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Environmental Effects Monitoring Program

Quarterly Report: July-September 2020

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Executive Summary

Tidal stream energy devices are an emerging renewable energy technology that use the ebb and flow of the tides to generate electricity. These devices are in various stages of research, development, operation and testing in 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 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 physical, biological, socioeconomic 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 project developers (≤100 metres from a turbine) at the FORCE site. 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 4,933'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

Sea Mammal Research Unit (SMRU) Consulting Ltd. provided their 3rd year report of harbour porpoise monitoring at the FORCE test site using C-PODs. The report describes the results of C-POD deployments #7-10 (May 2018 – August 2019), and places the results in the broader context of the overall marine mammal monitoring program implemented as part of FORCE's multiyear Environmental Effects Monitoring Program (EEMP). This ongoing monitoring program continues to show the prevalence of harbour porpoise at FORCE, with the species being detected on 98.8% of the 1,778 calendar days since monitoring with C-PODs commenced in 2011. Harbour porpoise detections at FORCE varies seasonally, with peak activity occurring during May – August, and lowest detections during December – March. Harbour porpoise detections also vary spatially, with C-PODs deployed at locations W2 and S2 recording the greatest detection rates, and D1 values typically low. Mean lost time across C-PODs, due to ambient flow noise saturating the detection buffer on the C-POD, averaged 22.6%. Interestingly, an analysis against past datasets that controlled for time of year, indicated that the effects of a non-operational turbine structure (see below) had no detectable effect on the rate of harbour porpoise detection. The report by SMRU is included here as Appendix I. An interim report provided by SMRU covering C-POD deployment #11 (August 2019 – January 2020) provided summary data and revealed that harbour porpoise were detected on a least one C-POD every day, with a median of 11 minutes of porpoise detection per day. The mean percent lost time due to ambient flow and sediment noise (19.5%) was comparable to previous deployments. The interim report is provided here as Appendix VI, and supports the findings of previous monitoring activities that harbour porpoise are prevalent at the FORCE test site. The report suggests that a sufficient amount of baseline data has been collected to meet the goals of the EEMP.

FORCE commissioned Envirosphere Consultants Ltd. and Dr. Phil Taylor (Acadia University) to synthesize the results of its observational seabird surveys at the FORCE test site, and to evaluate advanced statistical techniques for analysing seabird count data in relation to environmental predictor variables. The data were examined using Generalized Additive Models (GAMs) to characterize seabird abundance and to better understand the potential impacts of tidal turbines on seabirds at the FORCE test site. The results of the analysis revealed that overall model fit is suitable to characterize count data for some species, and that there are clear patterns of effects of time of year, wind speed and direction, tide height and time of day on the number of seabirds observed. This work contributes to the development of appropriate analytical methods for assessing the impacts of tidal power development in the Minas Passage on seabird populations and supports the continued responsible development of tidal energy at FORCE. The report by Envirosphere Consultants Ltd. is included here as Appendix II and includes the code (R script) used in the analysis of the seabird count data.

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. Phase I of the program consists of a ‘Global Capability Assessment’ that involved comprehensive literature reviews about the use of different classes of environmental monitoring technologies for monitoring tidal energy devices around the world. While this element of Phase I was completed in 2019, ongoing international engagement and knowledge exchange is fostered through a series of workshops. To that end, a workshop focused on data automation and data management was held in Halifax on March 4, 2020, and a virtual workshop focused on the application of passive acoustic monitoring (PAM) approaches for monitoring echolocating marine mammals in high tidal flows was held online on April 30, 2020. The report generated from the PAM workshop is provided here as Appendix IV. Additional workshops are planned for later this year. Phase II, ‘Advancing Data Processing and Analysis’, is well underway, and work with DeepSense (Dalhousie University) to automate the post-processing of hydroacoustic fish survey data is nearing completion. Automation of PAM data has commenced, and researchers at Oregon State University are in the process of developing better harbour porpoise click detector and classification algorithms for application to Minas Passage. Additionally, the Pathway Program team is currently exploring opportunities to automate the detection, tracking and classification of targets from multibeam imaging sonars with partners in Washington state. Phase III, ‘Technology Validation’, is well underway 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. FORCE recently completed a study that compared the efficacy of different PAM devices for monitoring harbour porpoise in the Minas Passage and the final report is included here as Appendix V.

