Environmental Effects Monitoring Program

2019 Annual Report

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Executive Summary

Generating electricity from tidal stream technology devices using the ebb and flow of the tides is an emerging marine renewable energy resource that is being explored by countries around 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 tidal stream energy 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 (OERA), and others. These studies have considered socioeconomics, 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 monitoring activities led by FORCE >100 metres from a turbine, and near-field or 'turbine-specific' monitoring led by individual tidal energy developers at the FORCE site ≤100 metres from a turbine. All plans are reviewed by FORCE's independent Environmental Monitoring Advisory Committee (EMAC) 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 start of this latest monitoring effort in 2016, FORCE has completed:

- ~408 hours of hydroacoustic fish surveys;
- more than 4,385 'C-POD' marine mammal monitoring days;
- bi-weekly shoreline observations;
- 49 observational seabird surveys;
- four drifting marine sound surveys and additional sound monitoring; and
- 11 days of lobster surveys

Analysis of fifteen hydroacoustic fish surveys conducted in the Minas Passage between 2011-2017 as part of FORCE's Environmental Effects Monitoring Program (EEMP) has been recently completed by the University of Maine and is included in this report and in Appendix IV. The report by the University of Maine provides an overall approach for understanding the information contained within the hydroacoustic data sets, including data visualization and statistical analyses. Moreover, the University of Maine has provided FORCE with the data scripts/coding required for analysis and data visualization so that deeper explorations of the data may be undertaken to investigate questions that are specific to the needs of FORCE.

FORCE recently completed the field component for the comparative passive acoustic monitoring (PAM) study outlined in its regulator approved 2019 EEMP plan. This study aims to understand the relative performance of multiple PAM devices (C-POD, F-POD, SoundTrap, icListenHF, and AMAR) across the range of tidal flows experienced at the FORCE site. The first phase of the study involved testing at Dalhousie University's Aquatron facility and confirmed that each device could detect synthetic click trains emitted by an icTalk used to mimic harbour porpoise vocalizations. FORCE recently completed the field trial component of this study and has sent the data to SMRU Consulting for analyses. Further information is included in this report.

In another PAM-related study, FORCE recently commissioned JASCO Applied Sciences (Canada) Ltd. to conduct a comparative integrated analysis of acoustic data sets collected by various hydrophones mounted on and deployed around the CSTV turbine at the FORCE site. Study details are contained herein, and the report is included as Appendix IX. Results demonstrated that flow noise increased with the height of the hydrophone off the seabed and impacted the hydrophone mounted on the top of the CSTV turbine the most. The least affected hydrophones were those mounted at the 'aft' position on the CSTV turbine and the autonomously deployed AMAR. In fact, flow noise at these locations was low enough to successfully measure the sound from the turbine during the brief period prior to the malfunction of the turbine's rotor in August 2018 (see below).

FORCE recently commissioned Envirosphere Consultants Ltd. to conduct the final year of wetlands monitoring at the FORCE site. This work was done to verify impact predictions made in relation to the trenching and installation of electrical and data cables across the marsh wetlands along Black Rock Beach in 2011. Botanical surveys have been ongoing since that time as part of FORCE's Wetlands Alteration Approval (issued by NS Environment). The survey conducted in 2019 demonstrated that the wetland is well-vegetated and has a healthy plant community (as determined by the presence of dominant species) and has now recovered from the trenching activities associated with cable installation. The report is provided in Appendix X.

FORCE worked collaboratively with TriNav Fisheries Consultants Ltd. to redesign FORCE's lobster monitoring program based on regulatory feedback, with the aim of making the monitoring program more statistically robust. The report outlines a scientifically defensible approach for monitoring lobster at FORCE using a combination of modified commercial lobster traps and tagging efforts and is provided in Appendix XI.

FORCE is working collaboratively with the OERA to advance 'The Pathway Program' to identify effective and regulator approved monitoring solutions for the tidal energy industry in Nova Scotia. The first phase of this program was a Global Capability Assessment that was recently completed. It involved comprehensive literature reviews about the use of different classes of environmental monitoring technologies such as PAM, imaging sonars, and echosounders for monitoring tidal energy devices around the world. Subject matter experts were commissioned to provide reports on these instrument classes, and FORCE has received final reports for these technology classes. Further information is included in this report and Appendix V (PAM), Appendix VI (imaging sonars), and Appendix VII (echosounders). Phase II, Advancing Data Processing and Analysis, has commenced and work is underway with DeepSense (Dalhousie University) to automate the post-processing of hydroacoustic fish survey data. Automation of other types of monitoring data such as PAM will commence in the near future. Phase III, Technology Validation, has also begun and FORCE is working collaboratively with Sustainable Marine Energy Canada (SME) to assess the capabilities of different classes of environmental monitoring technologies in high flow environments.

In July 2018, CSTV installed a two-megawatt OpenHydro turbine at 'Berth D' in the FORCE Crown Lease Area. Due to the insolvency of OpenHydro which was announced four days after turbine installation, the approved near-field monitoring program and contingency monitoring program for this turbine could not be immediately 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 4, 2018. At that time, it was confirmed that the turbine's rotor was not turning, and the turbine-mounted monitoring sensors were re-energized.

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 modified to monthly confirmation of the turbine rotor's status. This is done using data collected from turbine-mounted Acoustic Doppler Current Profilers (ADCP) during peak tidal flow. CSTV provided these monthly reports to regulators from October 2018 through February 2019, but notified Nova Scotia Environment and FORCE on March 15, 2019, that it intended to cease this monthly reporting requirement due to issues surrounding its insolvency. Consequently, FORCE took on this responsibility and has provided regulators with monthly turbine status reports from March 2019 through December 2019 that confirm the continued non-operational status of the CSTV turbine. FORCE intends to provide these monthly reports until the CSTV turbine is retrieved. Beyond the ADCPs, 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 I.

This report provides a summary of monitoring activities and data analysis completed at the FORCE site for 2019. In addition, it also highlights findings from international research efforts, previous data collection periods at the FORCE site, and additional research work that is being conducted by 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/document-collection.

Contents

Appendices

Acronyms

AAM	Active Acoustic Monitoring
ADCP	Acoustic Doppler Current Profiler
AMAR	Autonomous Multichannel Acoustic Recorder
BACI	Before/After, Control/Impact
BC	British Columbia
BoFEP	Bay of Fundy Ecosystem Partnership
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	Department of Energy and Mines (Nova Scotia)
EA	Environmental Assessment
EEMP	Environmental Effects Monitoring Program
EMAC	Environmental Monitoring Advisory Committee
EMP	Environmental Management Plan
FAD	Fish Aggregation Device
FAST	Fundy Advanced Sensor Technology
FAST-EMS	Fundy Advanced Sensor Technology – Environmental Monitoring System
FERN	Fundy Energy Research Network
FORCE	Fundy Ocean Research Center for Energy
GPS	Global Positioning System
hr	Hour(s)
IEA	International Energy Agency
kg	Kilogram(s)
km	Kilometer(s)
kW	Kilowatt(s)
m	Meter(s)
MET	Meteorological
MRE	Marine Renewable Energy
MREA	Marine Renewable-electricity Area
NL	Newfoundland and Labrador
NRCan	Natural Resources Canada
NS	Nova Scotia
NSDEM	Nova Scotia Department of Energy and Mines
NSE	Nova Scotia Department of Environment
NSERC	Natural Sciences and Engineering Research Council
NSPI	Nova Scotia Power Inc.
OERA	Offshore Energy Research Association of Nova Scotia
OES	Ocean Energy Systems
ONC	Ocean Networks Canada
ORJIP	Offshore Renewables Joint Industry Programme
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

TC114	Technical Committee 114
TISEC	Tidal In-Stream Energy Converter
SUBS	Streamlined Underwater Buoyancy System
SME	Sustainable Marine Energy (Canada)
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
VEC(s)	Valuable Ecosystem Component(s)

Introduction

This report outlines monitoring activities occurring at the Fundy Ocean Research Center for Energy test site in the Minas Passage, Bay of Fundy for 2019. Specifically, this report highlights results of environmental monitoring activities conducted in the mid-field and near-field zones and other research and development activities conducted at the FORCE site. This report also provides a summary of international research activities around tidal stream energy devices.

