FORCE

Fundy Ocean Research Center for Energy

Environmental Effects Monitoring Program

2018 Annual Report

Fundy Ocean Research Center for Energy
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Executive Summary

The Fundy Ocean Research Center for Energy (FORCE) is Canada's leading research centre for the demonstration and evaluation of in-stream tidal energy devices. The technology is part of an emerging sector designed to generate electricity from the ebb and flow of the tides that is being explored in countries throughout the world.

FORCE was established in 2009 after undergoing a joint federal-provincial environmental assessment with the mandate to enable the testing and demonstration of these devices. Since that time, more than 100 related research studies have been completed or are underway with funding from FORCE, the Offshore Energy Research Association of Nova Scotia, and others. These studies have considered socio-economics, biological, and other research areas.

The latest monitoring programs at the FORCE site were initiated in 2016 in anticipation of turbine deployments by one of FORCE's 'berth holders', Cape Sharp Tidal Venture (CSTV) in 2016. These efforts are divided into two components: mid-field (i.e., 100 m or greater from a turbine) monitoring activities led by FORCE, and near-field (i.e., less than 100 m from a turbine) or 'turbine-specific' monitoring led by individual tidal energy developers or 'berth holders' at the FORCE site. All plans are reviewed by FORCE's independent Environmental Monitoring Advisory Committee and federal and provincial regulators prior to implementation.

Mid-field monitoring at the FORCE site presently consists of monitoring for fish, marine mammals, seabirds, lobster, and marine sound. Since the commencement of this latest monitoring effort in 2016, FORCE has completed:

- ~408 hours of hydroacoustic fish surveys;
- more than 2,600 'C-POD' marine mammal monitoring days;
- bi-weekly shoreline observations;
- 42 observational seabird surveys;
- four drifting marine sound surveys and additional sound monitoring; and
- 11 days of lobster surveys.

In July 2018, CSTV installed a two-megawatt OpenHydro turbine at 'Berth D' of the FORCE site. Due to the insolvency of OpenHydro, announced four days after turbine installation, the approved near-field monitoring program and contingency monitoring program for this turbine could not be initiated. Efforts were taken to monitor the turbine in the interim, with a focus on fish and marine mammals, until the turbine was re-energized on September 4th, 2018. At that time, it was confirmed that the turbine's rotor was not turning, and the turbine-mounted monitoring sensors were re-energized (with the exception of one non-functioning hydrophone).

As a result of the status of the turbine's rotor, the monitoring requirements and reporting timelines approved as part of CSTV's authorization from Fisheries and Oceans Canada were subsequently modified to monthly confirmation of the turbine rotor's status. This is done through data collected from turbine-mounted acoustic Doppler current profilers during peak tidal flow. Data from other operating turbine-mounted sensors are being used by FORCE and its partners to inform research objectives.

Further information regarding the turbine's status, CSTV project updates, and contingency monitoring efforts, is included in this report and Appendix 1.

This Annual Report provides a summary of monitoring activities and data analysis completed at the FORCE site throughout 2018. In addition, it also highlights findings from international research efforts, previous data collection periods at the FORCE site, and additional research work of FORCE and its partners. This includes supporting fish tagging efforts with Acadia University and the Ocean Tracking Network, radar research projects, and subsea instrumentation platform deployments through the Fundy Advanced Sensor Technology (FAST) Program. Finally, the report presents details regarding future research and monitoring efforts at the FORCE test site.

All reports, including quarterly monitoring summaries, are available online at www.fundyforce.ca/environment.

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Appendices

Acronyms

AAM	Active Acoustic Monitoring
AARMS	Atlantic Association for Research in the Mathematical Sciences
ACER	Acadia Center for Estuarine Research
ADCP	Acoustic Doppler Current Profiler
AMAR	Autonomous Multichannel Acoustic Recorder
BoFEP	Bay of Fundy Ecosystem Partnership
dB	Decibel(s)
CFI	Canadian Foundation for Innovation
CLA	Crown Lease Area
cm	Centimetre(s)
CPUE	Catch Per Unit Effort
CSTV	Cape Sharp Tidal Venture
DFO	Department of Fisheries and Oceans (Canada)
DEM	Nova Scotia Department of Energy and Mines
EA	Environmental Assessment
EEM	Environmental Effects Monitoring
EEMP	Environmental Effects Monitoring Program
EJ	Exajoule
EMAC	Environmental Monitoring Advisory Committee
EMP	Environmental Management Plan
EMS	Environmental Monitoring System
FAST	Fundy Advanced Sensor Technology
FAST-EMS	Fundy Advanced Sensor Technology - Environmental Monitoring System
FORCE	Fundy Ocean Research Center for Energy
hr	Hour(s)
Hz	Hertz
IEA	International Energy Agency
IEC	International Electrotechnical Commission
km	Kilometre(s)
kW	Kilowatt(s)
m	Metre(s)
m/s	Metre(s) per second
MARS	Marine Animal Response Society
MET	Meteorological
MREA	Marine Renewable-electricity Area
MSc	Master of Science

MW	Megawatt
NL	Newfoundland and Labrador
NRCan	Natural Resources Canada
NS	Nova Scotia
NSE	Nova Scotia Department of Environment
NSERC	Natural Sciences and Engineering Research Council
NSPI	Nova Scotia Power Inc.
OERA	Offshore Energy Research Association
OES	Ocean Energy Systems
ONC	Ocean Networks Canada
OSC	Ocean Supercluster
OTN	Ocean Tracking Network
PAM	Passive Acoustic Monitoring
Q1/2/3	Quarter (1, 2, 3), based on a quarterly reporting schedule
R&D	Research and Development
RPM	Rotations/Revolutions Per Minute
TC114	Technical Committee 114
TISEC	Tidal In-Stream Energy Converter
UAV	Unmanned Aerial Vehicle
VEC(s)	Valuable Ecosystem Component(s)

Introduction

This report outlines monitoring activities occurring at the Fundy Ocean Research Center for Energy (FORCE) test site in the Minas Passage, Bay of Fundy throughout the course of 2018. Specifically, this report highlights environmental monitoring activities conducted in two 'zones' (mid-field and near-field) and other research and development (R&D) activities conducted at the FORCE site. This report also provides a summary of international research activities around tidal energy devices as well as findings from environmental effects monitoring programs at the FORCE site. Full analyses by third parties completed in 2018 are appended to this Annual Report.

About FORCE

FORCE was created in 2009 to lead research, demonstration, and testing for high flow, industrial-scale in-stream tidal energy devices, sometimes referred to as TISECs: tidal in-stream energy converters. Located just outside Parrsboro, Nova Scotia, FORCE is a not-for-profit facility that has received funding support from the Government of Canada, the Province of Nova Scotia, Encana Corporation, and participating developers.

FORCE has two central roles in relation to the demonstration of tidal energy converters in the Minas Passage:

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

As 'host,' 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 (NSPI) transmission system, and a Visitors/Operations Center. FORCE's onshore facilities, including its Visitor/Operations Centre and electrical substation, are located approximately 10 km west of Parrsboro, Nova Scotia.

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 1.0 km in area, in the Minas Passage. It is also identified as a 'Marine Renewable-electricity Area' (MREA) under the Province's *Marine Renewable-energy Act*. This area consists of five subsea 'berths' that are leased to tidal energy companies[1] selected by the Nova Scotia Department of Energy and Mines (DEM). These companies are:

Berth A: Minas Tidal
Berth B: Black Rock Tidal Power
Berth C: Atlantis Operations (Canada) Ltd./DP Energy[2]

[1] Further information about each company may be found online at: www.fundyforce.ca/technology

[2] On December 19th, 2018, SIMEC Atlantis (the parent company of Atlantis Operations (Canada) Ltd.) announced that it would be selling its shares in its Canadian operation to DP Energy. DP Energy intends to rename the company Rio Fundo Operations Canada Ltd. View story: https://renewablesnow.com/news/simec-atlantis-exits-canadian-tidal-jv-redeploys-meygen-turbines-637163/.

Berth D: Cape Sharp Tidal Venture (CSTV)
Berth E: Halagonia Tidal Energy[3]

As 'steward,' monitoring and associated reporting 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, 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 of different TISEC designs are expected to be phased in over the next several years, FORCE and regulators will have the opportunity to learn and adapt environmental monitoring approaches as lessons are learned.

Background

The FORCE demonstration project received its environmental assessment (EA) approval on September 15th, 2009 from the Nova Scotia Minister of Environment. The conditions of its EA approval[4] provide for comprehensive, ongoing, and adaptive environmental management. Since that time, the EA approval has amended to accommodate changes in technologies and inclusion of more berths to facilitate provincial demonstration goals.

Since its EA approval, 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 sound, benthic habitat, and other environmental variables. All reports on site monitoring are available online at: www.fundyforce.ca/environment.

Since 2009, more than 100 related research studies have been completed or are underway with funding from FORCE, the Offshore Energy Research Association of Nova Scotia (OERA), and others. These studies have considered socio-economics, biological, and other research areas.[5]

Presently, monitoring at the FORCE site is focused on lobster, fish, marine mammals, seabirds, and marine sound and is partially divided into 'near-field' (≤ 100 m from a turbine) and 'mid-field' or 'site-level' (> 100 m from a turbine). As approved by regulators, individual berth holders are responsible for conducting near-field monitoring in direct vicinity of their respective turbine(s) – this recognizes the unique design and requirements of each turbine design – and FORCE completes 'mid-field' monitoring activities as well as supporting integration of data analysis between these monitoring 'zones,' where applicable.