FORCE is also working with academic and First Nations partners to advance the Risk Assessment Program (RAP) for tidal stream energy. This program seeks to develop credible and statistically robust encounter rate models for migratory and resident fish species in Minas Passage with tidal turbines. This will be accomplished by combining physical oceanographic data related to flow and turbulence in the Minas Passage with hydroacoustic tagging information for various fish species in the region curated by the Ocean Tracking Network at Dalhousie University. Ultimately, this will contribute towards understanding the risk of instream tidal power development for fishes in the Bay of Fundy and will assist in the development of future environmental effects monitoring programs.

This report provides a summary of monitoring activities and data analysis completed at the FORCE site up to the end of the third quarter of 2020. 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. Although some FORCE staff continued to work from home during this period to reduce the risk of COVID-19 transmission, marine operations commenced in July following guidelines with respect to social distancing and the use of face masks that were developed in consultation with information provided by NS public health. This includes work in support of the Pathway Program in Grand Passage during August and September, and a series of mobile hydroacoustic fish surveys scheduled for fall 2020 that commenced in late September.

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 up to the end of the third quarter of 2020. Specifically, this report highlights results of environmental monitoring activities conducted in the mid-field zone 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: Big Moon Power Canada[4]
Berth E: Halagonia Tidal Energy Limited[5]

[1] Further information about each company may be found at: 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] Pending final approval
[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 (EMAC), 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.

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[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 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 that same day. On September 4, 2018, work began to re-energize the turbine, but soon afterwards 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. FORCE subsequently provided monthly reports to regulators confirming the continued non-operational status of the CSTV turbine from March 2019 – May 2020, and received authorization from the Nova Scotia Department of Environment on June 2, 2020 to conclude these monthly reports.

In September 2020, Big Moon Canada Corporation (Big Moon) was announced as the successful applicant to fill berth D at the FORCE test site following a procurement procedure administered by Power Advisory LLC. As part of the agreement, Big Moon has provided a $4.5 million security deposit to remove the non-operational CSTV turbine currently deployed at berth D, and has until December 31, 2024 to raise the turbine. The project start date for BigMoon is largely dependent on the economic recovery from the COVID-19 pandemic and the potential impact Big Moon's supply chain. As such, the project start date is not known at this time.

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

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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.

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.

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.

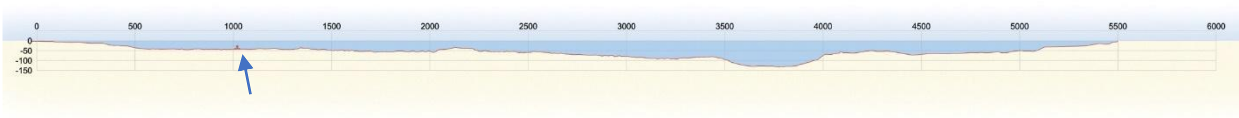

Figure 1: The scale of a single turbine (based on the dimensions of the OpenHydro turbine deployed by CSTV, indicated by the red dot and above the blue arrow) in relation to the cross-sectional area of the Minas Passage. The Passage reaches a width of ~ 5.4 km and a depth of 130 m.

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. 2018a), 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

[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.

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; a forum to explore the present state of environmental effects monitoring around MRE devices.[16] OES-Environmental released a landmark publication on June 8, 2020: '*The 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World'*[17]; an update from its 2016 State of the Science Report. FORCE played a significant role in the development of this publication; Dr. Daniel Hasselman, FORCE's science director, lead a team of 15 international researchers to write a chapter entitled "*Environmental Monitoring Technologies and Techniques for Detecting Interactions of Marine Animals with MRE Devices*"[18]. The objective of this chapter is to describe the state of the science in environmental monitoring technologies and techniques for MRE devices, with a focus on i) different instrument classes used for monitoring, ii) challenges of monitoring in highly dynamic marine environments, and iii) integrated monitoring platforms that are currently used for monitoring. To that end, the chapter overviews the state of the science in environmental monitoring and methodologies, provides information about lessons learned from monitoring activities, and conveys recommendations for quality data collection, management and analysis. The chapter was presented by Dr. Hasselman as a webinar on June 22, 2020 and is available online[19].

On August 18th, Dr. Hasselman participated in an international virtual workshop and interactive session for MRE environmental monitoring experts hosted by OES-Environmental on habitat change. The purpose of the workshop was to examine pathways for determining data needs, monitoring requirements, and possible mitigation measures for working towards 'risk retirement' of changes in habitat for permitting small MRE installations (1-2 devices). OES-Environmental presented the evidence base for habitat change effects due to MRE deployments followed by case studies from Oregon and the UK, and discussed the ability to retire the risk of habitat changes caused by MRE devices in project permitting processes. Experts agreed that information from surrogate industries (e.g., offshore wind, oil & gas) is valuable for understanding and predicting impacts on habitats from small MRE installations, but also identified that habitat change is a complicated risk with many facets that need to be considered before this risk can be retired.