About FORCE

FORCE was created in 2009 to lead research, demonstration, and testing for high flow, industrial-scale tidal stream energy devices. FORCE is a not-for-profit entity 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 stream 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.

The FORCE project currently consists of five undersea berths for subsea turbine generators, four subsea power cables to connect the turbines to land-based infrastructure, an onshore substation and power lines connected to the Nova Scotia Power transmission system, and a Visitor Centre that is free and open to the public from May to November annually. These onshore facilities are located approximately 10 km west of Parrsboro, Nova Scotia.

The marine portion of the project is located in a 1.6 km x 1.0 km Crown Lease Area in the Minas Passage. It is also identified as a Marine Renewable-electricity Area 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. Current berth holders at FORCE are:

Berth A: Minas Tidal Limited Partnership
Berth B: Sustainable Marine Energy (Canada)[2]
Berth C: Rio Fundo Operations Canada Limited[3]
Berth D: Unassigned (formerly Cape Sharp Tidal Venture)[4]
Berth E: Halagonia Tidal Energy Limited[5]

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

[2] On May 15, 2019 the Department of Energy and Mines issued an approval for Black Rock Tidal Power to change its name to Sustainable Marine Energy (Canada) Ltd. with the transfer of assets from SCHOTTEL to Sustainable Marine Energy. Learn more: sustainablemarine.com/news/schottel

[3] On April 30, 2019 the Department of Energy and Mines approved the transfer of the Project Agreement and FIT approvals from Atlantis Operations (Canada) Ltd. to Rio Fundo Operations Canada Ltd.

[4] On April 1, 2019 the Department of Energy and Mines revoked Cape Sharp Tidal's Marine Renewable Electricity License thereby triggering a default of the company's berth holder status at FORCE.

[5] Berth E does not have a subsea electrical cable provided to it.

Research, monitoring, and associated reporting is central to FORCE's steward role, to assess whether tidal stream energy devices can operate in the Minas Passage without causing significant adverse effects on the environment, electricity rates, and other users of the Bay.

As part of this mandate 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 technologies 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 15, 2009 from the Nova Scotia Minister of Environment. The conditions of its EA approval[6] provide for comprehensive, ongoing, and adaptive environmental management. The EA approval has been amended since it was issued to accommodate changes in technologies and inclusion of more berths to facilitate provincial demonstration goals.

In accordance with this EA approval, FORCE has been conducting an Environmental Effects Monitoring Program 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/document-collection.

Since 2009, more than 100 related research studies have been completed or are underway with funding from FORCE, the Offshore Energy Research Association (OERA) and others. These studies have considered socioeconomics, biological, and other research areas.[7]

Monitoring at the FORCE site is currently focused on lobster, fish, marine mammals, seabirds, and marine sound and is divided into 'near-field' (≤ 100 m from a turbine) and 'mid-field' or 'site-level' (> 100 m from a turbine) monitoring. As approved by regulators, individual berth holders are responsible for leading near-field monitoring in direct vicinity of their turbine(s), in recognition of the unique design and operational requirements of different turbine technologies. 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, which includes representatives from scientific, First Nations, and local fishing communities.[8] 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. EMP's include: environmental management roles and responsibilities and commitments, environmental protection plans, maintenance and inspection requirements, training and education requirements, reporting protocols, and more.

[6] FORCE's Environmental Assessment Registration Document and conditions of approval are found online at: www.fundyforce.ca/document-collection.

[7] 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.

[8] Information about EMAC may be found online at: www.fundyforce.ca/about-us

Turbine Deployments

Since FORCE's establishment 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 flow tidal environments.

On July 22, 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 two days later on July 24. On July 26, 2018, Naval Energies unexpectedly filed a petition with the High Court of Ireland for the liquidation of OpenHydro Group Limited and OpenHydro Technologies Limited.[9] For safety purposes, the turbine was isolated from the power grid on July 26. On September 4, 2018, work began to re-energize the turbine. In the days following, it was confirmed that the turbine's rotor was not turning. It is believed that an internal component failure in the generator caused sufficient damage to the rotor to prevent its operation. 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. 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 1, 2018 and was expected to continue until the removal of the turbine; however, as a result of the insolvency of OpenHydro Technology Ltd., all near-field reporting activities by CSTV ceased as of March 1, 2019. Since that time, FORCE has provided monthly reports to regulators confirming the continued non-operational status of the CSTV turbine. An update prepared by CSTV is included in Appendix I of this report.

Additional turbines are expected to be deployed at the FORCE site in the coming years. In 2018, Sustainable Marine Energy (formerly Black Rock Tidal Power) installed a PLAT-I system in Grand Passage, Nova Scotia under a Demonstration Permit.[10] This permit allows for a demonstration of the 280 kW system to help SME and its partners learn about how the device operates in the marine environment of the Bay of Fundy. Also in 2018, 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.[11] The project consists of 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 including Fisheries and Oceans Canada, the Nova Scotia Department of Environment, and the Nova Scotia Department of Energy and Mines prior to turbine installation.

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

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

[11] 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.

International Experience & Cooperation

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 technologies such as tidal range, tidal current, wave, and 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). Recent research includes assessments of operational sounds on marine fauna (Lossent et al., 2017; Schramm et al. 2017; Polagye et al. 2018; Pine et al. 2019), the utility of PAM sensors for monitoring marine mammal interactions with turbines (Malinka et al., 2018) and collision risk (Joy et al. 2018), and the influence of tidal turbines on fish behavior (Fraser et al. 2018).

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. This includes participation in the Fundy Energy Research Network,[12] the Bay of Fundy Ecosystem Partnership,[13] TC114,[14] and the Atlantic Canadian-based Ocean Supercluster.[15]

Another key group is OES Environmental (formerly Annex IV); a forum to explore the present state of environmental effects monitoring around MRE devices.[16] Last year FORCE worked with OES Environmental members[17] 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. FORCE will continue to work closely with OES Environmental and its members to document and improve the state of knowledge pertaining to MRE devices' interactions with the marine environment.

As part of this effort, Dr. Daniel Hasselman, FORCE's science director, attended a one-day workshop in Edinburgh, Scotland led by OES Environmental and the Offshore Renewables Joint Industry Programme (ORJIP)[18] to discuss collision risks associated with MRE devices. The purpose of the workshop was to overview pre-existing data in an effort to understand the risk profile of fish and marine mammal collision – that is, to determine the relative probability of a

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[12] FERN is a research network designed to" coordinate and foster research collaborations, capacity building and information exchange" (Source: fern.acadiau.ca/about.html). FORCE participates in the Natural Sciences, Engineering, and Socio-Economic Subcommittees of FERN.

[13] BoFEP is a 'virtual institute' interested in the well-being of the Bay of Fundy. To learn more, see www.bofep.org.

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

[15] The OSC was established with a mandate to "better leverage science and technology in Canada's ocean sectors and to build a digitally-powered, knowledge-based ocean economy." Learn more: www.oceansupercluster.ca.

[16] 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.

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

[18] ORJIP has a mandate to bring together industry, regulators, academia, and others to work on key environmental and consenting issues in the offshore wind and ocean energy sectors. To learn more, visit: www.orjip.org.uk.

collision with a turbine and the relative consequence of the collision, should it occur. The workshop included a series of presentations from key groups working to understand turbine-animal interactions and included an overview of various integrated sensor platforms used in monitoring. Break-out groups convened for the afternoon in an effort to develop detailed project plans for strategic research projects relevant to collision risk.

