# Environmental Effects Monitoring Program

## Quarterly Report: January – March 2018

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# Executive Summary

The Fundy Ocean Research Center for Energy (FORCE) is Canada's leading research centre for the demonstration and evaluation of tidal in-stream energy conversion (TISEC) technology. This technology (commonly known as "in-stream tidal turbines") is part of an emerging sector designed to generate electricity from the ebb and flow of the tide. It also has application in river systems and has the potential to introduce another non-carbon emitting source of electricity to the Nova Scotia electrical grid.

The first demonstration in-stream tidal energy turbine was operational at the FORCE site for a short time in 2009 and removed in 2010. There had been no turbines present at FORCE until Cape Sharp Tidal (CST) deployed a two-megawatt demonstration turbine in November 2016 and began a commissioning process. This turbine was disconnected in April 2017 and recovered in June 2017. CST is intending to re-deploy another two-megawatt demonstration turbine at the FORCE site in summer 2018. Additional deployments by other FORCE berth holders are scheduled to follow CST; however, firm dates have not yet been provided.

Baseline studies began at FORCE in 2009 and Environmental Effects Monitoring Programs (EEMPs) were implemented in 2016; to-date, over 90 tidal-related research studies have been completed or are underway with funding from FORCE and the Offshore Energy Research Association. This EEMP consists of a mid-field monitoring program (100 m - 1000 m from the turbine), led by FORCE, and near-field monitoring programs (< 100 m), led by individual developers, or 'berth holders'.

FORCE's EEMP has continued in 2018. The design and completion of data collection and analysis is being conducted with academic and research partners, including the University of Maine, the Sea Mammal Research Unit Consulting (Canada), Envirosphere Consultants, Acadia University, Luna Ocean Consulting, JASCO Applied Science, Ocean Sonics, GeoSpectrum Technologies Inc., and Nexus Coastal Resource Management.

A near-field EEMP was initiated by CST in 2016 upon turbine deployment and was conducted throughout the operation of its two-megawatt demonstration turbine. The 2016/2017 program focused on marine mammals, fish, and turbine sound. Data analysis was led by Ocean Sonics, JASCO Applied Sciences, Acadia University (Acadia Center for Estuarine Research), and Tritech Ltd.

This report provides a summary of monitoring and data analysis completed at the FORCE site by both FORCE and CST in the first quarter of 2018 (January 1$^{st}$ – March 31$^{st}$, 2018). CST does not currently have a turbine deployed (the next deployment date is planned for later in 2018); however, an update on 2018 EEMP planning and an operational update for CST is provided.

**Lobster monitoring**: FORCE's Lobster EEMP consists of a lobster catchability study in collaboration with NEXUS Coastal Resource Management. The goal of this study is to measure

whether the presence of a turbine affects the number of lobsters entering traps. Commercial lobster traps are used to compare catch volumes in different proximity to the turbine location.

A catchability study was completed at the FORCE site in October - November 2017, while no turbine was deployed. This study provides baseline catchability rates in the absence of a turbine.

Initial results indicate that catchability rates are high in the FORCE site, with catch rates ranging from 1.00-20.17 kg $trap^{-1}$. Catch rates declined slightly during the study period, likely in relation to increasing tidal velocities. The survey design consists of two concentric rings that increase in distance from where the turbine was located in 2016-2017. Preliminary qualitative analyses indicated that there were no differences between treatment rings, or with direction from the turbine location (North, East, South, West).

The next lobster catchability study will take place in October-November 2018, to coincide with the timing of the survey completed in 2017. The 2018 survey is contingent on the presence of a turbine at the site, which is needed to fully evaluate the effects of in-stream tidal turbines on lobster catchability rates.

**Fish monitoring**: Surveys were completed in 2016/2017 by FORCE and the University of Maine using a downward facing hydro-acoustic echosounder to describe and quantify fish distributional changes that reflect behavioural responses to the presence of a deployed turbine. Results to date have shown that the density of fish at turbine height was highly variable across tidal stage, time of year, and location within the FORCE site. Preliminary findings suggest no significant effect of the turbine on the density of fish in the mid-field of the turbine or on fish vertical distributions, but more data collection during additional turbine deployments is needed evaluate impacts to fish. A report outlining these preliminary findings can be found in FORCE's 2017 annual report, located at: www.fundyforce.ca/environment/monitoring

This work continued in Q1 2018 with a survey completed February 15th – 16th. This survey coincided with the operation of a subsea platform configured with similar instrumentation known as 'FAST-3.'

*Berth holder fish monitoring*: With no turbines presently deployed at the FORCE site, there are no updates to provide on data collection and analysis related to fish in the near-field environment. CST, in preparation for the next deployment, is working on the development on an updated 2018 monitoring program that will include lessons and recommendations learned from the 2016/2017 deployment in relation to monitoring fish in the near-field.

**Marine mammal monitoring**: The goal of the near-field and mid-field marine mammal monitoring programs is to detect changes in the distribution of marine mammals (predominately harbour porpoise at the FORCE site) in relation to operational in-stream turbines.

In collaboration with the Sea Mammal Research Unit (SMRU Consulting), FORCE monitors marine mammal presence using C-PODS deployed on a near-continuous basis in the mid-field of the turbine location. In 2016/2017, porpoises were detected on 98.4% of days, with presence varying by time of year, current speed, tidal height, time of day, and the lunar cycle. Initial results provide no evidence of permanent avoidance in the mid-field of the turbine, but there was a temporary decline in detection rate post turbine installation (41-46%), likely due to vessel activity. Tidal height was a more important factor in driving variation in porpoise abundance, with a 12-fold greater impact on detection rate than the presence of the turbine. A report outlining these preliminary findings can be found in FORCE's 2017 Annual Report, located at: www.fundyforce.ca/environment/monitoring.

In 2018, five C-PODs were recovered in January and redeployed two weeks later following a period of annual maintenance. During this time, beacons were added to aid with re-location in the event of premature resurfacing. All five C-PODs will be recovered in May and re-deployed following battery replacement.

In addition, FORCE has continued its beach walk and public observation program for marine mammals.

*Berth holder marine mammal monitoring*: With no turbines presently deployed at the FORCE site, there are no updates to provide on data collection and analysis related to marine mammals in the near-field environment. However, in preparation for the next deployment, CST is working on the development of an updated 2018 monitoring program that will include the lessons and recommendations learned from the 2016/2017 deployment in relation to monitoring of marine mammals in the near-field.

**Seabird monitoring**: The main objectives of the FORCE seabird monitoring program are to obtain site-specific species abundance and behaviour data, which can be used to establish whether the presence of a turbine causes displacement of surface-visible seabirds and marine mammals from habitual waters and to identify changes in behaviour. Initial results show seasonal peaks in water-associated birds in spring and fall, consistent with known migratory patterns of species of loons, cormorants, gulls, waterfowl, and alcids. Initial results suggest no significant effect of turbine operations on seabird abundance, but a formal statistical analysis of the data will be performed in 2018. Three surveys have been completed to date in Q1 of 2018, and survey protocols will continue as were conducted in 2017.

**Sound monitoring**: The goal of FORCE's sound monitoring program is to measure both ambient (in the immediate surroundings) and operational sound generated by in-stream turbines to understand the potential effects on marine life. Initial results using drifting hydrophones indicate that the main sources of sound in the study area included sediment movement associated with tidal flow and nearby vessel activity. Preliminary analyses indicated that sounds from the OpenHydro turbine were easily detectable above ambient sounds 650 m from the turbine, and were detectable with more sensitive signal processing to the farthest extent drifting hydrophone were deployed from the FORCE site (3 km). Sounds from the turbine were mostly in the range of 90-300 hz, but extended up beyond 10 khz.

Data collection during additional turbine deployments is needed to more fully characterize sounds from the turbine in the mid-field area (100 m - 1000 m), and verify predictions that sounds from in-stream turbines have minimal impacts on marine life. Additional drifter deployments are planned for 2018.

*Berth holder sound monitoring*: With no turbines presently deployed at the FORCE site, there are no updates to provide on data collection and analysis related to operational sound in the near-field environment. However, finalization of analysis of the data collected during 2016/2017 is on-going. The analysis will be completed for the Q2 monitoring report (April 1st – June 30th, 2018) with the objective of providing a clear description of the sound produced by the turbine relative to ambient (i.e., background) sound.

FORCE and CST have hired JASCO Applied Sciences to undertake a comparative analysis of bottom, turbine, and drifter-mounted hydrophone systems to validate data collected from each instrument and provide an evaluation of the relative utility of each system for ongoing sound monitoring at the FORCE site.

In preparation for the next deployment, CST is developing the scope for a new sound monitoring program, which will include the deployment of an acoustic (sound) recorder prior to deployment to capture additional baseline sound of the ambient environment in the area of the CST deployment site (Berth D). The updated 2018 monitoring program will include the lessons and recommendations learned from the 2016/2017 deployment in relation to monitoring of sound in the near-field.

**Other activities:** Independent of EEM programs, FORCE also conducts and supports additional research efforts, including fish tagging efforts in collaboration with Acadia University and Ocean Tracking Network, radar projects, and subsea instrument platform deployments through the Fundy Advanced Sensor Technology (FAST) program.

The FAST-2 platform is currently in trials to test directional sensors to collect data from a specific target, including the face of a turbine. Sensors currently include a Tritech Gemini imaging sonar, dynamic mount to position the sonar, and subsea cabling to allow for real-time data collection. Testing began March 22nd, 2018, between the FORCE beach and Black Rock.

The FAST-3 platform was recovered on February 22nd and redeployed on March 28th, 2018 with two hydroacoustic sonars and various environmental sensors to monitor fish densities in the mid-field of the turbine. FORCE will complete a comparative analysis of data collected by bottom (FAST-3) and ship-mounted hydroacoustic sonars (used as part of FORCE's fish EEMP) to evaluate the spatial and temporal representativeness of both instrument configurations and determine the degree to which results are corroborative. This project is supported by the Offshore Energy Research Association, the Province of Nova Scotia, and Natural Resources Canada.

Final reports prepared by EEMP contractors are published on FORCE's [www.fundyforce.ca/environment](www.fundyforce.ca/environment) and CST's website ([www.capesharptidal.com/eemp](www.capesharptidal.com/eemp)) following review by FORCE’s independent Environmental Monitoring Advisory Committee and regulators.

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# Acronyms

| | |
|---|---|
| ACER | Acadia Center for Estuarine Research |
| CFI | Canadian Foundation for Innovation |
| CLA | Crown Lease Area |
| CPUE | Catch Per Unit Effort |
| CST | Cape Sharp Tidal |
| DFO | Department of Fisheries and Oceans (Canada) |
| EA | Environmental Assessment |
| EEM | Environmental Effects Monitoring |
| EEMP | Environmental Effects Monitoring Program |
| EMAC | Environmental Monitoring Advisory Committee |
| FAST | Fundy Advanced Sensor Technology |
| FORCE | Fundy Ocean Research Center for Energy |
| MET | Meteorological |
| MW | Megawatt |
| NRCan | Natural Resources Canada |
| NSE | Nova Scotia Department of Environment |
| NSERC | Natural Sciences and Engineering Research Council |
| OERA | Offshore Energy Research Association |
| ONC | Ocean Networks Canada |
| OSC | Ocean Supercluster |
| OTN | Ocean Tracking Network |
| PAM | Passive Acoustic Monitoring |
| Q1/2/3 | Quarter (1, 2, 3), based on a quarterly reporting schedule |
| TCC | Turbine Control Centre |
| TISEC | Tidal In-Stream Energy Converter |
| VEC | Valuable Ecosystem Component(s) |

# Introduction

## About FORCE

FORCE was created to lead research, demonstration, and testing for high flow, industrial-scale in-stream tidal energy devices. Located near Parrsboro, Nova Scotia, in the Minas Passage of the Bay of Fundy, FORCE is a not-for-profit facility, with funding support from the Government of Canada, the Province of Nova Scotia, Encana Corporation, and participating developers.

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 transmission system, and a visitors/operations center. 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 by 1 km in area, in the Minas Passage, and the onshore facilities are located approximately 10 km West of Parrsboro, Nova Scotia.

Subsea 'berths' are leased to tidal energy companies who are selected by the Nova Scotia Department of Energy. These companies are[1]:

Berth A: Minas Tidal
Berth B: Black Rock Tidal Power
Berth C: Atlantic Operations (Canada) Ltd. (DP Energy)
Berth D: Cape Sharp Tidal
Berth E: Halagonia Tidal Energy

The FORCE demonstration project was approved on September 15th, 2009 by the Nova Scotia Minister of Environment, and the conditions of its approval[2] provide for comprehensive, ongoing, and adaptive environmental management.

FORCE has two central roles:

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

Monitoring and reporting of any environmental effects from tidal turbines at the FORCE site 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 or 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 are expected to be phased in over the next several years, FORCE and

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

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

regulators will have opportunity to adapt environmental monitoring approaches over time as lessons are learned.

The 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). While the impacts from a single device or small arrays of devices are generally anticipated to be low, our understanding of these potential impacts on a global level is based on only a few deployments to date (Copping, 2018). A full evaluation of the risks of tidal energy will not be possible until more devices are tested, with monitoring programs that document local impacts and add to our growing global knowledge base.

## Background

Since 2009, 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. FORCE's EEMP covers the mid-field area around the turbine, extending 100 -1000 m from the turbine locations as well as coordinating integration and reporting activities. All reports on the mid-field monitoring program are available online at: www.fundyforce.ca/environment.

FORCE's present EEMP was developed in consultation with SLR Consulting (Canada)[3] and strengthened by review and contributions by national and international experts and scientists, Fisheries and Oceans Canada (DFO) and the Nova Scotia Department of Environment (NSE), and FORCE's environmental monitoring advisory committee (EMAC), which includes representatives from scientific, First Nations, and local fishing communities.[4] The EEMP is designed to:

- address the predictions of the FORCE environmental assessment by monitoring the potential environmental effects of operating turbines; and
- be adaptive, based on monitoring results and input from regulators and EMAC, as well as ongoing turbine operations.

In addition to FORCE's mid-field monitoring programs, individual berth holders conduct near-field monitoring in direct vicinity (< 100 m) of each berth as they are occupied. Berth holder monitoring plans undergo review by EMAC as well as regulators prior to turbine installation.