All near-field and mid-field monitoring programs are reviewed by FORCE's environmental monitoring advisory committee (EMAC), which includes representatives from scientific, First

[3] Berth E does not have a subsea electrical cable provided to it.
[4] FORCE's Environmental Assessment Registration Document and conditions of approval are found online at: www.fundyforce.ca/environment/enviromental-assesment.
[5] OERA's Tidal Energy Research Portal (http://tidalportal.oera.ca/) includes studies pertaining to infrastructure, marine life, seabed characteristics, socio-economics and traditional use, technology, and site characterization.

Nations, and local fishing communities.[6] These programs are also reviewed by federal and provincial regulators prior to turbine installation. In addition, FORCE and berth holders also submit an Environmental Management Plan (EMP) to regulators for review prior to turbine installation. EMPs include: environmental management roles and responsibilities and commitments, environmental protection plans, maintenance and inspection requirements, training and education requirements, reporting protocols, and more.

Turbine Deployments

Since FORCE's creation in 2009, turbines have been installed at the FORCE site three times: once in 2009/2010, November 2016 – June 2017, and July 2018 – present. Given the limited timescales in which a tidal turbine has been present and operating at the FORCE site, environmental studies to-date have largely focused on the collection of baseline data and developing an understanding of the capabilities of monitoring devices in high tidal environments.

On July 22nd, 2018, CSTV installed a two-megawatt OpenHydro turbine at 'Berth D' of the FORCE site and successfully connected the subsea cable to the turbine. CSTV confirmed establishment of communication with the turbine systems on July 24th. On July 26th, 2018, Naval Energies unexpectedly filed a petition with the High Court of Ireland for the liquidation of OpenHydro Group Limited and OpenHydro Technologies Limited. [7] For safety purposes, the turbine was isolated from the power grid on July 26th. On September 4th, 2018, work began to re-start the turbine. In the days following, it was confirmed that the turbine's rotor was not turning. It is believed an internal component failure in the generator caused sufficient damage to the rotor. Environmental sensors located on the turbine and subsea base continued to function at that time with the exception of one hydrophone.

As a result of the status of the turbine, the monitoring requirements and reporting timelines set out in CSTV's environmental effects monitoring program were subsequently modified under CSTV's Authorization from Fisheries and Oceans Canada (DFO). The modification requires that CSTV provide written confirmation to regulators on a monthly basis that the turbine is not spinning by monitoring its status during the peak tidal flow of each month. This began October 1st, 2018 and will continue until the turbine is retrieved, or unless otherwise approved in writing by DFO. Acoustic Doppler current profilers (ADCPs) and other turbine sensors are being used to monitor the ongoing status of the turbine and to confirm that the device remains stationary. This information is reported to regulators on a monthly basis.

An update prepared by CSTV is included in Appendix 1 of this report. This report outlines the present status of the CSTV project.

Additional turbines are expected to be deployed at the FORCE site in the coming years. In 2018, Black Rock Tidal Power installed a PLAT-I system in Grand Passage, Nova Scotia under a

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[6] Information about EMAC may be found online at: www.fundyforce.ca/about/advisory-committees

[7] See original news report: https://www.irishexaminer.com/breakingnews/business/renewable-energy-firms-with-more-than-100-employees-to-be-wound-up-857995.html.

Demonstration Permit.[8] This permit allows for a six-month demonstration of the 280 kW system to help Black Rock Tidal Power and its partners learn about how the device operates in the marine environment. Also this year, Natural Resources Canada announced a $29.8 million contribution to Halagonia Tidal Energy's project at the FORCE site through its Emerging Renewable Power Program.[9] The project consists of floating and submerged turbines for a total of nine megawatts—enough capacity to provide electricity to an estimated 2,500 homes.

Each berth holder project will be required to develop a turbine-specific monitoring program, which will be reviewed by FORCE's EMAC and federal and provincial regulators—notably, Fisheries and Oceans Canada (DFO), the Nova Scotia Department of Environment (NSE), and the Nova Scotia Department of Energy and Mines (DEM)—prior to turbine installation.

International Experience

The research and monitoring being conducted at the FORCE test site is part of an international effort to evaluate the risks tidal energy poses to marine life (Copping et al., 2016). Presently, countries such as China, France, Italy, the Netherlands, South Korea, the United Kingdom, and the United States (Marine Renewables Canada, 2018) are exploring tidal energy, supporting environmental monitoring and innovative R&D projects. Tidal energy, and other marine renewable energy (MRE) technologies (i.e., tidal range, tidal current, wave, ocean thermal energy) offer significant opportunities to replace carbon fuel sources in a meaningful and permanent manner – some estimates place MRE's potential as exceeding current human energy needs (Gattuso et al., 2018; Lewis et al., 2011).[10]

Through connections to groups supporting tidal energy demonstration and R&D, FORCE is working to inform the global body of knowledge pertaining to environmental effects associated with tidal power projects. One such group is Annex IV, a forum to explore the present state of environmental effects monitoring around MRE devices.[11] In 2018, for instance, FORCE worked with Annex IV members[12] to discuss best management practices regarding data transferability, "using data from an already permitted/consented MRE project or analogous industry to be 'transferred' to inform potential environmental effects and consenting for a future MRE project" (Copping et al., 2018, p. 4), and collection consistency—that is, transferring practices and learnings across jurisdictions and project sites.

Presently, the global understanding of the potential impacts of MRE devices is based on a few deployments—often of single devices and increasing numbers of small arrays, notably the

[8] To learn more about this project, see: https://novascotia.ca/news/release/?id=20180919002.

[9] To learn more about this announcement, see: https://www.canada.ca/en/natural-resources-canada/news/2018/09/minister-sohi-announces-major-investment-in-renewable-tidal-energy-that-will-power-2500-homes-in-nova-scotia.html.

[10] This potential is estimated to be up to 7,400 EJ (exajoules) per year.

[11] Annex IV was established by the International Energy Agency (IEA) Ocean Energy Systems (OES) in January 2010 to examine environmental effects of marine renewable energy development. Further information is available at https://tethys.pnnl.gov.

[12] Member nations of Annex IV are: Australia, China, Canada, Denmark, France, India, Ireland, Japan, Norway, Portugal, South Africa, Spain, Sweden, United Kingdom, and United States.

MeyGen project in Pentland Firth, Scotland[13] and a project led by Nova Innovation in Bluemull Sound, Scotland.[14] Overall, the impacts of single device or small array projects are anticipated to be low given the relative size/scale of devices (Copping, 2018). At the FORCE site, for instance, a single two-megawatt OpenHydro turbine occupies ~ 1/1,000th of the cross-sectional area in the Minas Passage (Figure 1). A full evaluation of the risks of tidal energy turbines, however, will not be possible until more devices are tested, with monitoring that documents local impacts, considers far-field and cumulative effects, and adds to the growing global knowledge base.

Figure 1: The scale of a single turbine (based on the dimensions of the OpenHydro turbine deployed by CSTV, indicated by the red dot and above the blue arrow) in relation to the cross-sectional area of the Minas Passage. The Passage reaches a width of ~ 5.4 km and a depth of 130 m.

[13] To learn more about this project, visit https://simecatlantis.com/projects/meygen.
[14] To learn more about this project, visit https://www.novainnovation.com/bluemull-sound.

Mid-Field Monitoring Activities

FORCE's present monitoring effort focuses on the 'mid-field area' or 'site-level' (i.e., >100 m from a turbine). The FORCE environmental effects monitoring program (EEMP) is currently examining lobster, fish, marine mammals, seabirds, and marine sound. These programs were developed in consultation with SLR Consulting (Canada)[15] and strengthened by review and contributions by national and international experts and scientists, Fisheries and Oceans Canada (DFO) and the Nova Scotia Department of Environment (NSE), and FORCE's EMAC. The mid-field EEMP is designed to:

- test the predictions of the FORCE environmental assessment by monitoring the potential environmental effects of operating turbines; and
- be adaptive, based on monitoring results and input from regulators and EMAC, as well as ongoing turbine operations.

Since early 2016, when this latest effort was initiated, FORCE has completed ~408 hours of hydroacoustic fish surveys, more than 2,600 'C-POD' marine mammal monitoring days, bi-weekly shoreline observations, 42 observational seabird surveys, four drifting marine sound surveys and additional sound monitoring, and 11 days of lobster surveys.

The following pages provide a summary of the mid-field monitoring activities conducted at the FORCE site throughout 2018, including data collection, data analyses performed, initial results, and lessons learned building activities and analyses from previous years. Where applicable, this report also presents analyses that have integrated data collected through the near-field and mid-field monitoring programs in an effort to provide a more complete understanding of turbine/marine life interactions.

In addition, this report outlines, where applicable, adaptations that have been made to near-field and mid-field monitoring activities in light of the non-operational state of the OpenHydro turbine deployed by CSTV. As an operational turbine (i.e., a turbine with a spinning rotor) produces different characteristics a non-functional turbine, it will have different effects on marine life in the Minas Passage. Having an operational turbine at the FORCE site will enable the evaluation of the predictions made in the FORCE EA regarding impacts of turbines on marine life in the Minas Passage.