Overall, the risks associated with single device or small array projects are anticipated to be low given the relative size/scale of devices (Copping, 2018). For example, at the FORCE site 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 stream energy devices, however, will not be possible until more are tested over a longer-term period with monitoring that documents local impacts, considers far-field and cumulative effects, and adds to the growing global knowledge base.

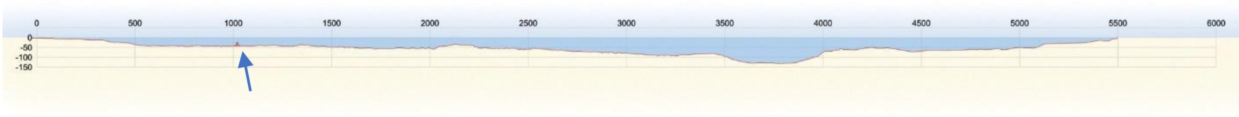

Figure 1: The scale of a single turbine (based on the dimensions of the OpenHydro turbine deployed by CSTV, indicated by the red dot and above the blue arrow) in relation to the cross-sectional area of the Minas Passage. The Passage reaches a width of ~ 5.4 km and a depth of 130 m.

The global understanding of the potential impacts of MRE devices is presently based on a few deployments—often of single devices and increasing numbers of small arrays, notably the MeyGen project in Pentland Firth, Scotland[19] and a project led by Nova Innovation in Bluemull Sound, Scotland.[20] To gain understanding of the environmental monitoring conducted for projects in the United Kingdom and insight into operational limitation of sensors used, staff from FORCE (Dr. Hasselman and two ocean technologists, Tyler Boucher and Ray Pieroway) visited Scotland in early February. FORCE met with staff and graduate students at Marine Scotland Science (MSS), the University of Aberdeen (UoA), and the University of Highlands and Islands-Environmental Research Unit (UHI-ERI). Each group provided overview presentations of monitoring activities and there was discussion about the common challenge of monitoring in high flow environments. While the regulatory environment may differ in the UK versus Canada, it's important to acknowledge that researchers in the UK are still working towards developing monitoring techniques that are suitable for turbine-animal interactions. A major take away from this trip was the difference in access to infrastructure and human resources and how that has influenced monitoring capabilities and the advancement of our understanding of how to monitor environmental effects. Marine Scotland Science has access to two research vessels, the 'Alba na Mara' and the 'Scotia', that can house multiple scientists and stay at sea for extended periods of time for monitoring. Similarly, UoA and UHI-ERI have access to a cadre to graduate students who have each dedicated 4-6 years of effort towards addressing monitoring challenges for the MRE sector. Overcoming the monitoring challenges at FORCE requires a similar level of dedication and access to resources.

Dr. Hasselman attended a workshop entitled 'Retiring Risks of Effects on Marine Animals from Electromagnetic Field (EMF) and Underwater Noise from Marine Energy Devices' hosted by OES Environmental and ORJIP at the recent European Wave and Tidal Energy Conference

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

(EWTEC) in Naples, Italy. The purpose of the workshop was to review the current state of knowledge about EMF and acoustics near MRE devices to determine whether enough information had been accumulated through research projects to retire the risk posed by EMF and MRE generated noise (from a single MRE device) to marine animals. The workshop was well attended by a host of international participants representing academia, industry, government, and NGOs, and included world experts in EMF (Dr. Andrew Gill) and marine acoustics (Dr. Brian Polagye). Break-out sessions were held and included an exercise where participants considered the information available for EMF and acoustics from a regulatory perspective and addressed whether enough data existed to retire the risks for consenting on single MRE devices. Although consenting on individual projects is context-specific, the break-out sessions largely revealed that enough data had been accumulated from EMF and acoustics research around MRE devices to justify retiring these risks for consenting on future single MRE devices.

On May 23, 2019, Dr. Hasselman co-chaired a round-table discussion by a panel of international subject matter experts on the use of active acoustics for monitoring in high flow environments. This panel was hosted at the Center for Ocean Ventures and Entrepreneurship (COVE) and the report is provided herein as Appendix VIII. The panel discussed the challenges presented by turbulence and entrained air that are common in high flow environments to monitoring using active acoustic devices. Specifically, entrained air and sediment in the water column generate a substantial amount of backscatter 'noise' for active acoustic devices, and the primary challenge lies in separating the signal generated by biological targets from the noise in these conditions. The group sought to address whether the challenge is a limitation of current active acoustic technologies that have not been optimized for high flow environments, or if these limits are imposed by the physics of the environment itself. The discussion generated multiple suggestions including increasing the frequency of the active acoustic devices to decrease the volume of backscatter noise or decreasing the frequency to reduce the amount of backscatter from entrained air. Ultimately, the panel reached consensus that while we are not at the limit of technology, commercially available technology might not be particularly well suited for monitoring in high flow environments.

To increase FORCE's international cooperation efforts even further, Dr. Hasselman is also leading a team of international researchers to draft a chapter for the OES Environmental 2020 State of the Science Report entitled 'Environmental Monitoring Technologies and Techniques for Detecting Interactions of Marine Animals with MRE Devices'. The objective of this chapter is to describe the state of the science in environmental monitoring technologies and techniques, with a focus on the i) instrument classes used for monitoring MRE devices, ii) challenges of monitoring around MRE devices, and iii) integrated monitoring platforms that are currently used to monitor MRE devices. To that end, the chapter overviews the state of the science in environmental monitoring and methodologies, and provides information about lessons learned from monitoring activities, and provides recommendations for quality data collection, management and analysis.

Mid-Field Monitoring Activities

FORCE has been leading 'mid-field area' or 'site-level' monitoring for a number of years, focusing on a variety of environmental variables. FORCE's present environmental effects monitoring program, introduced in May 2016, was developed in consultation with SLR Consulting (Canada)[21]. FORCE's EEMP was subsequently strengthened by review and contributions by national and international experts and scientists, DFO, NSE, and FORCE's

[21] This document is available online at: www.fundyforce.ca/document-collection.

EMAC, and has been adjusted based on experience and lessons learned; 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 establishment in 2009.[22]

FORCE's EEMP currently focuses on the impacts of operational turbines on lobster, fish, marine mammals, and seabirds as well as the impact of turbine-produced sound. Overall, these research and monitoring efforts, detailed below, were designed to test the predictions made in the FORCE EA. Since the latest EEMP was initiated in 2016, FORCE has completed approximately:

- 408 hours of hydroacoustic fish surveys;
- more than 4,385 'C-POD' (marine mammal monitoring) days;
- bi-weekly shoreline observations;
- 49 observational seabird surveys;
- four drifting marine sound surveys and additional bottom-mounted instrument sound data collection; and
- 11 days of lobster surveys.

The following pages provide a summary of the mid-field monitoring activities conducted at the FORCE site throughout 2019, 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.

This year represents a pivotal period in the continued adaptation of FORCE's EEMP. If the CSTV turbine is non-operational and its rotor is not spinning, its full range of environmental effects cannot be fully assessed. Further, some monitoring during this time may not contribute to enhancing baseline data as a non-functional turbine could serve as an artificial reef to which some marine animals might be attracted to seek shelter (Langhamer et al., 2009; Wilson and Elliott, 2009; Andersson and Öhman, 2010; Langhammer, 2012), thereby influencing the data collected. Consequently, FORCE used this period of time to continue to evaluate the utility of environmental sensors and protocols for environmental monitoring in high-flow sites. Building on advice from regulators and FORCE's EMAC, FORCE focused its efforts in 2019 on evaluating monitoring instrumentation capabilities, data synthesis and integration activities, and mid-field monitoring (elaborated below), where appropriate.