In 2016/2017, near-field monitoring was completed by CST in relation to its 2-megawatt, 16-metre diameter OpenHydro turbine at Berth D at the FORCE site. During turbine commissioning, CST conducted a near-field monitoring program that focused on fish, marine mammals, and turbine sound. Prior to this deployment, the only turbine present at the site was a 1-megawatt, 10-metre diameter in-stream tidal energy turbine, which operated for a short time in 2009. Since removal of this unit in 2010, no tidal turbines were present at the FORCE

[3] This document is available online at: www.fundyforce.ca/environment/monitoring.
[4] Information about EMAC may be found online at: www.fundyforce.ca/about/advisory-committees

site until 2016. Consequently, the environmental studies conducted up to 2016 have largely focused on the collection of baseline data.

## Monitoring Objectives

As part of its mandate, FORCE is tasked with monitoring and understanding the potential environmental effects of the activities undertaken at its site and reporting on these effects. The present EEMPs are based on the best available scientific advice regarding monitoring approaches and instrumentation and experience in the Minas Passage. The EEMPs will continue to evolve as results and research efforts suggest new approaches or different instruments, and as developments and lessons learned are ascertained, both at the FORCE site and internationally.

Since FORCE's creation in 2009, an adaptive management approach has been used to evaluate monitoring data and make informed, science-based decisions to modify monitoring and assess mitigation measures as necessary. This 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.

Outcomes are continuously reviewed with regulators, EMAC, and others; where required, approaches and methodologies are revised on the basis of accumulated experience and observed progress toward achieving the monitoring objectives. This approach assists with resolving gaps in the knowledge of the potential effects and usefulness of mitigation measures.

In general, the present FORCE EEMP was designed to guide monitoring over the next five years, but it remains responsive to changes in turbine deployment schedules, regulatory guidance, and as data is collected and analyzed. Further, as more devices are scheduled for deployment at the FORCE site, and as monitoring techniques are improved at the site (through FORCE's Fundy Advanced Sensor Technology (FAST) program), the EEMPs will be revisited, keeping with the adaptive management approach followed at the FORCE site.

The overarching purpose of environmental monitoring is to verify the accuracy of the environmental effect predictions made in FORCE's original environmental assessment, submitted in 2009. 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 project poses to components of the ecosystem. One of the conditions of the EA approval is that FORCE conduct environmental effects monitoring in the near and mid-field of the FORCE site in collaboration with its berth holders.

Specifically, EEMPs are aimed at effects monitoring in relation to an operating tidal turbine and will provide a fuller understanding of turbine/marine life interactions when integrated. Multi-year data collection will be required to consider seasonal variability at the site and appropriate and statistical analysis of this data will help to obtain a fuller understanding of marine life/turbine interactions.

Table 1 outlines the objectives of the respective monitoring programs conducted at the FORCE site. Further conclusions will be able to be made through integration of these programs with findings from near-field monitoring efforts, where applicable.

# Mid-Field Monitoring Activities

FORCE's latest monitoring program, which focuses on the 'mid-field area' (i.e., 100 m+ from a turbine), is currently examining lobster, fish, marine mammals, seabirds, and marine sound. This latest program was initiated in 2016 and has continued into 2018. The objectives of the mid-field monitoring programs are found below in Table 1. FORCE's EEMP is available online at: www.fundyforce.ca/environment/monitoring.

| ***Environmental Effects Monitoring Program*** | ***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<br>• 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<br>• to determine if there is a change in the distribution of a portion of the population across the mid-field study area |
| **Marine Sound (Acoustics)** | • to conduct ambient sound measurements to characterize the soundscape prior to and following deployment of the in-stream turbines |
| **Seabirds** | • to understand the occurrence and movement of bird species in the vicinity of in-stream tidal energy turbines<br>• to confirm FORCE's Environmental Assessment predictions relating to the avoidance and/or attraction of birds to in-stream tidal energy turbines |

Table 1: The objectives of each of the 'mid-field' environmental effects monitoring programs led by FORCE.

The following sections provide a summary of the mid-field monitoring activities conducted at the FORCE site from January 1st – March 31st, 2018, including data collection, data analyses performed, initial results, and lessons learned. There was no turbine operating at the FORCE site during this reporting period.

# Lobster

### Program Summary

FORCE's lobster monitoring program consists of 'catchability surveys' in the mid-field, where modified commercial lobster traps are deployed on two rings increasing in distance from the turbine location (as depicted in Figure 1). The objective of this study is to determine if the presence of an in-stream tidal energy turbine affects commercial lobster catches within the Minas Passage, and to verify the prediction of the EA, which is that in-stream turbines will have minimal impacts on lobster populations within the test site. This is based on the following characteristics of the site:

- Species diversity and population density is low;
- The substrate is scoured bedrock;

- The in-stream turbine and equipment has a small footprint in the area; and
- With minimal impact, populations will recover to baseline levels in the short-term (AECOM, 2009).

FORCE contracted NEXUS Coastal Resource Management Ltd. (Halifax, Nova Scotia) to conduct the catchability studies, analysis, and reporting. The first catchability study was completed in fall 2017 over 11 days of operations from October 23rd to November 15th, with a one-week break that suspended operations during the spring tide. Trap recovery rates were high during the survey (98%), and trap drift was minimal (~60 m average across traps). Lobsters retrieved from traps were measured (carapace length), the sex was designated (male, female, and berried female), and shell condition was evaluated. Upon completion of these measurements, lobsters were returned to the waters from which they were fished.

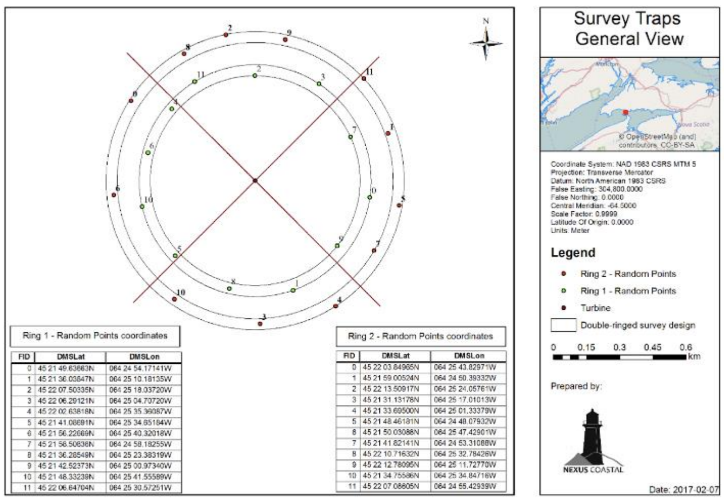


Figure 1: Double-ringed survey design proposed by Bayley (2010), with the dark centre representing the turbine and smaller circles representing lobster traps to be deployed (approximate distances shown) for the lobster monitoring program.

## 2018 Q1 ACTIVITIES

No additional lobster monitoring work has been conducted in Q1 of 2018, but data analysis and further operational planning have continued. FORCE and NEXUS are targeting a fall 2018 catchability study to occur during the same timeframe as the study conducted in 2017. This study will only be completed, however, if a turbine is deployed at the site during that time. Following this deployment, statistical analyses will be completed to test EA predictions of minimal impacts of in-stream turbines on lobster catchability rates. A report prepared by NEXUS outlining the results of the 2017 survey is included in Appendix 2.

### INITIAL RESULTS & LESSONS LEARNED

Catchability rates were 'high' (> 2.7 kg/trap) in nearly all traps during the study period, according to the following designation provided by DFO:

- Low: 0-0.7 kg CPUE (Catch Per Unit Effort)
- Moderately low: 0.8-1.1 kg CPUE

- Moderate: 1.2-1.7 kg CPUE
- Moderately high: 1.8-2.3 kg CPUE
- High: 2.4-10.7 kg CPUE (Serdynska & Coffen-Smout, 2017)

There was only one trap retrieved with catch ranked as 'moderately low' on the DFO scale, at 1.00 kg trap. The highest catch recorded was 20.17 kg trap. In total, 351 lobsters were caught and released during the study. Based on a carapace length to weight conversion, this amounted an estimated total weight of ~281.16 kg. Catch rates averaged across traps per day ranged from 4.79-8.99 kg trap (n= 7-8 traps per day for 6 days) across both study rings.

Preliminary qualitative analyses indicate that catch rates declined during the study period, likely due to increasing tidal velocities during the progression of the study. There was a statistically significant negative relationship between catch rates and maximum tidal range (m), indicating lower catch at higher flow rates. Catch rates did not increase significantly with depth, and qualitative analyses suggested that there was no significant difference in catch rates between the inner and outer survey rings. Survey rings were also divided by quadrant (i.e., North, South, East, and West quadrants) to track any directional effects of the turbine; qualitative comparisons did not reveal any differences between quadrants.

The EA prediction of minimal impacts of in-stream tidal turbines on lobster catchability rates relies, in part, on the condition of low population densities at the FORCE test site. Initial results showing high catchability rates in the FORCE test site may indicate that the impacts of turbines on lobster catchability is higher than anticipated. However, data collection in the presence of a deployed turbine is needed to fully verify EA predictions.

Significant lessons were learned during the survey operations. These lessons learned relate to survey design, logistical planning, and additional data collection, and were described in detail in the 2017 FORCE Annual Report.[5]

# Fish

### PROGRAM SUMMARY

The goals of the mid-field fish monitoring program led by FORCE and the University of Maine[6] are to:

1. test for indirect effects of in-stream devices on relative fish density throughout the water column;
2. test for indirect effects of devices on fish vertical distribution; and
3. estimate the probability of fish being at the same depth of the turbine based on the vertical distribution of fish relative to an operational tidal device.

[5] This report is available online at www.fundyforce.ca/environment/monitoring.

[6] Previous work completed by the University of Maine in relation to the Ocean Renewable Power Corporation's project in Cobscook Bay, Maine looked at evasion and avoidance behaviours of fish and marine mammals in relation to the turbine. This work found that the probability of a fish encountering the turbine's blade would be less than 2.9% (Shen et al., 2015; Viehman and Zydlewski, 2015) and that there was no difference in marine mammal behaviour in response to a turbine (ORPC, 2014).

These goals were laid out to test the EA prediction that in-stream turbines are unlikely to cause significant impacts (i.e., shifts in distribution) to marine fish within the project area. This prediction is based on the relatively small scale of the project (Copping et al., 2016) (i.e., a single turbine occupies 0.1% of the cross-section of Minas Passage).

The program uses a downward-facing hydro-acoustic echosounder (sonar) mounted onto a vessel,[7] which traverses transects across the FORCE site while collecting data on fish density and vertical distribution. Fish densities and distributions at the FORCE site are compared to those at a reference, or unimpacted site, located across the Minas Passage. Any changes occurring at the FORCE test site, and not at the reference site, are interpreted to possibly be attributed to turbine operations.

The 'mobile surveys' consist of a calibration period, followed by an approximate 24-hour survey to include two tidal cycles and day/night periods. Each transect is 1.8 km in length and is conducted twice—with and against the tidal current. The survey design is depicted in Figure 2.

In order to complete data collection for these surveys, winds must be below 10 - 15 knots during the neap tide window. There are two neap tides per month, but surveys are only completed during the neap tide of the month that has the lowest tidal range (e.g. < 10 m tidal range, optimally 8 m - 9 m). With higher winds and flow rates (i.e. spring tides), the occurrence of entrained air in the water column increases and significantly decreases the quality of the data collected. This is because it is often difficult to distinguish between entrained air and biological targets, which lengthens processing time and increases uncertainty in the measurements. Therefore, if weather conditions are not met during the optimal ~5-day neap tide window each month, the survey is not completed, and therefore postponed to the optimal neap tide during the following month. This may result in some losses of information for particular months of the year. However, maintaining seasonal coverage is generally more important biologically than maintaining monthly coverage, so compromises to data quality are minimized if surveys are completed at least once per season.

[7] The echosounder used is a Simrad EK80 (transducer and desktop unit). The EK80 transducer is attached onto the pole mount off the side of the vessel Nova Endeavor. This 'scientific grade' equipment uses sonar technology (split beam echosounder) to detect fish within the water column. GPS is used to verify location of the pole mount during data collection. This technology is preferred over single and multi-beam systems because it provides more detailed information on the 3D position of fish relative to a single beam sounder, and can survey over a further distance with higher resolution than a multi-beam system.

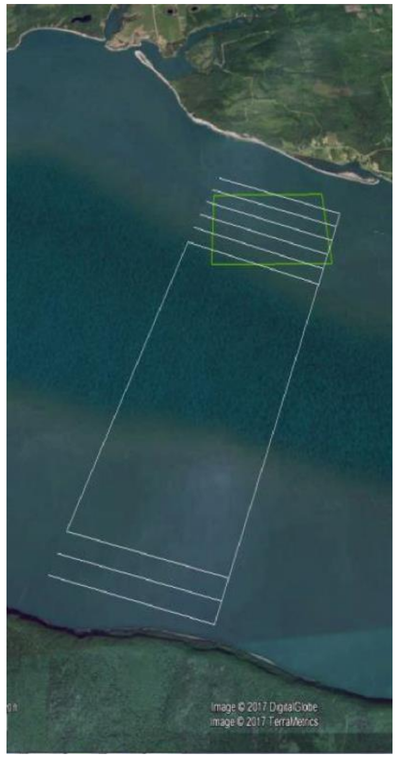


Figure 2: Transects completed for the fish hydroacoustic surveys. The green square indicates the FORCE test site whereas the white lines highlight the transects completed through the test site and control site (bottom of image) near Cape Split.

Data processing is done using the software Echoview® (version 7.1.35; Myriax, Hobart, Australia). For details on data processing and analysis, please consult FORCE's 2017 annual report.

## 2018 Q1 Activities

Surveys have continued in Q1 of 2018 as conducted previously in 2016-2017. A survey scheduled for January 2018 was postponed due to weather limitations (high winds during the appropriate tide times) and conducted on February 15th - 16th instead. In addition to the standard sampling array (Figure 2), the February survey included transects over the CST turbine location ('Berth D') as well as the FAST-3 Platform that houses similar instrumentation as the mobile surveys. This is part of a project funded by the OERA, Natural Resources Canada, and the Nova Scotia Department of Energy.[8]

A survey was also planned for March 2018, but not completed due to unfavourable weather conditions during the survey window. The survey has been rescheduled for the first neap tide of April, which will provide an important data point during spring fish migrations.

