force | Fundy Ocean Research Centre for Energy

Environmental Effects Monitoring Program
2024 Annual Report

December 31, 2024

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What's New?

OES-S 2024 STATE OF THE SCIENCE REPORT

Ocean Energy Systems Environment (OES-E) released their 2024 State of the Science Report on September 18, 2024. The information in this report represents the global state of knowledge about the environmental effects of marine renewable energy (MRE) devices from studies and monitoring activities, and is built on publicly available peer-reviewed scientific literature and reports published by researchers, developers, and government agencies, and as seen through the lens of many of the leading MRE researchers in the field. read more

TIDAL TASK FORCE - FINAL REPORT

The *Tidal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy* recently issued its Final Report. The report includes a revised staged approach to tidal stream energy project permitting at the FORCE site that was developed in collaboration with Fisheries and Oceans Canada, aligns with provincial licensing, and includes adaptive management conditions for environmental monitoring that improves understanding of how fish interact with tidal stream energy devices. read more

NEW INITIATIVES

FORCE has partnered with the Acadia Tidal Energy Institute on a new initiative that aligns with the priorities of the *Risk & Monitoring Working Group* of the *Tidal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy*. The initiative includes a series of complementary desktop studies to inform a larger field-based project to understand how fish interact with tidal stream energy devices at FORCE. read more

FORCE has partnered with Innovasea and a series of other collaborators on an Ocean Supercluster funded project to advance the application of artificial intelligence for monitoring fish around hydroelectric and tidal stream energy projects. read more

ONGOING MONITORING ACTIVITIES

As part of its ongoing monitoring program, FORCE collaborated with the Ocean Tracking Network (OTN) to re-deploy a line of 24 acoustic receiver stations across Minas Passage to detect the movement of acoustically tagged fish. FORCE also partnered with Acadia University and OTN to tag American shad from the Kennetcook River and Inner Bay of Fundy Atlantic Salmon kelts that were released in the Stewiacke River. read more

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 (OERA; now NetZero Atlantic (NZA)), and others. These studies have considered physical, biological, socioeconomic, and other research areas.

The current suite of monitoring programs implemented by FORCE build off those initiated during 2016-2020 that were conducted in anticipation of tidal stream energy device deployments at FORCE's tidal demonstration site. These efforts are divided into two components: FORCE 'site-level' monitoring activities (>100 metres from a device), and developer or 'device-specific' monitoring led by project developers (≤100 metres from a device) at the FORCE site. All monitoring plans are reviewed by FORCE's independent Environmental Monitoring Advisory Committee (EMAC) and federal and provincial regulators prior to implementation.

FORCE monitoring presently consists of monitoring for fish, marine mammals, seabirds, lobster, and marine sound. During monitoring from 2016 through 2020, FORCE completed:

- ~564 hours of hydroacoustic fish surveys;
- more than 5,083'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

The 2021-2023 EEMP was designed to prepare for effects testing with the deployment of operational tidal stream energy devices and adhered to the principles of adaptive management by evaluating existing datasets to ensure appropriate monitoring approaches are being implemented. Moreover, the plan adopted internationally accepted standards for monitoring where possible, including feasibility assessments for new monitoring approaches that were planned to be implemented. The 2021-2023 EEMP was intended to be implemented as designed and reviewed by FORCE's environmental monitoring advisory committee (EMAC). However, because device deployments did not occur during the 2021-2023 time frame, an opportunity for effects testing was not presented. Given these circumstances, FORCE requested an extension of the 2021-2023 EEMP to the 2024 calendar year; this request was approved by the *Nova Scotia Department of Environment and Climate Change*.

Since the beginning of the 2021-2023 EEMP, FORCE has completed;

- 8 days of lobster surveys;
- 6 multi-month deployments of acoustic receivers to detect tagged fish;
- a preliminary radar feasibility study to monitor for seabirds; and
- bi-weekly shoreline observations

FORCE is also working with academic and Indigenous partner organizations 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 stream energy devices. This will be accomplished by combining physical oceanographic data related to flow and turbulence in the Minas Passage with acoustic tagging information for various fish species in the region curated by the Ocean Tracking Network at Dalhousie University. Since the start of the project, FORCE has established a high-resolution radar network in Minas Passage and has started to quantify hydrodynamic features in the region and build the tidal flow atlas required for the program. FORCE has also started modelling the spatiotemporal distributions for the nine species for which sufficient acoustic tracking data is available and is developing species distribution maps for each species. In partnership, FORCE, the Mi'kmaw Conservation Group, local fishers and Acadia University have completed the fish tagging component of the program that is required for species distribution model development and encounter rate model validation. The results of this work are expected to be shared through the development of a user-friendly graphical-user interface for non-technical stakeholders, and an R-package (or similar) for regulators and academic stakeholders, as resources become available. Fish tagging has continued in 2024 and will extend into future years as part of FORCE's fish monitoring program. Ultimately, this work will contribute towards understanding the risk of tidal stream energy 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 analyses completed by FORCE up to the end of 2024. 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. This includes work in support of the adaptive nature of the EEMP and the RAP program.

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

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Introduction

This report outlines monitoring activities and results of data analyses conducted at the Fundy Ocean Research Centre for Energy test site in the Minas Passage, Bay of Fundy during 2024. Specifically, this report highlights results of environmental monitoring activities conducted by FORCE 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 tidal stream energy device generators, four subsea power cables to connect the devices 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 tidal demonstration 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 Natural Resources and Renewables. Current berth holders at FORCE are:

Berth A: Eauclaire Tidal Limited Partnership[2]
Berth B: Rio Fundo Operations Canada Limited[3]
Berth C: Sustainable Marine Energy (Canada)[4]
Berth D: Occurrent Power[5]
Berth E: Halagonia Tidal Energy Limited[6]

[1] Further information about each company may be found at: fundyforce.ca/partners
[2] On January 16, 2023 the Department of Natural Resources and Renewables approved the transfer of the Project Agreement and FIT approvals from Minas Tidal Limited Partnership to Eauclaire Tidal Limited Partnership.
[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] In June 2023, Sustainable Marine Energy announced voluntary bankruptcy, citing the lack of a regulatory pathway with DFO, with Deloitte Canada appointed as trustee.
[5] On September 4, 2024, Occurrent Power announced voluntary bankruptcy, citing financial insolvency issues.
[6] 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, rightsholders, 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[7] 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 (EEMP) to better understand the natural environment of the Minas Passage and the potential effects of tidal stream energy devices 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; now NetZero Atlantic (NZA)) and others. These studies have considered socioeconomics, biological, and other research areas.[8]

Monitoring at the FORCE site is currently focused on lobster, fish, marine mammals, seabirds, and marine sound and is divided into developer led 'device-specific' (≤ 100 m from a device) monitoring and FORCE led 'site-specific' (> 100 m from a device) monitoring. As approved by regulators, individual berth holders complete monitoring in direct vicinity of their device(s), in recognition of the unique design and operational requirements of different technologies. FORCE completes site level monitoring activities as well as supporting integration of data analysis between these monitoring zones, where applicable.