Monitoring Objectives

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

A comprehensive understanding of turbine-marine life interactions will not be possible until turbine-specific and site-level monitoring efforts are integrated, and additional data is collected

[22] The adaptive management approach is necessary due to the unknowns and difficulties inherent with gathering data in tidal environments such as the Minas Passage and allows for adjustments and constant improvements to be made as knowledge about the system and environmental interactions become known. This approach has been accepted by scientists and regulators.

in relation to operating turbines. Further, multi-year data collection will be required to consider seasonal variability at the FORCE test 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. Further information about near-field monitoring is included in this report and detailed information is provided by CSTV in Appendix I. Appendices and Near-field Monitoring Summary sections will be updated as additional turbines are scheduled for demonstration at the FORCE demonstration site.

At this time, and considering the scale of turbine deployments in the near-term at FORCE, it is unlikely that significant effects in the far-field will be measurable (SLR, 2015). Far-field studies such as sediment dynamics will be deferred until such time they are required. As more devices are scheduled for deployment at the FORCE site and as monitoring techniques are improved, monitoring protocols will be revised in keeping with the adaptive management approach. These studies will be developed in consultation with FORCE's EMAC, regulators, and key stakeholders.

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 a tidal stream energy turbine affects commercial lobster catches
Fish	● to test for indirect effects of tidal stream 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 tidal stream energy turbines ● to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to tidal stream energy turbines

Lobster

In fall 2017, FORCE conducted a baseline lobster catchability survey (NEXUS Coastal Resource Management Ltd., 2017). The survey design consists of the deployment of commercial lobster traps at varying distances from an operating turbine or, as the case was in 2017, the location for a turbine. The catch-and-release survey was completed by NEXUS Coastal Resource Management Ltd. (Halifax, NS) over 11 days in fall 2017. Lobsters were retrieved from traps and measured (carapace length), sex and reproductive stage were determined (male, female, and berried female), and shell condition evaluated.

Overall, the 2017 survey noted high catchability rates (> 2.7 kg/trap)[23] and measured 351 lobsters. Preliminary qualitative analysis by NEXUS indicates that catch rates declined during the survey 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, indicating lower catch rates during higher flows. Further, catch rates did not increase significantly with depth, and qualitative analyses suggested no significant difference in catch rates across separate locations from the proposed turbine deployment location. These initial results may indicate that the impact of turbines may be higher on lobster catchability than anticipated in the EA (AECOM, 2009); however, data collection in the presence of an operational turbine is needed to compare to the 2017 survey dataset and to verify the EA predictions.

FORCE and NEXUS had planned to conduct a second lobster catchability survey in fall 2018 to complete a comparative analysis with the baseline data from 2017. The intent of the comparative study was to determine if the presence of a tidal stream energy turbine affects commercial lobster catches within the Minas Passage. Specifically, this study – with pre-installation and operating turbine data collection periods – was designed to test the EA prediction that tidal stream turbines will have minimal impacts on lobster populations within the FORCE test site (AECOM, 2009). However, this study was contingent on the presence of an operational turbine in order to assess the impacts a turbine might have on lobster in the Minas Passage. Given the non-operational status of the CSTV turbine, the objectives of the 2018 survey effort could not be achieved, and the survey has been postponed until such time that an operational turbine is present at the site.

In 2019, FORCE commissioned TriNav Fisheries Consultants Ltd. to redesign FORCE's lobster monitoring program based on feedback from regulators to include a more statistically robust study design for monitoring lobster at the FORCE test site. TriNav Fisheries Consultants evaluated the efficacy of using a variety of methods including divers and hydroacoustic tags to track lobster movements. However, given the strong tidal flows and brief window available during periods of slack tide, divers are not a viable option due to safety concerns. Ultimately, TriNav Fisheries Consultants identified the combination of a modified catchability survey design and a mark-recapture study using conventional tags as the best approach for monitoring lobster at the FORCE site. The revised lobster monitoring plan is provided in Appendix XI of this report.

Fish

FORCE and its partner the University of Maine (Orono, Maine) have been conducting mobile fish surveys since May 2016 to:

- test for indirect effects of tidal stream energy turbines on water column fish density and fish vertical distribution; and
- 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 tidal stream turbines are unlikely to cause substantial impacts to fishes at the test site (AECOM, 2009). These surveys are designed to permit a comparison of data collected before a turbine is installed with data collected while a

[23] This is classified as 'high' according to DFO's Catch Per Unit Effort (CPUE) index (Serdynska and Coffen-Smout, 2017).

turbine is operational at the FORCE site as well as in relation to a reference site along the south side of the Minas Passage – the nature of this design is referred to as 'BACI': Before/After, Control/Impact.

The surveys occur over a 24-hour period to include two tidal cycles and day/night periods using a scientific grade echosounder, a Simrad EK80, mounted onto a vessel, the Nova Endeavor (Huntley's Sub-Aqua Construction, Wolfville, NS). This instrument is an active acoustic monitoring device as it uses sonar technology to detect fish by recording reflections of a fish's swim bladder. In January 2019, FORCE staff underwent additional training on the EK80 from Kongsberg Maritime Canada Ltd. (Dartmouth, NS) to learn about the software through an operational review detailing the features and new updates for the EK60, EK80 and WBAT instruments. The training highlighted ways to optimize data collection and options available for real-time trouble shooting. Throughout the course attendees presented their user experience to Kongsberg staff as well. These lessons will be an asset for future fish surveys to know the limits of the equipment and to ensure quality data is collected.

Analyses of hydroacoustic fish surveys completed during baseline studies in 2011 and 2012 (Melvin and Cochrane, 2014) and surveys May 2016 – August 2017 (Daroux and Zydlewski, 2017) have observed similar fish densities at the FORCE test site and the reference site, including similar patterns of seasonal change. These analyses also evaluated changes in fish densities in association with diel stage (day/night), tidal stage (ebb/flood), and turbine presence or absence. During the evaluated periods an OpenHydro turbine was present November 2016 – June 2017. Results to-date support the EA prediction that tidal stream devices have minimal impact on marine fishes; however, further data in relation to an operating turbine is required to fully test this prediction. FORCE has completed the processing of all mobile hydroacoustic fish surveys, and is pursuing the analyses of the most recent surveys that will help to contribute to the growing body of knowledge of fish species at the FORCE site.

The University of Maine has recently completed a thorough analysis and report for 15 hydroacoustic fish surveys conducted at FORCE from 2011-2017 (Appendix IV). The hydroacoustic data set included six 'historical' surveys conducted between August 2011 and May 2012, and nine 'contemporary' surveys conducted between May 2016 and August 2017. The report provides an overall approach for understanding the information contained within the hydroacoustic data sets, including data visualization and statistical analyses. Moreover, the University of Maine has provided FORCE with the data scripts/coding and hands-on training required for analysis and data visualization so that deeper explorations of the data may be undertaken to investigate questions that are specific to the needs of FORCE. The analyses included comparisons of fish presence/absence and relative fish density with respect to a series of temporal (historical vs. contemporary, or by survey), spatial (CLA vs. reference study area, or by transect) and environmental (tide phase, diel state, or with and against predicted tidal flow) explanatory variables. The report identified a statistically significant difference in fish presence/absence and relative fish density between the historical and contemporary data sets that may be attributable to differences in the survey design/execution between the time periods or could reflect changes in fish usage of the site. Considering this result, remaining analyses were restricted to the contemporary data sets alone. The authors identified a statistically significant difference in fish presence/absence and relative density between the CLA and the reference site suggesting that the reference site may not be sufficiently representative to serve as a reference for the CLA. Other key findings include: i) data collection during the ebb tide and during the night are both important factors for understanding fish presence in the CLA, ii) a variety of explanatory variables and their additive effects should be explored further, iii) increasing the frequency of surveys within each month (perhaps on consecutive days), particularly during May, may be required to understand patterns and variability of fish presence and density in Minas Passage, and iv) results suggest modifying the survey design to exclude adjacent pairings of transects.

