Environmental Effects Monitoring Program

Quarterly Report: January - March 2019

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Executive Summary

Tidal in-stream energy is an emerging marine renewable energy sector designed to generate electricity from the ebb and flow of the tides, and is being explored by countries around the world.

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

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

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

- ~408 hours of hydroacoustic fish surveys;
- more than 2,690 'C-POD' marine mammal monitoring days;
- bi-weekly shoreline observations;
- 42 observational seabird surveys;
- four drifting marine sound surveys and additional sound monitoring
- 11 days of lobster surveys

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

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

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

This report provides a summary of monitoring activities and data analysis completed at the FORCE site up to the end of the first quarter of 2019. In addition, it also highlights findings from international research efforts, previous data collection periods at the FORCE site, and additional research work of FORCE and its partners. This includes supporting fish tagging efforts with Acadia University and the Ocean Tracking Network, radar research projects, and subsea instrumentation platform deployments through the Fundy Advanced Sensor Technology (FAST) Program. Finally, the report presents details regarding future research and monitoring efforts at the FORCE test site.

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

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Appendices

Acronyms

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

Q1/2/3	Quarter (1, 2, 3), based on a quarterly reporting schedule
R&D	Research and Development
TC114	Technical Committee 114
TISEC	Tidal In-Stream Energy Converter
SUBS	Streamlined Underwater Buoyancy System
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
VEC(s)	Valuable Ecosystem Component(s)

Introduction

This report outlines monitoring activities occurring at the Fundy Ocean Research Center for Energy (FORCE) test site in the Minas Passage, Bay of Fundy throughout the first quarter of 2019 (January 1st – March 31st; 'Q1'). Specifically, this report highlights results of environmental monitoring activities conducted in the mid-field and near-field 'zones' and other research and development (R&D) activities conducted at the FORCE site. This report also provides a summary of international research activities around tidal energy devices.

About FORCE

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

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

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

As 'host,' the FORCE project currently consists of five undersea berths for subsea turbine generators, four subsea power cables that will connect the turbines to land-based infrastructure, an onshore substation and power lines connected to the Nova Scotia Power (NSPI) transmission system, and a Visitors/Operations Center. FORCE's onshore facilities, including its Visitor/Operations Centre and electrical substation, are located approximately 10 km west of Parrsboro, Nova Scotia.

The marine portion of the project is located in a leased area from the province (FORCE's Crown Lease Area, or 'CLA'), 1.6 km x 1.0 km in area, in the Minas Passage. It is also identified as a 'Marine Renewable-electricity Area' (MREA) under the Province's *Marine Renewable-energy Act*. This area consists of five subsea 'berths' that are leased to tidal energy companies[1] selected by the Nova Scotia Department of Energy and Mines (DEM). These companies are:

Berth A: Minas Tidal
Berth B: Black Rock Tidal Power[2]
Berth C: Atlantis Operations (Canada) Ltd./DP Energy[3]

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

[2] On January 17th, 2019, it was announced that Black Rock Tidal Power would be changing its name to Sustainable Marine Energy (Canada) Ltd. and would transfer assets from SCHOTTEL to Sustainable Marine Energy. Learn more: sustainablemarine.com/news/schottel

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

Berth D: Cape Sharp Tidal Venture (CSTV)
Berth E: Halagonia Tidal Energy[4]

As 'steward,' monitoring and associated reporting is fundamental to FORCE's mandate—to assess whether in-stream tidal energy turbines can operate in the Minas Passage without causing significant adverse effects on the environment, electricity rates, and other users of the Bay.

In this way, FORCE has a role to play in supporting informed, evidence-based decisions by regulators, industry, the scientific community, and the public. As deployments of different TISEC designs are expected to be phased in over the next several years, FORCE and regulators will have the opportunity to learn and adapt environmental monitoring approaches as lessons are learned.

Background

The FORCE demonstration project received its environmental assessment (EA) approval on September 15th, 2009 from the Nova Scotia Minister of Environment. The conditions of its EA approval[5] provide for comprehensive, ongoing, and adaptive environmental management. Since that time, the EA approval has been amended to accommodate changes in technologies and inclusion of more berths to facilitate provincial demonstration goals.

Since its EA approval, FORCE has been conducting an Environmental Effects Monitoring Program ('EEMP') to better understand the natural environment of the Minas Passage and the potential effects of turbines as related to fish, seabirds, marine mammals, lobster, marine sound, benthic habitat, and other environmental variables. All reports on site monitoring are available online at: www.fundyforce.ca/environment.

Since 2009, more than 100 related research studies have been completed or are underway with funding from FORCE, the Offshore Energy Research Association of Nova Scotia (OERA), and others. These studies have considered socio-economics, biological, and other research areas.[6]

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

All near-field and mid-field monitoring programs are reviewed by FORCE's Environmental Monitoring Advisory Committee (EMAC), which includes representatives from scientific, First

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

[5] FORCE's Environmental Assessment Registration Document and conditions of approval are found online at: www.fundyforce.ca/environment/enviromental-assesment.

[6] OERA's Tidal Energy Research Portal (http://tidalportal.oera.ca/) includes studies pertaining to infrastructure, marine life, seabed characteristics, socio-economics and traditional use, technology, and site characterization.

Nations, and local fishing communities.[7] These programs are also reviewed by federal and provincial regulators prior to turbine installation. In addition, FORCE and berth holders also submit an Environmental Management Plan (EMP) to regulators for review prior to turbine installation. EMPs include: environmental management roles and responsibilities and commitments, environmental protection plans, maintenance and inspection requirements, training and education requirements, reporting protocols, and more.

Turbine Deployments

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

On July 22nd, 2018, CSTV installed a two-megawatt OpenHydro turbine at 'Berth D' of the FORCE site and successfully connected the subsea cable to the turbine. CSTV confirmed establishment of communication with the turbine systems on July 24th. On July 26th, 2018, Naval Energies unexpectedly filed a petition with the High Court of Ireland for the liquidation of OpenHydro Group Limited and OpenHydro Technologies Limited. [8] For safety purposes, the turbine was isolated from the power grid on July 26th. On September 4th, 2018, work began to re-start the turbine. In the days following, it was confirmed that the turbine's rotor was not turning. It is believed an internal component failure in the generator caused sufficient damage to the rotor to prevent its operation. Environmental sensors located on the turbine and subsea base continued to function at that time with the exception of one hydrophone.

As a result of the status of the turbine, the monitoring requirements and reporting timelines set out in CSTV's environmental effects monitoring program were subsequently modified under CSTV's Authorization from Fisheries and Oceans Canada (DFO). The modification requires that CSTV provide written confirmation to regulators on a monthly basis that the turbine is not spinning by monitoring its status during the peak tidal flow of each month. This began October 1st, 2018 and was expected to continue until the removal of the turbine. However, as a result of the insolvency of OpenHydro Technology Ltd., all near-field reporting activities by CSTV ceased as of March 1st, 2019. Since that time, FORCE has begun reporting to regulators regarding the turbine rotor's status. An update prepared by CSTV is included in Appendix 1 of this report.

Additional turbines are expected to be deployed at the FORCE site in the coming years. In 2018, Black Rock Tidal Power installed a PLAT-I system in Grand Passage, Nova Scotia under a Demonstration Permit.[9] This permit allows for a demonstration of the 280 kW system to help Black Rock Tidal Power and its partners learn about how the device operates in the marine environment of the Bay of Fundy. Also in 2018, Natural Resources Canada announced a $29.8

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

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

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

million contribution to Halagonia Tidal Energy's project at the FORCE site through its Emerging Renewable Power Program.[10] The project consists of floating and submerged turbines for a total of nine megawatts—enough capacity to provide electricity to an estimated 2,500 homes.

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

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

International Experience & Cooperation

The research and monitoring being conducted at the FORCE test site is part of an international effort to evaluate the risks tidal energy poses to marine life (Copping et al., 2016). Presently, countries such as China, France, Italy, the Netherlands, South Korea, the United Kingdom, and the United States (Marine Renewables Canada, 2018) are exploring tidal energy, supporting environmental monitoring and innovative R&D projects. Tidal energy, and other marine renewable energy (MRE) technologies (i.e., tidal range, tidal current, wave, ocean thermal energy) offer significant opportunities to replace carbon fuel sources in a meaningful and permanent manner – some estimates place MRE's potential as exceeding current human energy needs (Gattuso et al., 2018; Lewis et al., 2011). Recent research includes assessments of operational sounds on marine fauna (Lossent et al., 2017; Schramm et al. 2017; Polagye et al. 2018; Pine et al. 2019), the utility of PAM sensors for monitoring marine mammal interactions with turbines (Malinka et al., 2018) and collision risk (Joy et al. 2018), and the influence of tidal turbines on fish behavior (Fraser et al. 2018).

Through connections to groups supporting tidal energy demonstration and R&D, FORCE is working to inform the global body of knowledge pertaining to environmental effects associated with tidal power projects. This includes participation in the Fundy Energy Research Network (FERN),[11] the Bay of Fundy Ecosystem Partnership (BoFEP),[12] TC114,[13] and the Atlantic Canadian-based Ocean Supercluster (OSC).[14]

Another key group is Annex IV (now known as OES Environmental), a forum to explore the present state of environmental effects monitoring around MRE devices.[15] Last year, for instance, FORCE worked with OES Environmental members[16] to discuss best management practices regarding data transferability, "using data from an already permitted/consented MRE project or analogous industry to be 'transferred' to inform potential environmental effects and consenting for a future MRE project" (Copping et al., 2018, p. 4), and collection consistency—that is, transferring practices and learnings across jurisdictions and project sites. Moving forward, FORCE will continue to work with Annex IV and its members to document and improve the state of knowledge pertaining to MRE devices' interactions with the marine environment.

To better do so, FORCE Science Director, Dr. Daniel Hasselman, attended a one-day workshop in Edinburgh, Scotland led by Annex IV and the Offshore Renewables Joint Industry Programme

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

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

[13] 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.

[14] 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.

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

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

(ORJIP)[17] to discuss collision risks associated with MRE devices. The purpose of the workshop was to overview pre-existing data in an effort to understand the risk profile of fish and marine mammal collision – that is, to determine the relative probability of a collision with a turbine and the relative consequence of the collision, should it occur. The workshop included a series of presentations from key groups working to understand turbine-animal interactions and included an overview of various integrated sensor platforms used in monitoring. Break out groups convened for the afternoon in an effort to develop detailed project plans for strategic research projects relevant to collision risk.

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

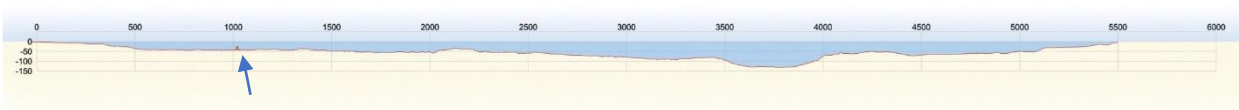

Figure 1: The scale of a single turbine (based on the dimensions of the OpenHydro turbine deployed by CSTV, indicated by the red dot and above the blue arrow) in relation to the cross-sectional area of the Minas Passage. The Passage reaches a width of ~ 5.4 km and a depth of 130 m.

Presently, the global understanding of the potential impacts of MRE devices is based on a few deployments—often of single devices and increasing numbers of small arrays, notably the MeyGen project in Pentland Firth, Scotland[18] and a project led by Nova Innovation in Bluemull Sound, Scotland.[19] To gain understanding of the environmental monitoring conducted for projects in the United Kingdom and insight into operational limitation of sensors used, FORCE staff (Dr. Dan Hasselman and two ocean technologists, Tyler Boucher and Ray Pieroway) visited Scotland in early February. FORCE met with staff and graduate students Marine Scotland Science (MSS), the University of Aberdeen (UoA), and the University of Highlands and Islands-Environmental Research Unit (UHI-ERI). Each group provided presentations (overviews) of monitoring activities to the other and discussed the common challenge of monitoring in high flow environments. While the regulatory environment may differ in the UK vs. Canada, it's important to acknowledge that researchers in the UK are still working towards developing monitoring techniques that are suitable for turbine-animal interactions. A major take away from this trip was the difference in access to infrastructure and human resources and how that

[17] ORJIP has a mandate to bring together industry, regulators, academia, and others to work on key environmental and consenting issues in the offshore wind and ocean energy sectors. To learn more, visit: www.orjip.org.uk.
[18] To learn more about this project, visit https://simecatlantis.com/projects/meygen.
[19] To learn more about this project, visit https://www.novainnovation.com/bluemull-sound.

has influenced monitoring capabilities and the advancement of our understanding of how to monitor environmental effects. Marine Scotland Science has access to two research vessels (i.e., 'Alba na Mara' and 'Scotia') that can house multiple scientists and stay at sea for extended periods of time for monitoring. Similarly, UoA and UHI-ERI have access to a cadre to graduate students who have each dedicated 4-6 years of effort towards addressing monitoring challenges for the MRE sector. Overcoming the monitoring challenges at FORCE requires a similar level of dedication and access to resources.

Mid-Field Monitoring Activities

FORCE has been leading 'mid-field area' or 'site-level' monitoring for a number of years, focusing a variety of environmental variables. FORCE's present environmental effects monitoring program (EEMP), introduced in May 2016, was developed in consultation with SLR Consulting (Canada);[20] strengthened by review and contributions by national and international experts and scientists, DFO, NSE, and FORCE's EMAC; and adjusted based on experience and lessons learned, in keeping with the adaptive management approach—the process of monitoring, evaluating and learning, and adapting (AECOM, 2009) that has been used at the FORCE site since its creation in 2009.[21]

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

- 408 hours of hydroacoustic fish surveys;
- more than 2,690 'C-POD' (marine mammal monitoring) days;
- bi-weekly shoreline observations;
- 42 observational seabird surveys;
- four drifting marine sound surveys and additional bottom-mounted instrument sound data collection; and
- 11 days of lobster surveys.

The following pages provide a summary of the mid-field monitoring activities conducted at the FORCE site thus far in 2019 (January 1st – March 31st), including data collection, data analyses performed, initial results, and lessons learned building activities and analyses from previous years. Where applicable, this report also presents analyses that have integrated data collected through the near-field and mid-field monitoring programs in an effort to provide a more complete understanding of turbine/marine life interactions.

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

[21] 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.

This year represents a pivotal period in the continued adaptation of FORCE's EEMP. Specifically, if the CSTV turbine is non-operational (i.e., the rotor is no longer spinning), its full range of environmental effects cannot be fully assessed. Further, some monitoring during this time may not contribute to enhancing baseline data as a non-functional turbine could serve as an artificial reef to which some marine animals might be attracted to seek shelter in and around (Langhamer et al., 2009; Wilson and Elliott, 2009; Andersson and Öhman, 2010; Langhammer, 2012), thereby influencing the data collected. As such, FORCE will use this period of time to continue to evaluate the utility of environmental sensors and protocols used for environmental monitoring in high-flow sites. Building on advice from regulators and FORCE's EMAC, FORCE will focus its efforts in 2019 on evaluating monitoring instrumentation capabilities, data synthesis and integration activities, and mid-field monitoring (elaborated below), where appropriate.