[8] See: www.oera.ca/press-release-research-investments-in-nova-scotia-in-stream-tidal-technology-research/

### Initial Results & Lessons Learned

Analyses to date include data collected during baseline studies in 2011 and 2012 (Melvin & Cochrane, 2014) and data collected during surveys conducted as part of FORCE's EEMP from March 2016 - August 2017. Analyses evaluate changes in fish density in association with month (i.e., season), year, site (FORCE site vs. reference site), diel stage (day/night), tidal stage (ebb/flood), and turbine presence/absence using 2-stage linear models (for details, please consult Appendix 1 of FORCE's 2017 Annual Report).

Across the contemporary (2016-2017) and historical (2011-2012) study periods, fish densities have been similar between the FORCE test site and reference site, including similar patterns of seasonal change. The highest fish densities were observed in May at both sites, likely driven by the spring migrations of alewife (*Alosa pseudoharengus*), Atlantic herring (*Clupea harengus*), striped bass (*Marone saxatilus*), Atlantic sturgeon (*Acipenser oxyrhynchus*), American shad (*Alosa sapidissma*), American mackerel *(Scomber scombrus*), and rainbow smelt (*Osmerus mordax*) (Baker et al., 2014, Stokesbury et al., 2016). High densities were also observed at both sites in November and January, likely due to migrations of Atlantic herring, river herring (*Alosa aestivalus*), and alewife out of Minas Passage during that time (Townsend et al., 1989). High densities in January could be caused by Atlantic herring that remain resident in Minas Passage throughout the winter. Fish densities were also greater during the ebb than the flood tide.

Fish densities increased at both the reference and FORCE test site in the four sampling periods post turbine installation (November 2016, January, March, and May 2017). Because densities increased at both sites, these changes are likely due to natural seasonal cycles or some other variable not accounted for here (e.g., decreasing temperatures) rather than turbine installation. Results to date support the EA prediction that in-stream turbines have a minimal impact on marine fish, but data during spanning the full seasonal cycle from multiple years of deployments are needed to verify this prediction. However, confidence in these conclusions will be greatly strengthened following the next deployment of a turbine in Berth D. Other turbine designs will require additional sampling to verify this prediction, as each device may have different impacts to fish.

## Marine Mammals

### Mid-Field Program Summary

FORCE's marine mammal monitoring program involves two main components, aimed at verifying the EA prediction that project activities and components are not likely to cause significant adverse residual effects on marine mammals within the project area (AECOM, 2009):

1. The monitoring of the presence of click-producing mammals using C-POD receivers; and
2. An observation program that includes shoreline, stationary, and (at times) vessel-based observations to locate any marine mammals in destress in the vicinity of the FORCE site.

The first component of FORCE's marine mammal monitoring program involves the use of passive acoustic monitoring (PAM) mammal detectors known as 'C-PODs' (Figure 3), which record the vocalizations of toothed whales, porpoises, and dolphins.[9] C-PODs are deployed on SUBS packages between 200 m - 1,710 m from where the CST turbine was deployed in 2016-2017 (Figure 4). The goal of this program is to understand if there is a change in marine mammal presence in proximity to deployed in-stream tidal energy turbines. Analysis of C-POD data is completed by Sea Mammal Research Unit Consulting (SMRU Consulting; Vancouver, British Columbia).[10]

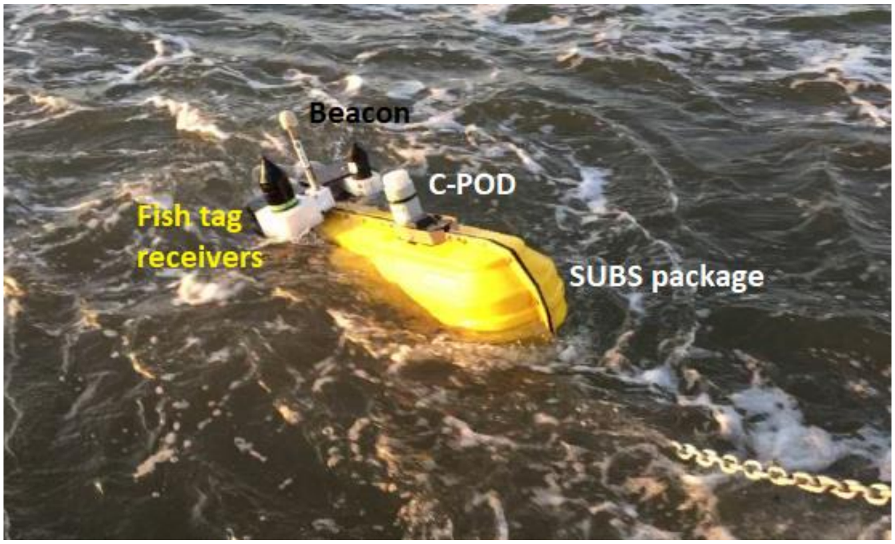


Figure 3: Recently deployed SUBS package containing two fish tag receivers, a beacon from MetOcean Telematics, and C-POD.

[9] The C-PODs, purchased from Chelonia Limited, are designed to passively detect marine mammal 'clicks' from toothed whales, dolphins, and porpoises. The species that C-PODS can potentially detect in the FORCE region are Killer Whale (Orca), Northern Bottlenose Whale, Dall's Porpoise, Harbour Porpoise and Pacific White-Sided Dolphin.

[10] SMRU Consulting, based in Vancouver, British Columbia, is a global leader in marine mammal research and has been involved in Fundy tidal energy research for marine mammals since 2009 (Tollit et al., 2011; Tollit and Redden, 2013).

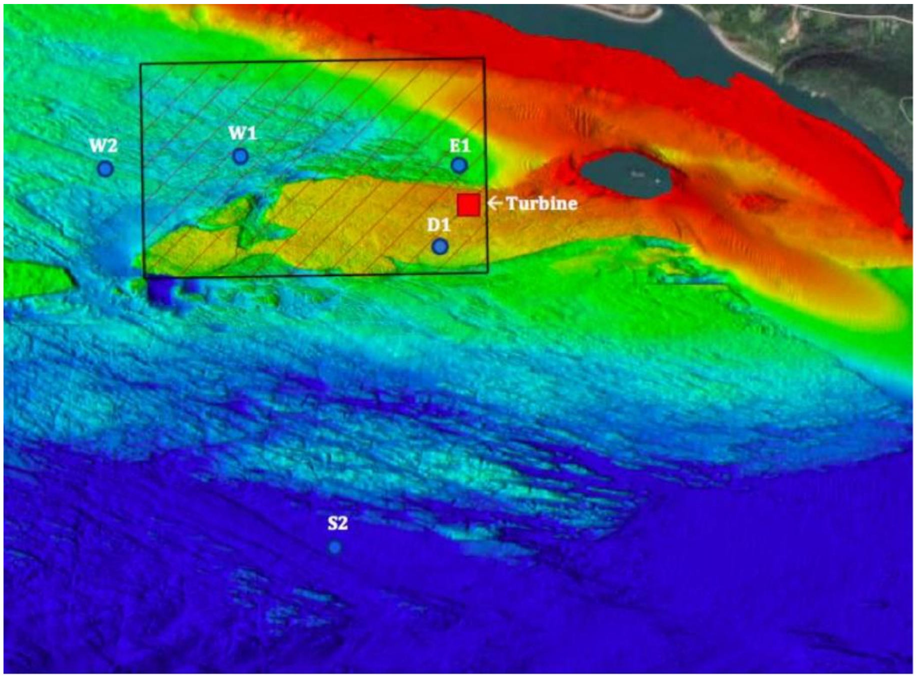


Figure 4: The five C-POD deployment locations in the mid-field of the turbine at the FORCE site, as deployed 2016 – present.

A second component of FORCE's marine mammal monitoring program is a visual observation program that includes observations through beach walks, stationary observations at the FORCE Visitor Centre, and, at times, marine-based observations during marine operations.

In addition, Envirosphere Consultants records any observations of marine mammals during its shore-based seabird monitoring surveys. These observations are shared with SMRU Consulting to support validation efforts of subsea-based C-POD marine mammal monitoring program and are presented in Envirosphere's reports.

## 2018 Q1 Activities

In the first quarter of 2018, FORCE recovered the 5 deployed C-PODs on January 9th. Upon recovery, the SUBS packages that house the C-PODs, acoustic releases, and fish tag receivers underwent a period of annual maintenance. In addition, the SUBS packages were outfitted with additional fish tag receivers (see 'Other Activities' below) and beacons from MetOcean Telematics to support recovery efforts in the event a SUBS package surfaces prematurely. The fully-furnished SUBS were re-deployed on January 22nd and will be recovered in May 2018.

*Video: View online (https://twitter.com/fundyforce/status/963499152867983360): FORCE staff ballast a new sub configuration in the pool at Falck Safety Services in Dartmouth. A new addition includes a VEMCO fish receiver that will work in partnership with Dr. Mike Stokesbury's tagged fish research at Acadia University. The wand-looking device is an Iridium Beacon from MetOcean Telematics in Dartmouth; it's able to send a satellite signal to a cell phone with the SUBS package's exact location...in case we can't find it.*

FORCE has also continued shoreline observations along areas of the Cumberland shore in proximity to the FORCE site, along with community volunteers. These shoreline observations typically record several bird species, including common loons, gulls, crows, some duck species, and an American bald eagle, though abundances have been low throughout Q1 of 2018. No observations were reported via FORCE's public reporting tool, https://mmo.fundyforce.ca/, during Q1 2018.

On February 13th, during a seabird observation survey, Envirosphere observed a single Harbour Porpoise moving in an easterly direction within the FORCE test site.

### Initial Results & Lessons Learned

Updated results and lessons learned were provided in Appendix 3 of FORCE's 2017 Annual Report. Initial results to date support the EA prediction that project activities are not likely to cause significant adverse residual effects on marine mammals within the project area, but additional data collection spanning multi-year turbine deployments and various device technologies is needed to fully verify this prediction.

## Seabirds

### Program Summary

The main objectives of the near and mid-field seabird monitoring program are to obtain site-specific species abundance and behaviour data, which can be used to verify the EA prediction that project activities are not likely to cause significant adverse residual effects on marine birds within the FORCE project area. More specifically, these abundance estimates are used to establish whether the presence of a tidal energy device causes displacement of surface-visible seabirds from habitual waters and to identify changes in behaviour.

The surveys use a geographic grid system to record observations in relation to various areas of the FORCE demonstration site and surrounding areas as depicted in Figure 5 below. The surveys are typically completed over a six hour period, coinciding with the ebb tide, and are conducted by a professional bird observer and a biologist. Weather conditions, including precipitation, wind, and temperature are also recorded.

Envirosphere Consultants (Windsor, Nova Scotia) was contracted to complete data collection, analysis, and reporting activities under FORCE's seabird monitoring program and has been conducting seabird and marine mammal monitoring at the FORCE site since 2008 (Envirosphere Consultants Limited, 2009 – 2013).

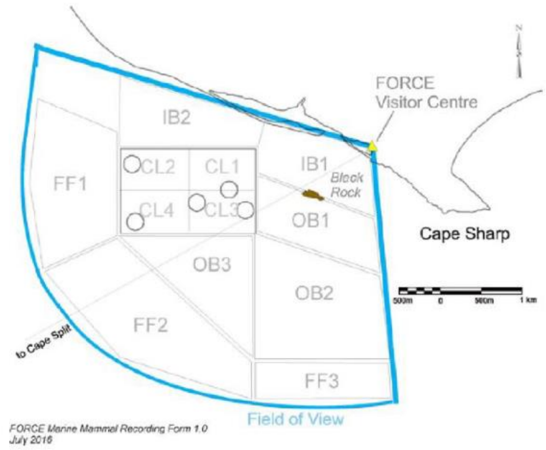


Figure 5: Subdivisions of the FORCE Crown Lease Area for the seabirds monitoring program where 'CL' indicates Crown Lease area; 'IB' indicates Inside Black Rock; 'OB' indicates Outside Black Rock; and 'FF' indicates Far-Field area.

### 2018 Q1 Activities

In 2018, 3 shore-based observational surveys have been completed on January 16th, February 13th, and March 19th. During migratory periods (April, May, and November), survey effort will increase to two surveys per month. Surveys generally took place over an approximate six-hour period with the outgoing tide, consistent with earlier surveys to help reduce statistical variability. Environmental factors expected to affect bird abundance were also recorded.

### Initial Results & Lessons Learned

Updated results and lessons learned were provided in FORCE's 2017 Annual Report. Initial findings support the EA prediction that project activities are not likely to cause significant adverse residual effects on marine birds within the FORCE area. However, data from at least one additional turbine deployment/operation spanning the full seasonal cycle is needed to perform a formal statistical analysis of the data to look for a turbine effect.

Further, technologies that are surface-piercing may be more likely to cause impacts to birds, so additional data collection during operations of those tidal energy devices are needed to verify the EA prediction.

## Marine Sound

### Mid-Field Program Summary

FORCE's marine sound program is designed to characterize the sound environment of the FORCE test site prior to and during the operation of in-stream tidal turbine(s). This information will be used to test EA predictions that sounds emitted from in-stream turbines are unlikely to cause mortality, physical injury, or hearing impairment to marine animals in the FORCE project area (AECOM, 2009).

Over the past few years, the emphasis has been on developing the approach for FORCE's acoustics monitoring program, which has been primarily focused on evaluating the utility of drifting hydrophone systems for acoustic monitoring. FORCE has partnered with Luna Ocean Consulting (Freeport and Shad Bay, Nova Scotia), OceanSonics (Great Village, NS), JASCO Applied Sciences (Dartmouth, NS), and GeoSpectrum Technologies (Dartmouth, NS) to complete data collection, data analysis, and program development work.

## 2018 Q1 Activities

During Q4 of 2017 and Q1 of 2018, GeoSpectrum Technologies completed an analysis of the data from the two drifting hydrophone configurations deployed by FORCE in 2016 and 2017. The purpose of this analysis was to provide recommendations to improve drifter configurations and data collection protocols for future deployments, and complete some preliminary analyses to identify turbine sounds in the March 2017 drifter data set. No additional drifting hydrophone surveys have been completed to date in 2018, but additional deployments are being planned.