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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] OES Environmental was established by the International Energy Agency (IEA) Ocean Energy Systems (OES) in January 2010 to examine environmental effects of marine renewable energy development. Member nations include: Australia, China, Canada, Denmark, France, India, Ireland, Japan, Norway, Portugal, South Africa, Spain, Sweden, United Kingdom, and United States. Further information is available at https://tethys.pnnl.gov.

[17] Available here: https://tethys.pnnl.gov/publications/state-of-the-science-2020

[18] Available here: https://tethys.pnnl.gov/sites/default/files/publications/2020-State-of-the-Science-Report-Chapter-10-LR.pdf

[19] Available here: https://tethys.pnnl.gov/events/oes-environmental-state-science-2020-collision-risk-environmental-monitoring

Dr. Hasselman also participated in the 1st International Forum on Marine Renewable Energy Environmental Research and Development; held online on April 22, 2020 and jointly sponsored by OES-Environmental and ORJIP. The purpose of the forum was to share the most recent environmental monitoring and research results with a broad audience (i.e., regulators, MRE device and project developers and other researchers). Dr. Hasselman provided a presentation on environmental monitoring using FORCE's FAST platforms that is also available online[20]. FORCE will continue to work closely with OES-Environmental and its members to document and improve the state of knowledge about the interactions of MRE devices interactions with the marine environment.

FORCE also fostered international engagement by co-sponsoring and participating in multiple workshops held alongside the 1st Pan-American Marine Energy Conference in San Jose, Costa Rica (January 26-28, 2020). FORCE general manager, Mr. Tony Wright, co-hosted a workshop entitled 'Test and Research Centers – Fostering International Collaboration' and Dr. Hasselman presented an overview of the FORCE demonstration site. Dr. Hasselman also participated in additional workshops focused on i) environmental effects of MRE devices, and ii) data systems and modelling approaches sponsored by OES-Environmental. These workshops included a series of presentations from key groups at various MRE test centres around the world (i.e., FORCE, EMEC, MERIC, IMARES, CEMIE, DMEC, and various test centres in the United States), and those actively engaged environmental monitoring, marine spatial planning and modelling. Break-out groups convened following presentations to discuss the role of test centres in fostering international collaboration, identifying priority areas for research and knowledge sharing, advancing monitoring capabilities and modelling approaches.

Additional opportunities to foster international collaboration were facilitated through an online workshop sponsored by the Pathway Program (see below) and hosted by EMEC on April 30, 2020. The workshop focused on passive acoustic monitoring for echolocating marine mammals in high tidal flow environments, and brought together over 40 PAM experts from Canada, Denmark, the United Kingdom and the United States. The workshop enabled information sharing between research institutes, industry, regulators and stakeholders about PAM activities being completed in support of the Pathway Program and elsewhere in the world. A report generated from the workshop suggests that recent advances in data collection and processing techniques allow for effective monitoring of harbour porpoise and other marine mammals in highly energetic tidal stream environments. The report also highlights the importance of open dialogue between regulators, the research community and stakeholders to ensure the design of effective, achievable and regulator-approved monitoring programs. The workshop report is included here as Appendix IV.

Information sharing about the use of PAM technologies for monitoring harbour porpoise in Minas Passage was facilitated through a Facebook live session hosted by Ocean Sonics on June 18, 2020. Dr. Hasselman provided an overview of how FORCE is contributing towards the advancement of harbour porpoise monitoring in tidal channels through a variety of monitoring and research projects. The webinar was recorded and is available online[21]. Additional information sharing took place on June 1, 2020, when FORCE's *Environmental Monitoring Lead*, Tyler Boucher, provided an overview on FORCE's Facebook page[22] about how

[20] Available here: https://tethys.pnnl.gov/events/oes-environmental-orjip-international-forum-2-design-application-integrated-monitoring

[21] Available here: https://www.youtube.com/watch?v=8mevioGRLgU

[22] Available here: https://www.facebook.com/fundyforce

multibeam data collected with an imaging sonar (Tritech Gemini 720) is processed prior to 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).[23] FORCE's EEMP was subsequently strengthened by review and contributions by national and international experts and scientists, DFO, NSE, and FORCE's EMAC, and has been adjusted based on experience and lessons learned. This is consistent with the adaptive management approach inherent to FORCE EEMP – the process of monitoring, evaluating and learning, and adapting (AECOM, 2009) that has been used at the FORCE site since its establishment in 2009.[24]

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. As mentioned above in the Executive Summary, since the latest EEMP was initiated in 2016, FORCE has completed approximately:

- 408 hours of hydroacoustic fish surveys;
- more than 4,933'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 up to the end of the third quarter of 2020, including data collection, data analyses performed, initial results, and lessons learned; building on 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 to provide a more complete understanding of turbine-marine life interactions.

