



# Environmental Effects Monitoring Program

## Quarterly Report: January-March 2024

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## What's New?

### 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](#)

## 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;
- 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 (MCG), 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 will continue in 2024 and beyond 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 during the first quarter 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](http://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 January through March 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<sup>1</sup> selected by the Nova Scotia Department of Natural Resources and Renewables. Current berth holders at FORCE are:

- Berth A: Eauclaire Tidal Limited Partnership<sup>2</sup>
- Berth B: Rio Fundo Operations Canada Limited<sup>3</sup>
- Berth C: Sustainable Marine Energy (Canada)<sup>4</sup>
- Berth D: Big Moon Power Canada
- Berth E: Halagonia Tidal Energy Limited<sup>5</sup>

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<sup>1</sup> Further information about each company may be found at: [fundyforce.ca/partners](https://fundyforce.ca/partners)

<sup>2</sup> 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.

<sup>3</sup> 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.

<sup>4</sup> In June 2023, Sustainable Marine Energy announced voluntary bankruptcy, citing the lack of a regulatory pathway with DFO, with Deloitte Canada appointed as trustee.

<sup>5</sup> 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<sup>6</sup> 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](http://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.<sup>7</sup>

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' ( $\leq 100$  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.<sup>8</sup> 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 commitments,

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

<sup>7</sup> 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.

<sup>8</sup> Information about EMAC may be found online at: [www.fundyforce.ca/about-us](http://www.fundyforce.ca/about-us)



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.<sup>9</sup> 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 has until December 31, 2024, to raise the turbine. The project start date for BigMoon is not known at this time, but is anticipated to commence in 2025.

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 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 (formerly Black Rock Tidal Power) installed a PLAT-I system in Grand

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

Passage, Nova Scotia under a Demonstration Permit.<sup>10</sup> 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.<sup>11</sup> 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.

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 ~ 1/1,000<sup>th</sup> 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

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

<sup>11</sup> 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>.

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<sup>12</sup>, TC114<sup>13</sup>, the Atlantic Canadian-based Ocean Supercluster<sup>14</sup>, and OES-Environmental<sup>15</sup>.

FORCE will continue to work closely with OES-Environmental and its members to document and improve the state of knowledge about the interactions of MRE devices interactions with the marine environment. For instance, OES-Environmental is pursuing the development of 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, between ecosystems and between ecosystem services. Dr. Daniel J. Hasselman, FORCE Science Director, is involved in the development of all three of these topics and lead 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 will be included in a chapter of the OES-E 2024 State of the Science Report that is scheduled for release in the fall of 2024.

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<sup>12</sup> BoFEP is a 'virtual institute' interested in the well-being of the Bay of Fundy. To learn more, see [www.bofep.org](http://www.bofep.org).

<sup>13</sup> 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](http://tc114.oreg.ca).

<sup>14</sup> 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](http://www.oceansupercluster.ca).

<sup>15</sup> 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>.

On January 20<sup>th</sup>, Dr. Hasselman chaired a workshop at the 3<sup>rd</sup> 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.

## 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)<sup>16</sup> 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 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.<sup>17</sup> A similar process will be used for the development of the next iteration of the EEMP (i.e., 2025-2028).

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:

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<sup>16</sup> This document is available online at: [www.fundyforce.ca/document-collection](http://www.fundyforce.ca/document-collection).

<sup>17</sup> 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.

- 8 days of lobster surveys;
- 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 January-March 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 effect predictions made in the original EA. These predictions were generated through an evaluation of existing physical, biological, and socioeconomic conditions of the study area, and an assessment of the risks the tidal energy demonstration project poses to components of the ecosystem.

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

| <b>FORCE Environmental Effects Monitoring VEC</b> | <b>Objectives</b>   |
|---|---|
| <b>Lobster</b>                                    | <ul style="list-style-type: none"> <li>• to determine if the presence of a tidal stream energy device affects commercial lobster catches</li> </ul> |



|                                 |   |
|---------------------------------|---|
| <b>Fish</b>                     | <ul style="list-style-type: none"> <li>● to test for indirect effects of tidal stream energy devices on water column fish density and fish vertical distribution</li> <li>● 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</li> </ul> |
| <b>Marine Mammals</b>           | <ul style="list-style-type: none"> <li>● to determine if there is permanent avoidance of the study area during device operations</li> <li>● to determine if there is a change in the distribution of a portion of the population across the study area</li> </ul>   |
| <b>Marine Sound (Acoustics)</b> | <ul style="list-style-type: none"> <li>● to conduct ambient sound measurements to characterize the soundscape prior to and following deployment of the tidal stream energy device</li> </ul>  |
| <b>Seabirds</b>                 | <ul style="list-style-type: none"> <li>● to understand the occurrence and movement of bird species in the vicinity of tidal stream energy devices</li> <li>● to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to tidal stream energy devices</li> </ul>                             |

## 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  $\geq$  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 has been conducting mobile fish surveys since May 2016 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 CL and reference site, suggesting that the reference site may not be sufficiently representative to serve as a control for the CLA, and for testing the effects of an operational 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 species of conservations concern, cultural relevance, and commercial and recreational value. The results of this synthesis project will be available in 2024 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 in 2024.