It is important to note, however, that like the lobster survey program, the fish monitoring program requires the presence of an operational turbine at the FORCE site in 2018 for testing its effects. Further, a non-operational turbine may bias baseline data collection as the turbine may serve as a Fish Aggregation Device (i.e., a 'FAD') (Wilhelmsson et al. 2006). FORCE was planning to conduct fish surveys during known periods of peak migration in 2019 – notably, in spring to capture migration periods of alewife, Atlantic herring, striped bass, Atlantic sturgeon, American shad, Atlantic mackerel, and rainbow smelt (Baker et al., 2014; Stokesbury et al., 2016) and also in late fall in consideration of outward migration of Atlantic herring, blueback herring, and alewife (Townsend et al., 1989). However, these data collection efforts were contingent on removal of the non-operational CSTV turbine from the FORCE site and suitable weather conditions. Given that the CSTV turbine currently remains at the FORCE site, these surveys were not conducted.

In the interim, FORCE in cooperation with Echoview Software (Tasmania, Australia) and the University of Maine, has been focusing efforts on data processing and analysis of fish survey data as well as in support of a comparative analysis with data collected from a bottom-mounted system (see 'Platform Projects' below). FORCE staff (Research Scientist Jeremy Locke and Ocean Technologists Jessica Douglas and Tyler Boucher) completed the Echoview software training course in Q2 2019 to build the skillset of processing hydroacoustic data within Nova Scotia. This training enables the FORCE team to better complete data collection activities moving forward. FORCE staff completed data processing to enable Echoview staff to conduct data analysis and reporting of the comparative hydroacoustic project discussed later in this report.

Marine Mammals

In 2019, FORCE continues to conduct two main activities aimed at testing the EA prediction that project activities are not likely to cause significant adverse residual effects on marine mammals within the FORCE test site (AECOM, 2009). These activities have been ongoing on a regular basis since 2016. Specifically, FORCE in continuing to:

- conduct passive acoustic monitoring (PAM) using 'click recorders' known as C-PODs; and
- implement an observation program that includes shoreline, stationary, and vessel-based observations.

Passive Acoustic Monitoring

The first component of FORCE's marine mammal monitoring program involves the use of PAM mammal detectors known as C-PODs, which record the vocalizations of toothed whales, porpoises, and dolphins.[24] The program focuses mainly on harbour porpoise – the key marine mammal species in the Minas Passage that is known to have a small population that inhabits the inner Bay of Fundy (Gaskin, 1992). The goal of this program is to understand if there is a change in marine mammal presence in proximity to a deployed tidal stream energy device and builds upon baseline C-POD data collection within the Minas Passage since 2011.

[24] The C-PODs, purchased from Chelonia Limited, are designed to passively detect marine mammal 'clicks' from toothed whales, dolphins, and porpoises.

From 2011 to early 2018, more than 4,695 'C-POD days'[25] of data were collected in the Minas Passage. Over the study period, it was found that harbour porpoise use and movement varies over long (i.e., seasonal peaks and lunar cycles) and short (i.e., nocturnal preference and tide stage) timescales. This analysis, completed by Sea Mammal Research Unit (Canada) (Vancouver, BC), showed some evidence to suggest marine mammal exclusion within the near-field of CSTV turbine when it was operational (November 2016 – June 2017) (Joy et al., 2018). This analysis showed that the C-PODs in closest proximity to the turbine (230 m and 210 m distance) had shown decreases in detections whereas there is no evidence of mid-field avoidance with a turbine present and operating. The latest findings also showed a decrease in detections during turbine installation activities which is consistent with previous findings (Joy et al., 2017), but will require additional data collected in relation to an operating turbine to allow for a full assessment of the EA predictions.

The C-PODs were initially deployed on December 6, 2018 and recovered on March 29, 2019. Following inspection and data-recovery, maintenance activities included replacement of CPOD batteries, replacement of acoustic release batteries, refurbishment of one SUBS package, and the fabrication and installment of mounts for the MetOcean Telematics (Dartmouth, NS) beacons. The C-PODs were subsequently re-deployed on May 3, 2019. The delay for the re-deployment was caused by the amount of maintenance required during that period as well as the vessel availability for the operation. The vessels normally used for this operation were both away on location for other jobs. It took a special weather window for a vessel to return to the area, and also have time for the deployment. This summer, the C-PODs were recovered on August 14th to download data and were re-deployed during the same day to continue collection of baseline data. They were subsequently recovered on December 13th and are currently undergoing refurbishment so they can be deployed again in early January 2020.

In 2019, FORCE received an F-POD from Chelonia Limited (makers of the C-PODs; Cornwall, UK), and deployed it at the FORCE site. This instrument was included in FORCE's comparative PAM study outlined in its 2019 EEMP plan. This study aims to understand the relative performance of multiple PAM devices (i.e., C-POD, F-POD, SoundTrap, icListenHF, and AMAR) across the range of tidal flows experienced at the FORCE site. The first phase (i.e., Aquatron testing; Figure 1) was completed and confirmed that each device could detect synthetic click trains emitted by an icTalk used to mimic harbour porpoise vocalizations. FORCE subsequently deployed the devices on a FAST platform at the FORCE site to complete the field trial component of this study (Figure 2, 3). The field trials included playing the synthetic click trains with the icTalk while passively drifting over the FAST platform over the course of a full tidal cycle, followed by a week of data collection for harbour porpoise transiting the FORCE site. The platform was recovered on September 13th, and the data was downloaded from the instruments and sent to Sea Mammal Research Unit (Canada) for analyses. FORCE expects to receive a report on the relative performance of each PAM device in early 2020.

Harbor porpoise (Phocoena phocoena) monitoring at the FORCE Test Site, Canada featured on Tethys (by FORCE and SMRU): https://tethys.pnnl.gov/tethys-stories/harbor-porpoise-phocoena-phocoena-monitoring-force-test-site-canada

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

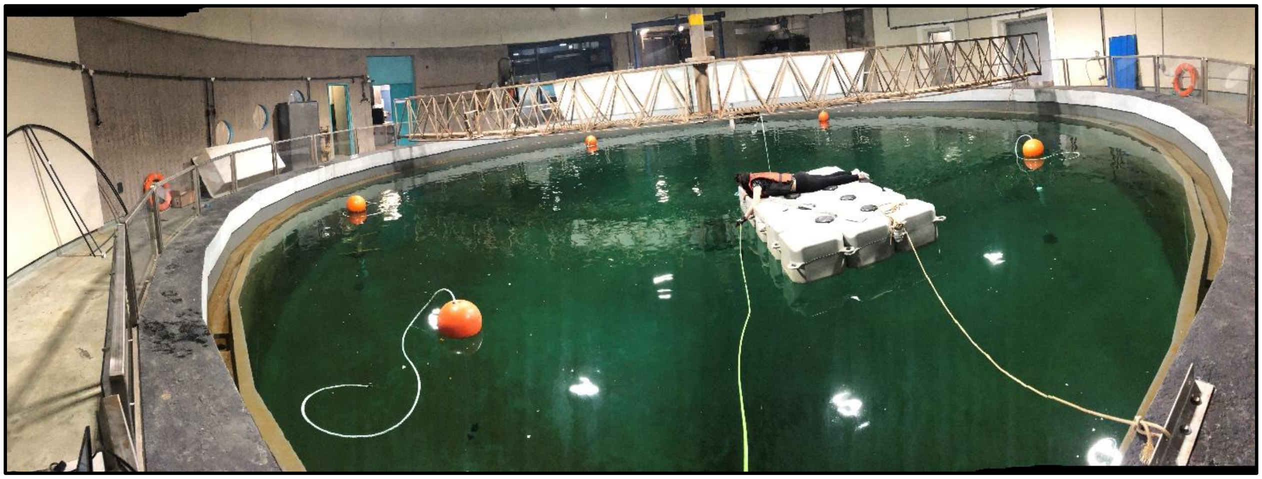

Figure 1: One of FORCE's Ocean Technologists assists with testing PAM devices in the Aquatron pool-tank facility at Dalhousie University.

