last quarter, FORCE has been investigating options to reduce equipment loss, including the potential use of beacons.

References

Bayley, P. 2010. *Comments on the Lobster Component of the Fundy Tidal Project*. *Appendix E. In FORCE. 2011. Fundy Tidal Energy Demonstration Project: Environmental Effects Monitoring Report*. 209, 2011.

Melvin, G. D. and N. A. Cochrane. 2014. Investigation of the vertical distribution, movement, and abundance of fish in the vicinity of proposed tidal power energy conversion devices. Final Report for Offshore Energy Research Association, Research Project 300-170-09-12.

ORPC Maine LLC. 2014. Cobscook Bay Tidal Energy Project: 2013 Environmental Monitoring Report. Ocean Renewable Power Company (ORPC), Portland, Maine. Pp. 502.

Shen, H., Zydlewski, G., Viehman, H., and Staines, G. 2015. Estimating the probability of fish encountering a marine hydrokinetic device. Proceedings of the 3rd Marine Energy Technology Symposium (METS), April 27–29, 2015, Washington, D.C.

Viehman, H., and Zydlewski, G.B. 2015. Fish interaction with a commercial-scale tidal energy device in the natural environment. Estuaries and Coasts 38(S1):241 252.

Appendix 1: Fish Environmental Effects Monitoring Plan Interim Report

Interim report summarizing analyses from fish surveys completed in May, August, October, and November 2016. Prepared by the University of Maine.

Report to FORCE
4th Fish Survey by UMaine
24-25 November 2016

Prepared by: Aurélie Daroux and Gayle Zydlewski, University of Maine, School of Marine Sciences

This report includes a complete description of the fourth fish monitoring survey in November 2016 (data handling, processing an analysis) as well as new data processing and analyses from the last three surveys (in May, Aug, Oct). This report supersedes the previous three survey reports in regard to **data processing and analyses**.

Overall relative fish densities were significantly different among months. Within each month, we found spatial variability in relative fish density. Spatial variability was related to differences among transect locations and co-varied with tide and day-night conditions. Results to date indicate that mean relative fish densities were significantly higher in the Crown Lease Area (CLA) than in the adjacent control area, *this pattern did not change even after turbine deployment*. However, monitoring of the region should continue in order to assess changes in fish distribution patterns over time.

Introduction

The Bay of Fundy has the largest tides in the world. The Fundy Ocean Research Center for Energy (FORCE) has taken advantage of these tides near Minas Passage and created a facility 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 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). This fourth survey occurred after one TISEC device was deployed at berth D.

The goal of this project is to quantify fish behavior changes, measured as spatial distribution, associated with the presence of deployed TISEC devices in the FORCE CLA. Specific objectives include: (1) testing for indirect effects of TISEC devices on water column relative fish density; (2) testing for indirect effects of TISEC devices on fish vertical distribution; and (3) estimating the probability of fish encountering a device based on relative fish density proportions in the water column relative to deployed TISEC device depth. These objectives are being accomplished using a mobile, down-looking hydroacoustics echosounder (EK80) from a medium-sized boat (the *Nova Endeavor*) using field methods, data processing and 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 revised the approach to suit the needs of the Minas Passage area.

Objectives and survey preparation

This survey was the first one after the first TISEC device installation which occurred on November, 7, 2016. On November 22, all of the hydroacoustic and electrical equipment were installed and connected on the RV *Nova Endeavor* which was docked in Delhaven, Nova Scotia. Calibration was not performed there because the water depth was not suitable (Figure 1).

Figure 1: Delhaven Harbour conditions at low tide.

On November 23rd, the boat was to arrive in Parrsboro to perform a calibration at the pier at slack tide. However, because of the shallow water in Delhaven, the crew needed to wait for high tide to depart and did not arrive to Parrsboro in time for slack water. The arrival time did not provide proper conditions to perform calibrations on November 23rd. So, we left the pier early on November 24th to perform calibrations immediately prior to the survey. We used a fishing line with the calibration sphere at the end, as in the last survey. The echosounder mount was adjusted at an angle to better position the calibration sphere in the echosounder beam. The CW mode calibration had an RMS error of 0.0348 (a calibration is considered good if this value is less than 0.2). The gain (since the last survey) was only modified by 0.1 dB, which is minimal and shows that the transducer settings did not change much between surveys. The FM mode calibration was also very good with an RMS error of 0.2.

The 24th – 25th November survey details

The survey began on 24 November 2016 at 8:30am and finished on 25 November 2016 at 9:15am. Four "grids", each grid composed of 6 impact transects (within the CLA), 3 control transects and 2 "along" transects (running from the CLA to the control site), were conducted. We added a turbine transect (T transect) over the turbine location. Two grids were conducted for each tidal cycle, grid 1 during the day, grid 3 during the night and grid 2 and 4 during both day and night.

Transducer settings were the same as previous surveys: pulse duration of 1.024ms (consistent with Melvin baseline settings), power of 250W (recommended by Simrad) and ping interval of 250ms.

Murray Scotney (FORCE subcontractor, OceanMoor Technical Services) and Aurélie Daroux (UMaine) conducted surveys during one ebb and one flood tide, from 0830 - 2050 on 24 November 2016. Tyler Boucher (FORCE staff) and Aurélie Daroux conducted the rest of the survey from 2100 - 0910 on 24 and 25 November 2016. Details (datasheets with filenames, transect durations, environmental measurements) concerning the proceedings of the survey are included in Appendix I.

The weather was amenable during the entire survey but due to the strong flood tide and the addition of a turbine transect, S2 and S3 control transects as well as the N5 CLA transect (with the tide) from grid 2 was not sampled. All transects in all other grids were completed.

Six Deep Cycle batteries wired in parallel were enough to supply the transceiver during the 24 hour survey. The 24 hour survey resulted in 53.5 Gb of data. Two copies of the data were stored at the end of the survey: (1) University of Maine has the data on a hard drive. At the end of the survey, the data were also copied on (2) Murray Scotney's hard drive and on (3) another hard drive from the University of Maine.

Data processing, preliminary results and conclusions

1) Processing improvements

This report includes analysis from all surveys to date because we improved our processing method and changed how the data were scaled for exporting. All previous surveys were reprocessed using the new methods and results are included here.

1.1) Turbulence detection

The presence of eddies (air entrained in water and in circular motion below the surface of the water) from the surface to 50 m depth impacted the quality of the data on some transects. During the data processing, this surface turbulence must be removed in order to not be integrated as fish.

With the help of Haley Viehman (Acadia University), a new method using reverse bottom detection was developed

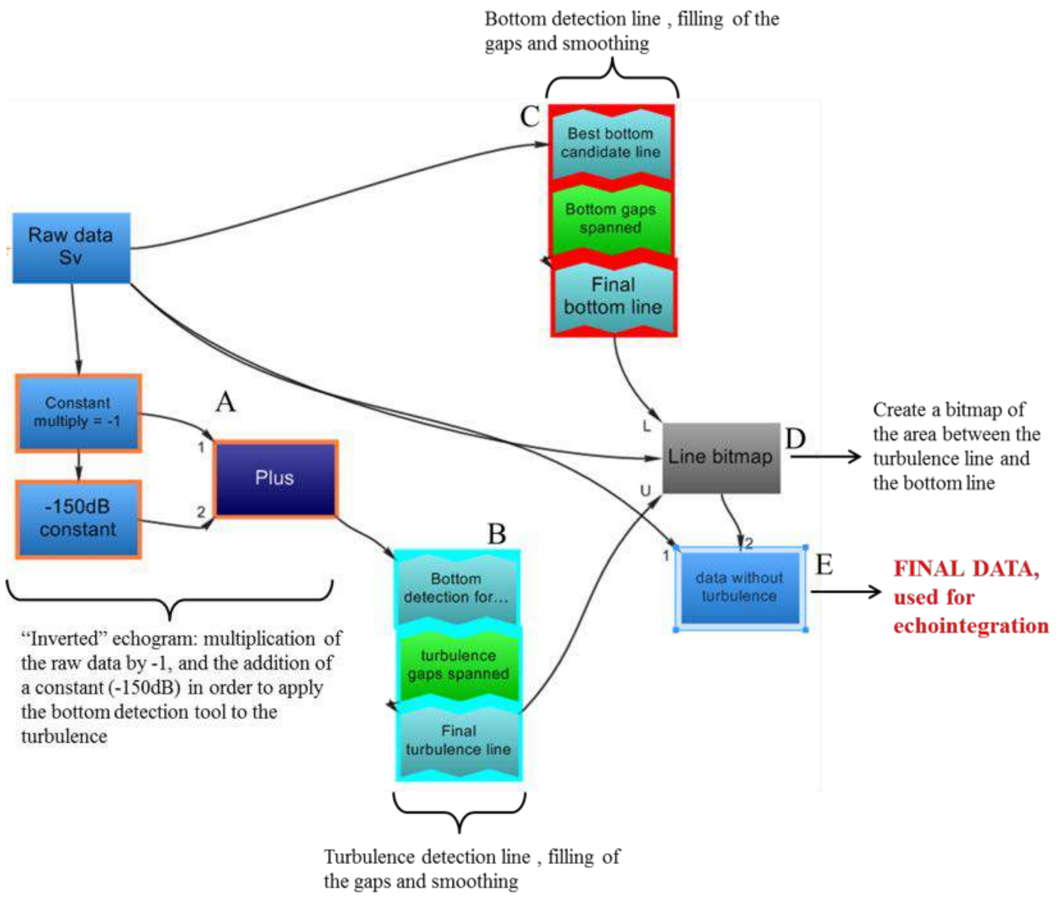


Figure 2: EchoView Dataflow of the processing of the data before echointegration.

The raw data were multiplied by -1.0 and a constant was added so the software interpreted the surface as the bottom of the water column (Figure 2A). Then a bottom detection algorithm was used on the new set of data to smooth the line (Figure 2B). In addition, the usual bottom detection algorithm was applied to detect the actual sea bottom (Figure 2C). A bitmap of the area between the turbulence line and the bottom line was then created (Figure 2D), and the data between those two lines were used for echointegration (Figure 2E and Figure 3). This method is not more time consuming than the previous one and allows us to export turbulence/eddy data. This new method has been applied to all surveys.

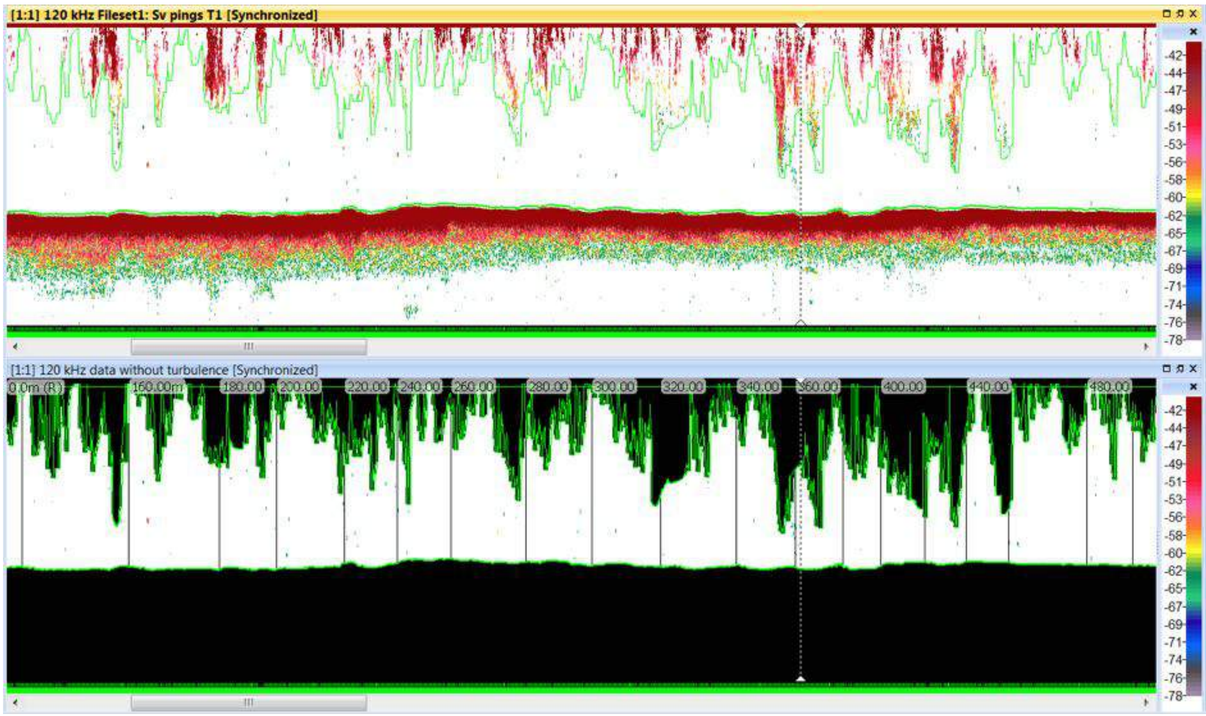


Figure 3: Snapshot of an echogram (Fileset1: Sv ping T1 (top), data without turbulence (bottom) of the Dataflow, see Figure2) where the new reverse bottom detection processing method has been performed. The exported area corresponds to the white part of the echogram between the two black areas in the bottom echogram shown.

1.2) Autocorrelation and data export grid

Previous survey data were exported in 1m vertical layer depth bins (Figure 4, left). This way of organizing the exported data is suitable for analyzing vertical distributions but is not ideal for quantifying total water column relative fish density and its variability within and among transects. Instead, full water column data grouped by distance or time (Figure 4, right) are more appropriate for assessing overall relative density of fish for comparison among transects and locations.

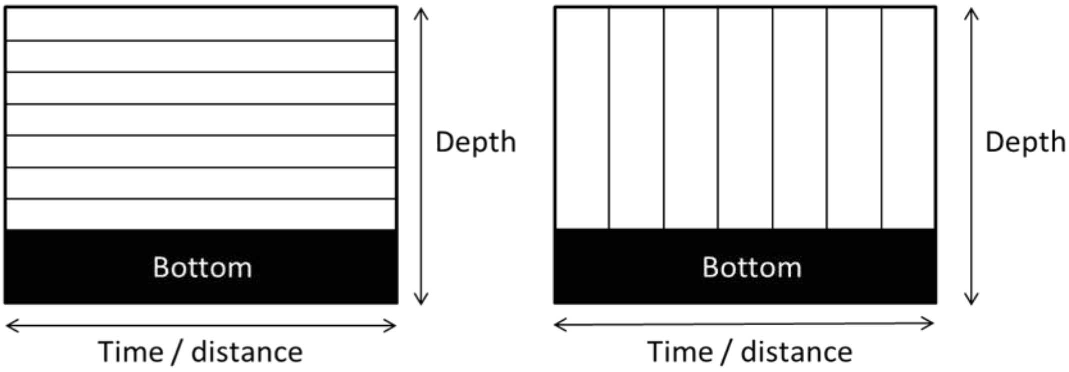


Figure 4: Representation of the data export by 1m depth bins (left) and by 20m vertical distance bins (right).

To assess the best time/distance scale to export data we performed autocorrelation using different intervals. Numerous time intervals (from 1min to 10min) and distance intervals (from 1m to 5m) were tested. We performed autocorrelation tests on 4 transects (GR1_N0A, GR2_N3A, GR3_N5W and GR4_S1W) of each survey. Distance intervals were chosen because time bins had higher within-transect and within-survey variability. Autocorrelation, using 5 m distance bins was then performed on the chosen 4 transects from each survey. As an example, in one sample transect, data were not correlated after 10 m (Figure 5). For the four tested transects of all surveys, 20m distance bins were consistently not correlated. As such, data were echointegrated for the entire water column in 20m distance bins for each transect of all surveys. Exported data were used for the GLM model and graphic display in boxplots. However, for vertical distribution analyses, exports were by 1m depth bins.

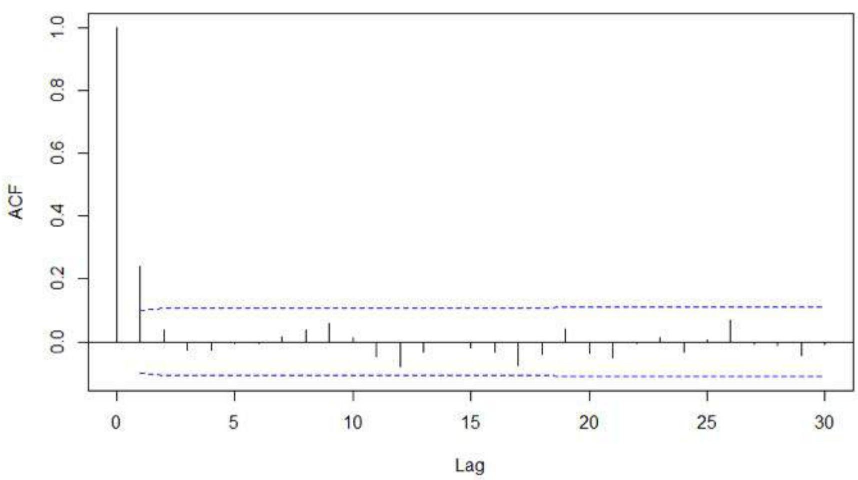


Figure 5: Example of an autocorrelation graph (for GR4_S1W from survey 1), ACF represents the autocorrelation value and the lag interval chosen, here 5 meters. When the ACF is below the blue dotted line the lag indicates the interval where the samples are no longer correlated.

1.3) Environmental parameter characterizations

With the re-processing of all the data, we decided to work on a better definition of the tide and diel variables. Before, datasheet written indications were used to determine the stage of the tide and the period of the day. This personal and subjective determination has been changed. Diel period has been characterized using civil sunrise and sunset hours in order to define dawn and dusk in the same way for each survey. Low tide and high tide have been defined as a 1-hour period around the lowest depth time and the highest depth time using the tide chart from Cape Sharp, http://tides.mobilegeographics.com. This characterization of slack tides will be improved or justified by simulation velocity data (at the time and date of the survey) which will be provided by Richard Karsten from Acadia University.

2) Results

2.1) Statistical Comparisons and variable effects using a generalized linear model

To examine whether there was an influence of environmental factors in the backscatter/relative fish densities, we used a generalized linear model (GLM). This GLM was performed on all surveys using linear relative fish density data (Sv), including all zero data.

The factors included in the GLM were:

- *transect*: the name of the transect
- *diel*: time of the day: day, night, dusk, dawn
- *location*: CLA or control
- *tide*: high, low, ebb and flood
- *turbine*: presence or absence
- *survey*: 1, 2, 3 or 4

with linear Sv, which is the linear acoustic backscatter, also equal to the summation of the contribution from all targets within the 20m distance bins.

$$\mathrm{Sv} \sim transect + diel + location + tide + turbine + survey + transect{*}diel + transect{*}tide$$

Akaike information criterion (AIC) is a measure of the relative quality of a given set of data statistical models (the smaller the value of this measure is, the better the model fits the data), we calculated the AIC to determine which model fit the data best (Table 1, 2).

Table 1: AIC results for GLM using linear relative fish density.

	AIC
NULL: Sv ~1	-471914.6
Sv ~ transect	-472502.5
Sv ~ transect + tide	-472664.5
Sv ~ transect + tide + survey	-472712.7
Sv ~ transect + tide + survey + diel	-472871.9
Sv ~ transect + tide + survey + diel + tide	-472871.9
Sv ~ transect + tide + survey + diel + tide + transect*diel	-473274.9
Sv ~ transect + tide + survey + diel + tide + transect*diel + transect*tide	**-473708.8**

Table 2: Results of the ANOVA between the NULL model (Sv ~ 1) and the model with factors (Sv ~ transect + diel + location + survey + tide + turbine + transect*diel + transect*tide)

	Df	Deviance	Resid. Df	Resid. Deviance	F	P-value
NULL	29208	0.00016456				
transect	9	3.38E-06	29199	0.00016118	70.971	<2.20E-16
tide	3	9.60E-07	29196	0.00016022	60.497	<2.20E-16
survey	3	9.78E-07	29193	0.00015924	61.605	<2.20E-16
diel	3	1.90E-07	29190	0.00015905	11.951	8.13E-08
transect*diel	17	2.27E-06	29173	0.00015678	25.214	<2.20E-16
transect*tide	16	2.57E-06	29157	0.00015421	30.379	<2.20E-16

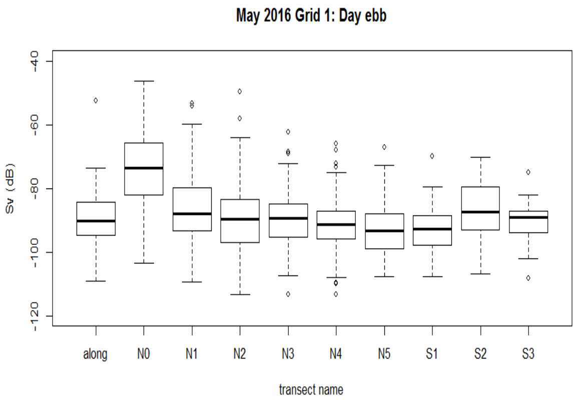
Transect, tide, survey and diel factors all contribute to the variability in relative fish density (Table 2). The interaction between transect and diel condition as well as the interaction between transect and tide support the fact that the difference between relative fish densities during different diel and tidal periods are related to the transect sampled at that time/ tide stage and not diel/tide effects separately.

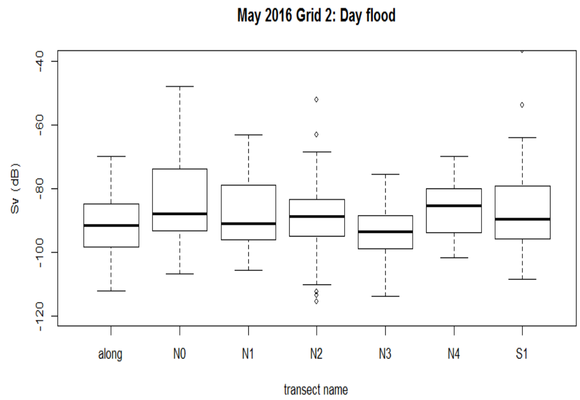
The turbine presence during the 4th survey did not appear to influence relative fish density in the CLA area. The turbine factor and the location factor did not appear in the results above because they are collinear (vary directly with) with survey (for turbine) and transect (for location) factors.

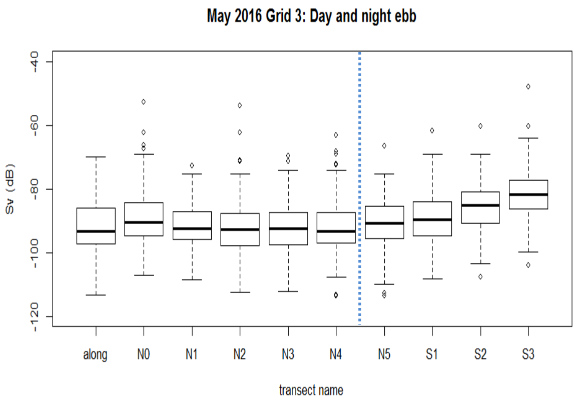
2.2) Study objectives and data overview

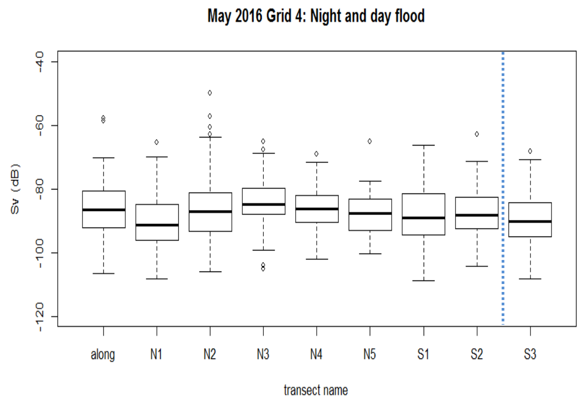
The overall goal of the fish survey study is to quantify fish distributional changes which can reflect behavioral responses to the presence of a deployed TISEC device. The objectives are to: *(1) test for indirect effects of TISEC devices on water column fish density; (2) test for indirect effects of TISEC devices on fish vertical distribution; and (3) estimate probability of fish encountering a device based on fish density proportions in the water column relative to TISEC device depth in the water column. These objectives will be met using a Before-After-Control-Impact (BACI) study design, multivariate analysis (Hotellings T2 tests) of fish vertical distributions, and an encounter probability model.*

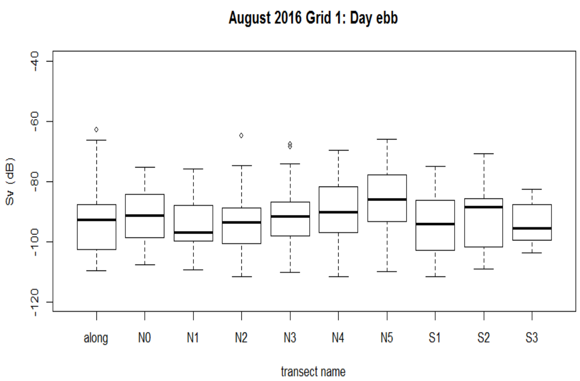
To address the first objective, we recorded density estimates by transects (with and against) exploring 4 grids. The data are presented as boxplots in Appendix II (for survey 4) and in Appendix IV (for survey 1 to 3) and are summarized below (Figure 6).

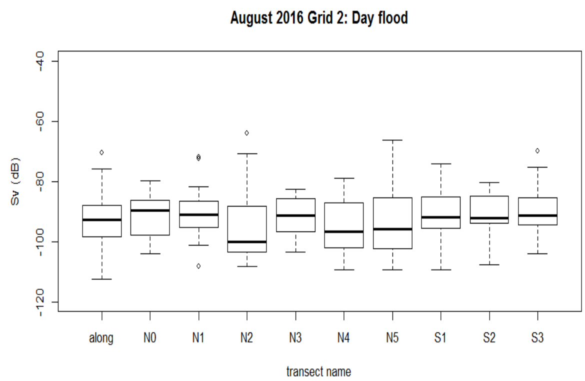

May 2016 Grid 1: Day ebb
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
N5
S1
S2
S3
transect name

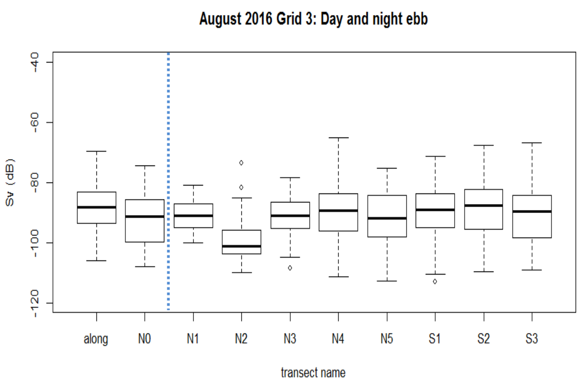

May 2016 Grid 2: Day flood
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
S1
transect name

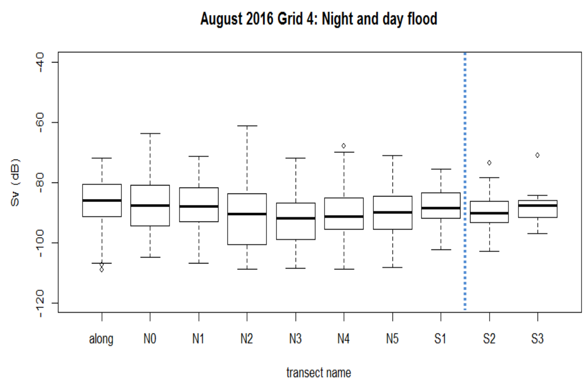

May 2016 Grid 3: Day and night ebb
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
N5
S1
S2
S3
transect name


May 2016 Grid 4: Night and day flood
Sv (dB)
-40
-60
-80
-100
-120
along
N1
N2
N3
N4
N5
S1
S2
S3
transect name


August 2016 Grid 1: Day ebb
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
N5
S1
S2
S3
transect name


August 2016 Grid 2: Day flood
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
N5
S1
S2
S3
transect name


August 2016 Grid 3: Day and night ebb
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
N5
S1
S2
S3
transect name


August 2016 Grid 4: Night and day flood
Sv (dB)
-40
-60
-80
-100
-120
along
N0
N1
N2
N3
N4
N5
S1
S2
S3
transect name

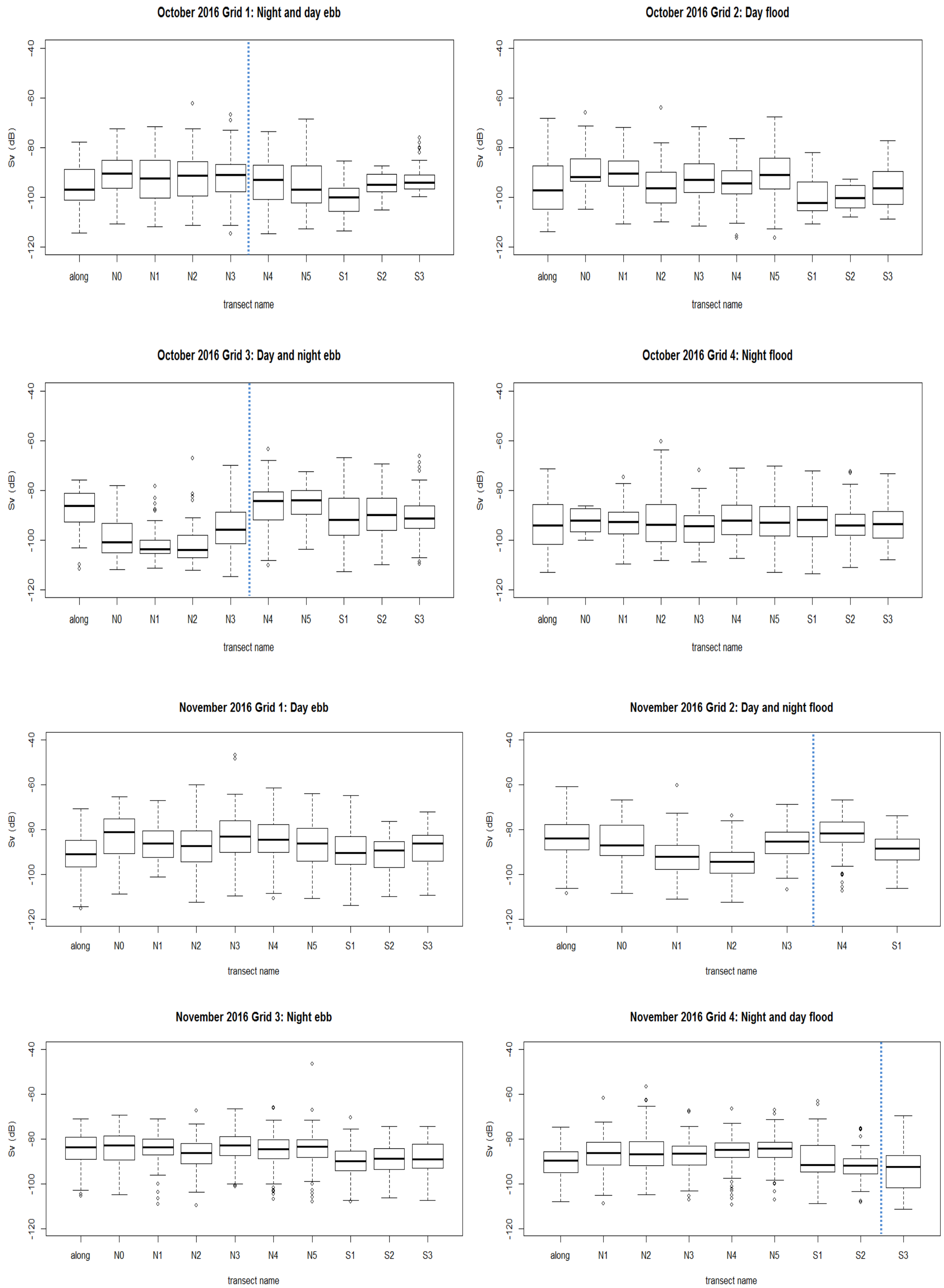


Figure 6: Boxplots of exported Sv (Volume backscattering strength) for the 4 grids conducted in May, August, October and November. The blue vertical dashed line represents the transition between day (to the left of the line) and night (to the right of the line) periods.

During the 4th survey, we observed that the N0 transect had a higher relative fish density, especially for grids 1, 3, and 4 (Figures A2.1, A2.2, A2.4, A2.6, A2.8). The N4 transect also had a higher relative fish density, especially in grid 2, during dusk (Figure A2.4).

Reminder: These boxplots are a visual representation of the relative fish density and not of the number of fish present in each transect. For example, two big fish which reflect a lot of energy can give a transect a higher fish density than a transect with many smaller fishes.

To address the second objective regarding fish vertical distribution, we processed the survey data for density estimates by 1 m vertical layers. To smooth the vertical distributions in each transect, area backscatter strength was averaged by 2 m depth bins (as in the previous reports). Data are presented in Appendix III.

The vertical distributions were variable from transect-to-transect and by grid, and not necessarily consistent between the test area and the channel even for common depths. The only time we observed a higher relative density of fish closer to the surface was in the N1 transect during grid 2 (Figure A3.3).

The "along" transects for each grid were variable with the along transect of grid 4 showing the lowest density and grid 2 one the highest (Figure A3.9).

2.3) Comparison with the previous surveys

The boxplot presentation of these data shows the variability of the relative fish density within surveys. All boxplot representations required zero values to be transformed to NA in order to visualize variation and not center plots on zero values (left panels of Figures 7-12). However, statistical comparisons included zero values As such, mean data plots (right panels of Figures 7-12) are provided to show the mean relative fish density with "zeros" not replaced by NA but using Sv = -999 to represent "zero" data (each point on the plot is the mean) A comparison of relative fish densities between surveys using an ANOVA showed significant differences (p-value <2e-16) among them, for all the statistical tests, 'zero' values have not been replaced by NA. To look at the difference between them more closely, we performed a Wilcoxon test by pair of surveys (Table 3).

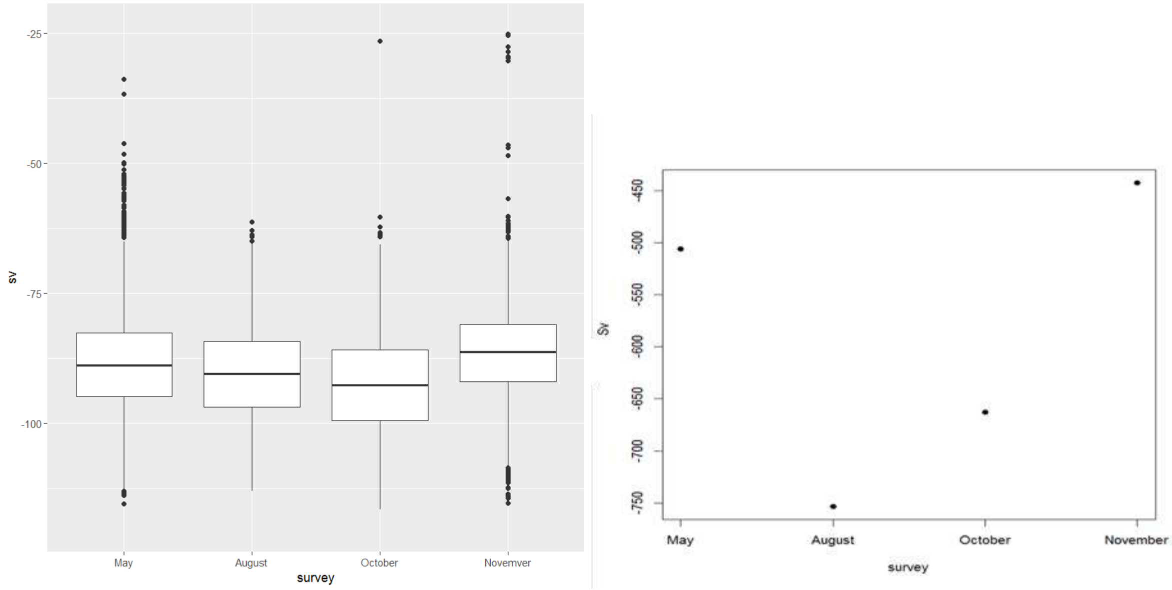


Figure 7: Boxplot of the Sv ("zero" replaced by NA, left) and mean Sv ("zero" not replaced by NA, right) for each survey (1: May, 2: August, 3: October, 4: November).

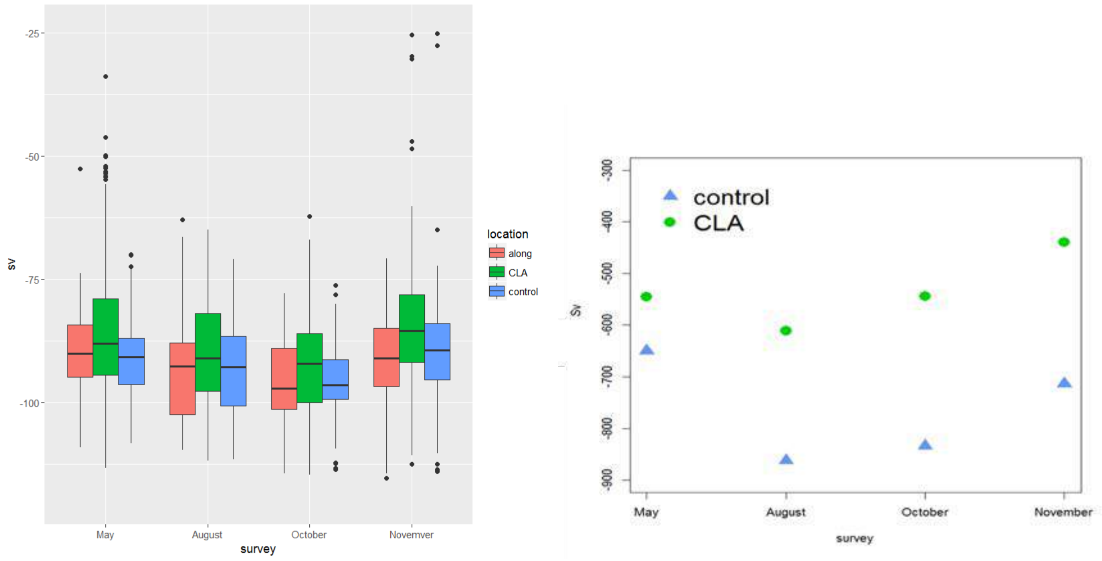


Figure 8: Boxplot of Sv data ("zero" replaced by NA, left) and mean Sv ("zero" not replaced by NA, right) for grid 1 (ebb tide) by location (CLA, control and along transect) and by survey (May, August, October and November).

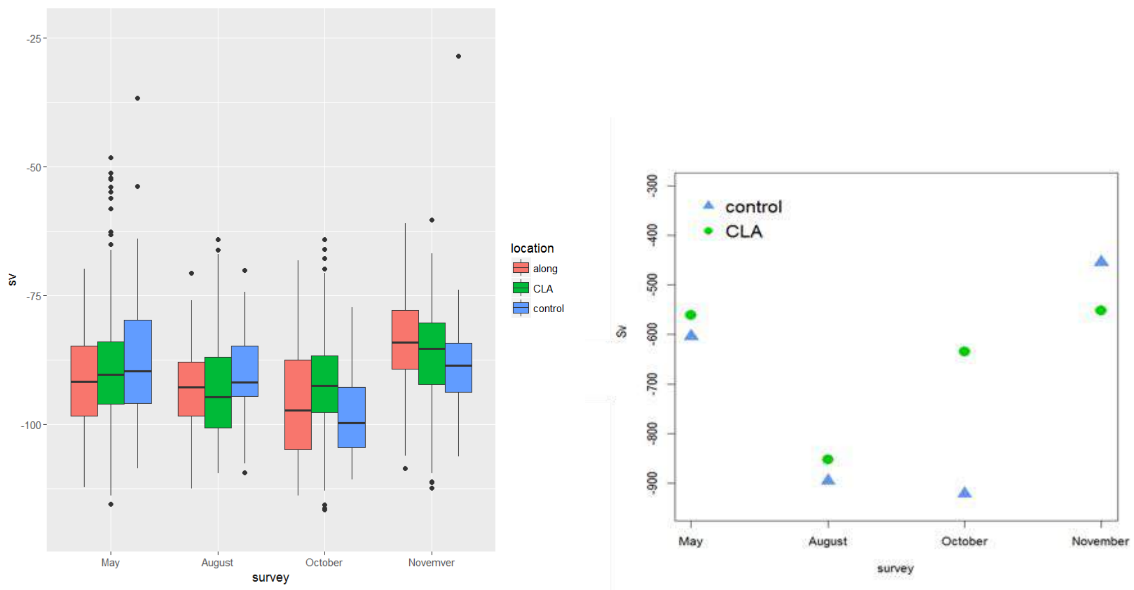


Figure 9: Boxplot of Sv data (“zero” replaced by NA, left) and mean Sv (“zero” not replaced by NA, right) for grid 2 (flood tide) by location (CLA, control and along transect) and by survey (May, August, October and November).

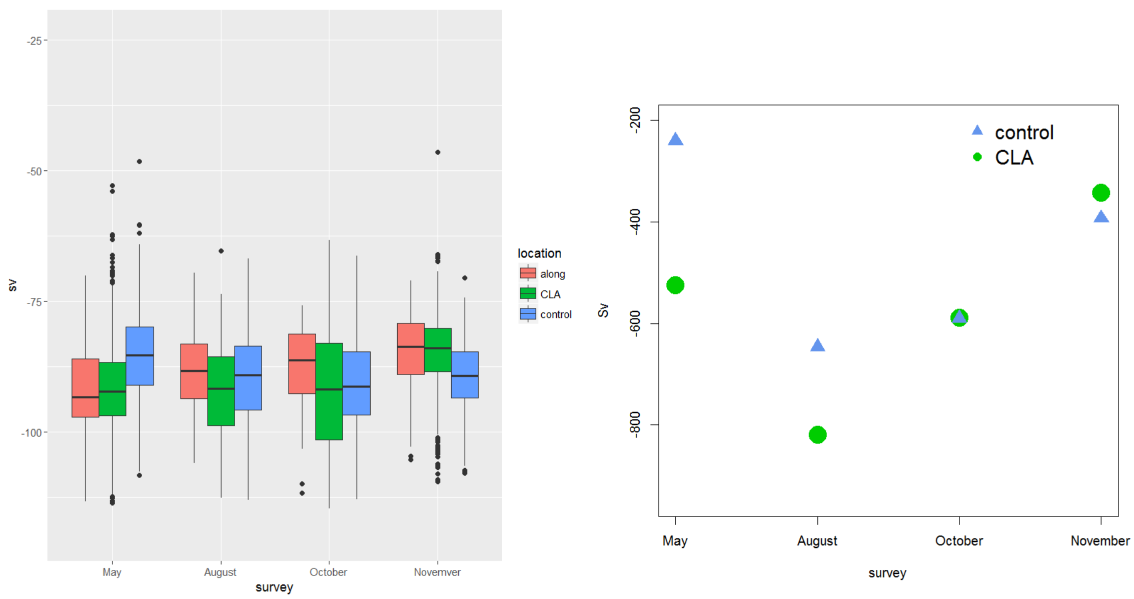


Figure 10: Boxplot of Sv data (“zero” replaced by NA, left) and mean Sv (“zero” not replaced by NA, right) for grid 3 (ebb tide) by location (CLA, control and along transect) and by survey (May, August, October and November).

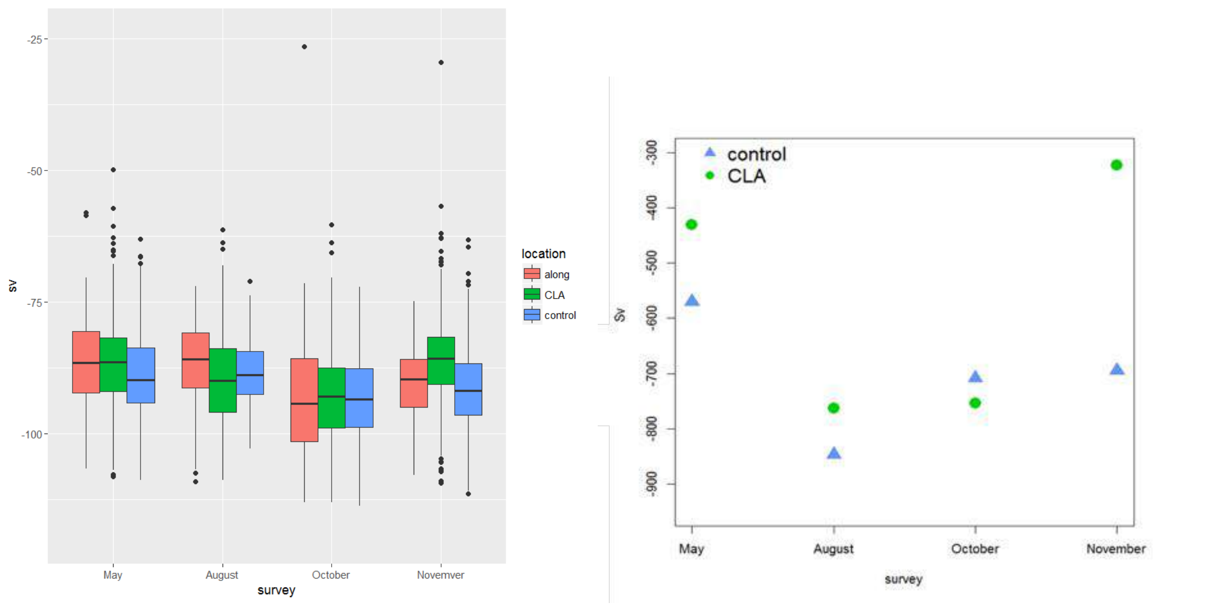


Figure 11: Boxplot of Sv data ("zero" replaced by NA, left) and mean Sv ("zero" not replaced by NA, right) for grid 4 (flood tide) by location (CLA, control and along transect) and by survey (May, August, October and November).