Monitoring Objectives

The overarching purpose of environmental monitoring is to test the accuracy of the environmental effect predictions made in the original EA. These predictions were generated through an evaluation of existing physical, biological, and socioeconomic conditions of the study area, and an assessment of the risks the tidal energy demonstration project poses to components of the ecosystem.

A comprehensive understanding of turbine/marine life interactions will not be possible until turbine-specific and site-level (i.e., near- and mid-field) monitoring efforts are integrated and additional data is collected in relation to operating turbine(s). Further, multi-year data collection will be required to consider seasonal variability at the FORCE test site and appropriate statistical analyses of this data will help to obtain a more complete understanding of marine life/turbine interactions.

Table 1 outlines the objectives of the respective mid-field monitoring activities conducted at the FORCE demonstration site. Further information about near-field monitoring is included in this report and detailed information is provided by CSTV in Appendix 1. Appendices and Near-field Monitoring Summary sections will be updated as additional turbines are scheduled for demonstration at the FORCE demonstration site.

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

Mid-Field Environmental Effects Monitoring VEC	***Objectives***
Lobster	● to determine if the presence of an in-stream tidal energy turbine affects commercial lobster catches
Fish	● to test for indirect effects of in-stream tidal energy turbines on water column fish density and fish vertical distribution ● to estimate probability of fish encountering a device based on fish density proportions in the water column relative to turbine depth in the water column
Marine Mammals	● to determine if there is permanent avoidance of the mid-field study area during turbine operations ● to determine if there is a change in the distribution of a portion of the population across the mid-field study area
Marine Sound	● to conduct ambient sound measurements to characterize the soundscape prior

(Acoustics)		to and following deployment of the in-stream turbines
Seabirds	●	to understand the occurrence and movement of bird species in the vicinity of in-stream tidal energy turbines
	●	to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to in-stream tidal energy turbines

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

Lobster

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

Overall, the 2016 survey noted high catchability rates (> 2.7 kg/trap)[22] and measured 351 lobsters. Preliminary qualitative analysis by NEXUS indicates that catch rates declined during the survey period, likely due to increasing tidal velocities during the progression of the study – there was a statistically significant negative relationship between catch rates and maximum tidal rang, indicating lower catch rates during higher flows. Catch rates, further, did not increase significantly with depth, and qualitative analyses suggested no significant different in catch rates across different locations from the turbine location. These initial results may indicate the impact of turbines may be higher on lobster catchability than anticipated in the EA (AECOM, 2009); however, data collection in the presence of an operational turbine is needed to compare to the 2017 survey dataset and to verify the EA predictions.

FORCE and NEXUS had planned to conduct a second lobster catchability survey in fall 2018 to complete a comparative analysis with the baseline data from 2017. The intent of the comparative study is to determine if the presence of an in-stream tidal energy turbine affects commercial lobster catches within the Minas Passage. Specifically, this study – with pre-installation and operating turbine data collection periods – is designed to test the EA prediction

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

that in-stream turbines will have minimal impacts on lobster populations within the FORCE test site (AECOM, 2009).

This plan, however, was contingent on the presence of an operational turbine in order to assess the impacts a turbine might have on lobster in the Minas Passage. Given the non-operational status of the CSTV turbine, the objectives of the 2018 survey effort could not be achieved, and therefore, the survey was postponed until such time as an operational turbine is present at the site. In the interim, FORCE is continuing to examine alternative lobster monitoring methods, including non-catchability studies, in the Minas Passage.

Fish

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

- test for indirect effects of in-stream tidal energy turbines on water column fish density and fish vertical distribution; and
- estimate the probability of fish encountering a device based on any 'co-occurrence' relative to turbine depth in the water column.

These goals were laid out to test the EA prediction that in-stream tidal turbines are unlikely to cause substantial impacts to fishes at the test site (AECOM, 2009). These surveys are designed to permit a comparison of data collected before a turbine is installed with data collected while a turbine is operational at the FORCE site as well as in relation to a reference site along the south side of the Minas Passage – the nature of this design is referred to as 'BACI': Before/After, Control/Impact.

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

Analyses of hydroacoustic fish surveys completed during baseline studies in 2011 and 2012 (Melvin and Cochrane, 2014) and surveys May 2016 – August 2017 (Daroux and Zydlewski, 2017) have observed similar fish densities at the FORCE test site and the reference site, including similar patterns of seasonal change. These analyses also evaluated changes in fish densities in association with diel stage (day/night), tidal stage (ebb/flood), and turbine presence or absence (during the evaluated periods, an OpenHydro turbine was present November 2016 – June 2017). Results to-date support the EA prediction that in-stream tidal turbines have minimal impact on marine fishes, but further data in relation to an operating turbine is required to fully test this prediction. FORCE and the University of Maine are continuing to process and analyze datasets from surveys conducted in late 2017 and throughout 2018, which will help to contribute to the growing body of knowledge of fish species at the FORCE site.

It is important to note, however, that like the lobster survey program, the fish monitoring program requires the presence of an operational turbine at the FORCE site in 2018 for testing its effects. Further, a non-operational turbine may bias baseline data collection as the turbine may serve as a Fish Aggregation Device (i.e., a 'FAD') (Wilhelmsson et al. 2006). Therefore, FORCE is planning to conduct fish surveys during known periods of peak migration in 2019 – notably, in spring to capture migration periods of alewife, Atlantic herring, striped bass, Atlantic sturgeon, American shad, Atlantic mackerel, and rainbow smelt (Baker et al., 2014; Stokesbury et al., 2016) and also in late fall in consideration of outward migration of Atlantic herring, blueback herring, and alewife (Townsend et al., 1989). However, these data collection efforts are contingent on operational status of the turbine and suitable weather conditions.

In the interim, FORCE staff, in cooperation with Echoview Software (Tasmania, Australia) and the University of Maine, have been focusing efforts on data processing and analysis of fish survey data as well as in support of a comparative analysis with data collected from a bottom-mounted system (see 'Platform Projects' below). Presently, FORCE staff are undertaking data processing to enable the University of Maine and Echoview staff to complete data analysis and reporting and to improve the efficiency data processing. In addition to building a skillset for processing within Nova Scotia, this process also enables the FORCE team to better complete data collection activities moving forward.

Marine Mammals

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

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

Passive Acoustic Monitoring

The first component of FORCE's marine mammal monitoring program involves the use of PAM mammal detectors known as C-PODs, which record the vocalizations of toothed whales, porpoises, and dolphins.[23] In particular, the program focuses 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 overall goal of this program is to understand

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

if there is a change in marine mammal presence in proximity to deployed in-stream tidal energy turbines and builds upon baseline C-POD data collection within the Minas Passage since 2011.

Since 2011 to early 2018, more than 4,650 'C-POD days'[24] have been completed in the Minas Passage. Over the study period, it was found that harbour porpoise use and movement varies over long (i.e., seasonal peaks and lunar cycles) and short (i.e., nocturnal preference and tide stage) timescales. This analysis, completed by Sea Mammal Research Unit (Canada) (Vancouver, BC), showed some evidence to suggest marine mammal exclusion within the near-field of CSTV turbine when it was operational (November 2016 – June 2017) (Joy et al., 2018). This analysis showed that the C-PODs in closest proximity to the turbine (230 m and 210 m distance) had shown decreases in detections whereas there is no evidence of mid-field avoidance with a turbine present and operating. The latest findings also showed a decrease in detections during turbine installation activities, consistent with previous findings (Joy et al., 2017), but will require additional data collected in relation to an operating turbine to allow for a proper assessment of the EA predictions.

In 2019, the C-PODs were recovered on March 29 (deployment took place on December 6th, 2018). The C-PODs will undergo inspection, maintenance, and data-recovery, led by FORCE ocean technologists. The C-PODs are deployed with weights and submersible buoys at varying locations in the Minas Passage. In addition to a C-POD, the buoys have included fish tag receivers (see 'Other FORCE Research Activities' below) and, at times, beacons from MetOcean Telematics (Dartmouth, NS).

In addition, in 2019, FORCE received an F-POD from Chelonia Limited (makers of the C-PODs; Cornwall, UK), which it will deploy at the FORCE site in 2019. This new instrument has an extended frequency range, more memory capacity, and more battery life than the C-POD, and may be beneficial in future monitoring efforts at the FORCE site.

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

Observation Program

FORCE's marine mammal observation program in 2019 includes observations made during bi-weekly shoreline surveys, stationary observations at the FORCE Visitor Centre, and marine-based observations during marine operations. All observations and sightings are recorded, along with weather data, tide state, and other environmental data. Any marine mammal observations are shared with SMRU Consulting to support validation efforts of PAM activities.

Additionally, FORCE will continue to explore the utility of using an Unmanned Aerial Vehicle (UAV) for collecting observational data along the shoreline, and over the FORCE site using five transects by programming GPS waypoints in the UAV to standardize the flight paths. FORCE staff received training from to operate a UAV in 2018, and are in the process of developing a

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

study design to assess the relative utility of UAV-based vs. walking-based observational surveys in spring 2019.

FORCE also hosts a public reporting tool allows members of the public to report observations of marine life: mmo.fundyforce.ca

Marine Sound (Acoustics)

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

In late 2018, FORCE convened a working group of experts in passive acoustic monitoring (PAM) data collection and analyses from local academic institutions, industry partners, and other stakeholders. The purpose of the workshop was to discuss the challenges and operational limitations inherent with using PAM technologies for marine mammal and sound monitoring in high-flow environments like the FORCE test site and to identify potential solutions to improve environmental effects monitoring capabilities for operational in-stream tidal energy turbines in the future. Specifically, the workshop sought to address questions from regulators regarding the integration or corroboration of results from multiple PAM technologies deployed in and around the FORCE test site. The workshop also explored potential future projects to support further environmental monitoring using PAM technologies with the end goal of lending confidence to environmental effects monitoring technologies and approaches used in support of tidal energy devices. A copy of the workshop report, including outcomes and identified next steps may be found in Appendix 2.

Building on this workshop, FORCE is undertaking an assessment of the relative performance of PAM technologies in partnership with Dalhousie University’s Oceanography Department (Halifax, NS) and industry partners GeoSpectrum Technologies (Dartmouth, NS), Ocean Sonics (Truro, NS), and JASCO Applied Sciences (Dartmouth, NS). This integrated comparative analysis looks at near-field sound data collected by hydrophones (i.e., underwater sound recorders) located:

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

In addition, an acoustic Doppler current profiler (ADCP) mounted on the CSTV turbine has collected current data since September 4th, 2018. This data will be used to understand how ambient sound varies with the tidal flow conditions.

Specifically, this work will continue to characterize ambient sound levels as a function of current speed and tidal cycle, and then evaluate the performance of each sensor with respect to ambient sound and compare the results of each system and its configuration. This comparative analysis will provide valuable information about future marine sound monitoring technologies and protocols while building on previous acoustics analysis at the FORCE site.

Results from previous acoustic analyses completed at the FORCE site indicate that the turbine is audible to marine life at varying distances from the turbine, but only exceeded the threshold for behavioural disturbance at very short ranges and during particular tide conditions (Martin et al., 2018). This is consistent with findings at the Paimpol-Bréhat site in France where an OpenHydro turbine was also deployed – data suggests that physiological trauma associated with a tidal turbine is improbable, but that behavioural disturbance may occur within 400 m of a turbine for marine mammals and at closer distances for some fish species (Lossent et al., 2017).

Seabirds

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

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

This year, FORCE has begun a collaboration with Envirosphere and Dr. Phil Taylor at Acadia University (Wolfville, NS) to synthesize previous observation-based seabird baseline datasets (2017-2018) and to integrate this information with data from radar-based monitoring (Walker and Taylor, 2018). Radar based monitoring, based on an X-band radar located at the FORCE Visitor Centre has typically been used for flow characterization, but can be used to monitor bird movements throughout and around the FORCE test site. Similar to the observational studies, radar analysis shows a clear seasonal pattern of activity with very few birds present in the winter and peaks during spring and fall migrations (Walker and Taylor, 2018; Appendix 3).

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

Near-field Monitoring Activities

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

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

Throughout 2018 and into Q1 2019, FORCE has been taking steps to enhance its near-field monitoring capabilities. In summer 2018, FORCE deployed multiple Fundy Advanced Sensor Technology (FAST) platforms in proximity to the Cape Sharp Tidal turbine (within 15m – 35m from the turbine) containing hydrophones and ADCPs to measure turbine-produced sound and flow impacts of the turbine respectively. These measurements are being used to inform marine acoustics (as per 'Mid-Field Monitoring' above) and also to better understand flow dynamics at the FORCE test site.

In addition, FORCE staff (Science Director Dan Hasselman and ocean technologists Ray Pieroway and Tyler Boucher) also underwent training in Q1 2019 to understand a near-field monitoring instrument, a Gemini imaging sonar. This training was led by the maker of the Gemini, Tritech International Ltd (Aberdeen, Scotland) and included an overview of the instrument's capabilities and limitations, best practices for use, and setting optimization for in-situ data recording. The training also incorporated the specialized software used to track targets (i.e., marine life) in the water column. This training will be greatly beneficial for use and testing of the Gemini at the FORCE test site.

Moving forward, each berth holder's monitoring activities will be included as appendices below. Updates from future berth holders will be provided as others develop and implement near-field, device-specific environmental effects monitoring programs.

Other FORCE Research Activities

Fundy Advanced Sensor Technology (FAST) Activities

FORCE's Fundy Advanced Sensor Technology Program ('FAST') is designed to advance capabilities to monitor and characterize the FORCE site. Specifically, the FAST Program was designed to achieve the following objectives:

1) To advance capabilities of site characterization;
2) To develop and refine environmental monitoring standards and technologies; and
3) To enhance marine operating methodologies.

FAST combines both onshore and offshore monitoring assets. Onshore assets include a meteorological (MET) station, video cameras, an X-band radar system, and tide gauge. Offshore assets include modular subsea platforms for both autonomous and cabled data collection and a suite of instrumentation for a variety of research purposes. Real-time data collected through FAST assets is broadcasted live on the Ocean Networks Canada's (ONC; Victoria, BC) website.[25]

Platform Projects

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

A smaller platform (known as 'FAST-3') has been used for the last two years to monitor fish densities in the mid-field of the turbine. Data collection activities for this project was completed in 2018 and FORCE and its partners, including Echoview Software and the University of Maine, will data processing and analysis in 2019. This project will integrate the data collected from the FAST-3 platform with data collected from a vessel-mounted hydroacoustic echosounder (used as part of the mid-field fish monitoring activities described above) to evaluate the temporal and spatial representativeness of each method and determine the degree to which results are corroborative (depicted in Figure 2). This project is funded by Natural Resources Canada (NRCan), the NSDEM, and the OERA.