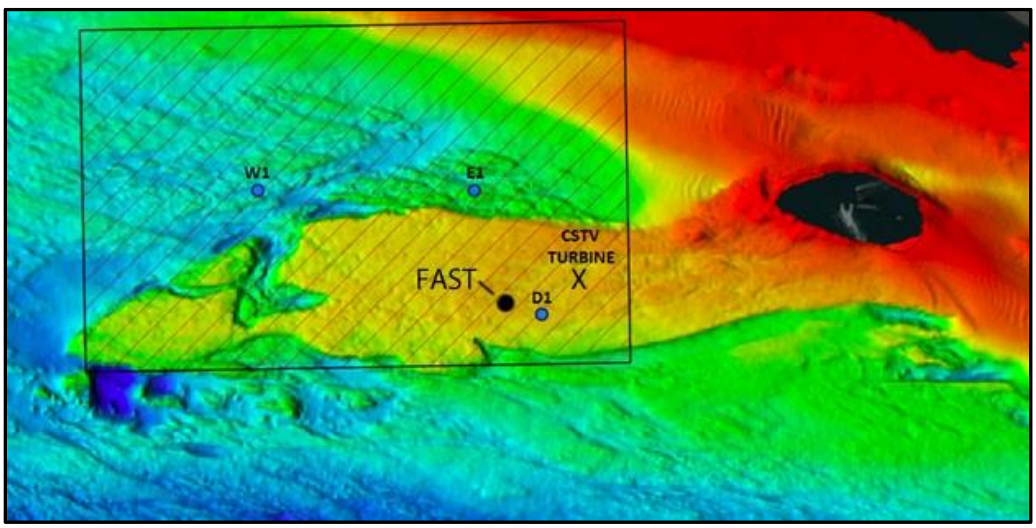

Figure 1: Map of FORCE test site showing approximate locations for C-PODs deployed on SUBS packages (W1, E1, D1), and the planned location for deployment of the FAST platform mounted with PAM devices (•). The location of the Cape Sharp Tidal Venture Turbine is indicated by an 'X'.

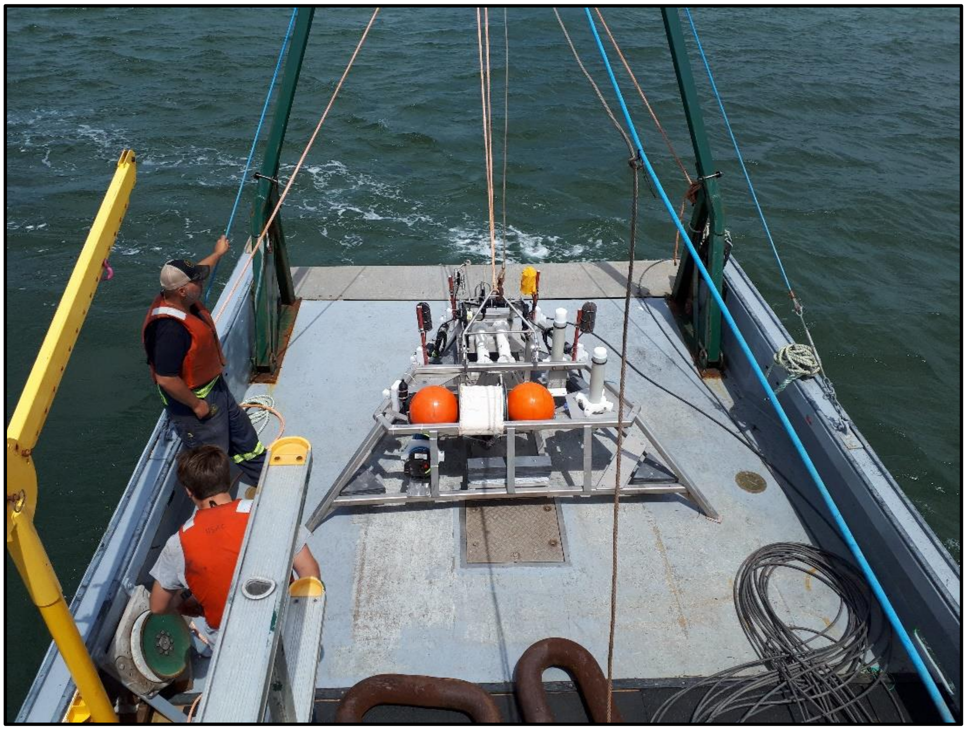

Figure 2: Five PAM devices were mounted on the FAST platform for the comparative PAM study. Photograph depicts the platform on the deck of the Nova Endeavour prior to deployment at the FORCE site.

Observation Program

FORCE's marine mammal observation program in 2019 includes observations made during bi-weekly shoreline surveys, 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.

FORCE will also continue to explore the utility of using an Unmanned Aerial Vehicle (UAV) for collecting observational data along the shoreline and over the FORCE site using transects by programming GPS waypoints in the UAV to standardize the flight paths. In recent months a number of FORCE staff including *Science Director* Dan Hasselman, *Facility Manager* Sandra Currie, and Ocean Technologists Ray Pieroway, Tyler Boucher, Jessica Douglas, and Megan Elliott received training to operate FORCE's UAV. Recent changes to Transport Canada's regulations for Remotely Piloted Aircraft Systems (RPAS) necessitated FORCE staff acquiring UAV pilot certification by successfully passing the 2019 Canadian Drone Pilot Basic Operations Examination. Several trained staff have now acquired this certification and are licensed to safely operate the UAV at the FORCE site. To assess the relative utility of a UAV-based versus walking-based observational survey, FORCE recently developed and conducted a preliminary study using a series of objects randomly distributed along the FORCE beach. This assessment revealed that the UAV performed as well as a walking-based observational survey, but requires less time and human resource to achieve. FORCE also hosts a public reporting tool that allows members of the public to report observations of marine life: mmo.fundyforce.ca

Marine Sound (Acoustics)

Marine sound – often referred to as 'acoustics' or 'noise' – monitoring efforts are designed to characterize the soundscape of the FORCE test site. Data collected from these monitoring efforts will be used to test the EA predictions that operational sounds produced from operating tidal stream turbines are unlikely to cause mortality, physical injury or hearing impairment to marine animals (AECOM, 2009).

FORCE convened a working group of experts in passive acoustic monitoring (PAM) data collection and analyses from local academic institutions, industry partners, and other stakeholders in late 2018. The purpose of the workshop was to discuss the challenges and operational limitations inherent with using PAM technologies for marine mammal and sound monitoring in high-flow environments like the FORCE test site and to identify potential solutions to improve environmental effects monitoring capabilities for operational tidal stream energy turbines in the future. The workshop sought to address questions from regulators regarding the integration or corroboration of results from multiple PAM technologies deployed in and around the FORCE test site. The workshop also explored potential future projects to support further environmental monitoring using PAM technologies with the end goal of lending confidence to environmental effects monitoring technologies and approaches used in support of tidal energy devices. A copy of the workshop report, including outcomes and identified next steps is provided in Appendix II.

Building on this workshop, FORCE commissioned JASCO Applied Sciences (Canada) Ltd. to conduct a comparative integrated analysis of acoustic data sets collected by various hydrophones (i.e., underwater sound recorders) mounted on and deployed autonomously around the CSTV turbine at the FORCE site (see Appendix IX). This integrated comparative analysis examined near-field sound data collected by hydrophones) located:

- on the CSTV turbine, collecting data since September 4, 2018 (three icListen hydrophones);
- two icListen hydrophones mounted on a Fundy Advanced Sensor Technology (FAST) platform deployed approximately 35 m from the turbine from September 5 – 21, 2018;
- an AMAR (Autonomous Multichannel Acoustic Recorder) deployed approximately 100 m from the turbine from June 29 – November 19, 2018.