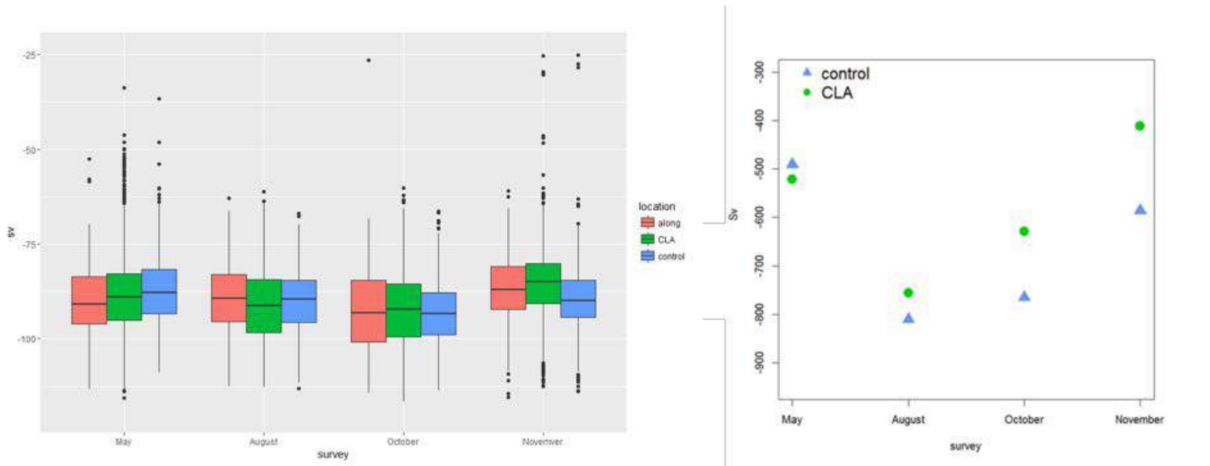


Figure 12: Boxplot of Sv data ("zero" replaced by NA, left) and mean Sv ("zero" not replaced by NA, right) for all surveys (May, August, October and November) by location (CLA, control and along transect)

Table 3: Wilcoxon comparison test results by pair of survey.

	survey 1	survey 2	survey 3	survey 4
survey 1		< 2.2e-16	< 2.2e-16	< 2.2e-16
survey 2			< 2.2e-16	< 2.2e-16
survey 3				< 2.2e-16

May and November had the highest mean relative fish density, and August and October the lowest (Figure 7). Relative fish density is significantly different among all surveys (Table 3). The highest relative fish density in May was predictable and may be associated with alewife spring spawning migrations and the presence of Atlantic herring (Baker et *al*., 2014). The November high density 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 (Ames and Lichter, 2013). After that period, they move to deeper, warmer depths though the winter (Townsend et *al*., 1989), and return to coastal nurseries in the spring.

For all surveys, during grid 1, CLA transects had a slightly higher (+2 dB on average compared to grid 2 and 3) relative fish density (Figure 8). Looking at the 4 surveys grid by grid, grid 1 and grid 2 (Figure 8 and 9, left) best reflected the global relative fish density by survey (Figure 7, left) with May and November surveys having generally higher relative fish density than August and October. Whereas, in grid 3 and grid 4 (Figure 10 and 11, left) of the 4 surveys, relative fish densities are visually smaller in August and October. Mean linear relative fish densities (Figure 8 to 11, right) had stable values between grids, similar to the global relative fish density.

Difference in relative fish densities between the CLA and control sites varied among grids and surveys, except (p-value= 0.2216) for the November survey during grid 3 (flood tide). For all surveys, expect the May survey, the CLA transects had significantly (p-value < 2.2 e-16) higher mean relative fish densities (Figure 12), which is generally due to the contribution of one transect in the CLA (for example, N5 for August and October surveys). This pattern was consistent for 3 surveys (August, September, and November), potentially indicating that in November, after the turbine installation, fish distribution did not change compared to prior deployment surveys. Nevertheless, continued monitoring is essential to assess the impact of the turbine on fish distributions.

References:

Ames, E.P. and Lichter, J., 2013. Gadids and alewives: structure within complexity in the Gulf of Maine. *Fisheries Research*. 141, pp.70-78.

Baker, M., M. Reed, and A.M. Redden. 2013. Temporal Patterns in Minas Basin Intertidal Weir Fish Catches and Presence of Harbour Porpoise during April – August 2013. *Acadia Centre for Estuarine Research*, Wolfville, NS, Tech. Rep. 120, 2014.

Townsend, D.W., Radtke, R.L., Morrison, M.A., Folsom, S., 1989. Recruitmentimplications of larval herring overwintering distributions in the Gulf of Maine, inferred using a new otolith technique. *Marine Ecolocial Progress Series*. 55, 1–13.

Viehman, H., Zydlewski, G.B., McCleave, J., Staines, G. 2015. Using acoustics to understand fish presence and vertical distribution in a tidally dynamic region targeted for energy extraction. *Estuaries and Coasts*. 38(S1): 215-226.

Appendix I: Scanned survey datasheets attached.

TW and T2 are just half transect.

T° = 9.0° for the calibration

Acoustics Water/Weather Observations

Salinity______ Crew ______________

Date start 11.24.2016 Time start 8:38:03 Vessel ______________ Notes:

Date end __________ Time end __________ Location ______________ Page 1/9

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR1	N0W_E	11.24.16	8:38:03	8:51:25	E	9.0	Y	Y	N	N	Day	<5	Y(1)	Y	4.2	<1/4	High at 8:40.
GR1	N0A_E	//	8:52:04	09:04:01	E	//	Y	Y	//	//	//	//	Y(1)	Y	5.2	//	
GR1	N1W_E	//	9:05:47	09:18:38	//	//	Y	Y	//	//	//	//	Y(3)	Y	5.0	//	
GR1	N1A_E	//	9:18:59	09:32:00	//	//	Y	Y	//	//	//	5.	Y(3)	Y	5.2	1/4 m	
GR1	N2W_E	//	9:34:46	09:46:47	//	//	Y	Y	//	//	//	5	Y(3)	Y	5.3	1/4	weird detection on the bottom have been seen both [illegible] & transects
GR1	N2A_E	//	09:47:48	10:04:40	//	//	Y	Y	//	//	//	5	Y(3)	Y	4.3	1/4	
(W+A) GR1	TW_E	//	10:06:43	10:28:25	//	//	Y	Y	//	//	//	<5	Y(3)	N	2.5 to 6.1	//	go back to see the turbine before the middle of the transect
(W+A) GR1	T2_E	//	10:30:35	10:45:59	//	//	Y	Y	//	//	//	//	Y(3)	N	3.4	//	
GR1	N3W_E	//	10:48:13	10:56:07	//	//	Y	Y	//	//	//	//	Y(3)	Y	6.5	//	
GR1	N3A_E	//	10:56:30	11:22:43	//	//	Y	Y	//	//	//	//	Y(3)	Y	4.0	//	

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR1	N4W_E	11.24.16	12:24:46	11:35:00	E	9.0	Y	Y	N	N	Day	<5	Y3	✓	6.5	<1/4	
GR1	N4A_E	"	11:35:30	12:04:50	"	"	"	"	"	"	"	"	"	✓	3.0	<1/4	
GR1	N5W-E	"	12:05:55	12:16:12	"	"	"	"	"	"	"	"	Y2	✓	5.8	<1/4	
"	N5A-E	"	12:17:02	12:41:36	E	9.0	"	"	"	"	"	"	"	✓	3.1	<1/4	
"	South-cut	"	12:43:02	13:01:50	"	"	"	"	"	"	"	<5	Y1	✓	5.0	<1/4	
"	S1W-E		13:02:46	13:12:40	"	"	"	"	"	"	"	<5	Y1	✓	5.5	<1/4	
"	S1A-E		13:13:30	13:29:05	"	"	Y	Y	"	"	"	"	Y(1)	Y	3.4	"	
"	S2W_E		13:30:41	13:43:37	"	9.0	Y	Y	"	"	"	"	Y(1)	Y	5.0	"	wind gust @ 5
"	S2A_E		13:44:38	13:58:03	"	"	Y	Y	"	"	"	"	Y(1)	Y	4.3	"	
"	S3W_E		13:59:41	14:12:26	"	"	Y	Y	"	"	"	"	Y(1)	Y	5.1	"	

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR1	S3A_E	11/24/16	14:13:41	14:24:53	E	9.0	Y	Y	N	N	Day	<5	Y(1)	Y	5.1	<1/4	turbine saw 2 times because the boat turned. (slack water)
GR1	North_FM	//	14:25:00	14:54:00	E	//	Y	Y	N	N	//	//	Y(1)	Y	6.5	//	part of the FM record is on the previous file (GR1-S3A_E) Low Tide at 2:50
GR2	N0A_F	//	14:54:48	15:06:52	F	//	Y	Y	N	N	//	//	Y(1)	Y	5.0	//	
GR2	N0W_F	//	15:07:24	15:18:35	F	//	Y	Y	N	N	//	//	Y(1)	Y	5.4	//	
GR2	N1A_F	//	15:20:05	15:33:13	F	//	Y	Y	N	N	//	//	Y(few)	Y	4.8	//	
GR2	N1W_F	"	15:33:55	15:44:29	F	//	Y	Y	N	N	//	//	Y()	Y	5.7	//	
GR2	N2A_F	"	15:46:47	16:03:00	F	"	"	"	"	"	"	"	N	Y	4.0	"	
GR2	N2W_F	"	16:03:36	16:14:27	F	"	"	"	"	"	"	"	few	Y	6.0	"	
GR2	TA-F	"	16:16:41	16:40:30	F	"	"	"	"	"	"	"	"	Y	2.5	"	turbine detected.
GR2	TW-F		16:41:18	16:50.17	F	"	"	"	"	"	Dusk	"	Y)		6.0	"	turbine detected.

Sunset = 4.40pm

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR2	N3A-F	11.24.16	16:52:30	17:50:10	F	9.0	Y	Y	N	N	Dusk Night	<5	Y(2)	Y	1.6	<1/4	Almost 1h
GR2	N3W-F	"	17:50:38	17:52:22	F	"	Y	Y	N	N	Night	"	Y(2)	Y	8.5	"	
GR2	N4A_F	"	17:59:10	19:12:02	F	"	Y	Y	N	N	Night	"	Y(3)	Y	22	"	
GR2	N4W_F	"	19:12:34	19:19:11	F	"	Y	Y	N	N	Night	"	Y(3)	Y	8.0	"	
GR2	N5A_F	"	19:21:00	19:25:12	F	"	Y	Y	N	N	"	"	Y(3)	N	2.5	"	Running out of time - over to South Side.
GR2	South-CW	"	19:25:40	19:48:58	F	"	Y	Y	N	N	"	"	Y3	N	6.8	"	
GR2	S1W-F	"	19:49:41	20:02:23	F	"	"	"	"	"	"	"	Y1	Y	5.2	"	Missing bottom -
GR2	S1A-F	"	20:02:57	20:15:12	F	"	"	"	"	"	"	"	Y(1)	Y	6.1	"	
GR2	North-FM	"	20:16:17	20:43:25	F	"	Y	Y	"	"	"	"	Y(2)	Y	8.3	"	background noise in the beginning + Missing bottom
			High tide at 9:00PM,						CREW SHIFT AT 20:50								

1.5 3 1.5 1.5 3 1.5
L M H M L

Crew ______________________

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR3	NOW_E	11/24/16	21:00:40	21:13:00	H	9,0	Y	Y	N	N	Night	<5	N	Y	4.8	<1/4 m	Only 75m range, why?
GR3	NOA_E	11/24/16	21:13:32	21:26:00	H	9.0	Y	Y	N	N	Night	<5	N	Y	4.6	<1/4 m	
GR3	N1W-E	11/24/16	21:27:30	21:39:32	E	9.0	Y	Y	N	N	Night	<5	N	Y	5.1	<1/4 m	
GR3	N1A_E	11/24/16	21:40:20	21:53:11	E	9.0	Y	Y	N	N	Night	<5	Y FEW	Y	4.4	<1/4 m	
GR3	N2W_E	11/24/16	21:55:22	22:06:30	E	9.0	Y	Y	N	N	Night	<5	Y FEW	Y	4.9	<1/4 m	
GR3	N2A_E	11/24/16	22:08:20	22:21:48	E	9,0	Y	Y	N	N	Night	<5	Y FEW	Y	4.7	<1/4 m	
GR3	TW_E	11/24/16	22:23:05	22:33:38	E	9.0	Y	Y	N	N	Night	<5	Y	Y	5.3	<1/4 m	- Turbine (Not well detected)
GR3	TA_E	11/24/16	22:35:02	22:57:25	E	9.0	Y	Y	N	N	Night	<5	Y	Y	3.0	<1/4 m	- Turn sine well detected
GR3	N3W_E	11/24/16	22:58:42	23:10:05	E	9.0	Y	Y	N	N	Night	<5	Y	Y	5.2	<1/4 m	
GR3	N3A_E	11/24/16	23:10:35	23:36:51	E	9.0	Y	Y	N	N	Night	<5	Y	Y	3.6	<1/4	Tyler hit "Ping off" By accident @ end of transect.

0046052

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR3	S3A_E	11/25/16	02:22:22	02:35:17	E	8.0	Y	Y	N	N	Night	<5	Y(1)	Y	3.9	<1/4m	
GR3	NORTH FM	11/25/16	02:35:49	02:56:50	E	8.0	Y	Y	N	N	Night	<5	Y(1)	Y	7.5	<1/4	
GR4	N1W_F	11/25/16	02:57:03	03:08:28	L	8.0	Y	Y	N	N	Night	<5	Y Few	Y	5.3	<1/4	beginning of the transect in FM mode Low TIDE = 03:15 am
GR4	N1A_F	11/25/16	03:09:20	03:21:40	L	8.0	Y	Y	N	N	Night	<5	Y	Y	5.4	<1/4	
GR4	N2W_F	11/25/16	03:23:25	03:35:10	L	8.0	Y	Y	N	N	Night	<5	Y Few	Y	5.3	<1/4	
GR4	N2A_F	11/25/16	03:36:45	03:49:09	L	8.0	Y	Y	N	N	Night	<5	Y FEW	Y	5.2	<1/4	
GR4	TW_F	11/25/16	03:50:10	04:01:16	F	8.0	Y	Y	N	N	Night	<5	Y FEW	Y	5.5	<1/4	- Good turbine detection
GR4	TA_F	11/25/16	04:03:15	04:16:50	F	8.0	Y	Y	N	N	Night	<5	Y Few	Y	4.5	<1/4	- turbine not well detected
GR4	N3W_F	11/25/16	04:18:20	04:28:00	F	8.0	Y	Y	N	N	Night	<5	N	Y	6.1	<1/4	
GR4	N3A_F	11/25/16	04:29:55	04:45:20	F	8.0	Y	Y	N	N	Night	<5	N	Y	4.0	<1/4	

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR4	N4W_F	11/25/16	04:48:20	04:57:50	F	8.0	Y	Y	N	N	Night	<5	Y	Y	6.8	< 1/4	
GR4	N4A_F	11/25/16	05:00:15	05:29:31	F	8.0	Y	Y	N	N	Night	<5	Y	Y	3.0	< 1/4	
GR4	N5W_F	11/25/16	05:31:10	05:39:35	F	8.0	Y	Y	N	N	Night	<5	Y	Y	7.1	< 1/4	
GR4	N5A_F	11/25/16	05:42:15	06:47:06	F	8.0	Y	Y	N	N	Night	<5	Y	Y	1.7	< 1/4	-Tide too strong still @ half way after 1 hour - crossing to control to make sure we have time.
GR4	South CW	11/25/16	06:49:00	07:02:50	F	8.0	Y	Y	N	N	DAWN	<5	Y	Y	5.3	< 1/4	
GR4	S1A_F	11/25/16	07:03:30	07:12:31	F	8.0	Y	Y	N	N	DAWN	<5	Y	Y	6.0	< 1/4	
GR4	S1W_F	11/25/16	07:13:01	07:23:42	F	8.0	Y	Y	N	N	DAWN	<5	Y	Y	5.5	< 1/4	
GR4	S2A_F	11/25/16	07:25:00	07:34:12	F	8.0	Y	Y	N	N	DAY	<5	Y	Y	6.5	< 1/4	
GR4	S2W_F	11/25/16	07:34:50	07:46:17	F	8.0	Y	Y	N	N	DAY	<5	Y	Y	5.0	< 1/4	
GR4	S3A_F	11/25/16	07:47:25	07:56:55	F	8.0	Y	Y	N	N	DAY	<5	Y few	Y	6.5	< 1/4	

6:00

6:30 swap 1 & W

Grid #	Transect number	Start Date	Start Time	End Time	Tide stage (E,F, H,L)	Temp (C°)	GPS	DATA	Precip. Y/N	Fog Y/N	Day, Night, Dawn, Dusk	Wind Dir Speed	Eddy Y/N + Level 1 to 3	Pass. data Y/N	Boat speed	Wave Height (1/4 m)	Comments
GR4	S3W_F	11/25/16	08:12:23	08:25:22	H	8.0	Y	Y	N	N	DAY	< 5	N	Y	4.3	< 1/4	
GR4	NORTH FM	11/25/16	08:27:10	9:07:28	H	8.0	Y	Y	N	N	DAY	< 5	Y	Y	6.4	< 1/4	_several turbine Passes at end of transect

Appendix II: Data overview for survey 4

Data summarized in Section 2.2 (Study objectives and data overview) for survey 4 are presented in more detail here, as multiple comparisons among groups. Data are presented using boxplots. Relative fish density (Sv) is plotted for each transect and each grid. Transects against and with the tide have been separated for better visualization of differences. The blue horizontal line in all plots is the mean Sv for the entire survey (all transects). Vertical lines of different colors provide a visual distinction between the CLA area and the control area (red dashed line), day and night periods and tide periods (blue dashed line).

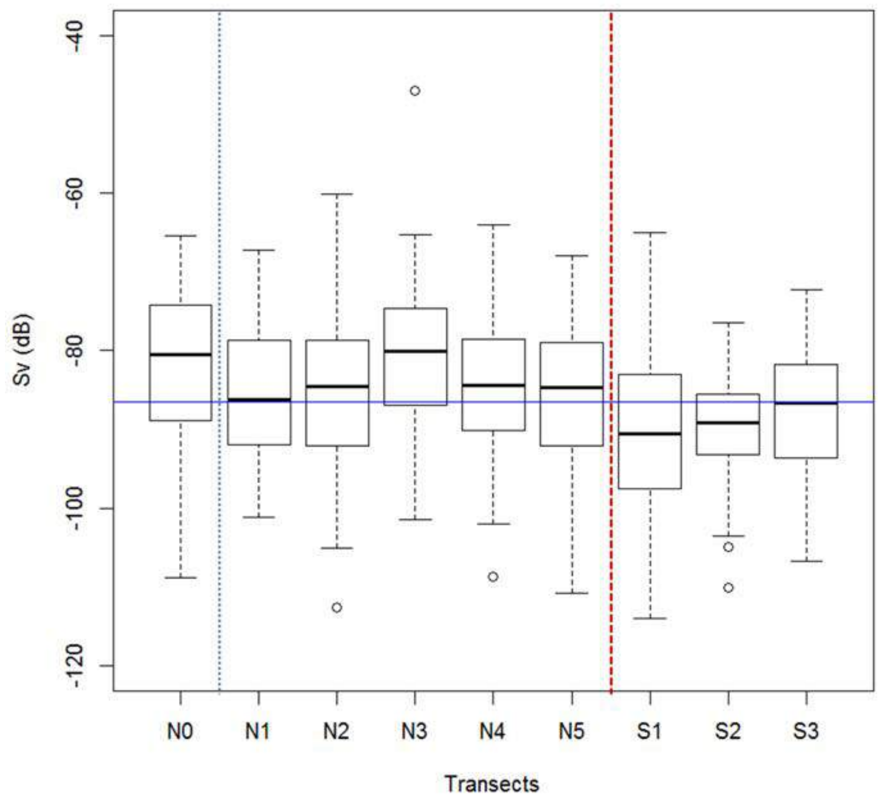


Figure A2.1: Boxplot of exported Sv (Volume backscattering strength) for the grid 1 (ebb) transects ***with*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3). The light blue vertical dashed line represents the transition between high tide (N0) and ebb tide (N1 to S3). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

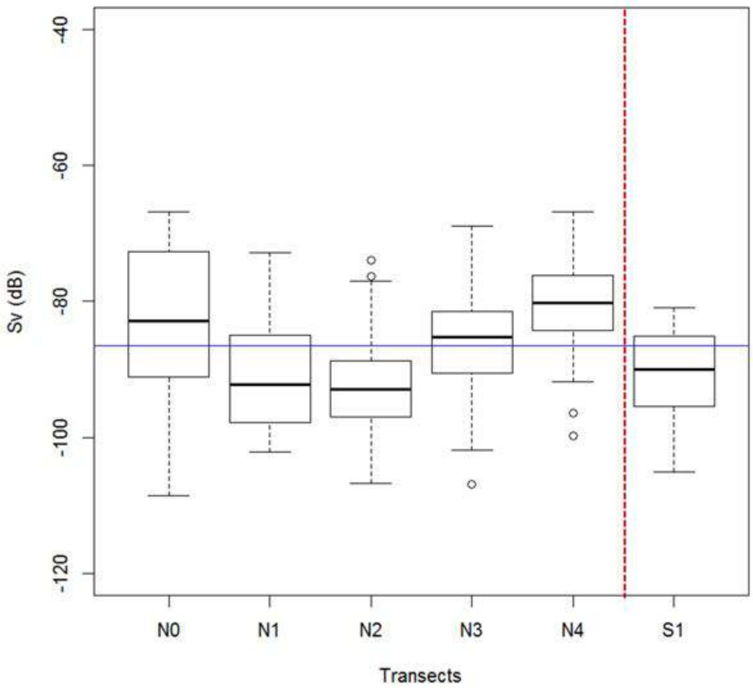


Figure A2.2: Boxplot of exported Sv (Volume backscattering strength) for the grid 1 (day ebb) transects ***against*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

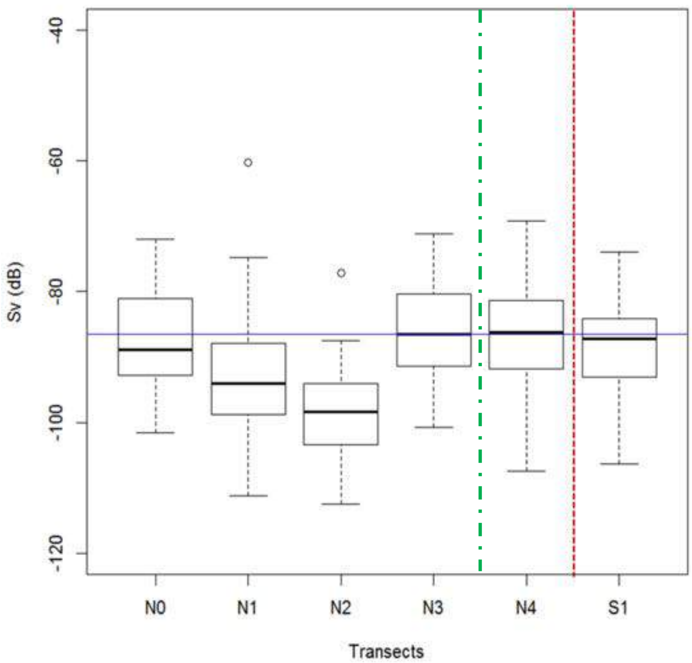


Figure A2.3: Boxplot of exported Sv (Volume backscattering strength) for the grid 2 (Day and night flood) transects ***with*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transect (S1). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

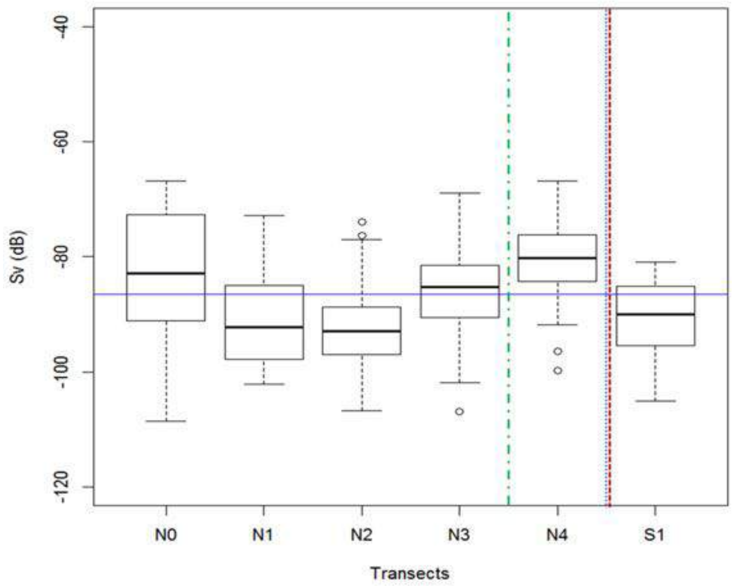


Figure A2.4: Boxplot of exported Sv (Volume backscattering strength) for grid 2 (Day and night flood) transects ***against*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3). The green vertical dashed line represents the transition between day (N0 to N3) and night (N4 to S1). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

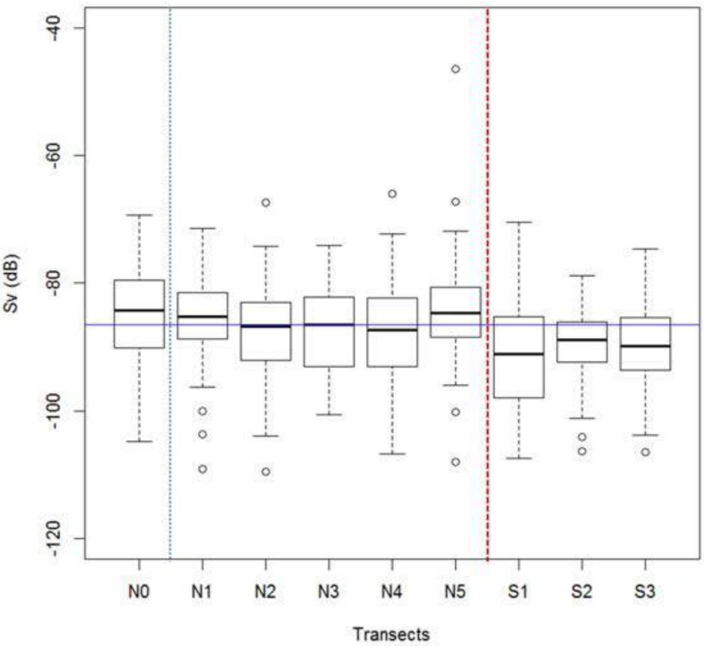


Figure A2.5: Boxplot of exported Sv (Volume backscattering strength) for grid 3 (night ebb) transects ***with*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3). The light blue vertical dashed line represents the transition between high (N0) and ebb tide (N1 to S3). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

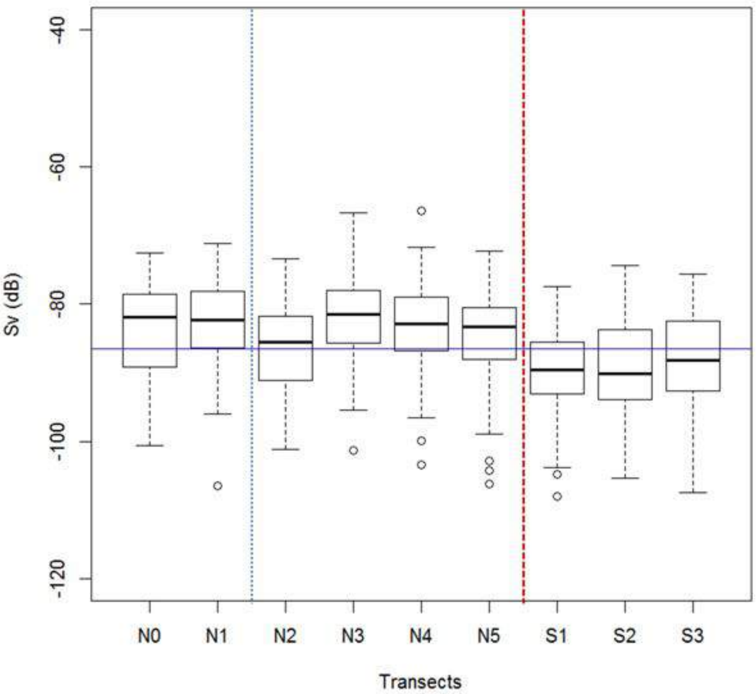


Figure A2.6: Boxplot of exported Sv (Volume backscattering strength) for grid 3 (Night ebb) transects ***against*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3).). The light blue vertical dashed line represents the transition between high (N0 to N1) and ebb tide (N2 to S3). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

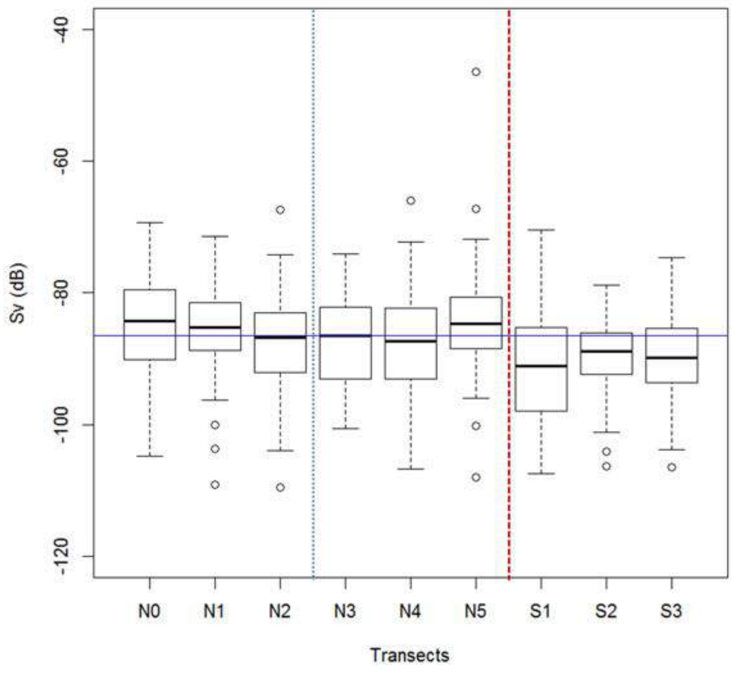


Figure A2.7: Boxplot of exported Sv (Volume backscattering strength) for grid 4 (Night flood) transects ***with*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3). The light blue vertical dashed line represents the transition between low (N0 to N2) and flood tide (N3 to S3). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

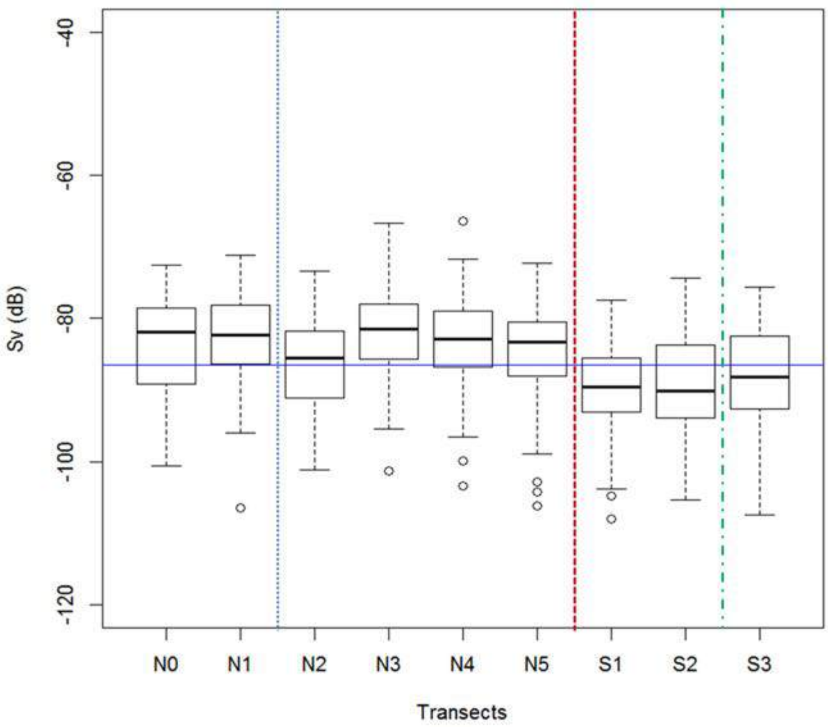


Figure A2.8: Boxplot of exported Sv (Volume backscattering strength) for grid 4 (Night flood) transects ***against*** the tide. The dashed red line separates CLA transects (N0 to N5) from control transects (S1 to S3). The light blue vertical dashed line represents the transition between low (N0 to N1) and flood tide (N2 to S3). The green vertical dashed line represents the transition between night (N0 to S2) and day (S3). The lower the negative number (closer to 0) the higher the relative fish density, the blue horizontal line represents the mean Sv for the entire survey (all transects).

Appendix III: Data overview for vertical distributions.

Section 2.2 (Study objectives and data overview) provides a description of the objectives for this work. Here we summarize details associated with the second objective regarding fish vertical distribution. Data were processed in 1 m vertical layers. To smooth the vertical distributions in each transect, area backscatter strength was averaged by 2 m depth bins. These data have been echointegrated from the bottom to the surface. The data are represented by number of layers (2 meters depth) from the bottom because the depth is not the same for all transects. The maximum depth for each transect was:

Transect	N0	N1	N2	N3	N4	N5	S1	S2	S3	along
Maximum depth (m)	41	50	55	58	54	52	64	52	56	140

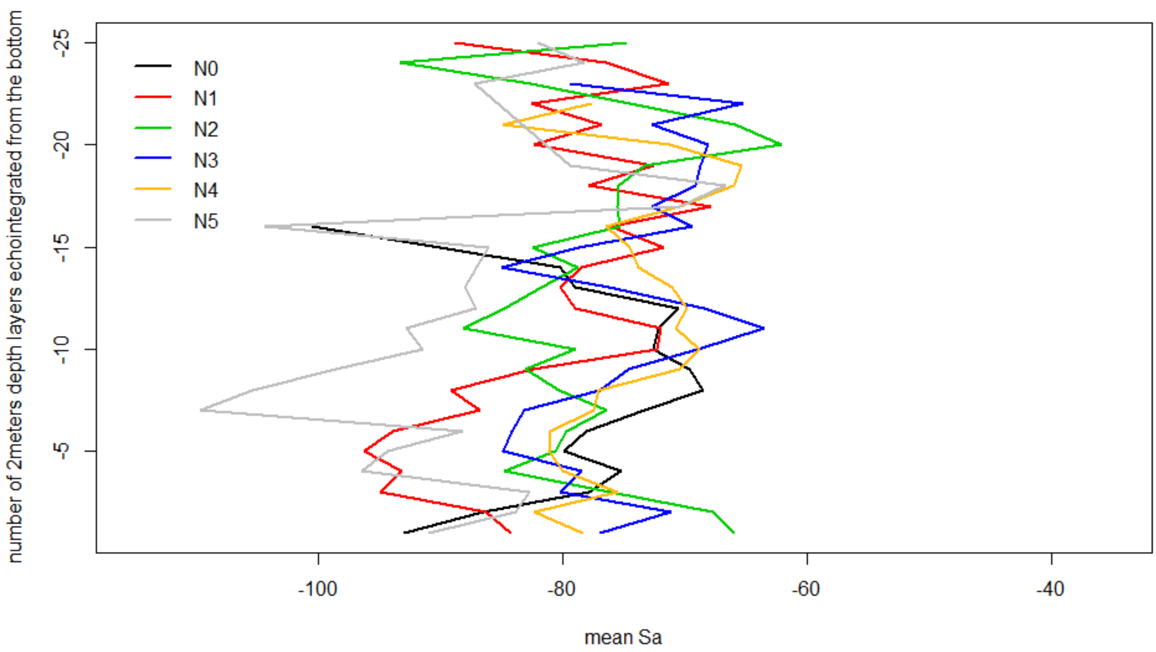


Figure A3.1: Vertical distribution of the mean area backscatter by 2 m depth layers for ***CLA*** transects of ***Grid 1.*** The echo-integration has been made from the bottom which depth varies between transects.

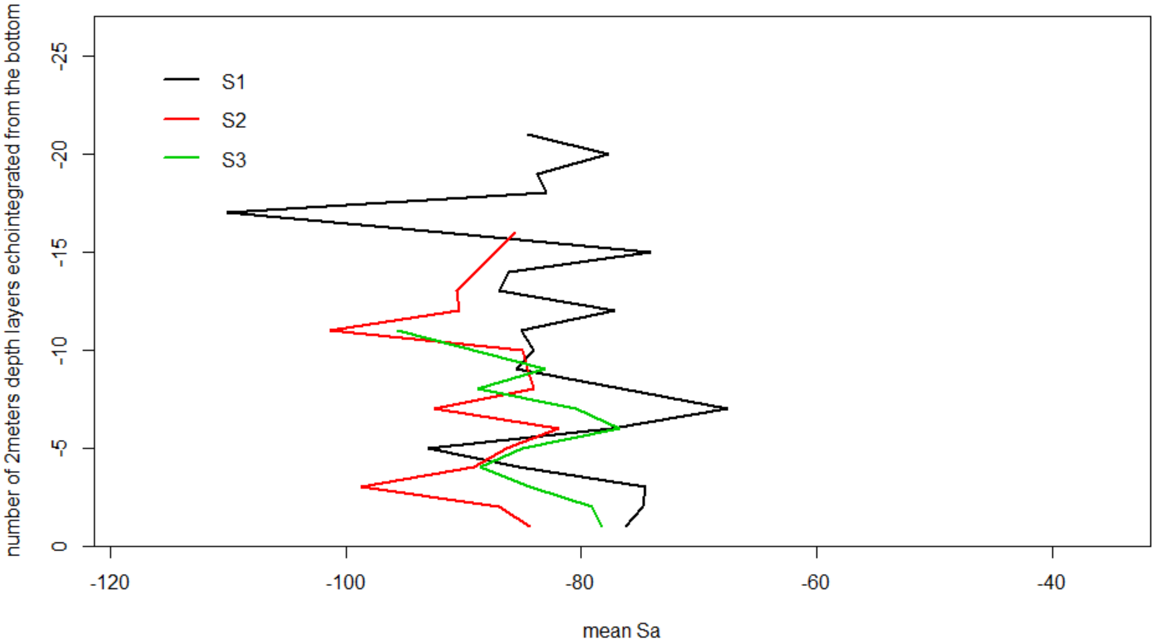


Figure A3.2: Vertical distribution of the mean area backscatter by 2 m depth layers for ***control*** transects of ***Grid 1***. The echo-integration has been made from the bottom which depth varies between transects.

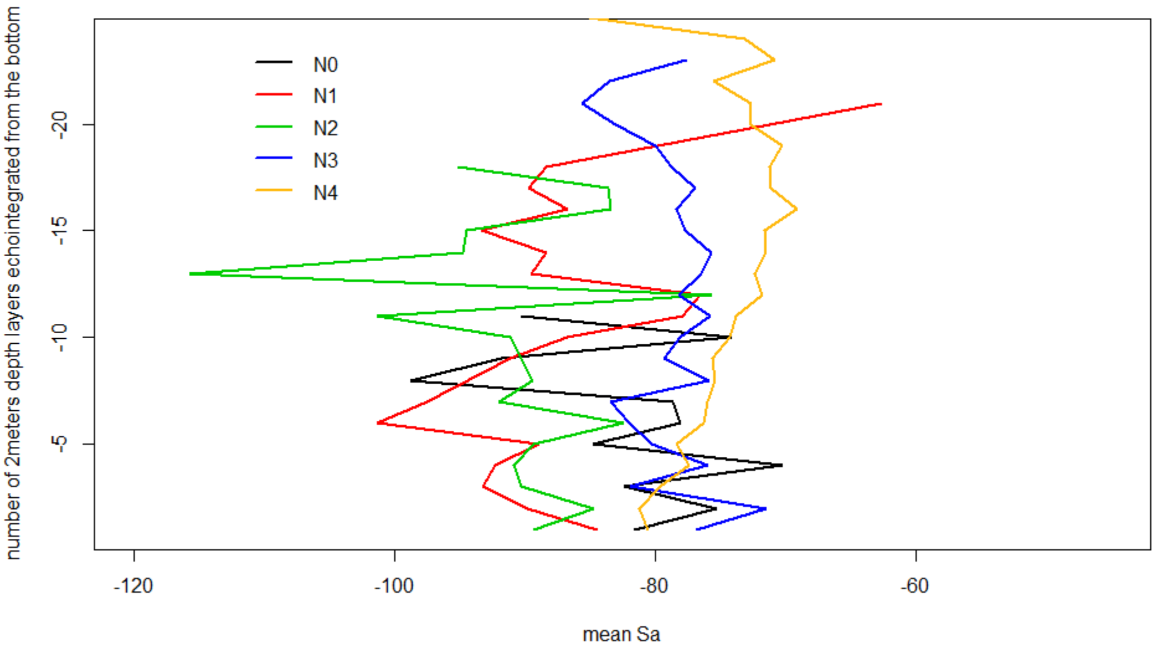


Figure A3.3: Vertical distribution of the mean area backscatter by 2 m depth layers for ***CLA*** transects of ***Grid 2***. The echo-integration has been made from the bottom which depth varies between transects.

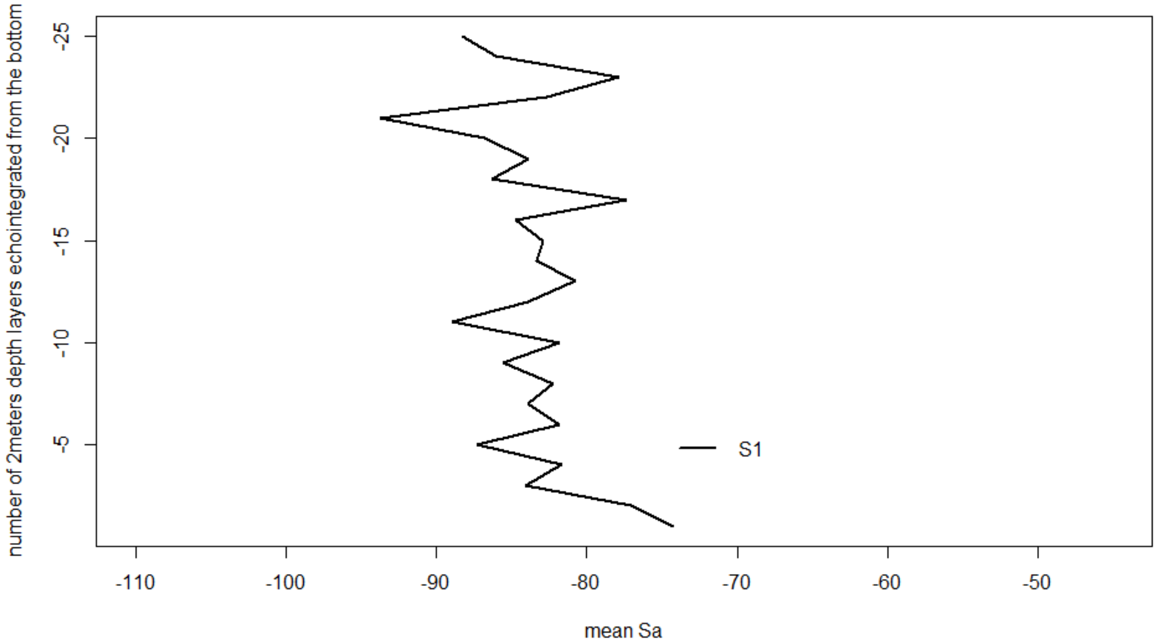


Figure A3.4: Vertical distribution of the mean area backscatter by 2 m depth layers for the c***ontrol*** transect of ***Grid 2***. The echo-integration has been made from the bottom which depth varies between transects.

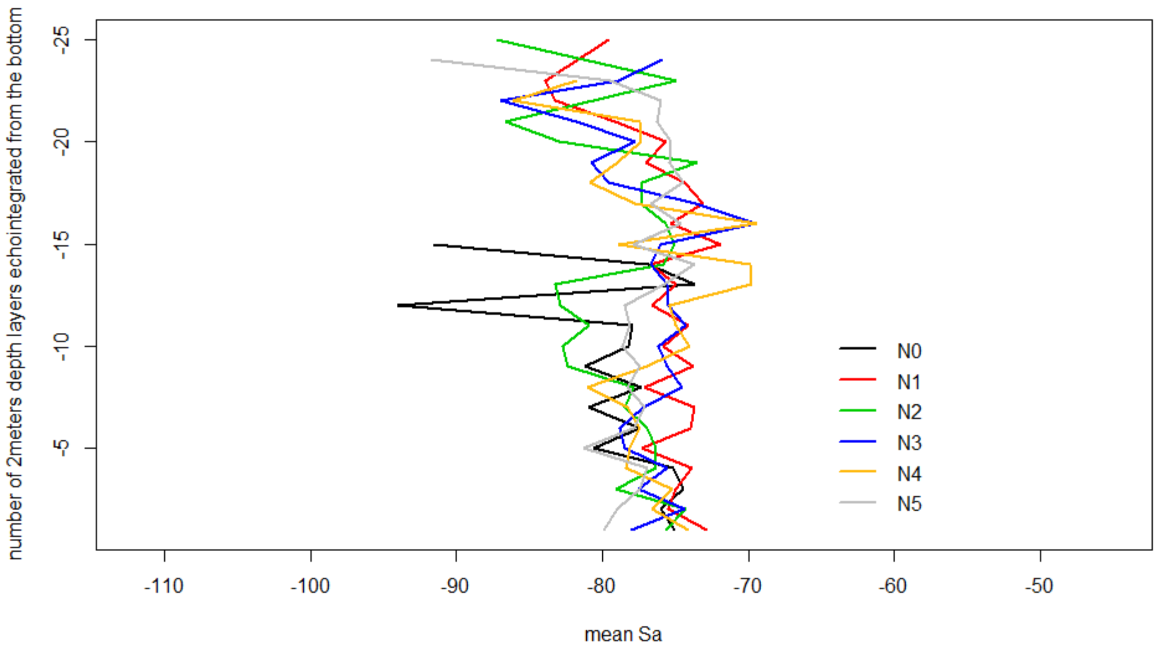


Figure A3.5: Vertical distribution of the mean area backscatter by 2 m depth layers for ***CLA*** transects of ***Grid 3***. The echo-integration has been made from the bottom which depth varies between transects.

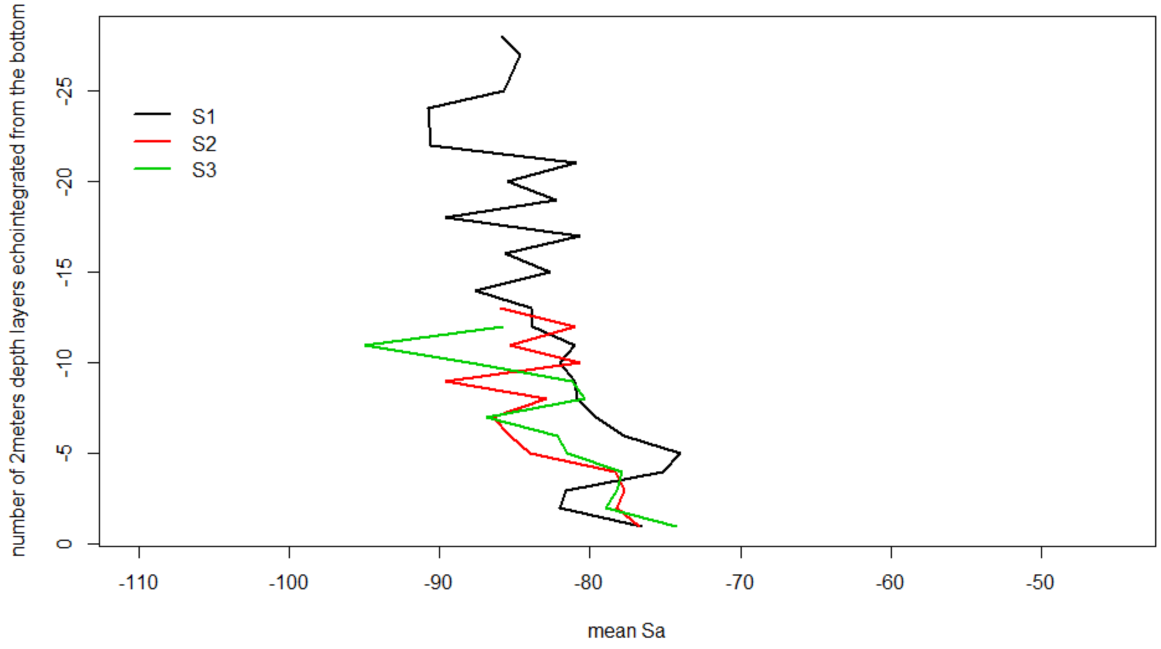


Figure A3.6: Vertical distribution of the mean area backscatter by 2 m depth layers for ***control*** transects of ***Grid 3***. The echo-integration has been made from the bottom which depth varies between transects.