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

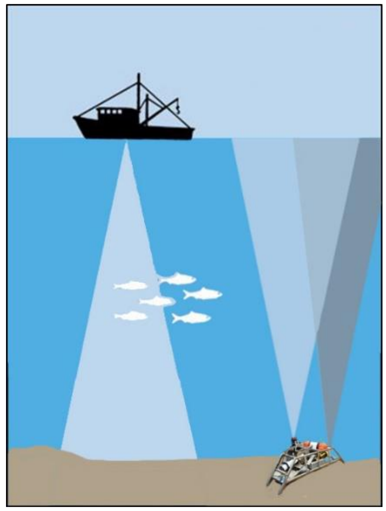

Figure 2: A representation of the data collection methods of the FORCE mid-field fish EEMP and the FAST-3 platform.

Marine Operations

FORCE has also partnered with Operational Excellence Consulting Inc. (Halifax, NS) to document lessons learned from various marine operations over the last few years. The report, *Lessons Learned: Marine Operations in the Minas Passage* (2019), documents operational constraints, information to address commonly-encountered situations, and learnings to-date in an effort to help support and de-risk future projects at the FORCE test site. This work was funded by the OERA.

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

Fish Tracking

To enhance fish monitoring and to expand its data collection capacity, FORCE partnered with the Ocean Tracking Network (OTN)[26] and attached one VEMCO[27] fish tag receiver (a VR2 receiver) to each C-POD mooring/SUBS (Streamlined Underwater Buoyancy System) package (see above). These receivers are used to supplement OTN's ongoing data collection program within the Minas Passage and are referred to as 'Buoys of Opportunity.' Upon retrieval of the C-PODs and receivers, instruments are shared with OTN where data is offloaded prior to redeployment. This effort will support increased knowledge of fish movement within the Minas Passage, which has applicability beyond tidal energy demonstration, as well as complement FORCE's hydroacoustic data collection efforts that do not allow for species identification.

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

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

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);
- MA Marine Fisheries Shark Research Program (Skomal, G.B., Chisholm, J., 2009);
- Curry Atlantic Sturgeon and Striped Bass (Curry, A., Linnansaari, T., Gautreau, M., 2010); and
- Inner Bay of Fundy Atlantic Salmon (Bradford, R., LeBlanc, P., 2012).

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

Starting in 2018, FORCE has worked in collaboration with Dr. Mike Stokesbury at Acadia University to install additional VEMCO receivers of a new design on FORCE's C-POD moorings/SUBS packages. These new receivers are expected to be even more effective in picking up acoustic detections in high flow environments, where tag signals can be obscured by noise. This partnership will contribute additional information regarding movement patterns of Atlantic salmon, sturgeon, striped bass, and alewife in Minas Passage and Basin. This work is sponsored by the OERA, NRCan, NSDEM, the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).[28]

Wetlands Monitoring

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

This monitoring work has been ongoing since the installation of the cables in 2014. Completed by Envirosphere Consultants, this includes periodic walkovers by a biologist and a botany survey in the disturbed area, repeating baseline work done in 2014 and monitoring work completed in 2015 and again in 2016.

To-date, this monitoring work has shown the wetland is well-vegetated and has largely recovered from the trenching operations associated with the cable installation.

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

Discussion

This year represents a strategic opportunity for FORCE and its partners to learn from previous experiences and to re-evaluate approaches to research and monitoring in the high-flows of the Minas Passage.

Given the present status of the CSTV turbine, monitoring efforts have been curtailed to avoid biasing datasets. This is because a non-operational turbine has implications for monitoring – a turbine that is not spinning does not allow us to test its true environmental effects while also potentially acting as an artificial reef, and thereby biasing any attempts at capturing baseline data. At this time, FORCE is not aware of any timelines for turbine removal but will continue to monitor its non-operational status and use, where applicable, its sensors in a way to advance monitoring capabilities.

Throughout 2019, FORCE and its partners plan to deliver a number of efforts that will improve monitoring capabilities – this will occur through continued learning from the experiences of local and international partners, training and skills development of FORCE staff, testing new sensor capabilities such as radar for seabird monitoring or testing new PAM devices like the F-POD, and integrating results from various instruments. Throughout the year, reports and updates will undergo review by FORCE's EMAC and regulators, along with continued results from FORCE's ongoing monitoring efforts. These efforts will provide an opportunity for adaptive management and further develop and refine the scientific approaches, tools, and techniques necessary in the near- and mid-field study areas to effectively monitor tidal energy turbines in high-flow environments.

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

Moving forward, FORCE will continue to conduct environmental research and monitoring within the Minas Passage. This continued effort will increase our understanding of the natural conditions within the Minas Passage and, when the next turbine(s) are deployed and operating, test the EA prediction that tidal energy is unlikely to cause significant harm to marine life. In the longer-term, monitoring will need to be conducted over the full seasonal cycle and in association with multiple different turbine technologies in order to understand if tidal energy can be a safe and responsibly-produced energy source. Through its mandate, 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 1

Cape Sharp Tidal Venture Update

About Cape Sharp Tidal Venture

Cape Sharp Tidal Venture (CSTV) is a joint venture between tidal energy technology developer, OpenHydro Technology, a Naval Energies company, and Halifax-based energy company Emera Inc. The CSTV project used OpenHydro's Open-Centre Turbine (Figure A.1). This turbine technology has four key components:

- a horizontal axis rotor;
- a magnet generator;
- a hydrodynamic duct; and
- a subsea gravity base foundation.

The turbine design has 10 fins, each approximately 2.4 m wide x 4.8 m long, manufactured from glass-reinforced plastic. The thickness of each fin ranges from 21 cm at the root (outer diameter) to 1.5 cm at the tip (inner diameter). The turbine is supported by a triangular-shaped gravity foundation subsea base structure. The entire unit sits on the sea floor without requiring drilling or any preparation to the substrate.

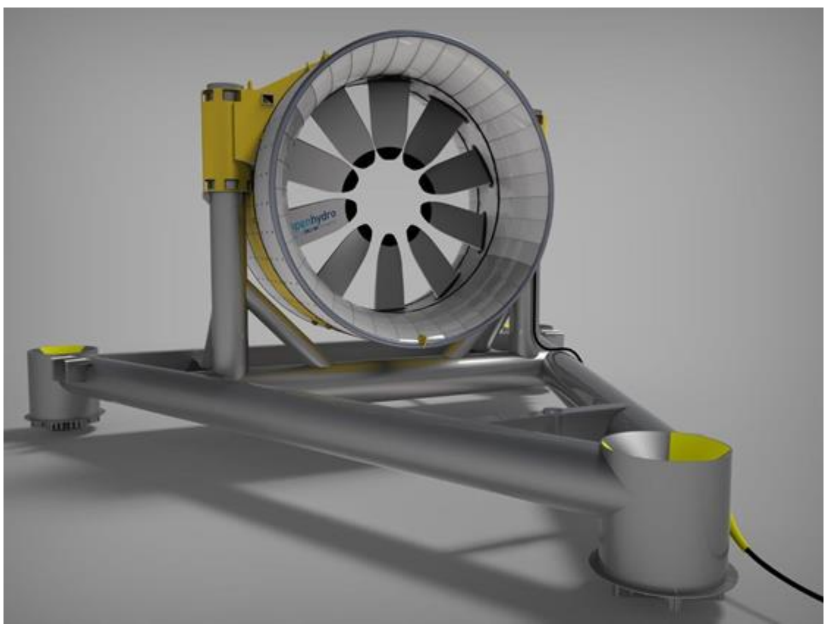

Figure A.1: An image of the OpenHydro Open-Centre Turbine design.

Previously, CSTV deployed a 2-megawatt (MW) in-stream tidal energy turbine at the FORCE site on November 7, 2016. This turbine was retrieved on June 15, 2017. Following retrieval, the turbine and subsea base were towed to port facilities in Saint John, New Brunswick. Details of the marine operations around the retrieval were provided in the 2017 Environmental Effects Monitoring (EEMP) Reports (www.capesharptidal.com/eemp/).

A second turbine was deployed on July 22, 2018 and on July 24, 2018 OpenHydro successfully connected the subsea cable to the turbine and confirmed establishment of communication with the turbine systems. Two days later, on July 26, 2018 Naval Energies filed a petition with the High Court of Ireland for the liquidation of OpenHydro Group Limited and OpenHydro Technologies

Limited. In order to ensure safety, the OpenHydro commissioning team isolated the turbine from the Nova Scotia Power Inc. grid, which consequently disabled the monitoring devices. On September 4, 2018 the turbine was re-energized and power was restored to the environmental sensors. At that time it was confirmed that the turbine was not spinning and that one hydrophone was not communicating.

As a result of the OpenHydro insolvency, on August 13, 2018, Emera formally notified OpenHydro and OpenHydro's provisional liquidator that the company was withdrawing from its involvement in Cape Sharp Tidal. These processes are ongoing in Q1 2019.

At this time, the turbine remains at the FORCE berth where it was deployed in July. The turbine rotor is stationary and some of the environmental sensors are operating and continuously transmitting data to shore. An internal component failure in the generator has caused sufficient damage to prevent the rotor from turning.

Q1 2019 OPERATIONAL UPDATE

The focus of operations during this reporting period (January 1 – March 31, 2019) was regular reports to regulators to confirm that the turbine rotor remains stationary (i.e., not turning).

On September 19, 2018, the Department of Fisheries and Oceans (DFO) confirmed a modification of monitoring requirements under the CSTV *Fisheries Act* Authorization to be comprised of a monthly status updates on the turbine to confirm that the rotor is not spinning by monitoring turbine status during the peak tidal flow of each month. This program began October 1, 2018. CSTV suspended reporting on March 1, 2019 due to lack of funds from OpenHydro Technology LTD (as it is presently in liquidation).

Acoustic Doppler current profiler (ADCP) data indicate that during the months of January and February the turbine rotor remained stationary.

NEAR-FIELD ENVIRONMENTAL EFFECTS MONITORING – Q1 2019 UPDATE

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

Moving forward, each berth holder's monitoring activities will be included as appendices below. Updates from future berth holders will be provided as others develop and implement near-field, device-specific environmental effects monitoring programs.

As noted above, CSTV is currently not completing near-field monitoring at 'Berth D' since it has been confirmed that the turbine rotor is not spinning.

Data is still being collected by two hydrophones (a third was confirmed to be non-operating in March 2019) mounted in separate locations on the turbine rotor and the subsea base. The three ADCP devices mounted on the turbine are also collecting data on water flow.

Appendix 2
Passive Acoustic Monitoring Workshop Report

Passive Acoustic Monitoring in association with Tidal Energy Turbines in the Minas Passage: Workshop Report

Original: 26 November 2018

Revised: 11 March 2019

Fundy Ocean Research Center for Energy
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Executive Summary

In November 2018, the Fundy Ocean Research Center for Energy (FORCE) convened a workshop of regional experts (i.e., industry partners, academics, stakeholders) in Passive Acoustic Monitoring (PAM) data collection and analyses. FORCE's Environmental Effects Monitoring Program (EEMP) utilizes PAM equipment as its primary means of monitoring marine mammals and for understanding the effects of sound generated by turbines deployed at the FORCE test site, located in the Minas Passage, Bay of Fundy. The FORCE test site is exposed to tidal flows that may restrict the utility of particular types of PAM equipment that are suitable for environmental monitoring elsewhere. Further, regulators have requested clarification regarding the ability of different PAM technologies to detect harbour porpoise (*Phocoena phocoena*) echolocations at the FORCE site, including rates of false-positive detections. Therefore, the purpose of the PAM workshop was to discuss the inherent challenges and operational limitations associated with PAM technologies and methodologies in high-flow environments, and to identify future projects that could facilitate the deployment of PAM technologies best suited for marine mammal and sound monitoring in the Minas Passage. Participants discussed previous and ongoing PAM projects in the Bay of Fundy including challenges, methodologies for overcoming the difficult conditions presented by high-flow environments and initial findings. Importantly, the group discussed opportunities for improvements to PAM technologies, and potential projects and collaborations for the near-future. It is anticipated that members of this group will continue to meet on a semi-regular basis to pursue collaborations and opportunities to improve the utility of PAM technologies in the challenging conditions of the Bay of Fundy.

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Acronyms

AAM	Active Acoustic Monitoring
ADCP	Acoustic Doppler Current Profiler
AMAR	Autonomous Multichannel Acoustic Recorder
CSTV	Cape Sharp Tidal Venture
dB	Decibel
DRDC	Defense Research and Development Canada
FAST	Fundy Advanced Sensor Technology
FORCE	Fundy Ocean Research Center for Energy
HR	High Residence
Hz	Hertz
ISEM	Integrated active and passive acoustic System for Environmental Monitoring of fish and marine mammals in tidal energy sites
kHz	Kilohertz
NS	Nova Scotia
NSERC	Natural Sciences and Engineering Research Council of Canada
OERA	Offshore Energy Research Association of Nova Scotia
PAM	Passive Acoustic Monitoring
PPM	Pulse Position Modulation
SMRU	Sea Mammal Research Unit
STREEM	Sensor Testing Research for Environmental Effects Monitoring
SUBS	Streamlined Underwater Buoyancy System
TL	Transmission Loss

Introduction

On 23 November 2018, the Fundy Ocean Research Center for Energy (FORCE) convened a workshop of regional experts (e.g., industry partners, academia, stakeholders) in passive acoustic monitoring (PAM) data collection and analyses. The purpose of the workshop was to discuss the challenges and operational limitations inherenet with using PAM technologies for marine mammal and sound monitoring in high-flow environments like the FORCE test site in Minas Passage, Bay of Fundy, and to identify potential solutions to improve environmental effects monitoring capabilities for operational in-stream tidal energy turbines in the future. The workshop sought to address questions from provincial (Nova Scotia Department of Environment) and federal (Canada Department of Fisheries and Oceans) regulators with respect to the integration or corroboration of results from multiple PAM technologies to inform predictions made in the FORCE Environmental Assessment (AECOM, 2009). The workshop also explored potential future projects to support further environmental monitoring using PAM technologies with the end goal of lending confidence to environmental effects monitoring technologies and approaches used in support of tidal energy devices.

Background

Passive acoustic monitoring has been ongoing at the FORCE test site for many years. Recent environmental effects monitoring efforts increased in 2016 in anticipation of the installation of a single two-megawatt OpenHydro turbine by Cape Sharp Tidal Venture (CSTV) at the FORCE site.