Monitoring Objectives

As part of its mandate, FORCE is tasked with monitoring, understanding, and reporting on potential environmental effects of the activities undertaken at its site. Part of this work includes integrating results, where applicable, and continuing to adapt based on the best available scientific advice, experience, and lessons learned.

The overarching purpose of environmental monitoring is to test the accuracy of the environmental effect predictions made in the original EA. These predictions were generated through an evaluation of existing physical, biological, and socioeconomic conditions of the

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

study area, and an assessment of the risks the tidal energy demonstration project poses to components of the ecosystem.

Specifically, EEMPs are aimed at effects monitoring in relation to an operating tidal turbine(s) and will provide a more comprehensive understanding of turbine/marine life interactions when integrated. Multi-year data collection obtained in proximity to operational turbine(s) will be required to consider seasonal variability at the site and appropriate statistical analyses of this data will help to obtain a more complete understanding of marine life/turbine interactions.

Table 1 outlines the objectives of the respective mid-field monitoring activities conducted at the FORCE demonstration site. Individual near-field monitoring objectives of the CSTV monitoring program are outlined in Appendix 1. Appendices and Near-field Monitoring Summary sections will be updated as additional turbines are deployed at the FORCE demonstration site. To address these objectives and to make conclusions about marine life/turbine interactions, continual efforts will be made to integrate the results of these monitoring activities, where applicable.[16]

Table 1: The objectives of each of the 'mid-field' environmental effects monitoring activity, which consider various Valued Ecosystem Components (VECs), led by FORCE.

Mid-Field Environmental Effects Monitoring VEC	***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 Sound (Acoustics)	● to conduct ambient sound measurements to characterize the soundscape prior to and following deployment of the in-stream turbines
Seabirds	● to understand the occurrence and movement of bird species in the vicinity of in-stream tidal energy turbines ● to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to in-stream tidal energy turbines

Monitoring efforts 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. This is in keeping with the adaptive management approach—the process of monitoring, evaluating and learning, and adapting (AECOM, 2009)—that has been used at the FORCE site since its creation in 2009. This approach is necessary due to the unknowns and difficulties inherent with gathering data in tidal environments such as the

[16] For instance, prey/predator relationships as the "distribution of fish is likely to drive the foraging behaviour of larger predators, such as marine mammals and seabirds" (Fraser et al., 2018, p. 69).

Minas Passage and allows for adjustments and constant improvements to be made as knowledge about the system and environmental interactions become known.

At this time, and considering the scale of deployment in the near-term at the FORCE site, it is unlikely that significant effects in the far-field will be measurable (SLR, 2015). Given this, far-field studies, such as sediment dynamics, will be deferred until such time it is required. Further, as more devices are scheduled for deployment at the FORCE site, and as monitoring techniques are improved at the site (i.e., through FORCE's Fundy Advanced Sensor Technology (FAST) program), monitoring protocols will be revised, keeping with the adaptive management approach followed at the FORCE site. These studies will be developed in consultation with FORCE's EMAC, regulators, and others.

Lobster

Program Summary

The objective of FORCE's lobster catchability study is to determine if the presence of an in-stream tidal energy turbine affects commercial lobster catches within the Minas Passage through the deployment of traps at varying distances from an operating turbine (depicted in Figure 2). The study design is also intended to test the prediction of the EA that in-stream turbines will have minimal impacts on lobster populations within the test site. This prediction is based on the following characteristics of the site:

- Species diversity and population density is low;
- The substrate is scoured bedrock;
- The in-stream turbine and equipment have a small footprint in the area; and
- With minimal impact, populations will recover to baseline levels in the short-term (AECOM, 2009).

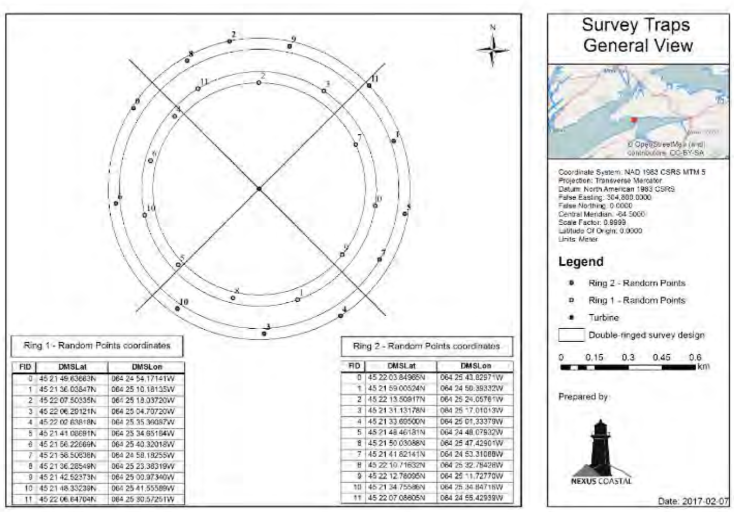

Figure 2: Double-ringed survey design proposed by Bayley (2010), with the dark centre representing the turbine and smaller circles representing lobster traps to be deployed (approximate distances shown) for the lobster monitoring program.

A survey was completed by NEXUS Coastal Resource Management Ltd. (Halifax, NS) in fall 2017 over 11 days of operations from October 23rd to November 15th, with a one-week break that suspended operations during the spring tide. Trap recovery rates were high during the survey (98%), and trap drift was minimal (~60 m average across traps). Lobsters retrieved from traps were measured (carapace length), sex and reproductive stage were determined (male, female, and berried female), and shell condition was evaluated. Upon completion of these measurements, lobsters were returned to the waters from which they were fished.

2018 Activities

FORCE had planned to conduct a second lobster catchability survey in fall 2018 to complete a comparative analysis with the 2017 dataset. However, this plan was contingent upon the presence of a functional turbine at the FORCE site to record catches of lobster in varying proximity to an operational turbine.

Given that the turbine's rotor was confirmed to be stationary in September 2018, the objectives of the lobster catchability study could not be effectively achieved. This is because an operational turbine would present different characteristics than a non-operational turbine in the Minas Passage. As such, FORCE will postpone this study until such time that an operational turbine is present at the FORCE site. When analysed in comparison to the 2017 survey, this survey would test predictions made in the FORCE Environmental Assessment (i.e., that in-stream turbines have minimal impacts on lobster populations and catchability rates within the test site).

Initial Results & Lessons Learned

As highlighted in NEXUS's 2017 survey report (Appendix 2), catchability rates were 'high' (> 2.7 kg/trap) in nearly all traps during the study period, according to the following designation provided by DFO:

- Low: 0-0.7 kg CPUE (Catch Per Unit Effort)
- Moderately low: 0.8-1.1 kg CPUE
- Moderate: 1.2-1.7 kg CPUE
- Moderately high: 1.8-2.3 kg CPUE
- High: 2.4-10.7 kg CPUE (Serdynska & Coffen-Smout, 2017)

There was only one trap retrieved with catch ranked as 'moderately low' at 1.00 kg trap. The highest catch recorded was 20.17 kg trap. In total, 351 lobsters were caught and released during the study. Based on a carapace length to weight conversion, this amounted to an estimated total weight of ~281.16 kg. Daily average catch rates ranged from 4.79-8.99 kg trap (n= 7-8 traps per day for 6 days) across both study rings.

Preliminary qualitative analyses indicate that catch rates declined during the study period, likely due to increasing tidal velocities during the progression of the study. There was a statistically significant negative relationship between catch rates and maximum tidal range (m), indicating lower catch at higher flow rates. Catch rates did not increase significantly with depth, and qualitative analyses suggested that there was no significant difference in catch rates between the inner and outer survey rings. Survey rings were also divided by quadrant (i.e., North, South, East, and West quadrants) to track any directional effects of the turbine. Qualitative comparisons did not reveal any differences between quadrants.

The EA prediction of minimal impacts of in-stream tidal turbines on lobster catchability rates partly relies on the condition of low population densities at the FORCE test site. Initial results showing high catchability rates in the FORCE test site may indicate that the impacts of turbines on lobster catchability may be higher than anticipated. However, data collection in the presence of an operational turbine to be used in comparison to the 2017 survey dataset is needed to fully verify EA predictions.

Fish

Program Summary

The goals of the mid-field fish monitoring program led by FORCE and the University of Maine[17] (Orono, Maine) are to i) test for indirect effects of in-stream tidal energy turbines on water column fish density and fish vertical distribution, and ii) estimate the probability of fish encountering a device based on any 'co-occurrence' relative to turbine depth in the water column. These goals were laid out to test the EA prediction that in-stream turbines are unlikely to cause significant impacts (i.e., shifts in distribution) to marine fish within the project area. This prediction is based on the relatively small scale of the project (Copping et al., 2016), as depicted in Figure 1 above.

The program uses a hydroacoustic echosounder (sonar) mounted onto a vessel[18] that looks downward to detect fish in the water column (sometimes, this equipment is referred to as a 'fish finder'). The 'scientific grade' echosounder, a Simrad EK80, provides detailed information on the 3D position of fish and surveys at a range long enough for the water column (Fraser et al., 2018).

Each survey operates over a 24-hour period (to include two tidal cycles and day/night periods with and against the tidal current) at both a reference, or unimpacted site, and the FORCE site (Figure 3). Each transect is 1.8 km in length. Fish densities and distributions between the sites are compared; any changes occurring at the FORCE test site, and not at the reference site, could be attributable to turbine operations.