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

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

[24] 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. Near-field monitoring summaries will be updated as turbines are scheduled for deployment at FORCE. 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

FORCE conducted a baseline lobster catchability survey in fall 2017 (NEXUS Coastal Resource Management Ltd., 2017). This catch-and-release survey design was conducted over 11 days and consisted of commercial traps deployed at varying distances around the future location of the CSTV turbine deployment planned for 2018. Captured lobsters were measured (carapace length), had their sex and reproductive stage determined (male, female, and berried female), and shell condition evaluated. This baseline survey captured 351 lobsters and reported a high catchability rate (> 2.7 kg/trap).[25] Preliminary qualitative analyses indicated that catch rates

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

declined during the survey and were associated with increasing tidal velocities; a statistically significant negative relationship was detected between catch rates and maximum tidal range. No significant difference in catch rates was detected across separate locations from the proposed turbine location. Cumulatively, these results suggested that the impact of turbines may be higher on lobster catchability than anticipated in the EA (AECOM, 2009), but a repeat of the study in the presence of an operational turbine is required to verify this prediction.

Indeed, a repeat of this catchability survey was planned for fall 2018 in the presence of an operational turbine to test the EA prediction (with pre-installation and operating turbine collection periods) that tidal stream turbines will have minimal have impacts on lobster populations within the FORCE test site (AECOM, 2009). However, 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. Given the operational restrictions generated from the COVID-19 pandemic in 2020, this new study design is intended to be implemented in 2021.

Fish

FORCE has been conducting mobile fish surveys since May 2016 to test the EA prediction that tidal stream turbines are unlikely to cause substantial impacts to fishes at the test site (AECOM, 2009). To that end, the surveys are designed 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.

Moreover, these surveys follow a 'BACI' (Before/After, Control/Impact) design to permit a comparison of data collected before a turbine is installed with data collected while a turbine is operational at the FORCE site, and in relation to a reference site along the south side of the Minas Passage. These 24-hour mobile surveys encompass two tidal cycles and day/night periods using a scientific echosounder, the Simrad EK80, mounted on a vessel, the Nova Endeavor (Huntley's Sub-Aqua Construction, Wolfville, NS). This instrument is an active acoustic monitoring device and uses sonar technology to detect fish by recording reflections of a fish's swim bladder.

Analyses of hydroacoustic fish surveys completed during baseline studies in 2011 and 2012 (Melvin and Cochrane, 2014) and surveys during May 2016 – August 2017 (Daroux and Zydlewski, 2017) evaluated changes in fish densities in association with diel stage (day/night), tidal stage (ebb/flood), and turbine presence or absence (an OpenHydro turbine was present November 2016 – June 2017). Results support the EA prediction that tidal stream devices have minimal impact on marine fishes. However, additional surveys in relation to an operating turbine are required to fully test this prediction.

In 2019, the University of Maine conducted a thorough analysis for 15 fish surveys conducted by FORCE from 2011-2017. 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 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/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. As such, remaining analyses were restricted to the contemporary data sets. The results revealed that: i) data collection during the ebb tide and at night are important for understanding fish presence in the CLA, ii) various explanatory variables and their additive effects should be explored further, and iii) increasing the frequency of surveys during migratory periods (consecutive days in spring/fall) may be required to understand patterns and variability of fish presence and density in Minas Passage. Importantly, the report suggested a statistically significant difference in fish presence/absence and relative density between the CL and reference site, suggesting that the reference site may not be sufficiently representative to serve as a control for the CLA, and for testing the effects of an operational turbine on fish density and distribution in Minas Passage. Additional work is underway using data from eight additional contemporary fish surveys (2017-2018) to determine whether this finding is biologically meaningful, or whether it is simply a statistical artefact of how the data was aggregated in the original analysis.

Marine Mammals

In 2020, FORCE continues to conduct two main activities to test 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.[26] 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

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

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.

From 2011 to early 2018, more than 4,695 'C-POD days'[27] 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., 2018b). This analysis revealed that the C-PODs in closest proximity to the turbine (230 m and 210 m distance) had reduced frequency of detections, but no evidence of mid-field avoidance with a turbine present and operating. The latest findings also revealed a decrease in detections during turbine installation activities; consistent with previous findings (Joy et al., 2017), but requiring additional data during an operational turbine to permit a full assessment of the EA predictions.