All developer and FORCE led monitoring programs are reviewed by FORCE's Environmental Monitoring Advisory Committee (EMAC), which includes representatives from scientific, First Nations, and local fishing communities.[9] These programs are also reviewed by federal and provincial regulators prior to device installation. In addition, FORCE and berth holders also submit an Environmental Management Plan (EMP) to regulators for review prior to device installation. EMP's include environmental management roles and responsibilities and

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

[8] Net Zero Atlantic Research (formerly Offshore Energy Research Association) Portal (https://netzeroatlantic.ca/research) includes studies pertaining to infrastructure, marine life, seabed characteristics, socio-economics and traditional use, technology, and site characterization.

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

commitments, environmental protection plans, maintenance and inspection requirements, training and education requirements, reporting protocols, and more.

Tidal Stream Energy Device Deployments

Since FORCE's establishment in 2009, tidal stream energy devices 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 device 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 instruments 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.[10] 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 except for 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 required that CSTV provide written confirmation to regulators monthly that the turbine was 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 developer 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 provided a $4.5 million security deposit to remove the non-operational CSTV turbine currently deployed at berth D, and had until December 31, 2024, to raise the turbine. The company was rebranded at 'Occurrent Power' on May 15, 2024, but announced voluntary bankruptcy on September 4, 2024, citing financial insolvency issues. FORCE is currently working with the Nova Scotia Department of Natural Resources and Renewables on plans to recover the CSTV turbine using the $4.5 million security deposit.

On December 5, 2023, Eauclaire Tidal Limited Partnership announced that Orbital Marine Power would provide the tidal stream technology for berth A at the FORCE test site. The technology (i.e., 'O2X') is a 2.4 megawatt floating device with two horizontal axis turbines. The

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

project start date for Eauclaire and Orbital is not known at this time, and the project description and an Environmental Effects Monitoring Program (see below) are currently under development.

Additional devices are expected to be deployed at the FORCE site in the coming years. In 2018, Sustainable Marine Energy (SME; formerly Black Rock Tidal Power) installed a PLAT-I system in Grand Passage, Nova Scotia under a Demonstration Permit.[11] 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. On May 11, 2022, SME announced it had successfully delivered the first floating tidal stream energy to Nova Scotia's power grid. However, on March 20, 2023, SME announced that it was withdrawing its application to Fisheries and Oceans Canada (DFO) for a Fisheries Act Authorization to deploy a PLAT-I system at FORCE, citing an unclear regulatory pathway for project build-out. Consequently, on May 12, 2023, SME was placed into voluntary bankruptcy and their Pempa'q project at the FORCE site will not proceed. FORCE has since worked with various governmental departments at both the federal and provincial level to define a regulatory path for tidal stream energy demonstration in Minas Passage that considers effective environmental monitoring approaches, includes proportionality with respect to environmental risks of tidal project development, and accounts for the needs of the tidal energy sector. Fisheries and Oceans Canada and Natural Resources Canada recently announced the formation of the *Tidal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy* (hereafter, 'the Task Force') to address regulatory uncertainty surrounding tidal project development in Minas Passage. Among other important findings, the final report outlines a revised staged approach to tidal stream energy project permitting at the FORCE site, and an expanded regulatory coordination role for FORCE. The final report was released on February 28, 2024, and is publicly available here. More information about the key findings of the final report are provided below.

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.[12] 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 will be required to develop a device-specific monitoring program for their project, 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 Climate Change, and the Nova Scotia Department of Natural Resources and Renewables, prior to device installation.

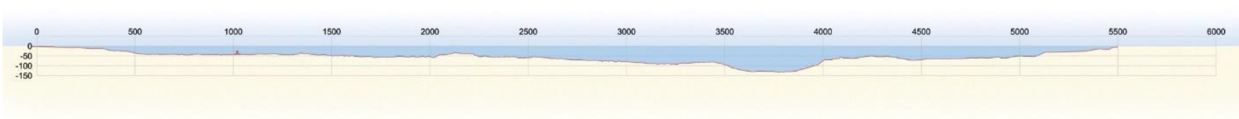

Figure 1: The scale of a single turbine (based on the dimensions of the OpenHydro turbine deployed by CSTV, indicated by the red dot and above the blue arrow) in relation to the cross-sectional area of the Minas Passage. The Passage reaches a width of ~ 5.4 km and a depth of 130 m.

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

[12] 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.

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.

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 2018; Copping and Hemery 2020). Presently, countries such as China, France, Italy, the Netherlands, South Korea, the United Kingdom, and the United States (Marine Renewables Canada 2018) are exploring tidal energy, supporting environmental monitoring and innovative R&D projects. Tidal energy and other marine renewable energy (MRE) technologies such as tidal range, tidal current, wave, and ocean thermal energy conversion, and salinity gradients offer significant opportunities to replace carbon fuel sources in a meaningful and sustainable manner. Some estimates place MRE's potential as exceeding current human energy needs (Lewis et al. 2011; Gattuso et al. 2018). Recent research includes assessments of operational sounds on marine fauna (Schramm et al. 2017; Lossent et al. 2018; Robertson 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. 2018b), demonstrated avoidance behavior by harbour porpoise around tidal turbines (Gillespie et al. 2021), a synthesis of known effects of marine renewable energy devices on fish (Copping et al. 2021), 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 Bay of Fundy Ecosystem Partnership[13], TC114[14], the Atlantic Canadian-based Ocean Supercluster[15], and OES-Environmental[16].

FORCE continues 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. For instance, OES-Environmental incorporated new research topics for the 2024 State of the Science Report related to i) knowledge of environmental effects as the tidal energy industry scales up from single devices to arrays, ii) understanding the cumulative impacts of marine renewable energy with other anthropogenic effects, and iii) an ecosystem approach for understanding environmental effects, including interactions between trophic levels,

[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.

between ecosystems and between ecosystem services. Dr. Daniel J. Hasselman, FORCE Science Director, was involved in the development of all three of these topics and led the effort to understand the 'scaling up' of environmental effects of devices as the tidal energy sector transitions towards the development of commercial arrays. A synopsis of this work and the other topics outlined above is included in chapter 9 of the OES-E 2024 State of the Science Report that was released on September 18, 2024.

On January 20th, Dr. Hasselman chaired a workshop at the 3rd Pan American Marine Energy Conference (PAMEC) in Barranquilla, Colombia, entitled 'Monitoring for Interactions Between Marine Animals and MRE Devices'. The afternoon session included 11 presentations by leading international researchers from Canada, the United States and United Kingdom on topics ranging from specific monitoring technologies (e.g., optical cameras, imaging sonars, acoustic telemetry) to applications of artificial intelligence, data management, and modelling approaches for understanding encounter rate and collision risk. The workshop reinforced the value of MRE test centres for demonstrating the utility of monitoring technologies and approaches for understanding environmental effects of MRE devices, and built on the prior PAMEC workshops (2020 and 2022) that explored the importance of test centres in building social license and addressing questions relevant to the establishment of MRE technologies regionally.