[17] Previous work completed by the University of Maine in relation to the Ocean Renewable Power Corporation's project in Cobscook Bay, Maine 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).

[18] The echosounder used is a Simrad EK80 (transducer and desktop unit). The EK80 transducer is attached onto the pole mount off the side of the vessel Nova Endeavor. This 'scientific grade' equipment uses sonar technology (split beam echosounder) to detect fish within the water column. GPS is used to verify location of the pole mount during data collection. This technology is preferred over single and multi-beam systems because it provides more detailed information on the 3D position of fish relative to a single beam sounder, and can survey at a range long enough for the water column (Fraser et al., 2018).

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

The window to complete these hydroacoustic surveys is limited to neap tides, which occur approximately twice per month. FORCE's surveys are completed during the neap tide of the month that has the lowest tidal range (e.g., less than 10 m tidal range, optimally 8 m – 9 m) to reduce the amount of entrained air in the water column, standardize tidal state across sampling periods, and overlap with previous sampling efforts. As a result, there is typically a five-day window per month suitable for completion of these surveys. This window may be further limited, or eliminated, due to weather conditions as winds must be below 10 - 15 knots to reduce positional accuracy, reduce entrained air, and maintain high-quality data.

Data processing is done using Echoview® software. In late 2017 and early 2018, FORCE staff participated in hydroacoustic training programs led by the University of Maine, Acadia University, and Echoview. In addition, FORCE has contracted and trained a student intern to assist with data processing efforts. FORCE staff are now undertaking data processing efforts for the mobile fish surveys, which involves removing non-biological targets – usually entrained air due to turbulence in the water column – from the dataset. An image of unprocessed data, referred to as an 'echogram' is depicted below in Figure 4.[19] After processing, the data will be sent to third parties for analysis.

[19] Information about data processing and analysis may be found in FORCE's 2017 Annual Monitoring Report (2018) or Daroux and Zydlewski (2017).

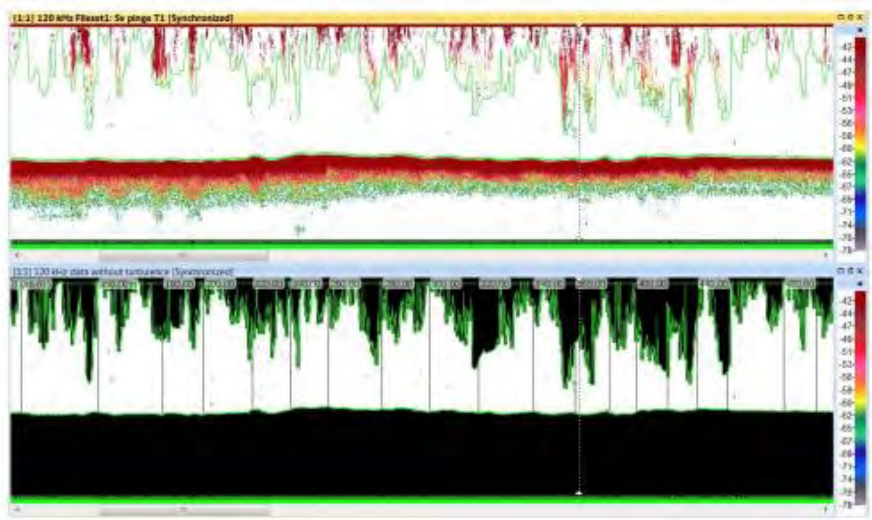

Figure 4: An echogram collected as part of a hydroacoustic fish survey program. This photo depicts the seafloor, entrained air, and fish biomass in the water column (top image). In processing, the seafloor disturbance, turbulence, and non-biological targets are removed (bottom image).

2018 Activities

Seven hydroacoustic fish surveys occurred in 2018:

- February 15th- 16th (originally scheduled for January 2018 but postponed due to weather limitations);
- April 10th – 11th (originally scheduled for March 2018 but postponed due to weather limitations);
- May 8th – 9th;
- June 7th – 8th;
- August 20th – 21st;
- September 20th – 21st; and
- October 20th – 21st (half a survey was completed due to inclement weather).

The CSTV turbine was in place during the August, September, and October surveys; however, it is presently unclear if the turbine was operating (i.e., if the turbine's rotor was spinning) during the August survey.

With the exception of the June and August surveys, all surveys occurred during the operation of the FAST-3 Platform that houses similar instrumentation as these mobile surveys. This is part of a project funded by the OERA, Natural Resources Canada (NRCan), and the Nova Scotia Department of Energy and Mines (see 'Platform Projects' under 'Other FORCE Research Activities' below).

Initial Results & Lessons Learned

Analyses include data collected during baseline studies in 2011 and 2012 (Melvin & Cochrane, 2014) and data collected during surveys conducted as part of FORCE's EEMP from March 2016 - August 2017. Across the contemporary (2016-2017) and historical (2011-2012) study periods, fish densities have been similar between the FORCE test site and reference site, including similar patterns of seasonal change. The highest fish densities were observed in May at both sites, likely driven by the spring migrations of alewife (*Alosa pseudoharengus*), Atlantic herring (*Clupea harengus*), striped bass (*Morone saxatilis*), Atlantic sturgeon (*Acipenser oxyrhynchus*), American shad (*A. sapidissima*), Atlantic mackerel *(Scomber scombrus*), and rainbow smelt (*Osmerus mordax*) (Baker et al., 2014, Stokesbury et al., 2016). High densities were also observed at both sites in November and January, likely due to migrations of Atlantic herring, blueback herring (*A. aestivalis*), and alewife out of Minas Passage during that time (Townsend et al., 1989). High densities in January could be caused by Atlantic herring that remain resident in Minas Passage throughout the winter. Townsend et al. (1989) also noted that fish densities were greater during the ebb than the flood tide. Analyses evaluated changes in fish density in association with month (i.e., season), year, site (FORCE site vs. reference site), diel stage (day/night), tidal stage (ebb/flood), and turbine presence/absence using 2-stage linear models (Daroux and Zydlewski, 2017).

Results to-date support the EA prediction that in-stream turbines have a minimal impact on marine fishes, but data spanning the full seasonal cycle from multiple years of deployments are needed to fully test this prediction. However, confidence in these conclusions will be strengthened following continued study around an operational turbine. In addition, there may be opportunities to validate this echosounder data with near-field monitoring data collected by berth holders at the FORCE site.

Marine Mammals

FORCE's marine mammal monitoring program in the mid-field involves two main components, aimed at testing the EA prediction that project activities are not likely to cause significant adverse residual effects on marine mammals within the project area (AECOM, 2009):

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

Passive Acoustic Monitoring

The first component of FORCE's marine mammal monitoring program involves the use of passive acoustic monitoring (PAM) mammal detectors known as 'C-PODs' (Figure 5), which record the vocalizations of toothed whales, porpoises, and dolphins.[20] In particular, the program focuses on harbour porpoise (*Phocoena phocoena*) – the key marine mammal species in the Minas Passage (Joy et al, 2017) that is known to have a small population that inhabits the inner Bay of Fundy (Gaskin, 1992).

[20] 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.

The C-PODs are deployed on SUBS packages between 200 m - 1,710 m from the location of the CSTV turbine (Figure 6). The goal of this monitoring efforts is to understand if there is a change in marine mammal presence in proximity to deployed in-stream tidal energy turbines and builds upon baseline C-POD data collection within the Minas Passage since 2011. Comparability with previous baseline research was a key rationale for the selection of C-PODs for FORCE's present marine mammal monitoring program. Analysis of C-POD data is completed by Sea Mammal Research Unit Consulting (SMRU Consulting; Vancouver, British Columbia).[21]

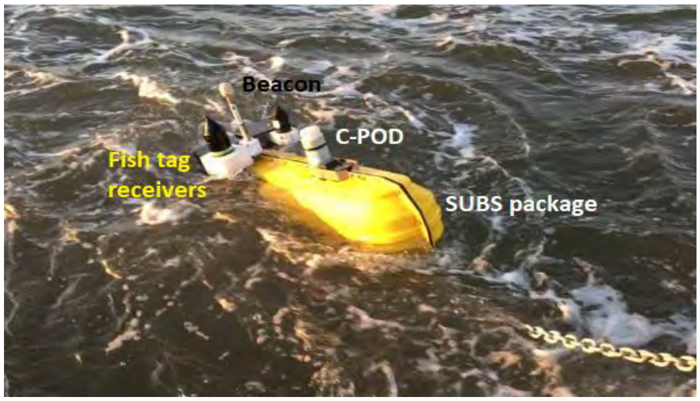

Figure 5: Recently deployed SUBS package containing two fish tag receivers, a beacon from MetOcean Telematics, and C-POD.

In addition to a C-POD, SUBS packages have been outfitted with a beacon (to evaluate their feasibility in aiding in recovery upon premature release)[22] and two fish tag receivers. Over the course of 2018, two beacons have been damaged/lost and were subsequently not replaced upon redeployment.