SMRU provided their 3rd year report of harbour porpoise monitoring using C-PODs at the FORCE test site (see Appendix I). The report describes the results of C-POD deployments #7-10 (i.e., 416 days from May 5, 2018 – August 14, 2019), and places the results in the broader context of the overall marine mammal monitoring program at FORCE. This ongoing monitoring program continues to show the prevalence of harbour porpoise at FORCE, with the species being detected on 98.8% of the 1,778 calendar days since monitoring with C-PODs commenced in 2011. Harbour porpoise detections at FORCE varies seasonally, with peak activity occurring during May – August, and lowest detections during December – March. Harbour porpoise detections also vary spatially, with C-PODs deployed at locations W2 and S2 recording the greatest detection rates, and D1 values typically low. Mean lost time across C-PODs, due to ambient flow noise saturating the detection buffer on the C-POD, averaged 22.6%. Interestingly, an analysis against past datasets that controlled for time of year, indicated that the effects of the non-operational CSTV turbine structure had no detectable effect on the rate of harbour porpoise detection.

SMRU provided an interim report (see Appendix VI) covering C-POD deployment #11 (August 2019 – January 2020) that included summary data which revealed that harbour porpoise were detected on a least one C-POD every day, with a median of 11 minutes of porpoise detection per day. The mean percent lost time due to ambient flow and sediment noise (19.5%) was comparable to previous deployments. The interim report supports the findings of previous monitoring activities that harbour porpoise are prevalent at the FORCE test site. The report suggests that enough baseline data has been collected to meet the goals of the EEMP.

C-PODs were not deployed during the first quarter of 2020 due to a combination of weather-related delays and the availability of vessels suitable for deployment during January and February, and the spread the COVID-19 virus in March and federal and provincial government requirements to maintain social distancing. This coincides with the period of reduced harbour porpoise activity at the FORCE site. However, C-PODs underwent regular annual maintenance in spring 2020 (i.e., replacement of CPOD batteries and acoustic release batteries, refurbishment of SUBS packages, and fabrication and installment of mounts for the MetOcean Telematics (Dartmouth, NS) beacons) and were deployed at the FORCE on June 12, 2020 to resume monitoring. On September 23rd, FORCE received an automated notification from a

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

beacon that the C-POD deployed at location D1 at the FORCE site had released from its mooring prematurely and was beached near Harbourville, NS. FORCE staff recovered the C-POD that same day and will redeploy it with the other C-PODs in mid-October; in line with our regular deployment schedule.

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

Observation Program

FORCE's marine mammal observation program in 2020 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 is preparing to use 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 flight paths. Several FORCE staff including *Science Director* Dr. Daniel Hasselman, *Facility Manager* Sandra Currie, and *Environmental Monitoring Lead* Tyler Boucher, and *Ocean Technologist* Jessica Douglas received training to operate FORCE's UAV, and have acquired UAV pilot certification by successfully passing the 2019 Canadian Drone Pilot Basic Operations Examination, administered by Transport Canada. These staff are now licensed to safely operate the UAV at the FORCE site. 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 functioning tidal stream turbines are unlikely to cause mortality, physical injury or hearing impairment to marine animals (AECOM, 2009).

Results from previous acoustic analyses completed at the FORCE site indicate that the CSTV turbine was 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).

In previous years, regulators have encouraged FORCE to pursue integration of results from multiple PAM instruments deployed in and around the FORCE test site. To that end, FORCE and its partner JASCO Applied Sciences (Canada) Ltd. pursued a comparative integrated analysis of sound data collected by various hydrophones (i.e., underwater sound recorders) deployed autonomously and mounted on the CSTV turbine. That work revealed that flow noise increased with the height of the hydrophone off the seabed but had little effect on hydrophones deployed closer to the sea floor. The comparative integrated analysis provided valuable information about future marine sound monitoring technologies and protocols while building on previous acoustics analyses at the FORCE site. Plans are currently being developed to test the capabilities of recent technological advancements (‘NoiseSpotter’; Raghukumar et al. 2019) for characterizing the soundscape of the FORCE test site and for assessing turbine generated sound in high-flow environments like the Minas Passage.

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). However, there has been limited opportunity to determine potential effects of an operational turbine on seabirds at the FORCE test site and to test the EA predictions.