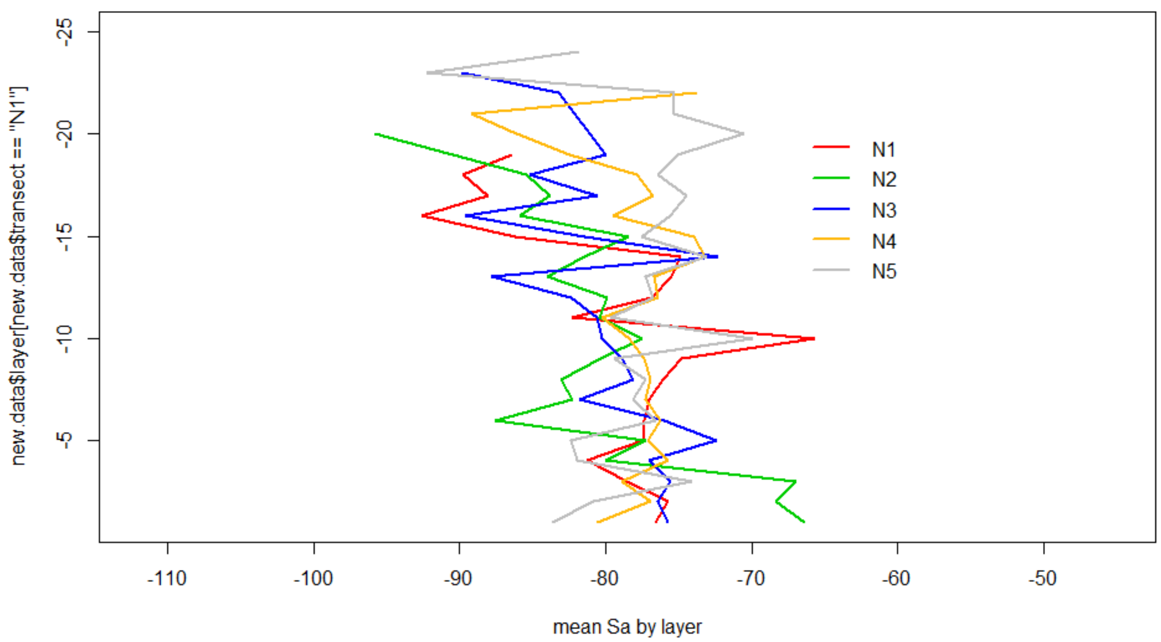


Figure A3.7: Vertical distribution of the mean area backscatter by 2 m depth layers for ***CLA*** transects of ***Grid 4***. The echo-integration has been made from the bottom which depth varies between transects.

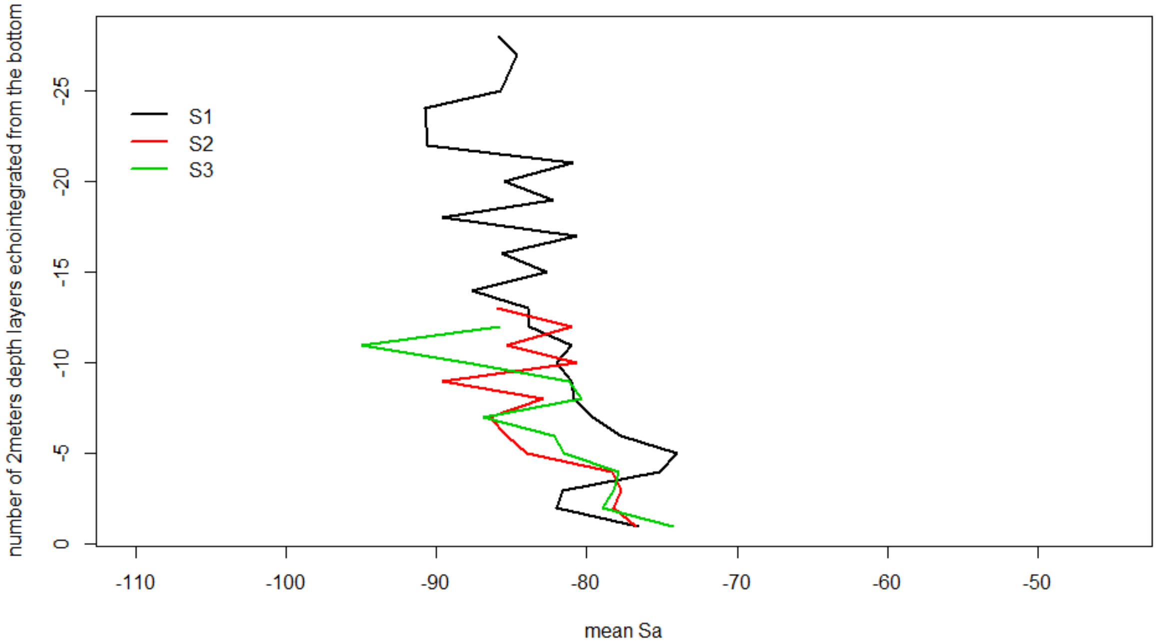


Figure A3.8: Vertical distribution of the mean area backscatter by 2 m depth layers for ***control*** transects of ***Grid 4***. The echo-integration has been made from the bottom which depth varies between transects.

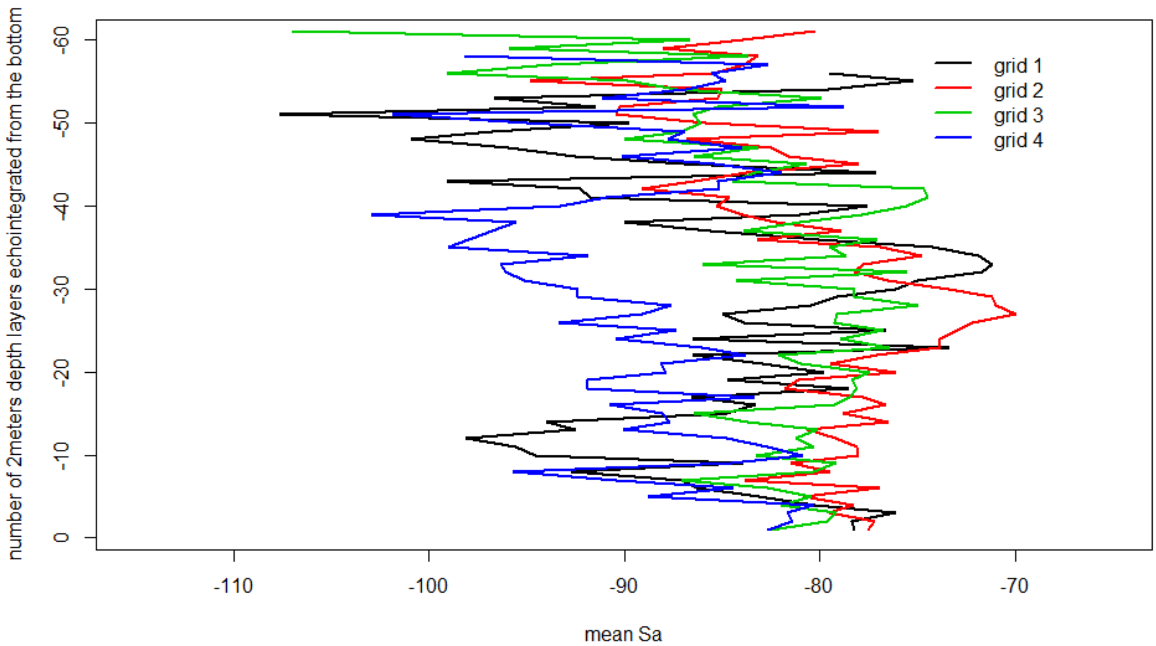


Figure A3.9: Vertical distribution of the mean area backscatter by 2 m depth layers for the ***along*** transects of the 4 grids. The echo-integration has been made from the bottom which depth varies between transects.

Appendix IV: Data overview for survey 1 to 3

Data summarized in Section 2.2 (Study objectives and data overview) for survey 1 to 3 are presented in more detail here, as multiple comparisons among groups. Data are presented using boxplots. Relative fish density (Sv) is plotted for each transect and each grid. Transects against and with the tide have been separated for better visualization of differences. The blue horizontal line in all plots is the mean Sv for the entire survey (all transects). These boxplot are very similar to the ones included in previous reports, any differences would be related to data here being exported in 20m distance bins instead of 1m depth layers.

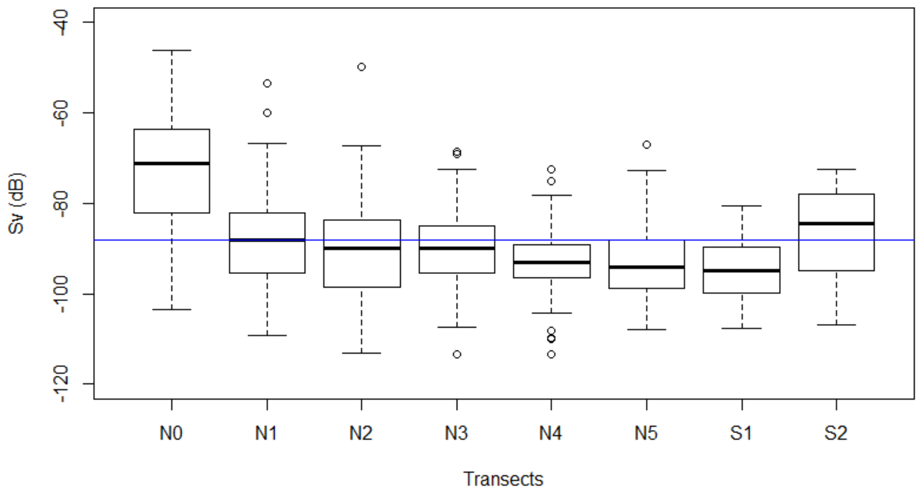


Figure A4.1: Boxplot of exported Sv (Volume backscattering strength) for grid 1 transects ***against*** the tide (ebb) of May survey.

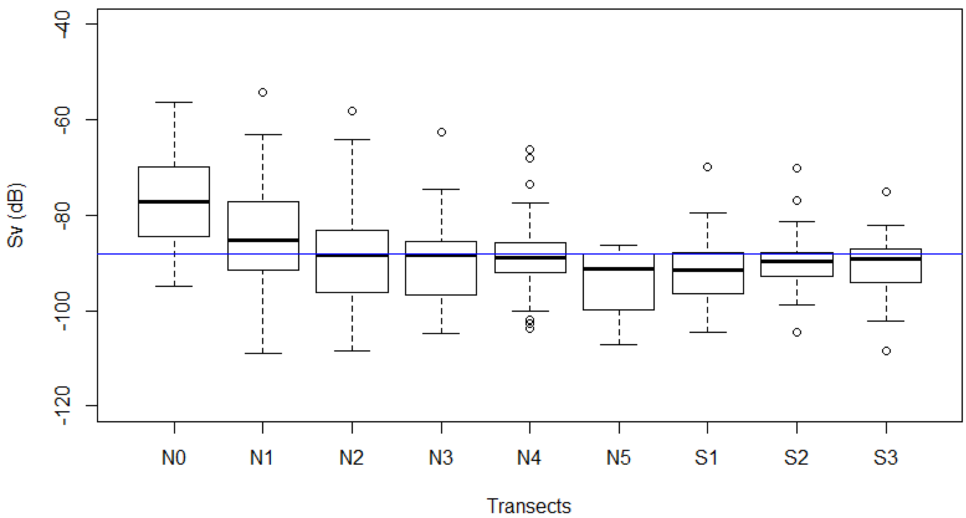


Figure A4.2: Boxplot of exported Sv (Volume backscattering strength) for ***grid 1*** transects ***with*** the tide (ebb) of ***May*** survey.

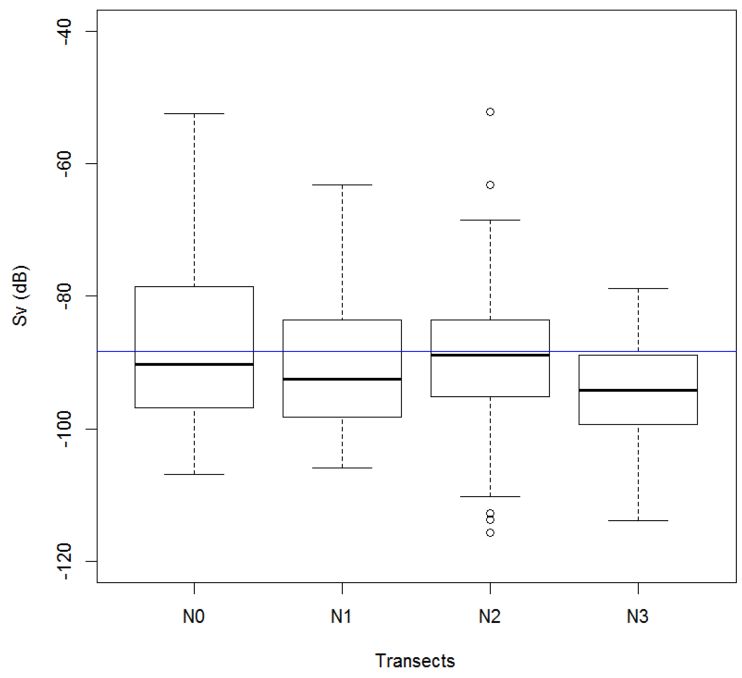


Figure A4.3: Boxplot of exported Sv (Volume backscattering strength) for ***grid 2*** transects ***against*** the tide (flood) of ***May*** survey.

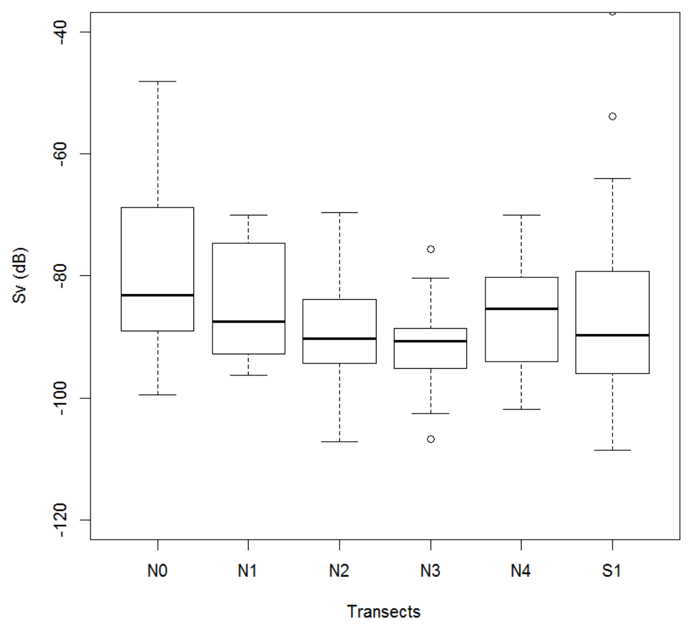


Figure A4.4: Boxplot of exported Sv (Volume backscattering strength) for ***grid 2*** transects ***with*** the tide (flood) of ***May*** survey.

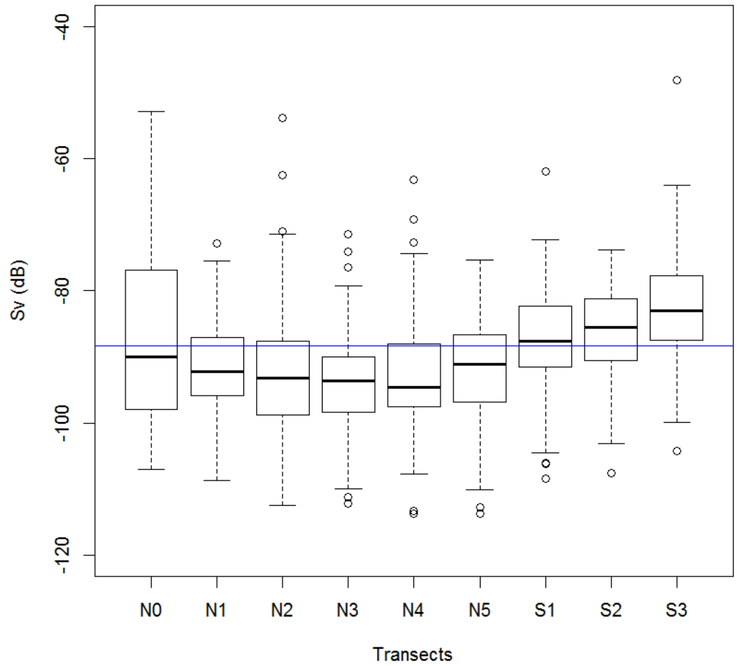


Figure A4.5: Boxplot of exported Sv (Volume backscattering strength) for ***grid 3*** transects ***against*** the tide (ebb) of ***May*** survey.

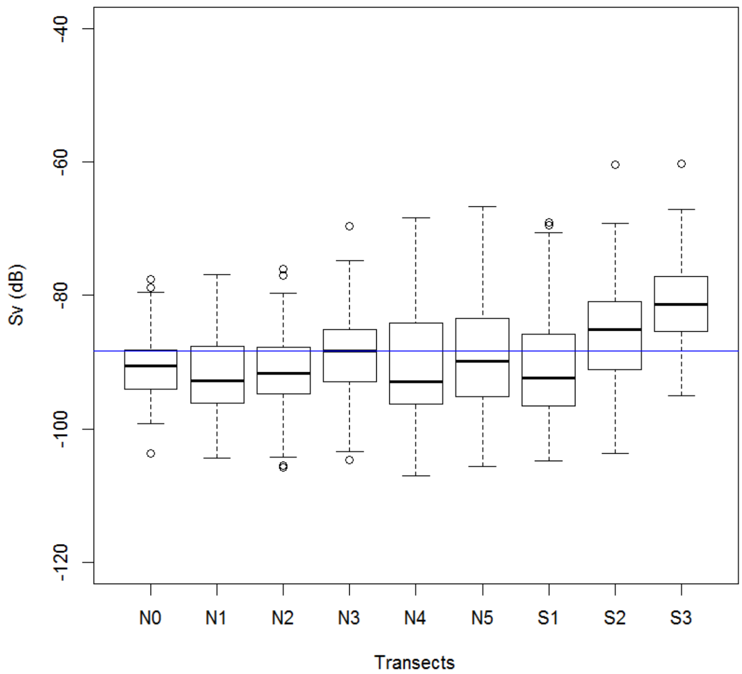


Figure A4.6: Boxplot of exported Sv (Volume backscattering strength) for ***grid 3*** transects ***with*** the tide (ebb) of ***May*** survey.

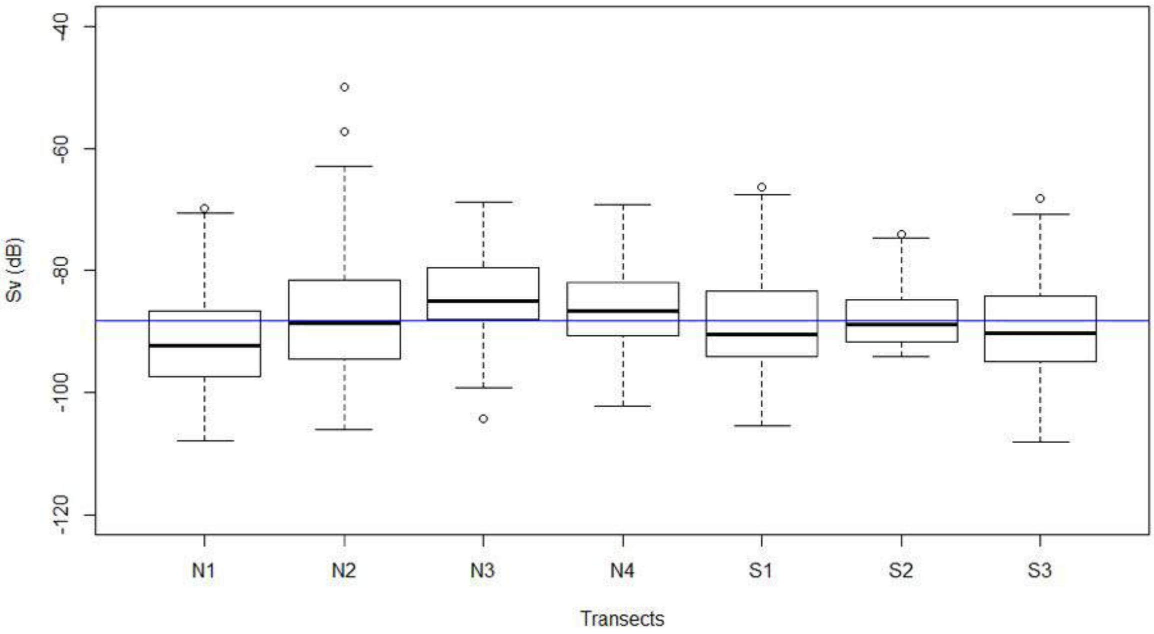


Figure A4.7: Boxplot of exported Sv (Volume backscattering strength) for ***grid 4*** transects ***against*** the tide (flood) of ***May*** survey.

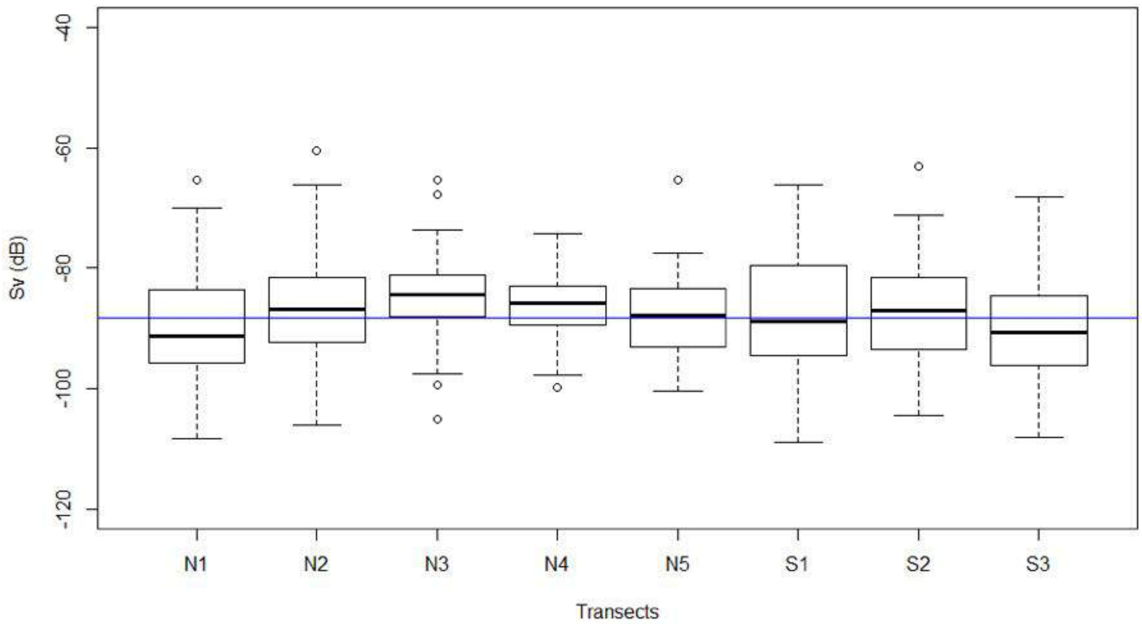


Figure A4.8: Boxplot of exported Sv (Volume backscattering strength) for ***grid 4*** transects ***with*** the tide (flood) of ***May*** survey.

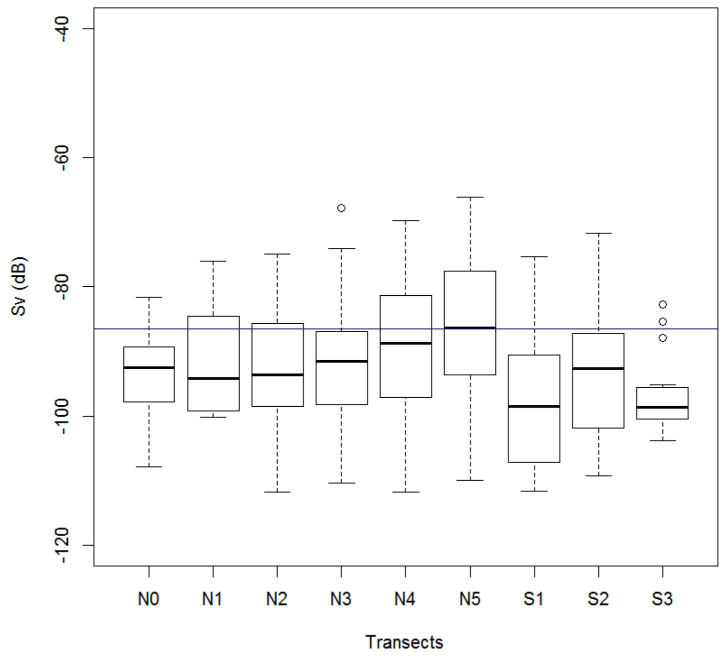


Figure A4.9: Boxplot of exported Sv (Volume backscattering strength) for ***grid 1*** transects ***against*** the tide (ebb) of **August** survey.

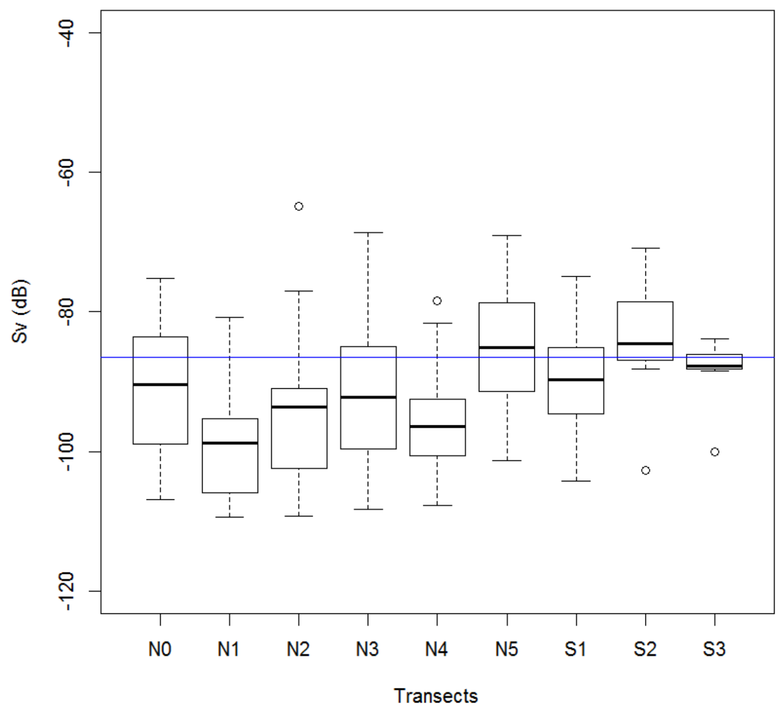


Figure A4.10: Boxplot of exported Sv (Volume backscattering strength) for ***grid 1*** transects ***with*** the tide (ebb) of ***August*** survey.

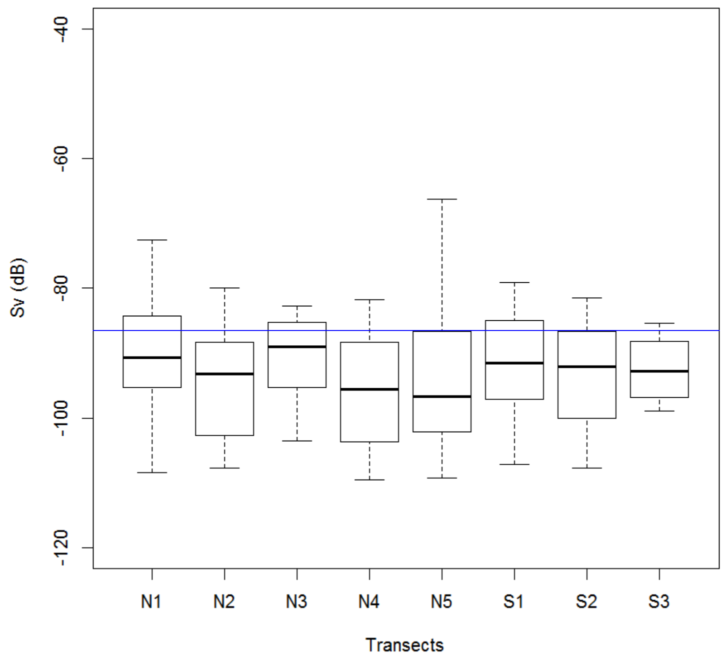


Figure A4.11: Boxplot of exported Sv (Volume backscattering strength) for ***grid 2*** transects ***against*** the tide (flood) of ***August*** survey.

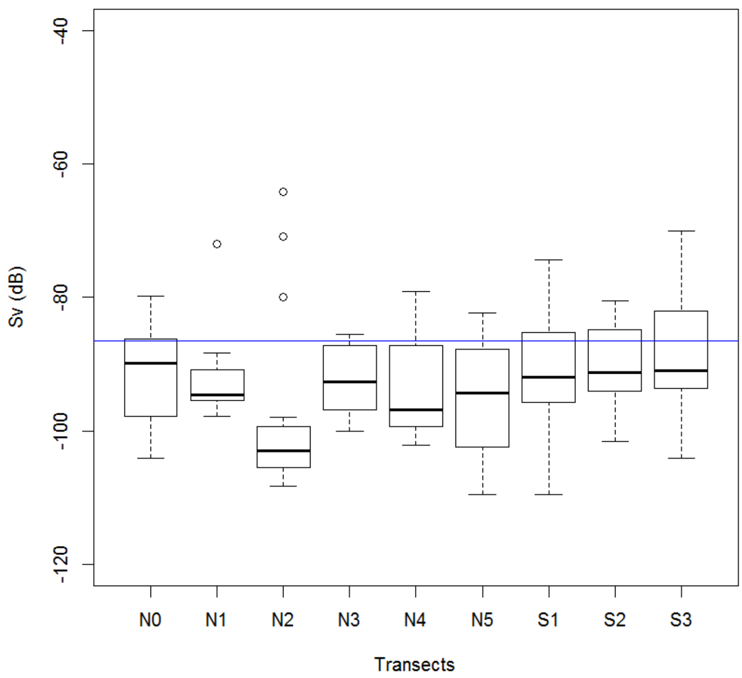


Figure A4.12: Boxplot of exported Sv (Volume backscattering strength) for ***grid 2*** transects ***with*** the tide (flood) of ***August*** survey.

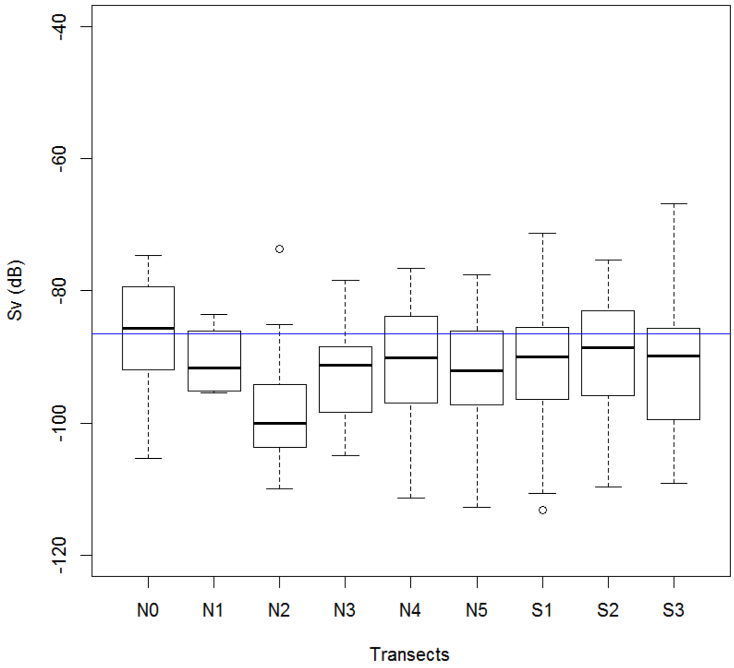


Figure A4.13: Boxplot of exported Sv (Volume backscattering strength) for ***grid 3*** transects ***against*** the tide (ebb) of ***August*** survey.

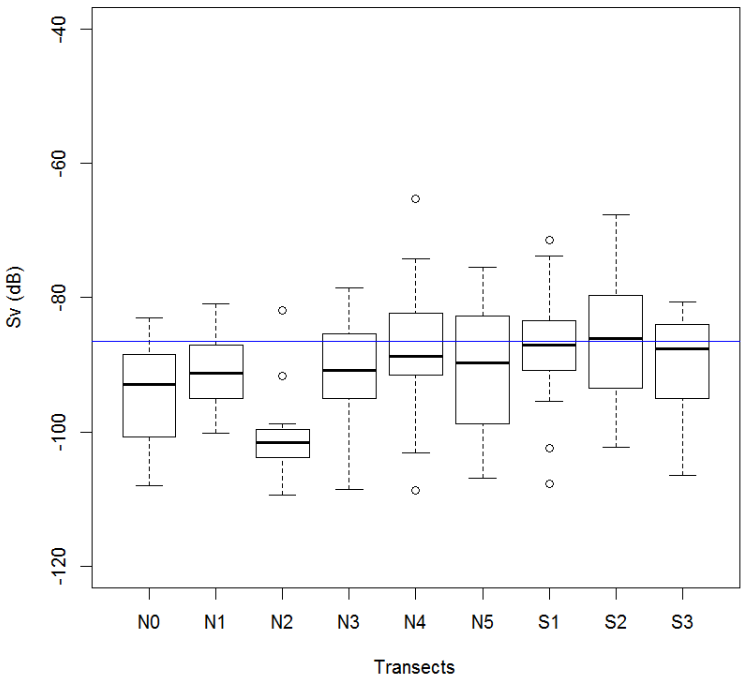


Figure A4.14: Boxplot of exported Sv (Volume backscattering strength) for ***grid 3*** transects ***with*** the tide (ebb) of ***August*** survey.

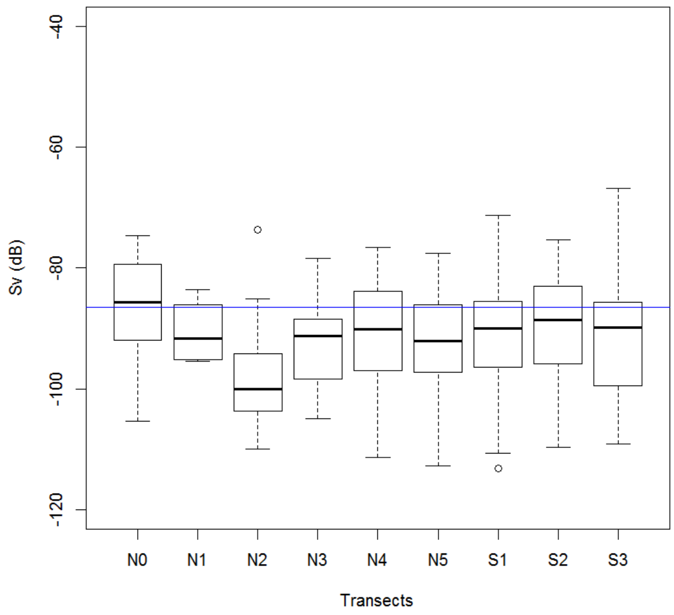


Figure A4.15: Boxplot of exported Sv (Volume backscattering strength) for ***grid 4*** transects ***against*** the tide (flood) of ***August*** survey.

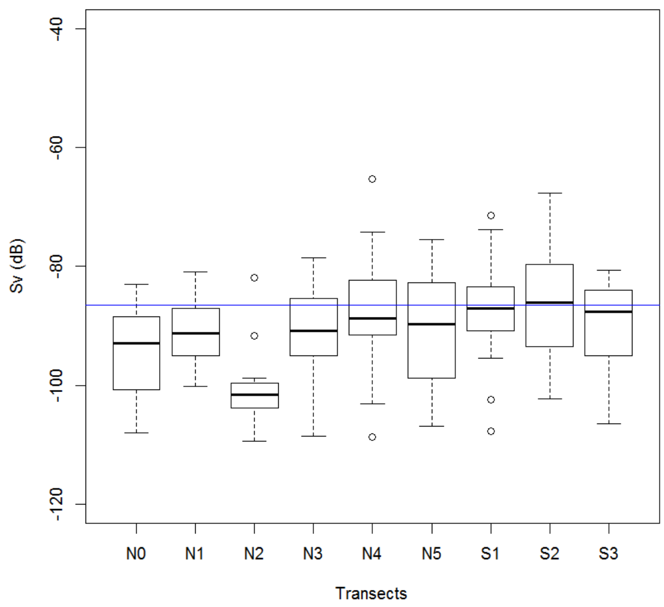


Figure A4.16: Boxplot of exported Sv (Volume backscattering strength) for ***grid 4*** transects ***with*** the tide (flood) of ***August*** survey.

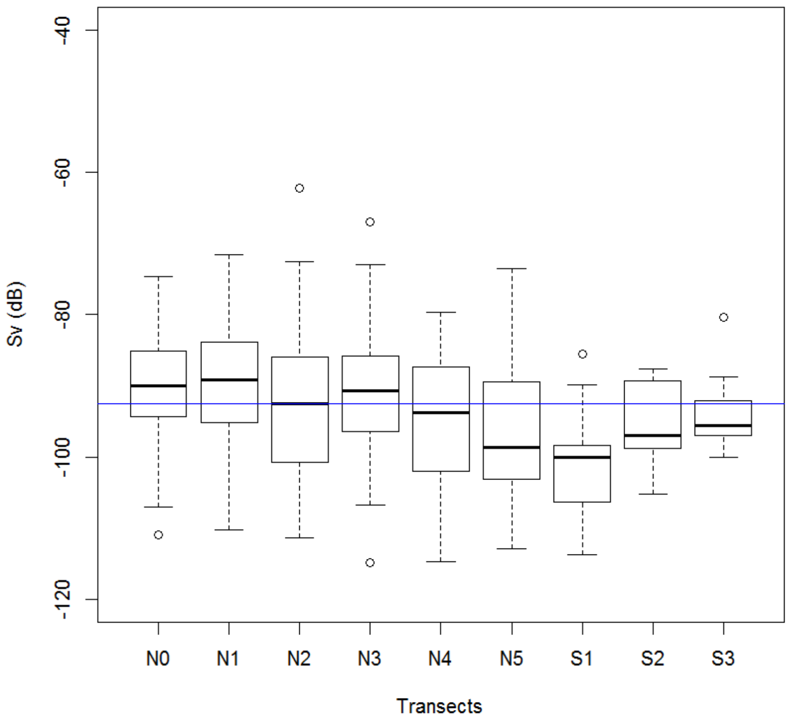


Figure A4.17: Boxplot of exported Sv (Volume backscattering strength) for ***grid 1*** transects ***against*** the tide (ebb) of ***October*** survey.

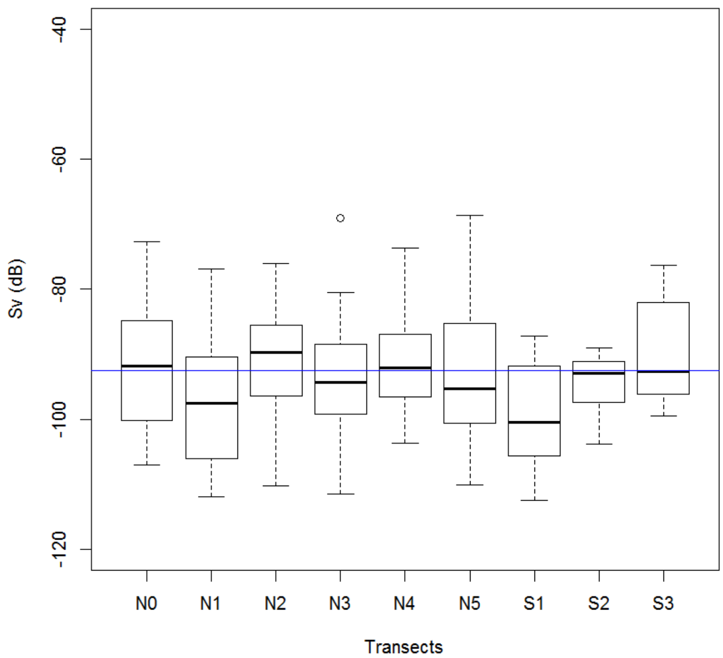


Figure A4.18: Boxplot of exported Sv (Volume backscattering strength) for ***grid 1*** transects ***with*** the tide (ebb) of ***October*** survey.

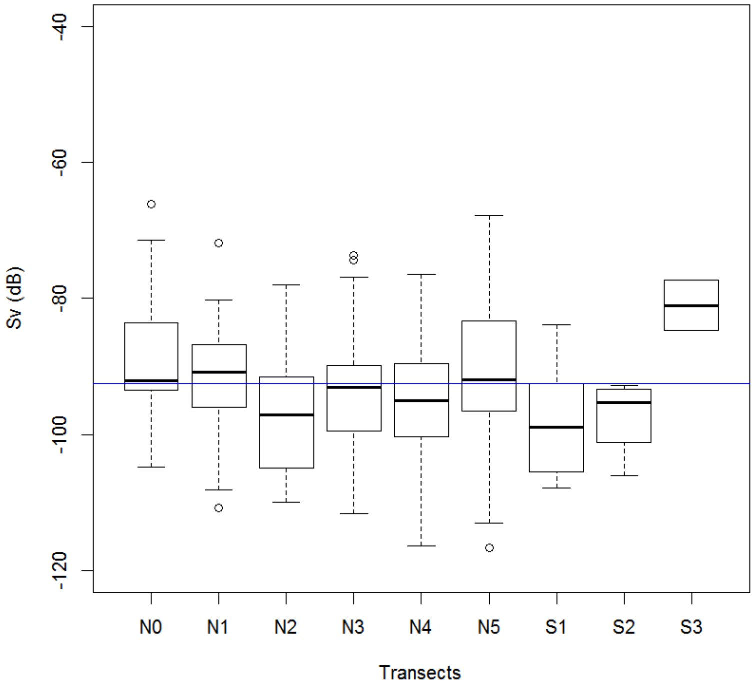


Figure A4.19: Boxplot of exported Sv (Volume backscattering strength) for ***grid 2*** transects ***against*** the tide (flood) of **October** survey.

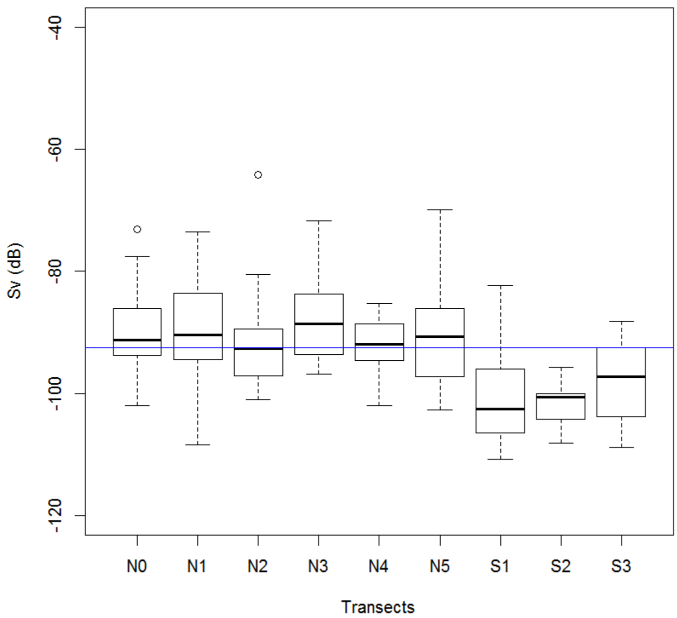


Figure A4.20: Boxplot of exported Sv (Volume backscattering strength) for ***grid 2*** transects ***with*** the tide(flood) of **October** survey.

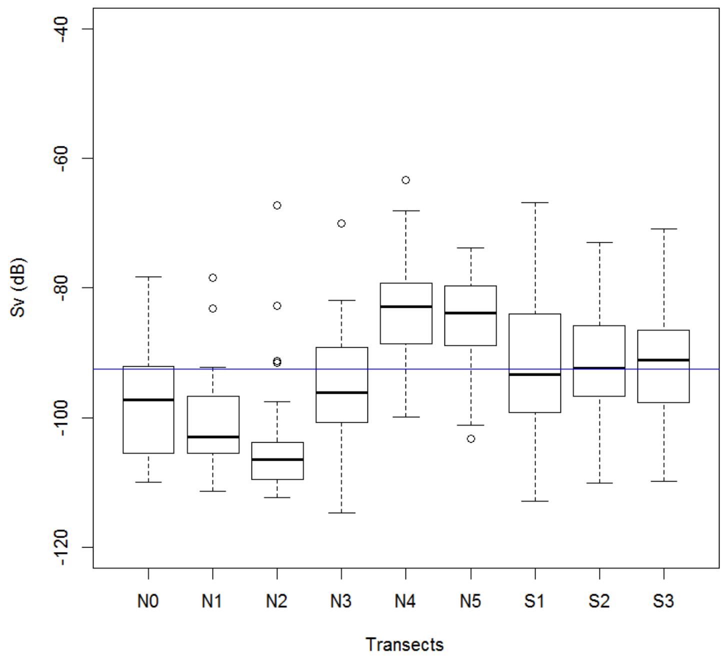


Figure A4.21: Boxplot of exported Sv (Volume backscattering strength) for ***grid 3*** transects ***against*** the tide (ebb) of ***October*** survey.