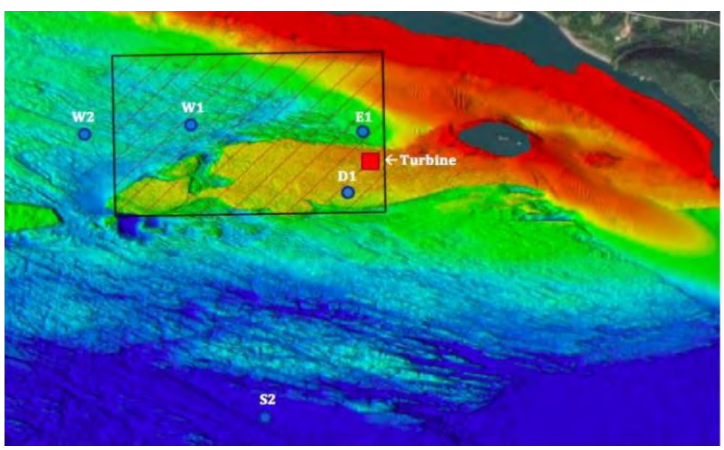

Figure 6: The five C-POD deployment locations in the mid-field of the turbine at the FORCE site (indicated by the black box), as deployed 2016 – present.

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[21] SMRU Consulting, based in Vancouver, British Columbia, is a global leader in marine mammal research and has been involved in Fundy tidal energy research for marine mammals since 2009 (Tollit et al., 2011; Tollit and Redden, 2013; Joy et al., 2017).

[22] Beacons were included on the SUBS packages to support recovery efforts in the event a package surfaces prematurely. The beacons are from MetOcean Telematics (Dartmouth, NS).

2018 Activities

In 2018, the SUBS packages that house the C-PODs, acoustic releases, fish tag receivers, and beacons underwent a period of annual maintenance upon recovery on January 9th. The C-PODs were deployed for the following periods in 2018:

- January 22nd – May 1st;
- May 3rd – August 23rd;
- September 6th – November 30th; and
- December 6th – ongoing.

After each recovery, the SUBS packages are inspected, regular maintenance and data-recovery activities are completed, and new battery packs are installed. When damage is discovered, repairs to the SUBS are made and efforts made to redeploy as quickly as possible.

Video: View online (https://twitter.com/fundyforce/status/963499152867983360): FORCE staff ballast a new sub configuration in the pool at Falck Safety Services in Dartmouth. A new addition includes a VEMCO fish receiver that will work in partnership with Dr. Mike Stokesbury's tagged fish research at Acadia University. The wand-looking device is an Iridium Beacon from MetOcean Telematics in Dartmouth; it's able to send a satellite signal to a cell phone with the SUBS package's exact location.

In summer 2018, FORCE was commissioned to deploy a subsea platform with high frequency hydrophones to estimate presence and absence of marine mammals, most notably harbour porpoise in the near-field area of the OpenHydro turbine. This platform was deployed approximately 35 m from the turbine on September 5th and recovered on September 21st. Analysis of the data from this platform is ongoing.

Observation Program

A second component of this program is a visual observation program that includes observations through shoreline walks, stationary observations at the FORCE Visitor Centre, and marine-based observations during marine operations. All observations and sightings are recorded, along with weather data, tide state, and other environmental data. Any marine mammal observations are shared with SMRU Consulting to support validation efforts of PAM activities.

2018 Activities

FORCE has also continued visual observations along areas of the Cumberland shore in proximity to the FORCE site, along with community volunteers. Vessel operators also report any observations of marine life during marine operations at the FORCE site. In addition, on June 8th (World Oceans Day), FORCE participated in the Great Canadian Shoreline Clean-up, an initiative of the Vancouver Aquarium and World Wildlife Fund Canada.[23] During these surveys, species of marine wildlife are typically observed with locations and behaviours are recorded.

In consideration of the isolation of the CSTV turbine from the power grid, FORCE increased the frequency of the shoreline surveys to daily frequency (weather dependent) until it was observed that the turbine's rotor was stationary. During this time regular behaviours of marine animals were observed – mostly seabirds and occasional marine mammals.

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[23] For further information about the Great Canadian Shoreline Clean-up, visit www.shorelinecleanup.ca.

FORCE also hosts a public reporting tool allows members of the public to report observations of marine life. No public reports were made online at https://mmo.fundyforce.ca/ in 2018.

In addition, FORCE also began the exploration of unmanned aerial vehicles (UAVs), or drones, for the purposes of monitoring. In 2018, FORCE acquired a DJI Mavic 2 Pro UAV and Special Flight Operations Certificate (from Transport Canada) to aid its shoreline survey monitoring and surface observations at the FORCE site for marine mammals, seabirds, and fish. Internationally, UAVs have proven helpful in other tidal environments in measuring animal distributions as well as fine-scale hydrodynamic surface characteristics (Williamson et al., n.d.). The purpose of the FORCE effort is to assess the utility of UAVs in shoreline surveying and marine life observations. This first data collection efforts will begin in spring 2019 when weather conditions permit safe operation of the UAV.

Integrated Analysis, Initial Results & Lessons Learned

From 2011 to May 1st, 2018, more than 4,650 'C-POD days'[24] have been completed at the FORCE site. Data collected and analysed by SMRU Consulting for the most recent monitoring effort ('Year Two' of the present FORCE monitoring program; February 2017 to May 2018) was added to this growing dataset.

As presented in *FORCE Marine Mammal EEMP 2nd Year Monitoring Report* (Joy et al., 2018), harbour porpoise were detected 98% of days by the C-PODs within the Minas Passage. In general, it was found that porpoise use and movement in the study area varies over long (i.e., seasonal peaks and lunar cycles) and short (i.e., nocturnal preference and tide state) timescales. During the most recent monitoring period, 166 days with a turbine present at Berth D were included.

In this analysis, there is some evidence to suggest marine mammal exclusion within the near-field of a turbine. A statistical model used by SMRU Consulting to evaluate the distribution and activity of harbour porpoise detected by the C-PODs (note: no dolphins were detected during of the C-POD deployments) confirmed an effect on porpoise presence at the two C-PODs closest to the deployed CSTV turbine. These C-PODS were located 230 m and 210 m from the turbine, respectively. While both of these sites had overall lower activity levels with and without the turbine, an effect was observed. Primarily, a decrease in detections was observed during turbine installation activities, consistent with previous findings of decreases in detections during periods of vessel activity associated with turbine installation (Joy et al., 2017).

At the same time, there was no evidence of porpoise exclusion within the mid-field study area (C-PODs located beyond 1,000 m from the turbine). These findings are consistent with other PAM results (see 'Marine Sound' below) that there is no evidence of mid-field avoidance with a turbine present and operating at the FORCE test site.

Continued monitoring in relation to an operating turbine for a longer period of time is required to allow for a better understanding of the variables that inform the environmental dynamics

[24] A 'C-POD day' refers to the number of days total each C-POD was deployed times the number of C-PODs deployed.

(including an operating turbine) at the FORCE test site. Results for the marine mammal monitoring program in 2018 are found in Appendix 3.

This analysis by SMRU also includes an assessment of the interaction of current speed and the memory limitations of C-PODs. It is known that C-PODs are limited at high current speeds and high-quality data is generally provided during current speeds less than 2 meters per second (m/s). It was noted that speeds above 3 m/s have a clear effect on C-POD performance; however, this analysis suggests only 2.8 percent of 625,000 10-minute monitoring periods are subject to a time loss of 80% or greater.

In November 2018, FORCE hosted a workshop with academic and industry partners involved in passive acoustic research and monitoring at the FORCE site. The purpose of the workshop was to explore various PAM solutions (such as C-PODs and hydrophones) specific to high-flow environments. The workshop explored potential projects to support further PAM advancement in the Minas Passage with the end goal of increasing regulatory and public confidence in environmental effects monitoring protocols used in support of in-stream tidal energy turbines. A workshop report is currently under development.

Seabirds

Program Summary

The main objective of the seabird monitoring program is to obtain site-specific species abundance, composition, and behaviour (including temporal and spatial distribution) data, which can be used to test the EA prediction that project activities are not likely to cause significant adverse residual effects on marine birds within the FORCE project area. More specifically, these abundance estimates are used to establish whether the presence of a tidal energy device causes displacement of surface-visible seabirds from habitual waters and to identify changes in behaviour.

The surveys use a geographic grid system to record observations in relation to various areas of the FORCE demonstration site and surrounding area (Figure 7). The surveys are typically completed over a six-hour period, coinciding with the ebb tide consistent with earlier surveys to help reduce statistical variability.

Envirosphere Consultants (Windsor, NS) has been conducting seabird and marine mammal monitoring at the FORCE site since 2008 (Envirosphere Consultants Limited, 2009 – 2013; 2017).

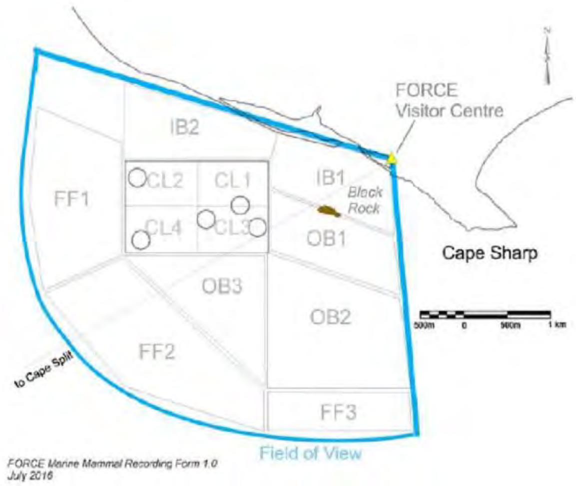

Figure 7: Subdivisions of the FORCE Crown Lease Area for the seabirds monitoring program where 'CL' indicates Crown Lease area; 'IB' indicates Inside Black Rock; 'OB' indicates Outside Black Rock; and 'FF' indicates Far-Field area.