Since 2011, FORCE and Envirosphere Consultants Ltd. (Windsor, NS) have collected observational data from the deck of the FORCE Visitor Centre, documenting seabird species presence, distribution, 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). FORCE recently commissioned Envirosphere Consultants Ltd. and Dr. Phil Taylor (Acadia University) to synthesize the results of its observational seabird surveys (2011-2018) at the FORCE test site, and to evaluate advanced statistical techniques for analysing seabird count data in relation to environmental predictor variables (see Appendix II). The seabird count data were examined using Generalized Additive Models (GAMs) to characterize seabird abundance and to better understand the potential impacts of tidal turbines on seabirds at the FORCE test site. The results of the analyses revealed that overall model fit is suitable to characterize count data for some species, and that there are clear patterns of effects of time of year, wind speed and direction, tide height and time of day on the number of seabirds observed. However, the analyses also revealed that not all species reported at FORCE have been observed frequently enough to be modelled effectively using the GAM approach. This is due in part to the variability in count data that is particularly relevant for modelling abundance of migratory species that are only present at the FORCE site for brief periods during annual migrations. This is consistent with observational data collected over the course of these surveys that have demonstrated that the FORCE site has a lower abundance of seabirds in relation to other areas of the Bay of Fundy, and even other regions of Atlantic Canada. Given these results, the report recommends that future monitoring and analyses focus on locally resident species (i.e., great black-backed gull, herring gull, black guillemot and common eider) so that the EA predictions can be tested most effectively. This work contributes to the development of appropriate analytical methods for assessing the impacts of tidal power development in the Minas Passage on relevant seabird populations and supports the continued responsible development of tidal energy at FORCE.

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 anticipation of a planned deployment at FORCE in late 2020, Sustainable Marine Energy Canada (SMEC) recently submitted a near-field EEMP plan that is undergoing internal review by FORCE staff before review by EMAC and submission to regulators for approval.

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 was managed and reported by FORCE to regulators on a monthly basis from March 2019 – May 2020, but was discontinued following an amendment to this requirement. Data is also still being collected from two of the four hydrophones on the CSTV turbine.

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, involved 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 these reports are publicly available.[28]

FORCE recently completed an assessment of the efficacy of different PAM instruments for harbour porpoise monitoring across various tidal flow conditions under Phase III (Technology validation) of the Pathway Program, and is provided herein as Appendix V. The 'Comparative PAM Assessment' project evaluated the operational limitations of two 'stand-alone' and three 'conventional' PAM instruments to detect synthetic and real harbour porpoise clicks across a range of tidal flow conditions. The five PAM instruments were mounted to a subsea platform and deployed at the FORCE site. A series of passive drifts were then conducted over the platform from a vessel across a range of tidal flow conditions while playing synthetic harbour porpoise clicks (pseudo-clicks) emitted from an icTalk. This was supplemented with data collected from real harbour porpoise transiting the FORCE site. The study revealed that pseudo-clicks were not similar enough to real harbour porpoise clicks to be classified by 'stand-alone' PAM instruments. Further, 'conventional' PAM instruments only detected synthetic click over short ranges due to the lower source level of the icTalk (~130 dB re 1µPa at 1m) relative to real porpoise clicks (~160 dB re 1µPa at 1m). Not surprisingly, detections of clicks decreased with increasing flow speed, with few detections above current velocity of 2 m/sec. One 'conventional' PAM instrument - the icListen - appeared to be less impacted by ambient noise at high frequencies, which allowed this instrument to detect more pseudo-clicks than the other 'conventional' PAM technologies assessed. While all five PAM technologies were able to detect real harbour porpoise clicks, the false positive detection rates for the three 'conventional' instruments were higher than the 'stand-alone' instruments, creating additional post-processing

[28] These are available online at: https://oera.ca/research/pathway-program-towards-regulatory-certainty-instream-tidal-energy-projects

steps. Reducing the sensitivity of the ‘conventional’ instruments decreased the instance of false positive detections, suggesting that further efforts on the classification of detections could reduce the rate of false positive detections while keeping recall high. An important take-away from this study is that if appropriate sensitivity settings are coupled with a very good click classifier algorithm, ‘conventional’ PAM instruments could be used for monitoring harbour porpoise around tidal turbines at the FORCE site. The development of advanced click detector and classifier algorithms is being pursued under Phase II (‘Advancing data processing and analytics) of the Pathway Program.