### Initial Results & Lessons Learned

Analyses of drifter data collected prior to turbine deployment identified sounds associated with tides, vessels, and the movement of water and particles in the water column around the drifter system. Sound generated by tidal flow was the main source of noise detected, with sound levels increasing with tidal flow speed. The majority of this energy was in frequencies above 1 kHz and was generated by sediment movement over the sea bed.

Preliminary analyses indicate that drifting hydrophone systems were able to detect sounds from the operational CST turbine throughout the mid-field area in March 2017. This sound was audible above background levels up to 650 m from the turbine, and detectable with more sensitive signal processing to the greatest extent of the drifts conducted (3 km). Sounds from the turbine were mainly in the frequency range of 90 hz and 300 hz, but energy was evident up to 10 kHz. Source levels were estimated to be 150-160 dB re uPa @ 1m (estimated from 2 drifts in March 2017).

Lessons learned from initial drifter studies have been provided in FORCE's 2017 Annual Report. Additional drifter studies during turbine deployments and under a broader array of environmental conditions and tidal states are needed to more fully characterize turbine, vessel, and natural sounds as well as to verify EA predictions.

### Near-Field and Mid-Field Integrated Analysis

An additional data analysis by JASCO Applied Sciences is ongoing to compare sound data collected from the drifting hydrophone systems deployed by FORCE with data collected in the near-field by a stationary, bottom-mounted system (JASCO's Autonomous Multichannel Acoustic Recorder - AMAR) and hydrophones mounted on the CST turbine. The purpose of this analysis is to evaluate the relative utility of these systems for ongoing monitoring, and to verify sound characterization by these systems where they overlap in time.

# Other FORCE Research Activities

## Fish Tracking

To enhance fish monitoring and to expand its data collection capacity, in partnership with the Ocean Tracking Network (OTN),[11] FORCE staff attached one VEMCO[12] fish tag receiver (a VR2 receiver) to each C-POD mooring/SUBS package (see 'Marine Mammal Program' 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, which currently does not allow for species identification.

OTN data managers are in the process of acquiring information, including species information, and sharing 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);
- 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);
- Gulf of Maine Sturgeon (Zydlewski, G., Wippelhauser, G. Sulikowski, J., Kieffer, M., Kinnison, M., 2006);
- Curry Atlantic Sturgeon and Striped Bass (Curry, A., Linnansaari, T., Gautreau, M., 2010);
- OTN Canada Atlantic Sturgeon Tracking (Dadswell, M., Litvak, M., Stokesbury, M., Bradford, R., Karsten, R., Redden, A., Sheng, J., Smith, P.C., 2010);
- Inner Bay of Fundy Atlantic Salmon (Bradford, R., LeBlanc, P., 2012); and
- Darren Porter Bay of Fundy Weir Fishing (Porter, D., Whoriskey, F., 2017).

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

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, Natural Resources Canada (NRCan), the Nova Scotia Department of Energy, the Natural

[11] Ocean Tracking Network's website: www.oceantrackingnetwork.org.
[12] 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.

Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI).[13]

## Fundy Advanced Sensor Technology (FAST) Program

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 develop marine operating methodologies.

FAST combines both onshore and offshore monitoring assets. Onshore assets include a meteorological (MET) station and radar system; the MET station broadcasts data live on the Ocean Networks Canada (ONC) website[14] while the radar system works to monitor surface currents. Offshore assets include three subsea data collection platforms for both autonomous and cabled data collection; cabled data collection is broadcasted live on the ONC website.

## Platform Projects

The first and largest of the FAST subsea platforms, 'FAST-1,' houses an instrument referred to as the 'Vectron.' Developed in partnership with Nortek Scientific, Memorial University, and Dalhousie University, the Vectron is the world's first stand-alone instrument to remotely measure turbulence at mid-water column. Measurements and analysis from the Vectron will help tidal energy companies to better design devices, plan marine operations, and characterize a site.

A second, smaller platform known as 'FAST-2' is currently being used to deploy directional sensors to collect data from a specific target, including the face of a turbine. Specifically, the sensor suit includes a Tritech Gemini imaging sonar, dynamic mount to position the sonar, and subsea cabling to allow for real-time data collection. This system began testing between the FORCE beach and Black Rock Island starting on March 22nd, 2018.

The 'FAST-3' platform houses two hydroacoustic and various environment sensors, and is currently in use at the FORCE site to monitor fish densities in the mid-field of the turbine. FORCE has received funding from NRCan and OERA to complete a comparative analysis of data collected by bottom (FAST-3) and ship-mounted hydroacoustic sonars (used as part of FORCE's Fish EEMP). The goals of this project are to evaluate the spatial and temporal representativeness of both instrument configurations and determine the degree to which results are corroborative. Data collection and the development of analysis techniques for this project are currently underway. The platform was recovered on February 22nd and redeployed on March 28th, 2018 (scheduled recovery late May 2018).

[13] 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/
[14] This is available online at: www.oceannetworks.ca/observatories/atlantic/bay-fundy

## Radar Projects

Presently, FORCE has two graduate student interns working on research and development projects - one focused on X-band radar and the other on surface wave characterization.  Both students are supervised by Dr. Joel Culina (on behalf of FORCE) and Dr. Richard Karsten (Acadia University). Jeremy Locke is a Master's student at Acadia University who is working towards establishing online atlases of eddies and surface current velocities using radar data, and potentially adding a second radar to the mix. Yuan Wang is a Ph.D. student at Dalhousie who is adding wave modelling capabilities to the existing model of the FORCE region, and connecting with turbine developers who need this tool for determining wave effects on their devices.

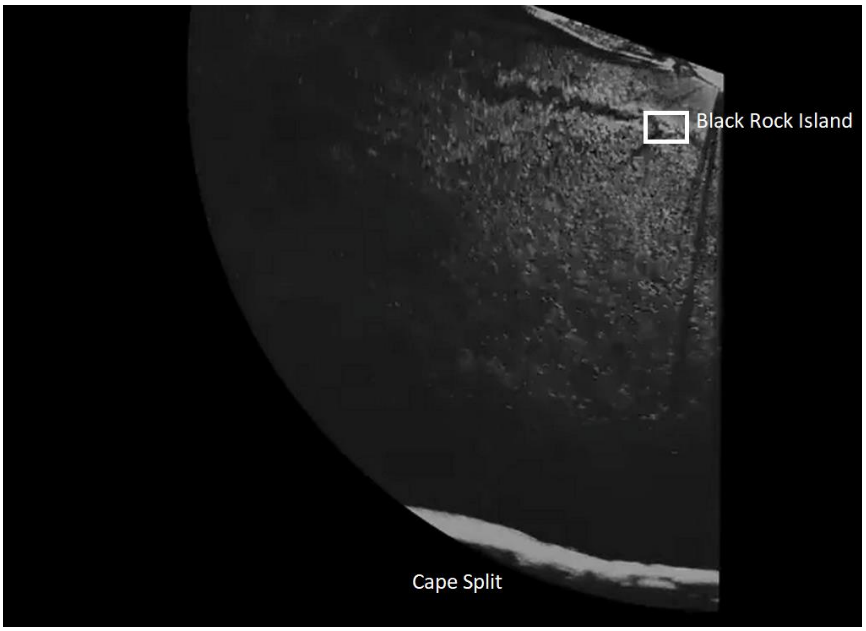


Figure 6: A screenshot of an X-band radar image with labels indicating land-based features. The radar is located on top of the FORCE Visitor Centre.

## Environmental Monitoring Advisory Committee (EMAC)

The purpose of FORCE's Environmental Monitoring Advisory Committee (EMAC) is to provide advice on monitoring programs, and to review and advise on monitoring results. Membership includes representatives from scientific, First Nations, and fishing communities. EMAC continues to meet in 2018 and provide advice to FORCE on berth holder EEMPs as they are submitted to FORCE.

EMAC is presently in the process of reviewing reports from the near-field monitoring program, providing advise to CST in advance of deployment in 2018.

More information on EMAC, including objectives, terms of reference, membership, and summary minutes from these meetings are available on the FORCE website: [www.fundyforce.ca/about/advisory-committees.](http://www.fundyforce.ca/about/advisory-committees)

## RESEARCH NETWORKS

It is also important to note that additional research projects are occurring within the Bay of Fundy, particularly the Minas Passage and the Minas Basin outside of the jurisdiction of FORCE. FORCE works closely with many research partners, such as the Acadia Tidal Energy Institute,[15] Dalhousie University, Nova Scotia Community College, and others to keep up-to-date on these activities and how they may contribute to the growing understanding of the monitoring turbine effects.

In addition, FORCE also participates in research forums to understanding the growing local and international knowledge of tidal energy effects monitoring. This includes the Fundy Energy Research Network (FERN), a research forum designed to "coordinate and foster research collaborations, capacity building and information exchange […] associated with tidal energy development in the Bay of Fundy,"[16] and Annex IV,[17] an international body connects those actively involved in marine renewable energy projects to share information and discuss progress in environmental monitoring efforts. These groups provide FORCE with the opportunity to learn from international experts and other marine energy projects as well as communicate its research and monitoring activities.

## OCEAN SUPERCLUSTER

The Government of Canada's February 2018 announcement of an Atlantic Canada-based Ocean Supercluster (OSC) supported a mandate to "better leverage science and technology in Canada's ocean sectors and to build a digitally-powered, knowledge-based ocean economy", and included marine renewables as part of its scope. OSC has also declared its intent to create cross-sector opportunities for activities such as the "customization of underwater sensors and communications systems to provide real-time data." Within OSC, it may be possible to create partnership opportunities to further enhance environmental effects monitoring efforts in the Minas Passage. Additional info is available at www.oceansupercluster.ca.

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[15] The Acadia Tidal Energy Institute is the lead organization behind the Nova Scotia Tidal Energy Atlas (http://tidalenergyatlas.acadiau.ca/). FORCE is a project partner to the Atlas.

[16] Source: http://fern.acadiau.ca/about.html. FORCE participates in the Natural Sciences, Engineering, and Socio-Economic Committees of FERN

[17] Annex IV is an initiative of the International Energy Agency's Ocean Energy Systems. Information about Annex IV is available online at https://tethys.pnnl.gov/about-annex-iv

## 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 100m of a turbine) is completed by individual berth holders. Like FORCE's monitoring programs, the near-field monitoring programs undergo review by FORCE's EMAC and regulators.

Moving forward, each berth holder's monitoring activities will be included as appendices below. Since CST is preparing for turbine redeployment in 2018, an update prepared by CST is included in Appendix 1 of this report.

Updates from future berth holder will be provided as others develop and implement environmental effects monitoring programs.

## Summary

The environmental effects monitoring programs conducted by FORCE, which will be further informed by berth holder near-field monitoring, continue to build our understanding of the risks tidal energy poses for marine life in the Minas Passage. Findings to-date follow the international body of research in the field – which has documented few negative impacts of in-stream tidal turbines on marine life (Copping et al., 2016; Copping, 2018) – but it is still too early to draw conclusions, particularly because of the challenges of working in turbulent, sediment-filled high flows. There have, however, been some encouraging findings: to-date, there have been no significant changes in the distribution and behavior of fish and seabirds at the FORCE site in relation to a deployed turbine, indicating that there is no evidence to suggest fish and seabirds avoid the near and mid-field area while a turbine is in operation. This is similar to studies elsewhere that have documented no changes in behavior of fish in the vicinity of an operating turbine (Bevelheimer et al., 2015). At finer scales (i.e., in the direct vicinity of the turbine), international research has shown that fish generally avoid turbines while they are in operation (Copping et al., 2016); more data is needed to fully evaluate avoidance behaviours at the FORCE site – that includes better positioning of near-field sensors on individual turbines.

FORCE's EEMP has also documented temporary declines in the presence of harbour porpoise during turbine installation, likely due to vessel activity. Marine mammals are known to be impacted by anthropogenic sounds, including those emitted by underwater construction and vessels, leading to injury or changes to behaviour and distribution (Gotz et al., 2009). Though sounds from marine renewable energy projects are considered unlikely to cause injury to marine life, more information is needed to evaluate how sounds from these projects cause deterrence behaviors (Copping et al., 2016). Further work at the FORCE test site will aim to more fully characterize behavioral shifts of harbour porpoise in association with turbine-related vessel traffic, and to evaluate the impacts of sounds from vessels and turbines on marine mammals in the vicinity of the FORCE site.

The monitoring technologies currently available for assessing fish behaviors around turbines and associated collision risk are limited, and those that are used (e.g., video cameras) are largely not effective in Minas Passage. Multi-beam imaging sonars and acoustic tagging technologies hold promise for this purpose, and methods are currently under development at the FORCE site by staff and associated research collaborators. As these technologies and techniques are improved, they will increasingly become available for the monitoring program at the FORCE site. While external research to-date is encouraging – indicating that marine animals are unlikely to come into contact with in-stream tidal turbines, and if they do, damage is likely minimal (Copping, 2018) – again, these findings must again be evaluated at the FORCE site.

The information gained during future turbine deployments at the FORCE test site in 2018 and beyond will be important towards evaluating the EA prediction that the project is unlikely to cause significant harm to marine life. While the deployment in 2016-2017 provided important preliminary findings to support this prediction, monitoring in association with an additional deployment of the same turbine technology will add significantly to our understanding of the potential impacts of this specific device. Further monitoring will need to be conducted in associated with turbine deployments that occur over the full seasonal cycle, and in association with multiple different turbine technologies.

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# Appendix 1:

# Cape Sharp Tidal Monitoring Program Update

# Cape Sharp Tidal Monitoring Program Update

Since CST is preparing for turbine redeployment in 2018 and does not have a turbine deployed at its site (Berth D) at the moment, there have not been any monitoring activities in Q1. However, a number of activities towards preparing for, and improving, the monitoring program for 2018 have taken place and are included in this update.

### About Cape Sharp Tidal

Cape Sharp Tidal (CST) is a joint venture between Halifax based energy company Emera Inc. and tidal technology company, OpenHydro, a Naval Energies company. The CST project uses 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. Simplicity is a key advantage of this device, resulting in reduced maintenance requirements and eliminating the potential for environmental biofouling. Seawater is used for both generator cooling and for lubrication. The turbine possesses one moving part, the rotor, and is bi-directional (i.e., the turbine is capable of extracting energy in both the ebb and the flood flow). There are 10 fins, each approximately 2.4 m wide x 4.8 m long, and manufactured from glass-reinforced plastic. The thickness varies from 21 cm at the root (outer diameter) to 1.5 cm at the tip (inner diameter). The turbine is supported within the flow 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.