2018 Activities

In 2018, 16 shore-based observational surveys were completed with increased efforts in known migratory periods (April, May, and November). Surveys were completed:

- January 16th;
- February 13th;
- March 19th;
- April 5th and 19th;
- May 10th and 29th;
- June 12th;
- July 10th;
- August 7th;
- September 6th;
- October 3rd and 22nd;
- November 8th and 22nd; and
- December 5th.

Initial Results & Lessons Learned

The latest monitoring effort (May 2017 to May 2018) builds upon baseline surveys completed from 2009 – 2012 (Envirosphere Consultants Limited, 2009 – 2013) and resumed in May 2016 (Envirosphere, 2017). These previous data collection efforts have provided a useful baseline for assessing trends in distribution and abundance near the FORCE test site.

The Minas Passage is often associated with migratory movements of water-associated birds; it has a lower abundance compared with other coastal areas of the Bay of Fundy and Atlantic Canada. Observation surveys have also noted that abundances in the Minas Passage follow a seasonal park that corresponds to migratory movements in spring and fall.

Throughout this survey period, abundance was similar to earlier surveys. In total, 36 species of water-associated birds and shorebirds were observed within the study area. Because of the short time period with a turbine present at the FORCE site, there was limited opportunity to determine potential effects and test the EA conditions. Statistical comparisons of abundance, as completed by Envirosphere (Appendix 4), have shown no evidence of turbine effect.

Marine Sound

Program Summary

Marine sound (often referred to as 'acoustics' or 'noise') monitoring efforts are designed to characterize the soundscape at and around the FORCE test site prior to and during the operation of in-stream tidal turbine(s). Data collected from these monitoring efforts will be used to test EA predictions that operational sounds produced from in-stream turbines are unlikely to cause mortality, physical injury, or hearing impairment to marine animals (AECOM, 2009). Data will also be useful for increasing knowledge of the general soundscape of the Minas Passage.

While marine sound monitoring has occurred at the FORCE site for a number of years, the most recent monitoring activities began in anticipation of the deployment of the CSTV turbine in 2016, using Passive Acoustic Monitoring (PAM) devices known as hydrophones (i.e., underwater recorders) in various configurations. In 2016 - 2017, mid-field sound monitoring was completed using 'drifters' - hydrophones connected to a drifting buoy system. These drifters were deployed from a vessel, which moves away from the drifter and shuts off, and the drifters are allowed to travel with the current across the FORCE demonstration site, recording sound measurements along the way. The results of this data, integrated with near-field monitoring from this same period, is presented in Appendix 5.

In 2018, acoustics monitoring has focused on near-field PAM. This plan, which integrates multiple sound sources and is led by FORCE, is outlined below.

2018 Activities

While the JASCO analysis provided recommendations to FORCE and CSTV regarding future data collection and analysis, FORCE revisited its plan upon learning that the CSTV turbine rotor is no longer spinning. In place of additional data collection in the absence of a spinning turbine rotor, FORCE commissioned JASCO Applied Science, GeoSpectrum Technologies Inc. (Dartmouth, NS) and Dalhousie University's Oceanography Department (Halifax, NS) to conduct an integrated comparative examination of the data collected in the near-field region of the OpenHydro turbine in summer/fall 2018. This analysis will include data collected from:

- Three turbine-mounted icListen high frequency hydrophones from Ocean Sonics (Great Village, NS);
- A stationary, bottom-mounted AMAR (Autonomous Multichannel Acoustic Recorder) from JASCO Applied Sciences (Dartmouth, NS) located approximately 100 m distance from the turbine location from June 29th to November 19th; and

- An autonomous platform containing two icListen hydrophones deployed ~35 m from the CSTV turbine from September 5th to September 21st, 2018 (see description in 'Marine Mammals' above[25]).

Utilization of this near-field data will advance our understanding of the soundscape of the site and will provide valuable information about future mid-field and near-field monitoring at the FORCE site.

Integrated Analysis, Initial Results & Lessons Learned

Data analysis that integrates and compares sound data from these various PAM recorders in the Minas Passage was completed by JASCO Applied Sciences in relation to the 2016 – 2017 operation of an OpenHydro turbine by CSTV (Appendix 5). The purpose of this analysis was to:

- compare turbine sound to flow noise relative to the existing environment, turbine state (generating, free-spinning, or not spinning), and measurement method;
- estimate the possible effects of turbine sound on marine life;
- evaluate the relative utility of the instrument configurations' use to record short-term (i.e., hours to days in duration) and long-term (i.e., weeks to months in duration) sound data in the Minas Passage; and
- provide guidance on methodologies for future acoustic measurements at the FORCE site.

JASCO's analysis found that sound levels increase with the current speed in the Minas Passage and are higher during flood tide than during ebb tide. With the turbine present at the site (regardless of operating state), it was observed that current direction did not influence sound levels, but current speed did. This was evidenced by increases in sound by 20 - 30 decibels (dB) in the generating and free-spinning states as the current speed increased. Likewise, the turbine was found to emit a band of sound in the 3150 – 4000 Hertz (Hz) while generating, and sound levels increased by ~10 dB as the current speed increased in this state.

Like current speed, the different turbine states (e.g., generating, free-spinning, or not spinning) were determined to have differing sound levels.[26] The JASCO study found that in the generating state, the turbine omitted a band of sound in the 1000–1250 Hz range that is nearly constant, and that when the turbine was in a free-spinning state, the sound produced was observed to be 5 - 25 dB quieter than the generating state.

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[25] Hydrophones record sounds, which include marine mammal vocalizations and turbine-produced sound and are, therefore, suitable for multiple monitoring programs.

[26] As indicated above, the turbine's rotor is presently not turning. Cape Sharp Tidal advises that when the turbine was in a generating mode, it turned while generating electricity. In 'free-spin,' the turbine rotor turned but did not generate electricity. Whether generating or in free-spin, the speed of the turbine varied with the velocity of the current, thereby changing the level of sound produced. Under normal operating conditions, the amount of time the turbine rotor was in free-spin was minimal, typically less than 1% of the time for each tide. There is a short period of approximately 30 to 60 seconds between when the turbine rotor started moving and when the turbine started generating. The same was true, although typically for a shorter period, at the end of the generating cycle. Short periods of free-spin (i.e., less than 60 secs) were anticipated to be a regular part of the turbine operation. These free-spin periods typically were predicted to occur at the start and end of each generating cycle and have a low rotations per minute (RPM) (i.e., less than 7 RPM).

It was found that turbine sound only exceeded the threshold for behavioural disturbance to fish at very short ranges and only at the highest current speeds on the flood tide. While the turbine may be audible to herring (or mask sounds a herring could hear) up to 1,000 m away, it was typically in the range of 500 m or less. Additional data collection when a turbine is reinstalled at the FORCE site will provide information regarding seasonality and upon device commissioning, further data in relation to an operational tidal energy turbine.

For porpoise, the sound range of the turbine was found to be up to 800 m. However, this distance was generally less than 300 m in the generating state. In the free-spinning state, the turbine did not generate sound levels in the porpoise hearing frequency band that were measurable above ambient sediment noise. The range where the turbine could cause temporary hearing shifts in porpoise, if one stayed beside the turbine for 24 hours, was 150 – 250 m on most days and increased to 500 m during spring tides. However, it is highly unlikely, that a porpoise would remain near the turbine for longer than one hour. Overall, it was found that the sound amplitude of vessels and the turbine were found to be at similar ranges for porpoise. As with fish monitoring, further data collection is required to make conclusions regarding sound impacts on marine mammals. However, initial results like those from the mid-field mammals program indicate no evidence that porpoise permanently avoided the site while the CSTV turbine was deployed from November 2016 – June 2017.

Near-Field Monitoring Activities

As highlighted above, while FORCE completes site-level or 'mid-field' monitoring activities at the FORCE site, near-field monitoring (i.e., device-specific monitoring within 100 m of a turbine) is completed by individual berth holders. Like the mid-field monitoring programs, the near-field monitoring plans and reports undergo review by FORCE's EMAC and regulators.

As noted above, CSTV is currently not completing near-field monitoring at 'Berth D' since it has been confirmed that the turbine rotor is not turning. At this time, the turbine remains at the FORCE berth where it was deployed in July 2018. Some environmental sensors continue to operate and transmit acoustic and flow data to the onshore substation. This includes three hydrophones and three ADCPs. The Gemini sonar ceased communication on October 26th, 2018. The autonomous multichannel acoustic recorder (AMAR) that was deployed in close proximity to the turbine on June 29th, 2018 as part of the CSTV environmental effects program was recovered in November 2018. The AMAR was deployed to collect CSTV turbine sound data before and after deployment. This data, along with data from the hydrophones will be compared and used to increase understanding of turbine sound and how it changes with flow speed, as well as ambient (natural) sound in the Minas Passage. Flow data from the ADCPs mounted on the turbine will be used to supplement other data sets.

The data from the AMAR and the devices on the turbine is important in the context of increasing understanding of the environment and is, therefore, useful for research purposes and for further development of the tidal industry.

The Gemini sonar (an active acoustic device) mounted on the turbine's subsea base continued to collect data until October 26th, 2018, when communication with the monitoring device was lost. Data collected from September 2018, after the turbine and monitoring devices were re-energized, is being assessed by researchers under a separate program funded through the OERA.