Mid-field or 'site-level' monitoring using PAM technologies and in relation to the FORCE Environmental Assessment (AECOM 2009) is completed by FORCE and its contractors. Presently, this monitoring has focused on two main initiatives: C-PODs and drifting hydrophones. Mid-field monitoring for marine mammals at FORCE consists of near-continuous autonomous deployment of five C-PODs (designed to record marine mammal echolocations) ranging from 210m – 1,700m from the turbine, building on previous years of C-POD deployments throughout the Minas Passage. FORCE deploys and recovers the instrumentation and analysis has been completed by Sea Mammal Research Unit (SMRU) Canada Ltd.

During the 2016 - 2017 deployment of the CSTV OpenHydro turbine, FORCE conducted a drifting hydrophone survey to coincide with the deployment of autonomous and turbine-mounted hydrophones to monitor turbine-generated sounds at the FORCE test site. An integrated analysis was completed by JASCO Applied Sciences (JASCO) (Martin et al., 2018).

Parallel to the FORCE's efforts, a research project was initiated by CSTV to study the potential for integrating active acoustic monitoring (AAM) and PAM technologies on an operating in-stream tidal energy turbine. This research project, 'Integrated Active and Passive Acoustic System for Environmental Monitoring of Fish and Marine Mammals in Tidal Energy Sites (ISEM)', was developed to explore technologies that could operate as an integrated environmental monitoring system using data analysis software and encompassing active and passive acoustic sensors in order to provide real time detection, classification, localization, and tracking of fish and marine mammals at high energy sites.

Although the success of the ISEM project tasks and objectives have been directly affected by the disruption of the CSTV turbine operation, some successes were realized and will be reported on in the final project report planned for spring 2019. The report will also address lessons learned and recommendations for moving these types of monitoring programs forward to increase understanding of monitoring in tidal energy sites.

Additional PAM activities happening in the Bay of Fundy include:

Integrated Lander Platform

Acadia University and collaborators at SMRU Canada Ltd. have been measuring harbour porpoise (*Phocoena phocoena*) detections in Minas Passage since 2010 (Tollit et al., 2011; Wood et al., 2013; Porskamp, 2013). Acadia University and SMRU Canada Ltd. established PAM (i.e., C-POD) monitoring sites in and around the FORCE test site during December 2013 – June 2014. In order to better assess PAM monitoring methods, Acadia and OceanSonics Ltd. deployed a lander (sub-sea) platform at the FORCE test site in June 2014. Among other instrumentation, the platform carried icListenHF hydrophones, C-PODs, and VR2W receivers that detect acoustic tags. Analysis of the data collected using this sensor suite provided a comparison of C-PODs and broadband hydrophones for monitoring harbour porpoise (Porskamp, 2015; Porskamp et al., 2015). Acadia has also undertaken a great deal of monitoring for acoustically tagged fish (Broome, 2014; Broome et al., 2015; Keyser et al., 2016).

Drifting Platform

Results from the integrated lander platform work generated questions that prompted a long series of experiments using a passive acoustic drifting platform (i.e., 'drifter') to make targeted PAM measurements. Drifter work in 2016 focused on detection range for acoustic tags (Sanderson et al., 2017) and PAM to measure ambient sound and harbour porpoise presence. Drifter work in June 2017 focused on comparison of C-POD data, icListen-coda, and visual harbour porpoise sightings (Adams, 2018; Adams et al., 2018). This work included some preliminary assessments of harbour porpoise localization (Sanderson et al., 2018b), and detections of tagged fish and comparisons of harbour porpoise detections with moored instruments (Sanderson, personal research notes). Drifter work in June 2018 used an array of four synchronized hydrophones and is presently being analysed for porpoise localization. Drifters were also used to demonstrate 'quasi-stable' platform trajectories in the currents of Minas Passage which may prove useful for future monitoring and research (Sanderson et al., 2018b). The 2018 work also undertook further range testing of acoustic tags, particularly to determine the efficacy of Pulse Position Modulation (PPM) transmissions relative to High Residence (HR) transmissions.

Passive and Active Acoustic Measurements

The 'Sensor Testing Research for Environmental Effects Monitoring' (STREEM) project in Grand Passage, Nova Scotia involves assessment of both passive and active acoustic instruments. Preliminary work (October 2018) involved passively drifting a variety of targets to quantify detection capabilities of an imaging sonar (i.e., Tritech Gemini 720is). Sometimes the targets were acoustically active, in which case their effects on the imaging sonar were identified. Other times, hydrophones were used as targets in order to measure how the imaging sonar interacted with PAM instruments. Interactions between echo-sounders, acoustic tags, the imaging sonar, broad-band hydrophones, and HR2 receivers were also measured. A drifting hydrophone array is also being used to measure sounds from the turbine platform (a PLAT-I from Sustainable Marine Energy Canada) installation. The major thrust for STREEM will be the application of imaging sonars, optical cameras, and hydrophones to study fish-turbine interactions. This work is ongoing, with the major experiment planned for spring/summer 2019.

Long-term Acoustic Monitoring

JASCO Applied Sciences Canada Ltd. and Dalhousie University (Dr. David Barclay; Oceanography Department) are undertaking a long-term acoustic monitoring AMAR (Autonomous Multichannel Acoustic Recorder) study in Grand Passage. The purpose of this work is to understand the effects of this turbulent environment on the ability to detect marine life and the ability of marine life to detect tidal turbines. Data analyses for this project has commenced.

Workshop Objective

In early 2018, regulators (Nova Scotia Department of Environment, 2018) provided feedback to FORCE and CSTV regarding passive acoustic data collection during the 2016-2017 deployment of an OpenHydro turbine at the FORCE site. Specifically, regulators requested clarity regarding harbour porpoise detections between turbine-mounted icListen hydrophones and C-PODs.

> "[Fisheries and Oceans Canada] requests that a direct comparison of data collected by the icListen hydrophone used for near-field monitoring at Berth D to data collected by the C-PODs deployed at East1 and D1 [C-POD locations] during the 2016/2017 deployment period be provided […] Specifically, provide a clear discussion of the results of the Days with Detected Porpoise Clicks with the Lucy Click Detector relative the Number of Calendar Days reported for deployment period" (Nova Scotia Department of Environment, 2018).

In response, FORCE consulted with the workshop attendees to develop a response for its second quarterly report in 2018 (FORCE, 2018) and began planning this workshop for fall 2018.

Problem Statement

Recognizing that C-POD data files are not comparable with icListen data files (Porskamp et al., 2015) and that there were observed discrepancies in 'Days with Detected Porpoise Clicks' between the turbine-mounted icListen hydrophones and the Chelonia C-PODs deployed in proximity to the CSTV turbine, a further examination of PAM devices is warranted at the FORCE site.

The differences in detection rates between these instruments can partly be attributable to their functioning. The icListen hydrophone is considered more sensitive but may be masked by the noise of the turbine during periods of high flow. Research has also demonstrated that C-POD units can sometimes record false positive detections (although this is at fairly low rates), whereas the icListen hydrophones and associated software programs have been developed to separate out the different high frequency sounds to make a positive identification of porpoise clicks. The icListen hydrophones appear to have a greater accuracy in detection rates of high frequency sounds in noisy environments; however, the continued use of C-PODs at the FORCE site is important as it provides a direct comparison to baseline data that was collected at the FORCE site prior to any turbine deployments within the mid-field study area.

A statistical model that accounted for relevant environmental variables and 'Percent Time Lost' was applied to the C-POD data, and was used to test for changes in the distribution and activity of harbour porpoise in relation to the installation and operation of the turbine. The overall effect of turbine operations on porpoise detection rates were found to be significant ($P < 0.01$). East1, a site 210 m north of the turbine at 41 m depth, and D1, a site 230 m south of the turbine at 33 m depth both showed significantly fewer porpoise detections post-installation of the turbine. Both of these sites had overall lower activity levels both with and without the turbine, whereas the sites > 1 km west and south of the turbine had overall higher activity levels and showed no decrease in porpoise detections with the turbine. Given that detection ranges of harbour porpoise are small (< 2-300 m), it is possible that the lower detection rates recorded by the icListen hydrophone mounted on the turbine reflect near-field avoidance by harbour porpoise.

For both types of monitoring devices, additional data collection will be required to cover seasonal and inter-annual variation to understand behaviours of marine mammals in relation to an operational turbine in the mid-field and near-field. The issues experienced during the 2016-2017 turbine deployment have been mitigated through a series of pre-deployment commissioning tests of the icListen hydrophones, new protocol for transfer and management of data, hydrophone synchronization and recognition of the importance of protective measures and specific cabling for all icListen hydrophones.

Attendees

Attendees included representatives from:

- Acadia University (Wolfville, NS): Mike Adams, Anna Redden, Brian Sanderson
- Dalhousie University (Halifax, NS): David Barclay
- Emera/Cape Sharp Tidal Venture (Halifax, NS): Carys Burgess
- FORCE: Tyler Boucher, Jessica Douglas, Dan Hasselman, Melissa Oldreive
- GeoSpectrum Technologies Inc. (Dartmouth, NS): Matt Coffin
- JASCO Applied Sciences (Dartmouth, NS): Bruce Martin
- Ocean Sonics (Great Village, NS): Mark Wood
- Offshore Energy Research Association of Nova Scotia (Halifax, NS): Jennifer Pinks

SMRU Canada Ltd. (Vancouver, British Columbia) was unable to attend due to travel restrictions and provided advice beforehand. In addition, Dr. Dom Tollit presented at the Marine Renewables Canada Research Forum on 20 November 2018, highlighting the experience of SMRU Canada Ltd. with marine mammal monitoring at the FORCE test site.

All parties have had experience in data collection methodologies and/or analysis experience with PAM data collected within the Minas Passage, Bay of Fundy.

Proceedings

After a general roundtable introduction amongst participants, the workshop's objectives and the intent to form broad-scale collaborations for dissemination of research and technical challenges and developing joint research project area were discussed. This is especially important as some valuable lessons learned are not always outlined in publications.

Present Situation at FORCE

Dan Hasselman provided an update regarding the present situation at the FORCE test site in consideration of the OpenHydro turbine (i.e., turbine itself is non-operational, but three of four turbine-mounted icListen hydrophones are operating). It was agreed that it is critical to focus on the near-field at this time: this is key to enable future device developments.

For instance, FORCE has commissioned GeoSpectrum Technologies Inc. and Dalhousie University to examine data from the three turbine-mounted icListen hydrophones (depicted in Figure 1: The locations of the four hydrophones placed on the OpenHydro turbine. Hydrophone 2 (fore port) is presently not communicating.), an autonomous Fundy Advanced Sensor Technology (FAST) platform with two icListen hydrophones, and an AMAR system deployed by JASCO Applied Sciences Canada Ltd. The purpose of this work is to examine the data collected in summer/fall 2018 in the near-field region of the OpenHydro turbine to i) characterize ambient noise levels with a stationary turbine, and ii) evaluate the performance of each hydrophone configuration to provide information about how best to monitor sound at the FORCE test site in the future. Utilization of this near-field data will advance our understanding of the soundscape of the site and will provide valuable information about future mid-field and near-field monitoring at the FORCE site.

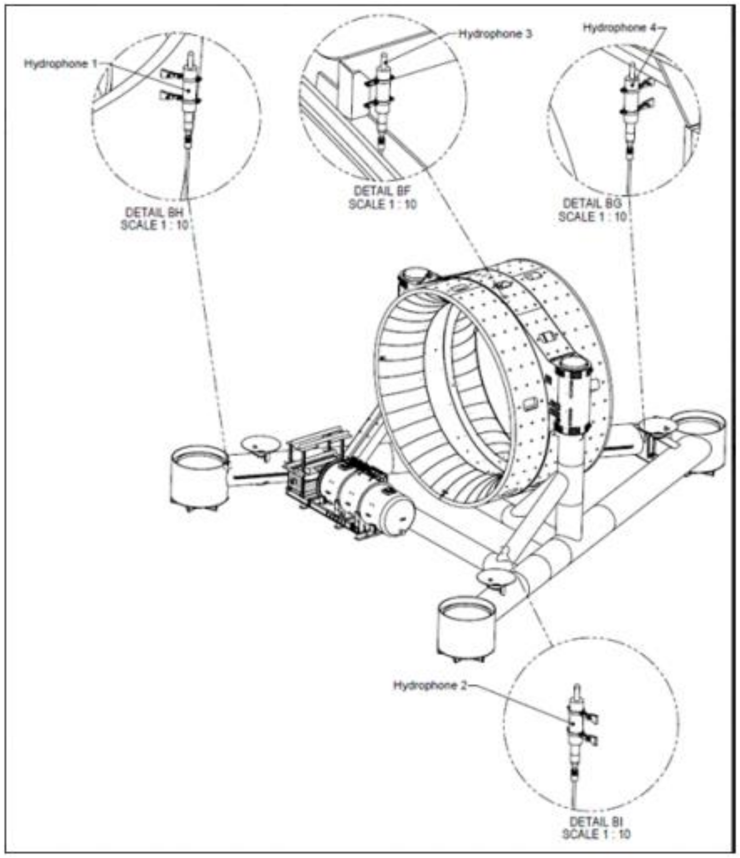

Figure 1: The locations of the four hydrophones placed on the OpenHydro turbine. Hydrophone 2 (fore port) is presently not communicating.

Matt Coffin (GeoSpectrum Technologies Inc.) elaborated on the data collected from the icListen hydrophones mounted on the FAST platform. Specifically, taking five-minute averages at two-hour intervals, flow noise can be seen in the spectra and is comparable to the flow noise observed in the data from the turbine-mounted icListen hydrophones. Matt pointed out that the sample rate of the raw icListen hydrophone data is 8 kHz, resulting in a 4 kHz cut-off frequency in the spectra. Mark Wood (Ocean Sonics) pointed out that high-frequency spectra are saved in addition to the raw time-series data. After the workshop, Matt located the high-frequency spectra and updated the spectral plots to include these data. Again, the spectra agree well with the turbine-mounted icListen hydrophone data.

Although Bruce Martin (JASCO Applied Sciences Canada Ltd.) has analyzed previous icListen hydrophone data, none of that data was collected when the turbine was non-operational. Therefore, the current data could be used to estimate ambient noise in the Minas Passage with the CSTV turbine present but stationary. This would be valuable information.

While there is accompanying ADCP (Acoustic Doppler Current Profiler) data for the data collection period, GeoSpectrum Technologies Inc. has not analyzed these data. For simplicity, Matt used tidal prediction times to estimate flow speed at the times corresponding to the spectral measurements instead.

Following the meeting, GeoSpectrum Technologies Inc., David Barclay, and Bruce Martin met to discuss the results of the preliminary analysis and developed a statement of work defining more in-depth analysis to follow.