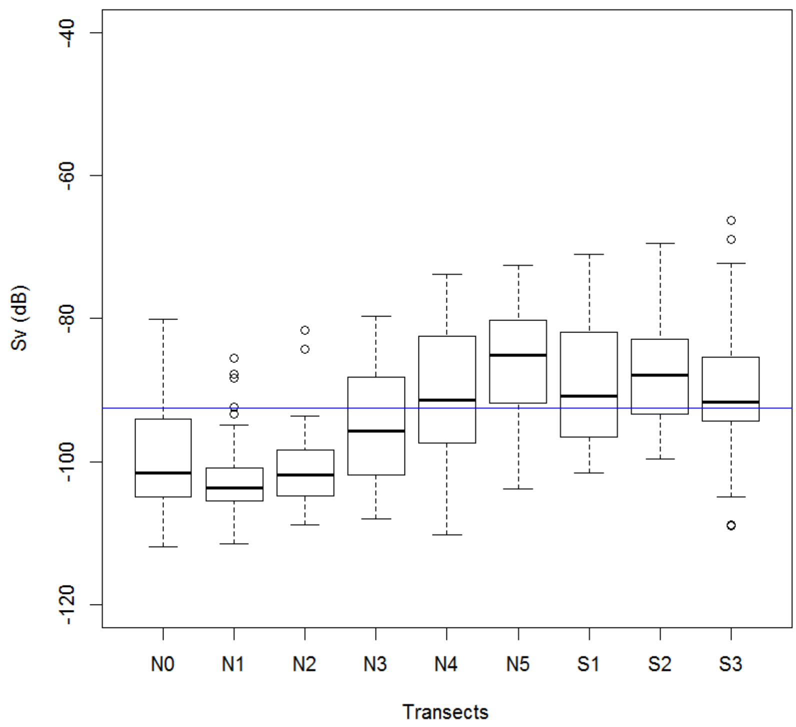


Figure A4.22: Boxplot of exported Sv (Volume backscattering strength) for ***grid 3*** transects ***with*** the tide (ebb) of ***October*** survey.

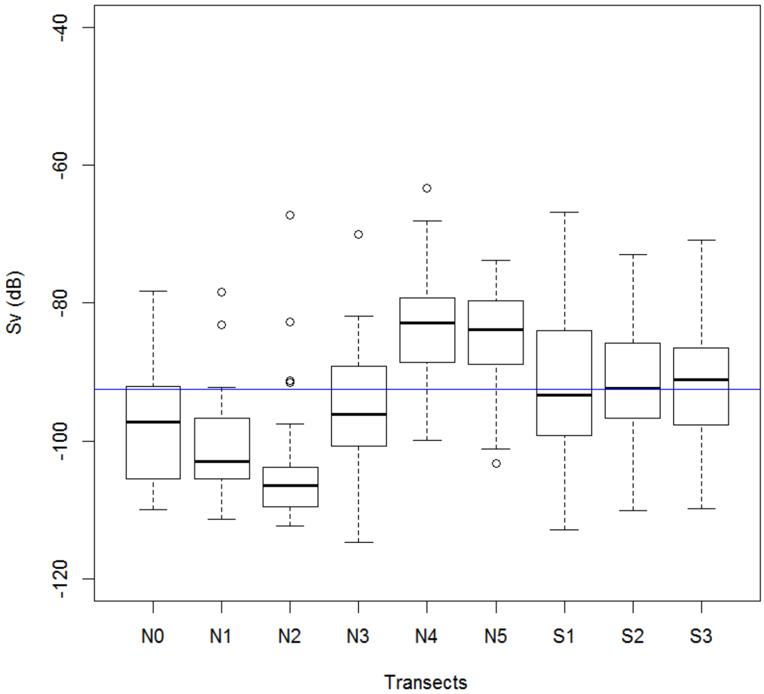


Figure A4.23: Boxplot of exported Sv (Volume backscattering strength) for ***grid 4*** transects ***against*** the tide (flood) of ***October*** survey.

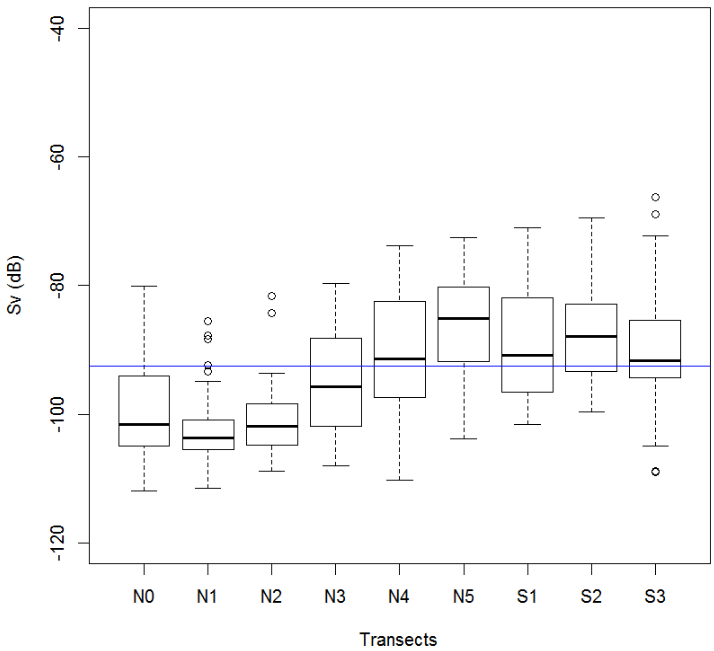


Figure A4.24: Boxplot of exported Sv (Volume backscattering strength) for ***grid 4*** transects ***with*** the tide (flood) of ***October*** survey.

Appendix 2: Marine Mammals Environmental Effects Monitoring Plan Interim Report

Interim report summarizing analyses from C-POD data collection from June – August 2016. Prepared by Sea Mammal Research Unit Consulting (Canada).

FORCE Marine Mammal EEMP - C-PODs in Minas Passage – Summer 2016 Interim Report

SMRU Consulting

[October 5, 2016]

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

Interim Report

Project Name:	**FORCE Marine Mammal EEMP - C-POD 2016**
Client:	FORCE
Project reference number:	SMRUC-2016-4-FEEMP
Lead Scientists:	Jason Wood, Ruth Joy, Dom Tollit
Project Manager:	Dom Tollit
FORCE Field Scientists:	Murray Scotney, Tyler Boucher

Written by:	Dom Tollit
Scientific approval:	Jason Wood
Date:	October 5, 2016

Table of Contents

1. Executive Summary

The main objectives of FORCE's marine mammal EEMP are to assess long-term effects of direct and indirect stressors on Harbour porpoise (*Phocoena phocoena)* by monitoring their activity and site use, with the primary objectives to assess firstly permanent avoidance of the mid field study area during turbine installation and operation and secondly large magnitude (~50%) change in the distribution (echolocation activity levels) of a portion of the population in the study mid-field area (see SLR Consulting Ltd. (2015).

Three C-PODs were successfully calibrated, deployed and recovered to monitor marine mammals (porpoise and dolphins) presence in Minas Passage as part of FORCE's marine mammal EEMP. All 3 C-PODs collected data across the whole 84-day deployment period (June 7th – August 30th 2016). Average percent time lost due to sediment interference was 20-29%, similar to previous studies at these locations. Harbour porpoise were detected across 99% of days, but at low rates with a median of 7 minutes per day with presence detected in 3.64% of all 10 minute periods. Across the previous 2011 and 2012 C-POD baseline study (Wood et al. 2013), porpoises were detected on 98% of days, with higher minutes per day (median = 22 minutes) and present 4.1% of all 10 minute periods (noting this previous study collected data over spring and fall as well as summer). No dolphins were detected as per previous baseline studies. Porpoise detection rates varied across the 84-day study and were at times higher in periods of July and August than observed previously in 2011 and 2012, but lower in June, highlighting inter-annual variability at sites within the demonstration area. While the site near berth D (D1) had higher apparent mean detection rates (0.09 detection positive minutes per 10 minute period) than at sites C1 (0.06) and E1 (0.05), the relative impact of percent time lost across sites (Figure 9a) has not yet been taken into account. This analysis will be undertaken during the GAM modelling planned for the final report, but overlapping standard deviations around these mean detection rates currently suggest insignificant site differences.

Recommend deployment of extra C-PODS at locations W2 and S2 as per past discussions. Maintain current C-POD settings and deployment methodology.

2. Introduction and EEMP Objectives.

Tidal energy is an 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 offshore test site is in the Minas Passage area of the Bay of Fundy near Cape Sharp, close to and west of Black Rock, roughly 10 km west of the town of Parrsboro (Figure 2).

Figure 1. Regional location of FORCE test site.

Figure 2. Detailed location in Minas Passage.

Harbour porpoise (*Phocoena phocoena*), the key marine mammal species in Minas Passage (Tollit et al. 2011, Wood et al. 2013 and Porskamp et al. 2015), use high frequency echolocation clicks to hunt and communicate and are known to be very susceptible to pulsed noise disturbance (Tougaard *et al.* 2009), but few studies have focused on exposure to continuous low frequency noise sources, such as those emitted by tidal turbines. This interim (Summer 2016) Status Report describes the results of the first 3 months of Marine Mammal C-POD Monitoring Program as part of the FORCE's March 2016 Environmental Effects Monitoring Program (EEMP) at its marine demonstration and testing facility in Minas Passage. The Summer 2016 interim Status Report aims to describe the current Programs objectives, methodology, problems encountered, detection rate results, along with any recommendations for the second deployment. Methodology included optimal site selection, a pre-deployment calibration test, data quality control assessment and preliminary porpoise detection data analysis.

The main objectives of the marine mammal EEMP are to assess long-term effects of direct and indirect stressors on Harbour porpoise by monitoring porpoise activity and site use, with the primary objectives to assess: 1) Permanent avoidance of the mid field 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 (see SLR Consulting Ltd. (2015).

SMRU Consulting Canada undertook the design, analysis and interpretation of marine mammal acoustic monitoring studies to collect previous baseline information in the FORCE tidal demonstration site in Minas Passage, Nova Scotia, Canada. Work was in collaboration with Acadia University and funded by FORCE and OERA. 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 7 C-POD devices to collect long-term baseline and assess reliability (Wood et al. 2013, Porskamp et al. 2015). A total of 1,342 C-POD site monitoring days were collected across this period. General Additive Models (GAM-GEE) were used to describe Harbour porpoise seasonal activity and key effect variables for a three-year data collection period (e.g., current, location, see Figure 3). This stage of the EEMP project plans to collect further C-POD marine mammal detection data to contrast with previously collected baseline data. Delays in the deployment of the Cape Sharp Tidal Venture turbine have allowed for the collection of additional baseline (rather than turbine effects) information on porpoise detections across 3 locations in summer 2016, with additional detection data to be collected at 5 locations in the fall of 2016, including areas of greater water depth outside of the demonstration area. Additional baseline data will improve future turbine effects analysis, not least in capturing the scale of inter-annual variability in porpoise presence in Minas Passage, but also in further confirming the consistency of key seasonal trends detected in previous 2011-2014 analyses (e.g., spring and fall peaks in presence, higher nighttime activity).

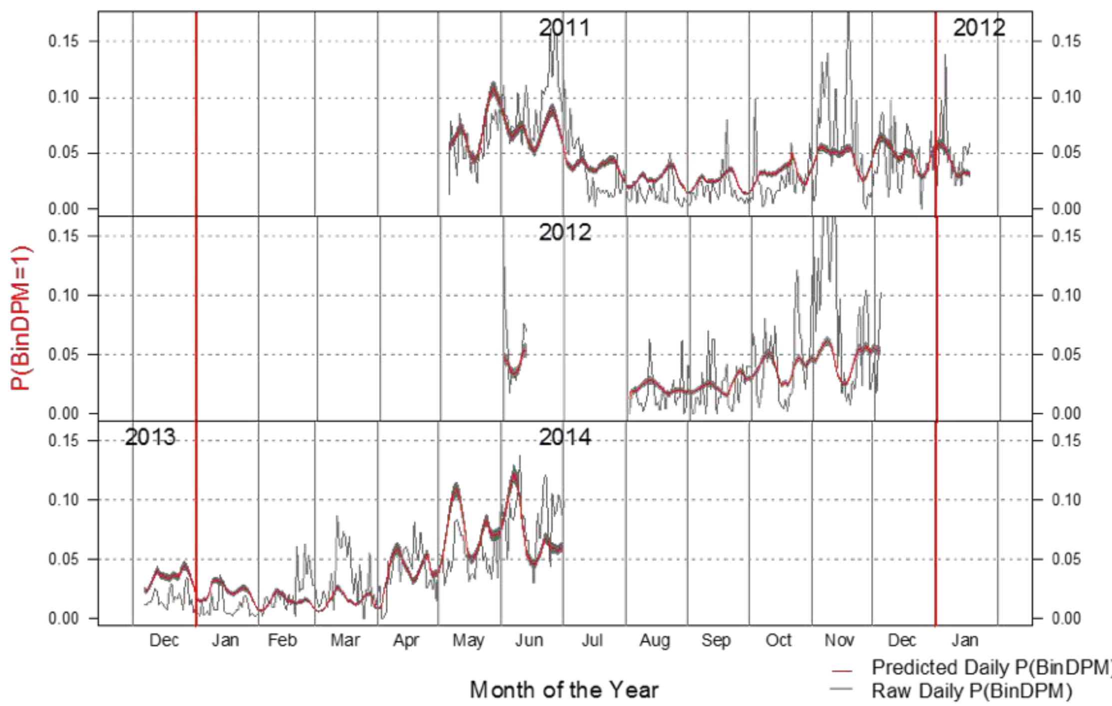


Figure 3. FORCE baseline data 2011-2014. Raw data BinDPM per day (grey lines) versus GAM-GEE model predictions of the overall mean probability of porpoise detection per time bin (PBinDPM) over time (red line), and the associated modeled 95% prediction errors (grey shading on red line).

3. Methods and Results

3.1 C-POD Calibrations

As recommended by FORCE's Marine Mammal EEMP, SMRU Consulting and FORCE staff conducted an echolocation click 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 loaded with settings that will be used for the FORCE EEMP as described in 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 icTalk

located at the center of the test tank (Figure 4), and recorded >100 clicks at each amplitude on each unit. C-PODs were mounted around the periphery of the tank (
Figure *4*). This was undertaken twice to test all 5 C-PODs, with one unit tested twice, to ensure between test compatibility.

Figure 4. Experimental setup with the icTalk in the center of the tank, 3 C-PODs around the periphery and an icListen reference hydrophone, also at the periphery.

All 5 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. Figure 5 shows the distribution of click Sound Pressure Levels (SPL) in units of Pascal for each C-POD unit and round (2973 was tested in both round 1 and 3), for each of the 5 amplitude clicks (left to right on 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.

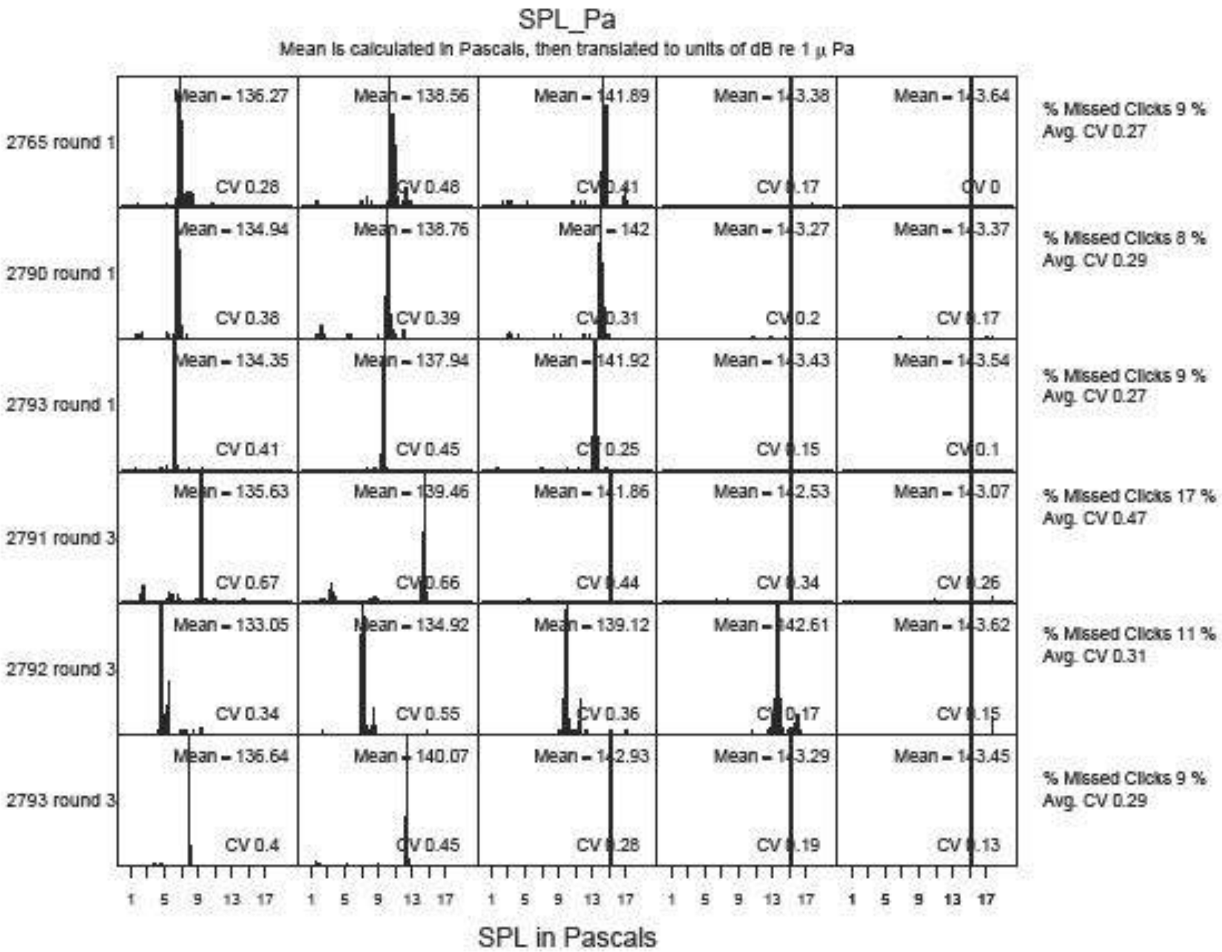


Figure 5. Distribution of click received levels (Sound Pressure Level reported in Pascals). Each column corresponds to each of the 5 amplitude levels of clicks generated by the icTalk. The loudest 2 sets of clicks exceeded the input level of the C-PODs and were thus recorded at the maximum SPL of the 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.

Based on the fact that C-PODs 2765, 2790 and 2793 consistently report similar SPL levels, and have the lowest CV and % missed clicks, we recommended the use of these 3 units in the current EEMP. The sensitivity of C-POD 2791 was clearly lower than all other CPODs with % clicks missed at 17% compared to 8-11% for the remaining CPODs. CPOD 2792 should therefore be the next unit selected for deployment. If C-POD 2791 is used in future deployments, these calibrations could be used to develop click correction factors to more robustly compare detection rates across all 5 units.

3.2 **C-POD Deployment and recovery information (conducted by FORCE Field Scientists)**

Three C-PODS and associated moorings and buoys were loaded onto the modified lobster fishing boat *Nova Endeavor* in Parrsboro, Nova Scotia on June 6, 2016. The deployment took place in a single tide, roughly 3 hours, on 7 June 2016. Each torpedo 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 6).

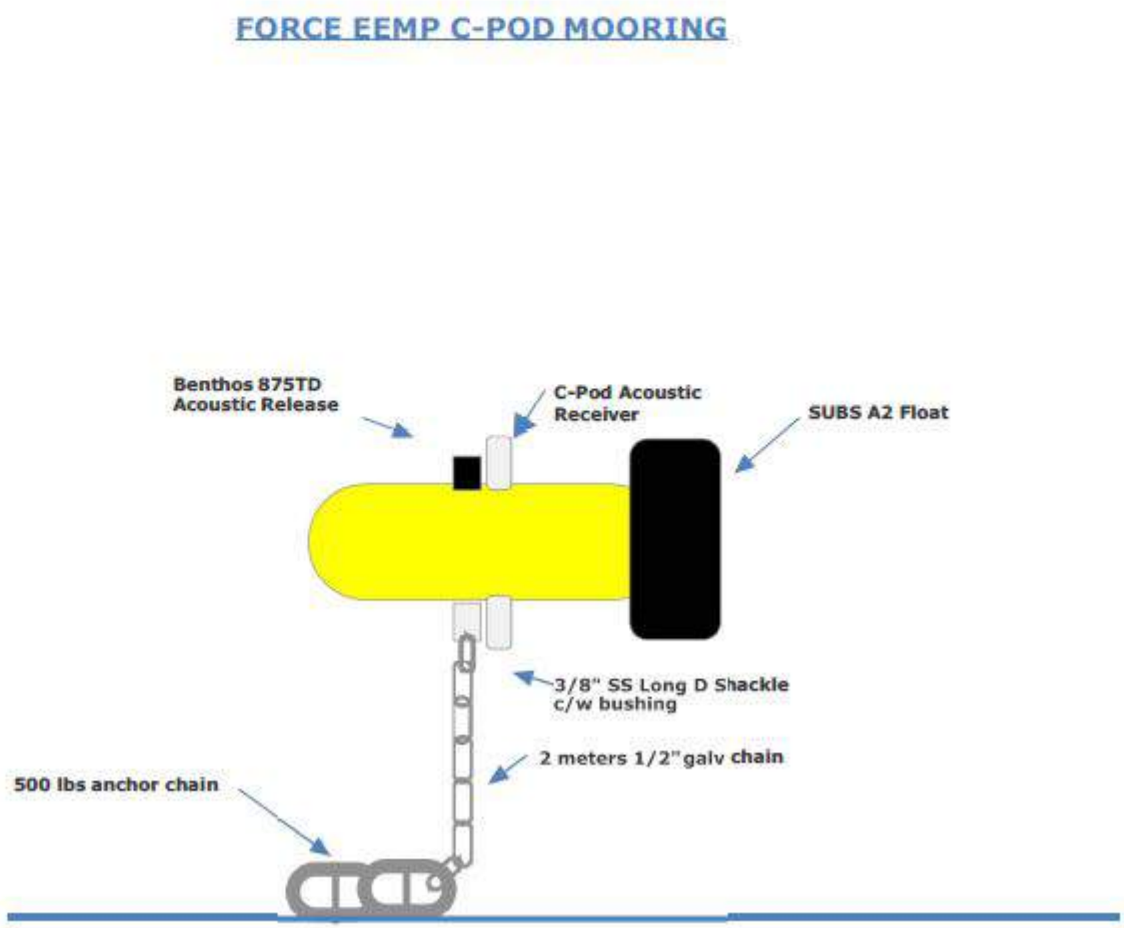


Figure 6. Diagram of FORCE C-POD mooring

Deployment (lowering overboard) of the C-PODs was achieved by assembling each individual mooring on board. The anchor was placed in the water over the stern, the anchor then raised with the capstan via the a-frame mounted on the stern, lifted clear of the deck, and pushed forward away from the vessel and released when safe to do so, allowing the C-POD and mooring to free fall to the sea bottom.

The following 3 deployment locations were selected (Table 1) and are depicted in Figure 7. Depths ranged from 44-66 m.

Table 1 Deployment locations of 3 C-PODs in Minas Passage

C-POD Number	Location goal	Actual location	Deployment depth
W1	-64 26.113 W 45 21.993 N	-64 26.125 W 45 21.944 N	66m
E1	-64 25.334 W 45 21.969 N	-64 25.333 W 45 21.973 N	53m
D1	-64 25.402 W, 45 21.765 N	-64 25.388 W, 45 21.766 N	44m

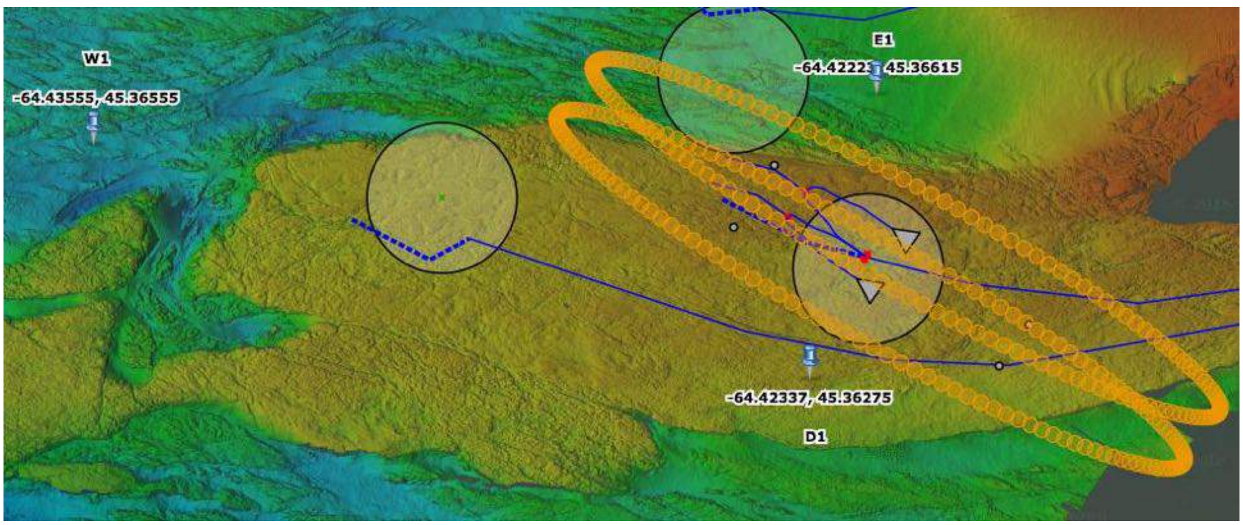


Figure 7. Locations selected for 3 C-POD locations depicted by dropped pins. The locations of the nearby berths are depicted by round black circles and berth D has the location of the two proposed turbines depicted by grey triangles.

Site selection was based on continuing to monitor the two core long-term baseline sites within the FORCE demonstration area (Sites W1 and E1). These sites represent the best baseline coverage for 2011-2014 with 535 and 470 days of coverage. The third site selected was D1, in the vicinity of Berth D – where CSTV planned to deploy two Open Hydro turbines in summer 2016. A vertical cone of safety (Figure 8) 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 OSP document.

Recovery of all 3-PODs was successfully achieved by the FORCE Field Scientists on the *Nova Endeavor* on 30 August, 2016.

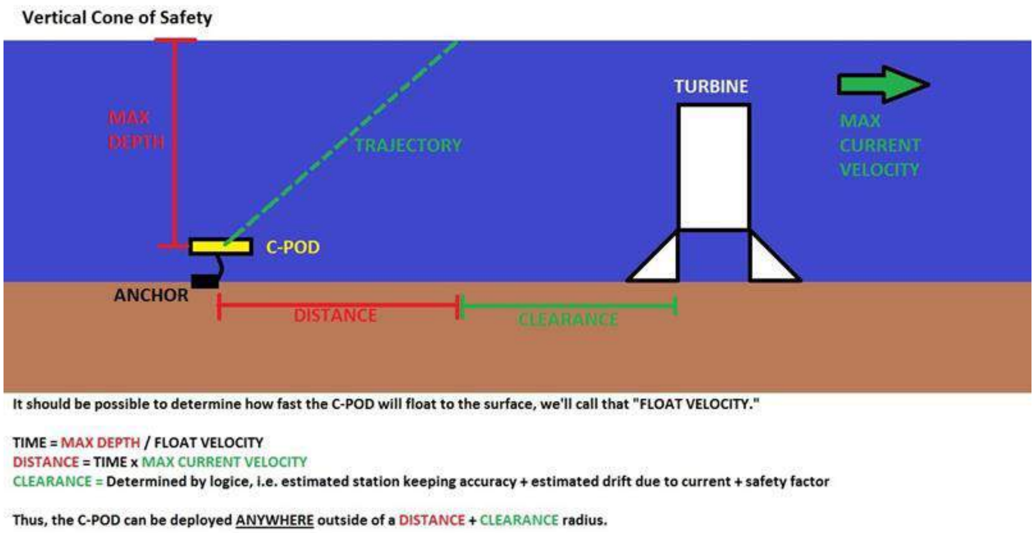


Figure. 8. Illustration of C-POD vertical cone of safety calculations

3.3 C-POD Data QA

C-POD.exe V2.044 was used to process the data and custom Matlab R2016a code used to calculate statistical outputs and create data plots using detection positive minutes (DPM) per day and DPM per 10-minute period (DPMp10M) as the key metric for comparison. The QA assessment specifically targets if non-biological interference has occurred, confirms that the porpoise click detector is operational and assess the scale of % time lost due to click maximum buffer exceedance (due to internal memory restrictions, non-target noise from sediment movement and moorings result in periods of lost recording time in each minute).

C-PODs were started, deployed and retrieved as shown in the Table 2 below. All dates and times in this report are given in UTC.

Table 2. C-POD deployment and retrieval information (date and time)

Location	C-POD number	Start	Deployment	Retrieval
W1	2793	27 May 2016 20:06	7 June 2016 17:52	30 August 2016 14:09
E1	2765	27 May 2016 20:06	7 June 2016 17:59	30 August 2016 13:50
D1	2790	27 May 2016 20:06	7 June 2016 18:08	30 August 2016 13:58

To allow for the hydrophone elements to reach their typical underwater sensitivity, data were analyzed from a day after deployment (8 June 2016 18:00) until just before retrieval (30 August 2016 13:30). This 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.

Percent time lost was calculated for each C-POD and is presented in Table 3. Mean % time lost ranges from 20-29%. Cumulative probabilities (Figure 9a) are similar to that found for sites W1, N1 and S2 in August 2011 (see 9b taken from Fig. 8 in Wood et al. 2013). Far higher rates were reported by this previous study for S1 and E2 and as a consequence these sites were omitted from consideration to be included in this EEMP.

Table 3. Percent time lost by C-POD location

Location	Mean % Time Lost
W1	26.44%
E1	29.35%
D1	20.03%

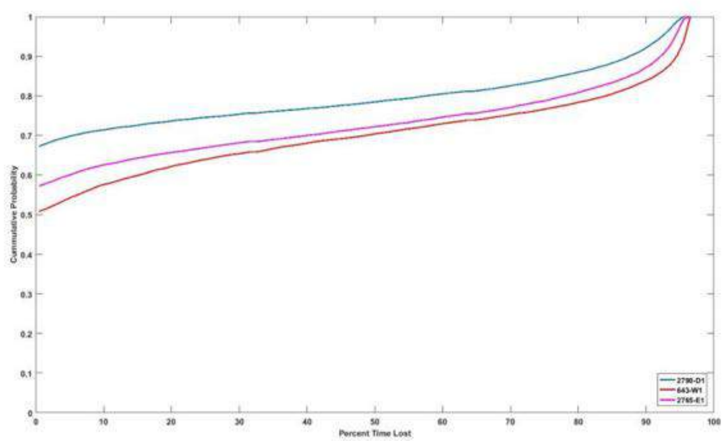


Figure 9a. Cumulative probability plot of percent time lost across 3 locations. D1 has the lowest rates of % time lost.

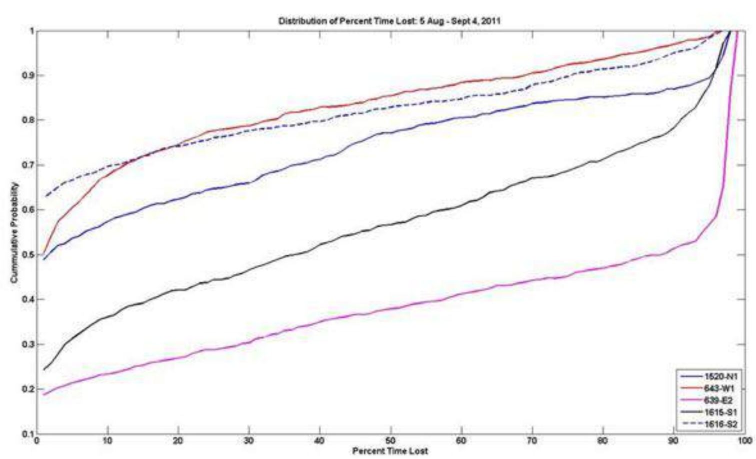


Figure 9b. Cumulative probability plot of percent time lost across 5 locations in August 2011.

3.4 **Porpoise click detection rates**

3.4.1 Overall summary of detection rates

While harbour porpoise were present in Minas Passage on 83 of the 84 calendar days (99%), they were present on average only 0.67% of the minutes in a day (median DPM/day = 7 minutes).

Descriptive statistic are provided in mean DPM per 10 minute period +/- standard deviation (SD). Mean DPMp10M was 0.07 and porpoise were detected in 3.64% of all 10 minute periods (Table4).

Table 4. Descriptive statistics for all the data collected. Percent of 10MP with DPM is the percentage of 10 minute periods with at least one porpoise detection.

Mean DPMp10M	SD	% of 10MP with DPM	No. of 10MP
0.07	0.42	3.64%	35,916

Across the 2011 and 2012 baseline data (Wood et al. 2013), porpoise were detected on 98% of days, present on average 1.5% of minutes per day (median DPM/day = 22 minutes), a mean DPMp10M of 0.08 and a % of 10MP with DPM of 4.1%. These average rates were somewhat higher than found in this June through August study and reflect the inclusion of peaks in presence previously reported during both May-June and late fall (see Figure 3).

Very few possible dolphin clicks were detected in Minas Passage during this studies' three C-POD deployments. These were checked and all confirmed to be false positives. As a consequence, no confirmed dolphin detections were made, as also found during 2011-2012 deployments (Wood et al. 2013).

3.4.2 Study period detection rates

Porpoise detection per day varied through the deployment period. Peaks at all three sites were observed in the second week of June, and mid July and mid August (Figure 10a). Compared to baseline data from 2011 and 2012 (Figure 10b), the June peak was lower than in 2011, but the other peaks noted were not clearly observed in the 2011 (or 2012), highlighting inter-annual variability in porpoise use of these site location in summer. This variability is further highlighted by DPMp10M plots from this study (Figure 11a) compared to those recorded for W1 in summer 2011 (Figure 11b).

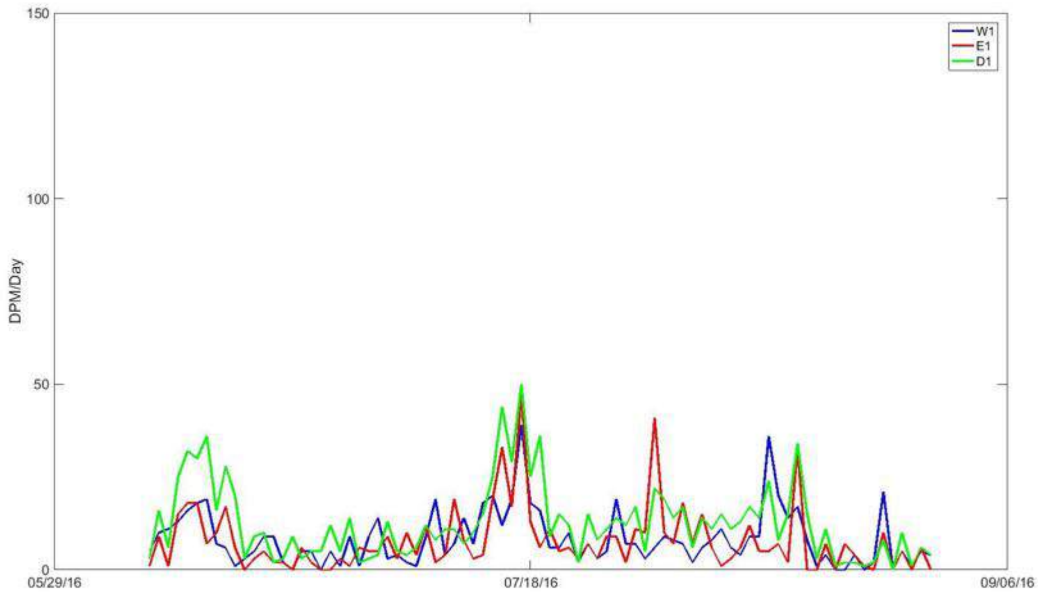


Figure 10a. DPM per day at 3 monitoring locations through the study period (7th June-August 30th 2016).

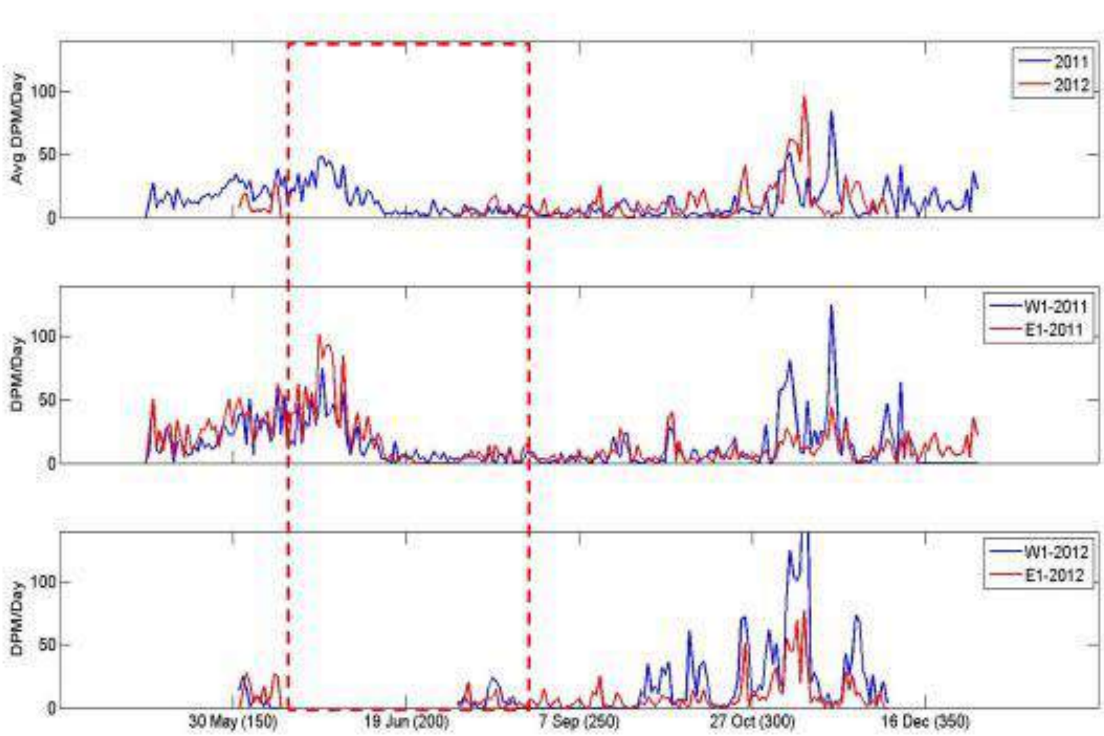


Figure 10b. DPM per day at location W1 and E1 through 2011 and 2012 baseline studies. The dashed red box depict the time period reported in this interim study.

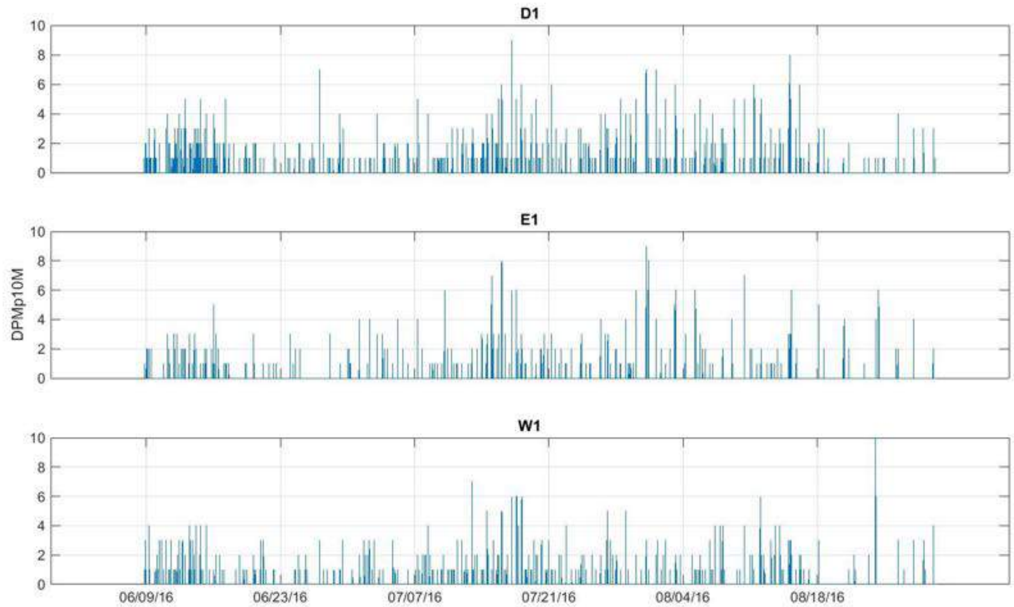


Figure 11a. DPMp10m at 3 monitoring locations through the study period (7th June-August 30th 2016)

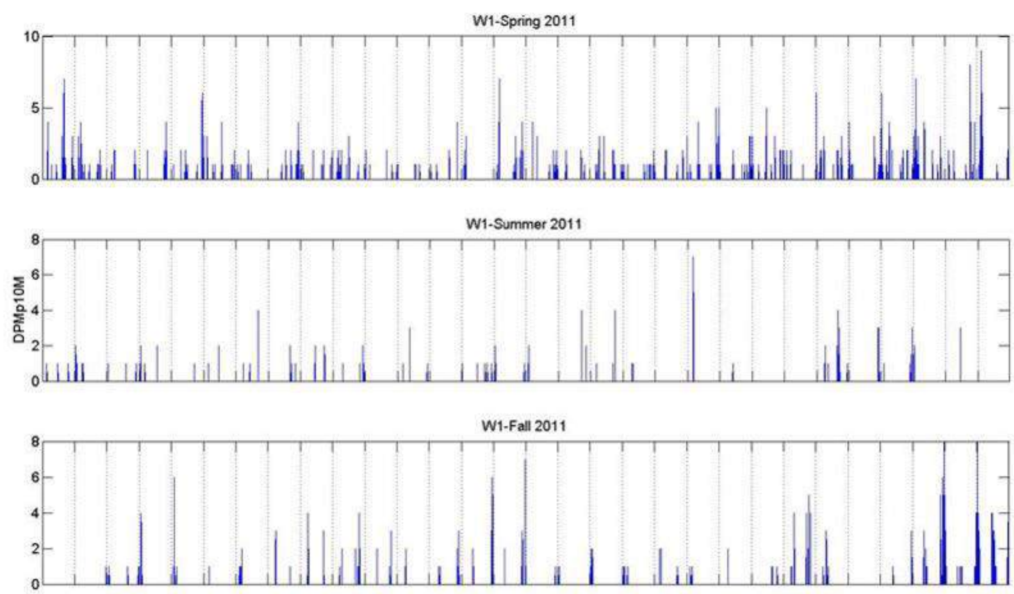


Figure 11b. DPMp10M at location W1 highlighting tends across and within month variability. Top trace is spring 2011, middle trace is summer 2011 (July 29th – August 28th), the bottom trace is fall 2011. Vertical dashed lines indicate the start of a new day (i.e. midnight). The middle trace is directly comparable with the August data presented for W1 in Figure 11a.

3.4.2 C-POD location detection rates

Porpoise detections rates varied across locations, with D1 on average higher than E1 and W1 (Table 5).

Table 5. Descriptive statistics for the three locations used in this study. Percent of 10MP with DPM is the percentage of 10 minute periods with at least one porpoise detection.

Location	Mean DPMp10M	SD	% of 10MP with DPM	No. of 10MP
E1	**0.05**	**0.40**	**2.73%**	**12,067**
W1	**0.06**	**0.38**	**3.35%**	**11,925**
D1	**0.09**	**0.48**	**4.85%**	**11,924**

4. Discussion

Three C-PODs were successfully calibrated, deployed and recovered to monitor marine mammals (porpoise and dolphins) presence in Minas Passage as part of FORCE's marine mammal EEMP. All 3 C-PODs collected data across the whole 84-day deployment period (June 7th – August 30th 2016). Average percent time lost due to sediment interference was 20-29%, similar to previous studies at these locations. Harbour porpoise were detected across 99% of days, but at low rates with a median of 7 minutes per day with presence detected in 3.64% of all 10 minute periods. Across the previous 2011 and 2012 C-POD baseline study (Wood et al. 2013), porpoises were detected on 98% of days, with higher minutes per day (median = 22 minutes) and present 4.1% of all 10 minute periods (noting this previous study collected data over spring and fall, as well as summer). No dolphins were detected as per previous baseline studies. Porpoise detection rates varied across the 84-day study and were at times higher in periods of July and August than observed previously in 2011 and 2012, but lower in June, highlighting inter-annual variability at sites within the demonstration area. While the site near berth D (D1) had higher apparent mean detection rates (0.09 detection positive minutes per 10 minute period) than at sites C1 (0.06) and E1 (0.05), the relative impact of percent time lost across sites (Figure 9a) has not yet been taken into account. This analysis will be undertaken during the GAM modelling planned for the final report, but overlapping standard deviations around these mean detection rates currently suggest insignificant site differences.

Recommend deployment of extra C-PODS at locations W2 and S2 as per past discussions. Maintain current C-POD settings and deployment methodology.

5. References

Porskamp, P, A. Redden, J. Broome, B. Sanderson and J. Wood. (2015). Assessing marine mammal presence in and near the FORCE Lease Area during winter and early spring – addressing baseline data gaps and sensor performance. Final Report to the Offshore Energy Research Association and Fundy Ocean Research Center for Energy.

SLR Consulting Ltd. (2015). Proposed Environmental Effects Monitoring Program for 2015 - 2020 Fundy Ocean Research Center for Energy (FORCE).

Tollit, D., J. Wood, J. Broome and A. Redden (2011). Detection of Marine Mammals and Effects Monitoring at the NSPI (OpenHydro) Turbine Site in the Minas Passage during 2010. Publication No. 101 of the Acadia Centre for Estuarine Research (ACER) Acadia University, Wolfville, NS, Canada prepared for Fundy Ocean Research Centre for Energy (FORCE). FORCE: Fundy Ocean Research Center for Energy. 2011. Environmental Effects Monitoring Report, September 2009 to January 2011. Appendix D.

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H., & Rasmussen, P. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (Phocoena phocoena (L.)). The Journal of the Acoustical Society of America, 126(1), 11–14. doi:10.1121/1.3132523

Wood, J., D. Tollit, A. Redden, P. Porskamp, J. Broome, L. Fogarty, C. Booth and R. Karsten (2013). Passive Acoustic Monitoring of Cetacean Activity Patterns and Movements in Minas Passage: Pre-Turbine Baseline Conditions (2011-2012). SMRU Consulting and ACER collaborative report prepared for Fundy Ocean Research Center for Energy (FORCE) and the Offshore Energy Research Association of Nova Scotia (OERANS). FORCE; Fundy Ocean Research Center for Energy. 2015. Environmental Effects Monitoring Report, 2011 to 2013. Appendices C.

Appendix 3: Seabirds Environmental Effects Monitoring Plan Interim Report 1

Interim report summarizing results from seabird surveys from May – July 2016. Prepared by Envirosphere Consultants Limited.