FORCE is collaborating with SMEC and using the floating tidal energy platform (PLAT-I) deployed in Grand Passage, NS, to conduct four projects outlined in Phase III (Technology validation) of the Pathway Program (Figure 1). Three of these projects focus on evaluating the utility of echosounders for quantifying biological targets in high flow environments. These projects evaluate the performance of echosounders in bottom and surface deployments and using a suite of complementary technologies (optical cameras and imaging sonars) to investigate target detections. The fourth project involves an assessment of the relative performance of PAM instruments for detecting synthetic harbour porpoise clicks in high flow environments using similar bottom and surface deployments (Figure 2). The data collection phase for these projects is complete, and data post-processing, analyses and report generation are currently underway.

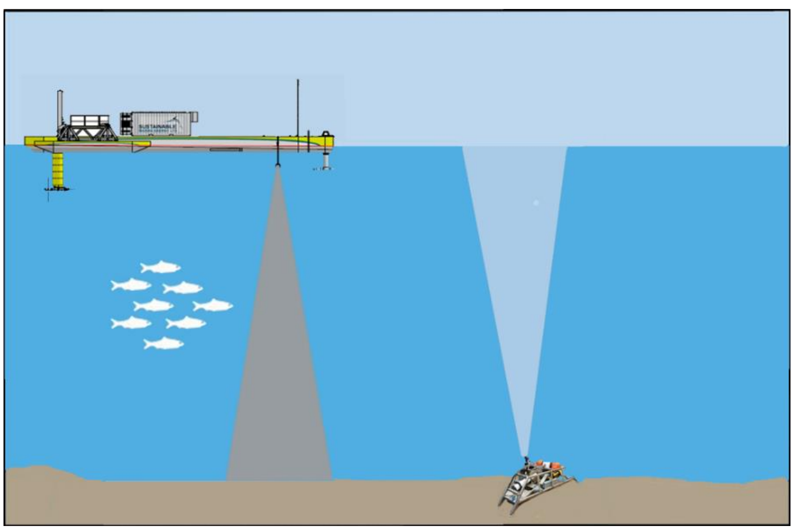

Figure 1: Schematic of the conceptual study design for an assessment of the relative performance of echosounders in bottom-deployments (FAST platform) surface deployments (PLAT-I). Shaded areas are intended for visualization purposes only, and do not accurately represent sample volumes.

Figure 2: Deployment of the FAST platform in Grand Passage for an assessment of PAM instrument performance.

Risk Assessment Program

The Risk Assessment Program (RAP) for instream tidal energy is a collaborative effort between FORCE, academic partners, First Nations, and industry to advance our understanding of the environmental risks of tidal stream development in Minas Passage. The greatest potential risk of tidal turbine operations continues to be perceived by regulators and stakeholders as collisions between marine animals and turbines blades (Copping and Hemery 2020). However, these types of interactions are difficult to observe directly due to the environmental conditions under which they would occur (i.e., fast flowing, turbid waters) and using the suite of environmental monitoring instrumentation currently available (i.e., standard oceanographic and remote sensing instruments intended for use in more benign marine conditions) (Hasselman et al. 2020), but can be modeled using appropriate baseline data. The objective of the RAP program is to develop statistically robust encounter rate models for migratory and resident fishes with tidal turbines in the Bay of Fundy using a combination of physical oceanographic data related to flow and turbulence in the Minas Passage and hydroacoustic tagging data for various fish species curated by the Ocean Tracking Network (OTN) at Dalhousie University.

Recent research has revealed how hydrodynamics (flow and turbulence-related features) in tidal stream environments can influence the distribution of marine animals, including fish (Lieber et al. 2018, 2019; McInturf et al. 2019). The Minas Passage is characterized by a series of turbulent hydrodynamics features (i.e., vortices, eddies, whirlpools, wakes, and shear currents) that could impact the spatiotemporal distribution of various fishes. The RAP will use a series of mobile ADCP transects combined with a high-resolution radar network to create the first spatiotemporal flow atlas of the Minas Passage to understand these hydrodynamic features. Concurrently, hydroacoustic data for various migratory and resident fish species in the Bay of Fundy that is curated by OTN will be compiled and analysed to understand their spatiotemporal distributions. The hydrodynamic and hydroacoustic data will then be combined with information about turbine specific parameters (e.g., turbine blade length, swept area, turbine height off the seabed) to develop encounter rate models for various fish species. These models will then be refined and validated through a series of hydroacoustic tagging efforts, ultimately leading to the development of a user-friendly Graphical User Interface (GUI) similar to what is available for the offshore wind energy industry in the United Kingdom (McGregor et al. 2018). Ultimately, the RAP will contribute towards improving our understanding of the risks of instream tidal power development for fishes of commercial, cultural, and conservation importance in the Bay of Fundy, and will assist in the development of future environmental effects monitoring programs.