Brian Sanderson (Acadia University) discussed how beam patterns from the various instruments can help with directionality and localization, allowing monitoring to move from presence/absence data to quantitative measurements (i.e., abundance estimates).

The three turbine-mounted icListen hydrophones provide an opportunity to continue PAM research objectives in the Minas Passage regardless of whether the turbine is operational or not. Mark Wood has been surprised by the level of animal activity recorded so far by the icListen hydrophones. Further examination during the winter months will provide additional information about harbour porpoise presence and activity. Mark also noted that this could provide an opportunity to better understand if AAM instruments are interfering with PAM devices. Data from the ADCPs mounted on the turbine are under review; an evaluation of PAM and AAM devices could be worthwhile right now.

Work with fish acoustic telemetry (i.e., fish tagging) (Mike Stokesbury; Acadia University) was discussed. A project that considers the new high-frequency hydroacoustic tags (180 and 170 signal) could provide further clarity about animal movements across instrumentation recorder locations. While tagging efforts are recognized as expensive and extensive, it was agreed that FORCE could coordinate multiple groups to develop a project that uses hydrophones to supplement tag receivers.

Instrumentation Evaluation

Brian Sanderson discussed how AAM devices such as ADCPs interfere with PAM devices. Dr. Haley Viehman (Echoview Software Pty Ltd.; previously Acadia University) has done work on the interference of active acoustic instrumentation on other AAM devices (e.g. Tritech Gemini sonar and ADCPs); additional work focused on AAM-AAM and AAM-PAM instrumentation interference is worthwhile and would facilitate discussions with regulators about the utility of setting duty cycles (i.e., sequentially turning acoustic monitoring devices on/off) to avoid interference and thereby improving the quality of data collected by all acoustic monitoring devices.

It was noted that SMRU Canada Ltd. had engaged the University of St Andrews (Scotland) to look at the interference between the Tritech Gemini imaging sonar with hydrophone data. The ISEM project (in collaboration with SMRU Canada Ltd., Acadia University, and Ocean Sonics) is presently examining the quality of Tritech Gemini data collected during the 2018 CSTV turbine deployment.

PAM Analysis from November 2016 – June 2017

Bruce Martin highlighted sections in the JASCO Applied Sciences Canada Ltd. report (Martin et al., 2018) that compared various turbine-mounted hydrophones to passively drifting icListen hydrophones deployed by FORCE and the AMAR (Figure 2: Median pressure spectral densities for three different long-term recording positions, the reference recording from the outer Bay of Fundy as well as the drifter measurements from 27 Mar 2017. Frequency-5/3 is the expected slope for turbulent flow noise (Martin et al., 2018).) during the 2016-2017 CSTV turbine operation. At 69 Hz, the data from the AMAR and the turbine-mounted hydrophones correlate well. Further, consistency was observed across instruments and tidal stage – the directional sound source could be due to sediment movement in the water column.

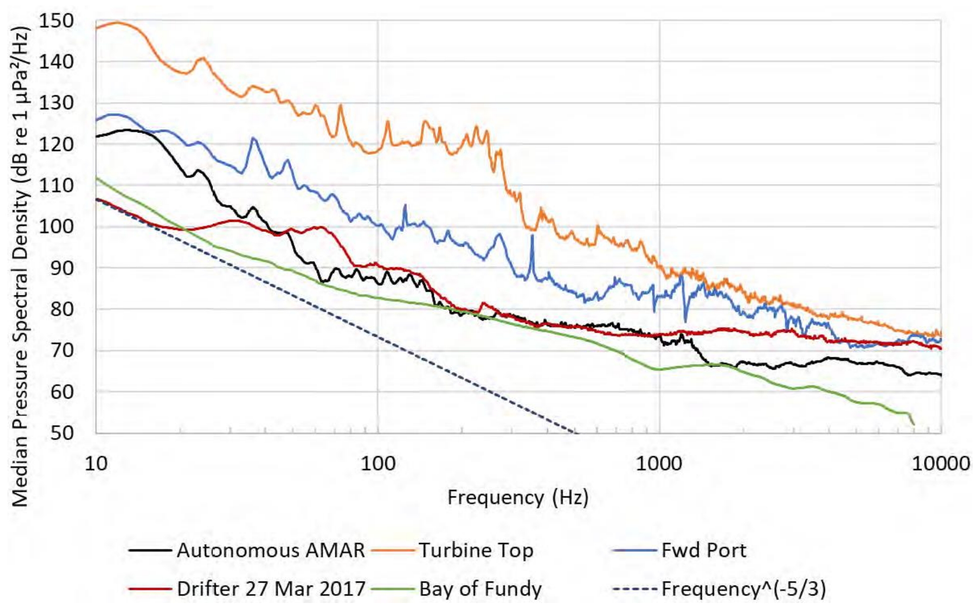

Figure 2: Median pressure spectral densities for three different long-term recording positions, the reference recording from the outer Bay of Fundy as well as the drifter measurements from 27 Mar 2017. Frequency-5/3 is the expected slope for turbulent flow noise (Martin et al., 2018).

It was also observed that the measurements from the AMAR had more vibrational energy, due to its proximity to the sound-source (i.e., CSTV turbine). It was observed that the shape of the lines for the AMAR data when the CSTV turbine was generating power were 'arrowed', indicating a stationary Lloyd's Mirror Effect. At higher frequencies, dramatically different ebb and flood characteristics were detected among the various hydrophone locations on the turbine.

There was discussion regarding the turbine-generated sound (in its various states) relative to vessel traffic elsewhere in the Bay of Fundy, as well as the pre-existing soundscape in the Bay of Fundy.

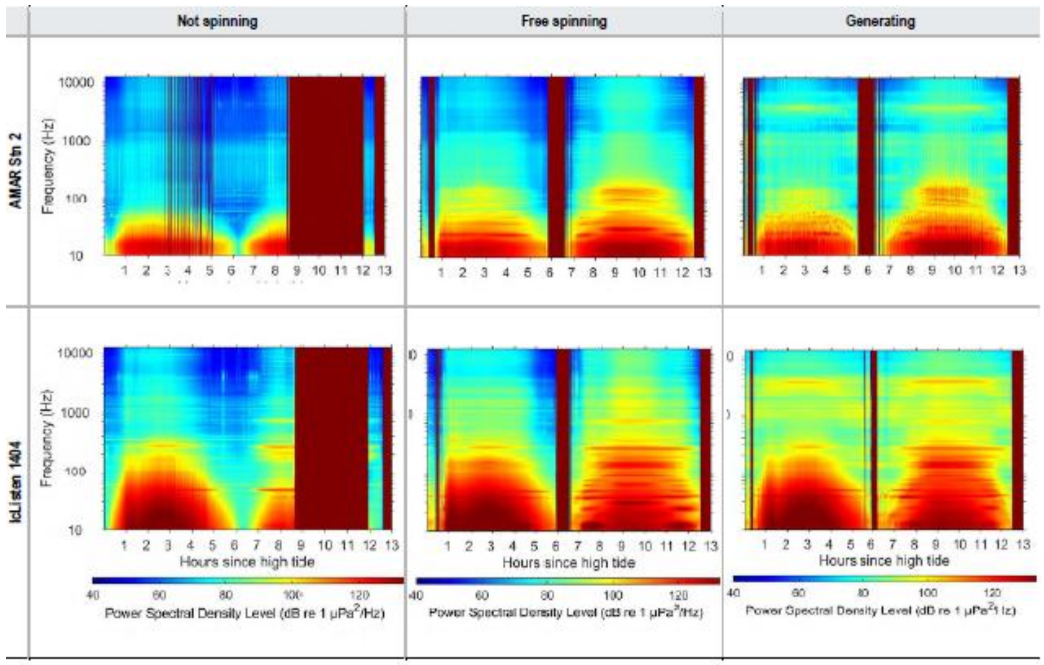

Figure 3: Power spectral density versus tidal increment time, turbine state, and recorder. The horizontal axis is time in hours since high tide. Times with less than 30 samples of data are blocked out in red (JASCO, 2018).

C-POD Utility

Brian Sanderson and Anna Redden (Acadia University) presented the issue of C-POD false detections, and issues with interfering noise and related data loss. C-POD performance is compromised above certain flow thresholds and does not assist with localization or abundance measurements. Some targeted experiments on the moorings used for C-PODs in the Minas Passage (known as SUBS – Streamlined Underwater Buoyancy System) are required.

SMRU Canada Ltd. undertook additional analyses to assess loss of data by C-PODs under high flow conditions. Data loss occurs when the 1-minute long internal memory buffer of the C-POD is filled with clicks before the end of that minute of monitoring (termed 'Percent Time Lost'). Percent Time Lost had little effect on data quality between ebb current speeds < 2.4 m/s (95.0% of 10-minute periods) and flood current speeds < 2 m/s (71% of 10-minute periods). At ebb current speeds up to 2.9 m/s (99.0% of 10-minute periods) and flood current speeds up to 3.5 m/s (95.5% of 10-minute periods), Percent Time Lost does not exceed 65.0%. Despite the use of statistical methods to take Percent Time Lost into account, C-POD monitoring performance above these current speeds appears less reliable, noting that these speeds only occur over a small fraction of the tidal cycle.

Bruce Martin mentioned how geometry and directionality (including beam patterns and signals) are critical elements for proposed experimental trial work and must be considered in instrument mounting configuration (either on platforms, moorings, or turbines).

Dan Hasselman highlighted communications from Dom Tollit regarding a new PAM instrument called 'Sound Trap 300 HF', which can achieve continuous audio recordings at a low sample rate, while simultaneously capturing short audio snippets of each click detection at full 576 kHz sample rate. This is a compact acoustic recorder developed by Ocean Instruments New Zealand in collaboration with SMRU Ltd.

and uses the PAMGuard software to detect porpoise clicks.[1] Bruce highlighted a new instrument, an F-POD, which is under development by Chelonia (provider of the C-PODs) and is available for testing.

Calibration and Instrumentation Life

It was noted that C-PODs operate best in the first year of life. There will be a need for FORCE to recalibrate/refurbish these instruments soon.

Laboratory and In Situ Tests

Mark Wood described a test completed at the Aquatron facility (Dalhousie University), which resulted in less useful data as the walls of the facility 'clip' the hydrophone.

Anna Redden and Brian Sanderson discussed open water testing, which suffered from interference with boats and echosounders (which can be quite large – 200 dBs at times).

While it was recognized that laboratory facilities are useful in certain contexts (e.g., isolate signals, turbidity changes, multiple instruments, etc.), it was determined that open water test sites are preferable for PAM. Some tests were done in Saint Mary's Bay, but the data is not yet analyzed. More data will be collected, but that work has been delayed until 2019 (spring/summer) due to weather.

Additional Studies & Resources

Care will be required in designing and interpreting any detection experiments. Ideally, all sensors being compared should be co-located. Where they are not co-located, the experiment should be designed to help reduce the impact of spatial and temporal variations in transmission loss (TL). GeoSpectrum Technologies Inc. has conducted a number of TL studies and similar experiments where many pulses have been transmitted over a period of time to various sensors. Even small changes in location and time (e.g., on the order of a wavelength and seconds to minutes) have resulted in TL variations on the order of 10 dB. Thus, any detection experiments should do their best to overlap sampling in space and time and ensure sufficiently long duration and variation in source location to try to ensure that all sensor locations are presented with similar test data.

Recommendations & Next Steps

All attendees agreed that it was useful for this group to reconvene again to discuss research projects (present and future) and lessons learned in greater detail. The strength in a group that shares best practices that are not necessarily found in publications is valuable and was recognized by all. It was also recognized that there is a good understanding of existing PAM technologies available, which provides a suitable background for beginning newer, innovative research projects.

The following were identified as potential research projects (in no particular order):

- Take advantage of the opportunity to continue acoustic research with the OpenHydro turbine before it is removed (options highlighted below).
- Assessment of beam patterns of commercially available tools and the potential for their interactions in a specific experimental design.

[1] More information: http://www.oceaninstruments.co.nz/soundtrap-click-detector/

- Exploration of mooring systems to optimize C-POD deployments and data collection. A comparison of existing C-POD mooring systems (utilizing SUBS packages), a (cabled) FAST platform, a lift-tilt system, and a deep-water drifter could provide a proper assessment of false positive detections, and most importantly differences in detection rate probabilities in the high-flows of the Minas Passage. This would allow for a comparison between previous baseline detection rates and detection rates using alternative devices and platforms. This approach could increase our understanding of C-POD limitations, possibly quantifying these limits.
- Synthesis of pre-existing data and baseline information collected by PAM receivers within the Minas Passage. This would include:
    - Revisiting C-POD data in consideration of poorer quality data points in order to evaluate the efficiency of these instruments;
    - Analysis of ambient conditions, including an AMAR deployment (June – November 2018); and
    - Quantify noise and transmission loss.
- Co-location of instrumentation near an operating tidal energy turbine. Potential options include:
    - Co-locating a C-POD with a newer Chelonia instrument known as an 'F-POD' (to be acquired from Chelonia);
    - Co-location of a C-POD with an icListen hydrophone on a FAST platform (cabled is preferred given the quantity of data from hydrophone); and
    - Placing a C-POD near the CSTV turbine, which has three operating hydrophones on it, on a FAST platform or with a SUBS package.
- An evaluation of harbour seal (*Phoca vitulina concolor*) and grey seal (*Halichoerus grypus*) within the Minas Passage. This could include an evaluation of habitat use, estimated abundance, and include the use of visual observations.
- Using synthetic clicks to assess instrumentation performance. Using a fixed-point source from Ocean Sonics, the ability of instruments to detect vocalizations across different tidal states, configurations, and in different sections of the water column would be assessed.
- Troubleshooting the fourth non-communicating icListen hydrophone on the OpenHydro turbine. Access to FORCE substation is required to communicate with the devices.
- Cumulative sound profiling at the FORCE site. This model could consider multiple turbines and their relative sound profile within the Minas Passage over different tidal stages but start with a single operating turbine when it is deployed.
- An evaluation of AAM interference with PAM devices in the Minas Passage.
- An examination of fish tag detections using pre-deployed hydrophones in the FORCE test site in cooperation with tag manufacturers.
- Continued PAM research options in Grand Passage as step-wise approach to Minas Passage deployments.

The possibility of working towards a submission to the OERA's Open Call Program was discussed.[2] A discussion was also had regarding the required resources to complete this work.

The group agreed to its continued value and will attempt to reconvene in 2019.