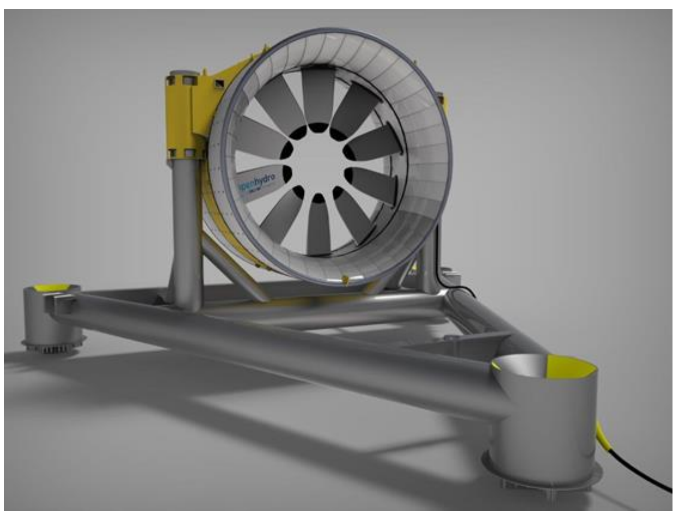


Figure A.1: An image of the OpenHydro Open-Centre Turbine design.

### CST Operational Update

CST deployed one, 2-megawatt (MW) in-stream tidal energy turbine at the FORCE site on November 7th, 2016. This turbine was retrieved June 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 Q2 and Q3 EEMP Reports (www.capesharptidal.com/eemp/).

The focus of operations during this reporting period (January 1st – March 31st, 2018) has been the ongoing examination and evaluation of the turbine from the 2017 deployment. This includes the monitoring devices, which were removed from the turbine late last summer and the application of lessons learned from the past deployment.

During Q1, the turbine that was deployed in 2017 has remained in Saint John, New Brunswick on the subsea base. Remounting of the turbine control centre (TCC) and preparations for deployment of the new turbine will begin in Q2 2018. CST has continued to work to improve the turbine technology and to increase the operating efficiency of the next turbine to be deployed at the FORCE site, at Berth D, in 2018. The date for this deployment has not yet been confirmed.

Later this spring, a heavy lift vessel will be used to place the next turbine to be deployed on the purpose-built Scotia Tide barge. The lifting mechanism on this vessel will be used to move the 'dry turbine' onto the barge after removing the 'wet turbine' off the barge. The turbine subsea base will be reused for the next deployment.

CST is collaborating with local and international scientists, universities, and independent research and technology companies to reach its goals of increased knowledge and environmental protection. As noted in previous reports by CST, the retrieval of the turbine provided an opportunity for CST and researchers involved in the monitoring studies to inspect all monitoring devices, evaluate, and improve device protection where needed and implement improvements based on what was learned during the first deployment. The results are being used to adjust and improve the use and positioning of the monitoring instruments for the 2018 deployment.

Work on the monitoring devices has included testing and evaluation to ensure proper functioning. To integrate the lessons learned from the 2017 deployment, CST hosted a researcher workshop in February to review the issues of the past deployment and brainstorm on testing schedules and ways to avoid and improve the functioning of all devices at the same time, improve link quality of data files, and facilitate data transfer and data access to allow for a more timely analysis process.  The result of the workshop, and of separate follow-up discussions, has resulted in the finalization and implementation of a Commissioning Plan and a Data Management Plan specific to the monitoring devices.

## Commissioning Plan

The Commissioning Plan details a systematic process to ensure that all monitoring devices are performing as expected in varying scenarios up to the final test, which will take place in the Minas Passage just prior to deployment. During Q1, monitoring device testing has focussed on ensuring that cables for each monitoring device is routed and protected and addressing the issues with link quality. The results of re-testing completed in Q1 indicate that the set-up has achieved 100% link quality with all five devices (the Gemini sonar and four hydrophones). This data will be validated in Q2. The Commissioning Plan was presented to regulators in Q1 and regular updates and testing results will be communicated leading up to deployment.

## Data Management Plan

The Data Management Plan will address two main components of infrastructure improvement that will facilitate the data collection at the FORCE test site and allow for a more timely process overall. The first component was the investigation towards an upgrade to the bandwidth available at FORCE for uploading data. This was completed in Q1, allowing for an increased capacity from the FORCE substation. The second element of infrastructure improvement was to investigate additional computers at the FORCE substation to move data from the sensors and allow remote access to devices from onshore. This will permit remote adjustment of the processing software and direct access to the data. Set-up will take place prior to deployment. The proposed solutions will provide a number of benefits for the CST project and address the data issues and lessons learning from the 2017 deployment:

1. Reduction in the volume of data collected, and accordingly, the data to be analysed, will be focused on relevant 'events;'
2. Maintains the quality of data collected;
3. Reduced volume of data combined with increased available bandwidth allows for upload of data direct from FORCE substation;
4. Remote access for equipment providers and analysts to the data coming from the sensors; and
5. Improved back-up facility: the data collected on hard drives is no longer the means of transmitting the information but is a dedicated backup facility allowing for increased capacity and longer fix time, if required.

## Contingency Plan

Based on lessons learned in the last deployment and from retrieval operations in spring of 2017 the need for a contingency plan for environmental monitoring was identified as a priority. A Contingency Plan was developed in Q1 and a draft has been presented to regulators.

Contingency planning is necessary to address specific conditions that may occur during the operation of the CST project that might lead to a temporary halt of environment monitoring or a disruption that affects the objectives of the EEMP. An essential element of contingency planning is the preparation of processes and plans that can be activated if these events occur.

The following unexpected events require contingency planning:

- Damage or loss of environmental monitoring devices;
- Gaps in the collection of monitoring data that are caused by activities related to deployment and/or retrieval operations; and
- Other unexpected events that lead to a disruption in the collection of monitoring data.

The scope of the Contingency Plan must be measurable to the scope of the monitoring program. For that reason, the contingency incorporates both a Gemini device and hydrophones. The set-up was developed and the first set of tests was completed, at the FORCE site in Q1, on the cabled on the FAST-2 platform. Further testing will take place into Q2. Testing associated with the Contingency Plan will also allow the testing of specific devices (i.e., the

Gemini sonar) and elements of the data management program including aspects of the *SeaTec* software used in conjunction with the Gemini sonar data. More information on the Gemini testing is provided below in the section addressing the monitoring update for marine fish.

## CST Environmental Effects Monitoring Program – 2018 Update

CST's EEMP was developed in collaboration with experts in the field of in-stream tidal energy and with input from government agencies, including DFO and NSE, as well as other in-stream tidal energy interests including the OERA, technology experts, and researchers. The CST EEMP is designed to be updated on an annual basis, in keeping with the adaptive management approach at the FORCE site.

The overarching purpose of CST's EEMP is to verify the accuracy of the environmental effect predictions made in the environmental assessment (EA) for the FORCE site. 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 project poses to components of the ecosystem.

The CST near-field monitoring program from the 2016/2017 deployment, focused on fish, marine mammals, and turbine sound, and commenced upon connection of the turbine to FORCE's subsea power cable in early November 2016. The CST environmental effects monitoring program, as well as 2017 updates, are available on the CST website: www.capesharptidal.com.

During Q1, the EEMP was updated. Although the main components of study remain the same (i.e., marine fish, marine mammals, and turbine sound) the process of defining the objectives was revisited and refined with greater focus on alignment with the EA predictions. The updated EEMP will also take into consideration the lessons learned from the last deployment, recommendations from researchers and EMAC, and requirements and recommendations of regulators. Another key focus of the monitoring program will be a better integration and analysis of near-field results with the results collected under the FORCE EEMP for a better understanding of the area, where applicable. The 2018 objectives of the CST EEMP are outlined in Table A.1 below. A draft of the EEMP was presented to regulators in Q1 and will be finalized in Q2 and posted on the CST website.

| EEMP Component | Monitoring Related to EA Predictions | 2018 Monitoring Objectives | Methodology |
|---|---|---|---|
| **Marine Fish including Species at Risk** | Increase knowledge of fish species and migration patterns in the Minas Passage | Collect visual data of seasonal fish in the near-field area of the CST turbine to address knowledge gaps on seasonal occurrence of fish and migratory patterns through the Minas Passage. | Active Acoustic Monitoring (AAM) with Gemini Imaging Sonar |
| | Increase knowledge of fish behaviour in the vicinity of specific instream turbine technologies to | Collect visual data of fish movements (individual and schools) on flood and ebb tides in the near-field area of the CST turbine and analyze fish movements/tracks and vertical distributions to better understand fish | |

| EEMP Component | Monitoring Related to EA Predictions | 2018 Monitoring Objectives | Methodology |
|---|---|---|---|
| | better understand the potential for interactions between fish and turbines in the Minas Passage | behaviour and potential risk. | |
| | | Explore the potential for fish behavioural data to be integrated into a strike risk model for fish in the Minas Passage. | |
| | | Imaging sonars could be an excellent tool to provide data on fish movements in the vicinity of instream tidal turbines in high flow environments, since these instruments can provide images in areas that are too dark or turbid (murky) for traditional video cameras and can operate and communicate data continuously. This objective will address the functionality of an imaging sonar unit and the potential to integrate the sonar with data acoustic devices (e.g. hydrophones) for an all-inclusive data set. | |
| | | Explore the potential to collect additional visual data of fish interactions in the immediate area of the CST turbine rotor. This will indicate the potential that a video camera may have as an ongoing element of the EEMP. The video files will be used to understand and compare the rate of occurrence of fish moving through the center of the rotor to those moving around the rotor, and the potential for interactions between fish and the fins of the turbine. *Note: this is a supplemental element of the EEMP. CST is interested in exploring the abilities of underwater video cameras in the Minas Passage environment to provide additional data on fish behaviour and species identification* | Underwater Video with an SAIS IP-CAM High Definition Ethernet underwater video camera |

| EEMP Component | Monitoring Related to EA Predictions | 2018 Monitoring Objectives | Methodology |
|---|---|---|---|
| **Marine Mammals including Species at Risk** | Increase knowledge on marine mammal (Harbour porpoise)[a] occurrence and spatial distribution in the in the Minas Passage | Collect acoustic data of Harbour porpoise vocalizations in the near-field area of the CST turbine and analyze data using specialized click detector programs to address knowledge gaps on seasonal occurrence in the Minas Passage. *Note: As per the 2017 recommendations, further investigation of the PAMGuard and CODA porpoise click detectors to determine the best programs for marine mammal detection.* | Passive Acoustic Monitoring (PAM) with hydrophones |
| | | Use combined acoustic data from multiple hydrophones of Harbour porpoise vocalizations in the near-field area of the CST turbine to address knowledge gaps on spatial distribution in the Minas Passage. | |
| | | Explore the potential for Harbour porpoise data to be integrated into a strike risk model for Harbour porpoise in the Minas Passage. | |
| **Turbine Sound** | Collection of sound data for each of the turbines during regular operation | Collect and analyze various components of CST turbine operational sound including sound propagation distance. | Bottom Moored Autonomous Multichannel Acoustic Recorder |
| | Address various components of acoustic emissions, including sound propagation distance | | |
| | Collection of noise data to determine interference potential with cetacean communication | Analyze CST turbine operational data on a biological level, in particular to effects on fish and marine mammals. | |
| | Collection of ambient noise levels in the area of the turbine device(s) | Collect and analyze ambient (natural) noise to understand how the CST turbine sound compares to ambient (natural) noise levels in the Minas Passage. | |

Table A.1: Objectives of the 2018 CST EEMP.

As part of the EEMP, and as noted above, CST has developed supplemental protocol to further address some of the issues and concerns from the past EEMP. These include the following documents:

- Commissioning Plan to plan and document the testing and results of all monitoring devices prior to deployment;
- Data Management Plan to document procedures for ensuring timely access and transfer of data from the monitoring devices on the turbine and subsea base to researchers for processing and analysis; and
- Contingency Plan to provide details of a second, measurable plan that can be implemented immediately in the event of a monitoring device failure (i.e., Gemini sonar

or hydrophones) that results in the inability to meet the objectives of the monitoring program. The Contingency Plan will be field tested prior to deployment and will also be used to test sensor operation and data management access and transfer capabilities.

These supplemental documents will be developed with input from regulators and finalized in Q2.

## CST Monitoring Program Summaries & Updates

### Marine Fish including Species at Risk

The focus for CST on fish monitoring in Q1 2018 has been ongoing evaluation of the devices for the 2018 monitoring program. This includes input from sensor device developers and researchers to ensure a successful monitoring program during the next deployment.

The Tritech Gemini imaging sonar will be used for fish monitoring. This device is an active acoustic device: a high frequency multi-beam sonar technology that uses reflected sound (similar to an echo) to build up a picture of an underwater environment. Images created by high frequency sonars are low resolution when compared with contemporary video technologies; however, when there is insufficient light or high turbidity (due to cloudiness or haziness of water caused by suspended solids [sand]) video cameras lose the ability to create a clear image.

During Q1 2018, CST continued evaluation and testing of this sensor with a focus on improving the link quality, which was only showing approximately 74% at the end of 2017. This built off work completed in end 2017 following turbine retrieval and is part of the Commissioning Plan and Data Management Program developed in Q1 for the 2018 deployment. During testing in Q1 the focus has been to improve link quality (i.e., consistent data file sizes) when tested with four hydrophones. As noted above, this has been achieved and CST now has 100% link quality. The data from the recent tests at 100% link quality will be validated in Q2.

An additional focus related to the Gemini unit in Q1 was the development of a Contingency Program for the CST EEMP. Under the Contingency Program, the Gemini unit will be tested prior to the 2018 deployment at different locations in the Minas Passage to ensure functionality of the unit and explore improvements to the *SeaTec* software, which uses specific algorithms to identify and track marine life and objects in open water environments around tidal turbines. Testing of the set-up was initiated in Q1 with an intertidal test or ‘wet’ test. The next test will take place at the end of Q1 in deeper water and will be followed up with further testing in Q2. The testing will allow researchers to ensure the functionality of the Gemini in the Minas Passage and the opportunity to collect pre-deployment data to help with algorithm improvements and the development of a subsampling methodology.