Since the program commenced in April, OTN has acquired acoustic tag data from 18 contributors, covering six species of fish in the Bay of Fundy (i.e., alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), Atlantic salmon (*Salmo salar*), Atlantic sturgeon (*Acipenser oxyrhinchus oxyrhinchus*), striped bass (*Morone saxatilis*), and white shark (*Carcharodon carcharias*)). Additional contributors are being approached to provide data from three additional species to the effort (i.e., American eel (*Anguilla rostrata*), Atlantic tomcod (*Microagadus tomcod*), and spiny dogfish (*Squalus acanthias*)). The integration of physical habitat variables with acoustic tag data has commenced, and a process for combining these data sets to develop encounter rate model is emerging and appears promising.

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.[29]

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 was equipped with an upward looking echosounder and deployed during 2017-2018 to monitor fish densities at the FORCE site. FORCE and its partners, including Echoview Software completed data processing and analysis in 2019. This data was integrated with the mobile hydroacoustic surveys that FORCE conducts as part of its EEMP to evaluate the temporal and spatial representativeness of each method and to

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

determine the degree to which results were corroborative (Figure 3). Although the spatial representative range of the stationary results could not be determined from the mobile data, it did reveal strong tidal and diel periods in fish density estimates at the site, with greater variation over shorter time frames than over the course of a year. These findings reinforce the importance of 24-hr data collection periods in ongoing monitoring efforts. The report reveals that collecting 24 hours of data allows the tidal and diel variability to be quantified and isolated from the longer-term trends in fish density and distribution that need to be monitored for testing the EA predictions. This project was funded by Natural Resources Canada (NRCan), the NSDEM, and the OERA, and the report is provided here as Appendix III.

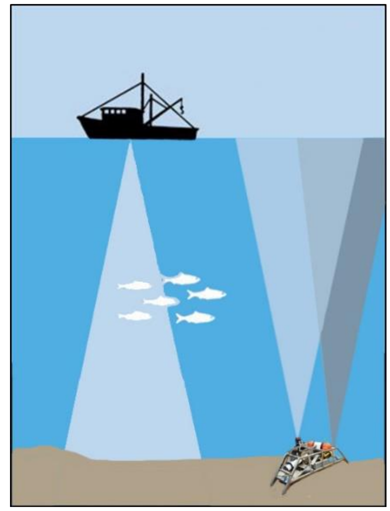

Figure 3: A representation of the data collection methods of the FORCE mid-field fish EEMP and the FAST-3 platform.

Fish Tracking

To enhance fish monitoring and to expand its data collection capacity, FORCE partnered with the Ocean Tracking Network (OTN)[30] and attached one VEMCO[31] 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

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

[31] 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.

- Inner Bay of Fundy Striped Bass (Bradford, R., LeBlanc, P., 2012).
- Minas Basin Salmon Kelt (McLean, M., Hardie, D., Reader, J., Stokesbury, M.J.W., 2019)

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 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).[32]

[32] 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 2020 represents 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.

In response to the COVID19 pandemic, the Nova Scotia provincial government had directed non-essential workers to remain home and practice social distancing for much of the year. For FORCE, that meant staff working from home, and regular office, engagement, and marine activities shifted to a focus on tackling a high volume of site data that required processing, integration and analyses. With three ocean techs now employed full-time in-house, FORCE has a unique capacity to process biological data with both Echoview (hydroacoustics) and Seatec (multibeam imaging sonar) software. While the COVID19 outbreak initially impacted our ability to gather data at our site and conduct marine operations – all of which require multiple people working in close proximity – our operations and monitoring data collection activities have resumed, and are following health guidelines to maintain social distancing and the wearing of face masks

As such, FORCE and its partners have resumed conducting monitoring, engaging in meaningful assessments of monitoring technology capabilities, and providing data analyses and interpretation that advance our ability to effectively monitor the effects of tidal turbines in high flow environments, and specifically at the FORCE test site. Reports from FORCE's partners and updates routinely underwent review by FORCE's EMAC and regulators, along with continued results from FORCE's ongoing monitoring efforts.

FORCE continues to implement lessons learned from the experiences of local and international partners, build local capacity and enhance skills development, test new sensor capabilities, and integrate results from various instruments. Cumulatively, these efforts provide an opportunity for adaptive management and the advancement and refinement of scientific approaches, tools, and techniques required for effectively monitoring the near- and mid-field areas of tidal stream energy devices in dynamic, high-flow marine 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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