FIRST QUARTERLY SHORE-BASED SEABIRD AND MARINE MAMMAL SURVEY – TIDAL ENERGY DEMONSTRATION SITE, FUNDY OCEAN RESEARCH CENTER FOR ENERGY: MAY 6, JUNE 2 & JULY 2 2016

22 July 2016 – *Revised*

Prepared for:

Melissa Oldreive, Acting Director of Operations
Fundy Ocean Research Center for Energy
1690 Hollis Street, Unit 1001
Halifax, Nova Scotia B3J 1V7

Prepared by:

Valerie Kendall, M.Env.Sc., Environmental Biologist
Patrick L. Stewart, M.Sc., President
Envirosphere Consultants Limited
120 Morison Drive, Windsor Nova Scotia Unit 5 B0N 2T0
902 798 4022 | enviroco@ns.sympatico.ca | www.envirosphere.ca

EXECUTIVE SUMMARY

Three shore-based surveys have been carried out at the FORCE Visitor Center for water-associated birds, with observations of Harbour Porpoises also documented. The surveys took place on May 6, June 2 and July 2, 2016 over a six-hour period in half hour increments on the out-going tide, beginning at high tide and concluding at low tide. The following is an initial quarterly field report for the shore-based surveys at the Black Rock site. Low to moderate densities of seabirds have been observed, lowest in July, followed by May and highest in June with 10 seabird and waterfowl species in total documented. Small numbers of Harbour Porpoise have also been observed on all occasions. A second quarterly field survey report will be submitted in the fall according to the proposed schedule.

Field observations and species identifications were conducted by a professional bird observer, Fulton Lavender of Halifax Nova Scotia, and timed and documented by Valerie Kendall (M.Env.Sc., Project Biologist) and Patrick Stewart (M.Sc., President, Envirosphere Consultants Ltd.). The observations were made in the same general way as earlier surveys (2010-2012)[1], surveying the waters from the interpretive center to mid-Minas Passage within the field of view, which includes the waters across Minas Passage on a line from Cape Sharp, and to the west down the shore into Minas Channel, as well as covering the area towards Cape Split and therefore covering the area proposed for turbine installation. Observations were made with a 22x magnification Bushnell spotting scope as well as 8x and 10x binoculars (Figures 1 and 2).

The seasonal timing of observations has been scheduled so that observations of migrating bird species are adequately represented in the data as much as possible. Abundance of water-associate birds (loons, cormorants, seaducks, gulls, alcids, and waterfowl) at the Minas Passage site shows seasonal peaks corresponding to migratory movements (March-April and October-November) and a late spring to early summer occupation of the area by local resident breeders such as Black Guillemot, Common Eider, Double-Crested Cormorant, and Herring and Great Black-backed Gulls (Envirosphere Consultants 2011-2013). There is a low summer abundance of local species, when migrants are not present and individuals of local breeding species such as gulls and cormorants move out of the area.

The observation team initially records separately all birds sitting or associated with the water in the subdivisions, including on Black Rock (Figure 1). Following this, a flying ‘snapshot’ is carried out to record all birds in flight observed throughout the subdivisions. The remainder of the 30-minute interval is used to record additional birds flying into the area or on the water. Birds observed in the vicinity of Black Rock and also in the crown lease area (“critical area”) are highlighted. A summary of bird and marine mammal observations to date are presented in Tables 1-8. Weather information and environmental data was recorded from the inside weather station operating at the FORCE facility.

[1] Observations from 2011 onward were made from the outdoor observation deck or inside the FORCE Visitor Center. Although this location is about 150 m from shore, the view was satisfactory when the spotting scope and binoculars were used, and the site provided a better overview of the site.

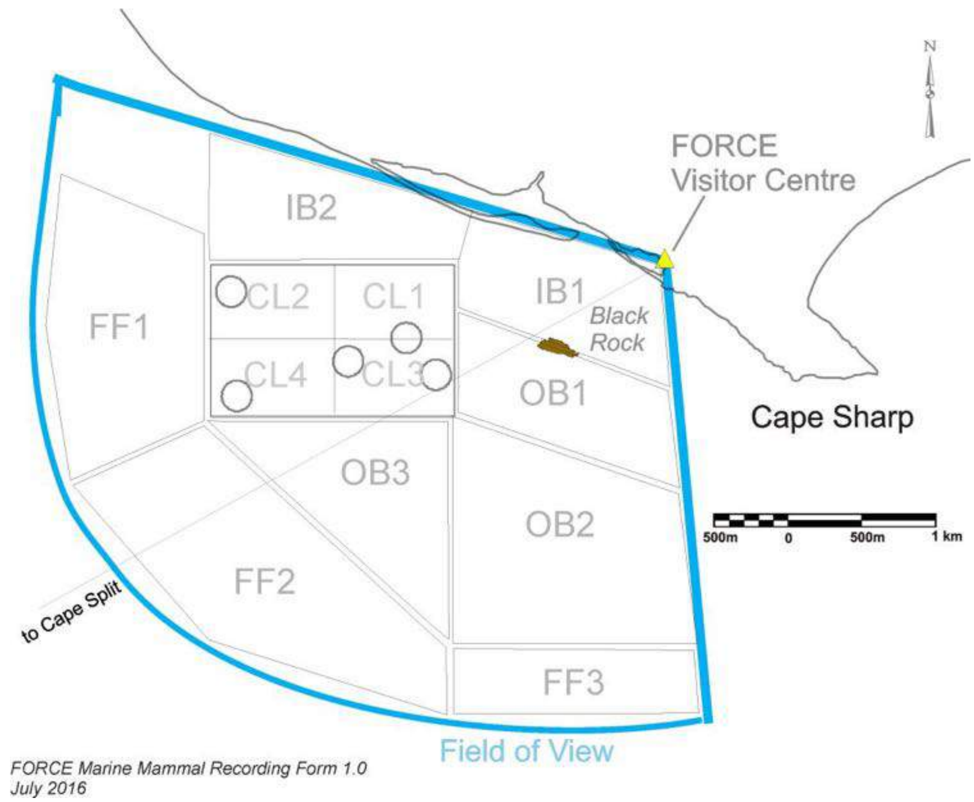


Figure 1. Study area field of view with grid showing open water subdivisions to document marine bird and mammal occurrences. (CL1-4 = turbine field/crown lease area; IB1-2 = Nearshore area/Inside Black Rock; OB1-3 Buffer area/outside Black Rock; FF1-3 Far-field buffer area.

Figure 2. Bird Observer, Fulton Lavender, counting bird occurrences in the nearshore (IB-1 & -2) subdivisions using a 22x magnification Bushnell spotting scope. June 2, 2016.

SUMMARY OF SURVEYS

Friday, May 6, 2016 – The field team arrived onsite at the FORCE Visitor Center, Parrsboro at approximately 0940 Friday morning, consisting of Patrick Stewart (Lead Biologist, Envirosphere Consultants Ltd), Valerie Kendall (Project Biologist, Envirosphere Consultants Ltd), Fulton Lavender (Seabird Observer), Richard Hatch (Assistant Bird Observer), and Joy Baker (Environmental Technician-Envirosphere Consultants Ltd). Objectives for this visit included a safety orientation with Mary McPhee, FORCE Facilities Manager, and an initial bird survey, beginning at 12:38 and ending at 18:12, conducted in 30-minute intervals and coinciding with the outgoing tide cycle.

On this occasion, the observers remained inside the building. Weather was overcast for the duration of the day (100% cloud cover), with light NE winds, ranging from approximately 25 km/h diminishing to less than 10 km/hr by evening. Mr. Lavender was the primary observer and Mr. Hatch and Ms. Baker recorded data.

Observed number of birds overall were low. The most abundant birds noted each half hour were Great Black-backed Gulls (GBBG) on Black Rock for most of the monitoring periods. Ten species of birds were recorded over the six-hour survey period: three species of gulls (Great Black-backed, Herring, and Lesser Black-backed), Double-crested Cormorant, Great Cormorant, Black Scoter, Black Guillemot, Common Eider, and Red-throated Loon.

Two Harbour Porpoises were briefly seen surfacing during the 15:12 – 15:42 observation period within the crown lease area and moving into the farfield region. A single Bald Eagle was observed flying through subdivision IB-1 between 14:12 and 14:42. Many land birds were present around the interpretive center.

June 2, 2016 – Field team, Fulton Lavender and Valerie Kendall, arrived on site in Parrsboro at approximately 10:45. Observations were conducted from the outdoor observation deck at the FORCE Visitor Center. Weather was sunny, with little cloud cover throughout the day. Temperature ranged from 11ºC at noon to a high of approximately 15.7ºC by late afternoon and early evening. Winds were light, approximately 15 km/h ESE diminishing to less than 10 km/h ESE by the end of the six-hour survey. Observations in 30-minute intervals began with high tide at 12:00 and continued until 18:15, in which all bird and mammal occurrences according to the study area subdivisions were recorded.

Overall, numbers of birds were low. The most abundant bird species noted each half hour were Great Black-backed Gulls (GBBG) resting on Black Rock. Ten species of birds were recorded through the day including: four species of gulls (Great Black-backed, Herring, Lesser Black-backed, and Ring-billed), Red-throated Loon and Common Loon, Black Guillemot, Common Eider, Double-crested Cormorant, and Great Cormorant.

Between 17:00 and 17:30, a single Harbour Porpoise was observed moving through IB-1 into IB-2 where it resurfaced momentarily. Prior to the survey start time two Turkey Vultures were noted flying above the shore before flying out of sight east of the visitor center. A number of land bird species, such as robin and hummingbird, were observed throughout the day in the gardens, surrounding forest and the clearing below the visitor center.

July 2, 2016 – Field team, of Fulton Lavender and Patrick Stewart, arrived on site in Parrsboro at approximately 11:00. Observations were conducted from the outdoor observation deck at the FORCE Visitor Center. Weather was slightly overcast with occasional showers and thunderstorms. Temperatures were warm between 16 and 20ºC with light ESE winds ranging from 8 to 18 km/h and shifting to SW at the end of the six-hour survey. Observations were made continuously every 30-minutes beginning at 11:20 and ending at 17:20 according to the survey protocol as described above.

Overall low numbers of birds were recorded. A small number of Great Black-backed Gulls were always present on Black Rock, and Herring Gull and Double-crested Cormorant also occasionally landed on the rock. Common Eiders were often seen on the edge of Black Rock or in the water alongside. Black Guillemots appear to be nesting in two locations in cavities on Black Rock. Adults were seen flying into the cavities and there are possibly two nests. The most abundant birds noted each half hour were Great Black-backed Gulls (GBBG) resting on Black Rock. Eight species of birds were recorded through the day: two gull species (Great Black-backed and Herring); Double-crested and Great Cormorants, as well as Black Guillemot, Common Eider, Red-throated and Common Loons.

An adult & juvenile pair of Harbour Porpoise was seen swimming with the outgoing tide from 12:08 to 12:10. The pair was seen in the OB-1 and OB-2 area just east of Black Rock, and they disappeared behind the rock, reappearing and moving through the CL area and disappearing near the northwest corner of the area. The individuals were close together (very close, almost bumping) and it was presumed the sighting represented a female and offspring, with the adult tending the juvenile. They were swimming in a single direction (with the current) and not feeding. An adult Harbour Porpoise was seen in the next survey period, about 10 minutes after the first sighting, at the western end of the OB-2 zone. This one was seen at the surface and went below the surface and was not seen again. We presumed it was the adult of the pair seen shortly before, but could not be sure. A Bald Eagle was also noted between 14:50 and 15:20 flying NW through subdivision IB-1.

TABLES & FIGURES

Table 1. 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 2. 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 3. 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 4. Number of individual sea- and shorebird species observed from the FORCE Visitor Center per 30-minute interval. May 6, June 2, July 2, 2016.

Species	May 6	June 2	July 2
BLGU	0.5	0.7	1.8
BLSC	0.3	0	0
COEI	1.3	3.4	2.3
COLO	0.1	0.3	0.2
DCCO	3.6	4.3	1.8
GBBG	17.1	19.3	7.8
GRCO	2.2	0.8	0.2
HEGU	6.2	13.0	4.5
LBBG	0.1	0.2	0
RBGU	0	0.1	0
RTLO	0.8	0.2	0.1
Total	32.1	42.0	18.7

Table 5. Comparison of species list of marine mammals and seabirds at Fundy Tidal Power Demonstration Site, from shore based observations, 2010, 2011 & 2016.

	2010	2011	2016
ABDU	✓	✓	
Alcid sp		✓	
ATPU	✓		
BLGU	✓	✓	✓
BLKI	✓	✓	
BLSC	✓	✓	✓
CAGO	✓	✓	
COEI	✓	✓	✓
COGO		✓	
COLO	✓	✓	✓
COME	✓		
COME	✓		
COMU	✓	✓	
DCCO	✓	✓	✓
GBBG	✓	✓	✓
GRCO	✓	✓	✓
HADU	✓		
HEGU	✓	✓	✓
HOGR	✓		
ICGU	✓		
KIEI		✓	
LAGU	✓		
LBBG	✓	✓	✓
LTDU	✓	✓	
MALL	✓		
MEGU	✓		
NOGA	✓	✓	
NSHO		✓	
PALO	✓	✓	
RAZO	✓	✓	
RBGU	✓	✓	✓
RBME	✓	✓	
RNGR	✓		
RTLO	✓	✓	✓
SCSP		✓	
SUSC	✓	✓	
TBMU	✓	✓	
WWSC	✓	✓	
TOTAL	33	28	11

Table 6. Seabirds observed at Fundy Tidal Power Demonstration Site, 2016, in shore-based surveys.

Species Code	Common Name	Scientific Name
WATERFOWL		
BLSC	Black Scoter	Melanitta americana
RTLO	Red-throated Loon	Gavia stellata
COLO	Common Loon	*Gavia immer*
COEI	Common Eider	*Somateria mollissima*
SEABIRDS		
DCCO	Double-crested Cormorant	Phalacrocorax auritus
GRCO	Great Cormorant	*Phalacrocorax carbo*
GBBG	Great Black-backed Gull	*Larus marinus*
HEGU	Herring Gull	*Larus argentatus*
LBBG	Lesser Black-backed Gull	*Larus* fuscus
RBGU	Ring-billed Gull	Larus delawarensis
BLGU	Black Guillemot	*Cepphus grylle*

Table 7. Marine mammal observations during shore-based seabird and marine mammal surveys, Fundy Tidal Power Demonstration Site, May 6, June 2, July 2, 2016.

Date	Time (ADT)	Survey Component	Location Sighted	Species	Number
May 6, 2016	15:12-15:42	Shore	Turbine Area (CL) into Farfield Area (FF)	Harbour Porpoise	2
June 2, 2016	17:00-17:30	Shore	Inside Black Rock	Harbour Porpoise	1
July 2, 2016	12:08-12:10	Shore	Outside Black Rock (OB1-2) into Turbine Area (CL)	Harbour Porpoise	2
	12:20-12:50	Shore	Inside Black Rock (IB2)	Harbour Porpoise	1

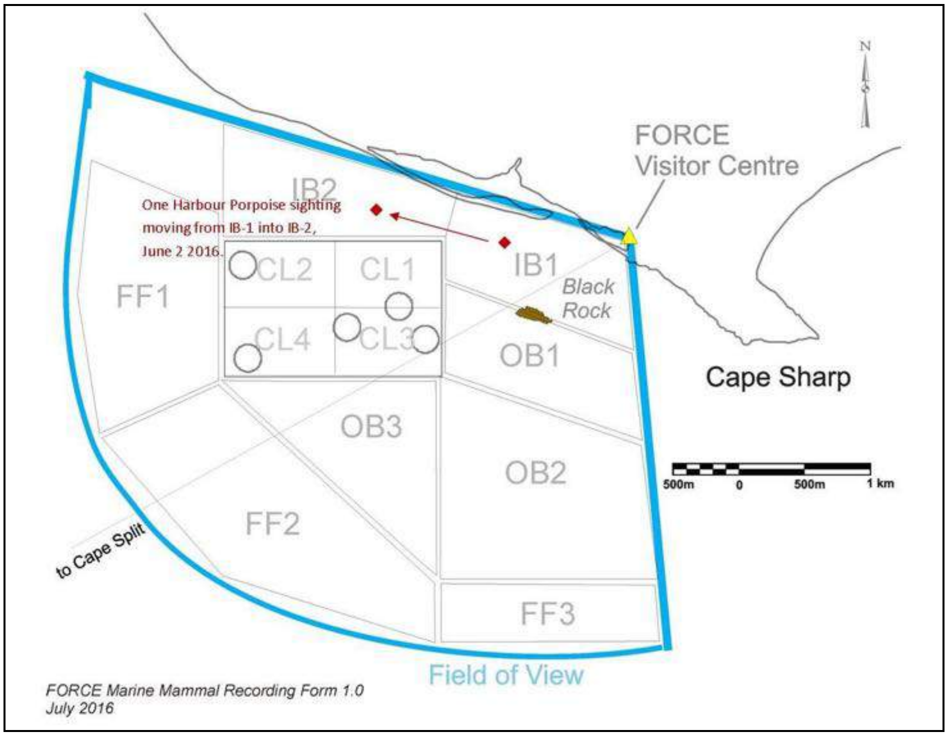


Figure 3. Depiction of a single Harbour Porpoise sighting on June 2 2016 from the FORCE Visitor Center outdoor observation deck.

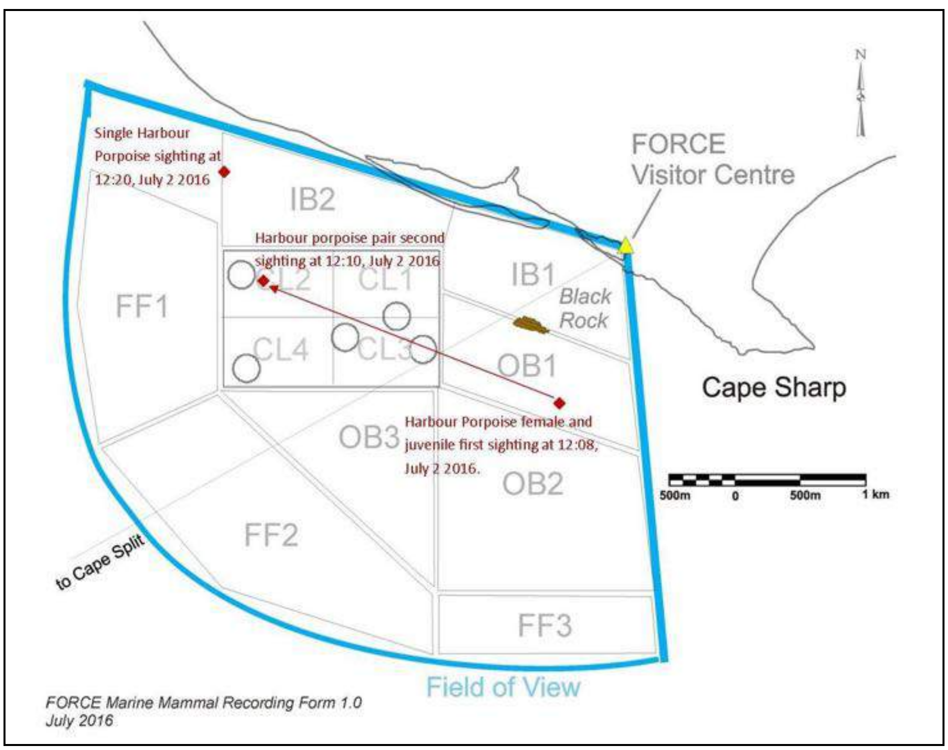


Figure 4. Depiction of Harbour Porpoise sightings on July 2 2016 from the FORCE Visitor Center outdoor observation deck.

Appendix 4: Seabirds Environmental Effects Monitoring Plan Interim Report 2

Interim report summarizing results from seabird surveys from August – November 2016. Prepared by Envirosphere Consultants Limited.

SECOND QUARTERLY SHORE-BASED SEABIRD AND MARINE MAMMAL SURVEY – TIDAL ENERGY DEMONSTRATION SITE, FUNDY OCEAN RESEARCH CENTER FOR ENERGY: AUGUST 2, SEPTEMBER 1, OCTOBER 1 & 17, NOVEMBER 3, 2016

21 November 2016 – *Revised-2*

Prepared for:

Melissa Oldreive, Director of Environmental and Regulatory Affairs
Fundy Ocean Research Center for Energy
1690 Hollis Street, Unit 1001
Halifax, Nova Scotia B3J 1V7

Prepared by:

Valerie Kendall, M.Env.Sc., Environmental Biologist
Patrick L. Stewart, M.Sc., President
Envirosphere Consultants Limited
120 Morison Drive, Windsor Nova Scotia Unit 5 B0N 2T0
902 798 4022 | enviroco@ns.sympatico.ca | www.envirosphere.ca

EXECUTIVE SUMMARY

Monthly shore-based surveys began at the FORCE Visitor Center for marine birds in the spring of 2016 during early to mid-breeding season. Surveys took place on May 6, June 2 and July 2, 2016 over a six-hour period in half hour increments on the out-going tide, beginning at high tide and concluding at low tide. Observations were summarized in an initial quarterly report dated July 22, 2016. Subsequent surveys, presented in this report, took place on August 2, September 1, October 1 &17, and November 3 during the late and post-breeding/moulting and migration season. To date, eight shore-based surveys have been carried out. In addition to seabirds, Harbour Porpoises have also been documented. Beginning in October, survey frequency was increased to twice monthly in order to capture the migratory period. Low to moderate densities of seabirds have been observed, lowest in October and August, and highest in September and November, with a total of 22 seabird, waterfowl and shorebird species observed. Small numbers of Harbour Porpoise were observed during August, September and October surveys. Overall, the number of birds seen at the site is lower than expected, based on earlier baseline surveys, and reflects the broader pattern of bird abundance not connected with activity at the FORCE site. A third quarterly field survey report will submitted in February according to the proposed schedule.

Field observations and species identifications were conducted by a professional bird observer, Fulton Lavender of Halifax Nova Scotia, and documented by Valerie Kendall (M.Env.Sc., Project Biologist), Patrick Stewart (M.Sc., President) and Richard Hatch (Bird Observer, Halifax Nova Scotia). The observations were made in the same general way as earlier surveys (2010-2012)[1], but using a grid system adopted for the present surveys. Waters were surveyed from the interpretive center to mid-Minas Passage within the field of view, which includes the waters across Minas Passage from the site and down the shore into Minas Channel, as well as covering the area towards Cape Split and therefore covering the area proposed for turbine installation. Observations were made with a 22x Celestron spotting scope as well as 8x and 10x binoculars (Figures 1 and 2).

Seasonal timing of observations has been scheduled so that critical times for birds, in particular for migrating birds, are adequately represented in the data as much as possible. Abundance of water-associated birds (loons, cormorants, seaducks, gulls, alcids, and waterfowl) at the Minas Passage site in past showed seasonal peaks corresponding to migratory movements (March-April and October-November) and a late spring to early summer occupation of the area by local resident breeders such as Black Guillemot, Common Eider, Double-Crested Cormorant, and Herring and Great Black-backed Gulls (Envirosphere Consultants 2011-2013). There is a low summer abundance of local species, when

[1] Observations from 2011 onward were made from the outdoor observation deck or inside the FORCE Visitor Center. Although this location is about 150 m from shore, the view was satisfactory when the spotting scope and binoculars were used, and the site provided a better overview of the site.

migrants are not present and individuals of local breeding species such as gulls and cormorants move out of the area.

The observation team initially records separately all birds sitting or associated with the water in the survey subdivisions, including on Black Rock (Figure 1). Following this, a flying 'snapshot' is carried out to record all birds in flight observed throughout the subdivisions. The remainder of the 30-minute interval is used to record additional birds flying into the area or on the water. Birds observed in the vicinity of Black Rock and also in the Crown Lease Area ("critical area") are highlighted. A summary of bird and marine mammal observations to date are presented in Tables 1-8. Weather information and environmental data was recorded from the weather station operating at the FORCE facility.

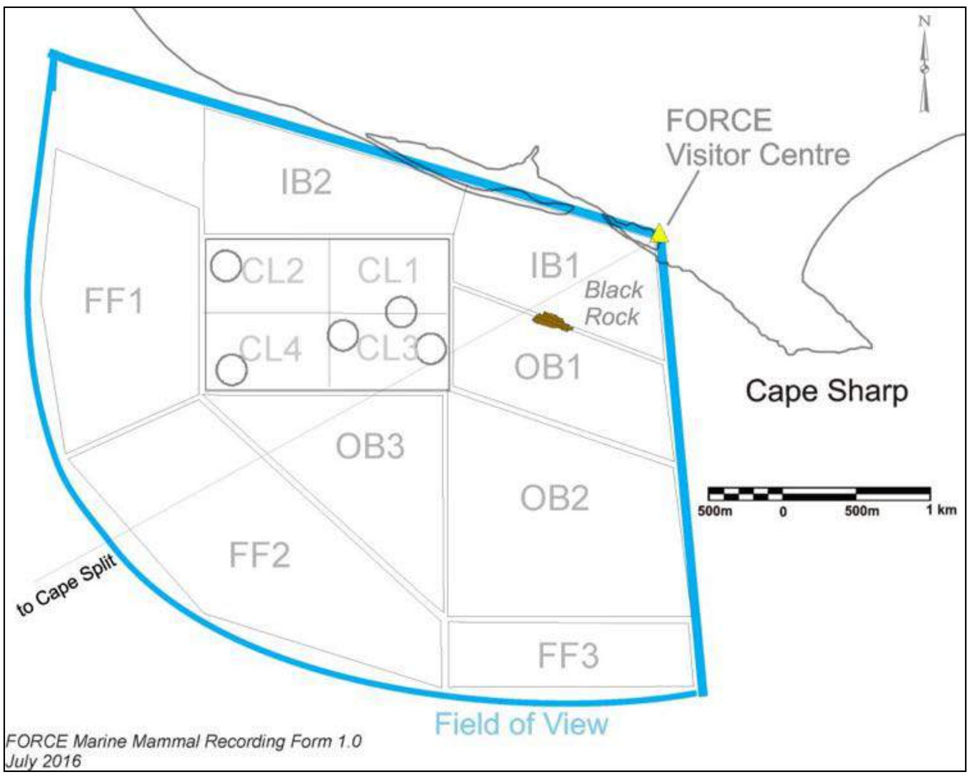


Figure 1. Study area field of view with grid showing open water subdivisions to document marine bird and mammal occurrences. (CL1-4 = turbine field/crown lease area; IB1-2 = Nearshore area/Inside Black Rock; OB1-3 Buffer area/outside Black Rock; FF1-3 Far-field buffer area.

Figure 2. A view of Minas Passage during a marine bird survey on October 17, 2016. Bird Observer: Fulton Lavender, using a 22x Celestron spotting scope.

SUMMARY OF SURVEYS

August 2, 2016 – Valerie Kendall (Project Biologist, Envirosphere Consultants Ltd) and Fulton Lavender (Seabird Observer) arrived at the FORCE Visitor Center, Parrsboro at approximately noon and began the survey at 13:00. Bird observations were made in 30-minute intervals coinciding with the outgoing tide for six hours. Peak high tide for Parrsboro was at 12:56 (www.tides.gc.ca). Mr. Lavender was the primary observer and Ms. Kendall recorded data.

The survey was completed outdoors on the FORCE Visitor Center outdoor observation platform overlooking the Passage. Weather was sunny with partial clouds throughout the day (50% cloud cover); winds were light from the east and east-southeast, and ranged from approximately 4 – 11.3 km/h.

Observed number of birds overall were low. The most abundant birds noted each half hour were Herring Gulls sitting on Black Rock for most of the monitoring periods. Birds were also actively flying through and circling within the observation area, and waterfowl were noted on the water. Twelve species of birds were recorded over the six-hour survey period: four species of gulls (Great Black-backed, Herring, Ringbilled, and Lesser Black-backed), Double-crested Cormorant, Great Cormorant, Black Scoter, Black Guillemot, Common Eider, and Common Loon, and two shorebird species, Spotted Sandpiper and Lesser Yellowlegs.

One Harbour Porpoise was briefly sighted surfacing within the Crown Lease Area at about 14:00. A single Bald Eagle was observed flying through subdivision IB-1 at approximately 13:40, and again at 14:24 closer to shore. Many land birds were also present around the interpretive center.

September 1, 2016 – The field team, Fulton Lavender and Valerie Kendall, arrived onsite at approximately 12:30 and began the survey at 13:15. Observations were conducted from the outdoor observation deck at the FORCE Visitor Center. Weather was overcast (100% cloud cover) but cleared to about 10% cloud cover by mid-afternoon. Temperature ranged from 19.5 ºC at 12:15 to a high of 22.2 ºC by late afternoon and early evening. Winds were light, ranging between 8.3 – 13.7 km/h E and ESE. Observations in 30-minute intervals began with high tide at 13:15 and continued until 19:15, in which all bird and mammal occurrences according to the study area subdivisions were recorded.

Overall, numbers of birds were low. The most abundant bird species noted each half hour were Double Crested Cormorant resting on Black Rock and occasionally flying or on the water feeding. Five species of birds were recorded through the day including Herring and Ring-billed Gulls, Double-crested Cormorant, Great Cormorant and Wilson's Storm Petrel. Birds were predominantly observed flying through the observation area. Breeding season has passed and sexes could not be distinguished.

At approximately 14:50, an estimated four Harbour Porpoise were observed at the surface in the Crown Lease Area and swimming in a northwest direction.

October 1, 2016 – Field team, Fulton Lavender, Patrick Stewart and birding assistant, Richard Hatch, arrived onsite in Parrsboro at approximately 11:00. Observations were conducted from the outdoor observation deck at the FORCE Visitor Center beginning at 11:30. Weather was mostly cloudy with occasional sunny breaks. Temperatures were warm between 14.7 and 17.2 ºC with light ESE winds ranging from 8 to 18 km/h and shifting to SW and W during the second half of the six-hour survey and generally wave conditions were flat/ripples. Observations were made every 30-minutes beginning at 11:30 until 14:30. Porpoise sightings delayed the start of the subsequent survey until 14:35. The complete survey ended at 17:05.

Overall, low numbers of birds, and a total of 12 seabird species, were observed and recorded. A pair of Bald Eagles were present on the western end of Black Rock for the early afternoon, from the beginning of the survey until 15:35 and may have deterred some of the gulls from landing there. Occasionally Great Cormorants and Double Crested Cormorants landed on Black Rock and on the surrounding water, and a Common Loon and Red-throated Loon were also noted in the study area. A small number of Herring and Ring-billed Gulls and a single Great Black-backed Gull were observed. Other species included a Black Duck, Canada Goose and Red-breasted Merganser, which were noted on the water within close proximity to Black Rock (ie. OB1, IB1, CL). A Peregrine Falcon was also observed flying westward along the beach at the site.

An adult-juvenile pair of Harbour Porpoise was seen swimming just east of Black Rock (see Figure 5) at 14:07. They were observed again in the northeast corner of OB1 at 14:10 and continued northwest through the northeast corner of CL1. They were last seen in IB2 at approximately 14:11. It appeared they were moving at a leisurely, feeding pace. Another individual porpoise was noticed in Minas Passage, swimming along the axis of the Passage and located roughly east of a line towards Cape Split. It appeared to be swimming at a faster pace and surfaced 3 to 4 times. It was first seen at 14:10 and last seen about 14:11. Since porpoises tend to travel in groups, it is likely additional animals were present in the outer passage accompanying the one that was sighted. Shortly after this sighting, five adults were seen approximately 300 meters from shore, at 14:28, between the observation point and Black Rock. The group was noted to be moving northwestward, largely parallel to the coast through IB1, near the northeast corner of CL1 and were sighted in IB2 at 14:31, resurfacing three more times as they moved west through IB2, and exhibited a behavior which appeared to be dive feeding.

October 17, 2016 – The field team, Fulton Lavender and Valerie Kendall, arrived onsite at approximately 11:10 and began the survey at 11:45. Observations were conducted from the outdoor observation deck at the FORCE Visitor Center. Weather conditions were relatively warm (15 – 18.4 ºC), with 100% cloud cover in the morning to almost completely clear by the end of the survey (5% cloud cover). Wind was from the west and ranged from about 18 kph in the morning to 30 kph by late afternoon, and dropping to about 23 kph by the final 30-minute survey interval (17:15). Wave conditions consisted of large wavelets and scattered white caps. Unlike the other surveys, which began around high tide, to accommodate for the change in daylight hours and earlier sunset, the survey was started at about mid-tide. This allowed completion of the survey before sunset. Peak tide was at 14:05.

Overall, numbers of birds were minimal, and lowest for all surveys so far, with a total of nine species. Black Rock did not have any birds for the majority of the day, with the exception of a single juvenile Great Cormorant that arrived about 14:15 and remained sitting on the rock until about 16:50, at which time it flew away in an easterly direction. Occasional Herring Gulls, and single Ring-billed and Great Black-backed Gulls were documented throughout the afternoon. During the final two 30-minute intervals, seven Herring Gulls were noted flying primarily eastward through the study area outside Black Rock. Double-crested Cormorant, Common Eider, Common Loon, Black Scoter and a single White-wing Scoter juvenile were also observed. The bird species noted most consistently each half hour was Herring Gull flying through the study area and feeding.

November 3, 2016 – The field team, Fulton Lavender and Valerie Kendall, arrived onsite at approximately 11:40 and began the survey at 12:15. Observations were conducted from the outdoor observation deck at the FORCE Visitor Center. Weather conditions were relatively cool and stable between 8.5 and 9.1ºC, with 100% cloud cover for the duration of the day. Wind speed was very low at less than one kph to about six kph resulting in flat water conditions. The survey began at about mid-tide in order to complete the survey during day light hours. Peak tide was at 15:01.

Overall, numbers of birds were minimal and eleven species were observed. Black Rock was unoccupied for the entire survey with the exception of a single Great Black-backed Gull that landed on the rock just after 18:00 in the final 30-minute interval. Black Scoters were the most abundant bird species, and Surf Scoters were also observed – these are migrants through the site at this time of year. Herring Gulls were present in small numbers for each interval; a single Iceland Gull flew in from the southeast and landed in the Crown Lease Area; and a single Atlantic Puffin was noted flying west through the Crown Lease Area during the second final survey interval. Long-tailed Duck, Razorbill, and Red-throated Loons were also observed.

During the survey, vessels from Cape Sharp Tidal Development Ltd. were onsite and a vessel and barge were present in the study area (OB3) by mid-afternoon (approximately 14:45, onward) testing equipment for a turbine deployment which took place on November 7, 2016. As daylight faded, it is possible the lights from the vessel and barge might attract birds but no association of sightings with these activities were noted.

TABLES & FIGURES

Table 1. 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 2. 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 3. 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
PEFA	0	0	0	0	0	0	0	0	0	0	0	1	0.1
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 4. 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 5. 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	21	16.0
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 6. Comparison of average number of individual sea- and shorebird species observed from the FORCE Visitor Center per 30-minute interval. August 2, September 1, October 1 & 17, November 3, 2016.

Species	August 2	September 1	October 1	October 17	November 3
BLDU	0	0	0.3	0	0
BLSC	0.1	0	0.9	0.5	16.0
CAGO	0	0	0.1	0	0
COEI	1.4	0	0	0.8	0.1
COLO	0.1	0	1.0	0.1	0.1
DCCO	2.3	10.5	0.8	0.1	0
GBBG	2.3	0	0.1	0.2	0.1
GRCO	2.3	5.9	1.0	1.0	0
HEGU	6.8	3.1	4.4	1.8	5.3
ICGU	0	0	0	0	0.1
LBBG	0.1	0	0	0	0
LEYE	0.3	0	0	0	0
LTDU	0	0	0	0	0.4
PEFA	0	0	0.1	0	0
ATPU	0	0	0	0	0.1
RAZO	0	0	0	0	0.1
RBGU	3.0	0	0	0	0
RBGU	0	2.2	0.7	0.1	0
RBME	0	0	0.1	0	0
RTLO	0	0	0.1	0	1.0
SPSA	0.2	0	0	0	0
SUSC	0	0	0	0	1.0
WISP	0	0.3	0	0	0
WWSC	0	0	0	0.1	0

Table 7. Comparison of species list of marine mammals and seabirds at Fundy Tidal Power Demonstration Site, from shore based observations, 2010, 2011 & 2016.

	2010 May, June, October, November	**2011** March, April, December	**2016** May – November
ABDU	✓	✓	
Alcid sp		✓	
ATPU	✓		✓
BLGU	✓	✓	✓
BLKI	✓	✓	
BLSC	✓	✓	✓
CAGO	✓	✓	✓
COEI	✓	✓	✓
COGO		✓	
COLO	✓	✓	✓
COME	✓		
COMU	✓	✓	
DCCO	✓	✓	✓
GBBG	✓	✓	✓
GRCO	✓	✓	✓
HADU	✓		
HEGU	✓	✓	✓
HOGR	✓		
ICGU	✓		✓
KIEI		✓	
LAGU	✓		
LBBG	✓	✓	✓
LEYE			✓
LTDU	✓	✓	✓
MALL	✓		
MEGU	✓		
NOGA	✓	✓	
NSHO		✓	
PALO	✓	✓	
RAZO	✓	✓	✓
RBGU	✓	✓	✓
RBME	✓	✓	✓
RNGR	✓		
RTLO	✓	✓	✓
SCSP		✓	
SPSA			✓
SUSC	✓	✓	✓
TBMU	✓	✓	
WISP			✓
WWSC	✓	✓	✓
TOTAL	33	28	22

Table 8. Seabirds observed at Fundy Tidal Power Demonstration Site, 2016, in shore-based surveys.

Species Code	Common Name	Scientific Name
WATERFOWL		
BLSC	Black Scoter	Melanitta americana
SUSC	Surf Scoter	Melanitta perspicillata
WWSC	White-winged Scoter	Melanitta deglandi
CAGO	Canada Goose	Branta canadensis
LTDU	Long-tail Duck	Clangula hyemalis
RBME	Red-breasted Merganser	Mergus serrator
RTLO	Red-throated Loon	Gavia stellata
COLO	Common Loon	*Gavia immer*
COEI	Common Eider	*Somateria mollissima*
SEABIRDS		
DCCO	Double-crested Cormorant	Phalacrocorax auritus
GRCO	Great Cormorant	*Phalacrocorax carbo*
GBBG	Great Black-backed Gull	*Larus marinus*
HEGU	Herring Gull	*Larus argentatus*
LBBG	Lesser Black-backed Gull	Larus fuscus
RBGU	Ring-billed Gull	Larus delawarensis
ICGU	Iceland Gull	*Larus glaucoides*
BLGU	Black Guillemot	*Cepphus grylle*
RAZO	Razorbill	*Alca torda*
ATPU	Atlantic Puffin	*Fratercula*
WISP	Wilson's Storm Petrel	*Oceanites oceanicus*
SHOREBIRDS		
LEYE	Lesser Yellowlegs	*Tringa flavipes*
SPSA	Spotted Sandpiper	*Actitis macularius*

Table 9. Marine mammal observations during shore-based seabird and marine mammal surveys, Fundy Tidal Power Demonstration Site. August 2, September 1, October 1 & 17, November 3, 2016.

Date	Time (ADT)	Survey Component	Location Sighted	Species	Number
August 2, 2016	14:00	Shore	Crown Lease Area (CL)	Harbour Porpoise	1
September 1, 2016	14:50	Shore	Crown Lease Area (CL) towards FF1	Harbour Porpoise	4
October 1, 2016	14:07 – 14:10 – 14:11	Shore	IB1 into OB1 through CL into IB2	Harbour Porpoise	2
	14:10 – 14:11	Shore	OB3	Harbour Porpoise	1
	14:28 – 14:31; 14:32 – 14:39	Shore	IB1 near northeast corner of CL, into IB2; West through IB2	Harbour Porpoise	4 & 5

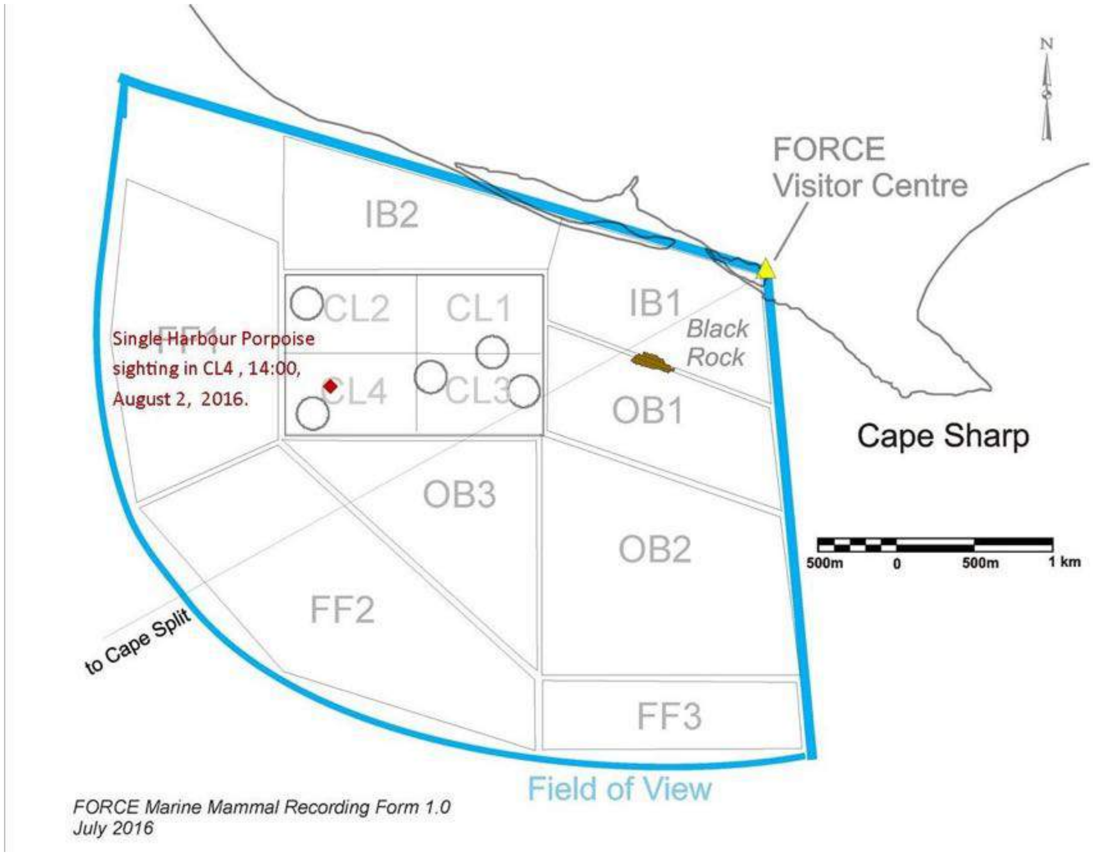


Figure 3. Depiction of a single Harbour Porpoise sighting on August 2, 2016 from the FORCE Visitor Center outdoor observation deck.

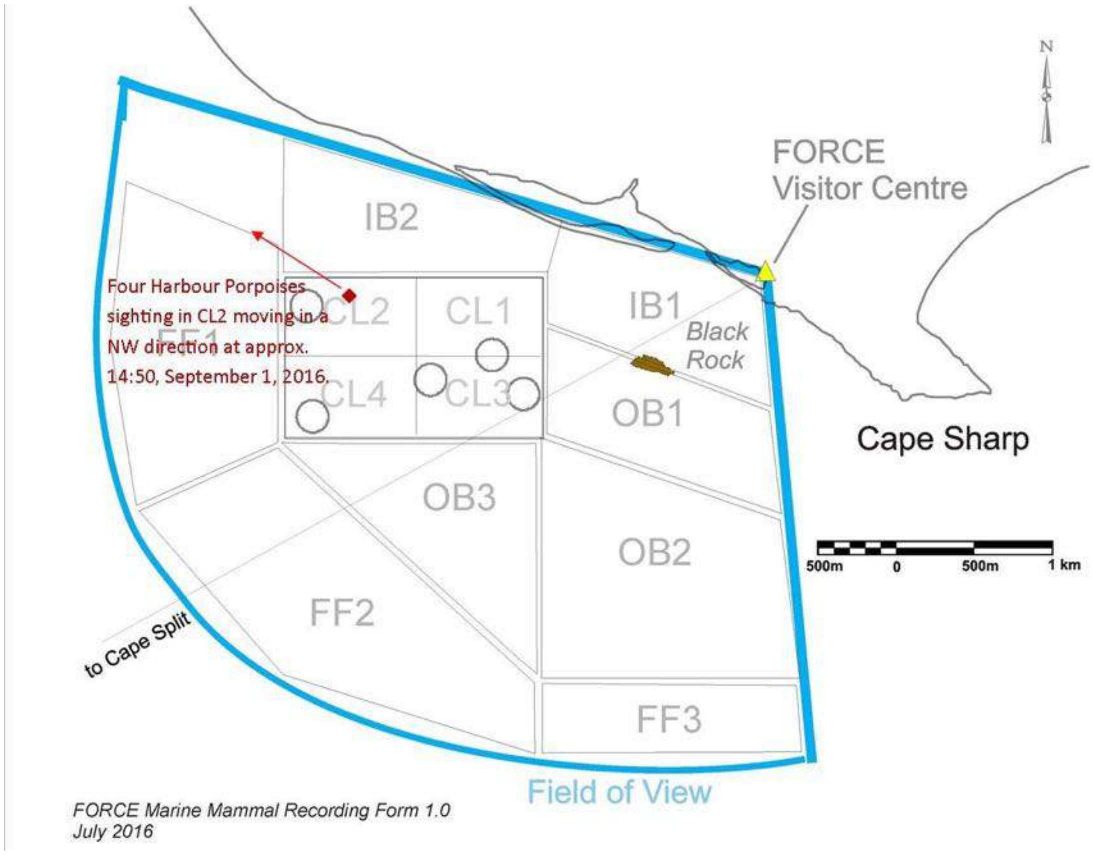


Figure 4. Depiction of Harbour Porpoise sightings on September 1, 2016 from the FORCE Visitor Center outdoor observation deck.