## 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.<sup>18</sup> 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’<sup>19</sup> 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 4<sup>th</sup> 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

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<sup>18</sup> The C-PODs, purchased from Chelonia Limited, are designed to passively detect marine mammal ‘clicks’ from toothed whales, dolphins, and porpoises.

<sup>19</sup> A ‘C-POD day’ refers to the number of total days each C-POD was deployed times the number of C-PODs deployed.

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 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](https://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 America. 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 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 already 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.

### 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 oxyrinchus oxyrinchus*), 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 2021-2023 in collaboration with the Mi'kmaw Conservation Group (MCG), Acadia University, 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 (Figure 3). Tagging efforts in 2024 will include Inner Bay of Fundy Atlantic salmon kelts (n=29; Stewiacke River – in collaboration with ATEI and OTN), and American shad (n=40 Kennetcook River).

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 4), 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 until spring 2024 to increase the temporal scale of monitoring. 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 3: Acoustic tagging of spiny dogfish from the Minas Basin by RAP partner organization Mi'kmaw Conservation Group in 2022.

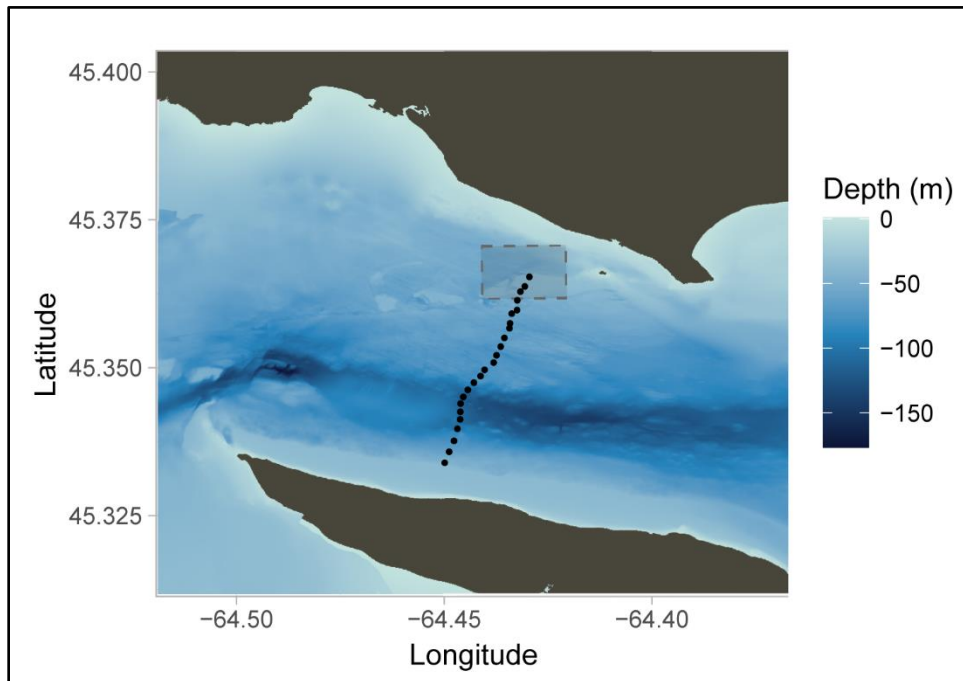


Figure 4: Acoustic receiver array deployment configuration (24 stations) in Minas Passage in 2023 and 2024. This more thorough coverage of Minas Passage for detecting tagged fish is made possible through collaboration between FORCE and OTN.

The RAP program has generated cutting-edge 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. 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.<sup>20</sup>

## 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 5). A Nortek 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 5: 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.

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<sup>20</sup> This is available online at: [https://catalogue.cioosatlantic.ca/dataset/ca-cioos\\_db15458d-df2c-4efb-b5a0-791e7561a0cb](https://catalogue.cioosatlantic.ca/dataset/ca-cioos_db15458d-df2c-4efb-b5a0-791e7561a0cb)

FORCE is also collaborating on an Ocean Supercluster funded project lead by Innovasea, and in partnership with DeepSense (Dalhousie University), BigMoon Power, 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)<sup>21</sup> and attached one Innovasea (formerly VEMCO)<sup>22</sup> 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 (Zydlowski, 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)

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<sup>21</sup> Ocean Tracking Network's website: [www.oceantrackingnetwork.org](http://www.oceantrackingnetwork.org).

<sup>22</sup> 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](http://www.innovasea.com).

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 sponsored by the OERA, NRCan, NSNRR, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).<sup>23</sup>

## 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.

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<sup>23</sup> 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>

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 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)        |