### Marine Mammals (Harbour Porpoise) including Marine Mammal Species at Risk

The focus for CST on marine mammal monitoring in Q1 2018 has been ongoing evaluation of the devices for the 2018 monitoring program. This includes input from sensor device developers and researchers to ensure a successful monitoring program during the next deployment.

The marine mammal monitoring program for CST will utilize four icListen hydrophones mounted in four different locations on the turbine and subsea base. The hydrophones act as an underwater microphone able to detect and record marine mammal vocalizations.

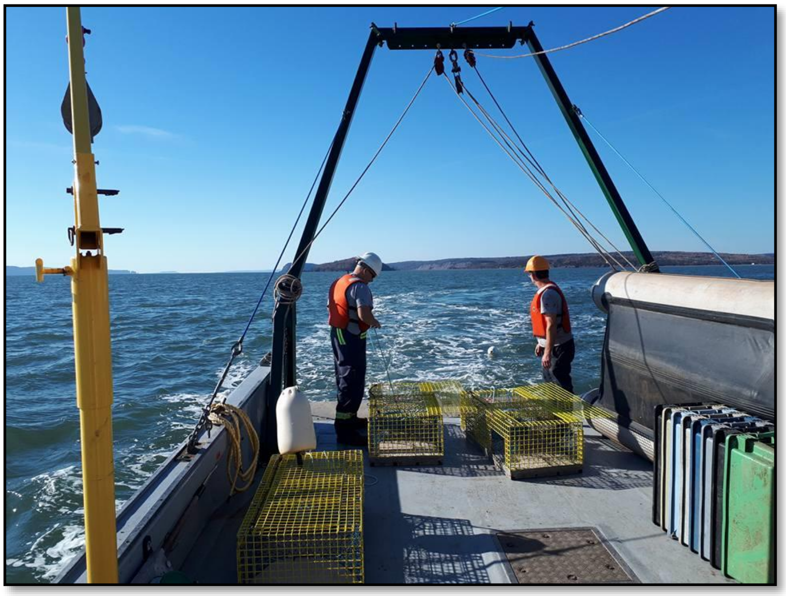
During Q1 2018, Cape Sharp Tidal continued evaluation and testing of the four icListen hydrophones. This work builds off work completed in end 2017 following turbine retrieval, and is part of the Commissioning Plan that was developed in Q1 for the 2018 deployment. During testing in Q1 the focus has been on ensuring synchronization and consistent communication of all four hydrophones when operated in conjunction with the Gemini sonar, which is also used to meet the objectives of the CST fish monitoring program.

### TURBINE SOUND

CST continues to analyze the turbine sound data gathered during the 2016/2017 deployment. Phase 2 of the study will be completed in 2018 and will complete the analysis of the source level of the turbine as a function of the operational state and flow speed. The Phase 2 report will address of the sound produced by the turbine relative to ambient (background) sound. This report will be provided as part of the 2018 Q2 report.

# Appendix 2:

# Mid-field Lobster Monitoring Report



# LOBSTER CATCHABILITY STUDY REPORT

PREPARED FOR: FORCE

NEXUS Coastal Resource Management Ltd. | December 2017

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# SECTION I: OBJECTIVES SUMMARY

The purpose of this study is to monitor lobster catchability within the FORCE Crown Lease Area (CLA; Figure 1). Lobster catchability is represented as catch per unit effort (CPUE), or catch per trap, which functions as a proxy measure for population density. Surveying prior to TISEC turbine deployment establishes initial data for future comparison. Comparing data collected during TISEC turbine deployment against the initial data assesses the level of impact the technology may have on lobster catchability. This research will also test the assumptions of the initial environmental assessment (EA). The AECOM (2009) report assumes minimal TISEC turbine impacts on lobster populations within the CLA, based on the following prescriptive characteristics:

- Species diversity and population density is low;
- The substrate is scoured bedrock;
- The TISEC turbine and equipment has a small footprint in the area;
- With minimal impact, populations will recover to baseline levels in the short-term (AECOM, 2009).

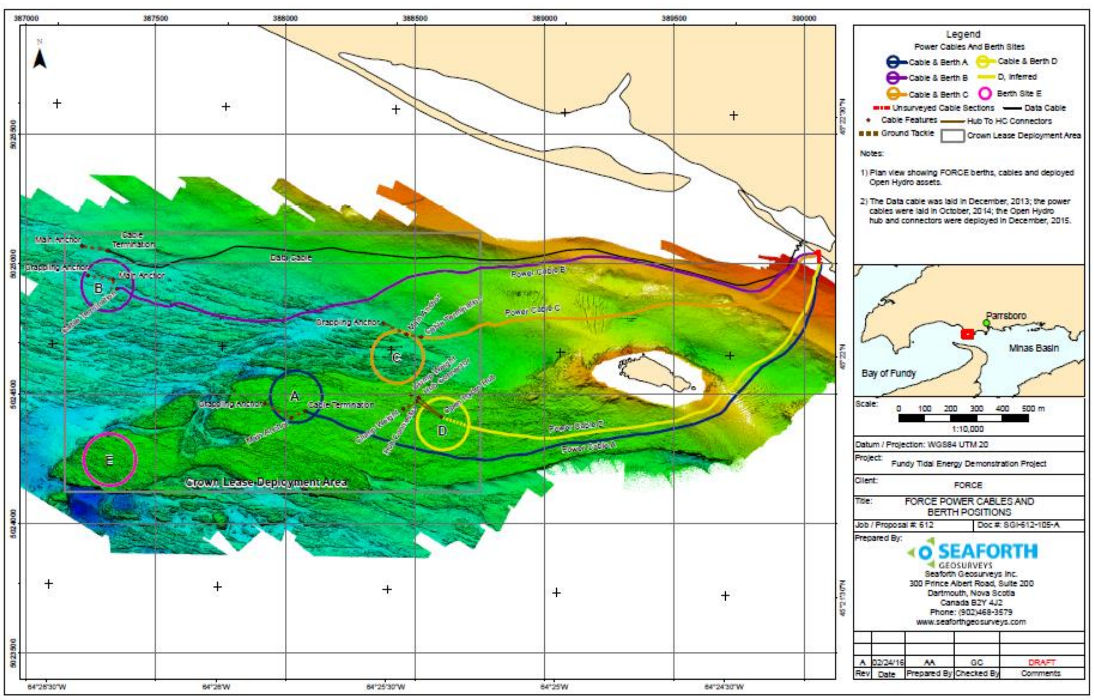



**Figure 1.** Map of Proposed TISEC device deployment berths (FORCE, 2016).

This study provided opportunity to test sampling methodologies and provided a reference point for comparison of the catchability statistics recorded within the CLA against the general fishery in the Minas Passage, as determined by Fisheries and Oceans Canada (DFO

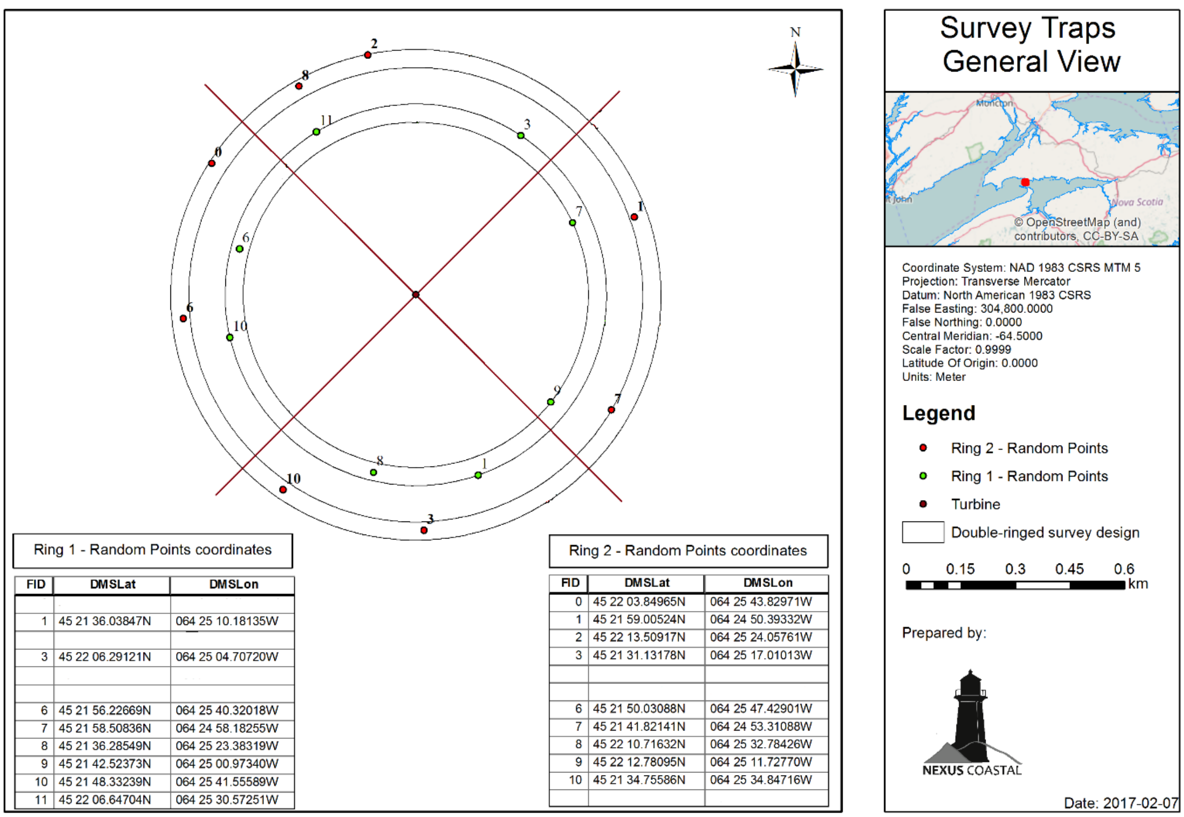
2014). According to the DFO 2014 report, lobster population density in the broader Minas Passage (outside the CLA) as high, using the following catchability gradients:

- 0 - 0.7 kg CPUE (low)
- 0.8 - 1.1 kg CPUE (moderately low)
- 1.2 - 1.7 kg CPUE (moderate)
- 1.8 – 2.3 kg CPUE (moderately high)
- 2.4 – 10.7 kg CPUE (high) (p. 22, Serdynska & Coffen-Smout, 2017)

# SECTION II: OVERVIEW OF METHODS

## FALL, IN-SEASON SURVEY

The survey plot (Figure 2) is a design modification proposed by Bayley (CEF, 2011). The plot consists of two interval rings centered around the turbine. The inner 'treatment' ring is 50m wide, positioned 475m-525m from the turbine. The 475m exclusion zone over compensates for trap drift due to currents and allows a broad buffer to protect against trap interference with the turbine. The outer 'control' ring is also 50m wide, positioned 575m-625m away from the turbine. In the Bayley design, each ring is comprised of 12 randomized, fixed stations – 24 stations in the entire survey plot. Bayley also recommended sampling stations 3 times for one complete survey (to correct against gear foul or loss), ensuring useable data is collected for each station. Bayley also proposed a soak time parameter of no longer than 24 hours after trap deployment. The survey plot is divided into North, East, South, and West quadrants.




Ring 1 - Random Points coordinates

| FID | DMSLat | DMSLon |
|---|---|---|
| | | |
| 1 | 45 21 36.03847N | 064 25 10.18135W |
| | | |
| 3 | 45 22 06.29121N | 064 25 04.70720W |
| | | |
| | | |
| 6 | 45 21 56.22669N | 064 25 40.32018W |
| 7 | 45 21 58.50836N | 064 24 58.18255W |
| 8 | 45 21 36.28549N | 064 25 23.38319W |
| 9 | 45 21 42.52373N | 064 25 00.97340W |
| 10 | 45 21 48.33239N | 064 25 41.55589W |
| 11 | 45 22 06.64704N | 064 25 30.57251W |

Ring 2 - Random Points coordinates

| FID | DMSLat | DMSLon |
|---|---|---|
| 0 | 45 22 03.84965N | 064 25 43.82971W |
| 1 | 45 21 59.00524N | 064 24 50.39332W |
| 2 | 45 22 13.50917N | 064 25 24.05761W |
| 3 | 45 21 31.13178N | 064 25 17.01013W |
| | | |
| | | |
| 6 | 45 21 50.03088N | 064 25 47.42901W |
| 7 | 45 21 41.82141N | 064 24 53.31088W |
| 8 | 45 22 10.71632N | 064 25 32.78426W |
| 9 | 45 22 12.78095N | 064 25 11.72770W |
| 10 | 45 21 34.75586N | 064 25 34.84716W |
| | | |

**Figure 2.** Adapted double-ringed survey plot.

Local fishing industry representatives advised that it would be difficult to sample more than 12 stations per day, based on tidal cycle and currents. Thus, the survey plot designed was adapted - comprising 16 randomized fixed stations, 8 traps per ring (Table 1).

**Table 1.** Corresponding coordinates for the 16 randomly selected fixed survey stations. Fixed identification (FID) numbers are also included.

| **Ring 1 – Coordinates** | | | | **Ring 2 - Coordinates** | | |
|---|---|---|---|---|---|---|
| FID | DMSLat | DMSLon | | FID | DMSLat | DMSLon |
| 1-1 | 45 21 36.03847N | 064 25 10.18135W | | 0 | 45 22 03.84965N | 064 25 43.82971W |
| 3-1 | 45 22 06.29121N | 064 25 04.70720W | | 1-2 | 45 21 59.00524N | 064 24 50.39332W |
| 6-1 | 45 21 56.22669N | 064 25 40.32018W | | 2 | 45 22 13.50917N | 064 25 24.05761W |
| 7-1 | 45 21 58.50836N | 064 24 58.18255W | | 3-2 | 45 21 31.13178N | 064 25 17.01013W |
| 8-1 | 45 21 36.28549N | 064 25 23.38319W | | 6-2 | 45 21 50.03088N | 064 25 47.42901W |
| 9 | 45 21 42.52373N | 064 25 00.97340W | | 7-2 | 45 21 41.82141N | 064 24 53.31088W |
| 10-1 | 45 21 48.33239N | 064 25 41.55589W | | 8-2 | 45 22 10.71632N | 064 25 32.78426W |
| 11 | 45 22 06.64704N | 064 25 30.57251W | | 10-2 | 45 21 34.75586N | 064 24 55.42939W |

The team used modified commercial American lobster traps made with 2.5 cm wire mesh and measuring 1.21 m (48”) x 0.38 m (15”) x 0.61 m (24”), with two 12.7 cm rings, and one blocked biodegradable escape vent (Figure 3). The traps were weighted with a 150kg concrete slab to minimize movement from the strong tides of the Bay of Fundy. Each trap was connected to a 75m buoy line and corresponding marked buoy (with vessel name and licence number). Each trap was freshly baited with 1.5 kg of redfish during each deployment to align with standard fishing industry practice in the area and affixed with DFO-approved identification tags (Table 2).