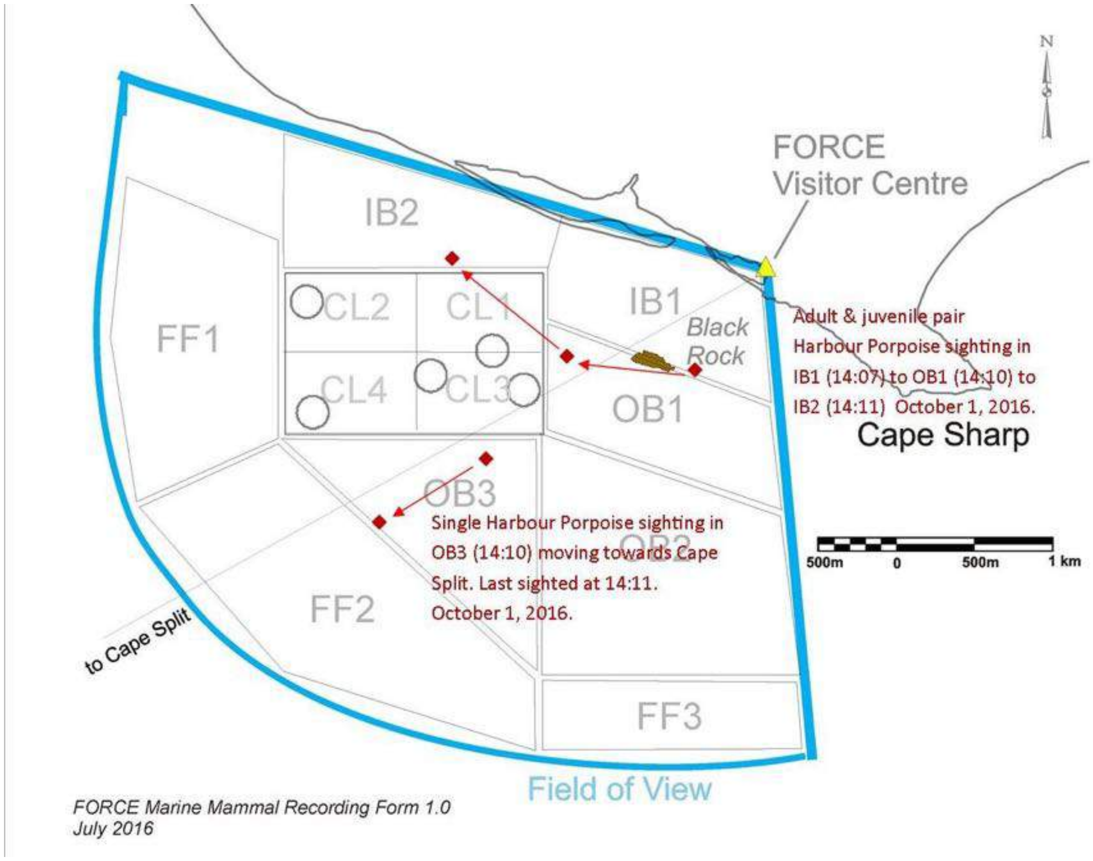


Figure 5. Depiction of first Harbour Porpoise sightings on October 1, 2016 from the FORCE Visitor Center outdoor observation deck.

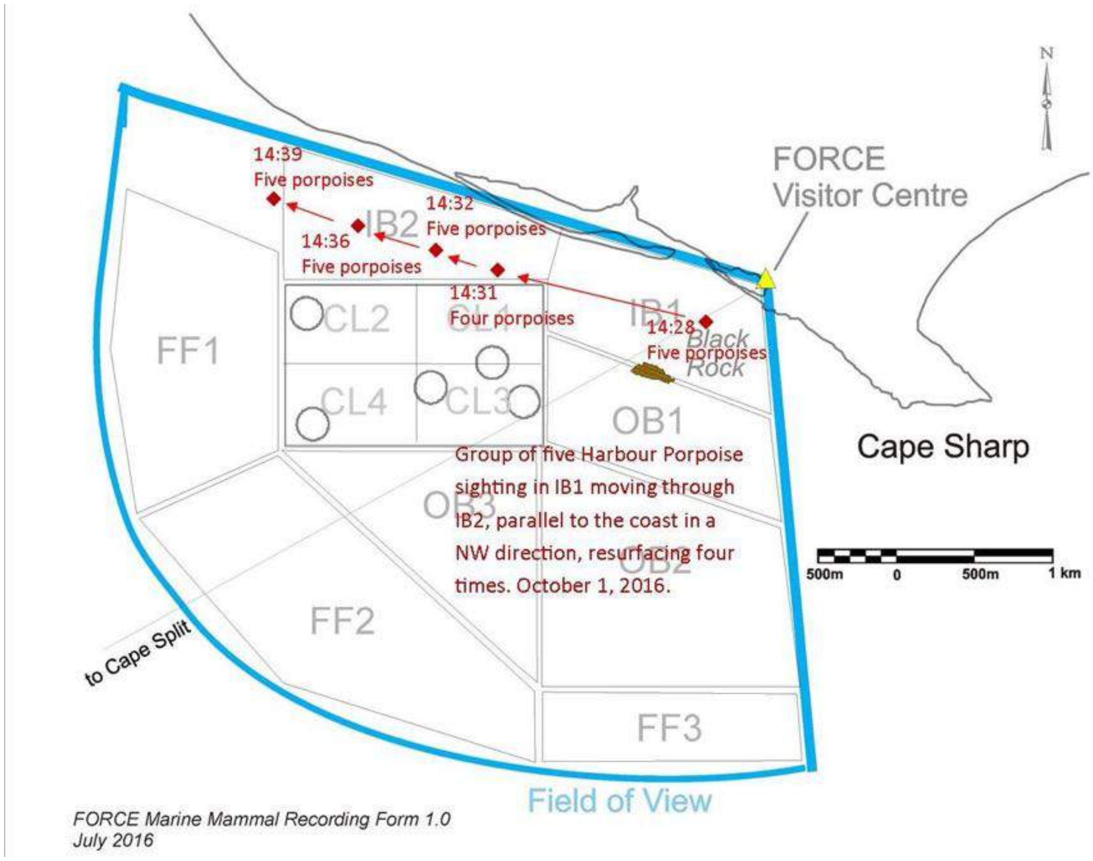


Figure 6. Depiction of second Harbour Porpoise sightings on October 1, 2016 from the FORCE Visitor Center outdoor observation deck.

APPENDIX

OBSERVATIONS FROM MAY 6, JUNE 2, JULY 2, 2016

Table 1. 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 2. 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 3. 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 7. Marine mammal observations during shore-based seabird and marine mammal surveys, Fundy Tidal Power Demonstration Site, May 6, June 2, July 2, 2016.

Date	Time (ADT)	Survey Component	Location Sighted	Species	Number
May 6, 2016	15:12-15:42	Shore	Turbine Area (CL) into Farfield Area (FF)	Harbour Porpoise	2
June 2, 2016	17:00-17:30	Shore	Inside Black Rock	Harbour Porpoise	1
July 2, 2016	12:08-12:10	Shore	Outside Black Rock (OB1-2) into Turbine Area (CL)	Harbour Porpoise	2
	12:20-12:50	Shore	Inside Black Rock (IB2)	Harbour Porpoise	1

Appendix 5: Seabirds Environmental Effects Monitoring Plan Interim Report 3

Interim report summarizing results from seabird surveys from November 2016 – February 2017. Prepared by Envirosphere Consultants Limited.

THIRD QUARTERLY SHORE-BASED SEABIRD AND MARINE MAMMAL SURVEY – TIDAL ENERGY DEMONSTRATION SITE, FUNDY OCEAN RESEARCH CENTER FOR ENERGY: NOVEMBER 17 2016; DECEMBER 1 2016; JANUARY 16 2017; FEBRUARY 21 2017

24 February 2017 – *Revised*

Prepared for:

Melissa Oldreive, Director of Environmental and Regulatory Affairs
Fundy Ocean Research Center for Energy
1690 Hollis Street, Unit 1001
Halifax, Nova Scotia B3J 1V7

Prepared by:

Valerie Kendall, M.Env.Sc., Environmental Biologist
Patrick L. Stewart, M.Sc., President
Envirosphere Consultants Limited
120 Morison Drive, Windsor Nova Scotia Unit 5 B0N 2T0
902 798 4022 | enviroco@ns.sympatico.ca | www.envirosphere.ca

EXECUTIVE SUMMARY

Monthly shore-based surveys for marine birds began at the FORCE Visitor Center in the spring of 2016 during early to mid-breeding season. Beginning in October and ending in December, survey frequency was increased to twice monthly in order to capture the migratory period. Surveys took place on May 6, June 2 and July 2, 2016 over a six-hour period in half hour increments on the out-going tide, beginning at high tide and concluding at low tide. Observations were summarized in an initial quarterly report dated July 22, 2016. Subsequent surveys took place on August 2, September 1, October 1 & 17, and November 3, 2016 during the late and post-breeding/moulting and migration season. These observations were reported in a second quarterly report submitted to FORCE on November 21, 2016.

Surveys presented in the following report were completed on November 17, 2016, December 1, 2016, January 16, 2017, and February 21, 2017, for a total of twelve shore-based surveys completed to date. Low to moderate abundances of seabirds were observed, lowest in November (113 individuals) and highest in January (558 individuals, primarily Herring and Great Black-backed Gulls), with a total of 17 seabird species observed. Individual harbour porpoises were observed during the November 17th 2016 and January 16th 2017 surveys. As well, a harbour seal was observed resting on Black Rock during the January 17th 2017 survey. Overall the number of birds observed at the site is lower than expected, based on earlier baseline surveys, and reflects the broader pattern of bird abundance not connected with activity at the FORCE site. A report will be submitted in the spring of 2017 providing a comprehensive analysis of the year-long seabird monitoring program according to the proposed schedule.

Due to poor weather condition, a second December survey (scheduled for December 15, 2016) was cancelled. In January, survey frequency returned to once monthly. Field observations and species identifications are conducted by a professional bird observer, Fulton Lavender of Halifax Nova Scotia, and documented by Valerie Kendall (M.Env.Sc., Project Biologist). Observations are made in the same general way as earlier surveys (2010-2012)[1], but using a grid system adopted for the present surveys. Waters are surveyed from the interpretive center to mid-Minas Passage within the field of view, which includes the waters across Minas Passage from the site and down the shore into Minas Channel, as well as covering the area towards Cape Split and therefore covering the area designated for turbine installation[2]. Observations are made with a 22x Celestron spotting scope as well as 8x and 10x binoculars (Figures 1 and 2).

Seasonal timing of observations have been scheduled so that critical times for birds, in particular for migrating birds, are adequately represented in the data as much as possible. Abundance of water-associated birds (loons, cormorants, waterfowl, gulls, alcids) at the Minas Passage site in past showed seasonal peaks corresponding to migratory movements (March-April and October-November) and a late

---

[1] Observations from 2011 onward were made from the outdoor observation deck or inside the FORCE Visitor Center. Although this location is about 150 m from shore, the view was satisfactory when the spotting scope and binoculars were used, and the site provided a better overview of the site.

[2] The Cape Sharp Tidal Development turbine was installed on November 7, 2016. Observations documented in the current survey include both pre- and post-installation.

120 Morison Drive, Unit 5, Windsor, Nova Scotia, B0N 2T0 | (902) 798 4022 | enviroco@ns.sympatico.ca | www.envirosphere.ca

spring to early summer occupation of the area by local resident breeders such as Black Guillemot, Common Eider, Double-Crested Cormorant, and Herring and Great Black-backed Gulls (Envirosphere Consultants 2011-2013). There is a low summer abundance of local species, when migrants are not present and individuals of local breeding species such as gulls and cormorants move out of the area.

The observation team initially records separately all birds sitting or associated with the water in the survey subdivisions, including on Black Rock (Figure 1). Following this, a flying 'snapshot' is carried out to record all birds in flight observed throughout the subdivisions. The remainder of the 30-minute interval is used to record additional birds flying into the area or on the water. Birds observed in the vicinity of Black Rock and also in the Crown Lease Area ("critical area") are highlighted. A summary of bird and marine mammal observations to date are presented in Tables 1-8. Weather information and environmental data was also recorded from the weather station operating at the FORCE facility.

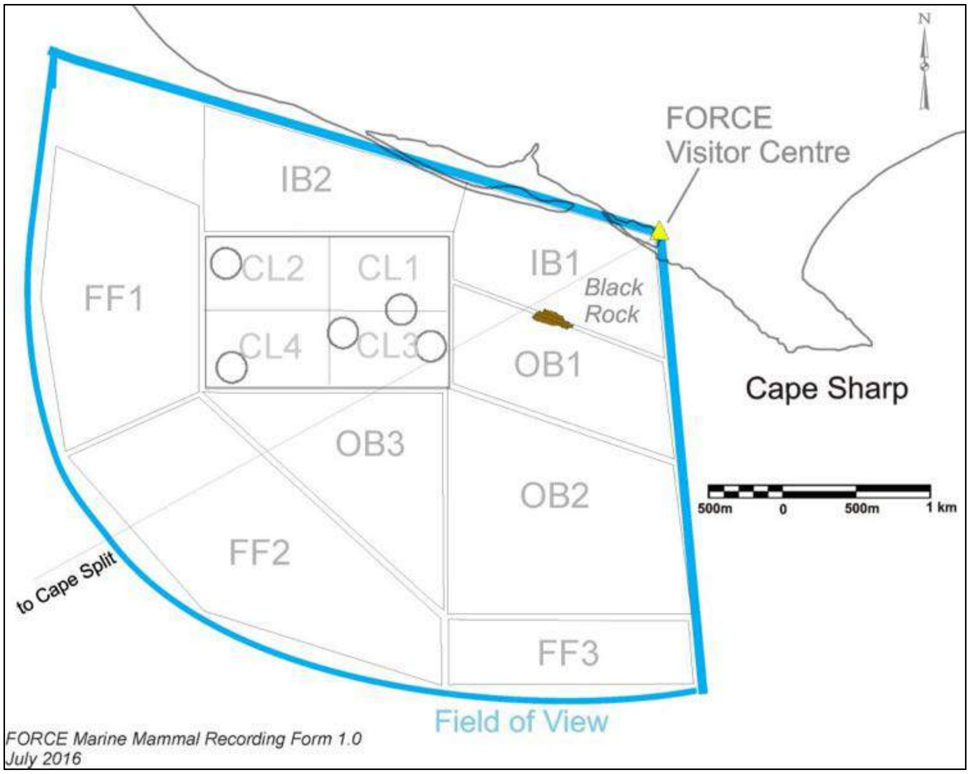


Figure 1. Study area field of view with grid showing open water subdivisions to document marine bird and mammal occurrences. (CL1-4 = turbine field/crown lease area; IB1-2 = Nearshore area/Inside Black Rock; OB1-3 Buffer area/outside Black Rock; FF1-3 Far-field buffer area.

Figure 2. A view of Minas Passage during a marine bird survey on January 16, 2017.

SUMMARY OF SURVEYS

November 17, 2016 – Valerie Kendall and Fulton Lavender arrived at the FORCE Visitor Center at 11:45 am and began the survey at 12:00 pm. The temperature was steady at about 11°C for the duration of the survey with an overcast sky. Winds were low and primarily from the west, shifting to southerly at the time of the final survey. Peak high tide was at 14:25. The survey was completed at 17:10 once daylight had ended.

A total of 12 bird species were observed during the survey including an Arctic Loon and Atlantic Puffin, both flying west through the CL subsection during the 14:30 survey segment; and Common Loon was also observed flying east through the CL subsection. Arctic Loon habitat in North America is along the Pacific coast, primarily Alaska. Over-wintering habitat in North America is not well documented, however observation of birds in Mexico and California indicate a preference for sheltered bays with calm water. The presence of a vagrant Arctic Loon in the Minas Basin is unusual and has not previously been documented (Fulton Lavender, pers comm 2016; Birds of North America, Online 2017).

Red-throated Loon was the most abundant bird, observed flying west through the Minas Passage, outside Black Rock and through the CL subsection. Over 60 loons were counted, attributed to migratory behavior of the species, which overwinters in coastal and estuary areas in Nova Scotia and further south along the Atlantic coastb. Other species in smaller abundances observed flying through the CL subsection included Black Scoter (4), Long-tailed Duck (3), Common Murre (8) and Red-necked Grebe (1). Common Eider were occasionally observed flying through IB1 and a single Razorbill was observed flying west through OB2. Small numbers of Herring Gull and Ring-billed Gull were observed throughout the survey circling or flying, generally west, in the CL and and IB1 subsections. Additionally, a single harbour porpoise was observed during the 13:30 – 14:00 survey segment in the OB1 subsection, west of Black Rock.

December 1 2016 – Valerie Kendall and Fulton Lavender arrived at the FORCE Visitor Center at 11:50 and began the survey at 12:30. Weather conditions were overcast with light rain on arrival that subsided by the survey start time; light fog remained throughout the day. The temperature increased throughout the day beginning at 3.7°C to reach 6.1°C by the final survey interval, which ended at 17:00. Visibility was poor by late afternoon (15:00) due to a fog bank from the south, allowing visibility to just beyond Black Rock (roughly one kilometer from shore). Winds were moderate and gusty, coming from an ESE direction, about 25 kph and causing rough water conditions (wavelets with white caps).

Bird abundance was low with no birds documented for five of the survey intervals. A single American Black Duck was observed during the 13:00 survey segment, and a single Herring Gull and a Great Black-back Gull were observed during two of the survey segments. During the final survey segment (16:30 – 15:00), 148 Herring Gulls, one Great Black-backed Gull and one Ring-billed Gull arrived and landed on Black Rock. Five Common Merganser were also observed flying east through IB1. A total of five bird species were observed. The survey concluded at 17:00 when daylight was ending.

December 15, 2016 – Upon arrival in Parrsboro, increasingly poor weather conditions prevented the survey from being completed as visibility of the survey site as well as travel conditions were unsuitable.

January 16, 2017 – Valerie Kendall and Fulton Lavender arrived at the FORCE Visitor Center at 11:30 and began the survey at 12:15. Cloud cover was sparse for the first hour of the survey, and became completely cloud covered for the remainder of the survey. Winds were light at about 30 kilometers per hour (kph) from the west, and the temperature ranged from about -4°C, at the survey start, to about -2°C at the survey end. Peak high tide was at 15:25.

Bird abundance was low during the first half of the survey. Six, and then eight, Common Goldeneye were present on the water close to shore in IB1. Black Duck (3), Common Eider (4), a Common Murre and a Common Loon were also observed flying through IB1 and the CL subsections. During the last two hours of the survey, a large number of Herring Gulls and Great Black-backed Gulls, and an Iceland Gull, flew in to land on Black Rock. By the completion of the survey, at 17:45, over 300 gulls were present on Black Rock. A total of eight bird species were observed. Additionally, a single harbor porpoise was observed at 13:09 swimming from the Crown Lease (CL) area into the OB1 subsection heading towards West Bay. It resurfaced at about 13:13 east of Black Rock in OB1. A harbour seal was also observed on the east end of Black Rock close to the water line at about 13:00. It remained until about 14:30 when the water level of the incoming tide submerged its resting place and the seal swam away.

February 21, 2017 – Valerie Kendall and Fulton Lavender arrived at the FORCE Visitor Center at 11:15 and began the marine bird survey at 12:00. Weather conditions were sunny with a clear sky, light winds and a temperature of about zero degrees Celsius. Peak high tide was at 8:23 and low tide at 14:42.

Bird abundance was low for the duration of the survey with a total of six species observed including a single Common Loon, a single Red-throated Loon, and three Great Cormorant, which were observed flying east through the CL subsection. Five Common Goldeneye were present on the water from the start of the survey until the end of the 14:00 survey segment, diving and feeding, near the shore in IB1. Single Herring Gulls were occasionally observed through the afternoon circling outside Black Rock and began to increase in number, along with Great Black-backed Gulls during the last three half-hour survey segments as they arrived to land on Black Rock. At the completion of the survey (18:00), 41 Herring Gulls and 58 Great Black-back Gulls were present on Black Rock.

TABLES

Table 1. 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 2. 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 3. 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 4. 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 5. Comparison of average number of individual sea- and shorebird species observed from the FORCE Visitor Center per 30-minute interval.
2016 –November 17 & December 1 | 2017 – January 16 & February 21

Species	Nov 17	Dec 1	Jan 16	Feb 21
ARLO	0.1	0	0	0
ATPU	0.1	0	0	0
ABDU	0	0.2	0.3	0
BLSC	0.5	0	0	0
CAGO	0	0	0	0
COEI	0.6	0	0.4	0
COGO	0	0	2	2.2
COLO	0.1	0	0.2	0.1
COMU	0.7	0.4	0.1	0
DCCO	0	0	0	0
GBBG	0	0.2	27.5	4.8
GRCO	0	0	0	0.3
HEGU	1.2	12.6	25.2	3.4
ICGU	0	0	0.1	0
LBBG	0	0	0	0
LEYE	0	0	0	0
LTDU	0.3	0	0	0
PEFA	0	0	0	0
RAZO	0.1	0	0	0
RBGU	0.5	0.1	0	0
RBGU	0	0	0	0
RBME	0	0	0	0
RNGR	0.1	0	0	0
RTLO	6.1	0	0	0.2
SPSA	0	0	0	0
SUSC	0	0	0	0
WISP	0	0	0	0
WWSC	0	0	0	0

Table 6. Comparison of species list of marine mammals and seabirds at Fundy Tidal Power Demonstration Site, from shore based observations, 2010, 2011 & 2016.

SPECIES	2010	2011	2016	2017
	MAY, JUNE, OCTOBER, NOVEMBER	MARCH, APRIL, DECEMBER	MAY – NOVEMBER	JANUARY - FEBRUARY
ARLO			✓	
ABDU	✓	✓		✓
Alcid sp		✓		
ATPU	✓		✓	
BLGU	✓	✓	✓	
BLKI	✓	✓		
BLSC	✓	✓	✓	
CAGO	✓	✓	✓	
COEI	✓	✓	✓	✓
COGO		✓		✓
COLO	✓	✓	✓	✓
COME	✓			
COMU	✓	✓	✓	✓
DCCO	✓	✓	✓	
GBBG	✓	✓	✓	✓
GRCO	✓	✓	✓	✓
HADU	✓			
HEGU	✓	✓	✓	✓
HOGR	✓			
ICGU	✓		✓	✓
KIEI		✓		
LAGU	✓			
LBBG	✓	✓	✓	
LEYE			✓	
LTDU	✓	✓	✓	
MALL	✓			
MEGU	✓			
NOGA	✓	✓		
NSHO		✓		
PALO	✓	✓		
RAZO	✓	✓	✓	
RBGU	✓	✓	✓	✓
RBME	✓	✓	✓	
RNGR	✓		✓	
RTLO	✓	✓	✓	✓
SCSP		✓		
SPSA			✓	
SUSC	✓	✓	✓	
TBMU	✓	✓		
WISP			✓	
WWSC	✓	✓	✓	
TOTAL # OF SPECIES	33	28	25	11

Table 7. Seabirds observed at Fundy Tidal Power Demonstration Site, 2016 - 2017 Shore-based Surveys.

Species Code	Common Name	Scientific Name
WATERFOWL		
BLSC	Black Scoter	*Melanitta americana*
ABDU	American Black Duck	*Anas rubripes*
CAGO	Canada Goose	*Branta canadensis*
COEI	Common Eider	*Somateria mollissima*
GOCO	Common Goldeneye	*Bucephala clangula*
COLO	Common Loon	*Gavia immer*
LTDU	Long-tail Duck	*Clangula hyemalis*
RBME	Red-breasted Merganser	*Mergus serrator*
RTLO	Red-throated Loon	*Gavia stellata*
SUSC	Surf Scoter	*Melanitta perspicillata*
WWSC	White-winged Scoter	*Melanitta deglandi*
SEABIRDS		
ARLO	Arctic Loon	*Gavia arctica*
ATPU	Atlantic Puffin	*Fratercula*
BLGU	Black Guillemot	*Cepphus grylle*
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*
GBBG	Great Black-backed Gull	*Larus marinus*
GRCO	Great Cormorant	*Phalacrocorax carbo*
HEGU	Herring Gull	*Larus argentatus*
ICGU	Iceland Gull	*Larus glaucoides*
LBBG	Lesser Black-backed Gull	*Larus fuscus*
RAZO	Razorbill	*Alca torda*
RBGU	Ring-billed Gull	*Larus delawarensis*
WISP	Wilson's Storm Petrel	*Oceanites oceanicus*
SHOREBIRDS		
LEYE	Lesser Yellowlegs	*Tringa flavipes*
SPSA	Spotted Sandpiper	*Actitis macularius*

Table 8. Marine mammal observations during shore-based seabird and marine mammal surveys, Fundy Tidal Power Demonstration Site. August 2, September 1, October 1 & 17, November 3, 2016.

Date	Time (ADT)	Survey Component	Location Sighted	Species	Number
November 17, 2016	13:30 – 14:00	Shore	OB1	Harbour Porpoise	1
January 16, 2017	13:09 & 13:13	Shore	OB1; East of Black Rock	Harbour Porpoise	1
January 16, 2017	13:00 – 14:30	Shore	Black Rock	Harbour Seal	1

APPENDIX

Observations from May 6, June 2, July 2, 2016

Table 1. 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 2. 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 3. 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 7. Marine mammal observations during shore-based seabird and marine mammal surveys, Fundy Tidal Power Demonstration Site, May 6, June 2, July 2, 2016.

Date	Time (ADT)	Survey Component	Location Sighted	Species	Number
May 6, 2016	15:12-15:42	Shore	Turbine Area (CL) into Farfield Area (FF)	Harbour Porpoise	2
June 2, 2016	17:00-17:30	Shore	Inside Black Rock	Harbour Porpoise	1
July 2, 2016	12:08-12:10	Shore	Outside Black Rock (OB1-2) into Turbine Area (CL)	Harbour Porpoise	2
	12:20-12:50	Shore	Inside Black Rock (IB2)	Harbour Porpoise	1

Observations from August 2, September 1, October 1 & 17, November 3, 2016

Table 9. 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 10. 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 11. 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
PEFA	0	0	0	0	0	0	0	0	0	0	0	1	0.1
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 12. 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 13. 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	21	16.0
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 14. Marine mammal observations during shore-based seabird and marine mammal surveys, Fundy Tidal Power Demonstration Site. August 2, September 1, October 1 & 17, November 3, 2016.

Date	Time (ADT)	Survey Component	Location Sighted	Species	Number
August 2, 2016	14:00	Shore	Crown Lease Area (CL)	Harbour Porpoise	1
September 1, 2016	14:50	Shore	Crown Lease Area (CL) towards FF1	Harbour Porpoise	4
October 1, 2016	14:07 – 14:10 – 14:11	Shore	IB1 into OB1 through CL into IB2	Harbour Porpoise	2
	14:10 – 14:11	Shore	OB3	Harbour Porpoise	1
	14:28 – 14:31; 14:32 – 14:39	Shore	IB1 near northeast corner of CL, into IB2; West through IB2	Harbour Porpoise	4 & 5

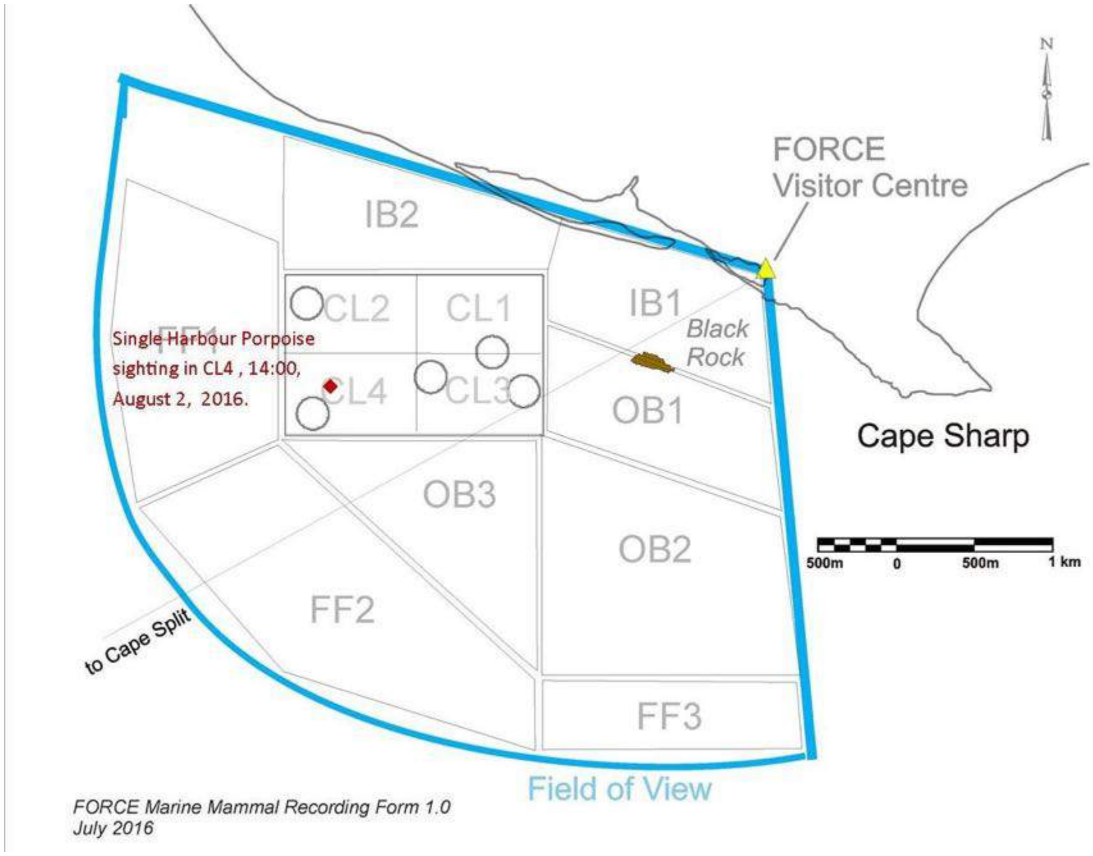


Figure 3. Depiction of a single Harbour Porpoise sighting on August 2, 2016 from the FORCE Visitor Center outdoor observation deck.

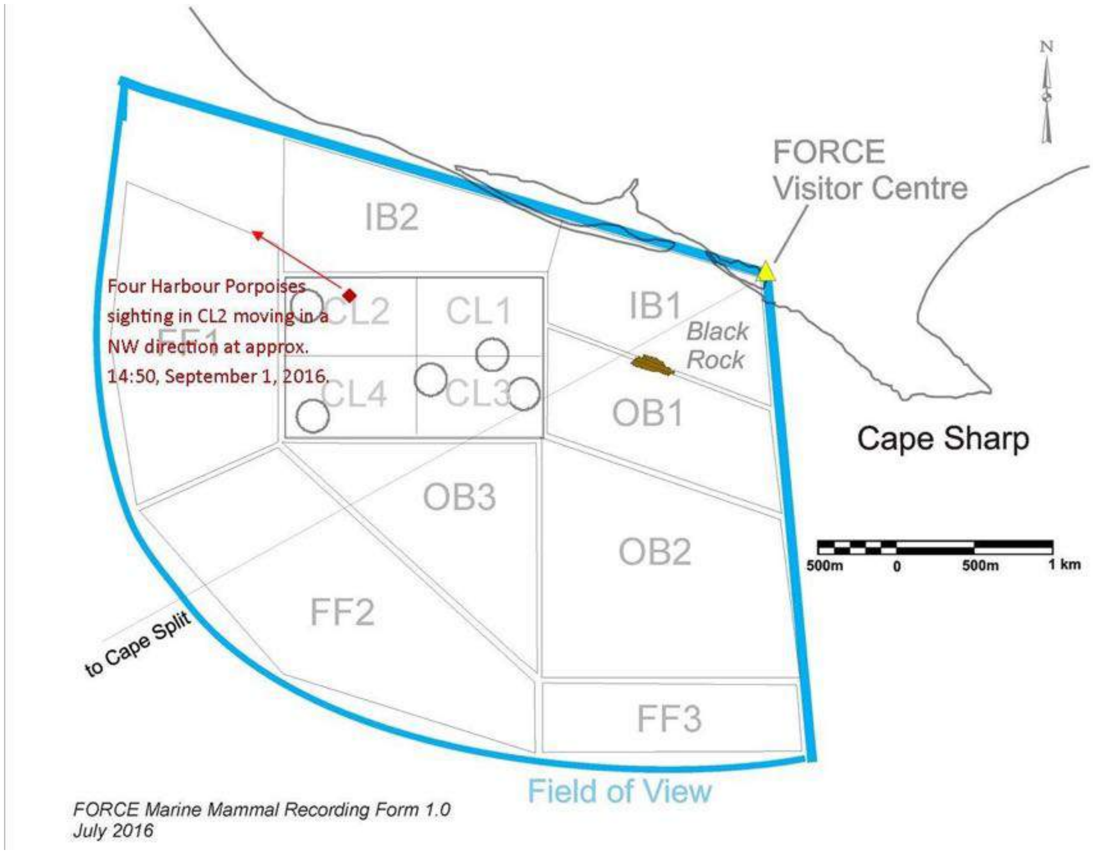


Figure 4. Depiction of Harbour Porpoise sightings on September 1, 2016 from the FORCE Visitor Center outdoor observation deck.

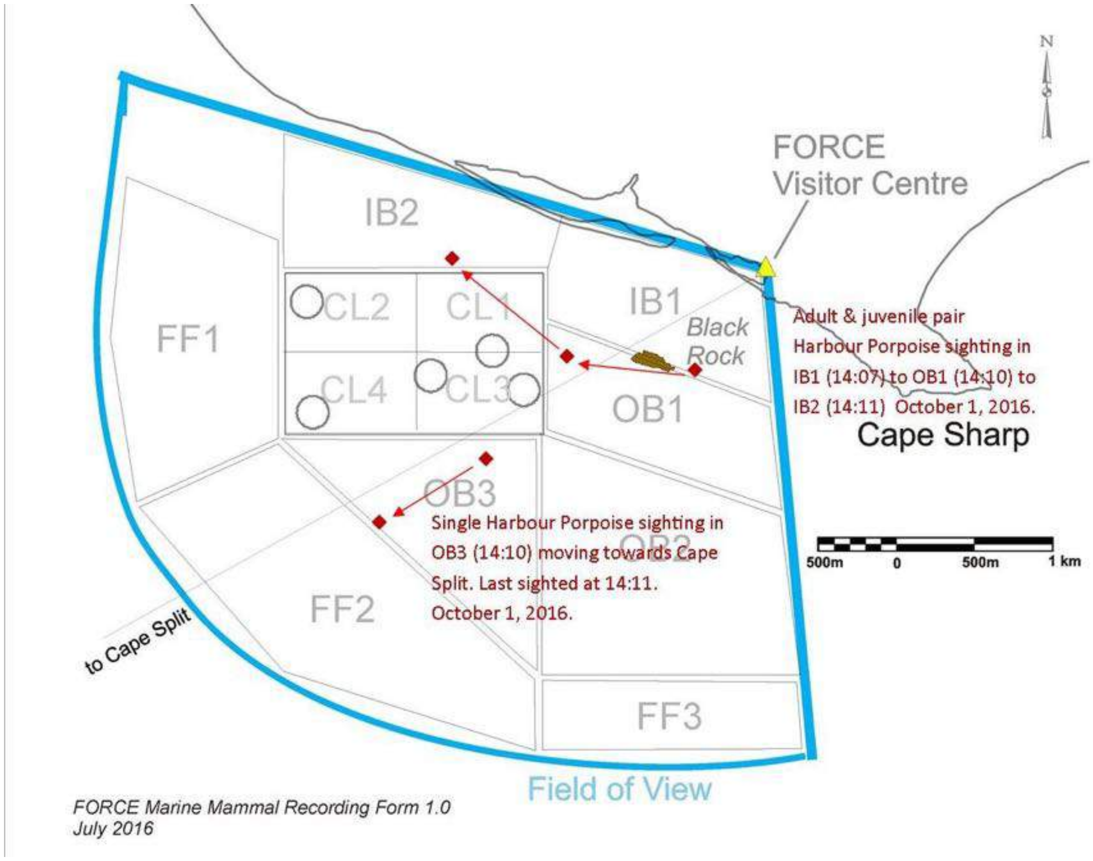


Figure 5. Depiction of first Harbour Porpoise sightings on October 1, 2016 from the FORCE Visitor Center outdoor observation deck.

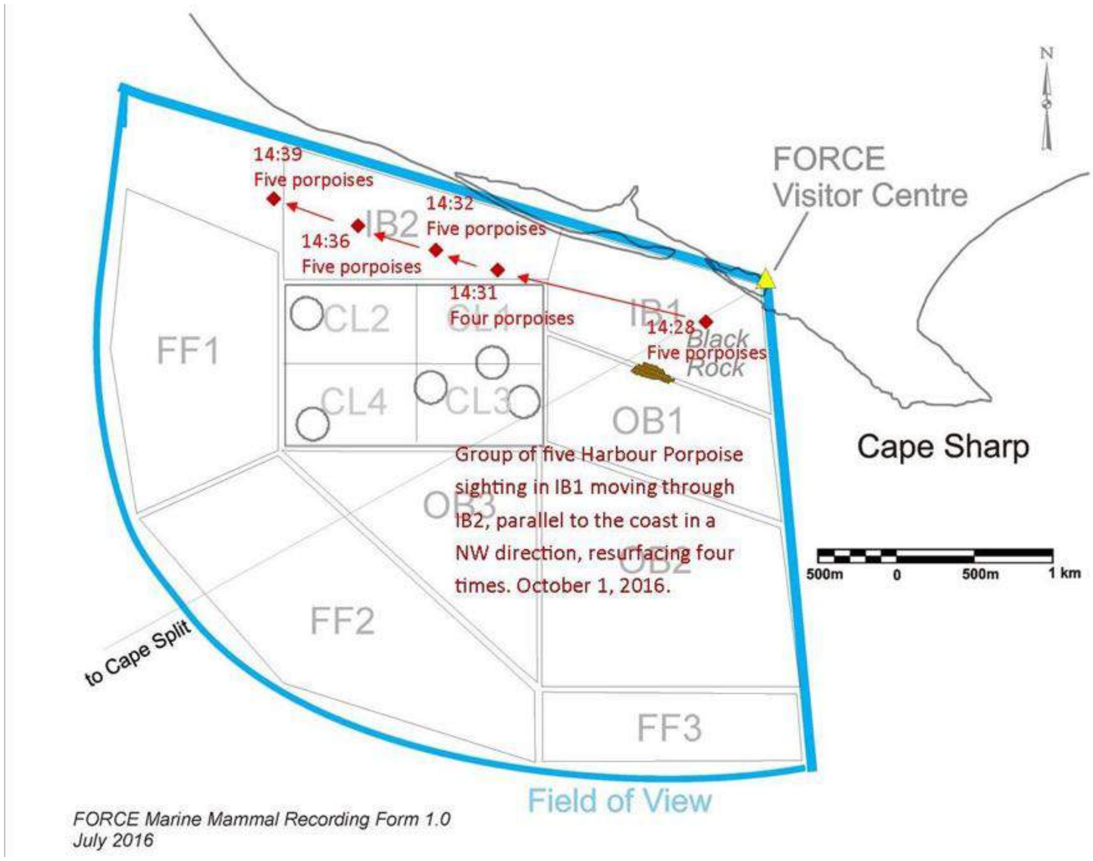


Figure 6. Depiction of second Harbour Porpoise sightings on October 1, 2016 from the FORCE Visitor Center outdoor observation deck.

Appendix 6: Environmental Monitoring Advisory Committee (EMAC)

EMAC membership includes:

- Gordon Beanlands, Ph.D., Retired, EMAC Chair
- Donald Aldous, Retired, Fisheries and Oceans Canada
- Sana Kavanagh, Nova Scotia Mi'kmaq Representative
- Graham Daborn, Ph.D., Emeritus Professor, AcadiaUniversity
- Andrew Hebda, M.Sc., Nova Scotia Museum
- Mike Stokesbury, Ph.D., Acadia University
- Mark Taylor, Fishers' Representative, President of Heavy Current Fishers Association
- Timothy Milligan, M.Sc., Emeritus Scientist, Bedford Institute of Oceanography
- Anna Metaxas, Ph.D, Dalhousie University
- John Tremblay, Ph.D., Scientist Emeritus, Bedford Institute of Oceanography, DFO

Additional information is available at: http://fundyforce.ca/about/advisory-committees/

Appendix 7: FAST-3 platform program: 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 8: Marine Mammal Monitoring Poster

Marine Animal Public Reporting

FORCE
Fundy Ocean Research Center for Energy

fundyforce.ca/environment/marine-animal-reporting

As part of FORCE's environmental effects monitoring program, we are asking for your help.

Our monitoring program relies on the public reporting of any unusual marine life behaviour. This includes, but isn't limited to:

- a marine mammal stranding or in distress
- marine animal mortalities
- unusual concentrations or behaviour of seabirds

Animal in Distress/Mortality

If you see a marine animal in distress or wish to report a marine animal mortality, please contact the Marine Animal Response Society (MARS) toll-free hotline (1-866-567-6277).

Public Reporting

FORCE staff and volunteers also conduct an ongoing shoreline survey program. We welcome your participation: please contact facilities manager Mary McPhee at reporting@fundyforce.ca or 902-254-2510.

To report observations at any time, you can:

1. Use the online observation form (https://mmo.fundyforce.ca/)

OR

2. Send a paper copy of the Marine Mammal Report Form (fundyforce.ca/environment/marine-animal-reporting/) to reporting@fundyforce.ca

OR

3. Send the following info to reporting@fundyforce.ca:
   • Photos/videos (if possible)
   • A description of what you see
   • Note your location, weather conditions, time of day, etc.

Harbour porpoise

Information Sharing

All observations will be shared with Fisheries and Oceans Canada (DFO) and the Nova Scotia Department of Environment and the public via the FORCE website (personal information is confidential and for contact purposes only).

Learn more about FORCE's environmental programs at fundyforce.ca/environment/

Online app:
https://mmo.fundyforce.ca/

fundyforce.ca

Appendix 9: 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.

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

Suggested citation: Joy, R., Wood, J., Robertson, F. and Tollit D. (2017). Force Marine Mammal Environmental Effects Monitoring Program – 1st Year (2017) Monitoring Report. Prepared by SMRU Consulting (Canada) on behalf of FORCE, May 2, 2017.

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.

Table of Contents

List of Figures

List of Tables

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).

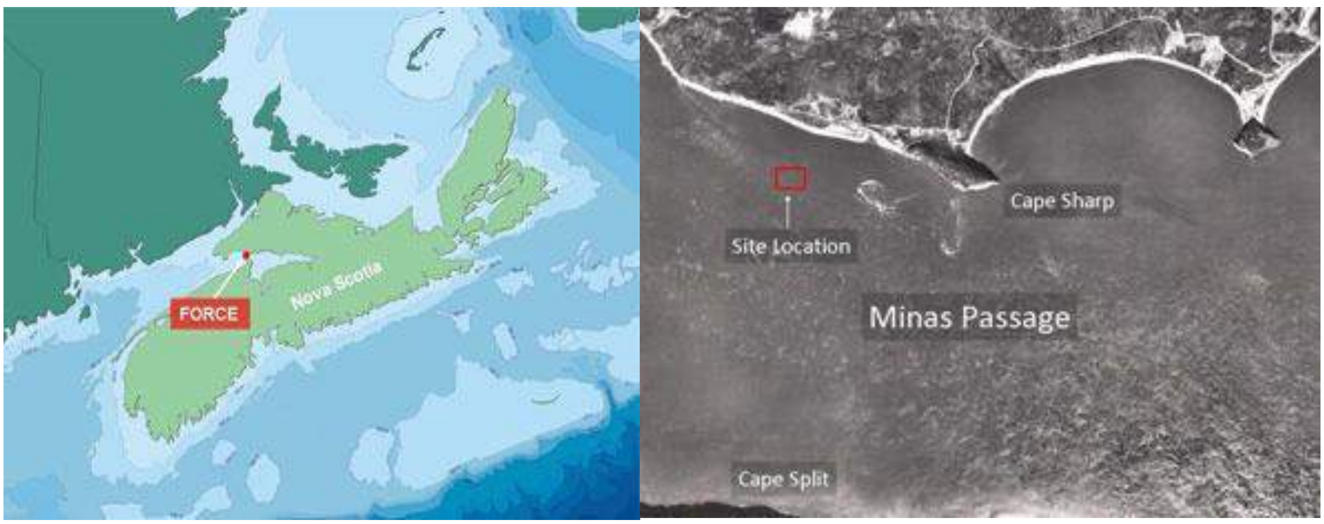


Figure 1. Reginal location of FORCE test site (Left Panel) and the location of the test site in Minas Passage (Right Panel).

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.

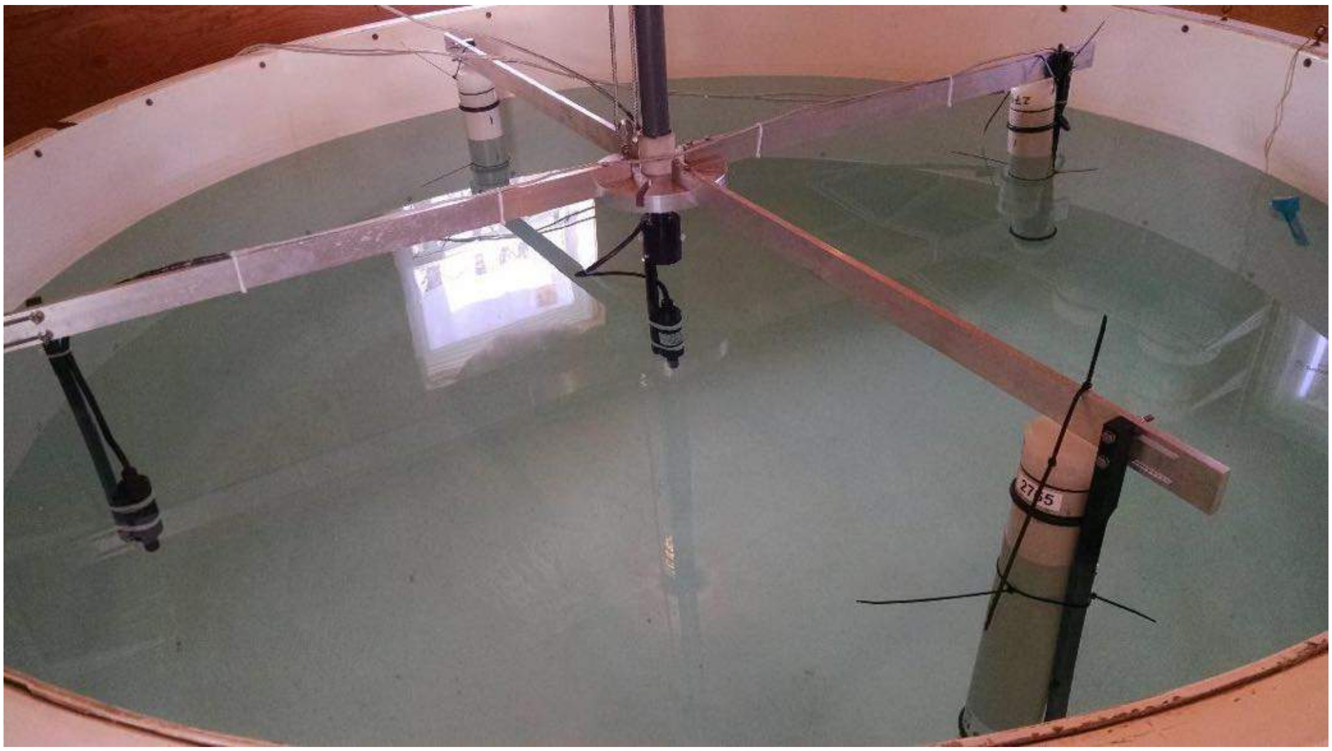


Figure 2. Experimental setup with the Ocean Sonics *icTalk* projector in the center of the tank, 3 C-PODs around the periphery and an Ocean Sonics *icListen* reference hydrophone, also at the periphery.