To keep abreast of advances in monitoring technologies, approaches and analyses, FORCE staff attended the 2024 *Environmental Interactions of Marine Renewables* (EIMR) conference from April 15-19 in Kirkwall, UK. This bi-annual conference is the only venue within the marine renewables sector that focuses exclusively on environmental effects. This highly-anticipated meeting was well attended with delegates from across Europe and the United States, and with a strong contingent from Nova Scotia, including colleagues from the Acadia Tidal Energy Institute at Acadia University, and Fisheries and Oceans Canada.

In collaboration with the European Marine Energy Centre (EMEC), FORCE hosted the 11th annual *International WaTERS Workshop* in Halifax during November 18-19, 2024. International WaTERS focuses on the experience of MRE test centers and associated organizations around the globe, with an aim to share knowledge, build relationships and foster collaboration. The workshop focused on permitting for wave and tidal energy projects at test centers, and included sessions focused on Canada's Tidal Energy Task Force and streamlining consenting processes in the UK, and breakout groups focused on regulatory uncertainty and managing risks associated with project delays. The International WaTERS Workshop was well attended, with 27 delegates from eight MRE test centers (AMEC, EMEC, PacWave, PRIMED, FORCE, Jennette's Pier, KRISO, K-TEC) and affiliated organizations (US. Department of Energy, National Renewable Energy Laboratory) from around the world. A workshop report is currently under development and will be included as an appendix in an upcoming quarterly EEMP report.

FORCE Monitoring Activities

FORCE has been leading site-level monitoring for several years, focusing on a variety of valued ecosystem components. FORCE's previous environmental effects monitoring program (2016-2020) was developed in consultation with SLR Consulting (Canada)[17] and was strengthened by review and contributions by national and international experts and scientists, DFO, NSECC, and FORCE's EMAC. The most recent version of the EEMP (2021-2023) was developed in

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

consultation with Atlantis Watershed Consultants Ltd. with input from national and international experts, including FORCE's EMAC, and was submitted to regulators for approval. The 2021-2023 EEMP was modified from the 2016-2020 EEMP based on results of previous monitoring activities, experience and lessons learned, and has been extended to 2024. This is consistent with the adaptive management approach inherent to the 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.[18] A similar process will be used for the development of the next iteration of the EEMP (i.e., 2026-2030).

FORCE's EEMP currently focuses on the impacts of operational tidal stream energy devices on lobster, fish, marine mammals, and seabirds as well as the impact of device-produced sound. Overall, these research and monitoring efforts, detailed below, were designed to test the predictions made in the FORCE EA. Over the course of the 2016-2020 EEMP, FORCE completed approximately:

- 564 hours of hydroacoustic fish surveys;
- more than 5,083'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.

Since the beginning of the 2021-2023 EEMP, FORCE has undertaken:

- 8 days of lobster surveys;
- 6 multi-month deployments of acoustic receivers to detect tagged fish;
- a preliminary radar feasibility study to monitor for seabirds; and
- bi-weekly shoreline observations

The following pages provide a summary of the site-level monitoring activities conducted at the FORCE site during 2024, including data collection, data analyses performed, initial results, and lessons learned, that builds on activities and analyses from previous years. Where applicable, this report also presents analyses that have integrated data collected through developer and FORCE monitoring programs to provide a more complete understanding of device-marine life interactions.

Monitoring Objectives

The overarching purpose of environmental monitoring is to test the accuracy of the environmental effects 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 device-marine life interactions will not be possible until device-specific and site-level monitoring efforts are integrated, and additional data is collected in

[18] 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.

relation to operating tidal stream energy devices. 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 device-marine life interactions.

Table 1 outlines the objectives of the site-level monitoring activities conducted at the FORCE demonstration site. FORCE led site-level monitoring summaries will be updated as devices are scheduled for deployment at FORCE. At this time, and considering the scale of device deployments in the near-term at FORCE, it is unlikely that significant effects in the far-field will be measurable (SLR Consulting 2015). Far-field studies such as sediment dynamics will be deferred until such time they are required. However, recent discussions with scientists serving on FORCE's EMAC suggests that the natural variability inherent to the upper Bay of Fundy ecosystem far exceeds what could be measured by far-field monitoring efforts. Moreover, the scale of tidal power development would need to surpass what is possible at the FORCE tidal demonstration site to extract sufficient energy from the system to have any measurable effects (Whiting et al. 2023). In short, far-field monitoring would be futile unless tidal power development transitions from demonstration scale to commercial arrays. 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 environmental effects monitoring activities, which consider various Valued Ecosystem Components (VECs), led by FORCE.

FORCE Environmental Effects Monitoring VEC	***Objectives***
Lobster	● to determine if the presence of a tidal stream energy device affects commercial lobster catches
Fish	● to test for indirect effects of tidal stream energy devices 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 device depth in the water column
Marine Mammals	● to determine if there is permanent avoidance of the study area during device operations ● to determine if there is a change in the distribution of a portion of the population across the study area
Marine Sound (Acoustics)	● to conduct ambient sound measurements to characterize the soundscape prior to and following deployment of the tidal stream energy device
Seabirds	● to understand the occurrence and movement of bird species in the vicinity of tidal stream energy devices ● to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to tidal stream energy devices

Lobster

FORCE conducted a baseline lobster catchability survey in fall 2021 (Fishermen and Scientists Research Society (FSRS), 2023) following the study design developed by TriNav Fisheries

Consultants Ltd. in 2019. This study design was implemented in partnership with the FSRS (Figure 2) and with the assistance of a local lobster fisher. The report from this work was provided in 2023, and the results indicated a ‘high’ catchability rate (i.e., CPUE ≥ 2.4 kg/trap haul) during the fall survey. This is consistent with a prior baseline survey at the FORCE site in 2017 (NEXUS Coastal Resource Management Ltd. 2017) and is comparable to available commercial landings data provided by Fisheries and Oceans Canada (DFO). The study design will be repeated once an operational device has been deployed at FORCE to gather effects testing data and test the predictions of the EA.

Figure 2: Lobster scientist from the Fishermen and Scientist Research Society showing a tagged lobster prior to release.

Fish

FORCE conducted 25 mobile hydroacoustic fish surveys from May 2016 – October 2020 to test the EA prediction that tidal stream energy devices 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 devices 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 device 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 device is installed with data collected while a device 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 device 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 device 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 CLA 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 device 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.

Because complex hydrodynamic features of the Minas Passage introduce turbulence and bubbles into the water column that interfere with the use of hydroacoustics, FORCE's mobile fish surveys have been optimized for collecting data during the best neap tidal cycle per month when turbulence is greatly reduced. However, this approach limits the number of surveys that can be conducted, and regulators have suggested that the scope of the program be expanded so that survey results are more representative of how fish use the Minas Passage. To that end, FORCE conducted multiple fish surveys during each of three neap tidal cycles in fall 2020 (i.e., September 25, 27, 29; October 7, 9, 13; and October 24, 26, 29) to determine whether variation in fish density and distribution for any given survey within a neap cycle was representative of the other surveys conducted during that same time frame. Previous work comparing stationary and mobile hydroacoustic surveys in Minas Passage found that the temporal representative range of a 24-hr mobile was approximately three days (Viehman et al. 2019).