**Figure 3.** Study trap configuration.

**Table 2.** Documented DFO Science ID tag numbers for each survey trap placed by NEXUS Coastal, which correspond to each survey station. Nexus mooring codes and survey traps are regulated by the provisions of DFO science license #347451.

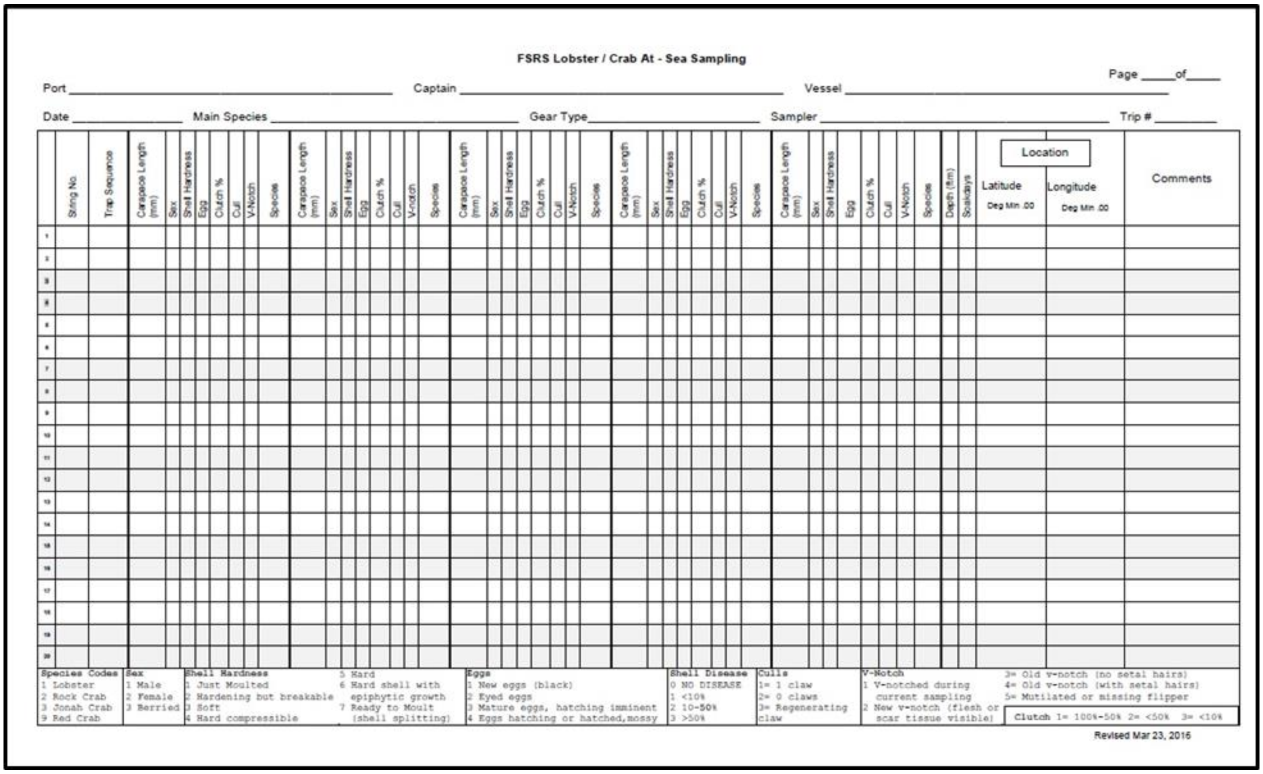
| NEXUS mooring codes | |
|---|---|
| R1-00-A-3018300 | **R2-00-A-3018324** |
| R1-01-A-3018301 | **R2-01-A-3018325** |
| R1-02-A-3018302 | **R2-02-A-3018326** |
| R1-03-A-3018303 | **R2-03-A-3018327** |
| R1-04-A-3018304 | **R2-04-A-3018328** |
| R1-05-A-3018305 | **R2-05-A-3018329** |
| R1-06-A-3018306 | **R2-06-A-3018330** |
| R1-07-A-3018307 | **R2-07-A-3018331** |
| R1-08-A-3018308 | **R2-08-A-3018332** |
| R1-09-A-3018309 | **R2-09-A-3018333** |
| R1-10-A-3018310 | **R2-10-A-3018334** |
| R1-11-A-3018311 | **R2-11-A-3018335** |
| R1-00-B-3018312 | **R2-00-B-3018336** |
| R1-01-B-3018313 | **R2-01-B-3018337** |
| R1-02-B-3018314 | **R2-02-B-3018338** |
| R1-03-B-3018315 | **R2-03-B-3018339** |
| R1-04-B-3018316 | **R2-04-B-3018340** |
| R1-05-B-3018317 | **R2-05-B-3018341** |
| R1-06-B-3018318 | **R2-06-B-3018342** |

| NEXUS mooring codes | |
|---|---|
| R1-07-B-3018319 | **R2-07-B-3018343** |
| R1-08-B-3018320 | **R2-08-B-3018344** |
| R1-09-B-3018321 | **R2-09-B-3018345** |
| R1-10-B-3018322 | **R2-10-B-3018346** |
| R1-11-B-3018323 | **R2-11-B-3018347** |

The field team conducted a Fall, in-season survey from October 24th to November 15th, 2017. Logistically, only 8 stations could be deployed and retrieved in one day. Marine operations in the CLA are greatly impacted by tidal speed, tidal range, and depth; therefore, stations were deployed and retrieved in the most efficient manner possible depending on these factors.

Station positions were entered into the vessel's (*Nova Endeavor*) Nobeltec® GPS plotter to ensure all traps were deployed appropriately. During trap deployment, date, time, station FID, latitude, longitude, ID tag number, and surface temperature were recorded in a logbook. During trap retrieval, ID tag numbers were used to verify station FID, and all other fields were recorded in the logbook. For each station retrieved, the following data was recorded on data sheets (Figure 4):

- Station FID
- Position
- Depth
- Time retrieved
- Species name
- Sex codes (e.g. male – 1; female – 2; and berried female – 3)
- Carapace length for relevant Crustacea– using standard issue calipers
- Total length for relevant fin fish – using a 1 cm offset measuring board
- By-catch total number of individual – for all other species


FSRS Lobster / Crab At - Sea Sampling

Page ____of____

Port ____ Captain ____ Vessel ____

Date ____ Main Species ____ Gear Type ____ Sampler ____ Trip # ____

String No. | Trap Sequence | Carapace Length (mm) | Sex | Shell Hardness | Egg | Clutch % | Cull | V-Notch | Species | Depth (ftm) | Soakdays | Location: Latitude Deg Min .00 | Longitude Deg Min .00 | Comments

Species Codes: 1 Lobster, 2 Rock Crab, 3 Jonah Crab, 9 Red Crab

Sex: 1 Male, 2 Female, 3 Berried

Shell Hardness: 1 Just Moulted, 2 Hardening but breakable, 3 Soft, 4 Hard compressible, 5 Hard, 6 Hard shell with epiphytic growth, 7 Ready to Moult (shell splitting)

Eggs: 1 New eggs (black), 2 Eyed eggs, 3 Mature eggs, hatching imminent, 4 Eggs hatching or hatched,mossy

Shell Disease: 0 NO DISEASE, 1 <10%, 2 10-50%, 3 >50%

Culls: 1= 1 claw, 2= 0 claws, 3= Regenerating claw

V-Notch: 1 V-notched during current sampling, 2 New v-notch (flesh or scar tissue visible), 3= Old v-notch (no setal hairs), 4= Old v-notch (with setal hairs), 5= Mutilated or missing flipper

Clutch 1= 100%-50% 2= <50% 3= <10%

Revised Mar 23, 2016

**Figure 4**. Lobster/Crab At-Sea Sampling data sheet.

Data was entered into the DFO Crustacean Research Information System (CRIS) and an output excel created. The analysis examines catch (kg) per trap by date, station FID, quadrant, and ring (i.e. inner vs. outer).

# SECTION III: PRELIMINARY RESULTS

## FALL, IN-SEASON SURVEY

Eight survey stations were successfully deployed on seven days between October 24th and November 15th, 2017. During this period three survey plot replications were completed with a retrieval success rate of 97.9% (47 of 48 traps). All stations were successfully retrieved within a soak period of 24 hours except for one station on October 24th. Due to weather conditions all stations set on October 25th were left for a longer soak period. Stations retrieved beyond the 24-hour soak period have been omitted from further analysis.

Within the survey period, daily catchability for survey stations within the CLA plot are categorized as high (>2.7 kg/trap), with one exception. On November 13th, 2017 the field team recorded 1.00kg of lobster caught at station 7-1 – which is moderately low on the DFO catchability scale. Although mean station catchability was high throughout the period, there appears to be a declining trend over time (Figure 5). Catch variability between stations appears to have lowered in the later period. Although we may glean a semblance of trends from these results, currently, the limited time scale prevents broader trend analysis.

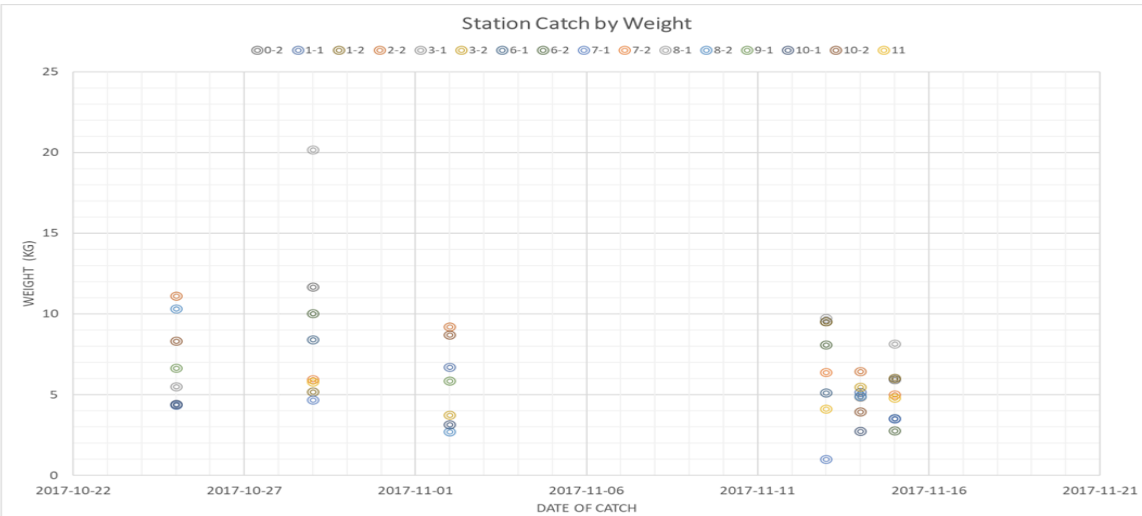



**Figure 5.** Daily station catchability.

In Figure 6, maximum tidal ranged between 10.5m to 12.3m, throughout the study. The figure depicts a strong negative relationship ($R^2$ = 0.75) between the two variables – as tidal height increases, catches decrease. Our team infers that lobsters limit their movements during periods of high tidal velocity. There was also increased rock debris and trap damage during high tidal velocity – which provides supporting evidence that it may be difficult for lobsters to move during these periods. In contrast, the team found no relationship ($R^2$ = 0.0845) between catch and depth (at mean tide) (Figure 7).