An update prepared by CSTV is included in Appendix 1 of this report. Moving forward, each berth holder's monitoring activities will be included as appendices below. Updates from future berth holders will be provided as others develop and implement near-field, device-specific environmental effects monitoring programs.

Other FORCE Research Activities

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 enhance 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; Victoria, BC) website[27] while the radar system works to monitor surface currents and seabirds. Offshore assets include three modular subsea platforms for both autonomous and cabled data collection. Real-time data collected through FAST assets is broadcasted live on the ONC website.

Online Feature: Working at the Bottom of the Bay, describes two contractors' experience in working on the FORCE project, including FAST marine operations. Link: (https://marineenergy.biz/2018/05/04/working-at-the-bottom-of-the-bay)

Platform Projects

The first and largest of the FAST subsea platforms houses an instrument referred to as the 'Vectron.' Developed in partnership with Nortek Scientific (Halifax, NS), Memorial University (St. John's, NL), and Dalhousie University (Halifax, NS), the Vectron is the world's first stand-alone instrument to remotely measure, in high resolution, turbulence in the mid-water column. Measurements and analysis from the Vectron will help tidal energy companies to better design devices, plan marine operations, and characterize the tidal energy resource.

A second, smaller platform is presently dedicated to a project called 'FAST-EMS' (Fundy Advanced Sensor Technology-Environmental Monitoring System). This cabled platform is designed to enhance real-time data collection regarding turbine-marine life interactions. The platform presently holds:

- an imaging sonar (a Tritech Gemini) that generates detailed 2-D imaging;
- a pan-tilt unit on which the imaging sonar is mounted that permits the sonar's orientation to be remotely adjusted while the platform is on the seabed;
- two icListen hydrophones from Ocean Sonics (Great Village, NS);
- an acoustic Doppler current profiler (ADCP) to understand water speeds from Nortek Scientific (Halifax, NS);
- a Sculpin HDC subsea camera from SubC Imaging (Clarenville, NL); and

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

- subsea cabling with multiplexer from MacArtney (Dartmouth, NS) to allow for real-time data collection.

The completed FAST-EMS system was successfully demonstrated near Black Rock Island in summer 2018. When validated within deeper and faster flows within the FORCE test site, the platform could serve to provide supplemental and/or contingency monitoring for the near-field monitoring.

The 'FAST-3' platform houses two hydroacoustic and various environment sensors to monitor fish densities in the mid-field of the turbine. FORCE has received funding from Natural Resources Canada (NRCan) and OERA to complete a comparative analysis of data collected by bottom (FAST-3) and vessel-mounted hydroacoustic echosounders (used as part of the mid-field fish EEMP), an outcome of a fish hydroacoustics workshop held by FORCE and Acadia University in May 2017. An analysis of the two data collection methods, and where the beams of the instruments intersect (Figure 8), will evaluate the temporal and spatial representativeness of each method and determine the degree to which results are corroborative.

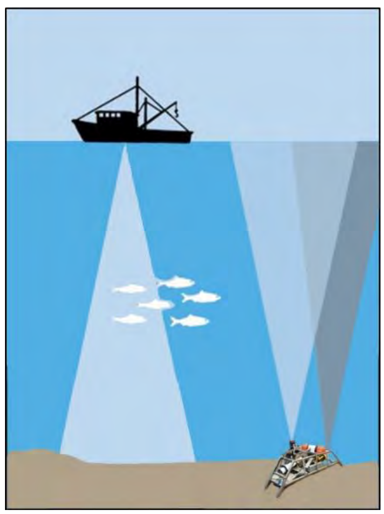

Figure 8: A representation of the data collection methods of the FORCE mid-field fish EEMP and the FAST-3 platform.

Data collection for this project is complete and the development of analysis techniques for this project are currently underway. In 2018, the platform was been deployed:

- December 12th, 2017 - February 22nd, 2018;
- March 28th - May 23rd, 2018; and
- September 14th – November 28th

FORCE and its partners have made efforts to ensure appropriate seasonal coverage among these overlapping (and to be integrated) datasets – one in winter (February 2018), two in spring (April and May 2018), and two in fall (September and October 2018).[28] Moving forward, the project will focus on data processing, analysis, and integration.

Online Feature: Webinar on 'Acoustic Assessment of Fish Presence and Vertical Distribution at the FORCE Tidal Turbine Test Site in the Minas Passage, Bay of Fundy' by Dr. Haley Viehman and Dr. Anna Redden. Available online: http://www.oera.ca/meetingsevents/webinar-series/oera-webinar-series-haley-viehman-anna-redden-acadia-university/

Radar Projects

In cooperation with Acadia University, FORCE operates an X-band marine radar on the FORCE Visitor Centre (Figures 9 and 10). This radar (similar to those mounted on fishing vessels) is used to support bird tracking research and to map surface velocities and eddies through the FORCE region waters.

Figure 9: The radar is located on the top right corner of the FORCE Visitor Centre.

Online Feature: Dr. Joel Culina, Melissa Oldreive, and Jeremy Locke lead a webinar hosted by the OERA on the radar project. Available online: http://www.oera.ca/meetingsevents/webinar-series/oera-webinar-series-joel-culina-fundy-ocean-research-center-for-energy/

[28] A third deployment of the FAST-3 platform was planned to cover the summer months of June – August 2018. However, the platform was not redeployed as scheduled due to challenges with instrumentation calibration. A firmware upgrade to one of the hydroacoustic echosounders required more from the instrument manufacturer, Kongsberg, to troubleshoot prior to re-installation. As a result of this time delay, it was decided to forgo a shorter summer 2018 deployment in favour of a full fall 2018 deployment – a key period of interest to scientists and regulators.

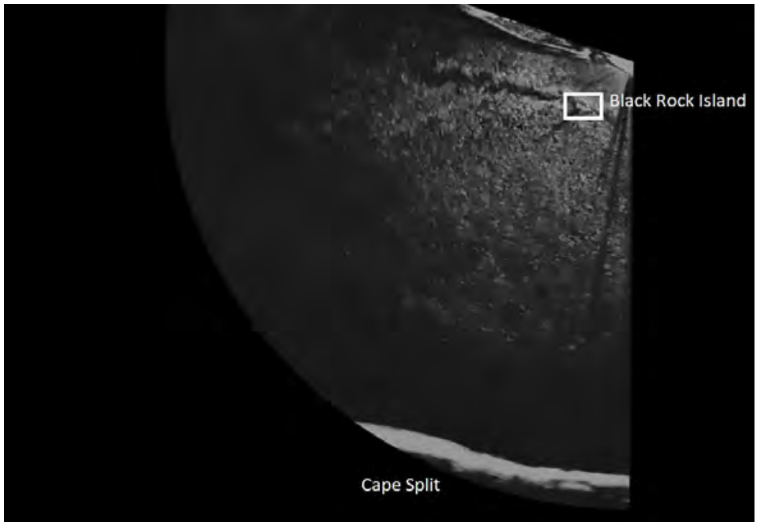

Figure 10: A screenshot of an X-band radar image with labels indicating land-based features. This radar is located on top of the FORCE Visitor Centre.

In cooperation with the Canadian Coast Guard, Dr. Joel Culina, Mr. Jeremy Locke (Acadia University MSc and FORCE intern), Dr. Phil Taylor (Acadia University), and Mr. John Brzustowski installed a second radar on Cape Sharp headland in spring 2018. This second radar provides a view of eastern Minas Passage to complement the view of western Minas Passage provided by the FORCE Visitor Centre radar.

In summer 2018, Dr. Culina, Mr. Locke, Dr. Richard Karsten and Mr. Amirreza Abbasnejad (Dalhousie University MSc) used the FORCE Visitor Centre radar and a FORCE-Acadia model to map and characterize the Black Rock Island wake, a key constraint on turbine placement and operation in the FORCE region and surrounding waters.

In fall 2018, Mr. John Brzustowski, with project partners FORCE and Acadia University, received OERA funding to establish a prototype, low-power, low-cost radar network, consisting of the FORCE Visitor Centre and Cape Sharp radars, for sea state/current mapping and target tracking through Minas Passage. This network would be the first of its kind for marine coastal monitoring.

A second project funded by OERA, led by Dr. Phil Taylor and his laboratory research team at Acadia University, will use 'rad R' software to assess bird use at different locations across the Maritimes. The team will use the FORCE radar dataset (going back to 2015) to inform stakeholders how seabird use changes with a variety of factors. Recommendations will also be made regarding the potential further use of radar for seabird environmental effects monitoring activities.

In July 2018, FORCE participated in an Industry Problem Solving Workshop led by Atlantic Association for Research in the Mathematical Sciences (AARMS) held at Dalhousie University. A synopsis of this workshop is available online at: https://aarms.math.ca/2018/08/13/aarms-industrial-problem-solving-workshop-2018/

Fish Tracking

To enhance fish monitoring and to expand its data collection capacity, FORCE partnered with the Ocean Tracking Network (OTN)[29] and attached one VEMCO[30] fish tag receiver (a VR2 receiver) to each C-POD mooring/SUBS package (see 'Marine Mammal Program' above). 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, as well as complement FORCE's hydroacoustic data collection which currently does not allow for species identification.