A recent study (Viehman et al. (2022)) examined entrained air contamination in echosounder data collected at the FORCE test site. It found that fish abundance estimates in the lower 70%

of the water column and current speeds less than 3 m/s were well represented in that there was little contamination of the data set from entrained air. However, undersampling of the upper water column and faster speeds strongly affected fish abundance estimates especially during strong spring tides. This means that data collected during neap tides are more likely to yield a more accurate picture of fish abundance and distribution than those collected during spring tides. The study also highlighted how estimates of fish abundance may be affected differently depending on where fish are in the water column. For example, (hypothetical) fish located at mid-depths were omitted from the data more often as current speeds increased. These findings indicate a complex and dynamic ecosystem where the interactions of water movement and fish distribution affect our ability to infer how fish populations may interact with tidal power devices in the Minas Passage. The use of acoustic telemetry being studied under the RAP program could be used to fill gaps in datasets and optimize what can be learned about fish abundance and distribution at tidal energy sites.

Another issue with the entrained air found in high flow environments is the need to remove the contaminated data prior to analysis which is often a tedious and time-consuming process. Existing algorithms used to identify the depth-of-penetration of entrained air are insufficient for a boundary that is discontinuous, depth-dynamic, porous, and varies with tidal flow speed. Using a case study from data obtained at the FORCE test site a recent study (Lowe et al. (2022)) described the development and application of a deep machine learning model called Echofilter. Echofilter was found to be highly responsive to dynamic range of turbulence conditions in the data and produced an entrained-air boundary line with an average error of less than half that of the existing algorithms. The model had a high level of agreement with human data trimming. This resulted in 50% reduction in the time required for manual edits to the data set when using currently available algorithms to trim the data.

FORCE is currently working towards the development of a comprehensive fish synthesis that will bring together existing knowledge of fish distribution, abundance, and use of the Minas Passage using existing literature from stock assessments, prior hydroacoustic surveys, acoustic telemetry-based surveys, as well as other relevant sources of information. This synthesis will focus on aquatic species at risk, those of cultural relevance, and commercial and recreational value. The results of this synthesis project will be available in 2025 and will help to determine the extent to which questions regarding fish and tidal energy project permitting have been answered and identifying remaining knowledge gaps. Dr. Graham Daborn at Acadia University is leading this work, and a final report is expected early in 2025.

Marine Mammals

Since 2016, FORCE has been conducting 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):

- passive acoustic monitoring (PAM) using ‘click recorders’ known as C-PODs; and
- 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.[19] 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.

From 2011 to early 2018, more than 4,845 'C-POD days'[20] 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 vicinity of CSTV turbine when it was operational (November 2016 – June 2017) (Joy et al. 2018a). 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 site avoidance with a device present and operating. These 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 device to permit a full assessment of the EA predictions.

This monitoring program demonstrates the prevalence of harbour porpoise at FORCE, with the species being detected on 98.8% of the 1,888 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 their 4th year final report of harbour porpoise monitoring using C-PODs at the FORCE test site (Palmer et al. 2021). The report describes the results of C-POD deployments #11-12 (i.e., 1,043 days of monitoring from August 2019 – September 2020), and places the results in the broader context of the overall marine mammal monitoring program at FORCE. The final report includes summary data that revealed that harbour porpoise was detected on a least one C-POD every day, with a median value of 11 and 17 minutes of porpoise detections per day during deployments 11 and 12, respectively. The mean percent lost time due to ambient flow and sediment noise was 19.5% and 23.8%, respectively, comparable to previous deployments. Overall, the final report supports previous findings of monitoring activities that harbour porpoise are prevalent at the FORCE test site.

The final report also reiterates that sufficient baseline data has been collected to meet the goals of the EEMP. As such, FORCE has recommended in its 2021-2023 EEMP proposal that the collection of additional baseline harbour porpoise data using C-PODs be suspended until an operational device is deployed at the FORCE site. Upon receiving confirmation that a device will be deployed at the tidal demonstration area, FORCE will deploy C-PODs prior to the

[19] The C-PODs, purchased from Chelonia Limited, are designed to passively detect marine mammal 'clicks' from toothed whales, dolphins, and porpoises.
[20] A 'C-POD day' refers to the number of total days each C-POD was deployed times the number of C-PODs deployed.

construction phase to begin collecting data and assessing any changes to harbour porpoise detections in the presence of an operational device. FORCE is currently working with SMRU to continue with this monitoring program when operational devices are present.

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

Observation Program

FORCE's marine mammal observation program in 2023 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 will be shared with SMRU Consulting to support validation efforts of PAM activities when C-PODs are deployed.

FORCE uses 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. FORCE staff 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. 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 energy devices 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 device is improbable, but that behavioural disturbance may occur within 400 m of a device for marine mammals and at closer distances for some fish species (Lossent et al. 2018).

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.

In its 2021-2023 EEMP proposal, FORCE has recommended conducting a test survey in the presence of an operational device using an internationally recognized standard methodology for monitoring sound (International Electrotechnical Commission 2019). This would permit the feasibility of the approach to be tested in the Minas Passage to ensure the method can be implemented as described. This work is pending an operational device being deployed at the FORCE tidal demonstration area. FORCE will work with JASCO to collect and analyze marine sound data once a device is deployed.

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 device 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 Ltd. 2017). Envirosphere Consultants Ltd. recently published the results of their monitoring from 2010-2012 and demonstrated that the species and seasonal cycles of seabirds in Minas Passage reflect patterns that are typical of the inner Bay of Fundy and the northeast Atlantic coast of North American. The report also highlights the importance of the Minas Passage as a migratory pathway for black scoter (*Melanitta americana*) and Red-throated loon (*Gavia stellata*).

In 2019, FORCE 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. The seabird count data were examined using Generalized Additive Models (GAMs) to characterize seabird abundance and to better understand the potential impacts of tidal stream energy devices 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.

In 2022 FORCE began working with Strum Consulting to test radar-based seabird monitoring capabilities and to adapt existing data processing algorithms and statistical analysis tools for quantifying seabird use of the FORCE site. Strum provided a technical report which highlighted challenges and options to move forward with this approach. Challenges with the quality of the radar data limited the assessment and the full study could not be completed. The feasibility study continued in 2023 with FORCE providing a new radar data set to Strum, but the challenges in locating avian targets from the radar data could not be resolved using current methods. A commercially available software option may resolve these issues, but requires further examination.

Developer Monitoring Activities

While FORCE completes site-level monitoring activities at the FORCE site, device specific monitoring is led by individual berth holders. Like the FORCE monitoring programs, the developer 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 monthly that the turbine is not operational by monitoring its status during the peak tidal flow of each month. However, because 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 monthly from March 2019 – May 2020 but was discontinued following an amendment to this requirement.