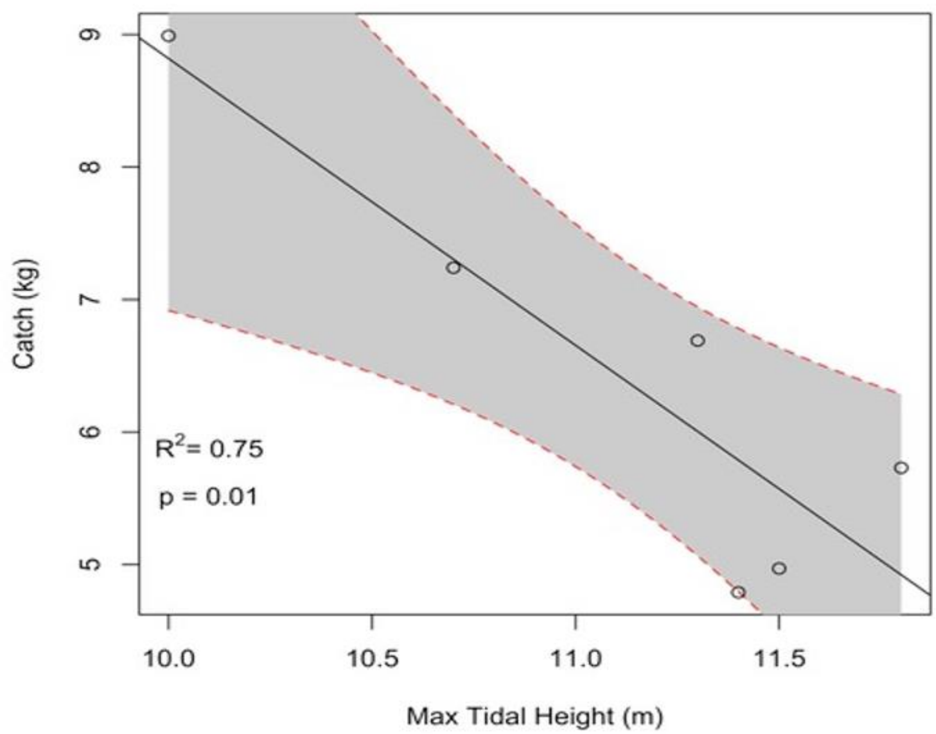



**Figure 6.** Mean daily station catchability relative to maximum daily tidal height.

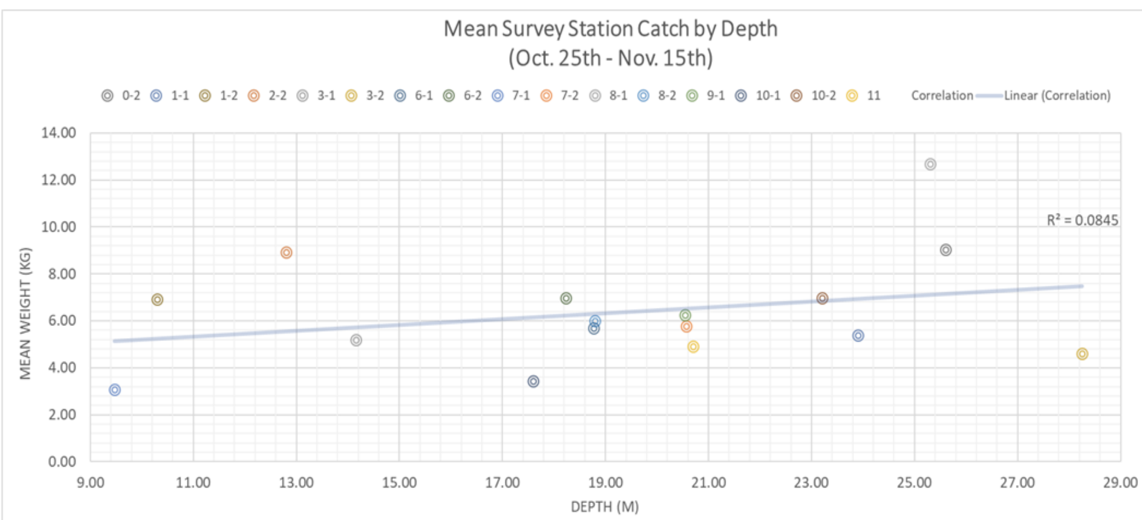



**Figure 7.** Mean station catchability relative to depth throughout the survey period.

Daily mean catchability for ring 1 was also high (> 2.7kg/trap) throughout the survey period (Figure 8). Ring 1 catch rates diminished slightly over time, and variability fluctuated with no clear trend. In figure 9, ring 2 daily catchability was also greater than 2.7kg/trap for the period. In contrast to ring 1, ring 2 mean catch rates reduced by a larger degree and variability also diminished. On November 2nd, 2017, ring 2 variability was almost negligible (0.13) and cannot be depicted on the chart.

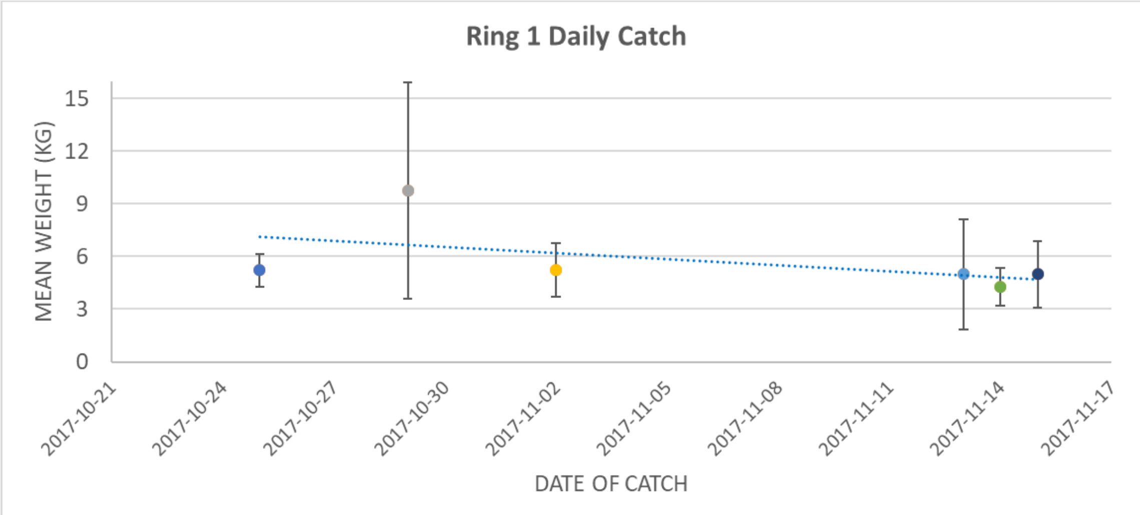



**Figure 8.** Mean daily ring 1 catchability and associated daily catch variability.

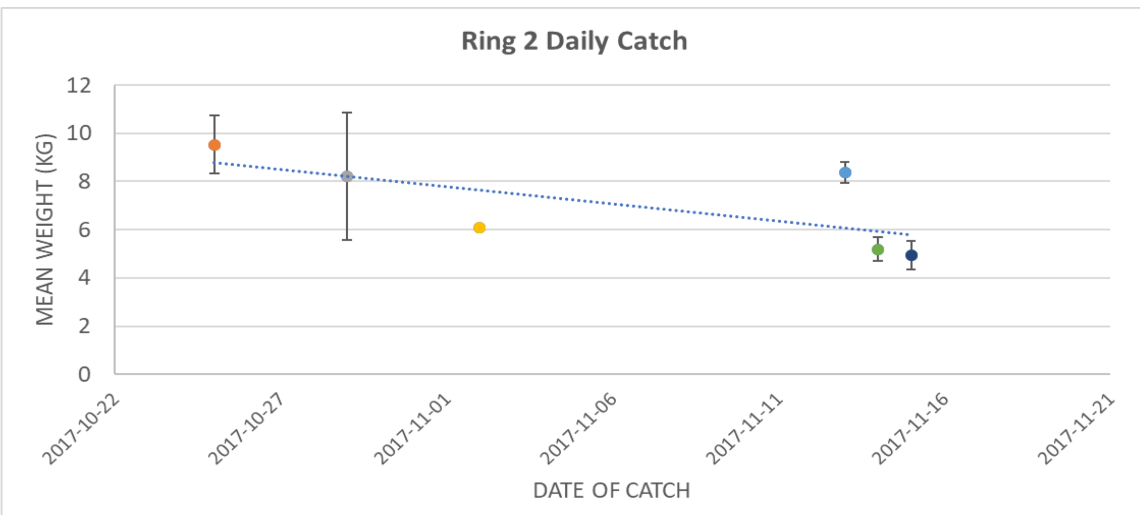



**Figure 9.** Mean daily ring 2 catchability and associated daily catch variability.

Mean ring 1 catchability for remained above 2.7kg/trap, for each quadrant throughout the period (Figure 10). Variability was high for the South quadrant (5.29) and moderate to low for the other quadrants. All quadrants in ring 2 also displayed high catchability throughout the period and variability was moderate. Catchability and variability trends are not depicted since these datasets are averaged across the survey period.

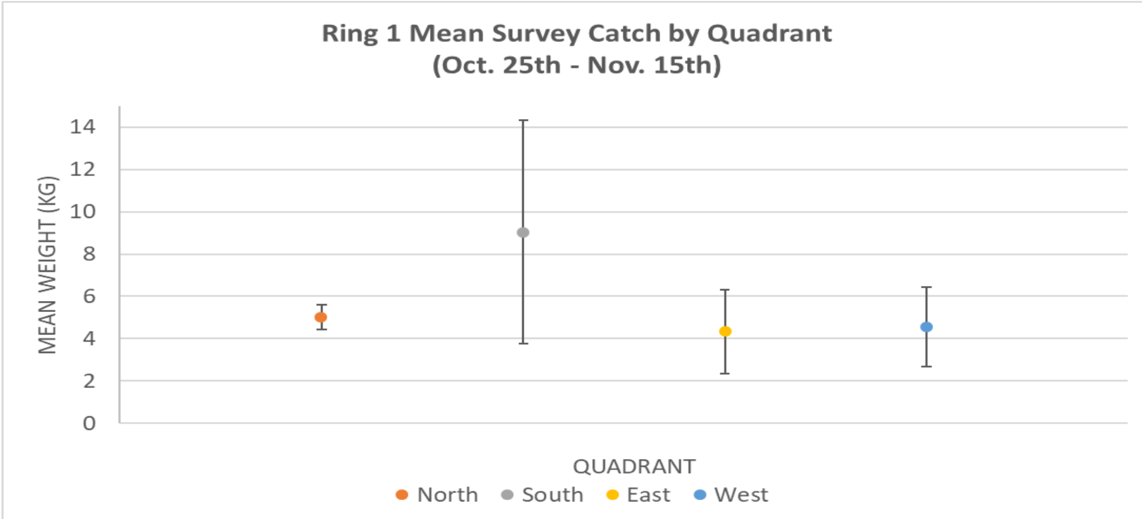



**Figure 10.** Mean ring 1 catchability and catch variability by corresponding quadrant.

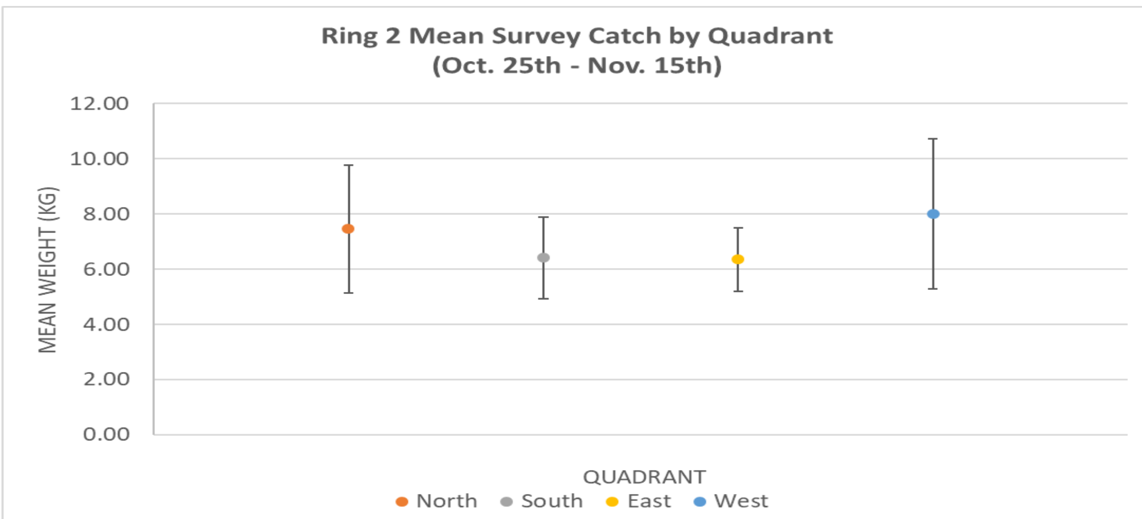



**Figure 11.** Mean ring 2 catchability and catch variability by corresponding quadrant.

# SECTION IV: DISCUSSION OVERVIEW

## FALL, IN-SEASON SURVEY

There is high catchability within the CLA, which indicates high lobster population density. Although catchability recorded by DFO is 2014 (above) is based on traps fished with open escape panels, the mean catchability for the CLA Fall survey trended within the baseline range of the broader Minas Passage fishery (DFO, 2017).

The following factors contribute to lobster population dynamics:

- Depth
- Temperature
- Currents (e.g. velocity and direction)
- Season
- Lobster mobility
- Lobster molt cycle
- Reproductive cycles (i.e. mating)
- Salinity
- Dissolved oxygen
- Photoperiod
- Natural mortality
- Fishing mortality (Factor, 1995)

Since mean tidal height trended within a narrow range of 0.10m, it is assumed that this tidal height will be a more significant factor to determine effect on catchability and will be used as a co-variant in the analysis of subsequent surveys. The potential effect of tidal height on future catchability studies can be mitigated by surveying within the same tidal period (neap tides; least variability between tides).

If we assume that the level of fishing efforts remains constant throughout the season (where all harvesters fish 300 traps per licence), then it may reasonable to assume this factor will not affect catchability if the survey is conducted during same period (commencing near the start of the fall lobster fishing season - October 15$^{th}$). This will also enable inter-annual catch comparisons.

Sampling the same random fixed stations during each survey mitigates any effects of changing trap depth on catchability. Surface temperature data was collected for each station; however, the temperature-catchability relationship was deemed outside of the scope of this initial study and not analyzed. Subsequent studies will include covariant analysis of catch with temperature, as well as salinity, data collected at the site by FORCE

The following factors constrained the operational execution of the survey: high current velocity affecting vessel mobility, buoy resurfacing (which is dependent on depth and buoy length,) and short tidal window (approximately 1 hour straddling low slack tide). Buoy resurfacing time can be reduced by increasing the length of buoy line from 75m to 100m –

thus, increasing length of time buoys remain on the surface, which should improve operational efficiency. Unfortunately, due to the area's oceanography, and the constraints on the vessel to dock and depart straddling high tides, the other factors affecting operations cannot be mitigated.

Geological features of the CLA also had an impact on operations. The vessel experienced difficulties maneuvering to survey stations near Black Rock during high current velocities. The field team mitigated this by ensuring traps at these survey stations were deployed and retrieved during low velocity (during slack tide; 15-minute window). Station 9 was fixed near Black Rock and there was a risk to trap retrieval. Additionally, the bathymetry of the Minas Passage Plateau constrains the spatial bounds of the survey plot. Station 3-2 was fixed along the plateau's edge, which presented a risk to trap retrieval. Subsequent studies (after deployment of the Turbine) will focus sampling along the flow axis, by increasing the number of stations in instream quadrants and reducing the number of stations in lateral quadrants.

## SECTION V: RECOMMENDATIONS

The 2017 Fall survey provided information on the nature and abundance of lobster in the immediate area around the FORCE site that will be essential for systematic evaluation on lobster catchability effects after future deployment of turbines at the site. The survey also provided an opportunity to test the methodology and survey design. Therefore, based on the findings from the survey the following recommendation are offered:

1. ***Modify survey design to ensure continued statistical validity of the study.***
2. ***Collect additional environmental information, specifically, temperature, salinity, turbidity.***
3. ***Adapt overall program design to consider cumulative effects of multiple pilot tidal energy projects.***

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