OTN data managers are in the process of acquiring information, including species identification, and sharing this with FORCE. Initial results show that the OTN receivers deployed by FORCE have detected tags from the following projects:

- Maritimes Region Atlantic salmon marine survival and migration (Hardie, D.C., 2017);
- Quebec MDDEFP Atlantic Sturgeon Tagging (Verreault, G., 2013);
- Gulf of Maine Sturgeon (Zydlewski, G., Wippelhauser, G. Sulikowski, J., Kieffer, M., Kinnison, M., 2006);
- OTN Canada Atlantic Sturgeon Tracking (Dadswell, M., Litvak, M., Stokesbury, M., Bradford, R., Karsten, R., Redden, A., Sheng, J., Smith, P.C., 2010);
- Darren Porter Bay of Fundy Weir Fishing (Porter, D., Whoriskey, F., 2017);
- Movement patterns of American lobsters in the Minas Basin, Minas Passage, and Bay of Fundy Canada (2017);
- MA Marine Fisheries Shark Research Program (Skomal, G.B., Chisholm, J., 2009);
- Curry Atlantic Sturgeon and Striped Bass (Curry, A., Linnansaari, T., Gautreau, M., 2010); and
- Inner Bay of Fundy Atlantic Salmon (Bradford, R., LeBlanc, P., 2012).

Further information about these Buoys of Opportunity, and the projects listed above, can be found on OTN's website: https://members.oceantrack.org/project?ccode=BOOFORCE

In 2018, FORCE has worked in collaboration with Dr. Mike Stokesbury at Acadia University to install additional VEMCO receivers of a new design on FORCE's C-POD moorings/SUBS packages. These new receivers are expected to be even more effective in picking up acoustic detections in high flow environments, where tag signals can be obscured by noise. This partnership will contribute additional information regarding movement patterns of Atlantic salmon, sturgeon, striped bass, and alewife in Minas Passage and Basin. This work is sponsored by the OERA,

[29] Ocean Tracking Network's website: www.oceantrackingnetwork.org.

[30] VEMCO is "the world leader in the design and manufacture of acoustic telemetry equipment used by researchers worldwide to study behaviour and migration patterns of a wide variety of aquatic animals." Learn more: www.vemco.com.

NRCan, the Nova Scotia Department of Energy and Mines, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).[31]

Environmental Monitoring Advisory Committee (EMAC)

The purpose of FORCE's Environmental Monitoring Advisory Committee (EMAC) is to provide advice on monitoring programs, and to review and advise on monitoring results. Membership includes representatives from scientific, First Nations, and fishing communities. This year, EMAC met three times to provide advice to FORCE on third-party EEM reports and results, berth holder EEMPs, and general monitoring program design.

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

Research Networks

It is also important to note that additional research projects are occurring within the Bay of Fundy, particularly the Minas Passage and the Minas Basin outside of the jurisdiction of FORCE. FORCE works closely with many research partners, such as the Acadia Tidal Energy Institute,[32] Dalhousie University, Nova Scotia Community College, and others to keep up-to-date on these activities and how they may contribute to the growing understanding of the monitoring turbine effects.

FORCE also participates in research forums to understanding the growing local and international knowledge of tidal energy effects monitoring. This includes the Fundy Energy Research Network (FERN), a research forum designed to "coordinate and foster research collaborations, capacity building and information exchange"[33] Annex IV,[34] an international body that connects those actively involved in marine renewable energy projects to share information and discuss progress in environmental monitoring efforts, the Bay of Fundy Ecosystem Partnership (BoFEP), a 'virtual institute' interested in the well being of the Bay of Fundy,[35] and TC114, a industry standards development group.[36]

In addition, the recently-announced Atlantic Canada-based Ocean Supercluster (OSC) supported a mandate to "better leverage science and technology in Canada's ocean sectors and to build a digitally-powered, knowledge-based ocean economy", and included marine renewables as part of its scope. OSC has also declared its intent to create cross-sector

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

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

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

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

[35] To learn more, see http://www.bofep.org/.

[36] TC114 is the Canadian Subcommittee created by the International Electrotechnical Commission (IEC) to prepare international standards for marine energy conversion systems. Learn more: http://tc114.oreg.ca/.

opportunities for activities such as the "customization of underwater sensors and communications systems to provide real-time data." Within OSC, it may be possible to create partnership opportunities to further enhance environmental effects monitoring efforts in the Minas Passage. Additional info is available at www.oceansupercluster.ca

Discussion

Environmental research and monitoring efforts at the FORCE site over the last several years has contributed to the growing body of knowledge with respect to the natural and physical environment of the Minas Passage. Though there have been limited periods of turbine operation at the FORCE site, initial findings are enhancing the collective understanding of the potential risks in-stream tidal energy devices pose to marine life and the marine environment, specifically within the Bay of Fundy context.

Within the mid-field area, there have been no significant changes observed in the distribution and behavior of fish (Daroux and Zydlewski, 2017), seabirds (Envirosphere Consultants Limited, 2017), or marine mammals (Joy et al., 2018) at the FORCE site in relation to the deployed OpenHydro turbine in 2016 – 2017. This is similar to studies elsewhere that have documented no changes in behavior of fish in the vicinity of an operating turbine (Bevelheimer et al., 2015), but will require further testing and analysis to make meaningful conclusions.

FORCE's mid-field monitoring has also documented temporary declines in the presence of harbour porpoise during turbine installation, which could be attributable to increased vessel activity associated with the installation of the OpenHydro turbine by CSTV in November 2016. Marine mammals are known to be impacted by anthropogenic sounds, including those emitted by underwater construction and vessels, leading to injury or changes to behaviour and distribution (Gotz et al., 2009). Though analysis shows sounds from the OpenHydro turbine were typically audible to fish and harbour porpoise in the 500 m – 800 m range (Martin et al., 2018; Appendix 5), it is considered unlikely for turbines to cause injury (Joy et al. 2018). Temporary declines in mammal presence have been observed in other tidal contexts – studies of the SeaGen project in Strangford Lough, N. Ireland (Royal Haskoning, 2011) documented temporary displacements of harbour porpoise during turbine installation activities. Similarly, this bird disturbances have been observed in association with turbine installation operations (Royal Haskoning, 2011; Long, 2017).

Within the near-field monitoring zone, long-term deployments of a turbine with effective monitoring instrumentation in place must be undertaken to understand marine animal behaviour directly near a turbine. At the FORCE site, there is some evidence to suggest marine mammal exclusion closer to the near-field area: PAM devices at locations within a 200 m range of the CSTV berth documented a reduction in detections upon the installation of the OpenHydro turbine (Joy et al., 2018 or Appendix 3). Further, long-term monitoring must be completed in relation to an operating turbine to assess the EA predictions while also considering natural and interannual variability at the FORCE site.

Overall, however, findings at the FORCE site to-date are comparable to the international body of research in the field, which has documented few negative impacts of in-stream tidal turbines on marine life (Copping et al., 2016; Copping, 2018). Internationally, it has been observed that fish generally avoid operating turbines (Copping et al., 2016), demonstrating fine-scale behavioural adjustments in response to devices. Further research on how sounds – among other factors – from these devices might affect behaviours is required to fully assess the FORCE

EA prediction that tidal energy demonstration projects are unlikely to cause significant harm to marine life.

While it still early to draw conclusions, initial findings internationally and at the FORCE test site provide an early picture of turbine/marine life interactions. These efforts also provide an opportunity for adaptive management and further develop and refine the scientific approaches, tools, and techniques necessary to effectively monitor tidal energy turbines in high-flow environments. For instance, initiatives like the FAST Program provide the ability to develop and enhance standard operating procedures for environmental effects monitoring.

Moving forward, it is crucial that effective near- and mid-field monitoring is in place to understand the environmental effects of deployed in-stream tidal energy devices. While the turbine deployment in 2016 - 2017 provided important preliminary findings to support this prediction, monitoring in association with an operating turbine will add significantly to our understanding of the potential impacts of this specific device. With permission from regulators, FORCE curtailed certain aspects of its fall 2018 monitoring program in response to the status of the CSTV turbine. This is because a non-operational turbine has implications for monitoring – a turbine that is not spinning does not allow us to test its true environmental effects. At the same time, a stationary turbine does not contribute to enhancing baseline data as it could serve as an artificial reef, and fish may be attracted to it and seek shelter in and around the structure, subsequently influencing their distribution. Therefore, fish monitoring during this time could generate biased data and introduce statistical outliers that may skew baseline data and negatively effect our ability to test the environmental effects of an operational turbine in the future. As a result, FORCE curtailed monitoring for fish, sound, and did not conduct a lobster catchability study in fall 2018.

FORCE is actively developing a monitoring plan for 2019. Considering the status of the CSTV turbine, regulators have advised FORCE to take this opportunity to critically evaluate the utility of equipment and protocols used for monitoring. Therefore, FORCE is engaging with experts from academia and industry as well as key stakeholders to develop a series of experiments and tests to assess the relative utility of various PAM devices used for monitoring sound and marine mammals in addition to various technologies (i.e., echosounders, imagine sonars) for monitoring fish.

The information gained during future turbine deployments at the FORCE test site will be important towards evaluating the EA prediction that the project is unlikely to cause significant harm to marine life. In the longer-term, monitoring will need to be conducted over the full seasonal cycle and in association with multiple different turbine technologies in order to understand if tidal energy can be a safe and responsibly-produced energy source. Through its mandate, FORCE will continue to report on progress and release results and lessons learned in keeping with its mandate to support evidence-based decision-making.

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