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

Other FORCE Research Activities

Tidal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy

The *Tidal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy* was struck on June 20, 2023. The Task Force is co-chaired by NRCan and DFO, includes members from the Government of Nova Scotia, industry, and research organizations, and released its final report on February 28, 2024. Among several important topics discussed, the final report provides an introspective examination about how risk for proposed tidal energy devices is determined, examines the *Fisheries Act* authorization process, and outlines a "revised staged approach" to tidal stream project permitting in Minas Passage that is intended to provide clarity for proponents and flexibility to regulators to ensure strong environmental protection. This revised staged approach was developed in collaboration with DFO and supports the staged deployment of small arrays of tidal energy devices at the FORCE tidal demonstration site with clear requirements for fish protection and monitoring. More specifically, the revised staged approach:

- reinforces the protections afforded to marine animals (and habitats) under the *Fisheries Act* and *Species at Risk Act*,
- aligns with Nova Scotia provincial licensing for developers at FORCE (i.e., a 5 MW licence for up to 15 years, per berth),

- outlines rigorous adaptive management conditions around environmental monitoring (development of an EEMP) that require proponents to demonstrate (through monitoring activities) how fish interact with their tidal energy device,
- includes stages that progressively advance the collective understanding of the impacts of tidal devices on fish, and
- provides confidence that developers can advance their projects and deploy additional devices under the same *Fisheries Act* authorization, provided that monitoring is effective and no unacceptable impacts to fish are observed.

For the revised staged approach to be effective, improved monitoring approaches are required to inform risk assessment. To that end, the Task Force has struck the *Risk & Monitoring Working Group* (RAM WG) to advance this work (see below.)

New Initiatives

FORCE has partnered with the Acadia Tidal Energy Institute (ATEI) to lead activities under the Risk & Monitoring Working Group that was established by the Task Force. This initiative includes a series of six complementary desktop studies (i.e., modules) that will be used to inform a larger field-based project to understand how fish interact with tidal stream energy devices at FORCE. The modules are as follows:

1. Develop a standardized Adaptive Environmental effects Monitoring Program (AEMP) Template and Guidance Document to assist tidal energy proponents with the development of project specific AEMPs in support of *Fisheries Act* Authorization and *Species at Risk Act* Permit applications,

2. Review approaches to measuring and modelling fish distribution and both encounter rate and collision risk probabilities, with probabilities determined for inner Bay of Fundy Atlantic salmon kelt,

3. Review and provide recommendations for underwater cameras and their practical and integrated/synchronized use in Minas Passage,

4. Design high-flow, net capture techniques for both monitoring fish species presence in Minas Passage and validating fish detections from installed optical cameras and other sensors,

5. Design streamlined, low-drag, zero-lift, sensor mount systems for placement at various depths for effective monitoring with vortex induced vibration, and

6. Review the needs and options for a data management system for analyzing, storing and sharing environmental effects monitoring data, and recommend a data management system that best suits the needs of FORCE and the tidal stream energy sector

Work under these series of modules has commenced and is expected to be completed by the end of 2024. Progress for each module will be reported in FORCE's quarterly EEMP reports. For instance, progress on the AEMP Template and Guidance Document (module 1) continues and includes collaboration with ATEI and DFO to standardize the overall structure of the document, and the development and review of draft materials that will be included in various sections of the AEMP Template. The final draft of the AEMP Guidance Document has been completed and is currently undergoing internal review before being finalized. The format and outline of the AEMP Template has been completed, and standardized text for various sections have been finalised (e.g., regulatory context, AEMP approach, comprehensive physical habitat description for Minas Passage) or are in various stages of completion (e.g., biological constituents of Minas Passage, effects of tidal devices on fish and fish habitat).

In support of module 2, ATEI and OES-E co-hosted a workshop at the 2024 EIMR Conference entitled 'modeling fish interactions with tidal turbines'. The workshop included a series of presentations, including encounter rate modeling for fish in Minas Passage by Dr. Richard Karsten (ATEI) (Figure 3), and break-out groups to discuss the usefulness of existing modeling frameworks for understanding risk to fish, and the adequacy of current data collection methods to provide the data necessary for modeling. Workshop participants identified that current collision risk models are not suitable for very low probabilities of encounter, and highlighted that there are challenges incorporating fish behaviour (i.e., avoidance, evasion) into existing model frameworks. However, agent-based fish models currently being developed in the United States may help refine collision risk models with behavioural inputs. Workshop participants also identified a series of data gaps in our understanding of fish in tidal channels (e.g., residency time, identification and tracking of individual animals, and turbulence measurements) that also impact encounter rate and collision risk modeling efforts. There are few reliable estimates of fish population size, even though this is an important parameter to know when regulators request information about the expected mortality in a certain area, or request information about population-level consequences of harm or mortality stemming from collisions. Overall, workshop participants agreed that there are too few datasets available to create or validate fish collision risk models and that more acoustic fish tagging studies need to be conducted, especially localized near turbines to inform an assessment of avoidance. The workshop report has been completed after having undergone review and approval by the Pacific Northwest National Laboratory and the Water Power Technologies Office of the US Department of Energy, and is available in Appendix II and on the Tethys website here.

FORCE staff have been working with ATEI to explore the suitability of various current 'off-the-shelf' optical camera technologies (module 3) for testing at the FORCE tidal demonstration site, and are currently working to develop a short-list of recommended options for field testing. Some preliminary field experimentation was conducted by FORCE and ATEI during September in Minas Passage to test capabilities of optical cameras for detecting a Secchi disk at 2m range at various depths.

Work to define the requirements of a data management system (module 6) to support multiple high-bandwidth monitoring instruments at FORCE has been completed. This work was lead by PISCES Research Project Management with input from ATEI and FORCE. A final report was submitted, and is proving a valuable resource in the design and build of the data management infrastructure needed to support future environmental monitoring activities at the FORCE tidal demonstration site.

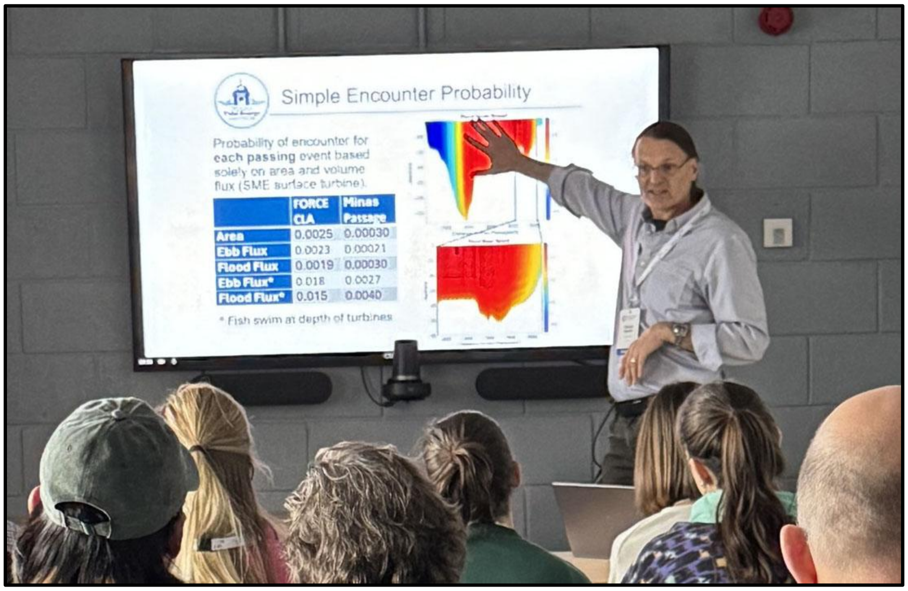

Figure 3: Dr. Richard Karsten (ATEI) presents finding of fish encounter rate modeling in Minas Passage at the EIMR 2024 workshop on modeling fish interactions with tidal turbines.