[2] More information: http://www.oera.ca/news/requests-for-proposals-funding/open-call-program/

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Appendix 3
Using radar data to evaluate seabird abundance and habitat use at the Fundy Ocean Research Centre for Energy site near Parrsboro, NS

Using radar data to evaluate seabird abundance and habitat use at the Fundy Ocean Research Centre for Energy site near Parrsboro, NS

Project #: 300-223

Final Report for April 1 to September 30, 2018

Recipient: Acadia University

Author: Jacob Walker

Project Lead: Dr. Philip Taylor

Submitted: September 28, 2018

CONTENTS

EXECUTIVE SUMMARY

Radar scans from an open-array Furuno marine radar at the Fundy Ocean Research Centre for Energy (FORCE) site were assessed to determine if the data could be used to monitor seabird activity at the site. The radar unit was installed to monitor the surface of the water in the Minas Passage, to determine flow rates and turbulence at the site. Radar scans from the site have been archived since 2015 in SQLite and .jpg formats, and have somewhat less resolution than the raw radar data. The archived radar scans in .jpg format were subsampled and converted into five-minute long clips, and analysed using the radR program in the R statistical programming language. After filtering out areas with persistent interference due to waves on the surface of the water, bird targets were successfully tracked using tracking algorithms in the radR program. Clips from a wide range of dates, tidal stages, and times of day were analysed to characterize seabird use at the site over four years. A general additive model was used to simultaneously account for the effects of wave clutter, date, tidal stage, time of day, and wind speed and direction on the number of bird tracks detected. The results showed a clear seasonal pattern, with few bird tracks detected in winter, peaks during spring and fall migration, and a period of high activity during the summer. Effects of time of day and tidal stage were complex, and intertwined, as the effect of tidal stage on the number of bird tracks detected was dependent on the time of day and vice versa. The effect of wind speed and direction indicated that strong southwest or southeast winds produce higher numbers of bird tracks at the site, but strong winds from other directions produce fewer bird tracks. Recommendations were made for future use of radar monitoring at the site, and for how the data from this study could be used to modify the sampling regime of observer-based seabird surveys.

INTRODUCTION

The Fundy Ocean Research Centre for Energy (herafter FORCE) is a demonstration site for in-stream tidal turbines in the Minas Passage, located west of Parrsboro, NS. To date, three turbines have been installed at the FORCE site, though no more than one have been deployed at any time (FORCE 2018). The Environmental Effects Monitoring Program (hereafter EEMP) was initiated in 2009 to monitor any effects of the turbines on the local ecosystem (FORCE 2018). Seabirds are one guild that have been selected for monitoring by the EEMP. Monthly observer-based seabird surveys have been conducted at the site from 2016 to present to determine species composition, habitat use, and effects of turbine placement at the site (FORCE 2018). To complement the observer-based seabird surveys, radar data from the FORCE site were analysed in this study to determine patterns of seabird use in relation to season, tidal cycle, time of day, and weather.

An open-array Furuno marine radar unit has been operating nearly continuously at the FORCE site since 2015. The radar was deployed to monitor the flow of water and turbulence at the FORCE site, however bird targets were also evident on the scans. The radar scans have been archived in two formats, initially in SQLite databases, and more recently in .jpg format. The raw radar scans were converted to .jpgs to save storage space, but in doing so some resolution was likely lost in the compression process. The primary objective of this study was to determine to what extent the existing radar data could be used to monitor seabirds at the FORCE site.

OBJECTIVES

To determine appropriate methodology for extracting bird targets from the radar scans archived in .jpg format from the radar unit at the FORCE site.

To provide a comprehensive analysis of bird use at the FORCE site, summarized by time of day, tidal cycle, and season.

METHODOLOGY

Data Processing

An open array Furuno marine radar unit was installed at the FORCE site in January 2015 to monitor tidal flow in the Minas Passage at the following coordinates (Latitude 45.3714°, Longitude -64.4029°). Scans from this radar unit were archived in SQLite databases until November 2015, and subsequent scans were and continue to be archived in .jpg format. Archived scans were acquired from John Brzustowski on several external hard drives. Analysis of scans was performed using radR program in the R statistical computing language (Taylor et al. 2010, R Core Team 2016). The radR program does not read in scans in either SQLite or .jpg formats, so scans were converted into .mp4 clips of 5-minute duration using the program FFmpeg, which could then be read into radR (FFmpeg Developers 2016). The scope of the project allowed for scans archived in .jpg format to be analysed in this study, but not those archived in SQLite databases. When splicing the .jpg scans into .mp4 clips, FFmpeg settings included a frame rate of 0.46 frames per second, the libx264 codec, and a pad of 1 black pixel (pad=1876:1866:0:0:black) on the side to make the dimensions in an even number of pixels.

Radar data in .jpg format were available between Nov 17, 2015 and July 2, 2016, and between May 22, 2017 and April 11, 2018. The hard drive containing scans between July 2016 and May 2017 was not obtained. Though radar data presently continue to be archived at the FORCE site, .jpgs were converted to .mp4s on Apr 11, 2018, hence the end date. The available radar data were subsampled to obtain 5-minute clips from four times of day (sunrise, three hours after sunrise [morning], three hours before sunset [afternoon], and sunset) thought to represent diurnal sea bird activity at the site. Clips from these four times of day were taken from one day per week throughout the year, and were selected from the day of that week that had the lowest average wind speed during diurnal hours. While the effects of wind and wind direction were of interest on sea bird use, it was clear after initially processing numerous clips from randomly selected days that the birds were not readily detectable over the waves when it was windy. Historic weather data were obtained for the Parrsboro, NS weather station from the Environment and Climate Change Canada website (http://climate.weather.gc.ca/climate_data/) to determine days with little wind and precipitation, and for use in the data analysis. Dates with >5mm of precipitation were not considered due to the difficulty in filtering rain or snow from of the radar data. By selecting clips from these four times of day and the range of dates, it also ensured that each stage of the tidal cycle would have adequate representation. Tide predictions were calculated for Cape Sharp using the following website: tides.mobilegeographics.com. Based on the above criteria, 305 clips were created and processed (some of the time periods were missing data on some days), though only 294 clips contained usable data due to radar malfunctions, fog, or other unknown reasons.

Each clip was read into radR using the video plugin, and processed using the radR settings shown in Appendix 1. The settings were selected after much trial and error specifically to reduce the effects of interference from waves on the surface of the water. Radar scans from the FORCE site are collected with an open-array antenna which records data in two dimensions, range and bearing, so objects detected at all altitudes are combined in a single plane. Additionally, the radar unit at the FORCE site was set up to intentionally detect the surface of the water, so there is significant amount of wave interference on most clips. The declutter plugin in radR was used to eliminate areas with persistent wave interference, which varied in each clip depending on wind speed, wind direction, and tidal stage. A separate clutter map was created for each clip, and was used to filter out waves on that clip and saved for use in the analysis. Additionally, the radar data were filtered to include only blips from within four kilometres of the radar, as there was an increasing amount of noise beyond that range.

Once the most problematic areas with persistent waves were removed from each clip, it was possible to use the tracker plug-in in radR to track flights of individual birds. The multi-frame correspondence algorithm was used, with the settings shown in Appendix 1, and the resulting tracks were saved in a .csv file. Finding appropriate settings that tracked birds effectively without producing unwanted tracks using blips from waves and other clutter was a difficult task, and the optimum settings found were a balance between the false positive and false negative tracks. The optimum settings were identified, however the process could not be fully automated due to excessive noise from the surface of the water, and manual corrections for false positive and false negative tracks were necessary. Specifically, each clip was watched as it was processed using the declutter, tracker, and blip trails (displays blips from previous scans in a different colour to help visualize tracks) plugins. The tracker plugin displays tracks it identifies by drawing a line through them on the plot of the radar scans. Tracks arising from clutter (false positives) were identified and deleted, and the beginning and endpoints of visible tracks not picked up by the tracking algorithm were recorded. An example of a clip being processed in radR is included in a separate .gif file as Appendix 2. Tracks are displayed in orange and blip-trails in green.

Data Analysis

Average velocities and bearings were calculated for tracks recorded by the tracking algorithm in radR. Tracks with average velocities below 20 kilometers per hour (kph) and bearings between 100 and 125 degrees or between 280 and 295 degrees were considered to be objects floating with the tides, and were removed from the other track data prior to further analysis. To determine the effects of date, time of day, and tidal stage on bird activity in the area, a general additive model was created using the package mgcv in R (Wood 2011). The number of tracks on a clip was the response variable, and predictor variables included a circular smoothed term for Julian day, the size of the wave clutter file (in Kilobytes), an interaction between tidal stage (factor with six levels) and time of day (factor with four levels), and an interaction between wind speed (hourly average kph from time of clip) and wind direction (factor with nine levels). The size of the clutter file from the declutter plugin is representative of the amount of wave clutter on each clip, so this term was used to account for the amount of interference from waves. The tidal stages used are as follows: High (one hour before to one hour after high tide), High Falling (one hour after high tide to mid tide), Low Falling (mid tide to one hour before low tide), Low (one hour before to one hour after low tide), Low Rising (one hour after low tide to mid tide), and High Rising (mid tide to one hour before high tide). The factor for wind direction included the directions: N, NE, E, SE, S, SW, W, NW, and a level for calm for which no wind direction was specified. A negative binomial distribution was used for the model as the counts of tracks were overdispersed, and the model fit much better than it did with a Poisson or quasi-Poisson distribution. Predicted values were calculated using the model to aid in interpretation of plots, and used the average amount of clutter, wind speeds of 0, 5, 10, 15, and 20 kph, and the full range of values for other variables. Data from multiple years were included in the model, however there was insufficient overlap in dates between years to model separate year effects.

RESULTS

Number of tracks

Bird flights were detected on 233 of the 294 (79%) clips processed. Most of the clips lacking birds had high levels of wave interference, however there were several clips from calm days that also lacked birds. A total of 12,753 tracks from birds were recorded, with an average of 54.84 tracks per clip on clips where at least one track was detected. Of the 12,753 tracks detected, 10,928 were identified by the tracking algorithm in radR and an additional 1,825 (14%) were detected manually. The maximum number of tracks detected on a clip was 628. The raw number of tracks detected by date is depicted in Figure 1, however these numbers are not corrected for the amount of clutter, wind, tide, or any other variables considered. An additional 1005 tracks were detected that were considered to be floating objects (Figure 2). While some of these tracks could have been birds sitting on the surface of the water, we have no way to distinguish them from other floating objects. Birds were detected up to the range cut-off of four kilometers, however there appeared to be a decrease in detection probability at ranges over one kilometer (Figure 3). Beginning and end points of tracks were plotted to determine core areas of bird activity, but the only clear pattern indicated that the area of water between Black Rock and the small inlet west of the FORCE site was heavily used (Figure 4). Similar plots were also examined with tracks separated by time of day and tide, but none of these plots indicated a pattern different from the overall pattern, and are not depicted.

Effects of date, time, tide, and wind

The general additive model considered the effects of multiple explanatory variables simultaneously, including the effects of wave interference, to enable interpretation of the effects of each variable separately after the effects of the other variables had been accounted for. The model converged with an adjusted R^2 of 0.347 and 65% of the deviance explained, and all terms including the interactions were statistically significant at $\alpha = 0.05$ (Table 1). Estimates of parametric coefficients are shown in Table 2. The term for clutter is the most explanatory, which was expected due to the strong influence of wave interference on the ability to isolate tracks from birds. The smoothed term for date was highly explanatory ($\chi^2_8 = 234$, $P < 0.0001$), and predicted values for the effect of date are shown in Figure 5. It was clear from the model, and the raw data, that there are very few bird tracks in the winter, and that the number of tracks increases markedly in March (Figures 1 and 5). An influx of spring migrants begins in March and peaks in late May, followed by a period of high activity in summer. There is another peak in late summer and early fall depicting fall migrants, which gradually tails off as winter approaches. A violin plot of track velocities by month helps document the presence of migrants, which should have higher track velocities than resident or breeding birds (Figure 6). Velocities are highest in March and April when many sea birds are migrating, and nearly bimodal in May when both migrant and breeding birds are present. Velocities in the summer are generally low, but increase again in the fall.

The effects of time of day, tide, and wind were not as easily interpretable due to the complex nature of the system involving multiple species of birds and their behaviours related to tidal cycles, times of day, and weather patterns. Two 2nd order interactions were modeled, both of which proved to be statistically significant, however these still likely downplay the complexity of the system. The interactions are most easily interpreted by plots of predicted values. Figure 7 depicts the interaction between time of day and tidal stage, and Figure 8 illustrates the interaction between wind speed and wind direction. The interaction between time of day and tidal stage indicates that bird species behave differently each day depending on the timing of the tides. A high tide in the afternoon, falling tide in the morning, or a low tide at sunset seem to produce the highest number of tracks (Figure 7). Strong winds from the SW or SE produce large numbers of bird tracks, but winds from due S or other directions do not have the same effect (Figure 8).

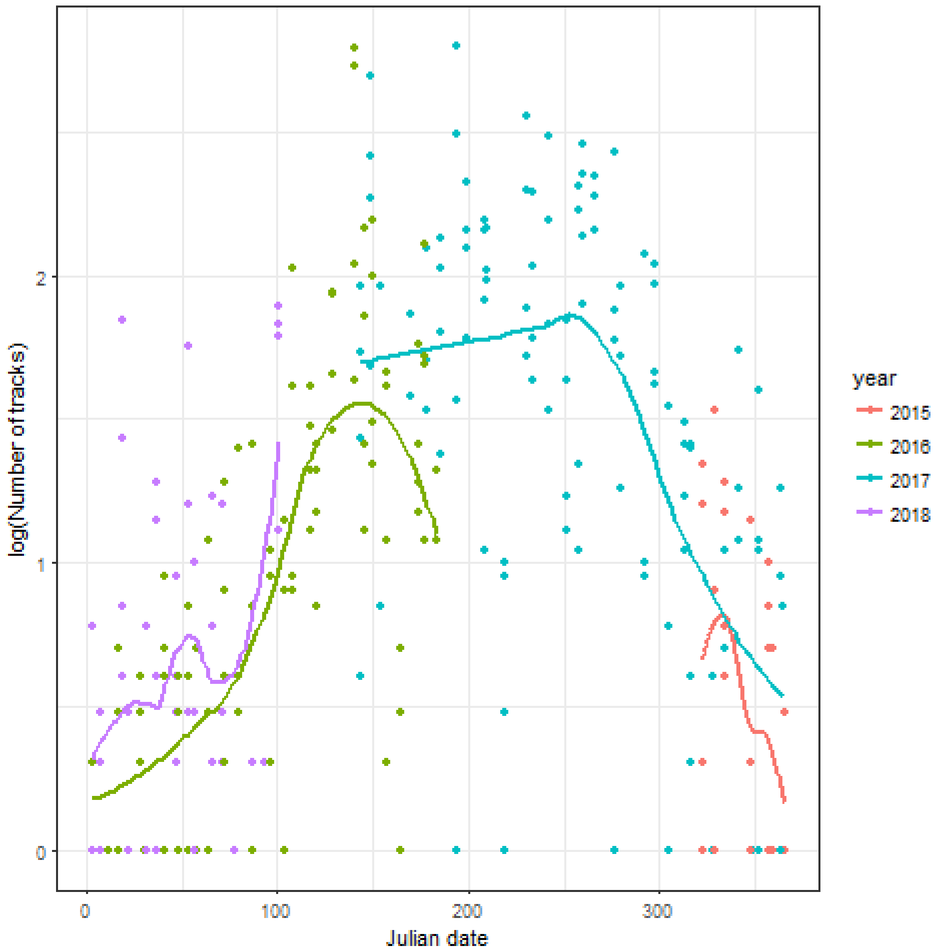

Figure 1. The number of tracks (log_{10} scale) detected on each five-minute clip, by Julian date, including a separate smooth for each year.