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

[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.

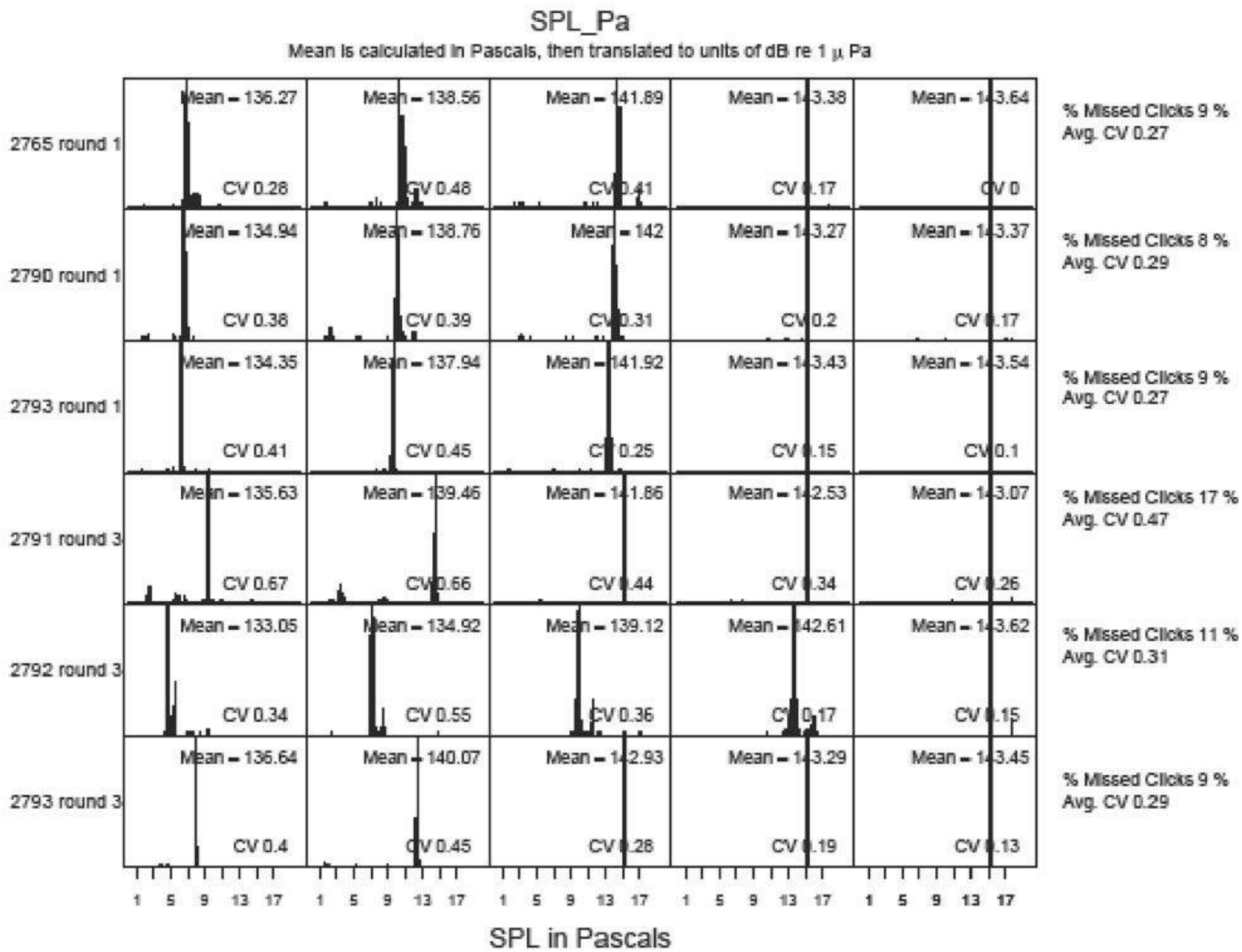


Figure 3. Distribution of click received levels (Sound Pressure Level reported in Pascals). Each column corresponds to each of the 5 amplitude levels of clicks generated by the *icTalk*. The loudest 2 sets of clicks exceeded the input level of the C-PODs and were thus recorded at the maximum SPL of the 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).

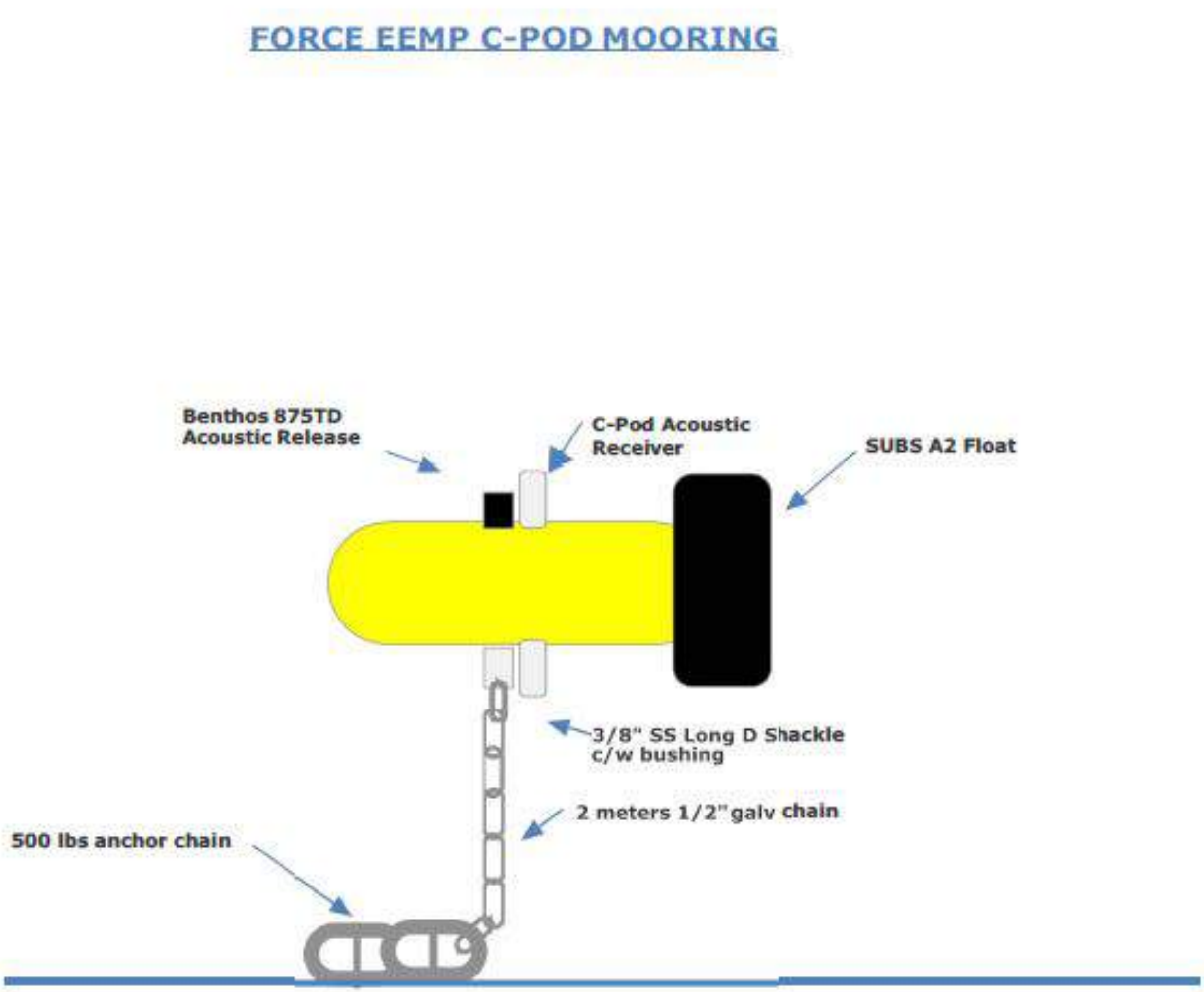


Figure 4. Diagram of FORCE C-POD mooring.

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

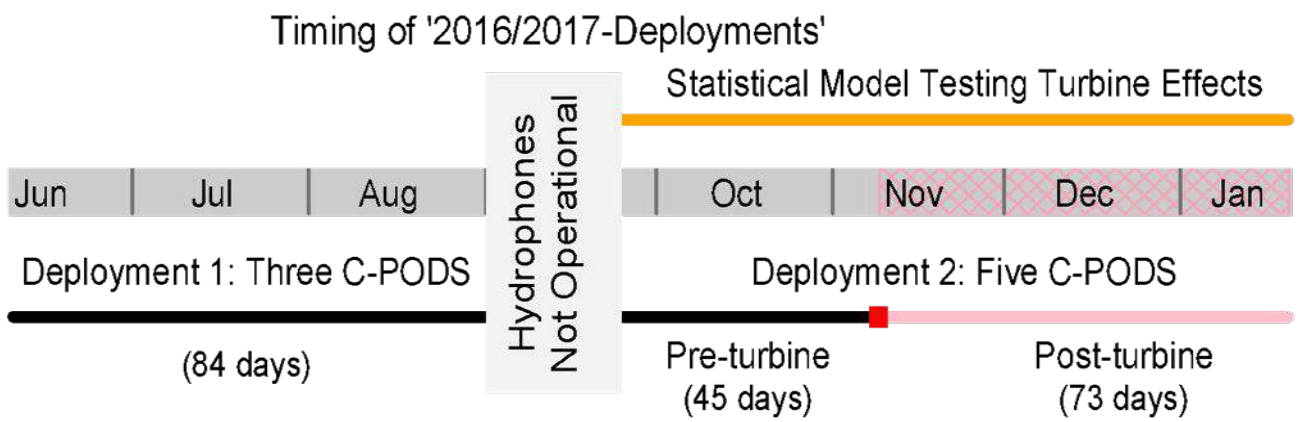


Figure 5. Timing of 2016/2017 deployments in which there were two periods of C-POD deployment to allow for retrieving acoustic data and for changing batteries. Deployment 1 included three C-PODS at D1, East1 and West1. Deployment 2 included an additional 2 C-PODS added to locations West2 and South2 (Figure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

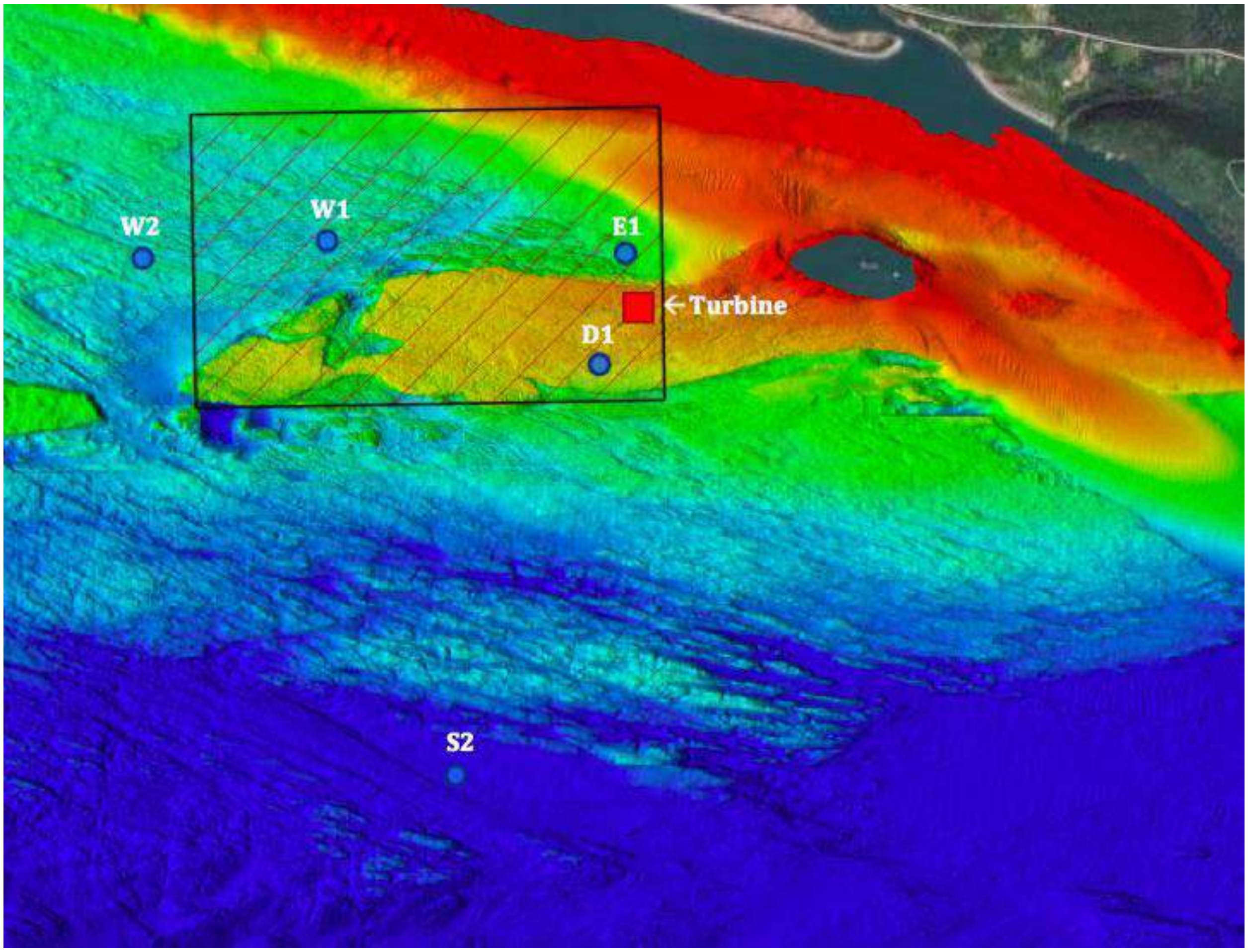


Figure 6. Locations of five monitoring C-PODs and CSTV turbine installed at Berth D. The hatched box denotes the FORCE demonstration area. Shallow water is depicted by warmer colours.

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.

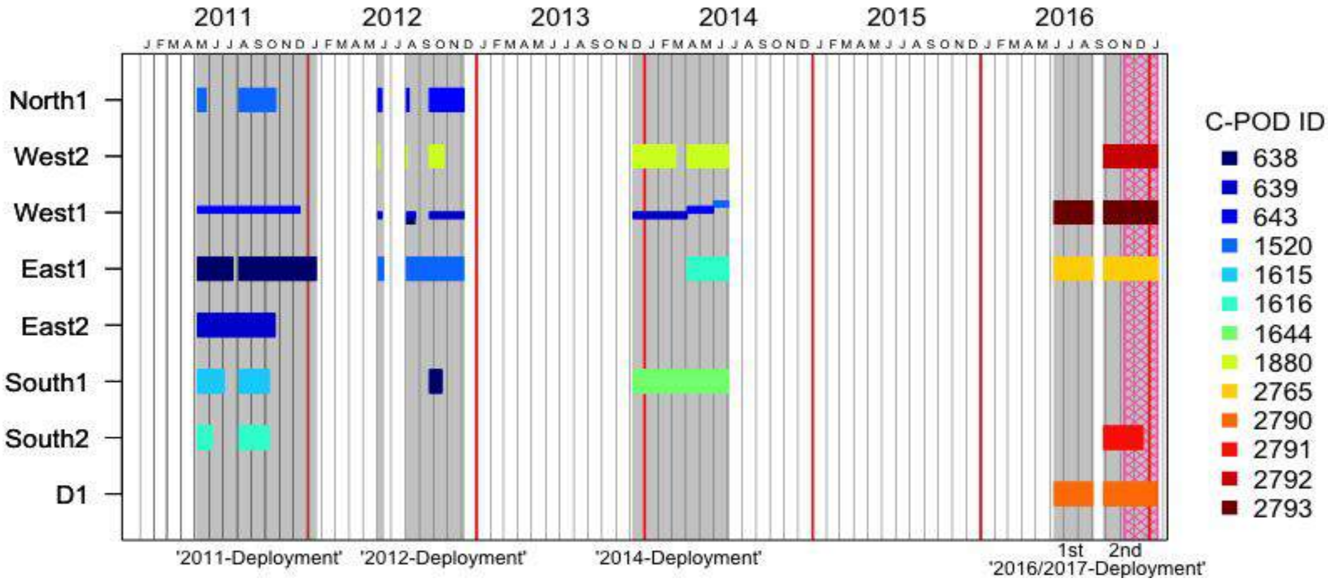


Figure 7. C-POD deployment history at 8 locations between 5 May 2011 and 18 January 2017. For descriptive purposes, this report describes four deployment periods denoted by the labels on the bottom x-axis. The 2nd of the 2016/2017 deployments includes the turbine installation on 7 November 2016 and covers 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.

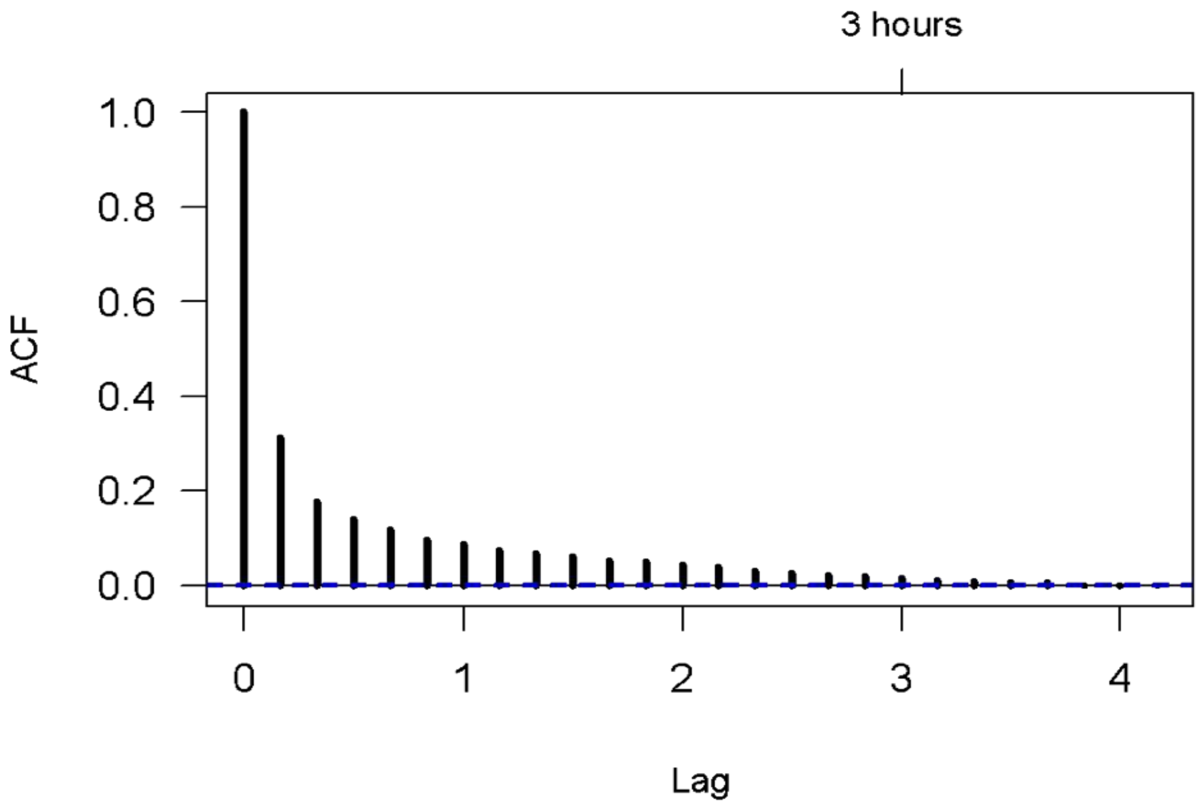


Figure 8. ACF of the model residuals without considering autocorrelation. This was used to set the autocorrelation structure of the GEE-GLM model, in which independence was assumed after a lag of 3 hours (after 18 time windows ACF=0.01).

[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.

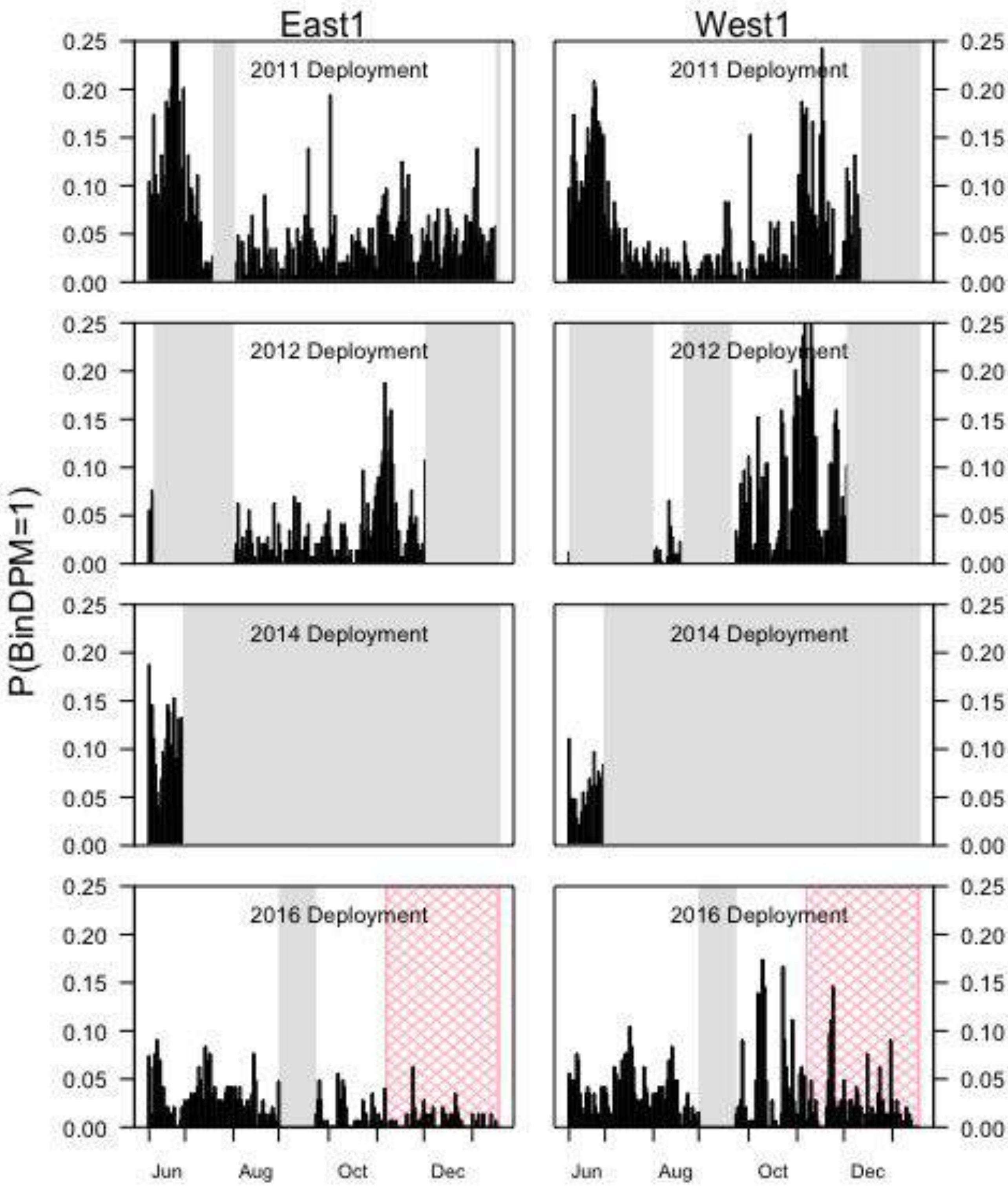


Figure 9. Comparing daily porpoise detections (P(BinDPM=1)) between 8 June and 18 January across 4 years of deployment. Grey periods denote when the hydrophones were not operational. The pink hatching on the bottom 2 panels denote the period when the turbine was installed.

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.

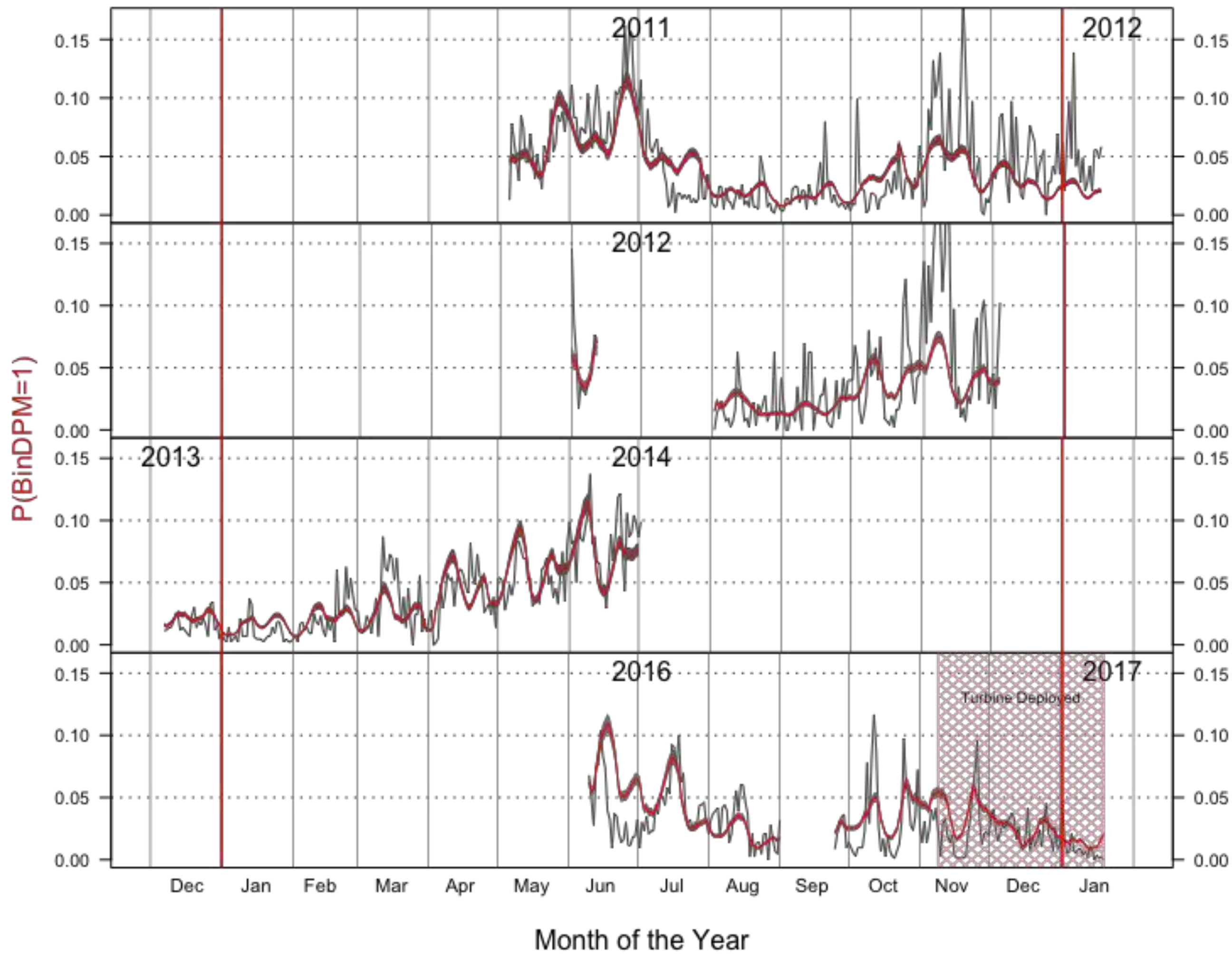


Figure 10. FORCE baseline data 2011-2017. Raw data BinDPM per day (grey lines) versus GEE-GLM model predictions of the overall mean probability of porpoise detection per time bin (PBinDPM) over time (red line).

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.

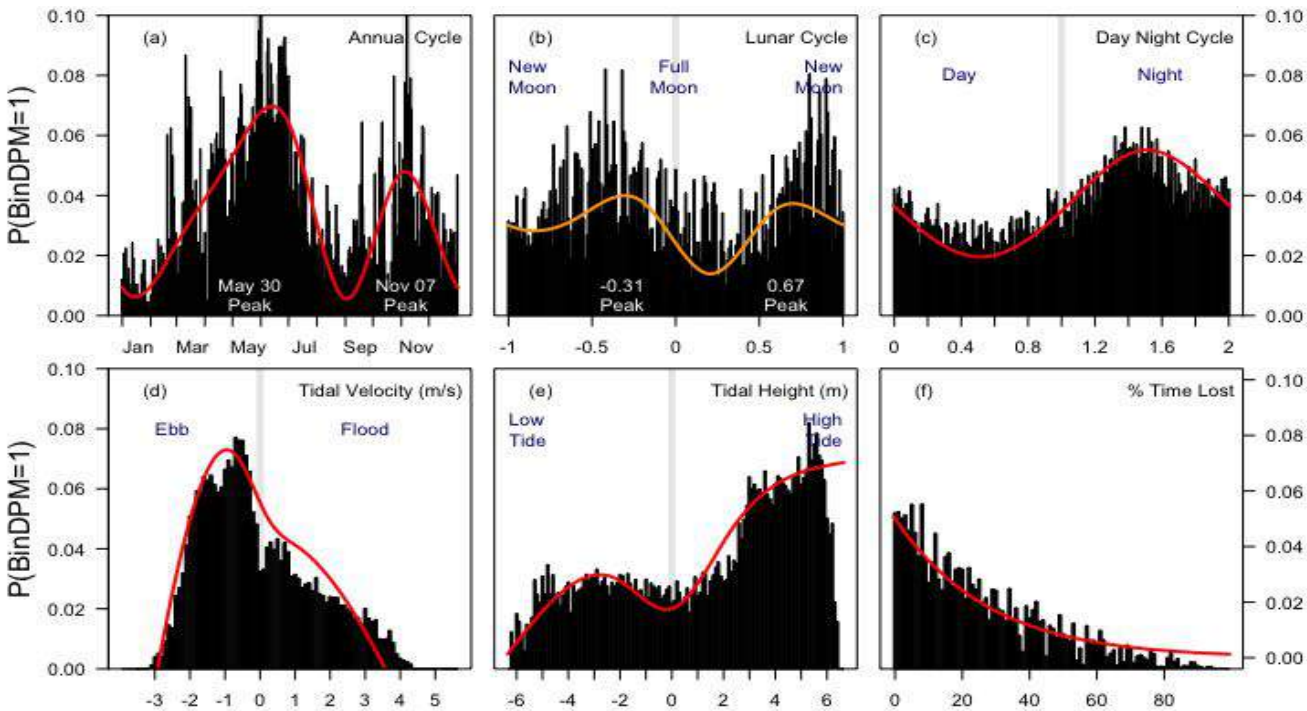


Figure 11. Shape of smoothing functions overlaid over the domain of a set of environmental variables. Black bars are P(BinDPM=1) frequency bars of raw data provided as a way to check the performance of the smoothing splines. Coloured lines are the cyclic (a, b, c) and non-cyclic (d, e) cubic regression 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.

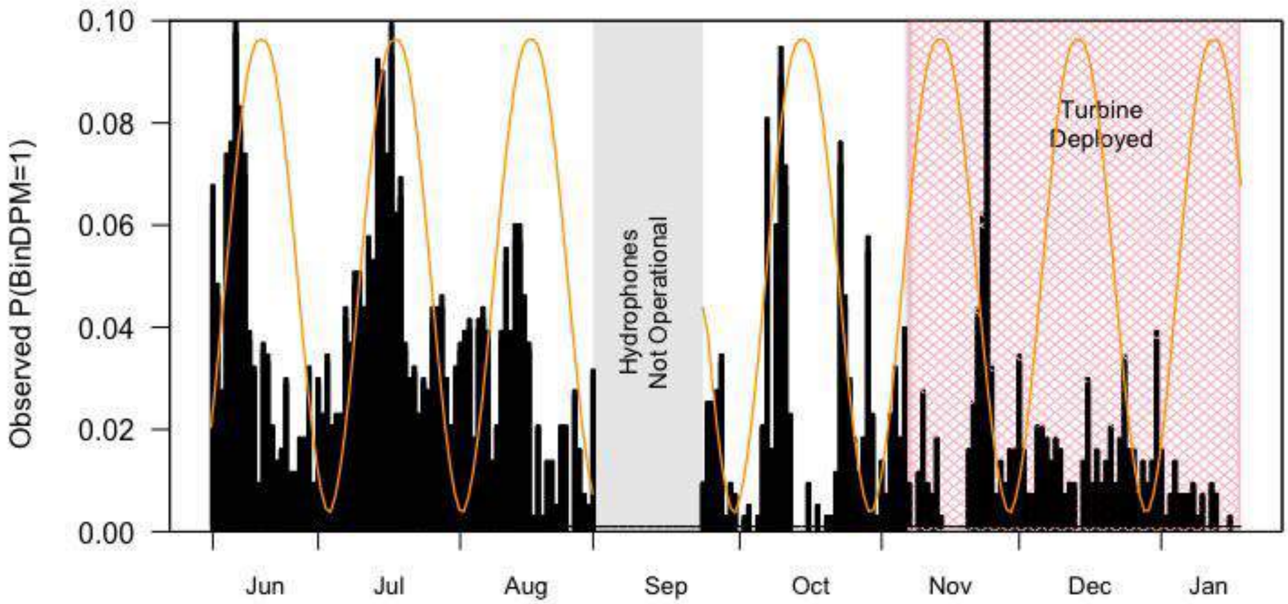


Figure 12. Raw Data from both time periods of 2016/2017 deployments: Lunar Cycle is overlaid in orange with spring tides at both the maximum and minimum of the cyclic function. Porpoise detections are maximized at just before (~70% along) the spring tide cycle.

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

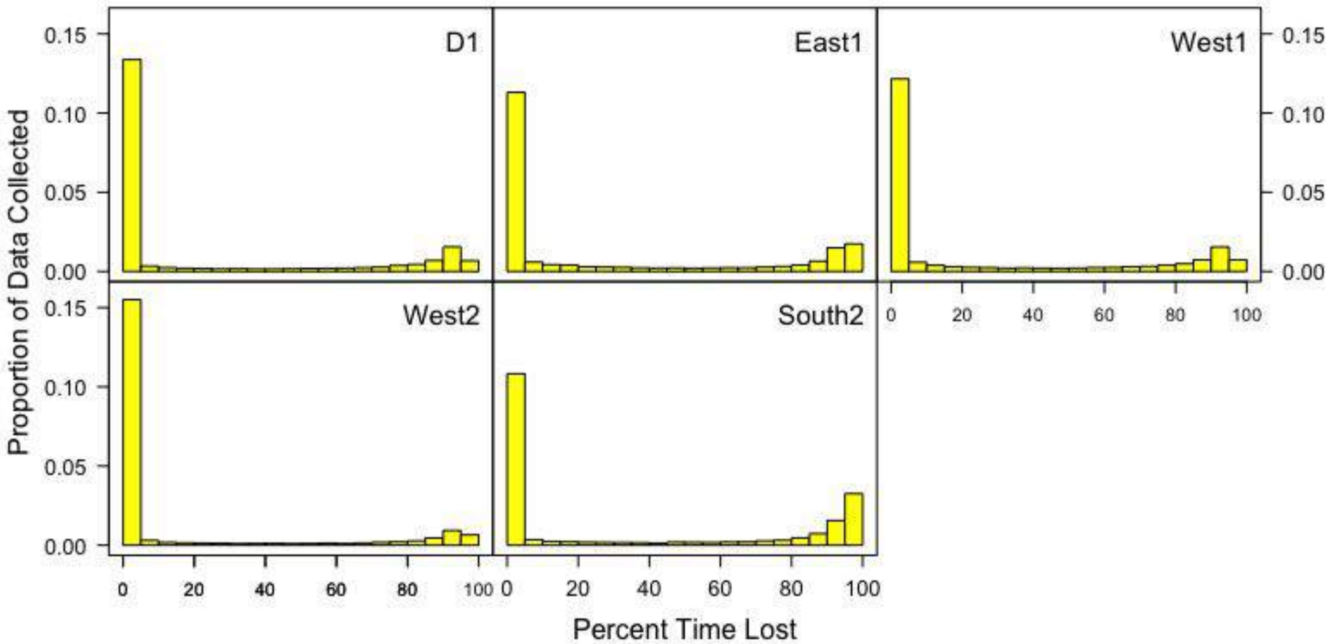


Figure 13. Distribution of % time-lost data from 5 hydrophone locations in the 2016/2017 deployments. For comparing between sites, both the X- and Y- axes are standardized to have the same limits.

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 α <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.

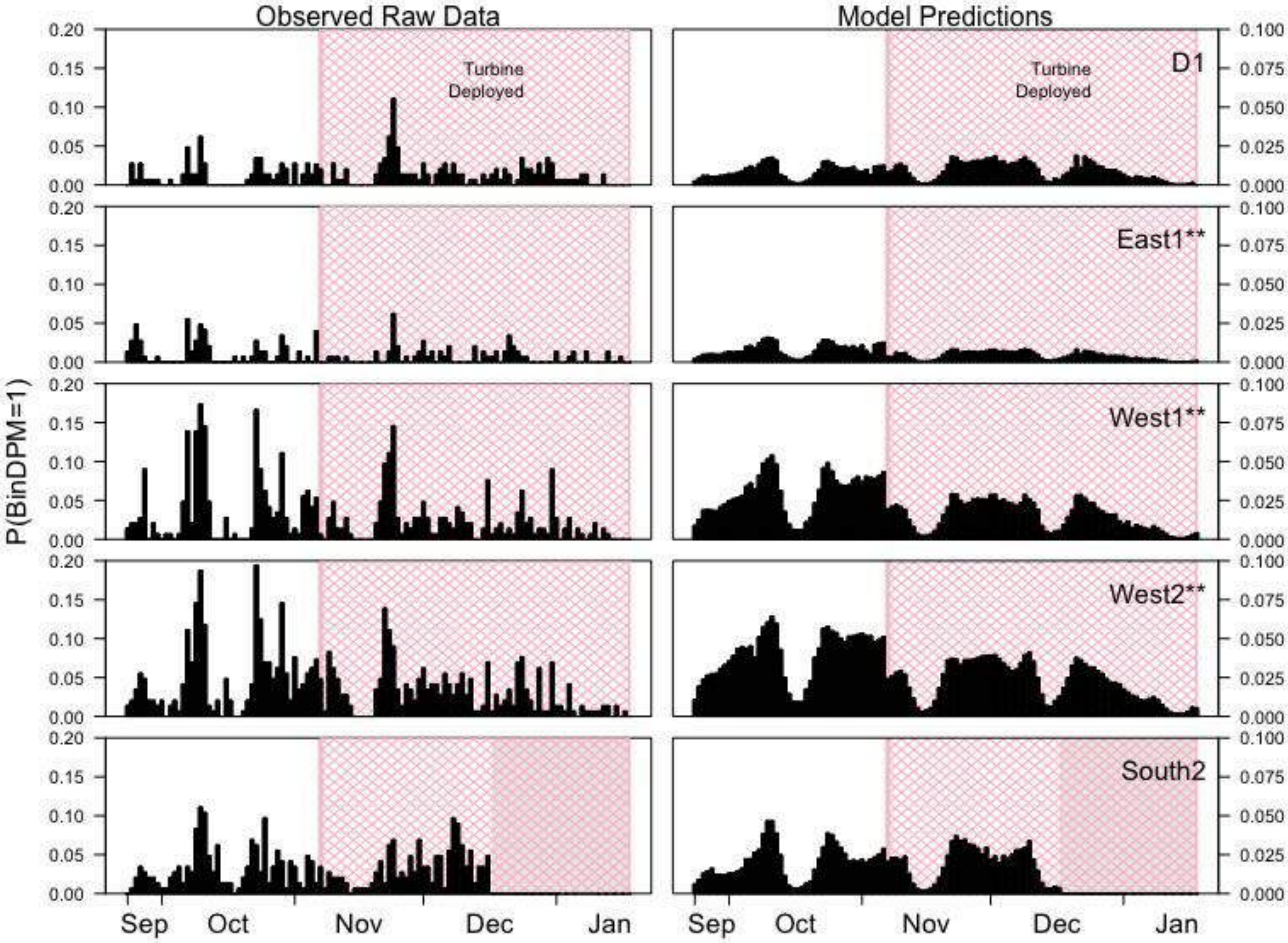


Figure 14. Probability of Porpoise detections, P(BinDPM=1) during the 2nd period of the 2016/2017 deployment. The left panels depict the raw data, the right panels depict the GEE model predictions for the same period. Locations with significantly lower probability in DPM post turbine installation are 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

We acknowledge the financial support of FORCE and previous funding from OERA and FORCE. We would like to thank Murray Scotney and Tyler Boucher (FORCE Ocean Technologist) for field support, Mark Wood at Ocean Sonics for logistical support in the calibrations and Brian Sanderson (Acadia University) in supply modelled current speed data. We also acknowledge collaborators on past studies in particular Anna Redden (Acadia University) and Cormac Booth (SMRU Consulting UK). We appreciate the constructive comments of the Environmental Monitoring Advisory Committee to a draft version of this report.

References

Benjamins, S., A. Dale, N. van Geel, and B. Wilson (2016) Riding the tide: use of a moving tidal-stream habitat by harbour porpoises. Mar Ecol Prog Ser 549: 275−288

Brandt, M.J., S. Hansen, A. Diederichs, and G. Nehls (2014) Do man-made structures and water depth affect the diel rhythms in click recordings of harbor porpoises (*Phocoena phocoena*)? Marine Mammal Science.30(3):1109–21.

Calderan, S.V. (2003) Fine-scale Temporal Distribution by Harbour Porpoise (*Phocoena phocoena*) in North Wales: Acoustic and Visual Survey Techniques. MSc Thesis. School of Biological Sciences, University of Wales, Bangor.

Carlström, J. (2005) Diel variation in echolocation behavior of wild harbor porpoises. Marine Mammal Science, 21(1): 1-12.

Ellison, W.T., B.L. Southall, C.W. Clark, and A.S. Frankel (2012) A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. Conservation Biology, 26(1):21-28.

Embling, C.B., J. Sharples, E. Armstrong, M. R. Palmer, and B.E. Scott (2013) Fish behaviour in response to tidal variability and internal waves over a shelf sea bank. Progress in Oceanography 117: 106−117

Embling, C.B., P.A. Gillibrand, J. Gordon, J. Shrimpton, P.T. Stevick, and P.S. Hammond (2010) Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (*Phocoena phocoena*). Biological Conservation, 143(2):267-279.

Hall, A.M. (2011) Foraging behaviour and reproductive season habitat selection of northeast Pacific porpoises (Doctoral dissertation, University of British Columbia).

Johnston, D.W., A.J. Westgate, and A.J. Read (2005) Effects of fine-scale oceanographic features on the distribution and movements of Harbor porpoises *Phocoena phocoena* in the Bay of Fundy. Mar Ecol Prog Ser, 295:279–293.

Johnston, D.W. and A.J. Read (2007) Flow-field observations of a tidally driven island wake used by marine mammals in the Bay of Fundy, Canada. Fisheries Oceanography, 16(5):422-435.

Kastelein, R.A., W.W. Au, and D. de Haan (2002) Audiogram of a harbour porpoises (*Phocoena phocoena*) measured with narrow-band frequency-modulated signals. J. Acoust. Soc. Am. 112():334-344.

Marubini, F., A. Gimona, P.G.H. Evans, P.J. Wright, G.J. Pierce (2009) Habitat preferences and interannual variability in occurrence of the harbour porpoise, *Phocoena phocoena*, in the north-west of Scotland (UK) Mar Ecol Prog Ser, 381: 297–310

Linnenschmidt, M., J. Teilmann, T. Akamatsu, R. Dietz, and L. A. Miller (2013) Biosonar, dive, and foraging activity of satellite tracked harbor porpoises (*Phocoena phocoena*). Marine Mammal Science 29(2): E77-E97.

Mikkelsen, L., K. Mouritsen, K. Dahl, J. Teilmann, and J. Tougaard (2013) Re-established stony reef attracts harbour porpoises *Phocoena phocoena*. Mar Ecol Prog Ser. 481:239–48.

Polagye, B., J. Wood, C. Bassett, D. Tollit, and J. Thomson (2011) Behavioral response of harbor porpoises to vessel noise in a tidal strait, Meeting of the Acoustical Society of America 2011. See https://tethys.pnnl.gov/sites/default/files/2011-12-14-4-Brian-Polagye.pdf

Porskamp, P., A. Redden, J. Broome, B. Sanderson and J. Wood (2015) Assessing marine mammal presence in and near the FORCE Lease Area during winter and early spring – addressing baseline data gaps and sensor performance. Final Report to the Offshore Energy Research Association and Fundy Ocean Research Center for Energy.

R Core Team. (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Raum-Suryan, K.L. and J.T. Harvey (1998) Distribution and abundance of and habitat use by harbour porpoise, *Phocoena phocoena*, off the northern San Juan Islands, Washington Fishery Bulletin, 96: 808–822

Read, A.J. and A.J. Westgate (1997) Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. Marine Biology, 130, 315-22.

SLR (2015) Proposed Environmental Effects Monitoring Programs 2015-2020 Fundy Ocean Research Center for Energy (FORCE).

Todd, V.L.G., W.D. Pearse, N.C. Tregenza, P.A. Lepper, I.B. Todd (2009) Diel echolocation activity of harbour porpoises (Phocoena phocoena) around North Sea offshore gas installations. ICES Journal of Marine Science: Journal du Conseil. 66(4):734–45.

Tougaard, J., J. Carstensen, J. Teilmann, H. Skov, and P. Rasmussen (2009) Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)). The Journal of the Acoustical Society of America, 126(1), 11–14. doi:10.1121/1.3132523

Tollit, D., J. Wood, J. Broome and A. Redden (2011) Detection of Marine Mammals and Effects Monitoring at the NSPI (OpenHydro) Turbine Site in the Minas Passage during 2010. Publication No. 101 of the Acadia Centre for Estuarine Research (ACER) Acadia University, Wolfville, NS, Canada prepared for Fundy Ocean Research Centre for Energy (FORCE). FORCE: Fundy Ocean Research Center for Energy. 2011. Environmental Effects Monitoring Report, September 2009 to January 2011. Appendix D.

Tollit, D., J. Wood, S. Veirs, S. Berta, H. Garrett, V. Veirs, R. Joy, N. Quick, and G. Hastie (2011) Admiralty Inlet Pilot Project Marine Mammal Pre-Installation Field Studies – Final Report to Snohomish Public Utility District.

Tollit, D.J., J. Wood, R. Joy (2017) FORCE Marine Mammal EEMP - C-PODs in Mina Passage - Summer 2016 Interim Report.

Watts, P., and D.E. Gaskin (1985) Habitat index analysis of the harbour porpoise (*Phocoena phocoena*) in the southern Bay of Fundy, Canada Journal of Mammalogy, 66:733–744

Williamson, L.D., K.L. Brookes, B.E. Scott, I.M. Graham, and P.M. Thompson (2017) Diurnal variation in harbour porpoise detection potential implications for management. Mar Ecol Prog Ser 570:.223-232.