In addition, an acoustic Doppler current profiler mounted on the CSTV turbine has collected current data since September 4, 2018. Analyses of the acoustic data revealed that flow noise increased with the height of the hydrophone off the seabed and impacted the hydrophone mounted on the top of the CSTV turbine the most. The least affected hydrophones were those mounted at the 'aft' position on the CSTV turbine and the autonomously deployed AMAR. In fact, flow noise at these locations was low enough to successfully measure the sound from the turbine during the brief period prior to the malfunction of the turbine's rotor in August 2018. Indeed, when the turbine was present (and presumably free spinning prior to this malfunction), the sound levels increased in the 30-1000 Hz band. Details are contained in the report provided as Appendix IX. This comparative analysis provides valuable information about future marine sound monitoring technologies and protocols while building on previous acoustics analysis at the FORCE site.

Results from previous acoustic analyses completed at the FORCE site indicate that the turbine is audible to marine life at varying distances from the turbine, but only exceeded the threshold for behavioural disturbance at very short ranges and during particular tide conditions (Martin et al., 2018). This is consistent with findings at the Paimpol-Bréhat site in France where an

OpenHydro turbine was also deployed – data suggests that physiological trauma associated with a tidal turbine is improbable, but that behavioural disturbance may occur within 400 m of a turbine for marine mammals and at closer distances for some fish species (Lossent et al., 2017).

Seabirds

FORCE's seabird monitoring program is designed to test the EA prediction that project activities are not likely to cause adverse residual effects on marine birds within the FORCE test area (AECOM, 2009). Over the last several years, FORCE and Envirosphere Consultants Ltd. (Windsor, NS) have collected observational data from the deck of the FORCE Visitor Centre, documenting bird species presence, behaviour, and seasonality throughout the FORCE site (Envirosphere Consultants, 2009, 2017; Stewart and Lavender, 2010; Stewart et al., 2011, 2012, 2013; Stewart et al., 2018). Overall, these surveys have documented the distribution, abundance, and seasonality of water-associated birds in the Minas Passage, but there has been limited opportunity to determine potential effects and test the EA predictions given the short time period with an operational turbine present at the FORCE site.

The non-operational turbine currently deployed at the FORCE site has the potential to serve as a FAD (Wilhelmsson et al., 2006). This could have potential cascading ecological effects for predatory diving seabirds (Wilson and Elliott, 2009; Boehlert and Gill, 2010), and therefore, have indirect consequences for seabird monitoring. Diving seabirds may be drawn to the FORCE site if the abundance of prey species increases as a consequence of the non-operational CSTV turbine (Wilhelmsson et al. 2006; Andersson and Öhman 2010; Boehlert and Gill 2010). Observational surveys under these circumstances contribute neither to effects testing nor to enhancing the seabird baseline. Consequently, FORCE did not conduct observational seabird surveys in 2019, but instead pursued a synthesis of existing baseline data and explored the potential for integration with radar-based monitoring to improve monitoring protocols for the future (see below).

FORCE has begun a collaboration with Envirosphere and Dr. Phil Taylor at Acadia University (Wolfville, NS) to synthesize previous observation-based seabird baseline datasets (2017-2018) and to integrate this information with data from radar-based monitoring (Walker and Taylor, 2018). Radar based monitoring, based on an X-band radar located at the FORCE Visitor Centre has typically been used for flow characterization, but can be used to monitor bird movements throughout and around the FORCE test site. Similar to the observational studies, radar analysis shows a clear seasonal pattern of activity with very few birds present in the winter and peaks during spring and fall migrations (Walker and Taylor, 2018; Appendix III).

This integrated work will help to quantify the risk for seabirds in relation to operating tidal energy turbines at the FORCE site. This work will examine the potential of statistical models to improve the precision and certainty in detecting impacts to seabirds. This work will advance the ability to describe seabird abundance, species composition, spatial and temporal distribution, and seasonality.

Near-field Monitoring Activities

While FORCE completes site-level or 'mid-field' monitoring activities at the FORCE site, near-field monitoring is led 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.

In September 2018, it was confirmed that that CSTV turbine rotor was not spinning. Since that time, CSTV had been providing written confirmation to regulators on a monthly basis that the turbine is not operational by monitoring its status during the peak tidal flow of each month. However, as a result of the insolvency of OpenHydro Technology Ltd., all reporting activities by CSTV ceased as of March 1, 2019. Data collection from the turbine-mounted ADCPs to confirm the turbine is no longer spinning is being managed and reported by FORCE to regulators on a monthly basis. Data is also still being collected from two of the four hydrophones on the CSTV turbine. An update prepared by CSTV is included in Appendix I of this report.

Throughout 2018 and 2019, FORCE has been taking steps to enhance its near-field monitoring capabilities. In 2018, FORCE deployed multiple Fundy Advanced Sensor Technology (FAST) platforms in proximity to the Cape Sharp Tidal turbine (within 15m – 35m from the turbine) containing hydrophones and ADCPs to measure turbine-produced sound and flow impacts of the turbine respectively. These measurements are being used to inform marine acoustics and also to better understand flow dynamics at the FORCE test site.

FORCE staff (Science Director Dan Hasselman and Ocean Technologists Ray Pieroway and Tyler Boucher) also underwent training in 2019 about the use of a near-field monitoring instrument, the Gemini 720is imaging sonar. This training was led by the manufacturer of the Gemini, Tritech International Ltd. (Aberdeen, Scotland) and included an overview of the instrument's capabilities and limitations, best practices for use, and setting optimization for in-situ data recording. The training also incorporated the specialized software used to track marine life targets in the water column. This training will serve to be beneficial for use and testing of the Gemini at the FORCE test site.

As additional near-field, device-specific environmental effects monitoring programs are required and implemented for deployed tidal stream devices, berth holder updates will be included as appendices to this report.

Other FORCE Research Activities

The Pathway Program

The Pathway Program is a collaborative effort between FORCE and OERA to identify an effective and regulator approved monitoring solution for the tidal energy industry in Nova Scotia. The Pathway Program involves several phases, including i) Global capability Assessment, ii) Advancing Data Processing and Analytics, and iii) Technology Validation. The first phase of this program, a Global Capability Assessment, involves a comprehensive literature review about the use of different classes of environmental monitoring technologies (i.e., PAM, imaging sonars, echosounders) for monitoring tidal energy devices around the world. Subject matter experts were commissioned to provide reports on these instrument classes, and FORCE has now received final reports for each of these.

Dr. David Barclay (Oceanography Department, Dalhousie University) authored a report that provides an overview of PAM technologies, methodologies, and data processing techniques used to make passive acoustic measurements in tidal channels, with a focus on the tools and techniques used for marine mammal monitoring around tidal energy devices (Appendix V). Despite a growing body of underwater acoustics research related to assessing the environmental effects of tidal power development, there are no commercially available, purpose-built acoustic monitoring systems that have been designed specifically for operation in turbulent tidal channels. Nonetheless, experimental deployments of various PAM technologies have been attempted in high-flow conditions for marine mammal monitoring, with varying success. Dr. Barclay's review suggests that the ideal PAM system for marine mammal monitoring in high flow environments has the highest sensitivity, best mitigation of flow noise, and records the entire pressure time series. This would include technologies like the SoundTrap, icListenHF, and AMAR-G4 series of hydrophones.