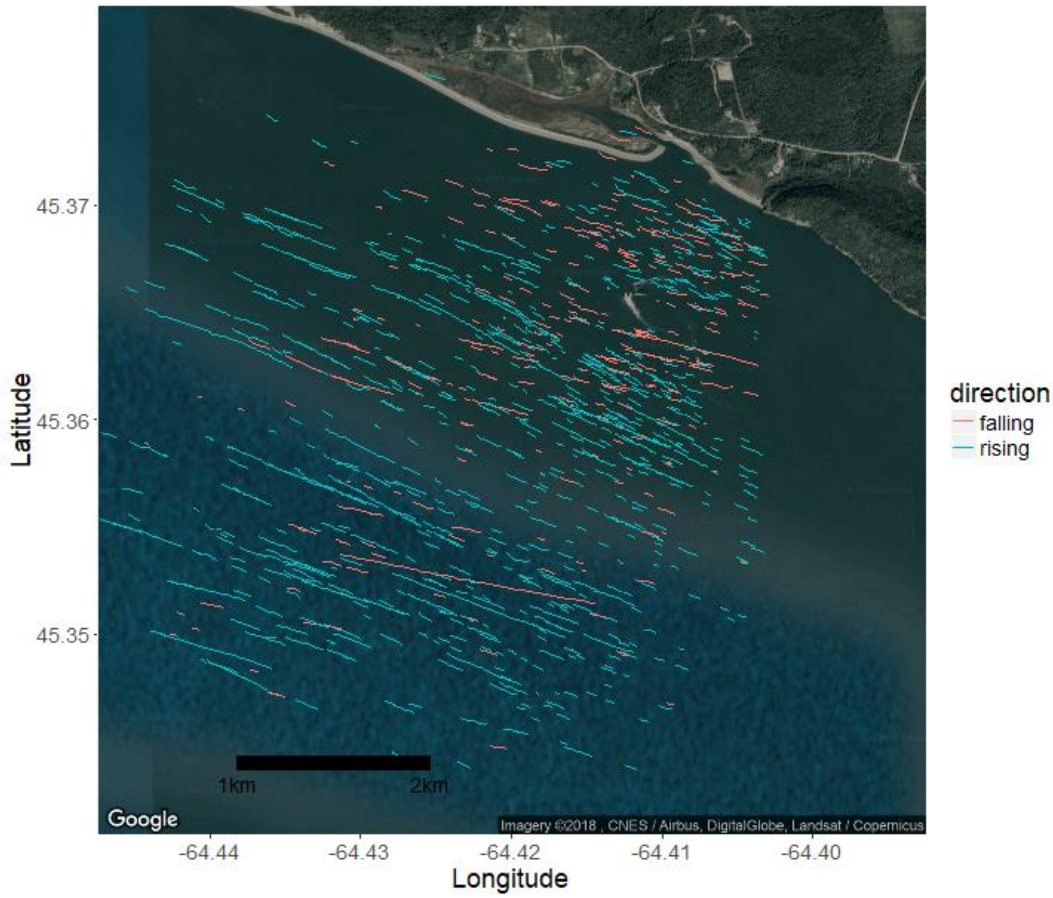

Figure 2. Map of tracks classified as floating objects, separated by tidal direction.

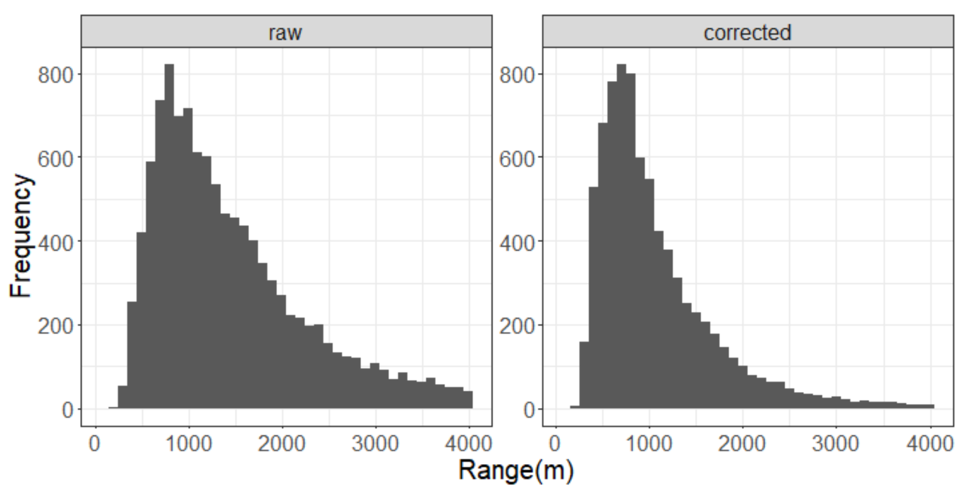

Figure 3. Histogram of the number of tracks detected by range. The left panel is the raw number of tracks and the right panel is corrected for the area sampled, which increases with range.

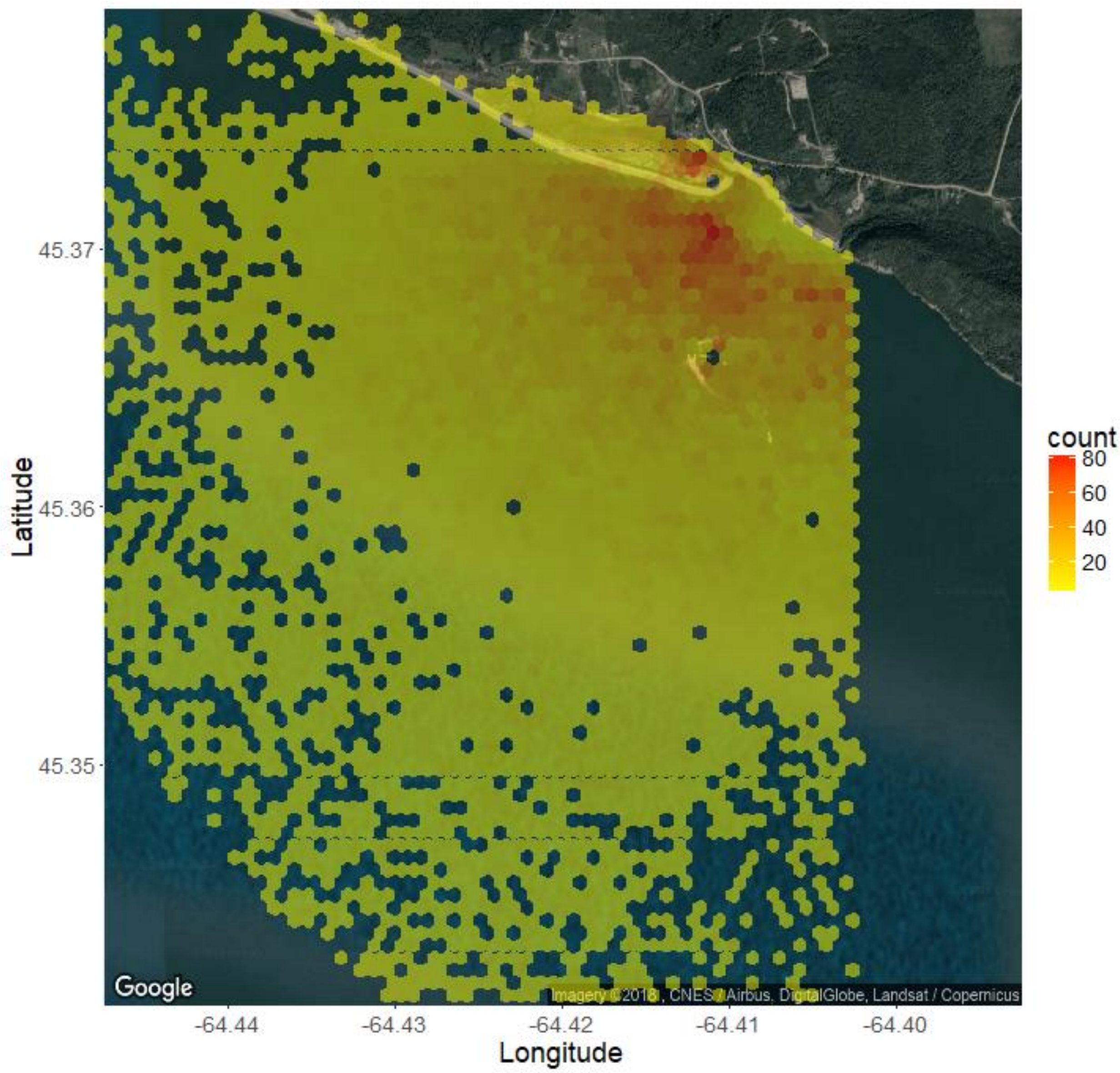

Figure 4. Map showing density of beginning and end points of bird tracks detected by the radar. The colors represent the number of tracks in each hexagonal bin.

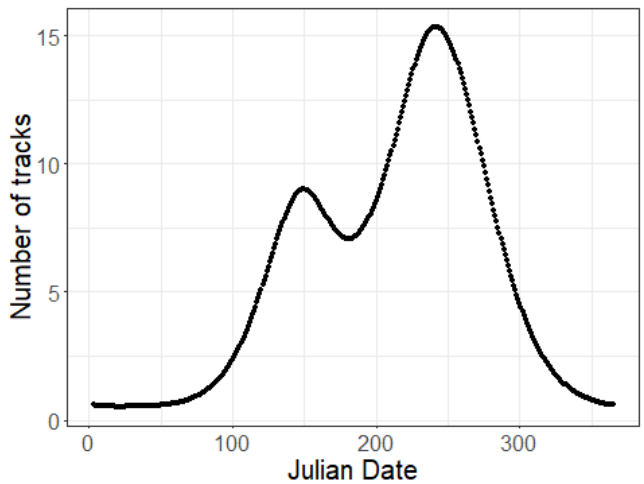

Figure 5. Predicted values from the general additive model for number of tracks by Julian date. The y-axis ticks are arbitrary, and based on the levels of the other variables in the model, but the relative effect of date remains constant. In this case, the levels of the other variables were: an average amount wave interference, at sunrise, at high tide, and with a north wind of 10kph.

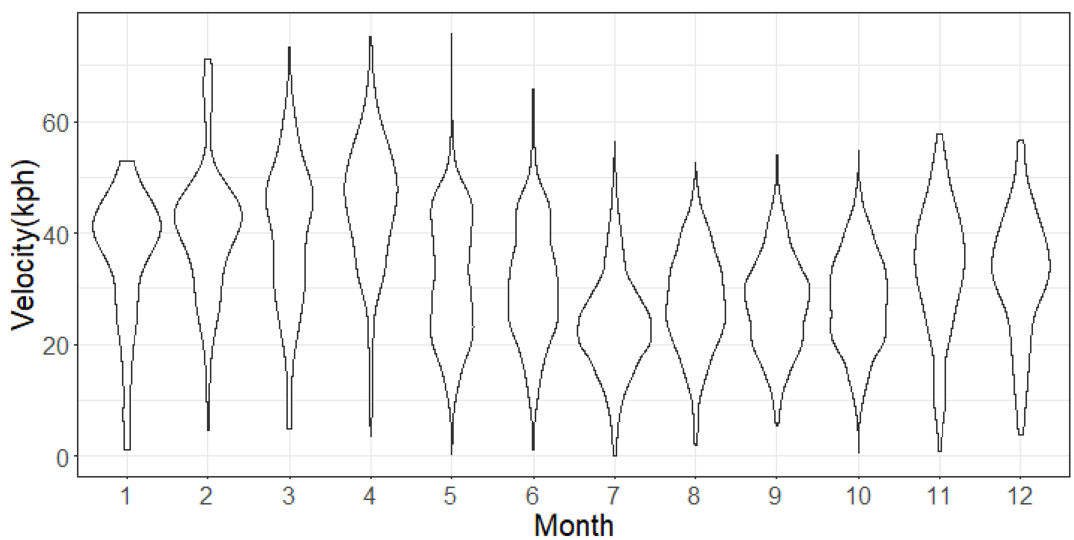

Figure 6. Violin plot showing histograms of track velocities by month.

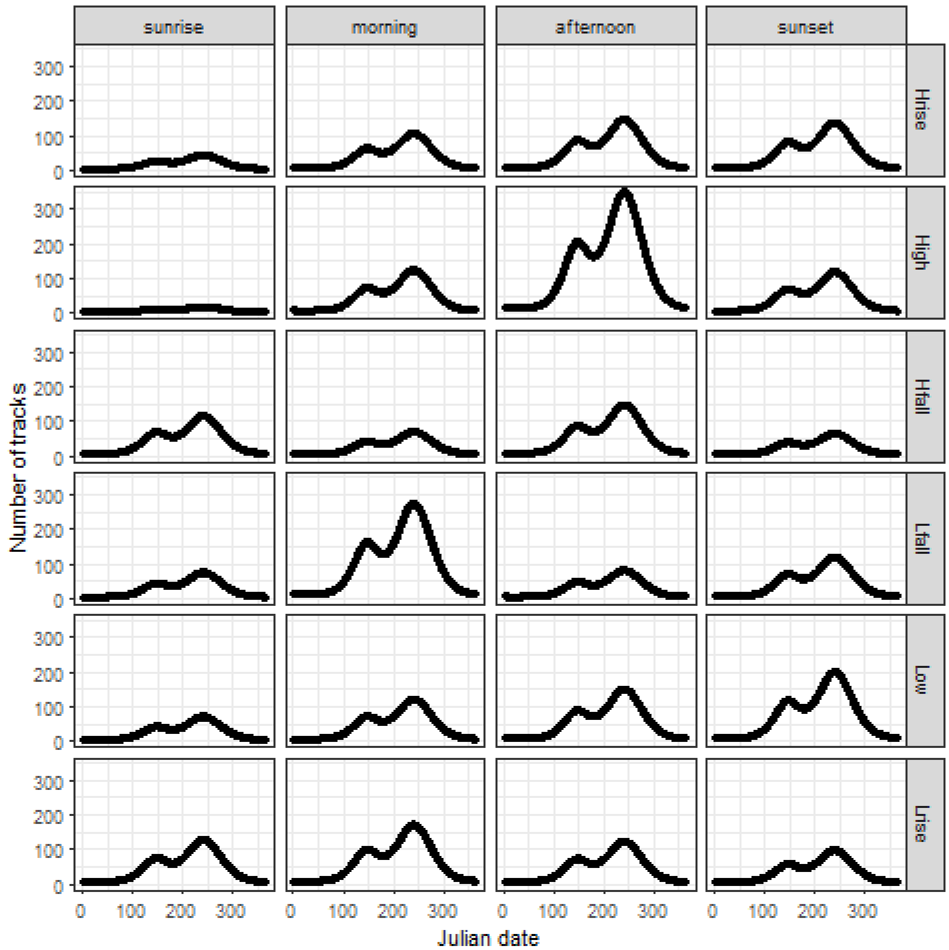

Figure 7. Interaction plot showing the number of tracks by Julian date for each combination of tidal stage and time of day.