Wood, J., D. Tollit, A. Redden, P. Porskamp, J. Broome, L. Fogarty, C. Booth and R. Karsten (2013). Passive Acoustic Monitoring of Cetacean Activity Patterns and Movements in Minas Passage: Pre-Turbine Baseline Conditions (2011-2012). SMRU Consulting and ACER collaborative report prepared for Fundy Ocean Research Center for Energy (FORCE) and the Offshore Energy Research Association of Nova Scotia (OERANS). FORCE; Fundy Ocean Research Center for Energy. 2015. Environmental Effects Monitoring Report, 2011 to 2013. Appendices C.

Zar, J.H. (1999) Biostatistical analysis. 4th edition. Prentice Hall, Upper Saddle River, NJ.

Appendix 10: European Wave & Tidal Energy Conference – Research Papers on FORCE Projects

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
1haley.viehman@acadiau.ca
3anna.redden@acadiau.ca
**Fundy Ocean Research Center for Energy*
PO Box 2573, Halifax, Nova Scotia B3J 1V7, Canada
2tyler.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·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

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 $m \cdot s^{-1}$ at peak flood tide and 3 $m \cdot s^{-1}$ 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.

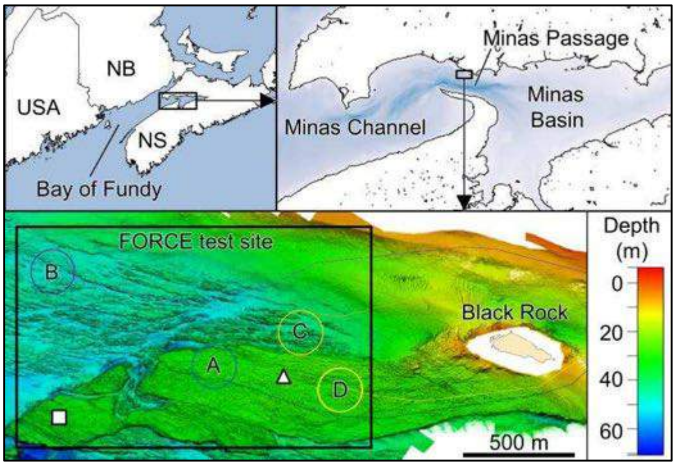


Fig. 2 Study site with deployment locations. Lower panel shows site bathymetry and proposed MHK device sites (A-D) at the FORCE test site. Location of the FAST-1 platform in winter 2015 indicated by □, summer by △. Upper panel maps made in QGIS with data obtained from GeoGratis Canada and bathymetry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

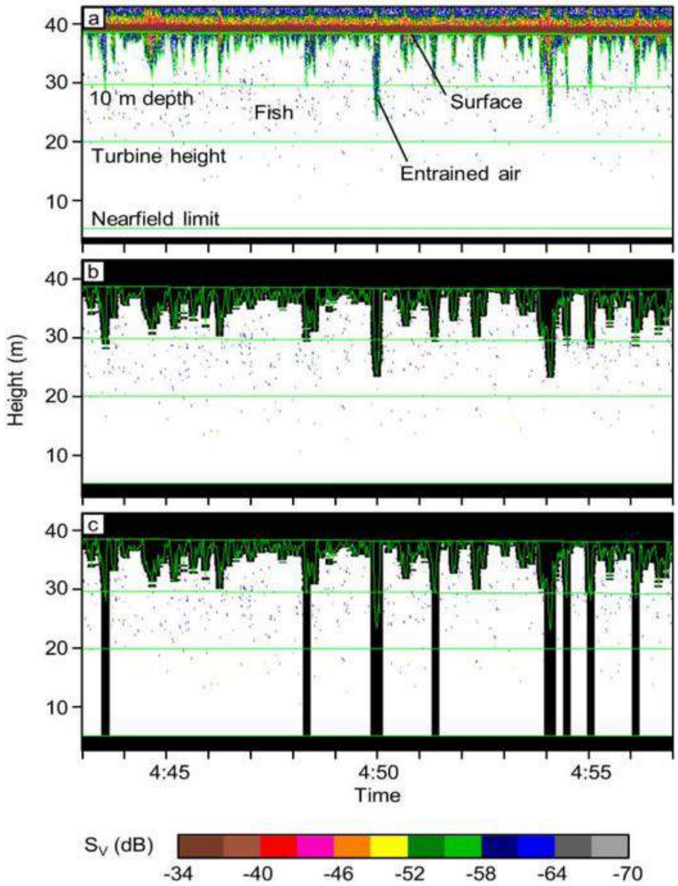


Fig. 3 Example of volume backscatter (S_V) data collected from 4:43 to 4:57 UTC on 9 December 2015. (a) Raw data, showing entrained air and lines in data processing. (b) Processed data, with entrained air removed. (c) Processed data with pings removed where depth of entrained air surpassed 10 m. Height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

December and June datasets are therefore comparable using the factory calibration settings, but this difference should be kept in mind when interpreting results.

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).

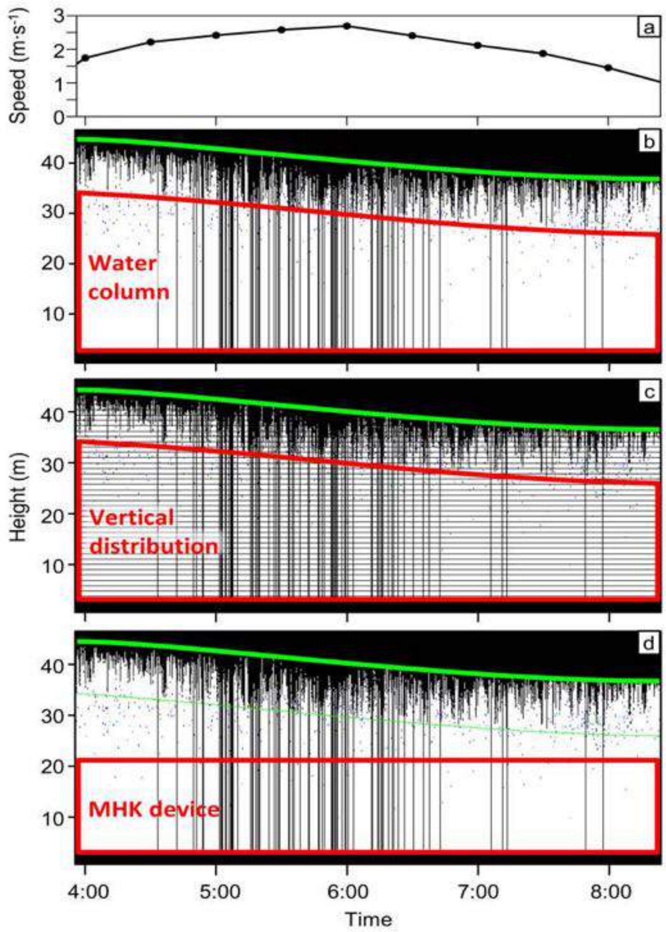


Fig. 4 Data from one ebb tide from 3:56 to 8:23 UTC on 9 December 2015. (a) Current speed from 16-17 m above the sea floor. (b-d) The three water column partitions used in analysis: (b) entire water column, defined as the acoustic nearfield to the 10-m depth line; (c) 1-m layers for vertical distribution 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 m·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 m^{-1}) or in the linear domain as s_v, with units of m^2·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 m^2·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).

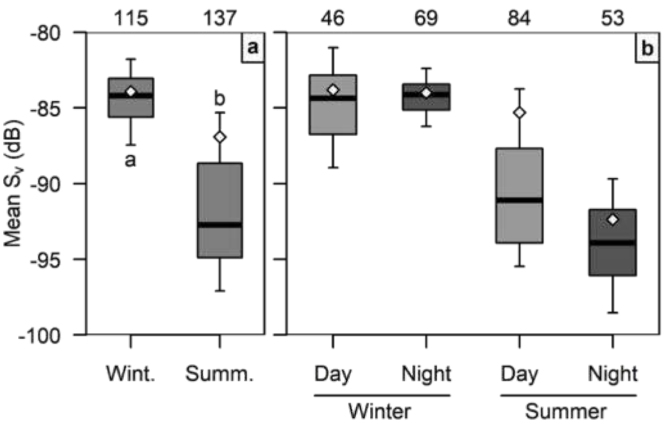


Fig. 6 Water column mean volume backscatter, S_V (proportional to fish density). (a) Winter vs. summer. (b) Day vs. night in winter and summer. Sample sizes are shown at top. Letters indicate groups with significantly different means (a highest, b lowest), where tested. White diamonds are means, horizontal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

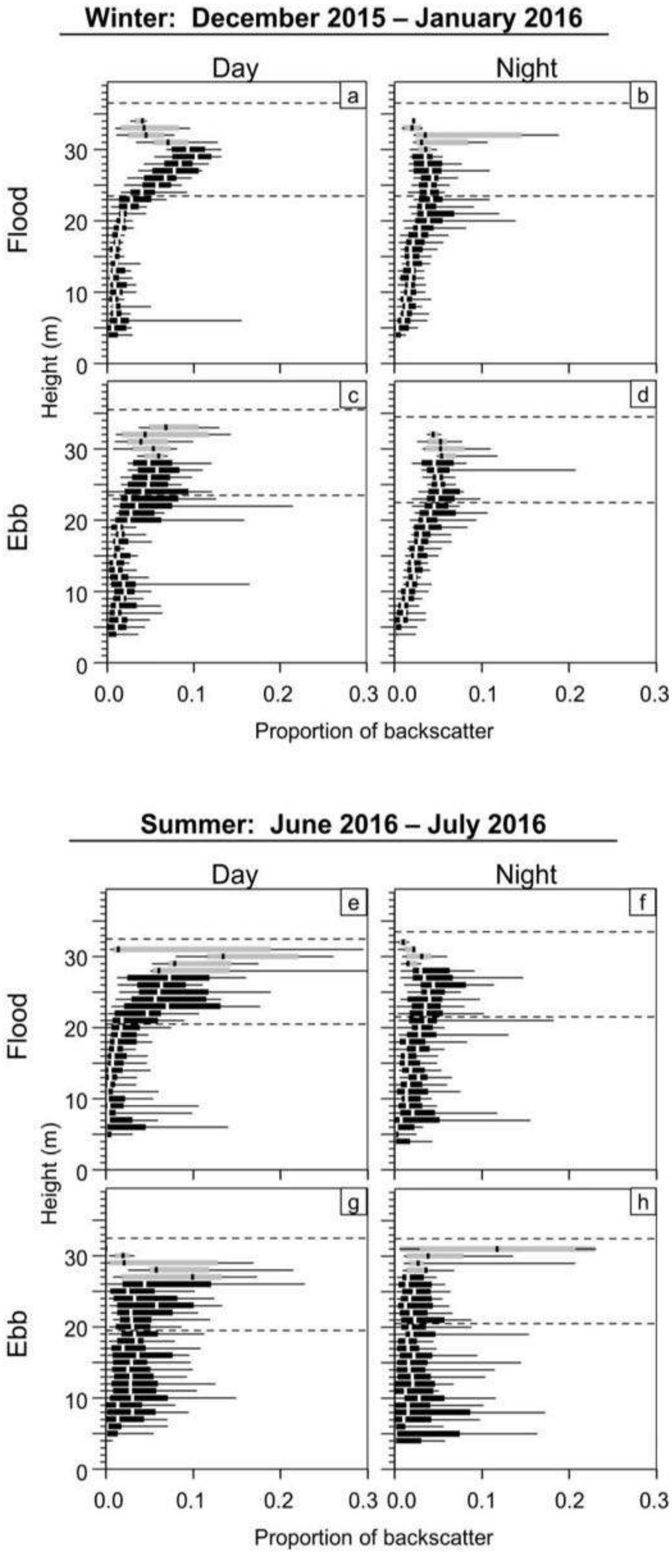


Fig. 7 Vertical distribution of area backscatter during time periods of interest, from the winter (a-d) and summer (e-h) datasets. Thick vertical lines indicate median, boxes encompass the interquartile range, and whiskers span the 10th to 90th percentiles of each 1-m layer of the water column. Grey 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.

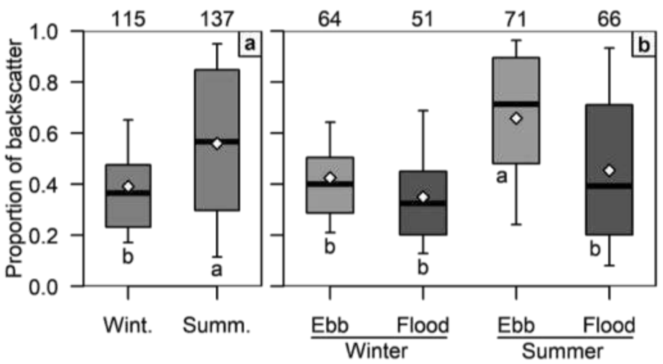


Fig. 8 Proportion of water column area backscatter, s_a, from depths spanned by the proposed MHK device (0-20 m above sea floor). (a) Winter vs. summer; (b) flood tide vs. ebb tide in winter and summer. Sample sizes shown at top. Letters indicate groups with significantly different means (a highest, 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.

Acknowledgment

We would like to thank the staff of FORCE for their contribution of time and resources to this research, and to Dominion Diving (Dartmouth, NS) for their aid in deploying and retrieving the sensor platform. Thanks also to the members of the Acadia Tidal Energy Institute for providing support and information, and to Briony Hutton and Toby Jarvis for their assistance with Echoview processing techniques. Funding for this work was provided by the Offshore Energy Research Association of Nova Scotia, the Mitacs Accelerate Program, and FORCE. The comments of two anonymous reviewers and Brian Sanderson improved this manuscript.

References

[1] R. Karsten, A. Swan, and J. Culina, “Assessment of arrays of in-stream tidal turbines in the Bay of Fundy,” Phil. Trans. R. Soc. A, vol. 371, 2013.

[2] M. Baker, M. Reed, and A.M. Redden, “Temporal Patterns in Minas Basin Intertidal Weir Fish Catches and Presence of Harbour Porpoise during April – August 2013.” ACER, Wolfville, NS, Tech. Rep. 120, 2014.

[3] F.M. Keyser, J.E. Broome, R.G. Bradford, B. Sanderson, and A.M. Redden, “Winter presence and temperature-related diel vertical migration of Striped Bass (*Morone saxatilis*) in an extreme high flow site in Minas Passage, Bay of Fundy,” Can. J. Fish. Aquat. Sci., vol. 73(12), pp. 1777-1786, 2016.

[4] R. Karsten, “Tidal energy resource assessment map for Nova Scotia,” Acadia University, Wolfville, NS, Canada, Report prepared for OEER/OETR, November, 2012.

[5] O. Nakken, K. Olsen, “Target strength measurements of fish,” Rap. Proces., vol. 170, pp. 52-69, 1977.

[6] A. Bonanno, S. Goncharov, T. Knutsen, T. van der Meeren, L. Calise, E. Montella, A.R. Angotzi, A. Cuttitta, B. Patti, G. Basilone, G. Buscaino, J. Brunskog, S. Mazzola, “Experimental evaluation of target strength for herring larvae (*Clupea harengus*) at early developmental stages,” in Proc. International Conference Underwater Acoustic Measurements: Technologies & Results, 2005.

[7] V. Ermolchev, M. Zaferman, “Results of experiments on the video-acoustic estimation of fish target strength *in situ*,” ICES Journal of Marine Science, vol. 60, pp. 544-547, 2003.

[8] J.R. Nielsen, B. Lundgren, “Hydroacoustic *ex situ* target strength measurements on juvenile cod (*Gadus morhua* L.),” ICES J. Mar. Sci., vol. 56, pp. 627-639, 1999.

[9] E. Ona, “Detailed *in situ* target strength measurements of O-group cod,” ICES CM 1994/B, vol. 30, 9 p.p., 1994.

[10] D. Chu, P.H. Wiebe, N.J. Copley, G.L. Lawson, V. Puvanendran, “Material properties of North Atlantic cod eggs and early-stage larvae and their influence on acoustic scattering,” ICES J. Mar. Sci., vol. 60, pp. 508-515, 2003.

[11] K.G. Foote, "Importance of the swimbladder in acoustic scattering by fish: a comparison of gadoid and mackerel target strengths. J. Acoust. Soc. Am., vol. 67(6), pp. 2084-2089, 1980.
[12] S. Fraser, V. Nikora, B.J. Williamson, B.E. Scott, "Automatic active acoustic target detection in turbulent aquatic environments," Limnol. Oceanogr.-Meth., vol. 15, pp. 184-190, 2017.
[13] G.D. Melvin, N.A. Cochrane, "Multibeam acoustic detection of fish and water column targets at high-flow sites," Estuar. Coast., vol. 38(suppl. 1), pp. S227-S240, 2015.
[14] H. Viehman, G.B. Zydlewski, J. McCleave, and G. Staines, "Using acoustics to understand fish presence and vertical distribution in a tidally dynamic region targeted for energy extraction," Estuar. Coast., vol. 38(suppl. 1), pp. S215-S226, 2015.
[15] K.G. Foote, "Linearity of fisheries acoustics, with addition theorems," J. Acoust. Soc. Am., vol. 73(6), pp. 1932-1940, 1983.
[16] J. Simmonds and D.N. MacLennan, Fisheries acoustics: theory and practice, Oxford: Blackwell, 2005.
[17] H.A. Viehman and G.B. Zydlewski, "Multi-scale temporal patterns in fish presence in a high-velocity tidal channel," PLoS ONE, accepted.
[18] S.S. Urmy and J.K. Horne, "Multi-scale responses of scattering layers to environmental variability in Monterey Bay, California," Deep Se Res. A., vol. 113, pp. 22-32, 2016.
[19] D.A. Jacques and J.K. Horne, "Scaling of spatial and temporal biological variability at marine renewable energy sites," Proc. 2nd Marine Energy Technology Symposium, 2014.
[20] S.S. Urmy, J.K. Horne, D.H. Barbee, "Measuring the vertical distributional variability of pelagic fauna in Monterey Bay," ICES J. Mar. Sci., vol. 69(2), pp. 184-196, 2012.
[21] M.J. Dadswell, "Occurrence and migration of fishes in Minas Passage and their potential for tidal turbine interaction," BioIdentification Associates, Report prepared for Fundy Ocean Research Centre for Energy, 2010.
[22] M.J.W. Stokesbury, L.M. Logan-Chesney, M.F. McLean, C.F. Buhariwalla, A.M. Redden, J.W. Beardsall, J.E. Broome, M.J. Dadswell, "Atlantic sturgeon and temporal distribution in Minas Passage, Nova Scotia, Canada, a region of future tidal energy extraction," PLoS ONE, vol. 11(7), e0158387, 2017.
[23] I. Solberg and S. Kaartvedt, "Surfacing behavior and gas release of the physostome sprat (*Sprattus sprattus*) in ice-free and ice-covered waters," Mar. Biol., vol. 161, pp. 285-296, 2014.
[24] B. Wilson, R.S. Batty, L.M. Dill, "Pacific and Atlantic herring produce burst pulse sounds," Proc. R. Soc. Lond. B, vol. 271(suppl.), pp. S95-S97, 2004.
[25] J.D. McCleave, R.C. Kleckner, "Selective tidal stream transport in the estuarine migration of glass eels of the American eel (*Anguilla rostrata*)," J. Cons. Int. Explor. Mer., vol. 40, pp. 262-271, 1982.
[26] J.J. Dodson and W.C. Leggett, "Behavior of adult American shad (*Alosa sapidissima*) homing to the Connecticut River from Long Island Sound," J. Fish. R. Board Can., vol. 30, pp. 1847-1860, 1973.
[27] G.P. Arnold, M. Greer Walker, L.S. Emerson, B.H. Holford, "Movements of cod (*Gadus morhua* L.) in relation to the tidal streams in the southern North Sea," ICES J. Mar. Sci., vol. 51, pp. 207-232, 1994.
[28] D.A. Levy and A.D. Cadenhead, "Selective tidal stream transport of adult sockeye salmon (*Oncorhynchus nerka*) in the Fraser River Estuary, Can. J. Fish. Aquat. Sci., vol. 52, pp. 1-12, 1995.
[29] A. Moore, M. Ives, M. Scott, S. Bamber, "The migratory behavior of wild sea trout (*Salmo trutta* L.) smolts in the estuary of the River Conwy, North Wales," Aquaculture, vol. 198, pp. 57-68, 1998.
[30] J.F. de Veen, "On selective tidal transport in the migration of North Sea Plaice (*Pleuronectes platessa*) and other flatfish species," Netherlands J. Sea Res., vol. 12(2), pp. 115-147, 1978.
[31] M. Greer Walker, F.R. Harden Jones, G.P. Arnold, "The movements of plaice (*Pleuronectes platessa* L.) tracked in the open sea," J. Cons. Int. Explor. Mer., vol. 38(1), pp. 58-86, 1978.
[32] M. Castonguay, D. Gilbert, "Effects of tidal streams on migrating Atlantic mackerel, *Scomber scombrus* L.," ICES J. Mar. Sci. vol. 52(6), pp. 941-954, 1995.
[33] K.N. Lacoste, J. Munro, M. Castonguay, F.J. Saucier, J.A. Gagné, "The influence of tidal streams on the pre-spawning movements of Atlantic herring, *Clupea harengus* L., in the St Lawrence estuary," ICES J. Mar. Sci., vol. 58, pp.1286-1298, 2001.
[34] J. Janssen, S.B. Brandt, "Feeding ecology and vertical migration of adult alewives (*Alosa pseudoharengus*) in Lake Michigan," Can. J. Fish. Aquat. Sci., vol. 37, pp. 177-184, 1980.
[35] J.G. Loesch, W.H. Kriete Jr., E.J. Foell, "Effects of light intensity on the catchability of juvenile anadromous *Alosa* species," T. Am. Fish. Soc., vol. 111(1), pp. 41-44, 1982.
[36] M. Cardinale, M. Casini, F. Arrhenius, N. Håkansson, "Diel spatial distribution and feeding activity of herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) in the Baltic sea," Aquat. Living Resour., vol. 16, pp. 283-292, 2003.
[37] C.W. Glass, C.S. Wardle, W.R. Mojsiewicz, "A light intensity threshold for schooling in the Atlantic mackerel, *Scomber scombrus*," J. Fish. Biol., vol. 29(suppl. A), pp. 71-81, 1986.
[38] L.A.F. Nilsson, U.H. Thygesen, B. Lundgren, B.F. Nielsen, J.R. Nielsen, J.E. Beyer, "Vertical migration and dispersion of sprat (Sprattus sprattus) and herring (*Clupea harengus*) schools at dusk in the Baltic Sea," Aquat. Living Resour., vol. 16, pp. 317-324, 2003.
[39] S. Benjamins, A. Dale, G. Hastie, J.J. Waggitt, M. Lea, B. Scott, B. Wilson, "Confusion reigns? A review of marine megafauna interactions with tidal-stream environments," In: Hughes RN, Hughes DJ, Smith IP, Dale AC, editors. Ocean. Mar. Biol., vol. 53, Boca Raton: CRC Press, pp. 1-54, 2015.
[40] M. Heath, K. Brander, P. Munk, P. Rankine, "Vertical distributions of autumn spawned larval herring (*Clupea harengus* L.) in the North Sea," Cont. Shelf Res., vol. 11(12), pp. 1425-1452, 1991.
[41] K.G. Foote, H.P. Knudsen, G. Vestnes, D.N. MacLennan, E.J. Simmonds, "Calibration of acoustic instruments for fish density estimation: a practical guide," ICES Coop. Res. Rep., vol. 144, 1987.
[42] R.J. Korneliussen and E. Ona, "Verified acoustic identification of Atlantic mackerel," ICES CM2004, paper R20, 14 pp., 2004.
[43] J.K. Horne, "Acoustic approaches to remote species identification: a review," Fish Oceanogr., vol. 9(4), pp. 356-371, 2000.
[44] G.D. Melvin, N.A. Cochrane, "Investigation of the vertical distribution, movement and abundance of fish in the vicinity of proposed tidal power energy conversion devices," Final report to the Offshore Energy Research Association, OEER/OETR Research Project 300-170-09-12, 2014.
[45] Fundy Ocean Research Center for Energy, "Environmental effects monitoring program quarterly report: January 1-March 31, 2017," available at http://fundyforce.ca/environment/monitoring.
[46] H. Shen, G.B. Zydlewski, H.A. Viehman, G. Staines, "Estimating the probability of fish encountering a marine hydrokinetic device," Renew. Energy, vol. 97, pp. 746-756, 2016.
[47] H. Viehman, G.B. Zydlewski, "Fish interaction with a commercial-scale tidal energy device in a field setting," Estuaries Coast., vol. 38(suppl. 1), pp. S241-S252, 2015.
[48] L. Hammar, S. Andersson, L. Eggertsen, J. Haglund, M. Gullström, Jimmy Ehnberg, Sverker Molander, "Hydrokinetic turbine effects on fish swimming behavior," PLoS ONE, vol. 8(12), e84141, 2013.
[49] A.N. Popper and C.R. Schilt, "Hearing and acoustic behavior (basic and applied)," in J.F. Webb, R.R. Fay, A.N. Popper, editors. Fish Bioacoustics, New York: Springer Science+Business Media, pp. 17-48, 2008.
[50] H. Bleckmann and R. Zelick, "Lateral line system of fish," Int. Zool., vol. 4, pp. 13-25, 2009.
[51] D.H. Evans, editor, The physiology of fishes, Boca Raton: CRC Press, 1993.
[52] J.H.S. Blaxter, "Development of sense organs and behavior of teleost larvae with special reference to feeding and predator avoidance," T. Am. Fish. Soc., vol. 115(1), pp. 98-114, 1986.
[53] F.W.H. Beamish, "Swimming capacity," in W.S. Hoar, D.J. Randal, editors, Fish Physiology, Volume VII: Locomotion, New York: Academic Press, pp.101-187, 1978.
[54] A. Avila, R. Hull, S. Matzner, G. Staines, C. Trostle, G.E.L. Harker-Klimeš, "Triton: Igiugig video analysis," Pacific Northwest National Laboratory, Richland, WA, Report prepared for the U.S. Department of Energy contract DE-AC05-76RL01830, September 2016.
[55] S.V. Amaral, M.S. Bevelhimer, G.F. Čada, D.J. Giza, P.T. Jacobson, B.J. McMahon, B.M. Pracheil, "Evaluation of behavior and survival of fish exposed to an axial-flow hydrokinetic turbine," N. M. J. Fish. Manage., vol. 35(1), pp. 97-113, 2015.
[56] T. Castro-Santos, A. Haro, "Survival and behavioral effects of exposure to a hydrokinetic turbine on juvenile Atlantic salmon and adult American shad," Estuar. Coast., vol. 38(suppl 1), pp. S203-S214, 2015.

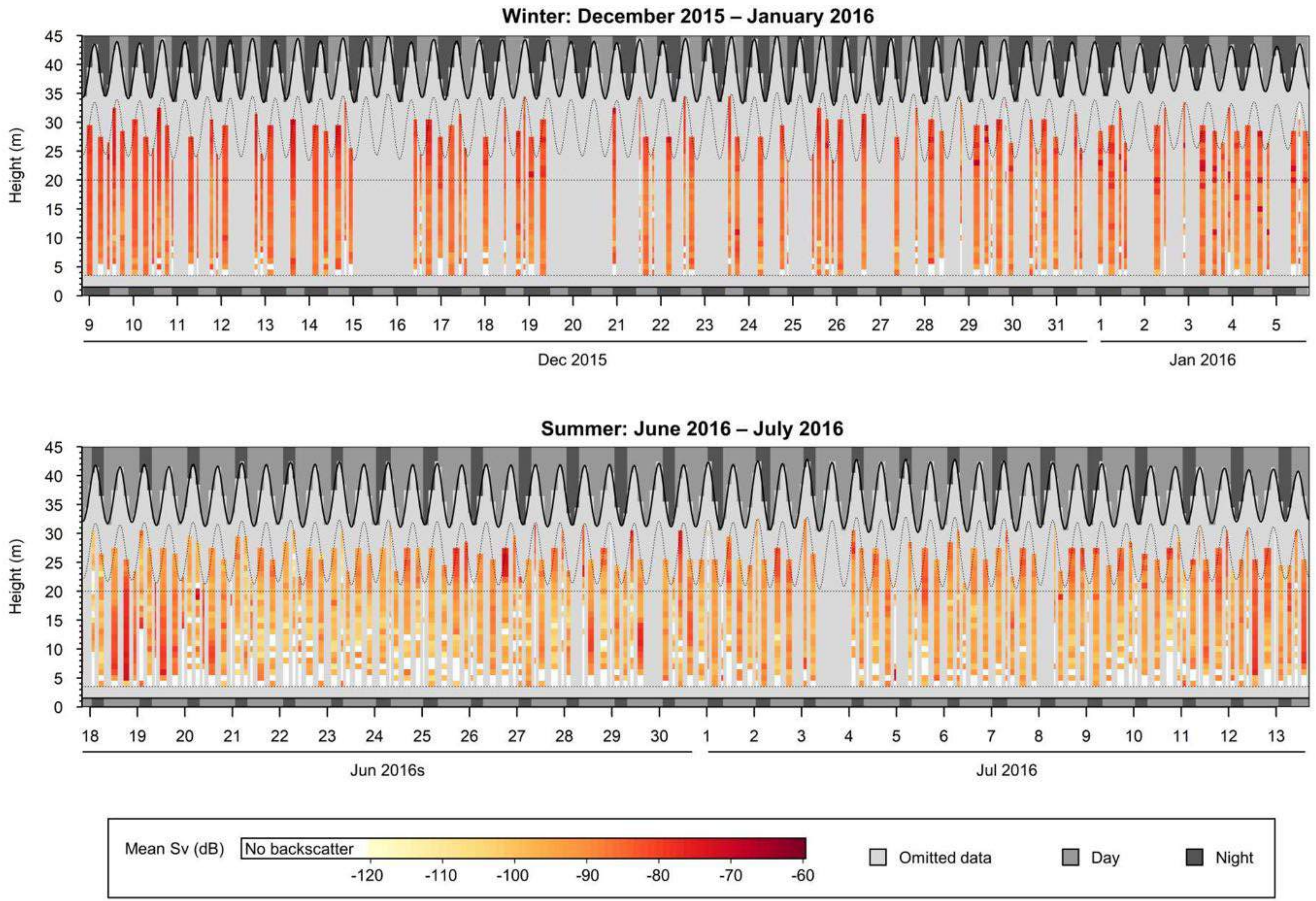


Fig. 5 Mean volume backscatter, S_V (proportional to fish density), from 1-m layers of the water column in each time increment used in analyses of hydroacoustic datasets collected in winter (top) and summer (bottom). Color reflects mean S_V, with white indicating no backscatter and darker, redder colors 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.

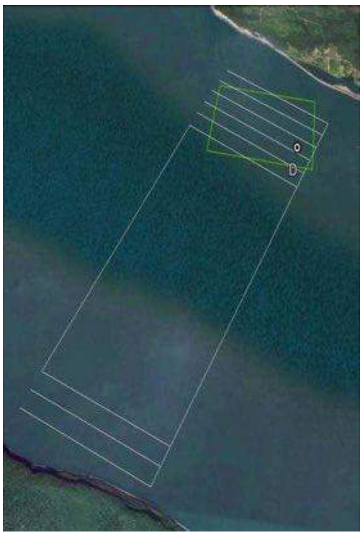


Fig. 1 Mobile survey design. The green square represents the CLA. White lines show one complete grid, with transects at the CLA (6 transects) and reference (3 transects) sites connected by cross-channel transects. The turbine is located at berth D.

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).

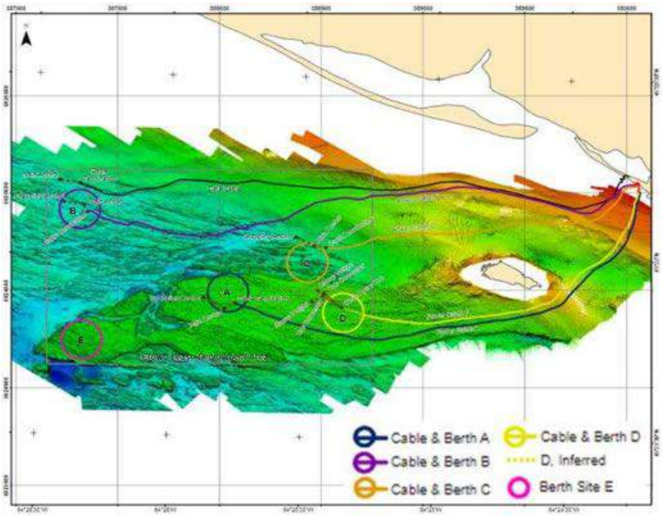


Fig. 2 Survey site CLA turbine deployment map (source: Environmental Effects Monitoring Program Fundy Ocean Research Center for Energy - March 2016)

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:

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

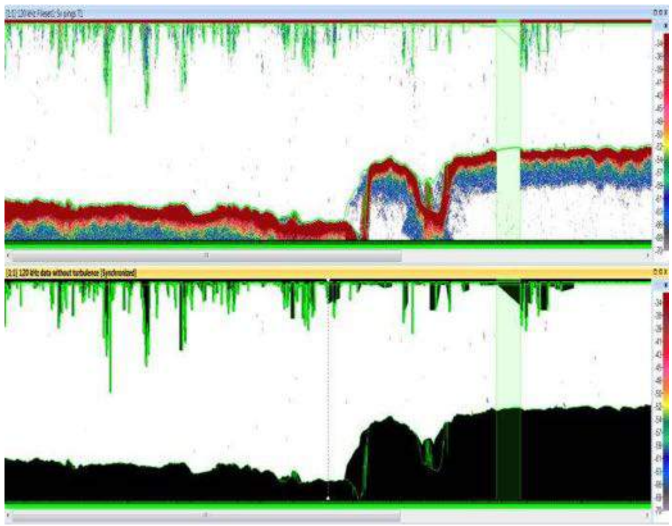


Fig. 3 Snapshot of an echogram from the August survey, first ebb tide, transect N1 against the tide (raw data, top and data corrected without turbulence, bottom) where the reverse bottom detection processing method has been performed. The analysed portion of the echogram corresponds to the white part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

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

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:

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

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.

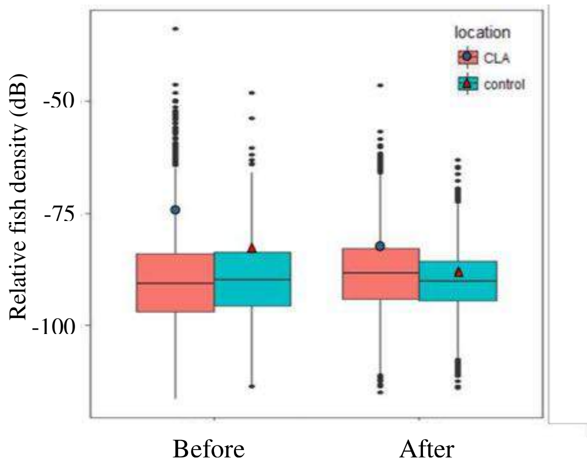


Fig. 4 Boxplot of the relative fish density (S_v in dB) for each survey (May, August, October before turbine deployment; November, January and March (after turbine deployment) and by site (CLA and reference). The blue circle (for CLA) and red triangle (for reference site) represent the mean S_v (calculated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

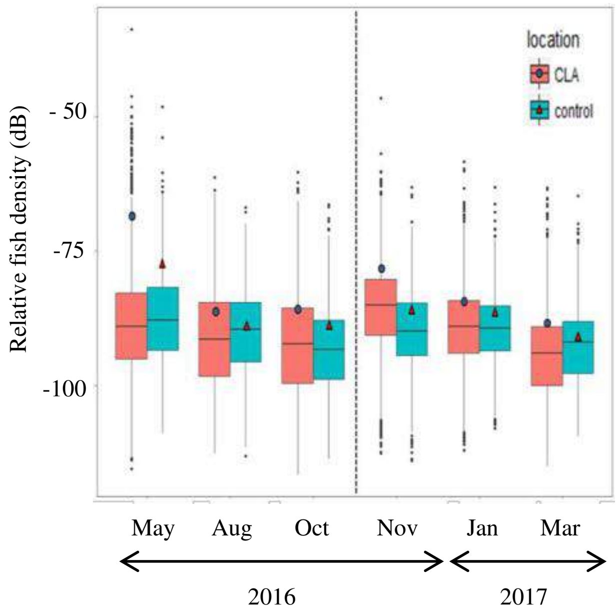


Fig. 5 Boxplot of the relative fish density (S_v) before and after the turbine deployment and by site (CLA and reference). The blue circle (for CLA) and red triangle (for reference site) represent the mean S_v (calculated via mean s_v). The dotted vertical line represents the relative turbine deployment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

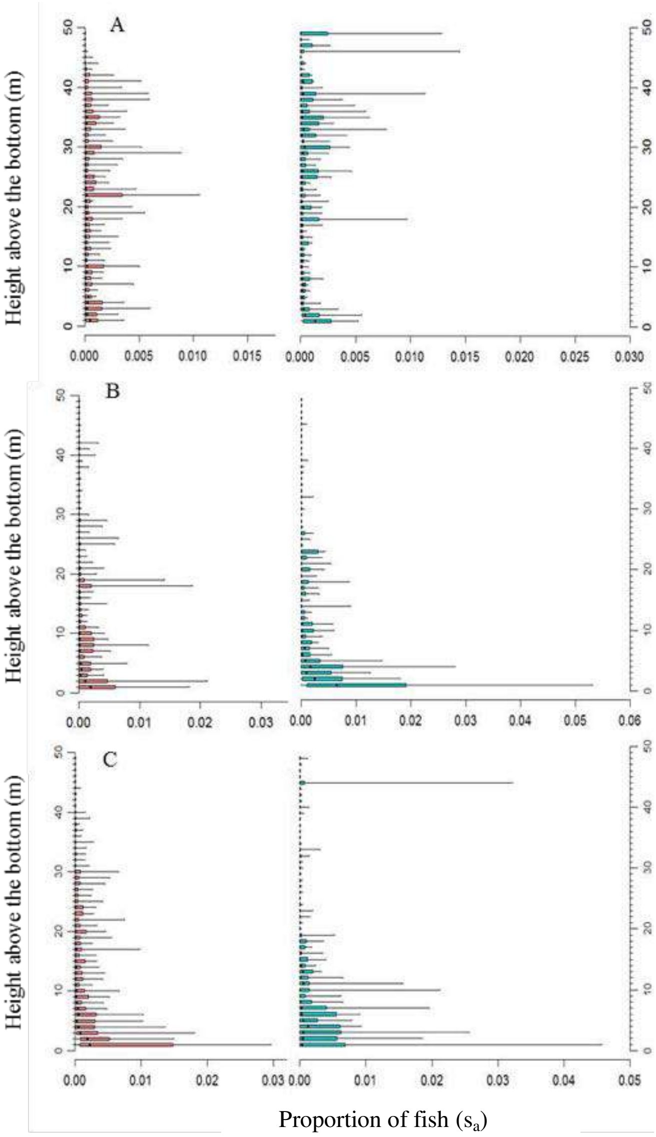


Fig. 6 Boxplot of proportion of the relative fish density (s_a) by 1meter depth layer for May (A), August (B) and November (C) 2016 before the turbine deployment and by site (CLA in red, left and reference in blue, right). The proportion of s_a (x axis) is very small reflecting the high variability and 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).

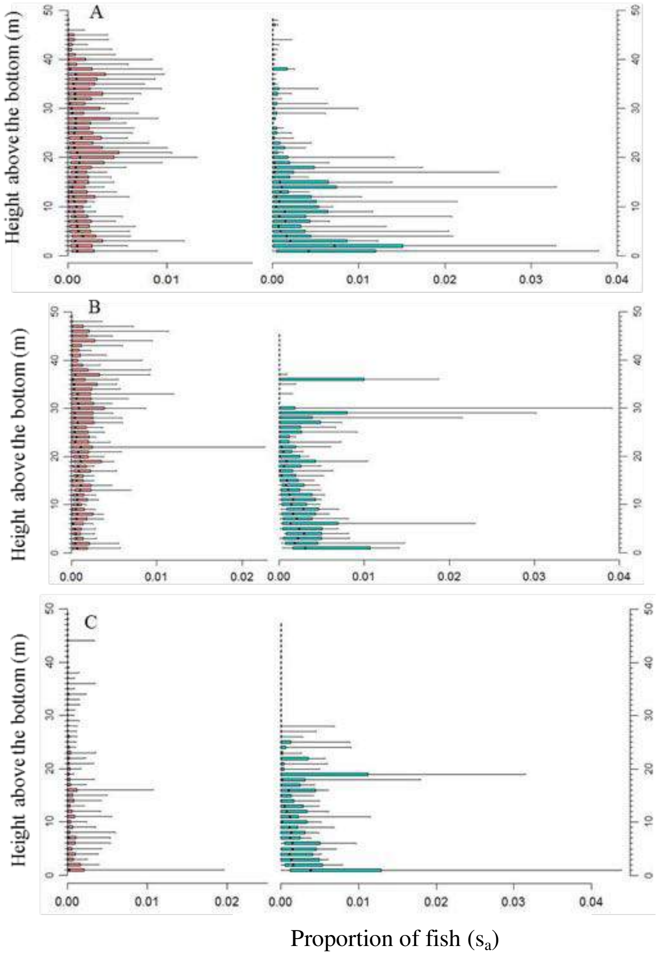


Fig. 7 Boxplot of proportion of the relative fish density (s_a) by 1m depth layer for November 2016 (A), January (B) and March (C) 2017 after the turbine deployment and by site (CLA in red, left and reference in blue, right). The proportion of s_a (x axis) is very small reflecting the high variability 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

Proportion of fish at the depth of the turbine

Distance bin

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).

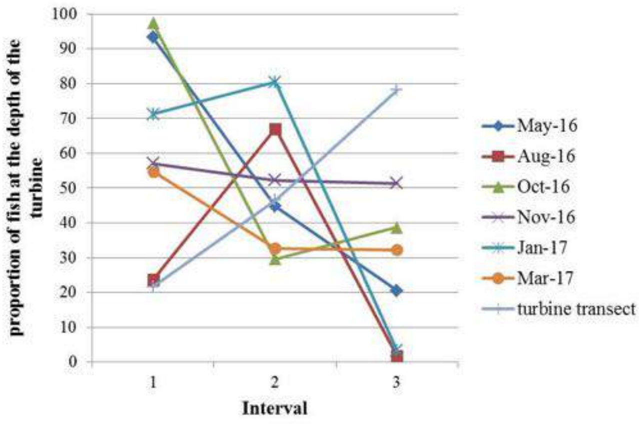


Figure 9: Percent of backscatter (relative fish density, s_v) at the depth of the turbine by distance bin and survey. This plot includes data from the two transects adjacent to the turbine for all surveys and for the turbine transect in November 2016

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.

ACKNOWLEDGMENT

This work is supported by FORCE (Marine fish monitoring program) and the School of Marine Sciences of the University of Maine. Thanks to the *Nova Endeavor* boat crew, Tyler Boucher, Murray Scotney, Melissa Oldreive, Haley Viehman and Mary McPhee for all the help during the surveys and Garrett Staines for initial project insights and development.

REFERENCES

[1] E. P. Ames, and J. Lichter, “Gadids and alewives: structure within complexity in the Gulf of Maine” *Fisheries Research*, 141, 70-78. 2013.
[2] M. Baker, M. Reed, and A. M. Redden, “Temporal Patterns in Minas Basin Intertidal Weir Fish Catches and Presence of Harbour Porpoise during April – August 2013”. Acadia Centre for Estuarine Research, Wolfville, NS, Tech. Rep. 120, 2014.
[3] M. J. Dadswell, “Occurrence and migration of fishes in minas passage and their potential for tidal turbine interaction”. 2010.
[4] K. G. Foote, H. P, Knudsen, G. Vestnes, D. N. Maclennan, and E. J. Simmonds, “Calibration of acoustic instruments for fish density estimation: a practical guide”. Int. Coun. Explor. Sea Coop. Res. Rep. No. 144. 1987.
[5] S. Fraser, V. Nikora, B. J. Williamson, and B. E. Scott, “Automatic active acoustic target detection in turbulent aquatic environments”. *Limnology and Oceanography: Methods*, 15(2), 184-199. 2017.
[6] R. N. Gibson, “Go with the flow: tidal migration in marine animals. In Migrations and Dispersal of Marine Organisms” (pp. 153-161). *Springer Netherlands*. 2003.
[7] I. Higginbottom, S. Woon, and P. Schneider, “Hydroacoustic data processing for standard stock assessment using Echoview: Technical manual”. Myriax Software Pty Ltd, Australia. 2008.
[8] T. W. Lohner, and D. A. Dixon, “The value of long-term environmental monitoring programs: an Ohio River case study”. *Environmental monitoring and assessment*, 185(11), 9385-9396. 2013.
[9] D. N. Maclennan, P. G. Fernandes and J. Dalen, “A consistent approach to definitions and symbols in fisheries acoustics”. *ICES Journal of Marine Science: Journal du Conseil*, 59(2), 365-369. 2002.
[10] D. N. MacLennan, and E. J. Simmonds, “Fisheries acoustics (Vol. 5)” *Springer Science & Business Media*. 2013.
[11] M. F. McLean, C. A. Simpfendorfer, M. R. Heupel, M. J. Dadswell, and M. J. Stokesbury, “Diversity of behavioural patterns displayed by a summer feeding aggregation of Atlantic sturgeon in the intertidal region of Minas Basin, Bay of Fundy, Canada” *Marine Ecology Progress Series*, 496, 59-69. 2014.
[12] G. D. Melvin, and N. A. Cochrane, “Investigation of the vertical distribution, movement and abundance of fish in the vicinity of proposed tidal power energy conversion devices.” Final Report submitted to Offshore Energy Research Association (OERA), Research Project 300-170-09-12. December. 2014.
[13] J. S. Scott, “Seasonal spatial distribution of groundfish of the Scotian Shelf and the Bay of Fundy 1974 -79 and 1980-84” Can. Tech. Rep. *Fish. Aquat. Sci*. 1853. 1988.
[14] H. Shen, G. Zydlewski, H. Viehman, and G. Staines, “Estimating the probability of fish encountering a marine hydrokinetic device” *Renewable Energy*, 97, 746-756. 2016.
[15] D. W. Townsend, R. L. Radtke, M. A. Morrison and S. Folsom, “Recruitment implications of larval herring overwintering distributions in the Gulf of Maine, inferred using a new otolith technique” *Marine Ecolocial Progress Series*. 55, 1–13. 1989.
[16] H. Viehman, “Hydroacoustic Analysis of the Effects of a Tidal Power Turbine on Fishes” Doctoral Dissertation. University of Maine. 2016.
[17] A. K. Whitfield, and M. Elliott, “Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future” *Journal of Fish Biology*, 61(sA), 229-250. 2002.