Dr. James Joslin (Applied Physics Laboratory, University of Washington) authored a report on the use of imaging (multibeam) sonars for monitoring fish and marine mammals around tidal energy devices (Appendix VI). While there are currently more than a dozen commercially available imaging sonars that have been developed for use in high energy marine environments (each differing in functional range, resolution, field of view, and mechanical configuration), the typical application is for underwater vehicle navigation and situational awareness. Further, not all imaging sonars have been designed for long term deployments without regular maintenance, and most use do not require the sonar control software to be integrated on a multi-instrument platform with other active acoustics. Thus, many of the commercially available imaging sonars are not well suited for monitoring tidal energy devices and the best options are those that have been demonstrated on previous projects. This report demonstrates how imaging sonars have been used successfully on both bottom and surface mounted platforms to monitor fish, marine mammals and seabirds. Further, target classification from imaging sonars is best achieved by pairing the instrument with optical cameras or echosounders. Dr. Joslin's report recommends that the best imaging sonars for fish and marine mammal monitoring at the FORCE site are the Tritech Gemini 720is and the Teledyne Blueview M900/2250.

Dr. John Horne (School of Aquatic and Fishery Sciences, University of Washington) provided a report on the features and performance of scientific echosounders for monitoring fish around tidal energy devices (Appendix VII). The report highlights the challenges of using active acoustic devices in high flow environments due to the presence of turbulence and entrained air and identifies the need to maximize the signal to noise ratio for using echosounders effectively. The report provides the required background, necessary context and relevant information to understand acoustic theory and how it relates to the challenge of monitoring fish in high flow environments using acoustic technology and contains a suite of manufacturer instrument specification sheets that some readers may find valuable. The report also makes recommendations about which scientific echosounders are most suitable for monitoring in high flow environments based on whether they i) can be calibrated, ii) have been vetted by the international scientific community, and iii) provide digital output. Based on these criteria, the report recommends using the Kongsberg-Simrad EK80 line of scientific echosounders. This includes instruments like the EK80, WBAT, WBT Mini, and WBT Tube; instruments that FORCE has been using for years in its fish monitoring efforts.

Fundy Advanced Sensor Technology (FAST) Activities

FORCE's Fundy Advanced Sensor Technology Program 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 station, video cameras, an X-band radar system, and tide gauge. Offshore assets include modular subsea platforms for both autonomous and cabled data collection and a suite of instrumentation for a variety of research purposes. Real-time data collected through FAST assets is broadcasted live on the Ocean Networks Canada's (ONC; Victoria, BC) website.[26]

The FORCE tide gauge began experiencing issues with data collection on April 9, 2019. The instrument was recovered for inspection, and it was determined that there was a leak in the data/power cable. The cable was replaced, re-terminated, and tested before re-deployment on June 6, 2019 (Figure 4).

Figure 3: One of FORCE's Ocean Technicians prepares the tide gauge for deployment.

Platform Projects

The first and largest of the FAST platforms houses an instrument called 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 smaller platform called FAST-3 has been used for the last two years to monitor fish densities in the mid-field of the turbine. Data collection activities for this project was completed in 2018 and FORCE and its partners, including Echoview Software, have conducted data processing and analysis in 2019. This project will integrate the data collected from the FAST-3 platform with data collected from a vessel-mounted hydroacoustic echosounder used as part of the mid-field fish monitoring activities previously referenced, to evaluate the temporal and spatial representativeness of each method and determine the degree to which results are corroborative (depicted in Figure 5). This project is funded by Natural Resources Canada (NRCan), the NSDEM, and the OERA, and the final report is expected in early 2020.

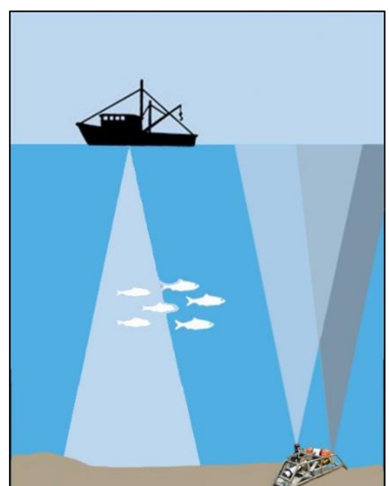

Figure 5: A representation of the data collection methods of the FORCE mid-field fish EEMP and the FAST-3 platform.

Marine Operations

FORCE has partnered with Operational Excellence Consulting Inc. (Halifax, NS) to document lessons learned from various marine

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

operations over the last few years. The report, *Lessons Learned: Marine Operations in the Minas Passage* (2019), documents operational constraints, information to address commonly-encountered situations, and learnings to-date in an effort to help support and de-risk future projects at the FORCE test site. This work was funded by the OERA.

FORCE and Operational Excellence webinar presentation: 'FORCE Site Marine Operations Lessoned Learned' (March 21st, 2019): http://www.oera.ca/oera-webinar-series-andrew-lowery-fundy-ocean-research-center-for-energy-force-jason-clarkson-operational-excellence-consulting/

Fish Tracking

To enhance fish monitoring and to expand its data collection capacity, FORCE partnered with the Ocean Tracking Network (OTN)[27] and attached one VEMCO[28] fish tag receiver (a VR2 receiver) to each C-POD mooring/SUBS (Streamlined Underwater Buoyancy System) package (see 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 efforts that do 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., Dussureault, J., 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);
- Shubenacadie River Monitoring Project: Tomcod (Marshall, J., Fleming, C., Hunt, A., and Beland, J., 2017);
- MA Marine Fisheries Shark Research Program (Skomal, G.B., Chisholm, J., 2009);
- UNB Atlantic Sturgeon and Striped Bass tracking (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

Starting 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

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

[28] 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.

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, NRCan, NSDEM, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).[29]

Wetlands Monitoring

In addition to marine monitoring, FORCE recently completed onshore terrestrial monitoring in 2019. This work was done to verify impact predictions made in relation to its work in the marsh wetlands along Black Rock Beach to install four electrical cables and a data cable.

This monitoring work has been ongoing since the installation of the cables in 2014. Completed by Envirosphere Consultants, this included botanical surveys by biologists in the disturbed area, repeating baseline work done in 2014 and monitoring work completed in 2015, 2016 and in 2019. This monitoring work has shown the wetland is well-vegetated, has a healthy plant community (as determined by dominant species present), and has recovered from the trenching operations associated with the cable installation. A report on the status of the recovery of the wetland was received fall 2019 and is included here as Appendix X.

[29] 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/

Discussion

The year 2019 represented a strategic opportunity for FORCE and its partners to learn from previous experiences, incorporate regulatory advice, and to re-evaluate approaches to research and monitoring in the high flows of the Minas Passage.

Given the present status of the CSTV turbine, monitoring efforts were curtailed to avoid biasing valuable baseline datasets. 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 while also potentially acting as an artificial reef, and thereby biasing any attempts at capturing baseline data. At this time, FORCE is not aware of any timelines for turbine removal but will continue to monitor its non-operational status and use, where applicable, its sensors in a way to advance monitoring capabilities.

In 2019, FORCE and its partners delivered a number of efforts that will improve monitoring capabilities – this will occur through continued learning from the experiences of local and international partners, local capacity and skills development, testing new sensor capabilities (i.e., integration of radar for seabird monitoring or testing new PAM devices like the F-POD), and integrating results from various instruments. Reports and updates routinely underwent review by FORCE's EMAC and regulators, along with continued results from FORCE's ongoing monitoring efforts. These efforts provided an opportunity for adaptive management and further developed and refined the scientific approaches, tools, and techniques necessary in the near- and mid-field study areas to effectively monitor tidal stream energy devices in high-flow environments.

Ongoing monitoring efforts will continue to build on the present body of knowledge of marine life-turbine interactions. While it is still early to draw conclusions, initial findings internationally and at the FORCE test site have documented some disturbance of marine mammals primarily during marine operations associated with turbine installation/removal activities, but otherwise have not observed significant effects.

FORCE will continue to conduct environmental research and monitoring to increase our understanding of the natural conditions within the Minas Passage and, when the next turbine(s) are deployed and operating, test the EA prediction that tidal energy 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. FORCE will continue to report on progress and release results and lessons learned in keeping with its mandate to inform decisions regarding future tidal energy projects.

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