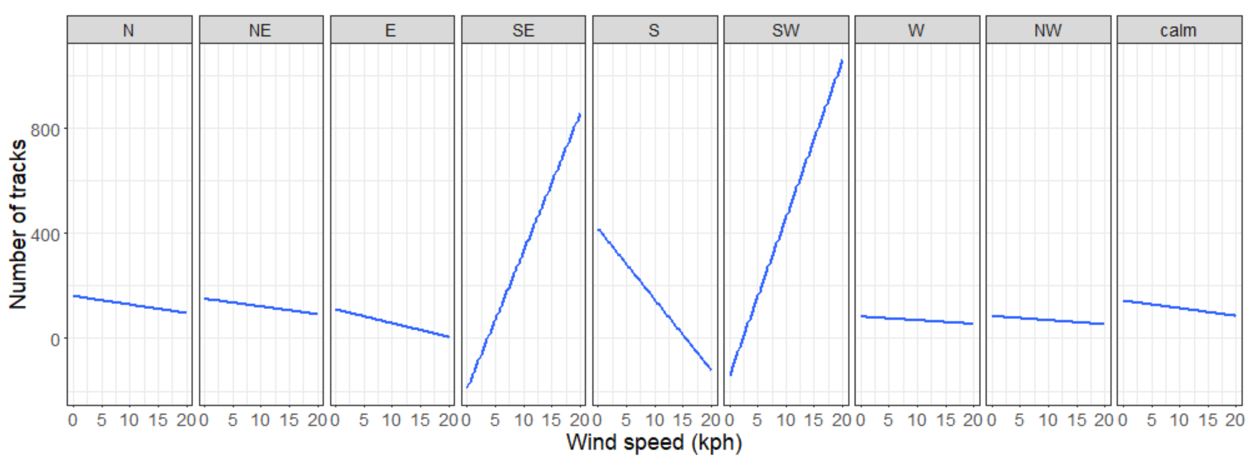

Figure 8. Interaction plot showing the how the effect of wind speed varies with wind direction.

Table 1. Anova table from the general additive model showing the degrees of freedom, χ2 value, and *P* value for each term in the model.

Term	df	χ^2	*P*
time	3	18.0542	0.0004
tide	5	12.4602	0.0290
clutter	1	88.1319	<0.0001
wind direction	8	18.6458	0.0169
wind speed	1	0.4858	0.4858
time:tide	15	30.3152	0.0108
wind speed:wind direction	7	14.8963	0.0374

Table 2. Parameter coefficients from the general additive model, with their standard errors (se), t values, and P values. Statistically significant parameters at a =0.05 are shown in bold font.

Parameter	Coefficient	se	*t*	*P*
intercept	**2.9352**	**0.6941**	**4.2289**	**<0.0001**
timemorning	**2.0641**	**0.7109**	**2.9034**	**0.0037**
timeafternoon	**3.1177**	**0.7407**	**4.2089**	**<0.0001**
timesunset	**2.0184**	**0.7107**	**2.8401**	**0.0045**
tideHfall	**1.9951**	**0.6996**	**2.8519**	**0.0043**
tideHrise	1.0004	0.7312	1.3681	0.1713
tideLfall	**1.5555**	**0.7029**	**2.2130**	**0.0269**
tideLow	1.5029	0.7798	1.9272	0.0540
tideLrise	**2.1051**	**0.7137**	**2.9495**	**0.0032**
clutter	**-0.0058**	**0.0006**	**-9.3879**	**<0.0001**
wdirNE	-0.0651	0.6154	-0.1058	0.9157
wdirE	-0.2742	0.6033	-0.4545	0.6495
wdirSE	**-2.7550**	**0.8200**	**-3.3599**	**0.0008**
wdirS	1.3517	0.9275	1.4574	0.1450
wdirSW	-1.2065	0.7299	-1.653	0.0983
wdirW	-0.6717	0.4410	-1.523	0.1278
wdirNW	-0.6456	0.5930	-1.0887	0.2763
wdircalm	-0.1167	0.3634	-0.3212	0.7480
windkph	-0.0255	0.0366	-0.697	0.4858
timemorning:tideHfall	**-2.5862**	**0.8680**	**-2.9796**	**0.0029**
timeafternoon:tideHfall	**-2.8656**	**0.8404**	**-3.4097**	**0.0007**
timesunset:tideHfall	**-2.6125**	**0.8834**	**-2.9574**	**0.0031**
timemorning:tideHrise	-1.1587	0.8762	-1.3225	0.1860
timeafternoon:tideHrise	**-1.8739**	**0.8939**	**-2.0962**	**0.0361**
timesunset:tideHrise	-0.8499	0.8867	-0.9585	0.3378
timemorning:tideLfall	-0.7446	0.8614	-0.8644	0.3874
timeafternoon:tideLfall	**-3.0377**	**0.8833**	**-3.4391**	**0.0006**

Parameter	Coefficient	se	*t*	*P*
timesunset:tideLfall	-1.5359	0.8341	-1.8415	0.0656
timemorning:tideLow	-1.5117	0.9050	-1.6703	0.0949
timeafternoon:tideLow	**-2.3483**	**0.9385**	**-2.5021**	**0.0123**
timesunset:tideLow	-0.9676	0.9364	-1.0332	0.3015
timemorning:tideLrise	**-1.7710**	**0.8549**	**-2.0716**	**0.0383**
timeafternoon:tideLrise	**-3.1605**	**0.8746**	**-3.6137**	**0.0003**
timesunset:tideLrise	**-2.3006**	**0.8645**	**-2.6611**	**0.0078**
wdirNE:windkph	0.0008	0.0899	0.0091	0.9928
wdirE:windkph	-0.0763	0.0931	-0.8198	0.4123
wdirSE:windkph	**0.2615**	**0.0993**	**2.6334**	**0.0085**
wdirS:windkph	-0.3510	0.1992	-1.7615	0.0781
wdirSW:windkph	0.1905	0.1037	1.8378	0.0661
wdirW:windkph	0.0052	0.0530	0.0989	0.9212
wdirNW:windkph	0.0025	0.0751	0.0339	0.9730
wdircalm:windkph	0	0	NA	NA

CONCLUSIONS

Data from the radar unit installed at the FORCE site to monitor currents, waves, and turbulence can be used to effectively monitor bird movements at the site, with some limitations. Bird targets were detected at ranges of at least up to four kilometers from the site. There was some evidence that fewer birds were detected as range increased, however if birds were selectively using areas closer to shore as indicated by the observer-based seabird surveys, it would confound this result. Interference from waves on the surface of the water are a major impediment to the identification of bird tracks, but methods were developed to eliminate areas with persistent wave clutter to enable tracking of birds in other parts of the study area. As a consequence, however, any birds using areas with persistent waves could not be isolated and tracked by the radar. It may be possible to develop algorithms to filter out wave interference while retaining blips from birds flying over the water, but this was beyond the scope of this project. Models using the radar data were corrected for the area obscured by wave interference, but the highly variable level of interference precluded an in-depth analysis of habitat use at the site.

The tracking algorithm in radR successfully tracked many of the birds present, though missed approximately 14% of the total based on manual estimates. Relaxing the settings of the tracking algorithm, such as allowing faster average velocities, allowing larger changes in bearing, or allowing more scans to be missing blips from the tracked target effectively reduced the number of bird tracks missed by the algorithm, but resulted in many spurious tracks consisting of wave clutter. Additionally, the tracking algorithm sometimes assigned multiple tracks to the same bird, which happened if the bird changed velocities, turned abruptly, or disappeared from the radar by passing behind a wave or by passing through an area filtered out by the declutter plugin. Also, any birds that landed and then later took off would be assigned a new track. As a consequence, the number of tracks presented in the results should not be interpreted as the number of birds detected during a five minute clip, but as a record of activity that should be reflective of and proportional to the number of birds present.

The results clearly show a seasonal pattern of activity at the site across years. There are very few birds present at the site during the winter, and peaks of activity during spring and fall migration are obvious. Bird activity at the site during the summer months is much higher than during the winter. There was no clear pattern of how birds use the site at different tidal cycles or times of day, though it was clear that both tidal stage and time of day do have effects on the number of bird flights at the site. This is likely due to the multitude of species that use the site which varies by season. Adding a seasonal component to the interaction between time of day and tidal stage might tease out some of these differences, but the added complexity would require an enormous quantity of data and would be difficult to interpret. The interaction between wind speed and direction matched our expectations, showing that strong SW winds blow seabirds into the inner Bay of Fundy, and strong SE winds aligned with the shorelines of the Minas Passage increased the number of birds present. There is likely a seasonal component to this interaction as well, but adding another variable to this interaction would increase the complexity of the model markedly. Many of the clips with numerous tracks come from the summer months, so the effects of the interactions between time of day and tide and between wind speed and direction may be driven by the dominant species present then, namely gulls and cormorants (FORCE 2018).

One major limitation of the radar data is that it is difficult or impossible to determine the species of birds tracked by the radar. It may be possible to differentiate some species based on the size of the blips and speed of the tracks, but there will always be a need for observer-based surveys to accurately determine species composition, and how different species utilize the site. The radar data largely agreed with the observer-based seabird surveys in terms of seasonal peaks in activity, however the radar data indicate higher levels of activity in the summer than the observer based surveys (FORCE 2018, Figures 1 and 3). Additionally, radar data from multiple years indicated that there were large quantities of birds present at the site in late May. To date, none of the observer-based surveys have been conducted in late May, so these large flights of birds have not been recorded by the monitoring program. Future observer-based monitoring should continue, and should use the results of this radar study as a guideline for scheduling survey dates so they coincide with periods of peak activity. Weather should be considered when scheduling these surveys, since SE and SW winds can have marked effects on the number of tracks detected.

RECOMMENDATIONS

Effective monitoring of sea birds using radar is inextricably dependent on filtering wave-clutter from the data. Many sea birds fly at low altitudes, often in the troughs of waves, so there is no effective way to detect sea birds without also detecting the surface of the water. To specifically monitor birds, data from a dish antenna may be easier to analyze and interpret than those from and open array antenna since the scans and data are recorded in three dimensions, including altitude. This would likely facilitate the separation of bird targets from waves, but would require running a separate radar unit specifically to monitor birds. Classifying tracks to species would still be nearly as difficult as with an open array antenna, but there would be additional information from the scans that could be used.

If bird monitoring via radar is to continue but using data from an open array antenna, the next advancement would be to develop an algorithm for detecting birds in sectors of the radar sweep with wave clutter. For the tracking algorithms to work effectively, the blips from waves will need to be removed while retaining those of the birds above the waves. This will be a complex and difficult task, especially considering that it is not possible to visually discern the blips from birds from the background noise with the human eye on the radR display. If wave clutter can be effectively filtered out, it would be possible to automate the processing of the radar data. This would provide a nearly complete record of bird activity at the site since 2015, allowing full analyses of inter-annual variability more detailed analyses of variation by weather, tide, and time of day. Additionally, modifications to the radR code should be made to allow .jpg files to be read into the program directly, so that .jpgs do not need to be spliced into videos prior to analysis. This modification would not only save time and computing power, but would preserve time stamp information included in the .jpg files.

Determining effects of a bottom-mounted turbine on sea birds at the FORCE site is very complex, especially due to the variation in sea bird abundance and behaviour by season, tidal stage, time of day, and weather. Each species of sea bird may need to be considered separately, since they use the site in different ways and are present at different times of year and under different weather conditions. Risk to birds would likely be restricted to diving species, though some species may be deterred from using the site by increased waves, noise, or turbulence. Some species could change their feeding patterns if there is an effect on fish or invertebrate species caused by the turbine. Detecting such varied effects in an already highly variable system will require careful thought as to which species are of interest and what the potential effects of a turbine might be.

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APPENDIX 1. TABLE OF radR SETTINGS USED FOR PROCESSING DATA

Plugin	Setting	Value
Video	frame rate	0.46 frames/sec
	image width	1876 pixels
	image height	1866 pixels
	x offset	-936 pixels
	y offset	-273 pixels
	scale	4.8 m/pixel
Antenna	angle of beam above rotaion	0 degrees
	horizontal aperture of beam	1 degree
	vertical aperture of beam	1 degree
	bearing offset	0 degrees
	elevation	10 metres
	true range of first sample	0 metres
	latitude	45.4 degrees
	longitude	-64.4 degrees
	rotation axis	90 degrees
	tilt	0 degrees
Blip processing	noise cutoff	0
	find blips	on
	learning scans	15
	update stats every scan	on
	exclude stats from blip update	on
	old stats weighting	0.95
	hot score threshold high	2.5
	hot score threshold low	-128
	samples per cell	4
	pulses per cell	4
	blips extend diagonally	off
	blip centroids by area not intensity	off
	filter blips	on
	min blip samples	8
	max blip samples	5000
	min blip area	150
	max blip area	20000
	min angular span	1
	max angular span	-1
	min radial span	1
	max radial span	-1

Plugin	Setting	Value
Blip processing	filter by logical expression	on
	logical expression	int > 0.08 & sqrt(x^2 + y^2)<4000 & 2*aspan>rspan
Declutter	blip cutoff for mean occupancy rate	0.03
Tracker controls	minimum number of blips required for a track	4
	maximum speed of tracked objects	80 kph
	minimum number of blips before track is plotted	4
	how long to retain plots of complete tracks	300
Multiframe correspondence controls	number of scans to backtrack over in building tracks	4
	weight of directional coherence vs proximity to prediction	0.64
	maximum gain for a blip to join a track (log units)	19
	small penalty for blips missing from tracks (gain units)	0