Risk Assessment Program

The Risk Assessment Program (RAP) for tidal stream energy is a collaborative effort between FORCE, academic partners, First Nations, and industry to advance our understanding of the environmental risks of tidal stream energy development in Minas Passage. The greatest potential risk of tidal stream energy device operations is believed to be from collisions between marine animals and turbine 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, turbulent 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 stream energy devices in the Bay of Fundy using a combination of physical oceanographic data related to flow and turbulence in the Minas Passage and acoustic tag detection 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 uses ADCP data combined with data from a high-resolution radar network to create the first spatiotemporal flow atlas of the Minas Passage to understand these hydrodynamic features. Concurrently, acoustic tag detection data for various migratory and resident fish species in the Bay of Fundy that is curated by OTN was compiled and is being analysed to understand their spatiotemporal distributions. The hydrodynamic and acoustic tag detection data will be combined with information about device 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 acoustic 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 tidal stream energy 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 2020, OTN has facilitated access to acoustic tag detection data from 22 contributors (17 projects), covering nine fish species in the Bay of Fundy (i.e., alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), American eel (*Anguilla rostrata*), Inner Bay of Fundy Atlantic salmon (*Salmo salar*), Atlantic sturgeon (*Acipenser oxyrhinchus oxyrhinchus*), Atlantic tomcod (*Microgadus tomcod*), spiny dogfish (*Squalus acanthias*), striped bass (*Morone saxatilis*), and white shark (*Carcharodon carcharias*)). FORCE has also established a high-resolution radar network in Minas Passage and has begun quantifying hydrodynamic features (turbulence, flow etc.) of Minas passage. The integration of physical habitat variables with acoustic tag detection data commenced in 2021, including the development of species distribution models for each species and species distribution maps. Fish tagging was undertaken during 2021-2024 in collaboration with the Mi'kmaw Conservation Group (MCG), Acadia University, Ocean Tracking Network, and DFO Science to validate predictions of the species distribution models, and focused on alewife, American shad, Atlantic sturgeon, spiny dogfish, and Inner Bay of Fundy Atlantic salmon post-smolts and kelts (Figure 4). Tagging efforts in 2024 included Inner Bay of Fundy Atlantic salmon kelts (Stewiacke River – in collaboration with ATEI and OTN) that were tagged and released in April (n=23) and December (n=79), and American shad (n=40 Kennetcook River – in collaboration with ATEI) that were tagged and released in May.

In 2021 and 2022, the FORCE array of acoustic receivers consisted of 12 stations set approximately 150 metres apart, and extended from the FORCE site out towards the middle of Minas Passage. However, this resulted in incomplete coverage of Minas Passage for detecting tagged fish. For 2023 and 2024, FORCE and OTN have collaborated to establish more complete coverage of the area by merging their respective lines of acoustic receivers into a 24-station array that spans the vast majority of Minas Passage (Figure 5), thereby increasing the probability of detecting tagged fish as they navigate through the area. This array was established in May 2023 and while the original intent was to recover the array in the fall, discussions between FORCE, Acadia and OTN extended the coverage through winter 2024 to increase the temporal scale of monitoring. FORCE's acoustic receivers were recovered for routine maintenance and battery replacement on May 14, but were quickly re-deployed on May 24 to ensure the integrity of the 24-station array was maintained to support data collection for FORCE and stakeholders in Minas Passage. On September 30, FORCE's acoustic receivers were recovered again for routine maintenance and battery replacement, and were redeployed on October 10. Advanced planning for spring 2025 is currently underway to ensure the integrity of the acoustic array is maintained while incurring minimal 'down time' for regular maintenance and battery replacement. Preliminary results suggest that merging the lines of acoustic receivers has improved the probability of detection of passing events for Inner Bay of Fundy Atlantic salmon post-smolts to p=0.979 (B. Sanderson, pers. comm 2024). Although this is encouraging, more work is needed to ensure the accuracy of this estimate.

Figure 4: Acoustic tagging of American shad from the Kennetcook River by Acadia University in 2024.

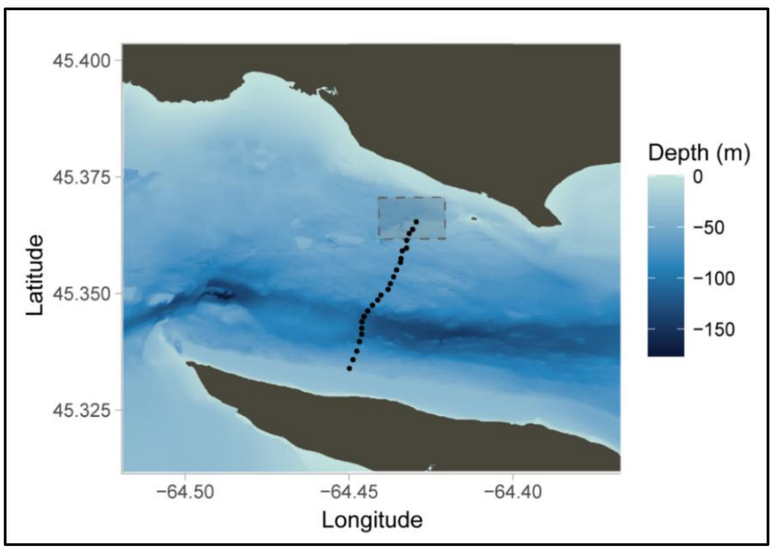

Figure 5: Acoustic receiver array deployment configuration (24 stations) in Minas Passage in 2023 and 2024. This more thorough coverage of Minas Passage for detecting tagged fish is made possible through collaboration between FORCE and OTN.

Several organizations have been independently conducting acoustic telemetry research for various fish species in the Bay of Fundy in recent years. To improve coordination of tagging activities and acoustic receiver deployments among these groups, improve efficiencies and share knowledge, FORCE initiated a meeting between ATEI, OTN, DFO St. Andrews, and The Confederacy of Mainland Mi’kmaq on October 28. Participants were enthusiastic to share knowledge about recent acoustic telemetry research and to explore ways to coordinate future activities. FORCE subsequently distributed a survey to meeting participants to gauge interest in level of engagement and to identify potentially important groups not included in the initial meeting that ought to be engaged with going forward. Interest in open dialogue and a coordinated approach to future research is well supported, and key participants in the initial meeting will discuss their work and the value of a coordinated effort during an upcoming session at the Atlantic Policy Congress Fisheries Conference and Awards Ceremony in Moncton, NB, in January 2025.

The RAP program has generated cutting-edge and award winning research on the application of acoustic telemetry for understanding the risk of tidal stream projects to fish in Minas Passage. Specifically, three manuscripts led by Dr. Brian Sanderson (Acadia University) have been published in a special issue of the *Journal of Marine Engineering and Science* entitled 'Interface between offshore renewable energy and the environment', and collectively highlight the efficacy of acoustic telemetry for estimating probability of fish-turbine encounter at the FORCE tidal demonstration site. The first of these papers, 'Measuring detection efficiency of high-residency acoustic signals for estimating probability of fish-turbine encounter in a fast-flowing tidal passage' was recently awarded the best paper for 2023 in the *Journal of Marine Science and Engineering.* All three of these papers are publicly available here.

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 will be broadcasted through the Canadian Integrated Ocean Observing System (CIOOS) later this year. Static ADCP data is currently available on the CIOOS website.[21]

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.

FORCE recently collaborated with Innovasea to test innovative new acoustic receiver technology in Minas Passage to assess instrument capabilities in high flow environments. Five different acoustic receiver technologies (with duplicates for redundancy) were mounted on the FAST-2 platform and deployed at the FORCE site in September 2023 (Figure 6). A Nortek

[21] This is available online at: https://catalogue.cioosatlantic.ca/dataset/ca-cioos_db15458d-df2c-4efb-b5a0-791e7561a0cb

Signature 500 Acoustic Doppler Current Profiler (ADCP) was deployed alongside the acoustic receivers to record flow speed, along with an OceanSonics icListen HF hydrophone to record underwater noise that can impact the detection of acoustic signals. A series of passive drifts were then conducted over the platform using acoustic tags of various frequencies deployed at differing depths. The drifts were conducted on the flood tide during the strong spring tides of late September and early October 2023. The platform was recovered in mid-October and the acoustic detection data downloaded from the receivers for analyses. Although preliminary, results of this work are encouraging, and suggest that a prototype acoustic receiver technology that is currently under development can detect acoustic tags at flow speeds up to 5 m/s; a considerable improvement over current 'off-the-shelf' acoustic receivers. FORCE continues to work with Innovasea to develop additional study designs to further assess the capabilities of this prototype technology.

Figure 6: FAST-2 platform equipped with five Innovasea acoustic receiver technologies (with duplicates for redundancy), an ADCP and hydrophone for recording flow speed and underwater noise.

FORCE is also collaborating on an Ocean Supercluster funded project lead by Innovasea, and in partnership with DeepSense (Dalhousie University), Nova Scotia Power Incorporated, and New Brunswick Power Corporation to advance the capabilities of artificial intelligence (AI) for monitoring fish around hydroelectric facilities and tidal stream energy devices. The HydroAware project will build off recent advances in the application of AI for detecting, identifying and tracking fish by Innovasea and DeepSense (Kandimalla et al. 2022), and shows promise for the renewable energy community, as improved fish monitoring capabilities may help address some of the challenges facing tidal stream energy projects in Canada.

Fish Tracking

To enhance fish monitoring and to expand its data collection capacity, FORCE partnered with the Ocean Tracking Network (OTN)[22] and attached one Innovasea (formerly VEMCO)[23] fish tag receiver (a VR2W 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. No C-POD mooring/SUBS have been deployed since 2020, however ongoing data collection for fish monitoring is occurring through the RAP acoustic receiver line.

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);
- 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);
- New York Juvenile White Shark Study (Tobey Curtis)
- Massachusetts White Shark Research Program (Greg Skomal); and
- St. Lawrence River Fish Monitoring (Valiquette, E., Légaré, J., Soulard, Y. 2020)

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 Innovasea 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

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

[23] Innovasea 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.innovasea.com.

sponsored by the OERA, NRCan, NSNRR, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).[24]

Discussion

Extension of the 2021-2023 EEMP to 2024 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. The EEMP is designed to prepare for effects testing with the deployment of operational devices, and adheres to the principles of adaptive management by evaluating existing datasets to ensure appropriate monitoring approaches are being implemented. Moreover, the plan adopts internationally accepted standards for monitoring where possible, including feasibility assessments for new monitoring approaches that are planned to be implemented.

Advances in monitoring capabilities made possible through programs like FORCE's Risk Assessment Program enhance our ability to understand how animals use Minas Passage, and contribute towards a better understanding of risk from the development of tidal stream power in the Upper Bay of Fundy. Ongoing research and the development of peer-reviewed publications add credibility to the innovative science activities that FORCE continues to undertake in support of its role as environmental steward. FORCE and its partners continue 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 stream energy devices in high flow environments, and specifically at the FORCE test site. Reports from FORCE's partners and updates are routinely subjected to 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 device and site-level 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-device 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 device 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 device(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 device technologies to understand if

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[24] Information about this project, and others funded through this program, is available online at: https://netzeroatlantic.ca/sites/default/files/2020-04/2020-04-09%20NRCan%20Public%20Report%20Final%20-%20Resize.pdf

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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Appendix I

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
CIOOS	Canadian Integrated Ocean Observing System
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	Kilometre(s)
kW	Kilowatt(s)
m	Metre(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
SUBS	Streamlined Underwater Buoyancy System
SME	Sustainable Marine Energy (Canada)
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
VEC(s)	Valuable Ecosystem Component(s)

Appendix II

Workshop on Modeling Fish Interactions with Tidal Turbines

April 19, 2024
Environmental Interactions of Marine Renewables
Kirkwall, Orkney, Scotland

Organizers

- Lysel Garavelli (Pacific Northwest National Laboratory)
- Anna Redden (Acadia University)

Contributors

- Charles Bangley (Dalhousie University)
- Richard Karsten (Acadia University)
- Jezella Peraza (University of Washington)
- Nicholas Horne (Queen's University Belfast)
- Lenaïg Hemery (Pacific Northwest National Laboratory)
- Daniel Hasselman (Fundy Ocean Research Center for Energy)

1. Context

The *Modeling Fish Interactions with Tidal Turbines* workshop was held at the Environmental Interactions of Marine Renewables (EIMR) 2024 conference to discuss the applicability of existing marine animal-turbine interaction approaches to fish, through numerical modeling. Consenting around tidal energy projects has been slowed in some jurisdictions by concerns about the risk to fish from tidal energy turbines, particularly the likelihood and potential consequence of collision risk. Concerns are emphasized for fish species of conservation concern and those that are commercially and recreationally important, and of cultural relevance to indigenous communities (e.g., salmonids, sturgeons). Obtaining high-quality, *in situ* data around operational devices in tidal channels and developing numerical models can help answer uncertainties that remain around fish-turbine interactions.

This workshop sought to bring together expertise on encounter rate and collision risk modeling to identify current approaches, knowledge gaps, challenges, and potential solutions for applying these techniques to fish-turbine interactions in a collaborative environment. The workshop consisted of a series of presentations that provided context on collision risk, collision risk and encounter rate models, and data around fish spatiotemporal distribution, and breakout groups with guided discussions that allowed workshop participants to engage and share their thoughts about models and data gaps. There were 25 participants in attendance at the workshop.

2. Structure of the Workshop

The workshop began with five short presentations from experts focused on collision risk and collision/encounter modeling. Anna Redden gave an introduction to collision risk as it pertains to fish, including some of the challenges with monitoring fish-turbine interactions, as well as introducing the agenda for the workshop and a game plan for the discussion section. Lysel Garavelli presented existing approaches to collision risk and encounter rate models and the input data required for those models. Charles Bangley and Richard Karsten gave a joint presentation on passive acoustic tagging of fish to build static spatiotemporal distribution maps and estimate the extent of overlap with areas of planned turbine installation. Jezella Peraza provided an overview of an agent-based model to examine fish avoidance and behavior on fish-turbine interactions. And lastly, Nicholas Horne gave a presentation on collision risk assessments with a simulation-based model.

After the presentations, participants were separated into three breakout groups, along with two facilitators per group. The facilitators used a series of questions to guide the discussion around the usefulness and suitability of models and the data needed to inform collision and encounter risk models.

Questions asked during the breakout discussions are below:

- Usefulness/suitability of models
  - Are existing models sufficient for the assessment of encounter rate and collision risk?
  - Can these models be used for assessing the effects on fish populations?
- Data for collision risk & encounter rate models
  - How adequate are the various data collection methods and associated data, used separately or in combination, in delineating the risk of collision?
  - What are the specific gaps in knowledge and data in the current encounter and collision risk models?
  - What methods and data do you recommend moving forward?
  - How can these methods and associated data be used to inform encounter and collision risk models?
  - What do we need to extract from the field data to parameterize and validate the models?

3. Breakout Discussions Summary

Usefulness and Suitability of Models

Participants discussed existing encounter rate and collision risk models, their limitations, and suggestions for improvement. Models are important for informing collision risk at each site because scientists cannot monitor every single turbine. However, participants agreed that collision risk models are not suitable for very low probabilities of encounter, and that there are challenges with understanding and incorporating behavior (i.e., avoidance, evasion) into models. Current collision risk models incorrectly assume that fish exhibit naïve behavior around turbines, when in fact field and laboratory evidence suggests that some fish species can exhibit avoidance/evasion behaviors under varying environmental conditions; it is important to incorporate these behaviors into model predictions. For example, agent-based fish models currently being developed in the US may help fine-tune models with behavioral inputs. In addition, collision risk models are sensitive to population density; however, this is often not accurately known for many fish species. Models that assume 100% mortality from collision are inaccurate and are no longer suitable for helping to contextualize the risk of fish-turbine interactions.

Participants discussed areas where monitoring and adaptive management are sufficient such as when the risk of collision is considered low (e.g., no collisions have been observed during the given study period). However, as the industry scales to arrays, monitoring and adaptive management will need to adapt.

As new data become available, experts from a variety of fields need to be involved in the development of collision risk models to ensure they provide realistic results. Participants described models as tools to instill confidence in regulatory decision-making; however, participants also cautioned that models require updating as new and better baseline and effects testing monitoring data are collected around operational turbines.

Data for Collision/Encounter Risk Models

Participants discussed data gaps for encounter rate and collision risk models, which include residency time, identification and tracking of individual animals, and turbulence measurement to determine fish school density. Detecting fish in high-flow speed areas remains challenging, as does measuring fine-scale evasion. There are few reliable estimates of fish population size, even though it is an important parameter to know when regulators ask for the expected number of fish mortality in a certain area or population-level consequences of harm or mortality stemming from collisions. Currently, there are too few datasets to create or validate fish collision models; more acoustic fish tagging studies need to be conducted, especially localized near turbines to inform an assessment of avoidance. The lack of deployed devices makes it challenging to obtain knowledge about collision risk. In addition, it was suggested multiple times throughout the discussions to conduct sensitivity analyses of the models to assess the influence of model parameters and understand which component influences the risk of collision the most (e.g., the size of a turbine blade). Some models are a little bit of a ‘black box’; understanding the key components driving each model and their relative influence on the outputs is crucial.

The biggest gap remains the lack of observations of fish-turbine interactions and actual evidence of collision events to inform models. Large amounts of data have not been processed yet and are waiting for review by trained scientists; these unprocessed data could be impeding advancements of these models. Datasets collected with video cameras or active acoustic technologies are large, so there is a need for motion detection algorithms and machine learning to speed up the post-processing, analyses, and automation of species identification.

Sharing environmental data among site developers and the scientific community will help the marine renewable energy industry progress; however, this requires increased levels of collaboration, cooperation, and trust. Broader collaborations are needed between modelers, developers, and those designing monitoring programs, collecting the data, and analyzing the data.

4. Recommendations

To improve collision risk and encounter rate models, workshop participants recommended that the following actions are important:

- Not assume that all collisions result in mortality;
- Assess and use periods of increased species prevalence to collect data and train models;
- Improve models as new observational data on fish-turbine interactions (e.g., avoidance, behavior) becomes available and use data-rich models to inform field study designs;
- Ensure realism during model refinement by involving experts from a variety of disciplines (e.g., computational fluid dynamics, fish behavior and locomotion, computer science, etc.);
- Broaden collaborations between modelers, project developers, marine engineers, those designing monitoring programs, those collecting data, and those processing and analyzing data, and reporting monitoring results; and
- Strengthen models using data to be used as proxies for fish species of concern that behave similarly.

To better inform encounter rate and collision risk models, participants recommended the need to:

- Increase data about behavioral responses to understand what an animal does when it detects a turbine;
- Use a combination of data collection methods such as acoustic tags, visualization surveys, and multibeam sonar;
- Collect quality fish detection data over all seasons to inform model refinement;
- Understand whether collisions occur on an individual level in the first instance before focusing on population-level consequences;
- Prioritize the development of motion detection algorithms and machine learning to identify fish species for faster post-processing of large active acoustic and optical datasets; and
- Share environmental data among site developers and the scientific community.

Participants also recommended that guidance materials about collision risk be updated regularly with the best available science as they can become outdated quickly. A coalition of subject matter experts (such as this workshop) should help guide these updates. It was also suggested that a review paper be prepared about fish-turbine interaction modeling approaches applicable to tidal energy device sites. While the workshop focused on collision risk, displacement was brought up a few times, with participants recommending that it be assessed at the same time as collision, especially as it becomes more relevant with the industry scaling up towards deploying arrays of devices.

Appendix 1: Workshop Agenda

9-9:30:

- **Anna Redden** – Introduction to collision risk
- **Lysel Garavelli** – Overview of known encounter rate and collision risk models

9:30-10:

- **Charles Bangley** and **Richard Karsten** – Using passive acoustic tracking to build fish distribution maps and calculate encounter probability

10-10:30:

- **Jezella Peraza** – Using an agent-based model to examine the effects of avoidance and behavior on fish-turbine interactions
- **Nicholas Horne** – Comprehensive collision risk assessments with a simulation-based model

10:30-10:45: Break

10:45-11:35: Breakout discussions

11:35-12:00: Report out and open discussion